

**Summary and tables/figures from the SFG-funded project  
'BERIGOLF: Benefits and environmental risks of fungicide application on  
Scandinavian golf greens'**

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**Summary**

Two one or two year old USGA-spec. golf greens; one of them a lysimeter facility established with or without organic matter (2,1%, w/w) in the sand-based rootzone (Tables 1 & 2) and seeded to creeping bentgrass (*Agrostis stolonifera*) 'Penn A4'; the other a sand/compost -based green seeded to either a mixture of red fescue (*Festuca rubra*) and browntop bent (*Agrostis capillaris*) or a blend of creeping bentgrass 'Cato' and 'Providence', were sprayed for two consecutive years with the fungicides Sportak EW (prochloraz, 450 g a.i./ha), Amistar Duo (azoxystrobin + propiconazole, 200 + 125 g a.i./ha), or Stratego 312,5 EC (187,5 trifloxystrobin + propiconazole 125 g a.i./ha), either curatively in early September to control take all patch (*Gauemannomyces graminis*) and pythium (*Pythium* spp.), or preventively in late October/early November to control pink (*Microdochium nivale*) and grey (*Typhula* spp.) snow mould. Rovral 75 WG (iprodione, 2250 g a.i./ha) was also included in one experiment, but not in the lysimeter facility. As compared with the unsprayed control treatment, none of the fungicides had any significant effect on take-all patch at the applied rates (Tables 4 and 5), but application of azoxystrobin + propiconazole and trifloxystrobin + propiconazole in early September reduced the occurrence of *Pythium* and/or *Fusarium* during a wet period in late autumn (Table 5). Mixtures of strobilurines and propiconazole were generally more efficient than prochloraz and iprodione in controlling winter diseases (Table 9). Inclusion of organic matter in the rootzone improved root development (Fig. 1) as well as tiller density and overall turfgrass quality (Fig. 1) but resulted also in a greater proportion of the turf area being infected by take-all patch (Tables 3 and 5). Soil samples taken immediately after one of the fungicide applications in the lysimeter facility showed that 26, 56, 21 and 17-34% of the applied rates of prochloraz, azoxystrobin, trifloxystrobin and propiconazole, respectively, could be dissolved from the pure sand, as opposed to only 3, 6, 1 and 1-4 % from the sand/compost (2,1% OM) mixture (Table 6). Rates of prochloraz or trifloxystrobin were not detected in water samples, neither in those taken in the first leachate 1-3 days after treatment, nor in samples pooled over the first month after application. Except for one determination of 0,16 µg/l, traces of propiconazole were also below the environmental safety level (ESL = 0,13 µg/l), set according to international NOEC ('NO Effect Concentration') guidelines (Tables 7-8). Azoxystrobin was found to exceed the ESL limit of 0,90 µg/l on four occasions, the highest value being 2,15 µg/l (Table 7), corresponding to a total leaching of 0,2% of the applied fungicide (Fig. 3). However, as soil organic matter efficiently prevented leaching, at least during the first month after application, high concentrations of azoxystrobin only occurred in leachate from pure sand rootzones. These findings are in general agreement with the sorption coefficients ( $K_d$ ,  $K_{oc}$ ) reported for the various fungicides. Since azoxystrobin + propiconazole and trifloxystrobin + propiconazole appear to have the same effect on turfgrass winter diseases, the latter should be the preferred choice for preventive applications in late autumn. Use of azoxystrobin + propiconazole should be limited to golf greens with organic matter in the rootzone.

**Key words:** Azoxystrobin, *Gauemannomyces graminis*, iprodione, leaching, *Microdochium nivale*, prochloraz, propiconazole, *Pythium*, rootzone organic matter, snow mould, take all, trifloxystrobin.



Table 3. Turfgrass quality (=visual merit, 1-9, 9 is best) and occurrence of take-all patch (*Gaeumannomyces graminis* var. *avena*) on plots with rootzones of pure sand or Green Mix as determined on 3 September and 1 October 2004. Figures for 1 October are means of four fungicide treatments.

