NIBIO
NORWEGIAN INSTITUTE OF
BIOECONOMY RESEARCH

Potential of NanoPro to reduce fungicide rate for control of *Microdochium nivale* on an annual bluegrass (*Poa annua*) green

Report from the first experimental year 2018-19

NIBIO REPORT | VOL. 5 | NR. 80 | 2019

Tatsiana Espevig, Trond O. Pettersen and Trygve S. Aamlid
Department of Urban Greening and Environmental Technology

TITTEL/TITLE

Potential of NanoPro to reduce fungicide rate for control *Microdochium nivale* on an annual bluegrass (*Poa annua*) green

FORFATTER(E)/AUTHOR(S)

Tatsiana Espevig, Trond O. Pettersen and Trygve S. Aamlid

DATO/DATE:	RAPPORT NR./ REPORT NO.:	TILGJENGELIGHET/AVAILABILITY:	PROSJEKTNR./PROJECT NO.:	SAKSNR./ARCHIVE NO.:
14.06.2019	5/80/2019	Open	11328	18/01329

ISBN	ISSN:	ANTALL SIDER/ NO. OF PAGES:	ANTALL VEDLEGG/ NO. OF APPENDICES:
978-82-17-02364-7	2464-1162	15	6

OPPDRAGSGIVER/EMPLOYER:	KONTAKTPERSON/CONTACT PERSON:
Østfold Gress AS, Norway	Johnny Trandem
Aqua-Yield, USA	Britney Hunter and Landon Bunderson

STIKKORD/KEYWORDS:	FAGOMRÅDE/FIELD OF WORK:
Golfgreen, tunrapp, tilsetningsstoffer, huminsyre, fungicider, mikrodochium flekk	Urban Greening and Environmental Engineering
Golf green, annual bluegrass, additives, humic acid, fungicides, microdochium patch	Turfgrass

SAMMENDRAG/SUMMARY:

Dette er den første rapporten om potensialet for additivet NanoPro til å redusere doseringen av de to mest brukte fungicider for bekjemping av mikrodochium flekk (*Microdochium nivale*), den økonomisk viktigste sykdommen på golfbaner i Skandinavia. Forsøket ble gjennomført fra 14.sept. 2018 til 1.mai 2019 på en tunrappgreen ved NIBIO Turfgrass Research Centre Landvik. Bruk av NanoPro 292 ml/ha i tankblanding, først med det systemiske fungicidet Delaro® SC 325 den 19.sept.18 og deretter med kontakt fungicidet Medallion® TL den 15.nov.18 gjorde det mulig å oppnå samme sykdomskontoll med 30-60 % mindre dose av fungicid. Virkningen av NanoPro var bedre med Medallion® TL enn med Delaro® SC 325. Våre foreløpige data tyder på at NanoPro kan være et viktig hjelpemiddel for å redusere forbruket av soppmidler på golfbaner. Forsøket bør gjentas ett år for å dokumentere effekten av NanoPro igjennom en artikkel i et vitenskapelig tidsskrift.

This is a first report on the potential of NanoPro to reduce the dosage of the two most commonly used fungicides for control of microdochium patch (*Microdochium nivale*), the economically most important disease in Scandinavia. The experiment was conducted from 14 Sept. 2018 to 1 May 2019 on an annual bluegrass golf green at the NIBIO Turfgrass Research Center Landvik. Use of NanoPro at a rate of 292 ml/ha in tank mixture with the systemic fungicide Delaro® SC 325 on 15 Nov.18 or/and the contact fungicide Medallion® TL on 15 Nov. 18 produced the same level of disease control with a 30-60% reduction in fungicide dosage as with full fungicide dosage without additive.

NIBIO
NORWEGIAN INSTITUTE OF BIOECONOMY RESEARCH

NanoPro was more effective with Medallion® TL than with Delaro® SC 325. We conclude that NanoPro may have a big potential in Scandinavia and other countries where authorities require reduced fungicide use. The experiment should be repeated one more year to document the effect of NanoPro in a scientific peer-reviewed journal.

LAND/COUNTRY:	Norway	**KOMMUNE/MUNICIPALITY:**	Grimstad
FYLKE/COUNTY:	Aust-Agder	**STED/LOKALITET:**	Landvik

GODKJENT /APPROVED	**PROSJEKTLEDER /PROJECT LEADER**
HÅKON BORCH	**TATSIANA ESPEVIG**

Content

1 Introduction

Microdochium patch is the economically most important disease in turfgrass in Scandinavia. On golf greens with susceptible species and winter conditions favourable for snow moulds the damage from microdochium patch can be up to 100% (Kvalbein et al., 2017). Thus, the use of systemic and contact fungicides in fall is necessary to protect golf greens from severe snow mould damage.

According to IPM principles, fungicide use should be sustainable. The use of fungicides can be significantly reduced by adding substances, which by themselves have no fungicidal properties but improve fungicide efficacy. In the late summer of 2018, Johnny Trandem, CEO of Østfold Gress AS, contacted NIBIO Turfgrass Research Group to test NanoPro™, an additive produced by Aqua-Yield, Salt Lake City, USA. NanoPro contains 99 % water and 1 % humic acid derived from Leonardite as the active ingredient. Humates are natural organic substances, high in humic acids and often containing trace minerals necessary for plants (Senn, 1991). Humates are an important soil component also because they constitute a stable fraction of carbon and improve water holding capacity and pH buffering (McDonnell et al., 2001). Benefits of humic acids in agriculture as additives to liquid fertilizer for foliar feeding and to granular fertilizer alone or to their combination applied to the soil are widely accepted. Reports on the application of humic acids to turfgrasses as a part of a fertilization program or for disease control are, however, limited (Zhang et al., 2003; Kaminski et al., 2004). To the best of our knowledge, there are no reports on use of humic acid as additives to fungicides for microdochium patch control on golf greens.

After a discussion by e-mails and a Skype-meeting with Østfold Gress and Aqua-Yield on 11 Sept. 2018, we started to test NanoPro on an annual bluegrass green at NIBIO Turfgrass Research Center, Norway. The objective of our study was to investigate the potential for NanoPro to reduce the dosage of the two most commonly used fungicides for control of microdochium patch. Our hypotheses were: (i) Use of NanoPro at a rate of 292 ml/ha in tank mixture reduces the required dosage of the systemic fungicide Delaro® SC 325 or/and the contact fungicide Medallion® TL on Norwegian golf greens by up to 60%, and (ii) NanoPro improves the effect and reduces dosage of the systemic fungicide (Delaro® SC 325) more than of the contact fungicide (Medallion® TL).

