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Evaluation of the plant growth regulator Primo MAXX® (trinexapac-ethyl) on Nordic golf courses

Results from the second evaluation year 2008 and recommendations

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Research technician Trond Pettersen measures ball roll distance in a Primo MAXX® green trial at Landvik, Norway, 2008. Photo: Trygve S. Aamlid

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Evaluation of the plant growth regulator Primo®MAXX® (trinexapac-ethyl) on Nordic golf courses. Results from the second evaluation year 2008 and recommendations.

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Summary:

This report presents second year results and recommendations based on a two year project evaluating the plant growth regulator Primo MAXX® (trineexapac-ethyl) on Nordic golf courses.

Sammendrag:

I denne rapporten presenteres andre års resultater og anbefalinger basert på et toårig prosjekt med utprøving av vekstreguleringsmidlet Primo MAXX® (trinexapac-etyl) på golfbaner i Norden.

Approved 19 Jan. 2009

Arne Sæbø

Leader,
Bioforsk's Section
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Project leader

Contents

1. Abstract

The plant growth regulator Primo MAXX® (trinexapac-ethyl) offers prospects for reduced mowing costs, lower CO_2-emissions, better winter survival, and improved playing quality on turfgrass areas used for golf. As the second in a series of two, this report presents results and recommendations from the final year (2008) of a two year project evaluating Primo MAXX® on Nordic golf courses. The project was funded by the Scandinavian Turfgrass and Environment Research Foundation (STERF) and Syngenta, and carried out by Bioforsk and MTT, the state agricultural research institutes in Norway and Finland, respectively. In addition to the official 'Good Experimental Practice' (GEP) trials needed for potential registration of Primo MAXX®, unreplicated demonstration trials were carried out on Norwegian Golf Courses under supervision of Bioforsk and with funding from the Norwegian Golf Federation (NGF).

GEP trials established in 2007 on greens and fairways at Landvik, Norway (58°34'N, 8°52'E), and Lepaa, Finland (61°08'N, 24°20'E), were followed up by registrations of turfgrass winter damage in spring 2008. While no winter damage was observed at Landvik, monthly applications of Primo MAXX®, with the last application on 4 Oct. 2007, resulted in significantly less snow mold (*Microdochium nivale*) and tendencies to higher overall turfgrass appearance in both the green and fairway trial at Lepaa.

New GEP trials were established on a creeping bentgrass green at Landvik and a Kentucky bluegrass / red fescue fairway at Lepaa in 2008. Because of the discoloration and post-suppression rebound effects reported in 2007, Primo MAXX® was applied more frequently and at lower rates than in 2007. In the green trial, weekly or biweekly applications of 0.15, 0.30 and 0.45 L ha^{-1} (17, 34 or 51 g a.i. trinexapac-ethyl ha^{-1}) were compared with an unsprayed control treatment. On average for rates, frequencies and fifteen to seventeen observation dates, Primo MAXX® resulted in significantly lower clipping yield (-25%), significantly longer ball roll distance (+6%), and a tendency (*P*=0.07) to lower plant height (-16%) than on unsprayed control plots. Primo MAXX® gave significantly darker color, but had no effect on turfgrass overall appearance or density. Differences between application rates were not significant for any character, and differences between application frequencies were significant only for turfgrass color.

In the new fairway trial at Lepaa, biweekly applications of Primo MAXX® resulted in significant reductions is clipping yields varying from 15% at the lowest (0.4 L ha^{-1}) to 34% at the highest (1.2 L ha^{-1}) rate. These reductions were accompanied by smaller, but significant reductions in plant height. The effects on turfgrass overall appearance, color or density were not significant.

In demonstration trials on Norwegian golf courses, the average increases in ball roll distance from repeated application of 0.30 L ha^{-1} Primo MAXX® varied from 3 to 8%. An initial application at this rate resulted in discoloration in one out of three green trials, while initial applications of 0.8 and 1.0 L ha^{-1} resulted in loss of turfgrass quality in trials on a fairway and a semirough, respectively. These effects were temporary as the turfgrass recovered within 3-4 weeks and sometimes acquired better quality than in the unsprayed control treatment after the second application.

In conclusion, we consider the documentation presented in this report to be sufficient to recommend Primo MAXX® being labeled for use on Nordic golf courses. We suggest that the following rates and application frequencies be printed on the label:

	Primo MAXX®, rate*	Application interval
Greens (creeping bentgrass)	0.2 – 0.4 L ha^{-1}	Every one to two weeks
Fairways (Kentucky bluegrass / red fescue)	0.6 – 1.2 L ha^{-1}	Every two to three weeks
Roughs & semi-roughs (Kentucky bluegrass / red fescue)	1.0 - 2.0 L ha^{-1}	Every three to four weeks

*Always use lowest rate for the first seasonal application of Primo MAXX®.

Key words: fairway, golf, green, plant growth regulator, Primo MAXX®, rough, trinexapac-ethyl

2. Introduction

The project 'Evaluation of the plant growth regulator Primo MAXX® (trinexapac-ethyl) on Nordic golf courses' started in 2007 with funding from Scandinavian Turfgrass and Environment Research Foundation (STERF), Syngenta, and the Norwegian Golf Federation. The background for the project and results from the first experimental year were presented by Aamlid et al. (2008). The results showed that the guidelines for use of Primo MAXX® in other European countries and North America were not directly applicable in the Nordic countries. Reductions in clipping yields were generally unstable, with significant reductions during the first one to two weeks after application often being followed by post-suppression rebound effects (Lickfeldt et al. 2001) three to six weeks after application. In some cases Primo MAXX® also caused discoloration and significant reductions in turfgrass overall appearance, especially if applied at high rates.

The results were discussed in a meeting between representatives for STERF and Syngenta on 26 March 2008. Besides following up the trials established in 2007 with observations of winter damage in spring 2008, it was decided to initiate new trials with lower rates and more frequent applications of Primo MAXX® to golf course greens and fairways. The present report provides results from these trials and gives recommendations for approval on Primo MAXX® on Nordic golf courses.

Photo 1. First application of Primo MAXX® in new fairway traial at Lepaa, Finland, 7 May 2008.

Photo: Oiva Niemelainen.

3. Methods

3.1. Follow-up registrations in trials established 2007

Three trials conducted according to Good Experimental Practice standard investigated the effects of Primo MAXX® in 2007:

1. Green trial at Lepaa, Finland (61°08'N, 24°20'E)
2. Fairway trial at Lepaa, Finland
3. Fairway trial at Landvik, Norway (58°34'N, 8°52'E; see map in Fig. 1)

Experimental procedures and results from 2007 were presented by Aamlid et al. (2008). In spring 2008, the three trials were followed up by registrations of snow mold infection (per cent of plot area), per cent green cover, and turfgrass overall appearance (1-9, 9 is best). At Lepaa, turfgrass height growth was also recorded.

The demonstration trials conducted on the Norwegian golf courses Ballerud and Bogstad GC in 2007 (Aamlid et al. 2008) were not followed up with any registrations in 2008.

3.2. New trials established 2008

3.2.1. GEP trial on a new creeping bentgrass green at Landvik, Norway

Preparation of experimental site

A new experimental USGA spec. green was constructed at Bioforsk Landvik Research Station (58°34'N, 8°52'E), South East Norway, in 2007. The root zone mineral matter consisted of 0.6% fine gravel (2-4 mm), 4.7% very coarse sand (1-2 mm), 27.1% coarse sand (0.5-1.0 mm), 48.6% medium sand (0.25-0.50 mm), 13.0% fine sand (0.125-0.250 mm), 1.5% very fine sand (0.063-0.125 mm) and 4.5% silt and clay (<0.063 mm) (European Turfgrass Laboratory, Stirling, Scotland). Soil samples taken in April 2008 showed 1.0% (w/w) ignition loss due to addition of 10% (v/v) well-humified peat to the sand during construction. Samples taken in October 2008 indicated a pH (H_2O) of 5.6 and low contents of phosphorus, potassium, magnesium and calcium (P-AL =1.0; K-AL=2.1; Mg-AL=1.7 and Ca-AL=11).

The green was seeded with creeping bentgrass (*Agrostis stolonifera*) 'Independence', 6.25 g m^{-2}, on 29 August 2007. After seeding, the green was covered with a permeable white tarp for about two weeks. Irrigation was accomplished several times per day after seeding and four times per week during a six week period with no natural rainfall from 2 May till 13 June 2008. During the grow-in period 29 Aug. - 15 Oct. 2007 and 15 Apr. - 17 June 2008, the green received mineral fertilizer (Andersson 13-2-13 and Arena Products, Hydro Agri, Landskrona, Sweden) at one to two week intervals, totaling 2.3 kg N, 0.4 kg P and 2.3 kg K (100 m^2)$^{-1}$. In spring and early summer 2008, the green was overseeded with creeping bentgrass 'Independence', 2.0 g m^{-2}, on 25 Apr., top-dressed four times totaling 2.0 mm of washed sand (0.2-0.8 mm, Baskarp, Sweden), aerated twice with 8 mm solid spikes and sprayed twice with surfactants (Primer 604 and Revolution, both at rates 18.5 L ha^{-1}) to prevent soil water repellency. Mowing height was gradually lowered from 9 mm at the first mowing after seeding on 26 Sep. 2007 and 5 mm at the first mowing after winter on 11 Apr. 2008 to 3.0 mm at the last mowing before the first application of Primo

MAXX® on 17 June 2008. At this point in time, the green had a uniform turf cover corresponding to 93% of the surface area (Photo 2).