	3 Sep 2004				1 Oct 2004				
	Visual merit (1-9)	% of plot infected by take all patch	No of patches per plot (6 m <sup>2</sup> )	Diameter of patches, cm	Visual merit (1-9)	% of plot infected by take all patch	No of patches per plot (6 m <sup>2</sup> )	Diameter of patches Outer, brown ring, cm    Inner, recovered ring, cm	
Pure Sand	4,9	1	1,6	18 ± 2 <sup>1)</sup>	3,7	6	1,6	26 ± 3 <sup>1)</sup>	5 ± 2 <sup>1)</sup>
Green Mix	6,8	4	3,4	20 ± 1 <sup>1)</sup>	4,3	18	3,6	28 ± 1 <sup>1)</sup>	6 ± 2 <sup>1)</sup>
Sign.	***	*	ns	-	ns	ns	ns	-	-

(P=0,09)

<sup>1)</sup>Twelve and twenty-five patches were monitored on plots with pure sand and GreenMix, respectively. ± 1 SE (Standard error or the mean) values are given for these measurements.

Table 4. Effect of fungicide treatments 3 September 2004 on visual merit, turfgrass colour (1-9, 9 is darkest green) and per cent of plot affected by take-all patch as evaluated on 1 Oct 2004.

	Visual merit (1-9)	Colour (1-9)	% of plot infected by take all
Unsprayed control	3,8	4,8	16
Prochloraz	4,0	4,9	10
Azoxystrobin + propiconazole	4,4	5,3	11
Trifloxystrobin + propiconazole	3,9	4,9	13
Sign.	ns	ns	ns

Table 5. Main effects of rootzone compositions and fungicide treatments in autumn 2004 and 2005 on per cent of turf area infected by disease in spring (31 March – 10 June), summer (1 June – 5 September) and autumn (after fungicide application on 5 September) 2005.

	Per cent of turf area affected by disease					
	<i>Gauemannomyces graminis</i>			Other diseases		
	Spring	Summer	Autumn	Spring	Summer	Autumn
Pure Sand	1	1	0	0	0	2
Green Mix	4	11	10	1	1	1
Sign.	**	ns	*	**	ns	ns
	(P=0,06)					
Unsprayed control	3	4	3	1	1	2
Prochloraz	2	5	3	1	1	2
Azoxystrobin + propiconazole	1	8	5	1	0	1
Trifloxystrobin + propiconazole	3	7	8	1	2	1
Sign.	ns	ns	ns	ns	ns	*
LSD 5%	-	-	-	-	-	1

Table 6. Fungicides detected in petri-dishes filled with pure sand or Green Mix that were placed on the plots before spraying on 3 September 2004. (As there was only one replicate per treatment, statistical comparisons of these treatments are not possible. Figures in parantheses indicate the percentage of fungicide applied that was detected in the soil sample)

Product / rate	Fungicide treatment  Active ingredient	Active ingredients extracted from soil sample			
		Pro- chloraz (g/ha)	Azoxy- strobin (g/ha)	Trifloxy- strobin (g/ha)	Propi- conazole (g/ha)
<b>Rootzone: Pure Sand</b>					
Unsprayed control		0,0	0,0	0,0	0,0
Sportak EW, 1,0 l/ha	prochloraz, 450 g a.i. / ha	116,9 (26%)	0,0	0,0	0,0
Amistar Duo, 1,0 l/ha	azoxystrobin, 200 g a.i. / ha + propiconazole, 125 g a.i. / ha	0,0	112,6 (56%)	0,0	42,2 (34%)
Stratego 312,5 EC, 1,0 l/ha	trifloxystrobin, 187,5 g a.i. / ha + propiconazole, 125 g a.i. / ha	0,0	0,0	39,5 (21%)	20,9 (17%)
<b>Rootzone: Green Mix</b>					
Unsprayed control		0,0	0,0	0,0	0,0
Sportak EW, 1,0 l/ha	prochloraz, 450 g a.i. / ha	12,3 (3%)	0,0	0,0	0,0
Amistar Duo, 1,0 l/ha	azoxystrobin, 200 g a.i. / ha + propiconazole, 125 g a.i. / ha	0,0	11,2 (6%)	0,0	5,3 (4%)
Stratego 312,5 EC, 1,0 l/ha	trifloxystrobin, 187,5 g a.i. / ha + propiconazole, 125 g a.i. / ha	0,0	0,0	1,4 (1%)	1,0 (1%)

Table 7. Concentration of fungicides in leachate from plots treated with various fungicides on 27 Oct 2004.