2 Materials and methods

2.1 Experimental site and general maintenance

The experiment was conducted from 14 Sept. 2018 to 1 May 2019 on an annual bluegrass (*Poa annua* L.) golf green at the NIBIO Turfgrass Research Centre Landvik, Grimstad, SE Norway (58°34'N, 8°52'E, 10 m a.s.l.). The root zone of the green was constructed according to USGA-specifications (USGA Green Section Staff 2018) in November 2004 and consisted of 88% sand (volume fraction) and 12% peat (volume fraction). On 24 May 2018 the green surface (annual bluegrass used in a previous experiment) was deturfed (due to poor survival during the winter 2016-17), these upper 3 cm of the green was filled with new 12% peat root zone media (Figure 1 and 2). A new annual bluegrass cover was established by spreading turf plugs taken from an old annual bluegrass green at Borregaard golf course in Sarpsborg, SE Norway, at a rate of 1.78 kg per m^2 on 30 May 2018 (Figure 3). As registered on 19 Sept. 2018 prior to the first treatment the turf coverage of the green was 99%.

Figure 1. Deturfing of annual bluegrass green at Landvik on 24 May 2018.

Photo: Tatsiana Espevig.

Figure 2. Replacing of 3-cm upper layer with new 12% peat growth media at Landvik on 30 May 2018.

Photo: Tatsiana Espevig.

From 13 July to 15 Oct. 2018 the green was mown three times per week to 5 mm using a single walk-behind green's mower and topdressed three times for a total amount of 1.25 mm sand. The last mowing for the season was at 5 mm on 15 October. Slicing was performed 2 times: 14 Sept. and 28 Sept. In 2018 the green was fertilized from 31 May to 7 November using either Wallco liquid fertilizer

5-1-4 or Greenmaster zero 14-0-10. The annual input amounted to 293 kg N, 56 kg P and 200 kg K ha^{-1} (including the first pre-seeding application with the organic product Marihøne Pluss 14-0-8). In the spring 2019 the green was fertilized on 4 and 15 April with a total of 32 kg N, 4 kg P and 23 kg K ha^{-1}. See Appendix 1 for the fertilization plan. The green was topdressed weekly from 6 July to 5 Oct. 2018 for a total height of 5 mm sand. The green was irrigated with 5 mm water after fertilization and/or topdressing and to field capacity each time the average volumetric soil water content in the 12 cm top layer dropped below 12% (v/v) as measured with a TDR meter (Field Scout 300; Spectrum Technologies, Aurora, Illinois, USA).

Figure 3. Re-establishment of annual bluegrass green from turf plugs at Landvik on 30 May 2018 (left) and on 12 June 2018 (right).

Photo: Tatsiana Espevig.

2.2 Experimental plan and implementation

The experiment was laid out according to a randomised complete block design with 4 replicates per treatment. Individual plot size was 3 m^2 (2.0 x 1.5 m) of which the registration plot area was 1.5 m^2 (1.0 x 1.5 m) to avoid border effects. The field map is shown in Appendix 2.

The one-factorial experiment consisted of the following 9 treatments:

1. No fungicide (negative control)
2. 100% fungicides (recommended dosage) (positive control):
   Delaro® SC 325 1 L/ha in 250 L water
   Medallion® TL 3 L/ha in 250 L water
3. 70% of recommended fungicide dosage (30% reduction):
   Delaro® SC 325 0.7 L/ha in 250 L water
   Medallion® TL 2.1 L/ha in 250 L water
4. 70% of recommended dosage (as 3) + NanoPro with Delaro only:
   Delaro® SC 325 0.7 L/ha + **NanoPro** 292 ml/ha in 250 L water
   Medallion® TL 2.1 L/ha
5. 70% of recommended dosage (as 3) + NanoPro with Medallion only:
   Delaro® SC 325 0.7 L/ha
   Medallion® TL 2.1 L/ha + **NanoPro** 292 ml/ha in 250 L water
6. 40% of recommended fungicide's dosage (60% reduction):

	Delaro® SC 325	0.4 L/ha in 250 L water
	Medallion® TL	1.2 L/ha in 250 L water
7.	40% of recommended dosage (as 6) + NanoPro with Delaro only:	
	Delaro® SC 325	0.4 L/ha + **NanoPro** 292 ml/ha in 250 L water
	Medallion® TL	1.2 L/ha
8.	40% of recommended dosage (as 6) + NanoPro with Medallion only:	
	Delaro® SC 325	0.4 L/ha
	Medallion® TL	1.2 L/ha+ **NanoPro** 292 ml/ha in 250 L water
9.	40% of recommended dosage (as 6) + NanoPro with both fungicides:	
	Delaro® SC 325	0.4 L/ha + **NanoPro** 292 ml/ha in 250 L water
	Medallion® TL	1.2 L/ha + **NanoPro** 292 ml/ha in 250 L water

Delaro® SC 325 (trifloxystrobin 150 g/L and protioconazole 175 g/L), a 'systemic' fungicide from Bayer Crop Science, was applied on 19 Sept. 2018, while Medallion® TL (fludioxonil 125 g/L), a 'contact' fungicide from Syngenta, was applied on 15 Nov 2018. The fungicides were applied in a water volume of 250 l/ha using an experimental backpack plot sprayer (Oxford/LTI) working at 150-200 kPa pressure. The spraying boom had three nozzles spaced 50 cm apart and screens on both sides that prevented drift to neighbour plots and secured that the boom was always 50 cm above the canopy. NanoPro™ from Aqua-Yield (Salt Lake City, USA) was applied in tank mixture with Delaro® SC 325 in treatments 4, 7 and 9 and with Medallion® TL in treatments 5, 8 and 9.

The actual application rates were recorded by weighing the tank before and after spraying. Table 1 shows that actual rates were slightly higher than the target values, but the deviation were

less than the ±10% limit set by the Norwegian Good Experimental Practice (GEP) protocol except for 12% higher realized rate of 100% Medallion® TL on 15 Nov. 2018 in Treatment 2 (Table 1).