Photo 2. Experimental green ready for the first application of Primo MAXX® on 17 June 2008.
Photo: Trygve S. Aamlid

Experimental plan

The trial was laid out according to a randomized complete block design with gross plot size L x W = 2.5 m x 2.0 m, three blocks (replicates) and the following treatments:

1. Usprayed control
2. Primo MAXX®, 0.15 L ha^{-1} (17 g a.i. ha^{-1}) every week
3. Primo MAXX®, 0.30 L ha^{-1} (34 g a.i. ha^{-1}) every week
4. Primo MAXX®, 0.45 L ha^{-1} (51 g a.i. ha^{-1}) every week
5. Primo MAXX®, 0.15 L ha^{-1} (17 g a.i. ha^{-1}) every second week
6. Primo MAXX®, 0.30 L ha^{-1} (34 g a.i. ha^{-1}) every second week
7. Primo MAXX®, 0.45 L ha^{-1} (51 g a.i. ha^{-1}) every second week

Primo MAXX® was applied in accordance with the Norwegian 'Good Experimental Practise' Protocol, (Tørresen 2007), using an experimental backpack plot sprayer (Oxford / LTI) working at 150-200 kPa pressure. The spraying boom had three nozzles (Teejet 11002) spaced 50 cm apart. The boom provided full coverage of the central 1.0 m in each plot which was later used for all registrations. The spraying volume corresponded to 300 L ha^{-1}. Actual application rates were recorded by weighing the tank before and after spraying. Table 1 shows actual rates and weather conditions for each spraying event. As far as weather permitted, spraying was accomplished every Tuesday morning.

Table 1. Application dates, weather conditions at application and actual application rates at the eighteen spraying events.

Appli-cation date	Time of day (hours)	Weather conditions at application			Treatment number / application rate (mL Primo MAXX® per ha)					
		Air temp. °C	Relative Humidity %	Wind Speed m s^{-1}	2. (target 150)	3. (target 300)	4. (target 450)	5. (target 150)	6. (target 300)	6. (target 450)
17 June	08-10	13.4	74	1.2	148	319	490	148	319	490
24 June	08-10	10.8	56	2.0	173	360	450	-	-	-
1 July	08-10	15.1	57	1.7	141	289	467	141	289	467
8 July	19-21	15.1	64	1.0	167	293	440	-	-	-
15 July	07-09	15.8	80	2.6	159	289	433	159	289	433
22 July	07-09	16.2	87	0.1	153	280	440	-	-	-
29 July	08-10	20.4	63	0.4	141	273	456	141	273	456
5 Aug.	07-09	14.5	68	1.4	160	280	460	-	-	-
12 Aug.	08-09	12.7	91	0.3	156	273	422	156	273	422
19 Aug.	08-09	11.4	90	0.1	140	333	500	-	-	-
26 Aug.	08-09	15.4	91	1.2	144	281	410	144	281	410
2 Sep.	08-09	10.8	91	0.3	147	280	420	-	-	-
9 Sep.	07-09	13.0	88	1.9	156	304	444	156	304	444
16 Sep.	18-19	10.0	66	1.1	153	293	440	-	-	-
23 Sep.	08-09	8.6	88	0.9	148	273	410	148	273	410
1 Oct.	09-10	6.7	89	0.7	160	307	460	-	-	-
7 Oct.	09-10	4.1	86	0.4	133	296	444	133	296	444
13 Oct.	08-10	6.9	81	1.0	167	307	460	-	-	-
Mean		12.3	78	1.0	153	296	447	147	289	442

Registrations

Throughout the experimental period 17 June – 1 Nov. 2008, turfgrass overall appearance, color and tiller density were assessed once a week using a scale from 1 to 9, where 9 is the best turf quality, darkest color, and highest density. Turfgrass height was recorded as the mean of three random measurements using a Turf Check Prism device (Check Signature Inc., Shoreview, MN) every Monday morning. After the height measurements, the green was mowed and the fresh weight of clippings weighed from the central 1.94 m x 0.56 m = 1.0864 m^2 area in each plot. The registrations of clipping weights on 14 July and 22 September were later discarded due to heavy loads of sand in the baskets, leaving a total of fifteen observations for this character. Daily height growth (mm) and daily production of clippings (g fresh weight per m^2) were recalculated from mowing heights and the number of days since last mowing (usually three).

Ball roll distance was measured every Tuesday afternoon, i.e. about 30 h after last mowing, using a stimpmeter modified for research plots (Gaussion et al. 1995). This stimpmeter had its ball release notch 38 cm rather than 76 cm from the beveled end, and measurements were always taken in two directions (Photo 3).

Management during the experimental period

The trial was mowed with a walk-behind greens mower every Monday, Wednesday and Friday morning. Mowing height was 3 mm from 17 June until 22 Sep., after which it was raised at 0.5 mm increments until 4.5 mm at the last mowing on 27 Oct. Following every mowing, the turf was exposed to abrasive wear and compaction corresponding to 30000 rounds of golf per year using a tractor-pulled drum with golf spikes attached. Granular fertilizer was applied every second week as shown in Photo 4 and Table

2. The green was verticut three times and top-dressed five times, but to avoid interference with clipping weights, the total amount of sand only corresponded to 1.5 mm. Irrigation was accomplished after each application of fertilizer and/or top-dressing, and otherwise up to four times a week based on pan evaporation values.

Photo 3. Research technician Trond Pettersen measuring ball roll distance using a modified stimpmeter with 38 cm distance from the notch to the beveled end. Photo: Trygve S. Aamlid.

Table 2. Fertilizer inputs during the experimental period 17 June – 1 Nov. 2008, green trial, Landvik.

		kg per 100 m^2								
Date	**Fertilizer type**	**product**	**N**	**P**	**K**	**Mg**	**S**	**Ca**	**Fe**	**Mn**
18 June	Arena Green Pluss 12-1-14	1.60	0.192	0.016	0.232	0.032	0.096	0.034	0.000	0.006
30 June	Arena Green Pluss 10-1-10	0.80	0.080	0.008	0.080	0.004	0.062	0.006	0.008	0.003
30 June	Ammoniumsulfate	0.70	0.148	0.000	0.000	0.000	0.169	0.000	0.000	0.000
04 July	Arena Høst Extra 3-3-15	1.00	0.032	0.033	0.146	0.012	0.123	0.000	0.068	0.004
15 July	Arena Score Extra 13-1-16	1.40	0.181	0.020	0.224	0.025	0.139	0.000	0.028	0.006
31 July	Andersson 13-2-13	1.40	0.182	0.012	0.151	0.000	0.256	0.000	0.028	0.001
12 Aug.	Arena Green Pluss 10-1-10	1.80	0.180	0.018	0.180	0.009	0.139	0.013	0.018	0.007
26 Aug.	Arena Golf 13-0-15	1.00	0.130	0.000	0.150	0.016	0.134	0.000	0.002	0.001
11 Sep.	Arena Green Pluss 10-1-10	0.90	0.090	0.009	0.090	0.005	0.069	0.006	0.009	0.004
24 Sep.	Andersson 13-2-13	0.60	0.078	0.005	0.065	0.000	0.110	0.000	0.012	0.001
14 Oct.	Arena Score Extra 13-1-16	0.50	0.065	0.007	0.080	0.009	0.050	0.000	0.010	0.002
28 Oct.	Arena Høst Extra 3-3-15	0.67	0.021	0.022	0.098	0.008	0.082	0.000	0.046	0.003
	Sum		1.379	0.150	1.496	0.120	1.428	0.058	0.229	0.038

Photo 4. Application of granular fertilizer with an experimental plot spreader, September 2008. Application was conducted perpendicularly to plot direction. Random patches of take-all (*Gaeumannomyces graminis*) can be seen on some plots. Photo: Trygve S. Aamlid.

Weather data

The first application of Primo MAXX®, on 17 June coincided with the end of a six week warm and dry period starting on 2 May. The other important deviation from 30 year normal values was a two weeks period with very high rainfall in early August (Table 3). The first night with freezing temperature was 27 Oct.

Table 3. Weather data for Landvik meteorological station, about 200 m from experimental field. Normal values for temperature and rainfall are 'official' values from the period 1961-90, while normal values for irradiance are calculated averages for the period 1994-2007.

	Mean temperature, °C		Precipitation, mm		Irradiance, MJ m^{-2} (305-2800 nm)	
	2008	30 yr normal	2008	30 yr normal	2008	14 yr average
May	11.9	10.4	19	82	695	540
June	14.7	14.7	75	71	670	600
July	17.3	16.2	101	92	643	632
Aug.	15.6	15.4	250	113	455	476
Sep.	11.6	11.8	137	136	234	262
Oct.	7.9	7.9	153	160	152	132
Mean / sum	13.2	12.7	735	654	2849	2642

3.2.2. GEP trial on a bluegrass / fescue fairway, Lepaa, Finland

Experimental site

A new fairway trial was established at the Lepaa Unit of the HAMK University of Applied Sciences, Lepaa, Finland (61°08'N, 24°20'E) on 5 May 2008 (Photo 1). The Lepaa golf course is used for educational and research purposes and is, at the same time, a pay-and-play course open to the public. Daily management of the trial and all observations were carried out by the HAMK Lepaa team.

