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

Results from the first evaluation year 2007

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SCANDINAVIAN TURFGRASS AND ENVIRONMENT RESEARCH FOUNDATION

Finnish team spraying fairway trial at Lepaa Golf Course.
Photo: Oiva Niemelainen

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Summary:

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

Sammendrag:

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

Approved

Arne Sæbø	Trygve S. Aamlid
Leader, Bioforsk's Section for Urban Greening	Project leader

Contents

1. Abstract

As an inhibitor of the last step in plant synthesis of bioactive gibberellin (GA_1), the plant growth regulator Primo MAXX® (trinexapac-ethyl) offers prospects of reduced energy use for mowing and improved turfgrass quality under Nordic long day conditions. This report presents first year results from 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 possible registration of Primo MAXX®, unreplicated demonstration trials were carried out at Ballerud and Bogstad Golf Courses in Oslo under supervision of Bioforsk and with funding from the Norwegian Golf Federation (NGF).

GEP trials on **fairways** (mowing height 12-18 mm) were carried out at Bioforsk Landvik, Norway (58°34'N, 8°52'E) and at the Lepaa Unit of the HAMK University of Applied Sciences, Finland (61°08'N, 24°20'E). Primo MAXX® was applied at monthly intervals at rates 0.5, 1.0, 1.5, 2.0 and 3.0 l/ha (56.5, 113, 169.5, 226 and 339 g a.i./ha trinexapac-ethyl) in comparison with an unsprayed control treatment. Turfgrass general appearance, tiller density, colour, height growth, and clipping yields were recorded two and four weeks after each application. Primo MAXX® had no effect on turfgrass general appearance but increased density at Lepaa. At Landvik, Primo MAXX® (>= 1.0 l/ha) reduced turfgrass general appearance and density, but resulted in significantly darker green colour. Quality reductions were most apparent during periods with either daily maximum temperatures >25 ºC, extreme rainfall probably causing nitrogen deficiency, or frost at night. Average reductions in clipping yield caused by Primo MAXX® (>= 1.0 l/ha) were 8 % in the GEP trial at Landvik, 18 % in the GEP trial at Lepaa and 37 % in the demonstration trial at Ballerud; to some extent this difference may be due to different botanical composition with red fescue (*Festuca rubra*) and annual meadowgrass (*Poa annua*) being the predominant species at Landvik and Ballerud, respectively. Clipping yield reductions due to Primo MAXX® were unstable, growth suppression two weeks after application often being followed by a rebound effect during the remaining two weeks until next application.

A GEP trial on creeping bentgrass **putting greens** was carried out at Lepaa, Finland, and demonstration trials at Ballerud and Bogstad, Norway. Primo MAXX® was sprayed at rates 0.2, 0.4, 0.6 or 0.8 l/ha at monthly intervals in the GEP trial, and at 0.4 l/ha every three weeks in the demonstration trials. On average for all observations, Primo MAXX® had no effect on turfgrass quality, but clipping yields were reduced by 16, 44 and 26% at Lepaa, Ballerud and Bogstad, respectively. As in the fairway trials, growth suppression at Lepaa was stronger when assessed at two than at four weeks after application. By contrast, Primo MAXX® produced a fairly stable effect when applied at three week intervals in the demonstration trials.

Use of Primo MAXX® on golf course **roughs** was investigated only in a demonstration trial at Ballerud. Application of 2.2 l/ha of Primo MAXX® every seven weeks resulted in discolouration and reduced quality of smooth meadow grass.

In conclusion, the first year of this project has shown that the guidelines for use of Primo MAXX® in other European countries are not directly applicable in Scandinavia. As the present results are too limited to apply for registration of Primo MAXX®, the project will continue in 2008 tentatively with new trials investigating application of Primo MAXX® at lower rates, but higher frequencies. Improved winter stress tolerance would be a convincing argument for registration of Primo MAXX® in the Nordic countries, and the on-going trials will therefore be followed by an assessment of effects of the last Primo MAXX® applications in September or October 2007 on winter survival and spring recovery.

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

2. Introduction

The plant growth regulator trinexapac-ethyl was developed by Syngenta in the 1980s. Since the active ingredient is available in different formulations, the chemical will, in this report, be referred to as Primo MAXX®, which is the product developed by Syngenta specifically for use on turf. Unlike earlier plant growth regulators, Primo MAXX®'s mode of action is highly specific as it blocks the conversion of GA_{20} til GA_1, i.e. the last step in the biosynthesis of gibberellic acid, a plant hormone stimulating cell elongation and thus vertical turf growth.

After its release, Primo MAXX® was rapidly adopted by the US and Canadian turf industries. In North America, there are several independent university studies documenting its positive effects on golf courses, athletic fields, home lawns, and sod production (for a recent review, see Erwin and Zhang 2008). These advantages include reduced leaf elongation and thus reduced mowing costs and energy use, improved tiller production (more lateral growth), darker green colour, and improved resistance to drought and shade.

While other formulations of trinexapac-ethyl have been approved for agricultural use in Europe for about a decade, the experience with Primo MAXX® to European turfgrass areas is relatively limited. During the past three to four years, Primo MAXX® has been approved for turf use in Italy, France and UK, and the evaluation and registration process has been initiated in many other countries.

