Disease control and leaching potential of fungicides on golf greens with and without organic amendment to the sand-based root zone and with and without use of surfactant

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Landvik, N-4886 Grimstad, Norway

The Norwegian Institute for Agricultural and Environmental Research /
Turfgrass diseases are a main concern on European golf courses, especially on *Poa* / bentgrass greens.

Cato +
Providence
Creeping bentgrass
(USA)

Browntop bentgrass,
(N)

Bioforsk
Winter diseases:

Gray snow mold
*(Typhula incarnata)*

Photo: Kristiina Laukkanen
Fruiting bodies of gray snow mold (October)

Photo: Bjørn Molteberg
Pink snow mold
*(Microdochium nivale)*

Photo: Arne Tronsmo
Susceptibility to pink snow mold (*Microdochium nivale*) varies among varieties.
In Scandinavia, turfgrass winter diseases result in the greatest economical losses, but diseases occurring within the growing season are also important

- *Microdochium (Fusarium)* - patch
- Take-all patch (*Gaeumannomyces graminis*)
- *Pythium* spp.
- Antracnose (*Colletotrichum graminicola*)
- (Dollar spot (*Sclerotinia homeocarpa*))
Microdochium patch in November (winter-mild areas)

Photo: Trygve S. Aamlid
Take-all patch
(Gaeumannomyces graminis)

Photo: Trygve S. Aamlid
*Pythium* (‘grease spot’) in newly established creeping bentgrass

- Most common under hot and humid conditions
- Some *Pythium*-species infect the turfgrass root system, even at temperatures as low as 5°C.
Red thread
*(Laetisaria fuciformis)*

In perennial ryegrass

In red fescue
Fairy rings

(*Basidiomycetes*)
Resistant lines

Sprayed plot

Unsprayed plot

Anthracnose
(Colletotricum graminicola)

Mostly in Poa annua
Dollar spot
(Sclerotinia homeocarpa)
(US photo)
To summarize:

The turfgrasses are infeced by a number of diseases. The objective of ’Integrated Pest Management’ is to reduced fungicide use as much as possible, but they can hardly be completely eliminated from our golf courses.

A good compromise is to use fungicides that are more environment–friendly, both to the golfers and to non-target organisms.
Fungicides approved for use on golf courses in the Nordic countries
(1 Sep 2009)

<table>
<thead>
<tr>
<th>Fungicide</th>
<th>Finland</th>
<th>Sweden</th>
<th>Norway</th>
<th>Denmark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iprodion (Rovral / Chipco)</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Bitertanol (Baycor 25 WP)</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thiophanatatmethyl (Topsin WG)</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Prochloraz (Sportak)</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Propiconazole (Tilt)</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tebuconazole (Folicur)</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Azoxystrobin + propiconazole</td>
<td></td>
<td>(X)</td>
<td>(Only azo)</td>
<td>X</td>
</tr>
<tr>
<td>(Amistar Duo)</td>
<td></td>
<td>(Only azo)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trifloxystobin + prococonazole</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>(Stratego)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
’State of the art’

• New fungicides are continuously being developed, many of which require lower amounts of active ingredient and are more environment-friendly than the older products.

• Legislation regarding pesticide approval is probably stricter in the Scandinavian countries than anywhere else in the world, especially for turf. Very few products are approved for use on golf courses.

• A main problem with repeated use of the same fungicides is that resistance may soon develop. This risk is especially high for systemic fungicides, such as DMIs and strobilurines.

• The benefit of introducing new fungicides on the market has to be weighed against unwanted effects, such as toxicity and leaching potential.
What happens to the pesticides after spraying?

- Volatilization (during spraying and shortly afterwards)
  - Dependent on temperature and vapour pressure of active ingredient. Often around 10%.

- Adsorption to soil particles.
  - Depends on clay and organic matter content.
    Sand-based golf greens: % OM is critical!

- Absorption by the plants (the desired effect!)

- Degradation (also desireable, but no too fast!)
  - Phytochemical, chemical or microbial degradation.
    Again, soil OM is critical for spoil microbial life!
  - Half life: An important character describing pesticide persistency.