Fungicide treatment	0-2 days after application: Leaching: 14 mm Rainfall: 20 mm				3-25 days after application Leaching: 61 mm Rainfall: 65 mm			
	Pro-chloraz	Azoxy-strobin	Trifloxy strobin	Propi-conazole	Pro-chloraz	Azoxy-strobin	Trifloxy strobin	Propi-conazole
	Rootzone: Pure Sand							
Usprayed Sportak EW (prochloraz)	0,00	0,00	0,01	0,02	0,00	0,00	0,01	0,01
Amistar Duo (Azoxy.+propic.)	0,00	2,15	0,00	0,07	0,00	0,97	0,00	0,02
Stratego 312,5 EC (Triflox.+propic.)	0,00	0,01	0,00	0,04	0,00	0,01	0,00	0,03
	Rootzone: Green Mix							
Usprayed Sportak EW (prochloraz)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Amistar Duo (Azoxy.+propic.)	0,00	0,00	0,00	0,00	0,00	0,02	0,01	0,13
Stratego 213,5 EC (Triflox.+propic.)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01
LSD 5%	ns	ns P=0,17	ns	0,03	ns	ns P=0,12	ns	ns
Detection level Environmental maximum residue level (MRL) *	0,02	0,02	0,01 not determined	0,01	0,02	0,02	0,01 not determined	0,01

\* Set by The Norwegian Environmental Soil Survey Programme (JOVÅ) based on 'No Effect Concentration (NOEC)' guidelines.

Table 8. Concentration of fungicides in leachate from plots treated with various fungicides on 5 Sep 2005.

Fungicide treatment	0-3 days after application: Leaching: 4 mm Rainfall: 3 mm + Irrigation: 6 mm				4-28 days after application Leaching: 67 mm Rainfall: 53 mm			
	Pro-chloraz	Azoxy-strobin	Trifloxy strobin	Propi-conazole	Pro-chloraz	Azoxy-strobin	Trifloxy strobin	Propi-conazole
	Rootzone: Pure sand							
Usprayed Sportak EW (prochloraz)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Amistar Duo (Azox.+propic.)	0,00	1,60	0,00	0,11	0,00	1,40	0,00	0,16
Stratego 250 EC (Triflox.+propic.)	0,00	0,00	0,00	0,06	0,00	0,01	0,00	0,07
Rootzone: Green Mix								
Usprayed Sportak EW (prochloraz)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Amistar Duo (Azox.+propic.)	0,00	0,03	0,00	0,00	0,00	0,00	0,00	0,00
Stratego 250 EC (Triflox.+propic.)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
LSD 5%	ns	0,46	ns	0,05	ns	0,23	ns	0,04
Detection level Environmental maximum residue level (MRL) *	0,02	0,02	0,01	0,01	0,02	0,02	0,01	0,01
	0,44	0,90	not determined	0,13	0,44	0,90	not determined	0,13

\* Set by The Norwegian Environmental Soil Survey Programme (JOVÅ) based on 'No Effect Concentration (NOEC)' guidelines.

Table 9. Effects of preventive fungicide treatments on per cent winter damage on USGA golf greens at the continental location Apelsvoll.

Fungicide treatment	Rate, g a.i./ha	2003-2004		2004-2005		Mean
		<i>Festuca rubra</i> / <i>Agrostis capillaris</i>	<i>Festuca rubra</i> / <i>A. capillaris</i>	<i>Agrostis stolonifera</i>		
Unsprayed	-	65	80	4		50
Prochloraz	450	45	90	2		46
Iprodione	2250	35	60	2		32
Azoxystrobin + propiconazole	200 + 125	30 <sup>§</sup>	35	1		22
Trifloxystrobin + propiconazole	187,5 + 125	20	50	1		24
Sign.		*	*	ns		ns (P=0,09)
LSD 5%		18	35	-		-

<sup>§</sup> On 17 Oct 2003, 'Amistar' was used instead of 'Amistar Duo'. The rate was 187,5 g a.i./ha azoxystrobin. 'Amistar' does not contain propiconazole.