Being an inhibitor of gibberellin biosynthesis, Primo MAXX® offers special prospects for turfgrass management in the Nordic counties Finland, Sweden, Norway, Iceland, and Denmark. At latitudes ranging form 55 to 71 °N, turfgrasses growing in these countries exposed not only to long photoperiods during most of the growing season, but also to lower photosynthetic flux densities and lower red to farred (R/FR) ratios than in countries further south. The natural turfgrass response to these northern light conditions is to devote more of its resources to shoot elongation (Heide et al. 1985a,b). Since this response is primarily mediated by the gibberellic acid GA_1, any specific growth regulator that controls the biosynthesis of this compound might be useful under Nordic conditions. Nevertheless, our experience from the introduction of trinexapac-ethyl for agricultural use in the Nordic counties suggests that the optimal dose rates and frequencies for application of Primo MAXX® to various types of turf are probably not the same as at lower latitudes. This is also due to different species and cultivars being grown compared with countries further south. Field trials under Nordic conditions are therefore required not only to produce data for the national certification agencies, but also to provide turf managers with recommendations for how to use the product.

This report presents first year preliminary results from a two year project evaluating the use of Primo MAXX® on golf courses in the Nordic countries. The project was funded by Syngenta and the Scandinavian Turfgrass and Environment Research Foundation (STERF) 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' trials needed to provide documentation for possible registrations of Primo MAXX® by the national authorities, a couple of practical demonstration trials were carried out on Norwegian golf courses under supervision from Bioforsk and with funding from the Norwegian Golf Federation (NGF).

3. Methods

3.1. Evaluation of Primo MAXX® under fairway conditions, Bioforsk Landvik, Norway

Experimental site

On 8 May 2007, a field trial was laid out on a fairway established on a sandy loam soil (topsoil: 68 % sand, 27% silt, 5 % clay) at Bioforsk Landvik Research Station (58°34'N, 8°52'E), SE Norway. Soil samples indicated a pH (H_2O) of 5.9, high phosphorus values (P-AL=19) and intermediate to low potassium values (K-AL = 8, K-HNO_3=58). The fairway had been seeded in September 2003 to a mixture of smooth meadowgrass (*Poa pratensis*), chewing fescue (*Festuca rubra* ssp. *commutata*), and browntop bent (*Agrostis capillaris*) (Table 1). Block 1 and 2 were located in one part, and block 3 and 4 in a different part of the fairway. Botanical analyses at the start of experimentation indicated that red fescue was the predominant species in all blocks, but presumably due to slightly less surface drainage, blocks 1 and 2 had a higher percentage of smooth and annual meadowgrass and broadleaved weeds (primarily white clover (*Trifolium repens*)) than blocks 3 and 4 (Table 1).

Table 1. Seed mixture used for fairway establishment in 2003 and botanical composition at the start of the Primo MAXX® trial in spring 2007.

Species	Cultivar	% (w/w) of seed mixture	% cover at initiation of Primo MAXX® trial		
			Block 1 and 2	Block 3 and 4	Mean
Poa pratensis	Conni	25	31	9	20
Poa pratensis	Eva	10			
Poa pratensis	Limousine	10			
Festuca rubra ssp. commutata	Bargreen	25	50	74	62
Festuca rubra ssp. commutata	Calliope	25			
Agrostis capillaris	Tracenta	5	5	15	10
Poa annua			8	2	5
Broadleaved weeds			6	0	3
Sum		100	100	100	100

Experimental plan

The experiment was laid out according to a randomized complete block design with plot size 2m x 3m, four blocks (replicates) and the following treatments:

1. Usprayed control
2. Primo MAXX, 0.5 l/ha (56.5 g a.i./ha) every four weeks
3. Primo MAXX, 1.0 l/ha (113 g a.i./ha) every four weeks
4. Primo MAXX, 1.5 l/ha (169.5 g a.i./ha) every four weeks
5. Primo MAXX, 2.0 l/ha (226 g a.i./ha) every four weeks
6. Primo MAXX, 3.0 l/ha (339 g a.i./ha) every four weeks

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. Actual application rates were recorded by weighing the tank before and after spraying. Table 2 shows actual rates and weather conditions for each spraying event.

Table 2. Weather conditions and actual application rates at the six spraying events.

Application date	Time of day (hours)	Weather conditions at application			Treatment number / application rate (l Primo MAXX® per ha)				
		Air temp. °C	Relative Humidity %	Wind Speed m/s	2. (target 0.5)	3. (target 1.0)	4. (target 1.5)	5. (target 2.0)	6. (target 3.0)
9 May	09-11	14	48	< 1.0	0.47	0.94	1.56	1.90	3.35
5 Jun.	09-11	15	60	< 1.0	0.58	1.06	1.67	1.93	3.19
4 Jul.	13-15	17	70	1.0-2.0	0.61	0.98	1.73	2.19	3.38
31 Jul.	08-10	18	55	1.0-2.0	0.55	1.05	1.66	2.28	3.41
28 Aug.	09-11	19	32	1.0-2.0	0.57	1.03	1.55	2.19	3.52
26 Sep.	09-11	11	69	< 1.0	0.52	1.07	1.55	2.01	3.15
Mean					0.55	1.02	1.62	2.08	3.33

Registrations

At two weeks intervals throughout the experimental period, turfgrass colour, tiller density, and turf general appearance were assessed by turfgrass scientist or technicians using a scale from 1 to 9 where 9 is darkest colour, highest tiller density and best turf quality. The assessments were conducted two and four weeks after application of Primo MAXX®. On the same dates, turfgrass diseases and broadleaf weed (including white clover) invasion were reported as per cent of plot area. Turfgrass height was recorded as the mean of three random measurements with a ordinary ruler in each plot, and the overall growth rate by weighing clippings in the basket of a walk-behind mower used in the 0.56 m x 1.88 m central area of each plot (Photo 1). Both raw weight and dry weight were recorded, the latter after drying for 24 h at 60ºC. By the end of the growing season, on 2 Nov., turfgrass dormancy colour was evaluated on a scale 1-9, where 1 is completely faded / brown turf, and 9 is completely green turf.