- Leaching to surface water and ground water!
Some Scandinavian golf course architects are worried about drop in aeration and percolation rates due to accumulation of organic matter and therefore advocate straight sand greens.

How will this affect:

• Disease occurrence?
• Fungicide leaching potential?
The objective of our research has been to:

1. Determine disease control by some of the most commonly used fungicides on golf greens with and without organic amendment to the sand-based rootzone.
2. Determine the leaching potential of commonly used fungicides from rootzones with and without organic amendment.
3. Determine the impact of fungicides on soil microbial life.
4. Determine the effect of surfactants on turfgrass quality and fungicide leaching.
In 2003, Bioforsk constructed a 32-plot field lysimeter facility at Landvik, Norway.
From the construction phase
Root zones with straight USGA-spec. sand and 20% compost amendment (GM: Green Mix)
# Soil analyses

<table>
<thead>
<tr>
<th></th>
<th>Ignition loss %</th>
<th>pH (H₂O)</th>
<th>P-AL mg/100g</th>
<th>K-AL mg/100g</th>
<th>Mg-AL mg/100g</th>
<th>Ca-AL mg/100g</th>
<th>CEC meq/100g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straight sand</td>
<td>0.4</td>
<td>6.6</td>
<td>1.3</td>
<td>2.1</td>
<td>2.1</td>
<td>17</td>
<td>0.4</td>
</tr>
<tr>
<td>Green Mix</td>
<td>2.1</td>
<td>7.5</td>
<td>6.3</td>
<td>6.9</td>
<td>8.8</td>
<td>173</td>
<td>5.4</td>
</tr>
<tr>
<td>Sign.</td>
<td>***</td>
<td>*</td>
<td>***</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>***</td>
</tr>
</tbody>
</table>
Experimental plan

FACTOR 1: Root zone

1. Straight sand
2. Green Mix (garden compost)

FAKTOR 2: Fungicide applications in Sept. and Oct.,

A. Unsprayed control
B. Prochloraz (Sportak EW), 1 L (0.45 kg a.i.) ha\(^{-1}\)
C. Azoxystrobin + propiconazole (Amistar Duo),
   1 L (= 0.20 + 0.125 kg a.i.) ha\(^{-1}\)
D. Trifloxystrobin + propiconazol (Stratego 250 EC),
   1 L (= 0.125 + 0.125 kg a.i.) ha\(^{-1}\)
- The green was seeded in September 2003
- Fungicide treatments were initiated in September 2004, after grow-in was completed.
- At this stage there was starting attack of take-all (*Gaeumannomyces graminis*), mostly on plots with garden compost in the rootzone

<table>
<thead>
<tr>
<th>Straight sand:</th>
<th>Green Mix:</th>
</tr>
</thead>
<tbody>
<tr>
<td>No organic matter</td>
<td>20% (v/v) garden compost</td>
</tr>
</tbody>
</table>
First application of fungicides to one year old green

Straight sand

Green Mix (compost)
Effect of first fungicide application on the number and size of take-all patches

Outer diameter (‘Infection’)

Inner diameter (‘Recovery’)

Bioforsk

Scandinavian Turfgrass Research Foundation
### Take-all: Main effects

<table>
<thead>
<tr>
<th></th>
<th>Evalutation one month after fungicide application</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of patches per plot 6 m²</td>
</tr>
<tr>
<td>Straight sand</td>
<td>1.6</td>
</tr>
<tr>
<td>Green Mix (20% compost)</td>
<td>3.6</td>
</tr>
<tr>
<td>Sign.</td>
<td>*</td>
</tr>
<tr>
<td>Unsprayed control</td>
<td>2.8</td>
</tr>
<tr>
<td>Prochloraz</td>
<td>2.0</td>
</tr>
<tr>
<td>Azoxyystrobin + propicaonazole</td>
<td>3.3</td>
</tr>
<tr>
<td>Triflloxystrobin + propicaonazole</td>
<td>2.5</td>
</tr>
<tr>
<td>Sign.</td>
<td>ns</td>
</tr>
</tbody>
</table>
Why did not azoxystrobin have any significant effect on the take-all disease in this trial?