Table 1. Application dates and realized rates for fungicides.

Wk	Date	Treatment	%	Product	Target rate, L/ha	Realized rate, L/ha	+/- %
38	19 Sept. 18	2	100	Delaro SC325	2.5	2.7	9.3
		3	70	Delaro SC325	2.5	2.7	9.3
		4	70	Delaro SC325 + NanoPro	2.5	2.7	6.7
		5	70	Delaro SC325	2.5	2.7	6.7
		6	40	Delaro SC325	2.5	2.6	4.0
		7	40	Delaro SC325 + NanoPro	2.5	2.7	6.7
		8	40	Delaro SC325	2.5	2.7	9.3
		9	40	Delaro SC325 + NanoPro	2.5	2.7	6.7
44	15 Nov. 18	2	100	Medallion	2.5	2.8	12.0
		3	70	Medallion	2.5	2.7	6.7
		4	70	Medallion	2.5	2.5	1.3
		5	70	Medallion + NanoPro	2.5	2.7	6.7
		6	40	Medallion	2.5	2.7	6.7
		7	40	Medallion	2.5	2.7	9.3
		8	40	Medallion + NanoPro	2.5	2.7	6.7
		9	40	Medallion + NanoPro	2.5	2.7	6.7

2.3 Registrations, statistical analysis and weather data

Visual assessments

Turf quality was assessed using a scale from 1 (poor and uneven turf) to 9 (even and very good turf), with 5 as the lowest value for acceptable turf quality. Colour was registered using a scale from 1 (very light) to 9 (very dark), and shoot density using a scale from 1 (very thin) to 9 (very dense). The incidence of microdochium patch, caused by *Microdochium nivale*, was registered as percentage of plot area covered with diseased turf. All visual assessments started on 19 Sept. and were done with 2-wk interval to 27 Nov. and then on 2 Jan., 26 Feb., 20 March and 23 April. The disease intensity was expressed by the area under disease progress curve (AUDPC) which was calculated by multiplying the average microdochium patch incidence on two subsequent observations by the time (days) between these observations from 19 Sept. to 23 April and taking the sum of all these multiplied numbers.

Statistics

All parameters were analysed using the SAS procedure PROC ANOVA for a 1-factorial randomized complete design with 4 blocks; the control-treatment was removed from the analysis . The Fisher's least significant difference (LSD) was used to separate mean values at the 5% probability level.

Weather data

Maximal, minimal and average temperature on monthly and daily basis and total precipitation on monthly basis were obtained from the local weather station (LandbruksMeteorologisk Tjeneste, https://lmt.nibio.no/agrometbase/getweatherdata_new.php) and shown in Table 2 and Figures 4 and 5. All months from September 2018 through April 2019 had higher temperatures than the 30 year average, the strongest deviation being recorded in February and March. October 2018 had a total precipitation 106 mm lower than normal, but the total precipitation in September, November and December 2018 was 78, 53 and 113 mm higher than normal. The duration of snow cover totalled 39 days (Figure 4).

Table 2. Monthly values for air temperature and precipitation at Landvik prior to and during the experiment. LandbruksMeteorologisk Tjeneste

		Temperature, °C			
Year	Month	Mean	Max.	Min.	Normal (1961-90)
2018	May	14.9	27.0	3.1	10.4
	June	17.0	31.2	7.5	14.7
	July	20.3	29.5	7.9	16.2
	August	16.1	28	5.1	15.4
	September	12.9	21.6	0.2	11.8
	October	8.7	17.7	-1.0	7.9
	November	5.5	11.2	-6.8	3.2
	December	2.0	10.1	-8.2	0.2
2019	January	-0.1	11.8	-17.1	-1.6
	February	3.1	18.7	-10.6	-1.9
	March	4.2	16.8	-6.3	1.0
	April	7.6	20.8	-4.6	5.1

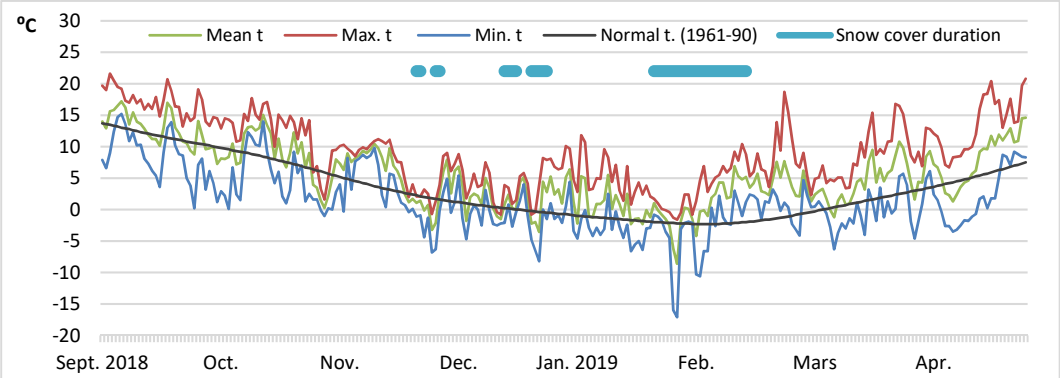


Figure 4. Daily values for air temperature prior to and during the experimental period (from May 2018 to April 2019) as compared with the 30 yr normal (1961-90)). The duration of snow cover has also been indicated. LandbruksMeteorologisk Tjeneste.