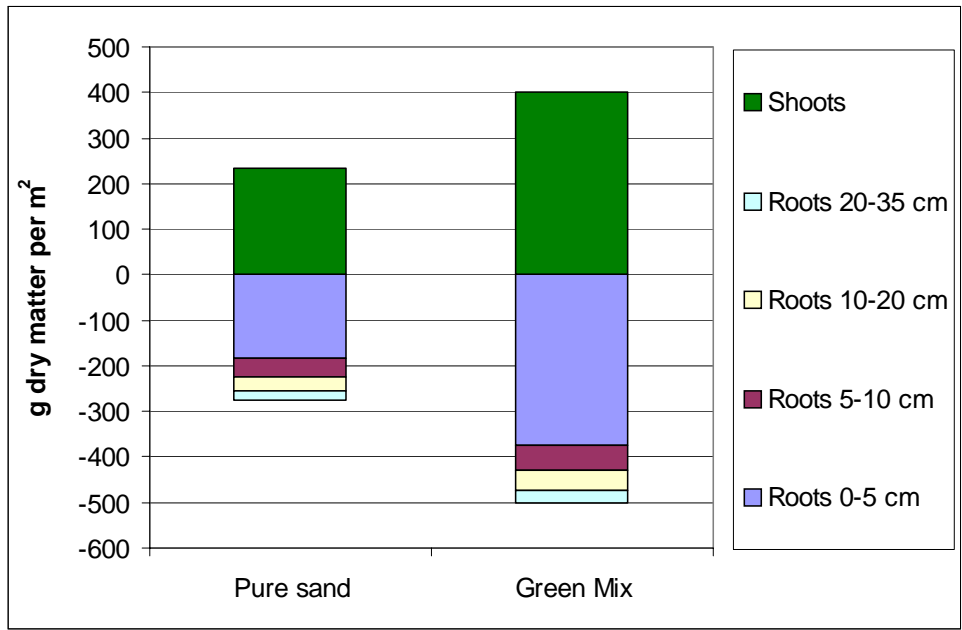


Figure 1. Turfgrass shoot and root weights in various layers as affected by rootzone composition. Samples were taken by the time of first fungicide application in September 2004.