• Too late application?
• Too low dosage (0.20 kg a.i./ha)?
• Too low application volume (250 L/ha)?
Effect on winter diseases
(Spring 2005)
Effects of root zone composition and profylactic fungicide application on winter diseases in spring

- Effect of root zone: ns
- Effect of fungicide: P<0.05
These results from Landvik confirm earlier results from the Bioforsk inland location Apelsvoll.
<table>
<thead>
<tr>
<th>Fungicides against winter diseases, inland location Apelsvoll 2004-05</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dosage</strong></td>
</tr>
<tr>
<td>Unsprayed control</td>
</tr>
<tr>
<td>Prochloraz (Sportak)</td>
</tr>
<tr>
<td>Iprodione (Rovral)</td>
</tr>
<tr>
<td>Azoxystrobin + propiconazole (Amistar Duo)</td>
</tr>
<tr>
<td>Trifloxoxystrobin + propiconazole (Stratego)</td>
</tr>
</tbody>
</table>
To summarize:
Fungicides that contain two or more active ingredients with different chemistries / modes of action, are the most efficient to control winter diseases and also imply the lowest risk for fungicide resistance to develop.

But what about the risk for fungicide leakage?
Fungicide leakage?

Green Mix plot

Straight sand plot
# Detection of fungicides in drain discharge, µg/L

## Straight sand root zones

<table>
<thead>
<tr>
<th></th>
<th>0-48 h after application</th>
<th></th>
<th>2 – 25 days after application</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Drain discharge: 14 mm</td>
<td>Drain discharge: 61 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Prochloraz</strong></td>
<td>Prochloraz</td>
<td>Azoxystrobin</td>
<td>Trifloxystrobin</td>
<td>Propiconazol</td>
</tr>
<tr>
<td>Unsprayed</td>
<td>0.00</td>
<td>0.00</td>
<td>0.01</td>
<td>0.02</td>
</tr>
<tr>
<td>Sportak EW (prochloraz)</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Amistar Duo (Aoxyst. + propic.)</td>
<td>0.00</td>
<td><strong>2.15</strong></td>
<td>0.00</td>
<td>0.07</td>
</tr>
<tr>
<td>Stratego 250 EC (Triflox. + propic.)</td>
<td>0.00</td>
<td>0.01</td>
<td>0.00</td>
<td>0.04</td>
</tr>
<tr>
<td><strong>No effect limit</strong></td>
<td><strong>0.44</strong></td>
<td>0.90</td>
<td>0.19</td>
<td>0.13</td>
</tr>
</tbody>
</table>
## Detection of fungicides in drain discharge, µg/L

Green Mix root zones (compost)

<table>
<thead>
<tr>
<th></th>
<th>0-48 h after application</th>
<th>2 – 25 days after application</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Draiu discharge: 14 mm</td>
<td>Drain discharge : 61 mm</td>
</tr>
<tr>
<td>Pro klor az</td>
<td>Azoxy strobin</td>
<td>Tri floxy-strobin</td>
</tr>
<tr>
<td>Spray treatment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unsprayed</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Sportak EW (prochloraz)</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Amistar Duo (Aoxyst. + propic.)</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Stratego 250 EC (Triflox. + propic.)</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>No effect limit</td>
<td>0.44</td>
<td>0.90</td>
</tr>
</tbody>
</table>
What proportion of the applied amount of fungicide was found in discharge?