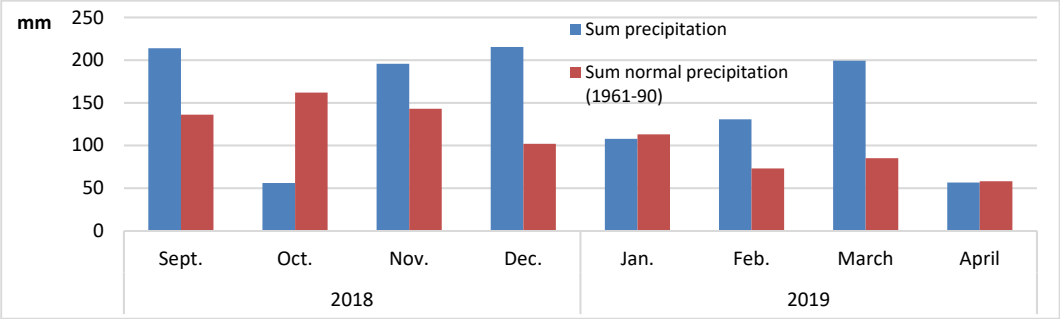


Figure 5. Monthly values for precipitation prior to and during the experimental period (from May 2018 to April 2019 vs. normal for 30 yr (1961-90)). LandbruksMeteorologisk Tjeneste

3 Results and discussion

The first sign of microdochium patch appeared in early September 2018. A significant increase in the disease started in late October. Thus, on unsprayed control plots microdochium patch covered 29% of plot area on 12 November (Figure 6 and Appendix 3). The further development of microdochium patch during the winter resulted in 64% microdochium patch on unsprayed plots on 20 March 2019. After this, the diseases started to decline and on 23 April (the last registration in the experiment) it amounted to 55%.

In September-October the differences among treatments were not significant except for 17 October (1 month after application of the systemic fungicide Delaro on 19 September) when unsprayed plots had 2.4 percentage points more microdochium patch than on average for all treated plots (3.9 % vs. 1.5%, respectively) (Figure 6).

In November-January, the coverage by microdochium patch was on average 27 percentage points higher on unsprayed plots than on average for all treated plots (33% vs. 6%, respectively) (Figure 6 and 7, Appendix 3). Compared with the unsprayed plots 100%, 70% and 40% of the recommended fungicide dosage gave 92%, 81% and 71% microdochium patch reduction. However, neither these differences nor the additive effects of NanoPro were significant.

In February-April, when microdochium patch covered 59% of plot area on unsprayed plots (on average for the 3 last registrations), 100%, 70% and 40% fungicide dosage reduced microdochium patch coverage by 94%, 83% and only 47%, respectively (Figure 6, Appendix 3, 5 and 6). The use of NanoPro as additive to 70% fungicide dosage resulted in 6% and 13% stronger disease reduction with Delaro and Medallion, respectively, as compared to 70% fungicide dosage alone. The use of NanoPro as additive to 40% fungicide dosage resulted in 23%, 37% and 41% stronger disease reduction with Delaro, Medallion and both fungicides, respectively, as compared with 40% fungicide dosage alone. Yet, the effect of adding NanoPro to 70% nor with 40% fungicide dosage was not significant when percentage coverage of Microdochum patch was subjected to statistical analysis.

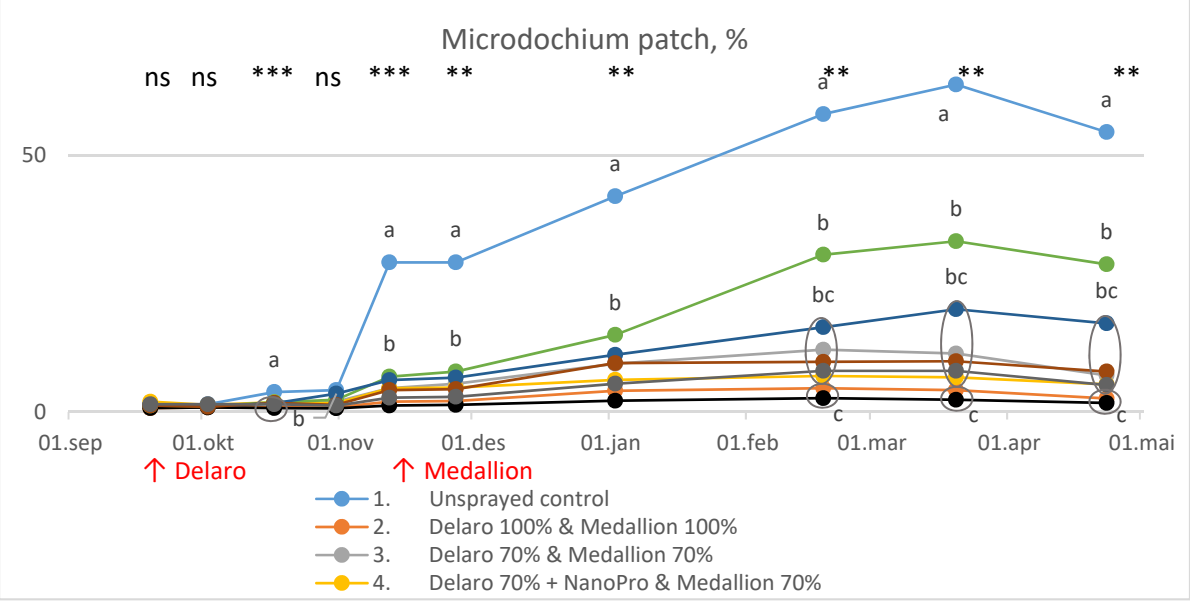


Figure 6. Effect of NanoPro used as additive to fungicides on microdochium patch on annual bluegrass green. The stars indicate when differences among the treatments were significant: * significant at 0.05 probability level, ** significant at 0.01 probability level, * significant at 0.001 probability level, and ns when non-significant.**

Figure 7. Microdochium patch on a unsprayed annual bluegrass plot on 20 Nov. 2018

Photo: Tatsiana Espevig

When we look at the area under disease progress curve (AUDPC) which describes and gives a quantitative summary of disease intensity during the experimental period from 19 Sept. 2018 to 20 March 2019, the additive effect of NanoPro became more pronounced at both 70% and 40% fungicide dosage and it was also statistically significant at 40% fungicide dosage (Table 3). Thus, 100%, 70% and 40% dosage reduced microdochium patch by 94%, 82% and only 31%, respectively, as compared with unsprayed plots. NanoPro in tank mixture with 70% fungicide dosage led to 11% and 15% higher microdochium patch reduction when used with Delaro and Medallion, respectively, but differences were not significant. When tank-mixed with 40 % dosages of Delaro, Medallion and both fungicides, NanoPro resulted in 36%, 56% and 55% higher microdochium patch reductions than the 40% fungicide dosage used alone. Moreover , the use of NanoPro with 40% fungicide dosage resulted in an equally good microdochium patch control (reduction) as the 100% (reccomended) fungicide dosage. We also found that the additive affect of NanoPro was more pronounced with Medallion than with Delaro when used with 40% fungicide dosage: 31%, 67%, 87% and 86% microdochium patch reduction of unsprayed plots for 40%, 40%+Delaro, 40%+Medallion and 40%+both, respectively. This finding is contrary to our hypothesis and needs more investigation.