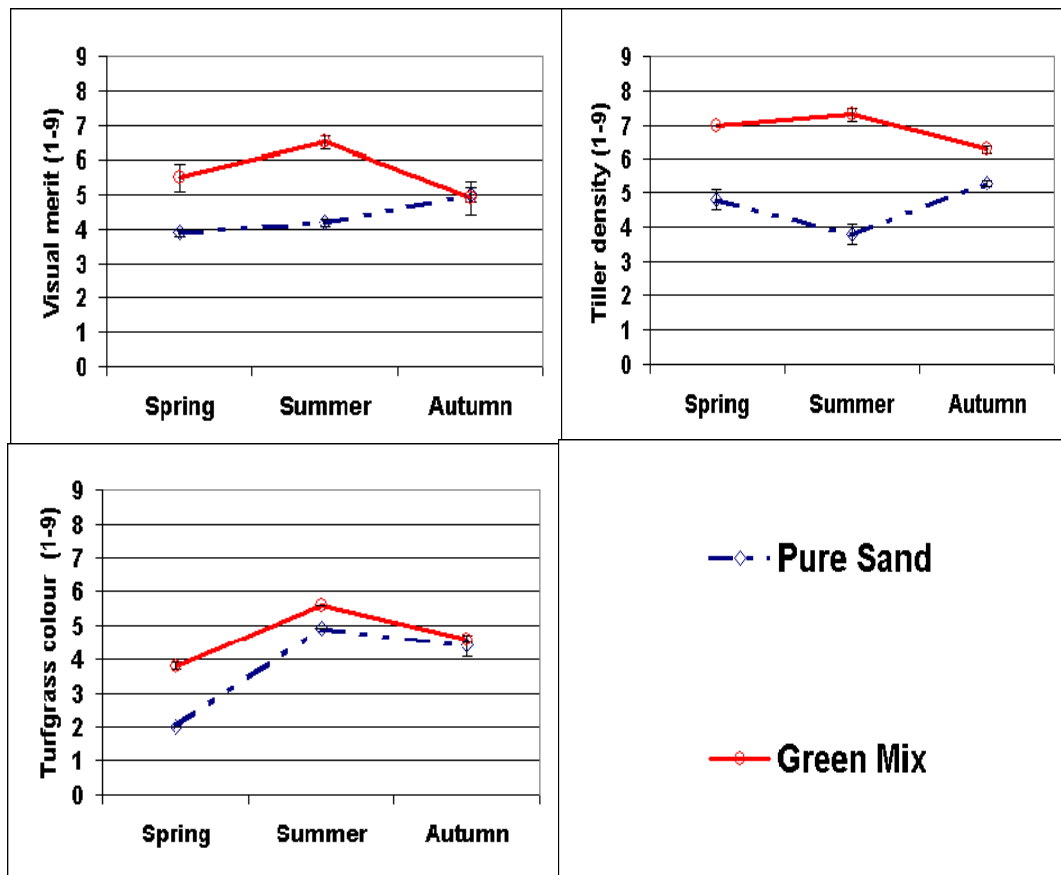


Figure 2. Effects of rootzone composition on visual merit (=overall turfgrass quality), tiller density and turfgrass colour during the season 2005 in the lysimeter experiment at Landvik. Means of various fungicide treatments.  $\pm 1$  SE has been indicated.

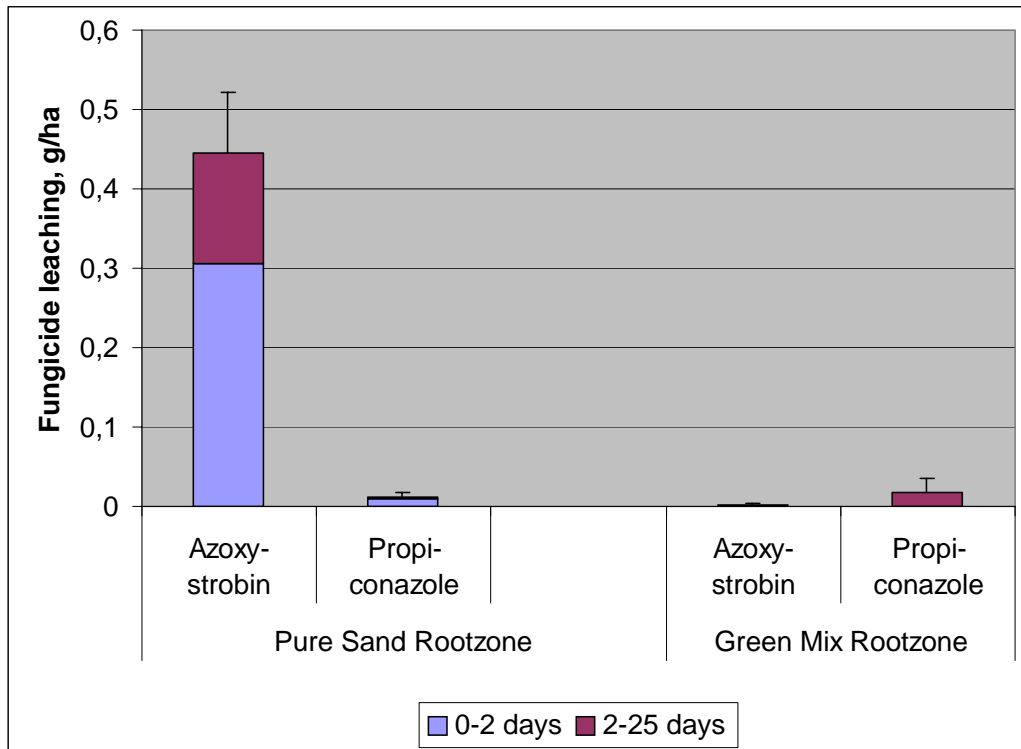


Figure 3. Total amount of azoxystrobin and propiconazole leached from two rootzones during the first two or subsequent twenty-three days after application of Amistar Duo (1 l/ha) on 27 October 2004.  $\pm$  1 SE has been indicated.