<table>
<thead>
<tr>
<th>Total leakage, ug/m²</th>
<th>Day no 3-28 after spraying</th>
<th>First two days after spraying</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straight sand 0% compost</td>
<td>0.2%</td>
<td>0.001%</td>
</tr>
<tr>
<td>Straight sand 20% compost</td>
<td>0.01%</td>
<td>0.01%</td>
</tr>
<tr>
<td>20% compost</td>
<td>0.01%</td>
<td></td>
</tr>
</tbody>
</table>

Azoxystrobin

Propiconazole
Leakage can be explained from how strongly the fungicides are bound to soil organic matter (and how quickly they are degraded)

<table>
<thead>
<tr>
<th>Sorption $K_{OC}$ (mg/g)</th>
<th>Half life days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trifloksystrobin (Stratego / Compass)</td>
<td>2377</td>
</tr>
<tr>
<td>Prokloraz (Sportak)</td>
<td>2225</td>
</tr>
<tr>
<td>Propikonazol (Tilt m.fl.)</td>
<td>1086</td>
</tr>
<tr>
<td>Azoxystrobin (Amistar / Heritage)</td>
<td>423</td>
</tr>
</tbody>
</table>

Increasing risk for leakage
How does other fungicides fit into this picture?

<table>
<thead>
<tr>
<th>Fungicide</th>
<th>Sorption $K_{OC}$ (mg/g)</th>
<th>Half life days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pyraclostrobin (Comet)</td>
<td>11000</td>
<td>32</td>
</tr>
<tr>
<td>Trifloksystrobin (Stratego / Compass)</td>
<td>2377</td>
<td>7</td>
</tr>
<tr>
<td>Prokloraz (Sportak)</td>
<td>2225</td>
<td>556</td>
</tr>
<tr>
<td>Propikonazol (Tilt m.fl.)</td>
<td>1086</td>
<td>214</td>
</tr>
<tr>
<td>Pikoxystrobin (Acanto)</td>
<td>898</td>
<td>20</td>
</tr>
<tr>
<td>Tebuconazole (Folicur)</td>
<td>769</td>
<td>62</td>
</tr>
<tr>
<td>Azoxystrobin (Amistar / Heritage)</td>
<td>423</td>
<td>21</td>
</tr>
<tr>
<td>Iprodion (Rovral / Chipco G.)</td>
<td>373</td>
<td>84</td>
</tr>
</tbody>
</table>

Increasing risk for leakage
Effects of fungicides on the number of soil microbiota

a) Aerobic bacteria

- More aerobic soil bacteria in compost-amended than in straight sand root zones.
- No effect of fungicides on total bacterial number, but perhaps on bacterial diversity?
To summarize

- Inclusion of 20% (v/v) garden compost into the sand-based root zone did not result in control of either take-all patch or turfgrass winter diseases. However, inclusion of 20% compost improved turfgrass visual quality and eliminated fungicide leaching from the golf green.

- None of the fungicides, even not azoxystrobin + propiconazole given at the approved rate of 0.20 kg a.i. + 0.125 kg a.i. provided control of take-all patch. Probable reasons for this are too late application, too low rates and/or too low water volumes.

- Applied in combination with propiconazole, the strobilurines azoxystrobin (in Amistar Duo) and trifloxystobin (in Stratego) were equally effective to control turfgrass winter diseases. Since azoxystrobin is more prone to leaching than is trifloxystrobin, Stratego should be preferred to Amistar Duo for profylactic applications, at least on straight sand root zones.

- Fungicide use does not lower microbial numbers in turfgrass soils. There may, however, be an effect on microbial diversity.
We have seen that straight sand root zones are susceptible to fungicide leaching. Is there nothing we can do to reduce leaching from such root zones?

What about surfactants?

During the past four years, Bioforsk has evaluated the surfactants Primer 604 and Revolution.
Water droplet penetration tests performed on soil samples from many of the straight sand plots used in this study indicated extreme soil water repellency (SWR)
## Water droplet penetration times

<table>
<thead>
<tr>
<th>Depth</th>
<th>1 cm</th>
<th>2 cm</th>
<th>3 cm</th>
<th>5 cm</th>
<th>10 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straight sand, no surfactant</td>
<td>6 min</td>
<td>21 min</td>
<td>30 min</td>
<td>20 min</td>
<td>3 sec</td>
</tr>
<tr>
<td></td>
<td>11 sec</td>
<td>40 sec</td>
<td>15 sec</td>
<td>50 sec</td>
<td></td>
</tr>
<tr>
<td>Straight sand, monthly application of Primer 604</td>
<td>44 sec</td>
<td>37 sec</td>
<td>21 sec</td>
<td>11 sec</td>
<td>2 sec</td>
</tr>
<tr>
<td>Green Mix (20% compost), no surfactant</td>
<td>8 min</td>
<td>1 min</td>
<td>28 sec</td>
<td>5 sec</td>
<td>2 sec</td>
</tr>
<tr>
<td></td>
<td>51 sec</td>
<td>46 sec</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green Mix, monthly application of Primer 604</td>
<td>3 sec</td>
<td>2 sec</td>
<td>2 sec</td>
<td>2 sec</td>
<td>2 sec</td>
</tr>
</tbody>
</table>