Photo 1a and b. Tatsiana Espevig collecting clippings in fairway trial at Landvik. Photos: Trygve S. Aamlid

Management

The experiment was mowed at 15 mm two times a week, usually on Monday and Friday. A triplex fairway mower without collection of clippings was used except when clipping weights were to be recorded. Granular fertilizer was applied at approximately monthly intervals as outlined in Table 3. The experiment was not irrigated except for small amounts of water to dissolve fertilizer after application. On 7 Aug., the trial was aerated using a vertidrain with 15 mm solid tines to 15 cm depth. Topdressing was accomplished on 8 Aug. and 5 Nov. at rates 0.75 and 1.5 kg pure sand per m^2, respectively.

The fairway trial at Landvik was not exposed to ordinary play, but it was was subjected to artifical wear from a wear drum one to two times per week.

Table 3. Fertilizer inputs, fairway trial, Landvik.

		Per ha							
Date	Fertilizer type	kg fertilizer	kg N	kg P	kg K	kg Mg	kg S	kg Ca	kg Fe
17 Apr.	Fullgjødsel 22-2-12	40	9	1	5	0	1	0	0
16 May	Fullgjødsel 22-2-12	70	15	1	8	1	2	1	0
12 Jun.	Arena Golf Extra 13-0-15	150	20	0	23	2	21	0	3
23 Jul.	Arena Golf Extra 13-0-15	130	17	0	20	2	18	0	3
9 Aug.	Arena Golf Extra 13-0-15	135	18	0	21	2	18	0	3
5 Sep.	Arena Golf Extra 13-0-15	150	20	0	23	2	21	0	3
SUM			99	2	100	10	80	1	11

Weather data

In SE Norway, the growing season 2007 was characterized by exceptionally high rainfall, especially in July, but also in May, June and August (Table 4). By contrast, September was unusually dry. Precipitation was recorded on 16 out of the 31 days in July; the cloudy summer weather is also reflected by a rather low irradiance during this month. The warmest period, with daily maximum temperatures in the range 23-29 ºC was recorded from 6 to 12 June.

Table 4. Weather data for Landvik meteorological station, about 200 m for experimental field. Normal values for temperature and rainfall are 'official' values for from the period 1961-90, while normal values for irradiance are calculated averages for the period 1994-2006.

	Mean temperature, ˚C		Precipitation, mm		Irradiance, MJ/m^2 (305-2800 nm)	
	2007	30 yr normal	2007	30 yr normal	2007	13 yr average
May	10.2	10.4	107	82	518	540
June	15.9	14.7	109	71	604	600
July	15.5	16.2	213	92	492	632
Aug.	16.2	15.4	132	113	476	476
Sep.	12.0	11.8	59	136	321	262
Mean / sum	14.0	13.7	620	494	2411	2510

3.2. Evaluation of Primo MAXX® on a golf course fairway, Lepaa, Finland

Experimental site

The Finnish fairway trial was laid out on 11 May 2007. The fairway was seeded to a mixture of smooth meadowgrass and chewing fescue (*Festuca rubra* spp. *commutata*) on a heavy clay soil (15% sand, 37% silt, 48% clay) at the Lepaa Unit of HAMK University of Applied Sciences, Finland (61°08'N, 24°20'E). 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. All observations and management of the trial was carried out by the HAMK Lepaa greenkeepers Petteri Lehmuskoski and Tommi Turunen except for the spraying treatments which were carried out by MTT's 'Good Experimental Practice' certified spraying team from Jokioinen (90 km from Lepaa).

Experimental plan and registrations

The experiment was laid out following the same plan and plot size as at Landvik, Norway (previous paragraph). Primo MAXX® was applied in accordance with the Finnish 'Good Experimental Practise' protocol, using a portable, compressed air-powered 'van der Weij' plot sprayer, mounted with a windshield and flat fan nozzles (Hardi 4110-12) and working at 180-250 kPa pressure. The spraying boom had four nozzles spaced 50 cm apart. The spraying volume corresponded to 200 l/ha. Full spray coverage was on the central 1.5m x 2.5 m of each plot. Table 5 shows application dates and weather conditions for each spraying event. The last application on 4 Oct. was conducted especially to evaluate potential effects of Primo MAXX® on turfgrass winter damage.

Table 5. Application dates and weather conditions in fairway and green trials at Lepaa.

Application date	Time of day (hours)	Air temp. °C	Relative humidity %	Wind Speed m/s	% cloud cover
11 May	09-11	11	29	0	25
8 Jun.	09-11	20	56	1.5	1
5 Jul.	13-15	23	47	2.5	70
3 Aug.	09-11	17	78	2.0	90
4 Sep.	09-11	11	90	1.0	90
4 Oct.	13-15	11	92	1.5	100

Photo 2. Austen Sutton, Syngenta (left) and greenkeeper Petteri Lehmuskoski, HAMK Lepaa Unit, in fairway trial at Lepaa, Finland, 29 Aug. 2007.

Photo: Oiva Niemelainen.

Registrations

Registrations were carried out at two-week intervals following the same program as at Landvik (previous section) except that weed occurrence and dormancy colour were not recorded. Plant height at Lepaa was determined using a Turf Check Prism device (Check Signature Inc., Shoreview, MN).

Management and wear

The experiment was mowed with a triplex fairway mower about three times per week. Mowing height ranged from 12 to 18 mm. Granular fertilizer Sportsmaster 26-2-9 was applied at equal rates on 8 May and 12 July, the total input corresponding to 156 kg N, 12 kg P, 54 kg K and 0.9 kg Fe per ha. Information about irrigation is given in Table 6. The trial was aerated or top-dressed in late autumn, after the completion of registrations.

During the growing season period, the trial was exposed to approximately 3.500 rounds of golf.

Weather data

Temperatures at Lepaa were higher the 30 yr normal values throughout the growing season (Table 6). August had the greatest deviation from the long-term average value. July had 49 % more, and August 42 % less rainfall than usual; over the whole experimental season, rainfall was close to the 30 yr normal value.