The main turfgrass species on the fairway were Kentucky bluegrass *(Poa pratensis)*, chewings fescue *(Festuca rubra* ssp. *commutata)* and annual bluegrass *(Poa annua)*. The soil was heavy with a particle size distribution of 47.7% clay (<0.002 mm), 33.4% silt (0.002-0.06 mm) and 20.9% sand (0.06 – 2 mm).

Experimental plan

The experiment was laid out according to a randomized complete block design with gross plot size L x W = 3.0 m x 2.0m, four blocks (replicates) and the following treatments:

1. Unsprayed control
2. Primo MAXX®, 0.4 L ha^{-1}(45.2 g a.i. ha^{-1}) every second week
3. Primo MAXX®, 0.8 L ha^{-1} (90.4 g a.i. ha^{-1}) every second week
4. Primo MAXX®, 1.2 L ha^{-1} (135.6 g a.i. ha^{-1}) every second week
5. Primo MAXX®, 1.6 L ha^{-1} (180.8 g a.i. ha^{-1}) every second week

The net plot size receiving full coverage of Primo MAXX® was 1.5 m x 2.5 m and the area to be used in all recordings 1.0 m x 2.0 m. Application of Primo MAXX® was carried out by the MTT Agrifood Research certified spraying team according to the Finnish 'Good Experimental Practice' Protocol. A portable, 'van der Weij' -type plot sprayer, powered by compressed air and with a windshield and flat-fan nozzles (Hardi 4110-12) was used (Photo 1). The 2.0 m spraying boom had four nozzles spaced 50 cm apart The spraying pressure was 180-250 kPa and the spraying volume 200 L ha^{-1}. Application dates and weather conditions are given in Table 4.

Table 4. Application dates for Primo MAXX® and weather conditions in the Lepaa fairway trial, 2008.

Application date	Time of day (hours)	Air temp. °C	Relative Humidity, %	Wind speed m s^{-1}	% cloud cover
5 May	10-11	10.6	64	4.5	30
22 May	10-11	13.3	35	2.5	10
4 June	10-11	16.1	44	1.0	0
19 June	11-12	16.7	58	5.0	80
2 July	11-12	15.8	80	1.0	70
17 July*	8-9	15.0	86	1.5	99
31 July	9-10	19.4	56	2.0	0
12 Aug.	9-11	18.1	75	2.5	80
27 Aug.	10-11	12.3	73	1.0	100
9 Sep.	10-11	10.4	69	1.5	40
23 Sep.	10-11	10.3	84	0.0	60
Mean	-	14.4	66	2.0	52

* On 17 July plot 405 (treatment 4) accidentally received also the treatment 5 rate. This plot was therefore excluded from registrations on 24 July.

Registrations

The following registations were carried out every second week throughout the experiment, always one week after application of Primo MAXX®:

- Plant height, using a TurfCheck Prism device (Check Signature Inc., Shoreview, MN).
- Weight of clippings collected from the central 2 x 0.6 m area in each plot. Clippings were collected in a basket on the central back unit of a triplex green mower and dried at 105 ºC for 36 h before weighing. Based on the number of days since last mowing (usually between one and four), clipping weight was recalculated as gram daily dry matter production per m^2.
- Overall appearance (visual merit, 1-9, 9 is best)
- Tiller density (1-9, 9 is most dense)
- Color (1-9, 9 is darkest green)

Because of several consecutive days with rainfall, registrations on 19 Aug. (one week after application of Primo MAXX® on 12 Aug.) had to be cancelled.

Management during the experimental period

The fairway was mowed on average three times per week. A triplex fairway mower was used and clippings returned except for the biweekly registrations of clipping yields. Mowing height varied from 12 to 18 mm depending on the time of season.

The fairway maintained good growth and color with only one fertilizer application for the whole season: Greencare 13-3-11 was applied on 29 May at a rate corresponding to 22 kg N, 5 kg P and 18 kg K ha^{-1}. Irrigation was performed when considered necessary; irrigation quantities are given in Table 5.

Weather data

The weather conditions during the experimental period were close to the long term averages (Table 5). However, the latter part of August was exceptionally rainy and October was much (2.5 ºC) warmer than the 30 yr normal values.

Table 5. Weather and irrigation data for Lepaa in 2008. Thirty year (1971-2000) normal values for temperature and precipitation are from the Finnish Meteorological Institute weather stations Hattula Lepaa and Hämeenlinna Katinen, respectively.

	Mean temperature, °C		Precipitation, mm		Irrigation, mm
	2008	30 yr normal	2008	30 yr normal	2008
May	10.2	9.8	26	34	16
June	14.0	14.5	83	55	18
July	16.4	16.4	33	80	33
Aug.	14.2	14.6	108	74	1
Sep.	8.8	9.4	26	54	0
Oct.	7.0	4.5	107	55	0
Mean / sum	11.8	11.5	382	352	68

3.2.3. Demonstration trial at Byneset GC, Trondheim, Norway

On 7 Aug. 2008 large scale demonstration trials with low and high rates of Primo MAXX® were established on green, fairway and semiroughs at Byneset GC, Trondheim (Fig. 1, Photo 5). The plant cover on the green was 50% creeping bentgrass and 50% annual bluegrass, and on the fairway and semirough 40% Kentucky bluegrass and 60% red fescue. Mowing heights were 3.8 mm on the green, 15 mm on the fairway and 25 mm on the semirough. Application dates and rates of Primo MAXX® are given in Table 6. Turfgrass color and overall appearance were evaluated five times in August and September.

Table 6. Application dates rand rates in demonstration trials at Byneset GC, Trondheim.

Date	Green		Fairway		Semirough	
	Low rate	High rate	Low rate	High rate	Low rate	High rate
7 Aug.	0.30 L ha^{-1}		0.80 L ha^{-1}		1.0 L ha^{-1}	
14 Aug.		0.60 L ha^{-1}		1.60 L ha^{-1}		2.0 L ha^{-1}
21 Aug.	0.30 L ha^{-1}		0.80 L ha^{-1}		1.0 L ha^{-1}	
8 Sep.		0.60 L ha^{-1}		1.60 L ha^{-1}		1.0 L ha^{-1}
23 Sep.	0.30 L ha^{-1}		0.80 L ha^{-1}		1.0 L ha^{-1}	

Photo 5.

Greenkeeper Atle Haug showing the semirough trial at Byneset GC, 9 Aug. 2008.

Photo: Trygve S. Aamlid

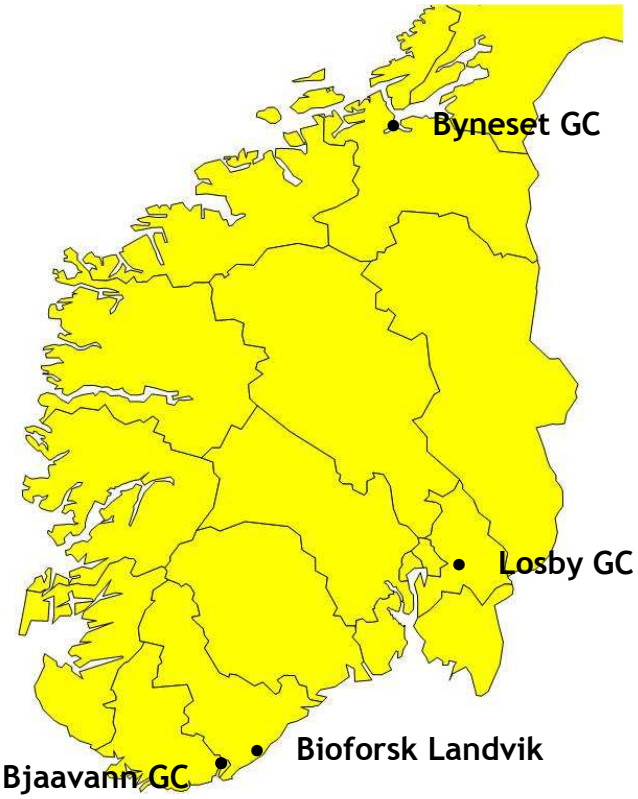


Fig. 1.

Map of South Norway showing experimental sites.

3.2.4. Demonstration trial at Losby GC, Lørenskog, Norway

A ten-year old practice green built according to USGA specifications and with a plant cover of 80% creeping bentgrass (originally 'Penncross', later overseeded with 'Penn A-4') and 20% annual bluegrass (*Poa annua)* was used for this demonstration trial (Photo 6). The green was split into three equal parts. Treatment 1 received Primo MAXX® at a rate of 0.15 L ha^{-1} on 20 June and 0.30 L ha^{-1} on 4 July, 18 July, 5 Aug. and 18 Aug. In treatment 2 the rate was doubled to 0.30 L ha^{-1} at the first application and 0.60 L ha^{-1} at later applications. Treatment 3 was the unsprayed control treatment. Turfgrass overall appearance and color were assessed seven times and clipping yields weighed three times during the season.