By the start of the experiment on 19 September the turf quality scored 7 on average for all plots (Figure 8 and Appendix 4). From 2 October the turf quality was obviously lower on the plots with the higher amount of microdochium patch and it was negatively correlated with amount of disease (r=-0.9). Based on the criterion that 5.0 is the lowest score for acceptable turf, the turf became unacceptable from 12 November onwards in the unsprayed control treatment and in treatments sprayed with 40% fungicide dosage, but remained acceptable until January if NanoPro was added to the 40% dosage of Delaro. The five other treatments maintained acceptable turf quality throughout the experiment and had an average score of 5.7 by the end of the experiment on 23 April.

The colour on 19 September scored 7 on all plots (data not shown). It gradually declined and scored 6.5 in September-October, 6.2 in November-January and 5 in March. After fertilization in the spring 2019 the colour was improved and scored 7 by 23 April. No significant differences in colour were observed among treatments.

Table 3. Effect of NanoPro on area under disease progress curve (AUDPC) from 19 Sept. 2018 to 20 March 2019 and on shoot density of annual bluegrass on 23 April 2019.

Treatments				
Nr.	Delaro, % of reccom. dosage	Medallion, % of reccom. dosage	Microdochium patch, AUDPC	Density 23 Apr. 2019
1	0 (control)	0 (control)	906 a	6.8 b
2	100	100	54 c	7.4 a
3	70	70	166 bc	7.1 ab
4	70+NanoPro	70	62 c	7.3 a
5	70	70+NanoPro	29 c	7.5 a
6	40	40	630 ab	7.1 ab
7	40+NanoPro	40	301 bc	7.3 a
8	40	40+NanoPro	119 c	7.4 a
9	40+NanoPro	40+NanoPro	123 c	7.4 a
	p		*	*

* - significant differences among the treatments at 0.05 probability level. The same letter indicate no difference among the means based on Fisher protected LSD test (α=0.05).

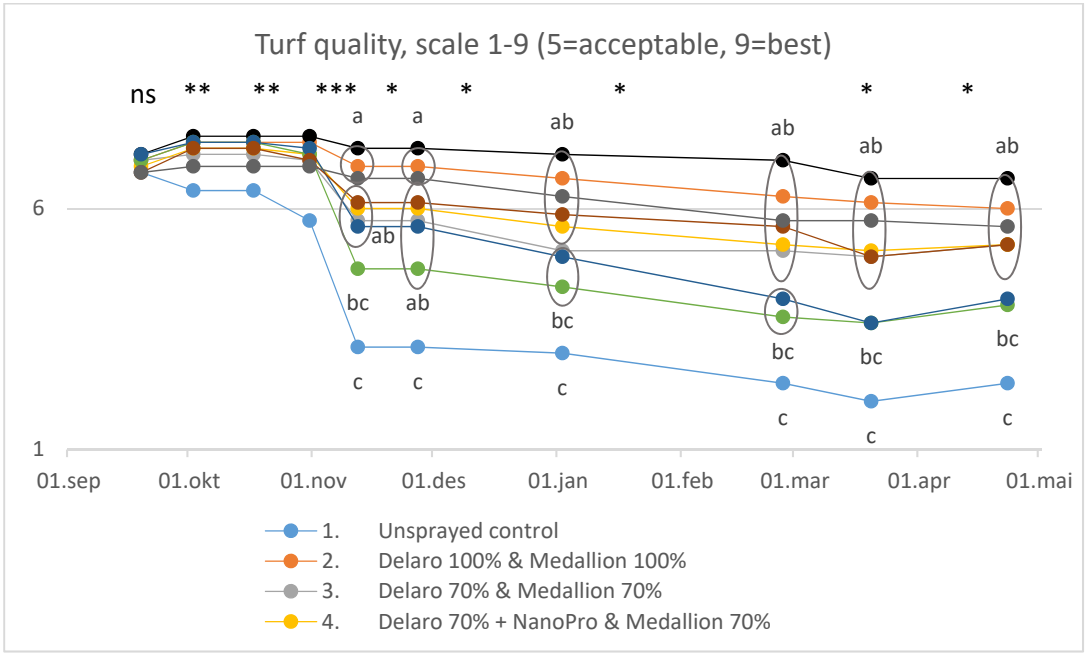


Figure 8. Effect of NanoPro used as addative to fungicides on turf quality of annual bluegrass green. The stars indicate when differences among the treatments were significant: * significant at 0.05 probability level, ** significant at 0.01 probability level, *** significant at 0.001 probability level, and ns when non-significant.

The shoot density on all plots was 7.5 in September-November (data not shown). On 23 April, the lowest density of 6.8 was registered on unsprayed plots, and it was not significantly different from that on 70% fungicide and 40% fungicide plots (Table 3). NanoPro improved density by 0.6 units on average for all plots which received the additive as compared with unsprayed plots.

4 Conclusions

This is a first report on the potential of NanoPro to reduce the dosage of the systemic and contact fungicides for control of microdochium patch, the economically most important disease in Scandinavia.

Use of NanoPro at a rate of 292 ml/ha in tank mixture with the systemic fungicide Delaro or/and the contact fungicide Medallion in this experiment on an annual bluegrass golf green confirmed its potential to produce the same level of disease control with a 30-60% reduction in fungicide dosage as with full fungicide dosage without additive. It appears that NanoPro's additive effect was more pronounced with Medallion than with Delaro.

According to IPM principles, Scandinavian authorities currently have a strong focus on how to reduce pesticide use in green amenity areas. Restrictions on the total use of fungicides have been introduced in all Scandinavian countries. In this context NanoPro should have a big market potential for Scandinavia and probably elsewhere. We therefore strongly recommend that this field experiment is repeated one more year in order to document the effect of NanoPro in a peer-reviewed scientific journal.

In a Skype meeting on 7 May 2019 Aqua-Yield expressed interested to repeat the experiment during the winter 2019-20 in order to be able to publish the results scientifically and present them at the I4th International Turfgrass Conference in July 2021.