Table 6. Weather data for Hattula Lepaa weather station and irrigation in fairway and green trial at Lepaa golf course, 2007. Normal values for temperature and rainfall are official values for from the period 1971-2000 (Finnish Meteorological Institute)

	Mean temperature, °C		Rainfall, mm		Irrigation, mm (2007)	
	2007	30 yr normal	2007	30 yr normal	Fairway trial	Green trial
May	10.6	9.8	30	34	*	*
June	15.1	14.5	54	55	26	79
July	16.6	16.4	119	80	5	47
Aug.	16.4	14.6	43	74	7	50
Sep.	9.9	9.4	58	54	0	6
Mean / sum	13.7	12.4	304	297	37	188

* Data are unavailable for the period 1-26 May 2007 due to change of irrigation computer.

3.3. Evaluation of Primo MAXX® on a golf course putting green, Lepaa, Finland

Experimental site

The Finnish green trial was established on 11 May 2007 on a USGA green seeded to creeping bentgrass (*Agrostis stolonifera*, seed blend of 50% 'Penn A-4' and 50% 'Penn G-6') at Lepaa Golf Course.

Experimental plan

The experimental plan comprised five rates of Primo MAXX plus the unsprayed control treatment:

1. Usprayed control
2. Primo MAXX, 0.2 l/ha (22.6 g a.i./ha) every four weeks
3. Primo MAXX, 0.4 l/ha (45.2 g a.i./ha) every four weeks
4. Primo MAXX, 0.6 l/ha (67.8 g a.i./ha) every four weeks
5. Primo MAXX, 0.8 l/ha (90.4 g a.i./ha) every four weeks

The trial had four replicates, and a gross plot size of 2 m x 3 m. It was sprayed on the same dates and following the same GEP procedures as the fairway trial on the same location (Table 5).

Photo 3. Green trial at Lepaa ready for the first treatment on 11 May 2007. Photo: Oiva Niemelainen.

Registrations

Registrations followed the same program as in the Finnish fairway trial (previous section).

Management and wear

The experiment was mowed with a Triplex greens mower for an average of six times per week. Depending on weather and turfgrass density, mowing height was 5–7 mm in May and September and 3-4 mm from June to August. Information about irrigation and fertilizer inputs are given in Tables 6 and 7, respectively.

To avoid thatch accumulation, the trial was aerated with deep slitting knives every second week and with 8 mm needle tines once a month. Verticutting was accomplished every second week and topdressing with 0.1-0.7 mm finely graded sand at a rate of 1 kg per m2 every third week. The sand was brushed/irrigated into the green and the dressing was never done in close proximity to weighing of clippings.

Being located on a practise green, the experiment received wear from about 10.000 rounds of golf over the season. When placing holes on the green, care was taken to create as uniform wear as possible.

Table 7. Fertilizer inputs in green trial at Lepaa.

		Per ha							
Date	Fertilizer type	kg fertilizer	kg N	kg P	kg K	kg Mg	kg S	kg Ca	kg Fe
28.3.2007	Floratine Kevätstartti*	35	5.4	1.2	2.1				
5.4.2007	Floratine Kevätstartti	35	5.4	1.2	2.1				
19.4.2007	Floratine Kevätstartti	35	5.4	1.2	2.1				
26.4.2007	Sierraform Springstart (16-0-13)	250	40	0	32.5				2.50
15.5.2007	Sierraform All Season (18-3-15)	250	45	7.5	37.5	3.0			1.25
30.5.2007	Kemigreen Basic (23-4-14)	40	9	1.6	5.6	0.6	0.8		0.04
5.6.2007	Kemigreen Basic (23-4-14)	40	9	1.6	5.6	0.6	0.8		0.04
11.6.2007	Sierraform All Season (18-3-15)	250	45	7.5	38				
25.6.2007	Osmosol 614R (19-2-10)	40	7.6	0.8	4.0	0.5		1.7	0.04
2.7.2007	Osmosol 614R (19-2-10)	40	7.6	0.8	4.0	0.5		1.7	0.04
13.7.2007	Kemigreen Summer (18-0-17)	40	7.2	0	6.8			2.0	0.40
18.7.2007	Kemigreen Summer (18-0-17)	40	7.2	0	6.8			2.0	0.40
26.7.2007	Sierraform All Season (18-3-15)	250	45	7.5	37.5	3.0			1.25
14.8.2007	Kemigreen Summer (18-0-17)	40	7.2	0	6.8			2.0	0.40
27.8.2007	Greenmaster Autumn (6-2-8)	300	18	6	24	5.4			1.50
30.8.2007	Kemigreen Basic (23-4-14)	40	9	1.6	5.6	0.6	0.8		0.04
11.9.2007	Sierraform Springstart (16-0-13)	200	32	0	39				2.00
SUM			305	39	260	14.0	2.4	9.4	10

* Floratine Kevätstartti (Springstart) is composed of P-48 (10-21-6.6), Per 4 Max (15-0-0), Protesyn (3.5-0.6-1.8), and Plant Marvel (28-3-15).

3.4. Demonstration trials with Primo MAXX® at Ballerud Golf Course, Oslo, Norway

Experimental site and set-up

Ballerud GC is located on an old horticultural farm in a suburban area SW of Oslo. The course has greens with mostly dominated by creeping bentgrass, fairways almost exclusively dominated by annual meadowgrass, and smooth meadowgrass roughs with some tufts of perennial ryegrass (*Lolium perenne*).