3.2.5. Demonstration trial at Bjaavann GC, Kristiansand, Norway

The third demonstration trial was established on 27 July 2008 on an intensely trafficked practice green just outside the club house at Bjaavann GC, Kristiansand, about 50 km from Landvik research station (Fig. 1). The green was a straight sand construction (California green) with a plant cover of creeping bentgrass (originally 'Pennlinks', but overseeded with 'Penn A-4', 'Penn G-6' and 'Independence'). In 2008, the green was fertilized at one to two week intervals, mostly with Floratine products, for a total of 1.90 kg N, 0.29 kg P and 1.99 kg K $(100\ m^2)^{-1}$. The southern half of the green was sprayed with Primo MAXX®, 0.3 L ha^{-1}, on 27 July, 26 Aug., 11 Sep. and 9 Oct, the northern half of the green being maintained as an unsprayed control. During the experimental period, the green was mowed at 3.2 mm from 27 July till 26 Aug. and at 3.6 mm after that. Registrations included turfgrass color, overall appearance and ball roll distance (using an ordinary stimpmeter) at one to two week intervals. Clipping yields were weighed on 9 Oct.

Photo 6.

Former head-greenkeeper Michael Waldner showing the green demonstration trial at Losby GC, 13 Oct. 2008.

Photo: Trygve S. Aamlid

3.3. Statistical calculations and presentation of results

The experimental data from the GEP trials at Landvik and Lepaa were subjected to conventional analyses of variance (PROC ANOVA, Statistical Analyses System). These analyses were conducted both separately for each observation date and on values which had been averaged over the whole growing season. In the green trial at Landvik, treatment effects were split into the orthogonal contrasts (1) no Primo MAXX® vs. Primo MAXX®; (2) application every week vs. every second week; (3) rate of Primo MAXX®; and (4) The interaction application interval x application rate. While the significance symbols ***, **, * (*) and ns have been used to indicate, in turn, the probability levels $P<0.001$, $P<0.01$, $P<0.05$, $P<0.1$, and $P> 0.1$, in tables and figures, least significant differences (LSD values) in tables and the term 'significant' in the text always refer to $P<0.05$. As an indication of the variability for each character, coefficients of variation (CV %) have also been given in the tables.

4. Results

4.1. Follow-up of trials established 2007

4.1.1 . Green trial, Lepaa, Finland

Monthly applications of Primo MAXX® in 2007, the last on 4 Oct. had a positive effect on winter survival of creeping bentgrass (50% 'Penn A-4' and 50% 'Penn G-6') in the green trial at Lepaa (Table 7). When evaluated on 11 Apr., shortly after snow melt, all rates of Primo MAXX® significantly reduced snow mold infection (mostly *Microdochium nivale*, Photo 7) compared with the unsprayed control treatment. On the same date, per cent green ground cover tended (*P*=0.07) to be higher after applications of 0.4 L ha^{-1} than after use of either lower or higher rates, and a similar tendency was recorded also for turfgrass overall appearance one week later (*P*=0.09). However, at the final recording on 6 May (Photo 8), there was a tendency (*P*=0.07) for the best green cover to be found on plots that had received the highest rate of Primo MAXX® in 2007

Table 7. Turfgrass overwintering and spring growth characteristics in Lepaa green trial after six applications of Primo MAXX® in 2007 (last application on 4 Oct.) All values are means of four blocks.

	Snow mold infection (%) 11 Apr.	Green ground cover (%) 11 Apr.	Overall appearance (1-9) 18 Apr.	Turfgrass height (mm) 18 Apr	Live green cover (%) 6 May	Overall appearance (1-9) 6 May
0 = Control	7	63	5.8	6.8	71	5.8
0.2 L ha^{-1}	3	60	6.0	6.3	79	6.3
0.4 L ha^{-1}	3	71	6.3	6.0	78	6.3
0.6 L ha^{-1}	2	69	6.0	6.0	79	6.3
0.8 L ha^{-1}	2	64	5.5	6.0	84	6.8
Sign.	*	(*)	(*)	ns	(*)	ns
LSD 5%	4	-	-	-	8	-
CV%	68	8	6	10	7	8

The significance symbols ***, **, * (*), and ns indicate the probability levels *P*<0.001, *P*<0.01, *P*<0.05, *P*<0.1, and *P*> 0.1, respectively.

Photo 7.

Typical patch of pink snow mold, *Microdochium nivale*, in green trial at Lepaa.

Photo taken on 11 Apr. 2008 by Oiva Niemelainen.

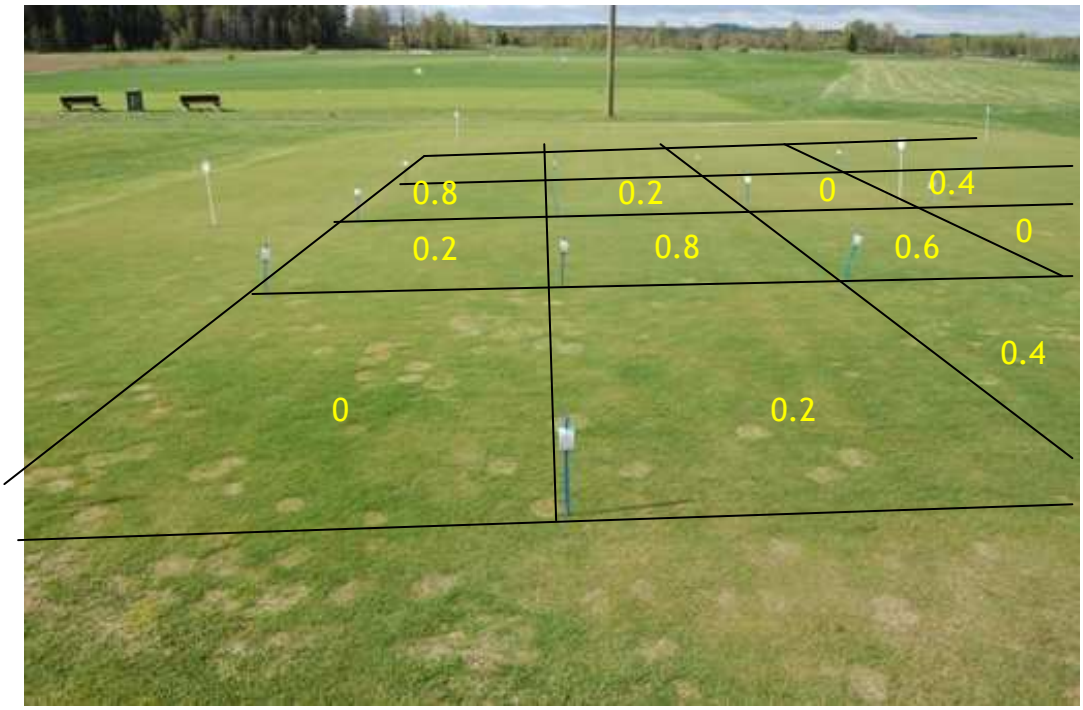


Photo 8. Snow mold patches and overall appearance in part of green trial at Lepaa, 6 May 2008. Figures indicate rate of Primo MAXX® (L ha^{-1}) sprayed at the monthly applications in 2007. Photo: Oiva Niemelainen.

4.1.2 . Fairway trials

No snow mold infection or other types of winter damage were observed in the fairway trial conducted at Landvik, Norway, in 2007 (data not shown). In the fairway trial at Lepaa, Finland, plots that had received monthly applications of Primo MAXX® at rates 1.0 L ha^{-1} or higher in 2007 had significantly less snow mold than unsprayed control plots on 11 Apr. (Table 8). One week later, turfgrass height was significantly lower on plots that had received 1.5, 2.0 or 3.0 L ha^{-1}, but there was also a trend to lower overall appearance in these treatments on these than in the control treatment. On 6 May, all plots had recovered completely from winter damage and there were no differences in ground cover or overall appearance.

Table 8. Turfgrass overwintering characteristics in Lepaa fairway trial after six applications of Primo MAXX® in 2007 (last application on 4 Oct.) All values are means of four blocks.

	Snow mold infection (%) 11 Apr.	Overall appearance (1-9) 18 Apr.	Turfgrass height (mm) 18 Apr.	Live green cover (%) 6 May	Overall appearance (1-9) 6 May
0 = Control	17	5.0	19.3	93	7.0
0.5 L ha^{-1}	15	5.5	19.3	94	7.3
1.0 L ha^{-1}	11	5.0	18.5	94	7.5
1.5 L ha^{-1}	5	4.5	16.5	93	7.5
2.0 L ha^{-1}	2	4.5	16.0	93	7.8
3.0 L ha^{-1}	1	3.8	16.0	91	7.8
Sign.	***	(*)	***	ns	ns
LSD5%	5	-	1.5	-	-
CV%	41	15	10	3	6

The significance symbols ***, **, * (*), and ns, indicate the probability levels P<0.001, P<0.01, P<0.05, P<0.1, and P> 0.1, respectively.