- **Highest water repellency on straight sand plots**
- **Significant effect of surfactant**
Soil water content at various depths before winter

- Primer 604 caused higher water content in thatch layer. This may be negative for winter hardening!
The following spring:

<table>
<thead>
<tr>
<th></th>
<th>% injury from pink snow mold</th>
</tr>
</thead>
<tbody>
<tr>
<td>No surfactant</td>
<td>31 %</td>
</tr>
<tr>
<td>Primer 604</td>
<td>64 %</td>
</tr>
</tbody>
</table>
Effect of Primer 604 on leaching of azoxystrobin from straight sand rootzones

![Graph showing leaching reduction](image)

- **Jun 06**: After two apps. of wetting agent
- **Jul 06**: After three apps. of wetting agent
- **Oct. 06 and Apr. 07**: After five apps. of wetting agent

**Concentration, ug/l**
- Without... With Primer...

**Total leaching, ug/m²**
- Without... With Primer...

**Reduction**
- 91% reduction
- 98% reduction
- 72% reduction
- 26% reduction

**Concentration**
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0
- 6.0
- 7.0
- 8.0

**Total leaching, ug/m²**
- 0
- 20
- 40
- 60
- 80
- 100
- 120
- 140
- 160

**Legend**
- Concentration, ug/l
- Total, ug/m²
Effect of Primer 604 on leaching of propiconazole from straight sand rootzones

Jun 06: After two apps. of wetting agent  
Jul 06: After three apps. of wetting agent  
Oct 06 and Apr 07: After five apps. of wetting agent
Effect of Primer 604 on leaching of iprodione from straight sand rootzones

Jun. 06: After two apps. of wetting agent
Jul. 06: After three apps. of wetting agent
Oct. 06 and Apr. 07: After five apps. of wetting agent
To summarize

The widely used surfactant Primer 604 resulted in

• Less dry spots / soil water repellency

• More water in thatch layer and thus more winter diseases

• 85 % reduction in fungicide leaching
Experiments with the ’novel’ surfactant ’Revolution’, 2007

FACTOR 1: Root zone

1. Straight sand
2. Sand + 30 % Sphagnum-peat

FACTOR 2: Fungicid / surfactant

A. Azoxystrobin + propiconazole (Amistar Duo)
   3 l/ha = 0.6 + 0.375 kg a.i. /ha.

B. As C + monthly application of Revolution (20 L + 730 L water /ha)
10 Sept  2007

Straight sand, no surfactant

Straight sand, Revolution
Unlike Primer 604, Revolution decreased the average soil water content in the thatch on peat-amended rootzones.
Effect of the Revolution on the concentration of azoxystrobin in leakage water (mean of two collection periods)

Concentration, ug/l

- No surfactant: 87% reduction
- Revolution: 79% reduction

EU no impact value

Straight sand 30% (v/v) peat
Effect of Revolution on the concentration of nitrate in leakage water

(mean of two collection periods)

Concentration, mg/l

87% reduction

56% reduction

No surfactant
Revolution

Straight sand
30% peat
Final conclusion

• Revolution had the same positive effect on turfgrass quality and fungicide leaching as Primer 604. It also reduced the leaching of nitrate.

• Unlike Primer 604, the these positive effects of Revolution were not accompanied by any negative effect on thatch water content.

• All in all, regular use of surfactant seems to reduce the risk of fungicide leaching from straight sand golf greens by 80-95 %.
Thanks for your attention and welcome to visit our research facilities in Scandinavia!