Large-scale, unreplicated demonstration trials were laid out on green no. 9, fairway no. 9 and rough no. 9 on 5 June 2007. Plots sizes varied from 80 to 130 m^2. Unsprayed control plots were compared with plots sprayed with Primo MAXX® at rates 0.4, 1.5 and 2.2 l/ha and application intervals of approximately 3, 4 and 7 weeks on green, fairway and rough, respectively. In compliance with the Norwegian Food Authority's rule for complete closure of all sprayed areas for 48 h after each application, the trial on green no. 9 had to be discontinued after the second application on 18 June.

Three weeks later, it was replaced by a new trial laid out on the golf course' nursery green. Actual application dates in the green, fairway and rough trials are given in Table 8. The growth regulator was applied using a battery-operated electric Hardy Defender plot sprayer (Photo 4).

Table 8. Application dates for Primo MAXX in demonstration trials at Ballerud GC.

Green no. 9	Nursery green	Fairway no. 9	Rough no. 9
5 June		5 June	5 June
18 June			
	9 July	2 July	
	31 July	31 July	28 July
	21 Aug.		
	13. Sep.	3 Sep.	11 Sep.
	4 Oct.	28 Sep.	

Photo 4. Sprayer used in demonstrations trials at Ballerud Golf Course.

Photo: Terje Haugen.

Registrations

In all trials at Ballerud, turfgrass general appearance was evaluated by the headgreenkeeper at one to two week intervals throughout the growing season. In the green and fairway trials, turfgrass clipping yields were recorded on a fresh weight basis. Registrations in the green trials also included regular assessments of green speed using a standard stimpmeter.

Maintenance

The green trials at Ballerud were mowed daily at 3.4-3.8 mm and the fairway trial at 20 mm three to four times a week. The rough area was only mowed upon need.

Due to the rich soil from decades of vegetable production, the rough trial was not fertilized in 2007, and the fairway trial only received one application of 200 kg Fullgjødsel® 11-5-18 (22 kg N/ha) on 8 May. The green trials received monthly applications of granuar fertilizer (Gro Power 5-1-1, Anderson 14-0-9, Anderson 8-0-16, and/or Roots 12-2-12), and weekly applications of liquid fertilizers /

biostimulants, mostly Floratine products. Total rates of N, P, K, Mg, Ca, S and Fe over the season were 155, 14, 142, 27, 30, 73 and 14 kg/ha, respectively. The greens were aerated, mostly using Envirojet, six times during the season and top-dressed, also six times, giving a total of 6.3 kg sand per m^2.

Weather data and irrigation

Table 3 shows recordings from Ballerud GC's weather station. Although the rainfall in 2007 was higher than usual, there were periods, especially in May, June and August when the green trials needed irrigation. The fairway and rough trials were never irrigated.

Table 9. Weather recordings and irrigation at Ballerud GC, 2007. Monthly temperatures are means of daily maximum and minimum temperatures.

	Mean monthly temperature, °C	Monthly rainfall, mm	Monthly irrigation, mm (greens only)
May	11.2	94	42
June	17.1	185	52
July	16.9	173	10
Aug.	16.6	83	47
Sep.	11.1	71	21
Mean / sum	14.6	606	172

3.5. Demonstration trial with Primo MAXX® at Oslo Golf Club, Bogstad, Norway

To evaluate the effect of Primo MAXX® on a typical annual meadowgrass green, an unreplicated demonstation trial with plot size 250 m^2 was laid out at Oslo GK on 20 June 2007. Primo MAXX® was sprayed at a rate 0.4 l/ha on 20 June, 10 July and 31 July using the same sprayer as at Ballerud GC, about 10 km from Bogstad (Photo 4). Turfgrass quality (general appearance) and fresh weight clipping yields were determined on 4 July, 13 July and 14 August. Unfortunately, the trial had to be discontinued in mid August due to reconstruction of the green.

3.6. 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 on each plot and on plot values which had been averaged, either over the whole growing season, separately over the spring (before 10 June), summer (10 June – 1 Sep.) and autumn (after 1 Sep.) periods, or for observations conducted two versus four weeks after the last application of Primo MAXX®. The significance levels P%<0.1, P%<1, P%<5 and ns (not significant) have been indicated in the tables along with LSD values for effects significant at P%<5. In a few cases exact P-values have been given for tendencies in the 5-15% probability range. As an indications of the variability for each character, coeffcients of variation, (CV %), have also been given in the tables.

4. Results

4.1. Evaluation of Primo MAXX® under fairway conditions, Bioforsk Landvik, Norway

Turfgrass quality and related characteristics

Table 10 shows results from the visual observations of turfgrass quality and related characters in the fairway trial at Landvik. Both within the three seasons and as a mean value, turfgrass general appearance was significantly lower on plots receiving monthly applications of Primo MAXX® at 1.0 l/ha or higher rates than on unsprayed control plots and plots receiving 0.5 l/ha. Within these two groups, differences in generall appearance were not significant. Separate analyses for blocks 1 and 2 versus 3 and 4 indicated that these responses were practically identical regardless of botanical composition (data not shown).

Individual registrations of turfgrass quality are further depicted in Fig. 1. There was a dramatic decline in quality after the first application on 9 May. After this the turf recovered and there was no significant effect of Primo MAXX® at the two subsequent evaluations. Applications of 1.0 l/ha or higher rates on 4 July lead to new quality reductions in July, August and September (Photo 5); these effects were especially apparent at the last evaluation in early November (Photo 6). By contrast, there tended to be a small quality improvement due to the lowest rate of Primo MAXX® from late August to October. This improvement was reflected also in a significant increase in tiller density on average for the whole growing season (Table 10).

Increasing rates of Primo MAXX® consistently led to darker turf throughout the growing season, but also to earlier growth cessation and a less attractive dormancy colour in late autumn (Table 10). The only visible disease in the trial was a slight attack of red thread (*Laetisaria fuciformis*) during the wet period in July; however, these spots were unaffected by Primo MAXX® which also had no effect on the occurrence of broadleaved weeds, primarily white clover, in the trial.