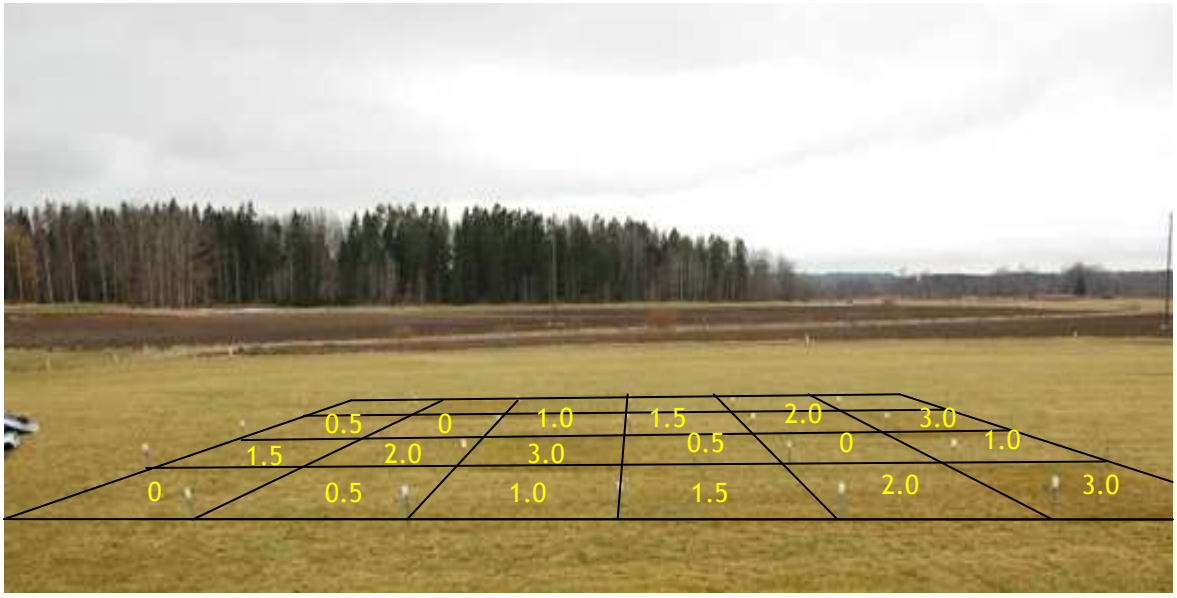


Photo 9. Fairway trial at Lepaa, 11 Apr. 2008. Figures indicate rate of Primo MAXX® (L ha^{-1}) used at the monthly applications in 2007. Photo: Oiva Niemelainen.

4.2. New trials established 2008

4.2.1. Green trial, Landvik, Norway

Application of Primo MAXX® had no significant effect on turfgrass overall appearance or tiller density, but resulted in a darker and more grayish color of creeping bentgrass in the green trial at Landvik (Table 9, Photo 10). Small patches of take-all (*Gaeumannomyces graminis*) were observed in August and September (Photo 4), but the disease occurred randomly, irrespective of experimental treatments. Ball roll distance was significantly longer and clipping yields significantly lower on plots with Primo MAXX®, than on plots without Primo MAXX®, but the other contrasts revealed no effect of application interval or application rate on any of these characters. This was also the case for daily height increment, which according to the first contrast tended (P=0.07) to be lower on plots sprayed with Primo MAXX® than on unsprayed control plots.

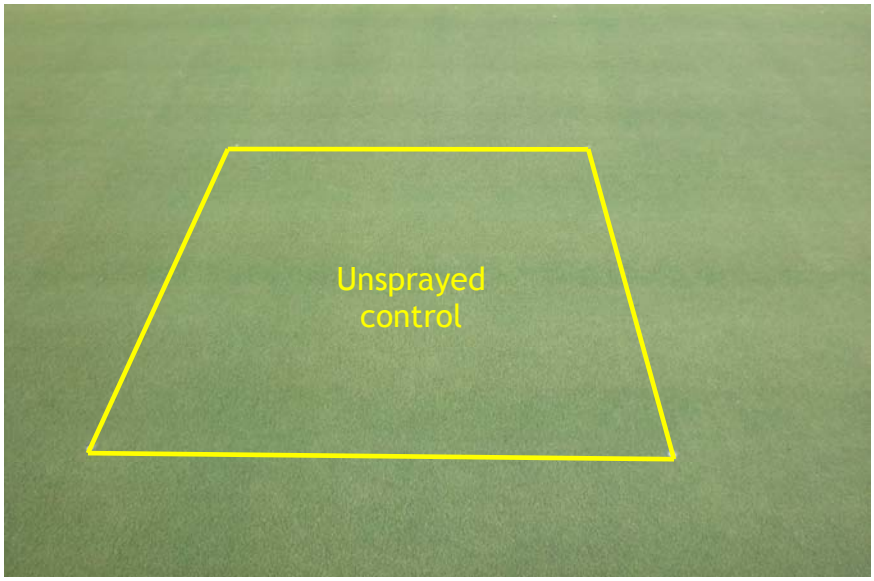


Photo 10.

Unsprayed control plot surrounded by plots sprayed with Primo MAXX® in green trial at Landvik, 10 Sep. 2008.

Photo:
Trygve S. Aamlid.

Table 9. Results of contrast analysis on the effect on Primo MAXX® on turfgrass overall apperance, turfgrass color, turfgrass tiller density, ball roll distance (measured with a 38 cm long stimpmeter), daily height growth and daily fresh weight production of turfgrass clippings in the creeping bentgrass green trial at Landvik in 2008. Mean of fifteen observations.

	Turfgrass overall appearance (1-9)	Turf-grass color (1-9)	Turfgrass tiller density (1-9)	Ball roll distance, cm	Daily height increment, mm	Turf-grass clippings g m^{-2} d^{-1}
Contrast 1.						
No Primo MAXX®	6.5	5.5	6.2	119	0.93	2.42
Primo MAXX®	6.3	6.1	6.3	126	0.78	1.82
Sign.	ns	*	ns	**	(*)	**
Contrast 2. Application interval						
Every week	6.5	6.3	6.4	126	0.76	1.77
Every second week	6.1	5.9	6.2	126	0.79	1.86
Sign.	ns	*	ns	ns	ns	ns
Contrast 3. Application rate						
0.15 L ha^{-1}	6.3	5.8	6.1	124	0.78	1.85
0.30 L ha^{-1}	6.5	6.2	6.5	126	0.82	1.90
0.45 L ha^{-1}	6.3	6.3	6.4	127	0.72	1.72
Sign.	ns	ns	ns	ns	ns	ns
Overall ANOVA	ns	ns	ns	(*)	ns	(*)
CV%	12	7	5	3	16	16

The significance symbols ***, **, * (*), and ns indicate the probability levels *P*<0.001, *P*<0.01, *P*<0.05, *P*<0.1, and P> 0.1, respectively.

Absolute and relative clipping yield at the individual registrations during the growing season are shown in Fig. 2. The contrast 'No Primo MAXX® vs. Primo MAXX®' was significant at five and showed tendencies at another two of the fifteen observations. On average for all observations, reductions in turfgrass height growth and fresh weight clipping yield were 16 and 25 %, respectively. The most consistent effect of Primo MAXX® on clipping yield was found in September (Fig. 2).