References

Kaminski J.E., P.H. Dernoeden and C.A. Bigelow2004. Soil amendments and fertilizer source effects on creeping bentgrass establishment, soil microbial activity, thatch, and disease. HortSci. 39:620-626.

Kvalbein A., W.M. Marie Waalen, L. Bjørnstad, T.S. Aamlid and T. Espevig. 2017. Winter injuries on golf greens in the Nordic countries: Survey of causes and economic consequences. Int. Turfgrass Soc. Res. J. 13:604-609. doi:10.2134/itsrj2016.09.0826

McDonnell R., N.M. Holden, S.M. Ward, J.F. Collins, E.P. Farrell and M.H.B. Hayes, 2001. Characteristics of humic substances in healthland and forested peat soils of the Wicklow mountains. Biology and Environment, 101(3): 187-197.

Senn T.L., 1991. Humates in Agriculture. Acres USA, Jan.

Siddiqui Y., S. Meon, R. Ismail, M. Rahmani, and A. Ali. 2009. *In vitro* Fungicidal Activity of Humic Acid Fraction from Oil Palm Compost. Int. J. Agric. Biol. 11:448-452.

Zhang X., E.H. Ervin and R.E. Schmidt. 2003. Physiological effects of liquid applications of a seaweed extract and a humic acid on creeping bentgrass. J. Amer. Soc. Hort. Sci. 128:492-496.

USGA Green Section Staff, 2018. USGA recommendations for a method of putting green construction. Available at http://archive.lib.msu.edu/tic/usgamisc/monos/2018recommendationsmethodputtinggreen.pdf accessed 21 May 2018.

Appendix 1. Fertilization plan of annual bluegrass experimental green in 2018-19.

			Rate pr 100m2											
Week	**Product**	**kg/100m2**	**kg N**	**kg P**	**kg K**	**kg Mg**	**kg S**	**kg Ca**	**kg Fe**	**kg Mn**	**kg Cu**	**kg Zn**	**kg Mo**	**kg B**
2018														
22	Marihøne Pluss	6.25	0.5	0.3125	0.25	0.000	0.000	0.375	0.000	0.000	0.000	0.000	0.000	0.000
24	Greenmaster zero 14-0-10	2.00	0.28	0.000	0.166	0.036	0.000	0.000	0.0200	0.0000	0.0000	0.0000	0.0000	0.000
25	Wallco flytende 5-1-4	5.49	0.28	0.055	0.236	0.022	0.022	0.022	0.0009	0.0011	0.0001	0.0002	0.0000	0.001
26	Wallco flytende 5-1-4	5.29	0.27	0.053	0.228	0.021	0.021	0.021	0.0009	0.0011	0.0001	0.0002	0.0000	0.001
28	Greenmaster zero 14-0-10	1.93	0.27	0.000	0.160	0.035	0.000	0.000	0.0193	0.0000	0.0000	0.0000	0.0000	0.000
30	Wallco flytende 5-1-4	4.71	0.24	0.047	0.202	0.019	0.019	0.019	0.0008	0.0009	0.0001	0.0001	0.0000	0.000
32	Greenmaster zero 14-0-10	1.36	0.19	0.000	0.113	0.024	0.000	0.000	0.0136	0.0000	0.0000	0.0000	0.0000	0.000
34	Wallco flytende 5-1-4	3.53	0.18	0.035	0.152	0.014	0.014	0.014	0.0006	0.0007	0.0001	0.0001	0.0000	0.000
36	Greenmaster zero 14-0-10	1.14	0.16	0.000	0.095	0.021	0.000	0.000	0.0114	0.0000	0.0000	0.0000	0.0000	0.000
38	Greenmaster zero 14-0-10	1.07	0.15	0.000	0.089	0.019	0.000	0.000	0.0107	0.0000	0.0000	0.0000	0.0000	0.000
40	Wallco flytende 5-1-4	2.75	0.14	0.027	0.118	0.011	0.011	0.011	0.0005	0.0005	0.0000	0.0001	0.0000	0.000
42	Wallco flytende 5-1-4	2.75	0.14	0.027	0.118	0.011	0.011	0.011	0.0005	0.0005	0.0000	0.0001	0.0000	0.000
44	Greenmaster zero 14-0-10	0.93	0.13	0.000	0.077	0.017	0.000	0.000	0.0093	0.0000	0.0000	0.0000	0.0000	0.000
2019														
14	Greenmaster zero 14-0-10	1.00	0.14	0.000	0.083	0.018	0.000	0.000	0.0100	0.0000	0.0000	0.0000	0.0000	0.000
16	Wallco flytende 5-1-4	3.53	0.18	0.035	0.152	0.014	0.014	0.014	0.0006	0.0007	0.0001	0.0001	0.0000	0.000
SUM			**3.250**	**0.593**	**2.238**	**0.282**	**0.112**	**0.487**	**0.099**	**0.006**	**0.000**	**0.001**	**0.000**	**0.003**

Appendix 2. Field map.

1.5 m ← N

2 m

	Border	2.3 m	→							
Border	101 **8**	102 **7**	103 **6**	104 **1**	105 **3**	106 **2**	107 **4**	108 **5**	109 **9**	Border
1.05 m	201 **4**	202 **7**	203 **1**	204 **6**	205 **2**	206 **5**	207 **9**	208 **8**	209 **3**	0.65 m
↓	301 **1**	302 **2**	303 **9**	304 **7**	305 **3**	306 **4**	307 **6**	308 **5**	309 **8**	↓
	401 **6**	402 **4**	403 **3**	404 **8**	405 **5**	406 **7**	407 **2**	408 **9**	409 **1**	
	Border	2.5 m	→							

Total trial area excl. borders: 13.5 m x 8 m = 108 m²
Treatment plot area: 1.5 m x 2 m = 3 m²
Registration plot area: 1.0 m x 1.5 m = 1.5 m²