Table 10. Turfgrass quality, tiller density, within-season colour, dormancy colour and infestation of weeds and red thread (*Laetisaria fuciformis*) in fairway at Landvik as affected by increasing rates of Primo MAXX®, 2007. Visual merit and tiller density are means of twelve observations (two in spring, i.e. before 10 June, six in summer, i.e. from 10 June to 1 Sep., and four in autumn, i.e. after 1 Sep. Within season colour (green darkness) and occurrence weeds and red thread are means of twelve, three (all in July) and two (June and Nov.) observations, respectively. Dormancy colour was evaluated on 2 Nov. All values are means of four blocks.

Primo MAXX®, rate	Turf quality (general appearance, 1-9)				Tiller density (1-9)	Within season colour (1-9)	Dor-mancy colour (1-9)	% of plot area	
	Mean	Spring	Summer	Autumn				Dicot weeds	Red thread
0 = Control	6.2	6.1	6.4	6.0	6.3	5.2	6.8	4	4
0.5 l/ha	6.1	5.6	6.3	6.2	6.5	5.6	6.3	2	3
1.0 l/ha	5.5	4.5	5.9	5.3	6.1	5.8	5.0	5	2
1.5 l/ha	5.3	4.6	5.5	5.4	6.0	5.9	4.1	4	3
2.0 l/ha	5.5	4.6	5.9	5.3	6.1	6.0	4.3	3	2
3.0 l/ha	5.1	4.2	5.5	4.9	6.0	6.2	3.5	4	3
P%	<0.1	<0.1	<1	<0.1	<1	<1	<0.1	ns	ns
LSD 5%	0.3	0.5	0.4	0.4	0.2	0.4	1.2	-	-
CV%	4	7	5	5	3	5	15	-	-

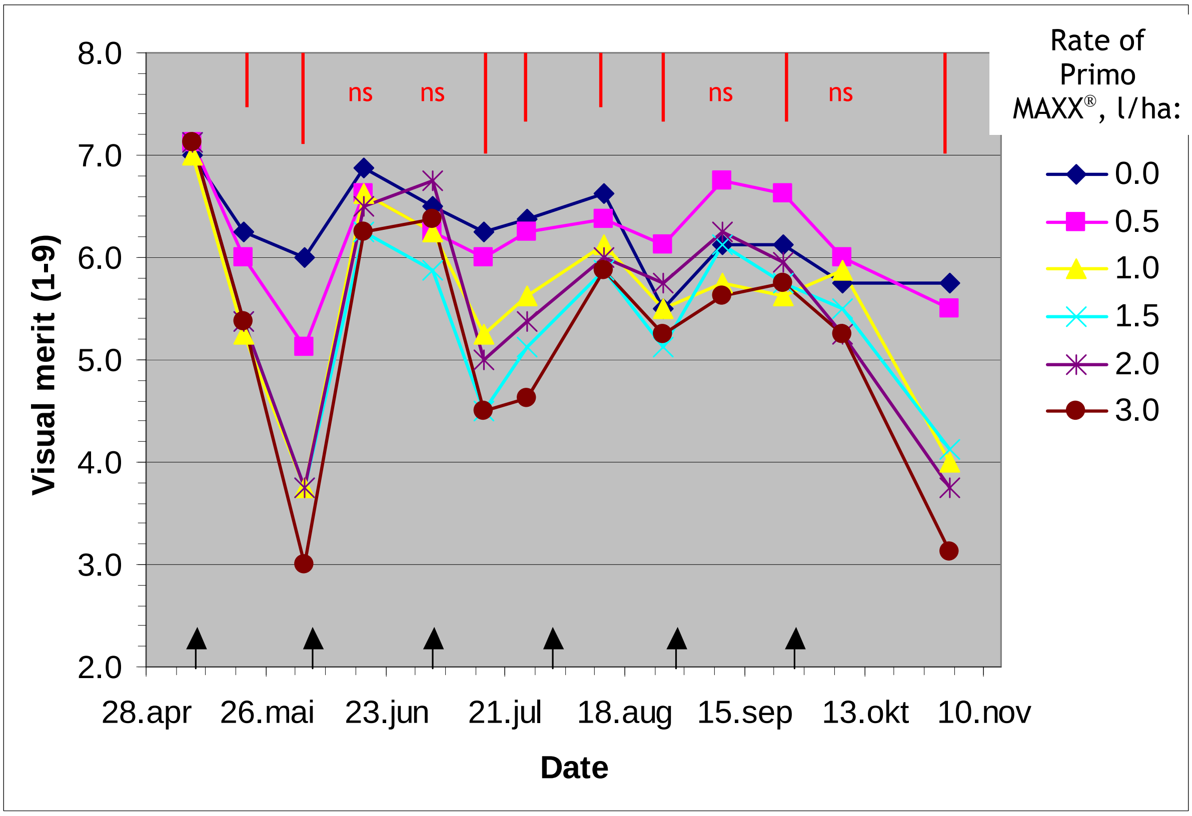


Fig.1. Turfgrass overall quality as affected by increasing rates of Primo MAXX® in fairway trial at Landvik, 2007. Mean of four replicates (blocks). The application dates 9 May, 5 June, 4 July, 31 July, 28 Aug. and 26. Sep. are indicated by black arrows. Red bars indicate LSD 5%.