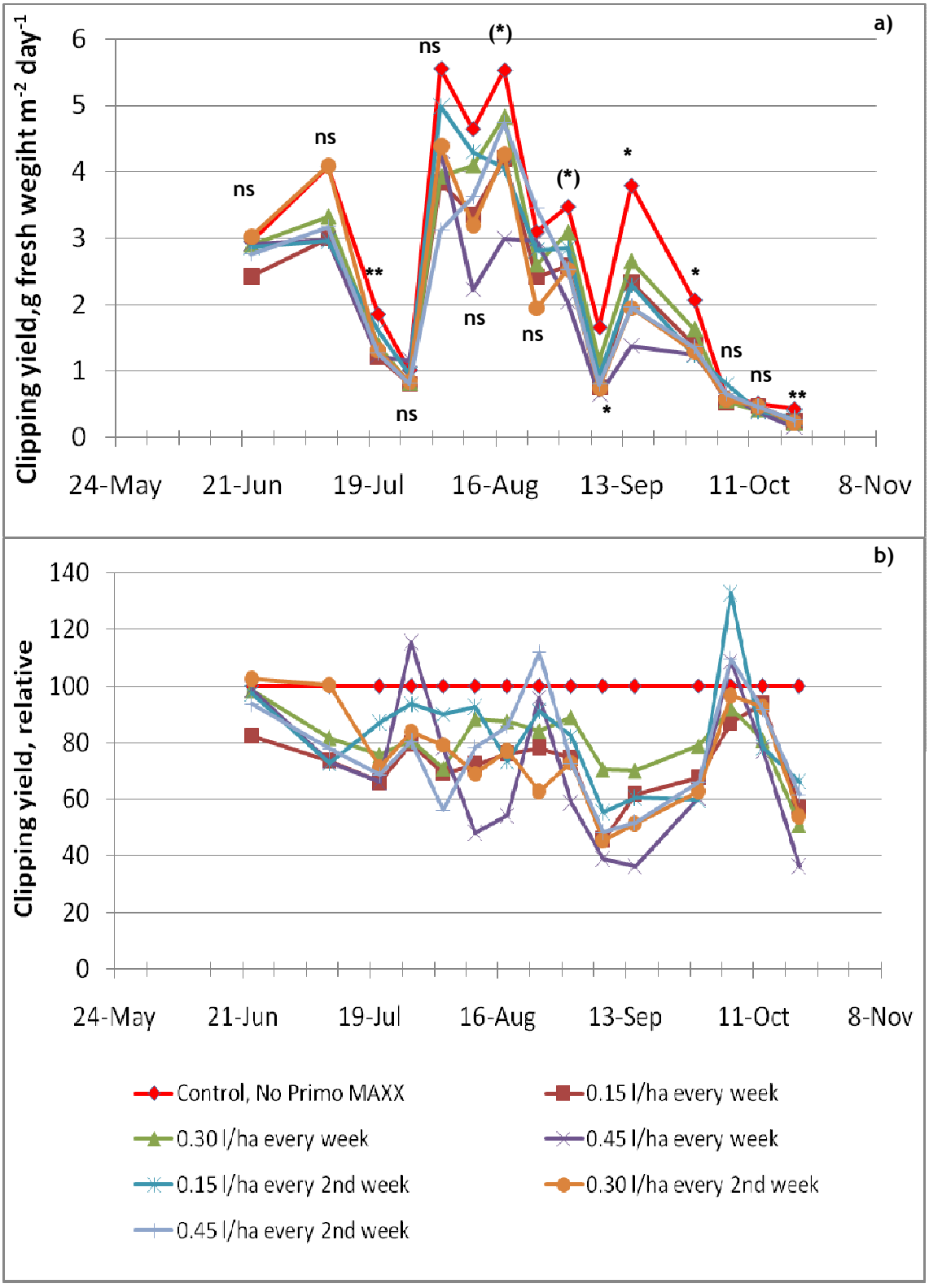


Fig. 2. Absolute (a) and (b) relative (unsprayed = 100) clipping yields in green trial at Landvik, 2008. The significance symbols ***, **, * (*), and ns have been used to indicate, in turn, the probability levels *P*<0.001, *P*<0.01, *P*<0.05, *P*<0.1, and P> 0.1 for the contrast 'No Primo MAXX® vs. Primo MAXX®'. Recordings on 14 July and 22 Sep. were discarded due to sand in the samples.

4.2.2. Fairway trial, Lepaa, Finland

Primo MAXX® had no effect on turfgrass overall appearance, tiller density or color in the new fairway trial at Lepaa. Primo MAXX® reduced turfgrass height growth significantly if applied at 0.4 L ha^{-1} and at rates 1.2 L ha^{-1} or higher. Clipping yield reductions vareied from 15% at 0.4 L ha^{-1} to 34% at 1.2 L ha^{-1} (Table 10). These reductions were consistent except for the first observation, and there were no signs of rebound effects (Fig. 3).

No diseases were observed in the fairway trial at Lepaa.

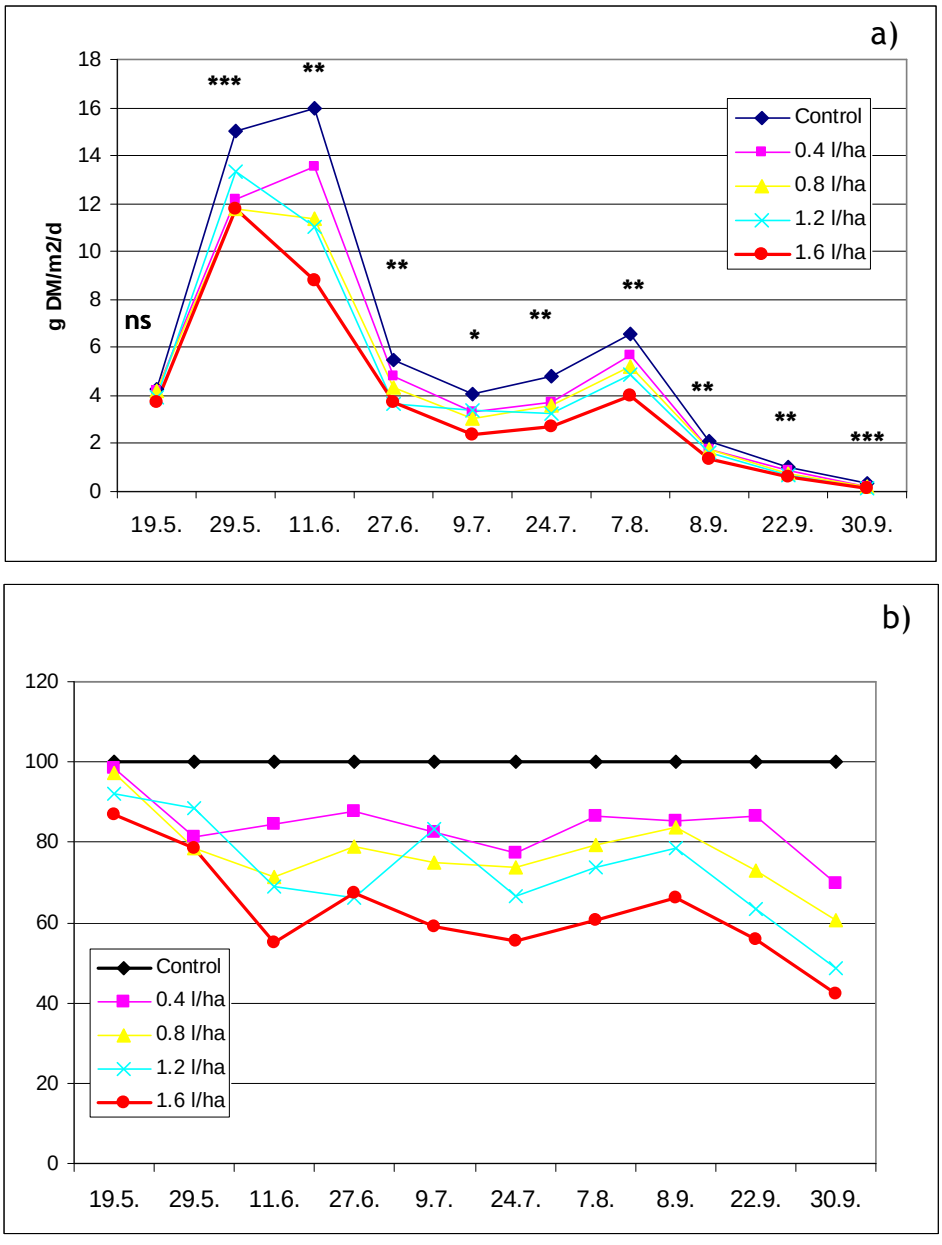


Fig. 3. Absolute (a) and (b) relative (unsprayed = 100) clipping yields in fairway trial at Lepaa, 2008. The significance symbols ***, **, * (*), and ns indicate the probability levels *P*<0.001, *P*<0.01, *P*<0.05, *P*<0.1, and P> 0.1, respectively.

Table 10. Turfgrass overall impression, tiller density, and color in fairway trial at Lepaa as affected by increasing rates of Primo MAXX® in 2008. Means of ten observations for general impression, tiller density, plant height, and clipping yield, and nine observations for color. All values are means of four blocks. Observations were conducted one week after the last application of Primo MAXX®.

Primo MAXX® rate	Overall appearance (1-9)	Tiller density (1-9)	Turfgrass color (1-9)	Plant height		Daily production of clippings	
				mm	Rel.	g DM m^{-2} d^{-1}	Rel.
0 = Control	6.2	5.3	6.1	16.4	100	5.97	100
0.4 L ha^{-1}	6.1	5.3	5.9	15.6	95	5.05	85
0.8 L ha^{-1}	6.2	5.3	6.0	15.8	96	4.62	77
1.2 L ha^{-1}	6.2	5.3	5.9	15.0	91	4.59	77
1.6 L ha^{-1}	6.2	5.3	6.0	15.0	91	3.92	66
Sign.	ns	ns	ns	**	-	***	-
LSD 5%	-	-	-	0.8	-	0.45	-
CV%	2	0	3	3		6	

The significance symbols ***, **, * (*), and ns indicate the probability levels *P*<0.001, *P*<0.01, *P*<0.05, *P*<0.1, and *P*> 0.1, respectively.