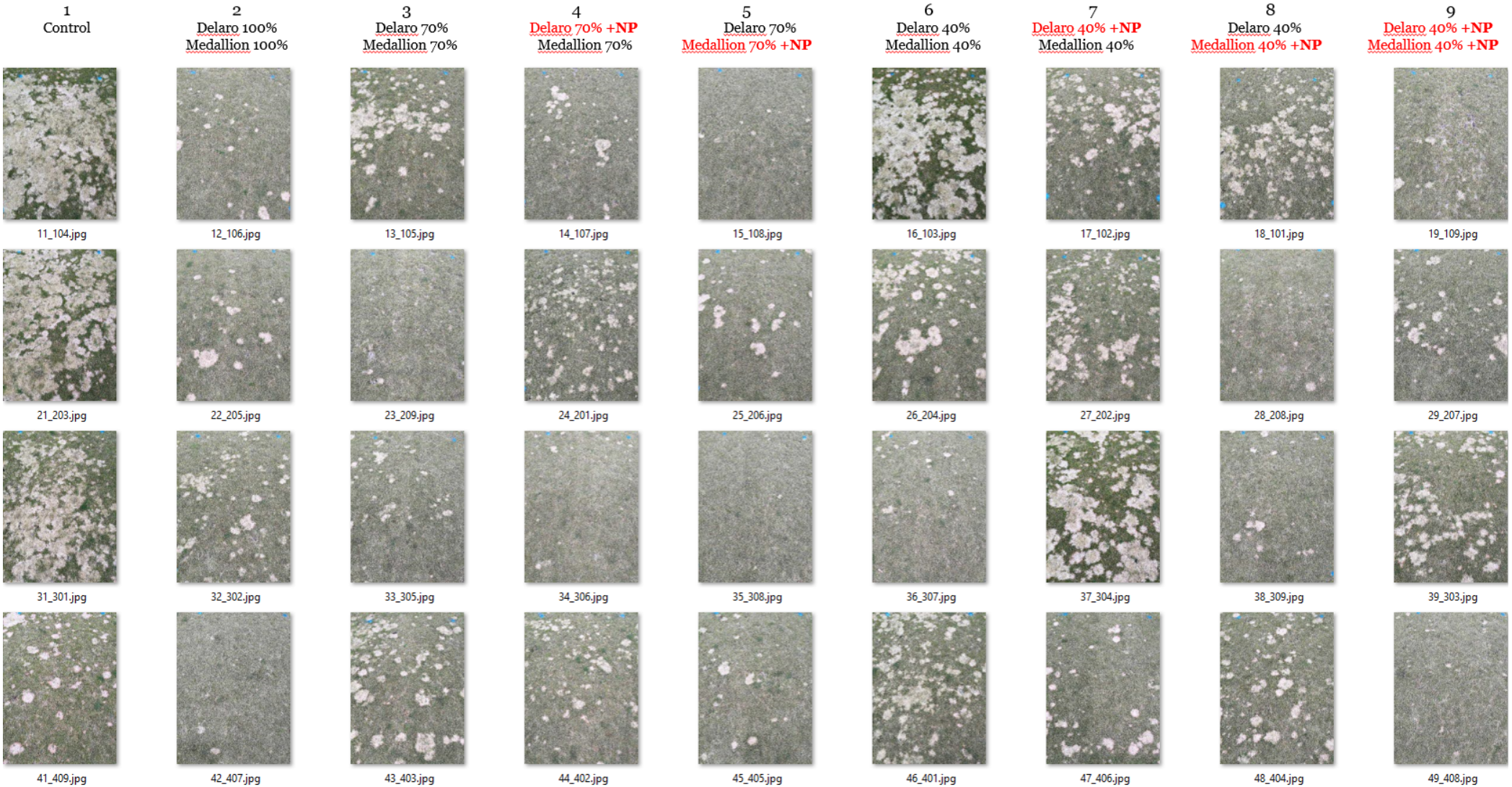
Appendix 3. Effect of NanoPro used as additive to fungicides on microdochium patch on annual bluegrass green in 2018-19.

Nr.	Treatments: Delaro, % of reccom. dosage	Treatments: Medallion, % of reccom. dosage	Microdochium patch, %: 19 Sept.	2 Oct.	17 Oct.	31 Oct.	12 Nov.	27 Nov.	2 Jan.	18 Feb.	20 Mar.	23 Apr.
1	0 (control)	0 (control)	1.4	1.5	3.9	4.3	29.1	29.1	42.0	58.0	63.8	54.5
2	100	100	0.8	0.9	1.0	0.9	2.0	2.1	4.1	4.6	4.3	2.6
3	70	70	1.1	0.9	1.6	2.0	4.6	5.5	9.4	12.1	11.4	7.1
4	70+NanoPro	70	2.0	1.4	1.9	1.7	4.6	4.8	6.3	7.0	6.8	5.4
5	70	70+NanoPro	0.8	0.9	0.8	0.7	1.3	1.4	2.2	2.7	2.4	1.8
6	40	40	1.3	1.1	1.9	2.4	6.9	7.9	15.0	30.6	33.3	28.8
7	40+NanoPro	40	1.4	1.1	1.7	3.6	6.2	6.7	11.1	16.5	20.0	17.3
8	40	40+NanoPro	1.3	1.0	1.8	1.4	4.3	4.4	9.5	9.8	9.9	7.9
9	40+NanoPro	40+NanoPro	1.5	1.5	1.5	1.2	2.8	2.9	5.5	8.0	8.0	5.3
	p		*0.120*	*0.264*	*0.000*	*0.087*	*0.000*	*0.001*	*0.002*	*0.004*	*0.003*	*0.003*
	$LSD_{0.05}$		-	-	1.1	-	9.9	10.5	16.4	25.4	27.7	24.8