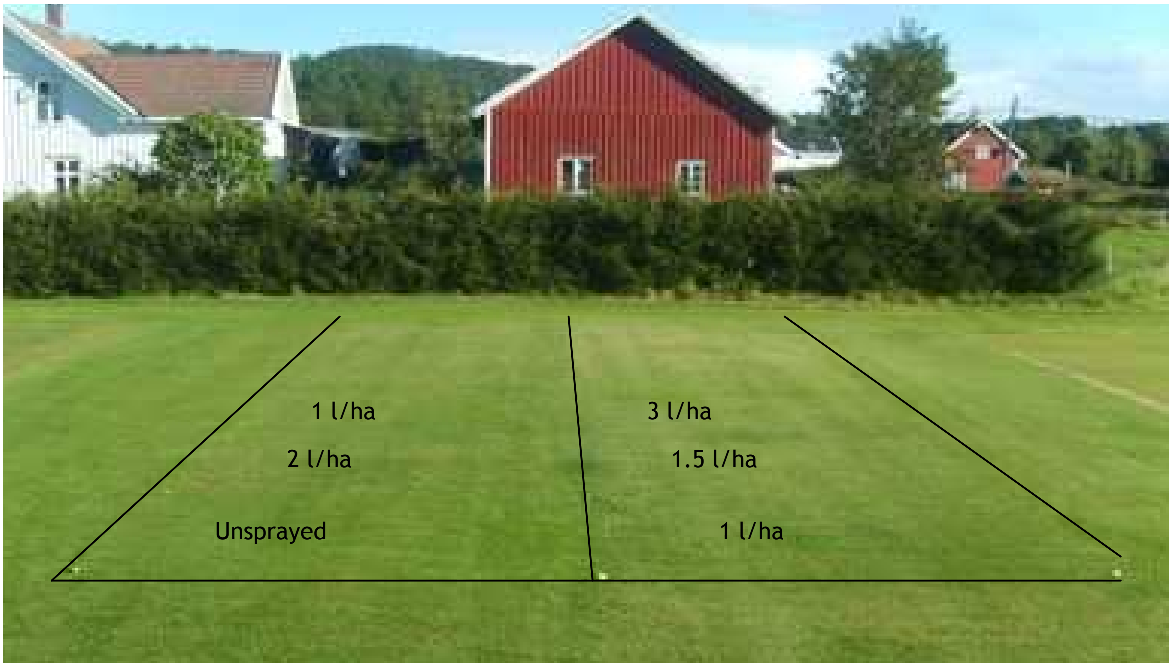


Photo 5. Visual appearance of fairway trial at Landvik, block 1 and 2, on 10 Sept. Within each block, the treatments closest to the photographer have been labeled. High rates of Primo MAXX® resulted in darker, in some cases, almost brown, turf. Photo: Trygve S. Aamlid.

Photo 6.

Turf quality / dormancy colour at growth cessation on 2 Nov. 2007 after application of Primo Maxx at 3.0 l/ha (left) and 0.5 l/ha (right), last application on 26 Sep.

Photo: Trygve S. Aamlid.

Turfgrass height and dry matter production

The average effect of Primo MAXX® on plant height and clipping yields are given in Table 11. In all blocks, the growth regulator caused a significant reduction in plant height even at the lowest rate, but contrary to expectation, this low rate also tended to increase aboveground dry matter production as compared with the unsprayed control treatment. This might reflect a higher tiller density, as also suggested in Table 10. Separate analyses for various parts of trial showed that the average reduction in clipping yield due to Primo MAXX® was stronger in blocks 1 & 2 which had more *Poa* species less red fescue and browntop bent and than blocks 3 & 4. On average for eleven harvests and all replicates, there was a slight tendency for Primo MAXX® to increase the dry matter percentage of turfgrass clippings (P% = 16, Table 11).

Table 11. Absolute and relative effects of increasing rates of Primo MAXX® on turfgrass height, turfgrass dry matter production, and per cent dry matter of clippings in fairway trial at Landvik, 2007. Mean of eleven observations. Plant height above 15 mm represents an average of four days' growth.

Primo MAXX, rate	Plant height, mm		Production of turfgrass clippings, g/m^2/day				% dry matter in clippings
	mm	Rel.	Block 1&2	Block 3&4	Mean	Rel.	
0 = Control	21.9	100	1.78	1.62	1.70	100	31.5
0.5 l/ha	20.9	95	1.91	1.93	1.92	113	32.2
1.0 l/ha	20.7	95	1.65	1.72	1.69	99	32.5
1.5 l/ha	20.0	91	1.46	1.46	1.46	86	33.6
2.0 l/ha	20.3	93	1.55	1.61	1.58	93	32.4
3.0 l/ha	19.5	89	1.31	1.70	1.51	88	33.1
P%.	<0.1	-	10	ns	<5	-	16
LSD 5%	0.7	-	-	-	0.29	-	-
CV%	2	-	10	14	12	-	3

In absolute terms, turfgrass clipping yield showed a distinct seasonal pattern with peaks during the warm and sunny periods in early June and late August (Fig. 2a). The low clipping yield on 17 July was probably due to 280 mm rainfall, and thus nutrient leaching, since the last fertilizer application on 12 June (Tables 3 and 4). Separate analyses of variance for each day indicated a significant effect of Primo MAXX® on clipping yield only on 4 June.