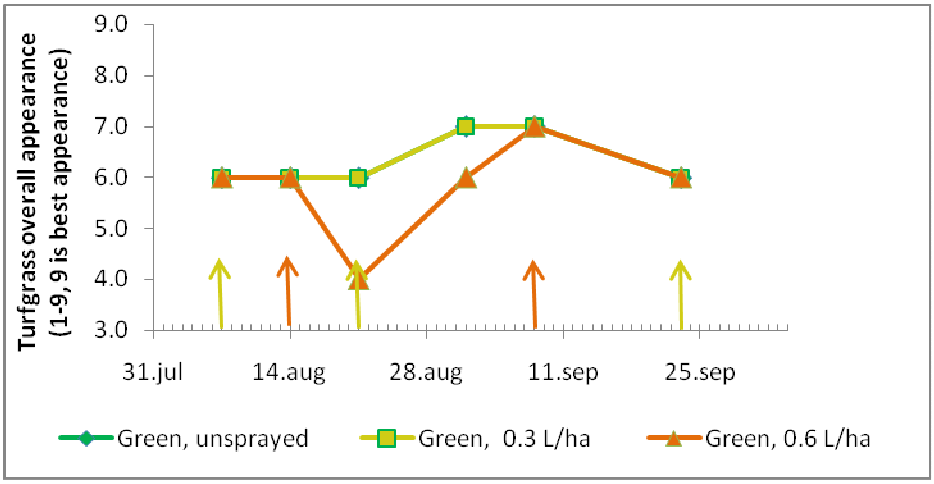
4.2.3. Demonstration trial at Byneset GC, Trondheim, Norway

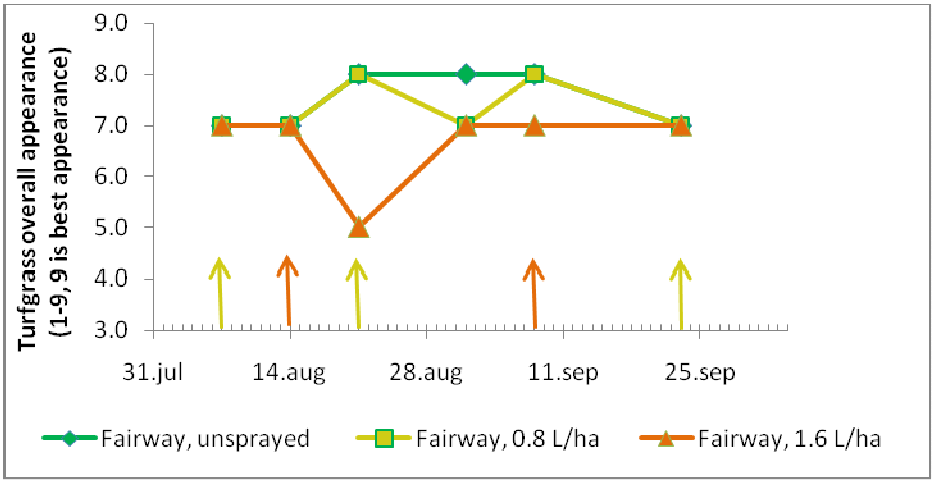
Repeated applications of 0.3, 0.8 and 1.0 L ha^{-1} Primo MAXX® to green, fairway and semirough, respectively, had no major impact on turfgrass overall appearance, but the initial application of the double rates on 14 Aug. resulted in discoloration and inferior quality on all types of turf for almost one month (Fig. 4, Photo 11). Clipping yields were not weighed, but basket numbers were reported lower after application of Primo MAXX®, especially at the higher rate. On average for five observations, ball roll distance using an ordinary stimpmeter in the green trial was 2.01 m (6.6 feet) in the unsprayed control treatment versus 2.07 and 2.13 m on greens receiving the lower and higher rate of Primo MAXX®, respectively.

Photo 11.

Effect of Primo MAXX® in demonstration trial on fairway at Byneset GC, Trondheim, Norway. The area in the foreground had been sprayed with 1.6 L ha^{-1} on 14 Aug. Area in background was unsprayed control.

Photo taken on 24 Aug. by Olav Noteng.





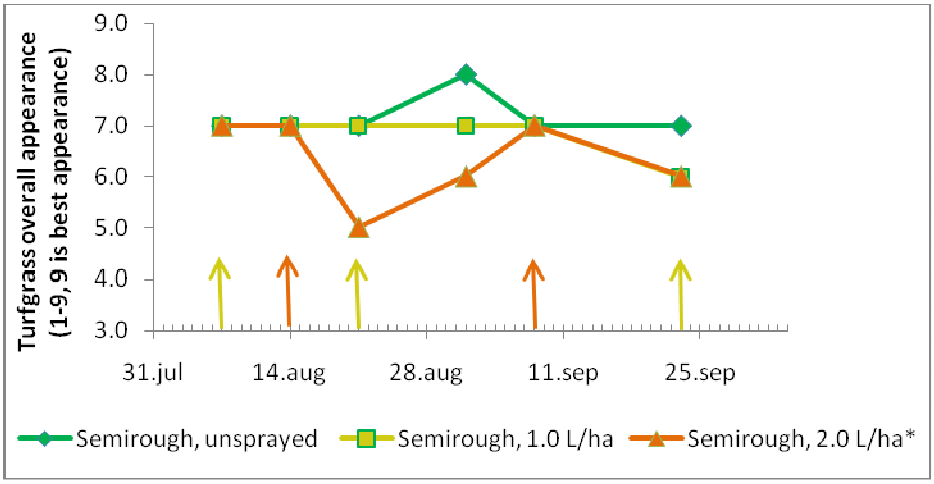


Fig. 4. Turfgrass overall appearance as affected by application of a lower and a higher rate of Primo MAXX® in demonstration trials on green, fairway and semirough at Byneset GC, Trondheim, Norway. Application dates are indicated by arrows. (*: By mistake, the semirough only received 1.0 L ha^{-1} on 8 Sep.; see Table 6)

4.2.4. Demonstration trial at Losby GC, Lørenskog, Norway

Neither the lower (0.15 L ha^{-1} in the first application on 20 June; 0.3 L ha^{-1} in later applications) or higher (0.3 L ha^{-1} in the first application on 20 June; 0.6 L ha^{-1} in later applications) rates of Primo MAXX® had any negative effects on turfgrass quality on the practice green at Losby (data not shown). On average for three observations, the fresh weight of turfgrass clippings was reduced by 13 % at the lower rate. Doubling the rate to 0.6 L ha^{-1} produced no further reduction, primarily because of a rebound effect at the last observation on 18 Aug. (clipping weights 44% higher than in control treatment). This was only thirteen days since the previous application of Primo MAXX®.

4.2.5. Demonstration trial at Bjaavann GC, Kristiansand, Norway

Application of 0.3 L ha^{-1} Primo MAXX® to the practice green at Bjaavann on 27 July resulted in pronounced discoloration (Photo 12a) from which the turf needed almost one month to recover. One of the reasons for this may be high temperatures and relatively dry conditions at and shortly after application. By contrast, after the second application on 26 Aug. the turf had better color on the sprayed than on the unsprayed part of the green (Fig. 5, Photo 12b). Primo MAXX® improved ball roll distances by 0.5 to 1.0 foot (6-13 %) at all observations (Fig. 5) and reduced clipping yields on 9 October by 52%.

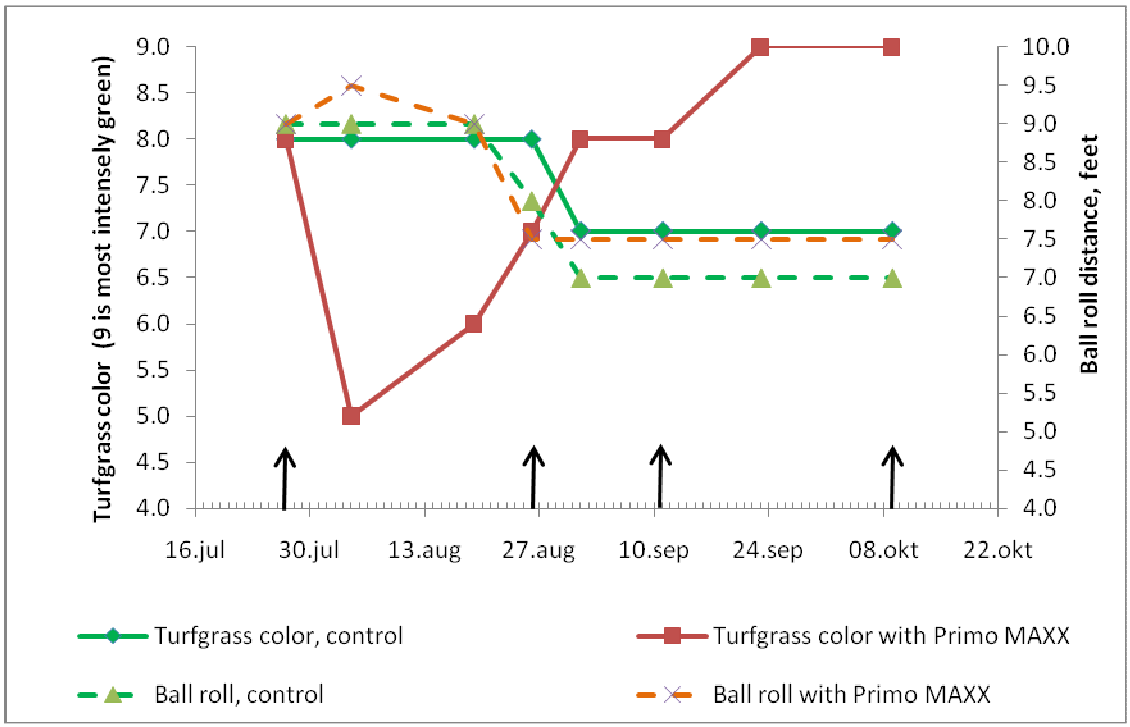


Fig. 5. Turfgrass color and ball roll distance as affected by repeated applications of 0.3 L ha^{-1} Primo MAXX® on practice green at Bjaavann GC. Application dates are indicated by arrows.