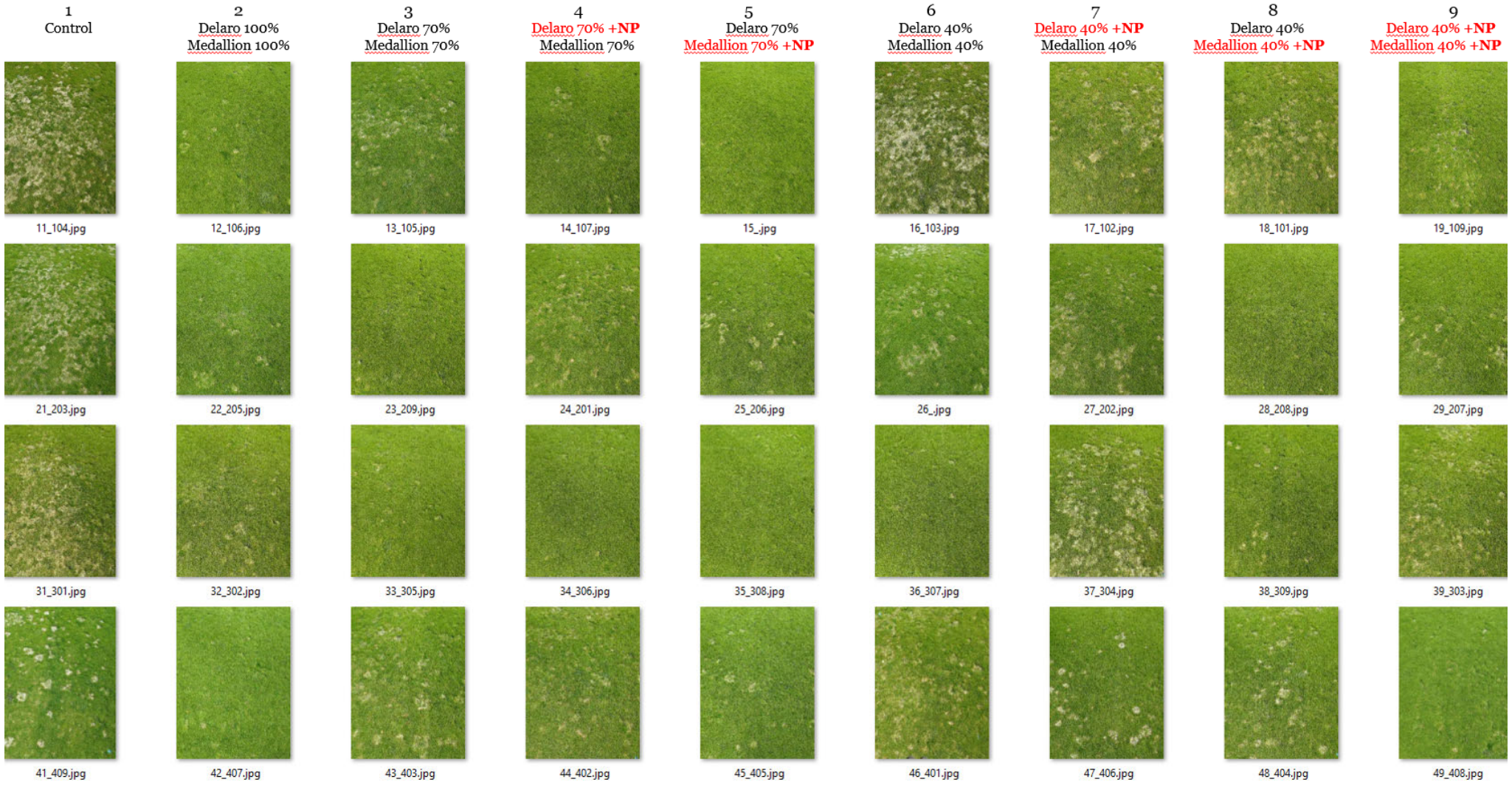
Appendix 4. Effect of NanoPro used as additive to fungicides on turf quality on annual bluegrass green in 2018-19.

Nr.	Treatments: Delaro, % of reccom. dosage	Treatments: Medallion, % of reccom. dosage	Turf quality, scale 1-9 (5=acceptable, 9=best): 19 Sept.	2 Oct.	17 Oct.	31 Oct.	12 Nov.	27 Nov.	2 Jan.	26 Feb.	20 Mar.	23 Apr.
1	0 (control)	0 (control)	6.8	6.4	6.4	5.8	3.1	3.1	3.0	2.4	2.0	2.4
2	100	100	7.0	7.4	7.4	7.4	6.9	6.9	6.6	6.3	6.1	6.0
3	70	70	7.0	7.1	7.1	7.0	5.8	5.8	5.1	5.1	5.0	5.3
4	70+NanoPro	70	6.9	7.3	7.3	7.1	6.0	6.0	5.6	5.3	5.1	5.3
5	70	70+NanoPro	7.1	7.5	7.5	7.5	7.3	7.3	7.1	7.0	6.6	6.6
6	40	40	7.0	7.4	7.4	7.1	4.8	4.8	4.4	3.8	3.6	4.0
7	40+NanoPro	40	7.1	7.4	7.4	7.3	5.6	5.6	5.0	4.1	3.6	4.1
8	40	40+NanoPro	6.8	7.3	7.3	7.0	6.1	6.1	5.9	5.6	5.0	5.3
9	40+NanoPro	40+NanoPro	6.8	6.9	6.9	6.9	6.6	6.6	6.3	5.8	5.8	5.6
	p		*0.727*	*0.002*	*0.002*	*<.0001*	*0.013*	*0.013*	*0.033*	*0.031*	*0.018*	*0.022*
	$LSD_{0.05}$		-	0.5	0.5	0.5	2.0	2.0	2.3	2.5	2.4	2.2

Appendix 5. Effect of NanoPro used as additive to fungicides on microdochium patch on annual bluegrass green on 29 March 2019.



Appendix 6. Effect of NanoPro used as additive to fungicides on microdochium patch on annual bluegrass green on 2 May 2019.



NIBIO
NORWEGIAN INSTITUTE OF
BIOECONOMY RESEARCH

NIBIO - Norwegian Institute of Bioeconomy Research was established July 1 2015 as a merger between the Norwegian Institute for Agricultural and Environmental Research, the Norwegian Agricultural Economics Research Institute and Norwegian Forest and Landscape Institute.

The basis of bioeconomics is the utilisation and management of fresh photosynthesis, rather than a fossile economy based on preserved photosynthesis (oil). NIBIO is to become the leading national centre for development of knowledge in bioeconomics. The goal of the Institute is to contribute to food security, sustainable resource management, innovation and value creation through research and knowledge production within food, forestry and other biobased industries. The Institute will deliver research, managerial support and knowledge for use in national preparedness, as well as for businesses and the society at large.
NIBIO is owned by the Ministry of Agriculture and Food as an administrative agency with special authorization and its own board. The main office is located at Ås. The Institute has several regional divisions and a branch office in Oslo.

Cover photo: 28 March 2019, Tatsiana Espevig

nibio.no