Photo 12. Effect of Primo MAXX® in demonstration trial on a practice green at Bjaavann GK, Kristiansand, Norway. The left (southern) half of the green was sprayed with Primo MAXX® at a rate 0.3 l ha^{-1} on 27 July, 26 Aug., 11 Sep. and 9 Oct. Upper photo (a) taken on 7 Aug. by Terje Haugen, lower photo (b) on 10 Oct. by Trygve S. Aamlid.

5. Discussion and recommendations

In our previous report (Aamlid et al. 2008), we stated that the most convincing argument for approval of Primo MAXX® on Nordic golf courses would be a clear documentation that it improves winter survival. The overwintering data from the green and fairway trials at Lepaa, Finland (Tables 6 and 7; Photos 8 and 9) provides this documentation. There may be several physiological explanations for the suppressive effect of Primo MAXX® on snow mold infection, but most likely it was due to higher accumulation of carbohydrates in plant tissue before winter. This would be in line with Gaudet et al. (1999) who found a significant connection between carbohydrate content and infection of *Microdochium nivale* in winter wheat; McBeath (2003) who reasoned that plants maintaining a high proportion of water soluble carbohydrates in autumn would be less susceptible to snow mold damage, and Goss et al. (2002) who found 40 and 37% higher contents of fructans in creeping bentgrass tissue that had been sprayed with, in turn, 42 and 70 g a.i. ha^{-1} of trinexapac-ethyl (corresponding to 0.37 and 0.62 L ha^{-1} of Primo MAXX®) at two to three week intervals. As pointed out by Ervin & Zhang (2008), there is a clear need for more studies into the physiological effects of Primo MAXX® on turfgrass winter survival.

Unlike in 2007, no phytotoxic effects of Primo MAXX® were found in the GEP trials in 2008. This was probably due to the change in experimental plans in favor of smaller and more frequent applications, which also mostly (green trial Landvik, Fig. 2) or completely (fairway trial, Lepaa, Fig. 3) eliminated the rebound effect that was so prominent in 2007. Based on experiments in growth chambers, Branham & Beasley (2007) reported that the half-life of trinexapac-ethyl in creeping bentgrass was 6.4 days at 18 ºC and only 3.1 days at 30 ºC. While the authors did not mention the light conditions under which these studies were conducted, photoperiod and light quality (red/far-red ratios) may be equally important for the half-life of trinexapac-ethyl under Nordic conditions. The beneficial effects of Primo MAXX® at low irradiance conditions has been well documented using artificial shade cloths (e.g. Goss et al. 2002, Steinke & Stier 2003), but it remains unclear to what extent and for how long time the growth regulator will also counteract the morphogenetic effects of long photoperiods or reduced red/far-red ratios (Gardner & Wherley 2005) at high latitudes. This aspect also warrants further investigation.

Many golfer players consider ball roll distance as the foremost criterion for playing quality of a golf green. The increase in ball roll distance measured at Landvik, on average 6% (Table 8), is of the same magnitude as reported in American studies (Fagerness et al. 2000, McCullough et al. 2004). On high quality golf greens, this reduction is hardly sufficient to compensate for the daily mowing routine, but it may eliminate the need for additional mowing or rolling treatments in the afternooen during tournaments. Regular application of Primo MAXX® may also allow many greenkeepers to increase fertilizer levels slightly without compromising green speed, thus reducing the risk for anthracnose (*Colletotrichum graminicola*) and other turfgrass diseases which are commonly observed on Nordic golf courses.

For Nordic greenkeepers the take-home message from two year research project is that Primo MAXX® must be applied at 1-2 week intervals on greens, 2-3 week intervals on fairways and 3-4 weeks on semiroughs and roughs in order to produce consistent effects. As the maintenance of greens on high-quality golf courses usually implies spoon-feeding every 1-2 weeks of liquid fertilizers with which small rates of Primo MAXX® can be tank-mixed, most greenkeepers will probably be comfortable with such a frequent application practice on the greens. On the other hand, many greenkeepers may hesitate to spray the fairways regularly at 2-3 week intervals, as this, in most cases, means a new management operation. Provided 25-30% reduction in turfgrass growth rate, the prospect of reducing the number of fairway clippings from three to two per week may, nevertheless, well be attractive to many golf clubs, and it may also contribute to reduced CO_2 emissions from golf courses. Many greenkeepers will probably also find it helpful to spray Primo MAXX® at three to four week intervals in roughs that are steep or otherwise difficult to reach using ordinary mowing equipment.

In the demonstration trials, initial application of 0.3 L ha^{-1} Primo MAXX® to the greens at Bjaavann GC, 1.6 L ha^{-1} Primo MAXX® to the fairway at Byneset GC, and 2.0 L ha^{-1} to the semirough at Byneset GC all resulted in temporary discoloration. This strongly suggests that a reduced rate, e.g. 50% of the normal rate, has to be used for the first one or two seasonal application of Primo MAXX® to a new turfgrass area, much in the same was as it was done in the green trial at Losby GC. Somehow, it seems that the turf needs to adapt to being sprayed with Primo MAXX®. This is also supported by the GEP trials at Landvik and Lepaa, in which the effects of Primo MAXX® on clipping yields were more consistent during the latter than during the first half of the growing season (Figs. 2 and 3).

In conclusion, we consider the agronomic documentation presented in this report to be clear enough to justify Primo MAXX® being labeled for use on Nordic golf courses. As a starting point, we suggest that the following rates and application frequencies are printed on the label:

	Rate		Application
	Primo MAXX®, L ha^{-1}	trinexapac-ethyl, g a.i. ha^{-1}	frequency
Greens (creeping bentgrass)	0.2 – 0.4	22.5 - 45	Every one to two weeks
Fairways (Kentucky bluegrass / red fescue)	0.6 – 1.2	56.5 - 113	Every two to three weeks
Roughs & semi-roughs (Ken. bluegr. / fescue)	1.0 - 2.0	113 - 226	Every three to four weeks

Apart from these instructions, the label must include a general prescription to always use the lowest rate of Primo MAXX® at the first seasonal application and during warm and dry periods. The label must also include a warning of the loss of turfgrass quality that may occur should Primo MAXX® be applied at higher rates.

As the trials in this project were conducted on creeping bentgrass greens and bluegrass / red fescue fairways and semiroughs, there is a need for more research concerning optimal application rates and frequencies of Primo MAXX® for turfgrass areas dominated by other species, e.g. greens dominated by red fescue or annual bluegrass, and fairways or tees dominated by perennial ryegrass (*Lolium perenne*).

6. References

Aamlid, T.S., O. Niemelainen, M. Rannikko, T. Haugen, S. Junnila, T. Espevig & Å. Susort 2008. Evaluation of the plant growth regulator Primo MAXX® (trinexapac-ethyl) on Nordic golf courses. Bioforsk Report 3(1): 1-30.

Branham, B. & J. Beasley 2007. PGRs: Metabolism and plant responses. Golf Course Management. July 2007: 95-99.

Ervin, E.H. & X. Zhang 2008. Applied physiology of natural and synthetic plant growth regulators on turfgrasses. *In:* Pessarakli, M. (ed.). Handbook of turfgrass management and physiology. CRC Press, Boca Raton, FL. pp.171-200.

Fagerness, M.J., F.H. Yelverton, J. Isgrigg & R.J. Cooper 2000. Plant growth regulators and mowing height affect ball roll and quality of creeping bentgrass putting greens. HortScience 35: 755-759.

Gaudet, D.A., Laroche, A., & Yoshida, M. 1999. Low-temperature-wheat-fungal interactions: A carbohydrate connection. Physiologia Plantarum 106: 437-444.

Gardner, D.S. & B.G. Wherley 2005. Growth response of three turfgrass species to trinexapac-ethyl in shade. HortScience 40: 1911-1915.

Gaussoin, R., J. Nus & L. Leuthold 1995. A modified stimpmeter for small-plot turfgrass research HortScience 30: 547-548.

Goss, R.M., J.H. Baird, S.L. Kelm & R.N. Calhoun 2002. Trinexapac-ethyl and nitrogen effects on creeping bentgrass grown under reduced light conditions. Crop Science 42: 472-479.

Lickfeldt, D.W., D.S. Gardner, B.E. Branham & T.B. Voigt 2001. Implications of repeated trinexapac-ethyl applications on Kentucky Bluegrass. Agronomy Journal 93: 1164-1168.

McBeath, J.H. 2003. Snow mold: Winter turfgrass nemesis. Golf Course Management 71 (2): 121-124.

McCullough, P., H. Liu & B. McCarthy 2004. Effects of mowing and PGRs on ball roll distance. Golf Course Management 72 (12): 82-86.

Steinke, K. & J.C. Stier 2003. Nitrogen selection and growth regulator applications for improving shaded turfgrass performance. Crop Science 43: 1399-1406.

Tørresen, K.S. 2007. Kvalitetshåndbok for gjennomføring av godkjenningsforsøk med plantevernmidler. Utgave VI.