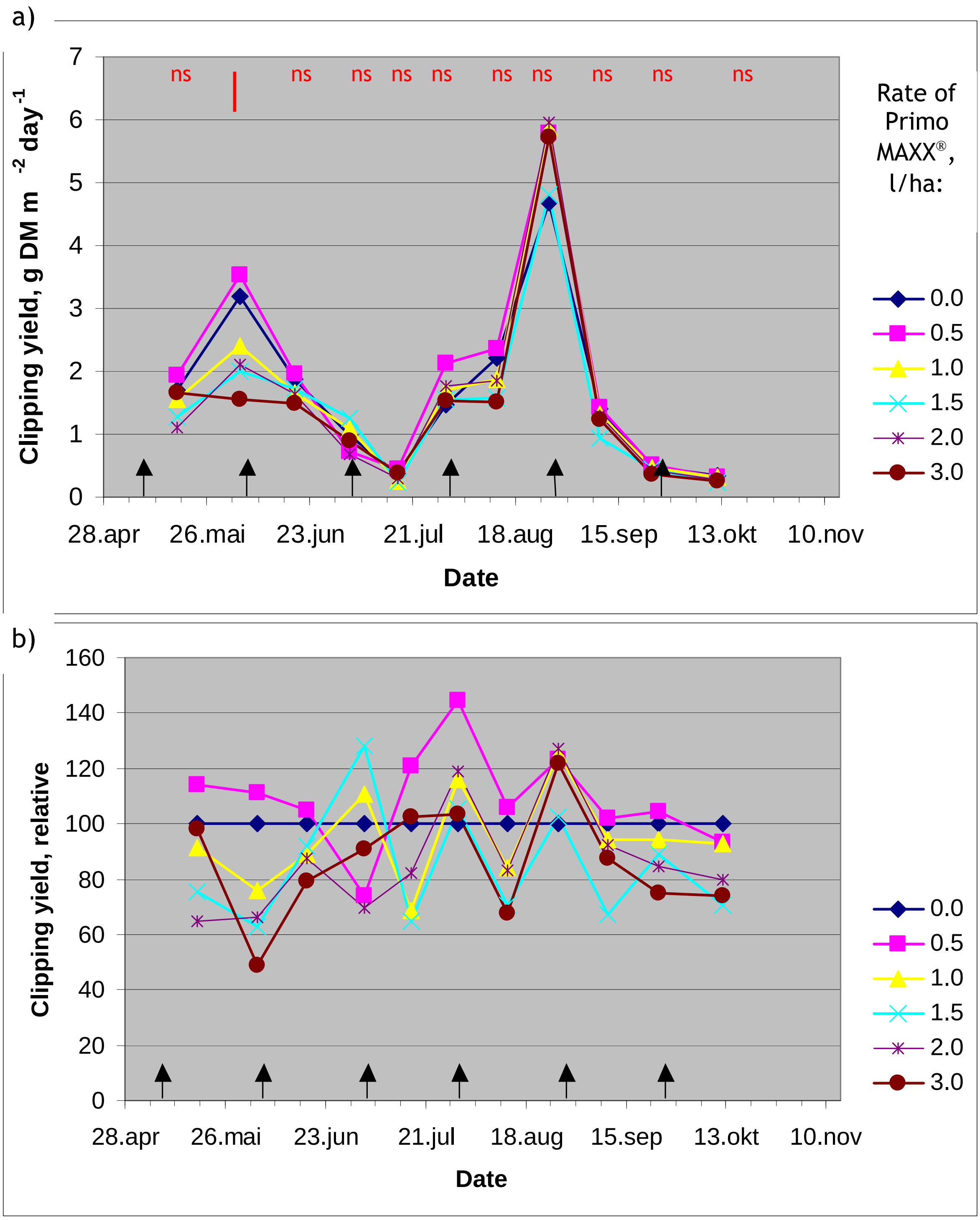


Fig. 2. Absolute (a) and relative (b) reductions in daily dry matter production of turfgrass clippings as affected by increasing rates of Primo MAXX® in fairway trial at Landvik. Red text/bars and black arrows indicate probability / LSD values and application dates 9 May, 5 June, 4 July, 31 July, 28 Aug. and 26 Sep., respectively. In (b), the clipping yield on each date was set to 100 in the unsprayed control treatment.

In relative terms, none of the Primo MAXX® treatments produced clipping yields that were lower than the unsprayed control at all harvests (Fig. 2b). Many of the treatments showed a typical suppression / rebound pattern with clipping yields lower than the control treatment at one harvest, but higher than control treatment at the next harvest.

4.2. Evaluation of Primo MAXX® on a golf course fairway, Lepaa, Finland

On average for two observations in spring, five observations in summer and two observations in autumn, Primo MAXX® had no effect on turfgrass general appearance in the fairway trial at Lepaa. Among the nine observation dates, significant differences were recorded only on 21 August when the plots sprayed with the highest dose (3.0 l/ha) had an average visual merit score of 5.5 as opposed to 6.8 for unsprayed control plots and plots sprayed with the lowest dose (0.5 l/ha).

On average for observations, increasing rates of Primo Max caused an overall increase in tiller density, while turfgrass colour was not significantly affected. No diseases were observed during the growing season.

Table 12. Turfgrass quality (1-9, 9 is best quality), tiller density (1-9, 9 is highest density) and within-season colour (1-9, 9 is darkest green) in fairway trial at Lepaa as affected by increasing rates of Primo MAXX®. Means of nine observations (two in spring, i.e. before 10 June, five in summer, i.e. from 10 June to 1 Sep., and two in autumn, i.e. after 1 Sep.). All values are means of four blocks.

Primo MAXX®, rate	Turf quality (general appearance, 1-9)				Tiller density (1-9)	Within season colour (1-9)
	Mean	Spring	Summer	Autumn		
0 = Control	6.1	5.5	6.1	6.8	5.5	6.1
0.5 l/ha	6.2	5.5	6.1	7.0	5.8	6.2
1.0 l/ha	6.1	5.4	6.1	6.9	5.8	6.1
1.5 l/ha	6.2	5.5	6.2	7.0	6.0	6.3
2.0 l/ha	6.2	5.6	6.1	6.9	6.1	6.3
3.0 l/ha	6.2	5.6	6.1	7.0	6.4	6.2
P%	ns	ns	ns	ns	<0.1	ns
LSD 5%	-	-	-	-	0.4	-
CV%	5	4	8	3	3	4

The effect of Primo MAXX® on turfgrass plant height and clipping yield depended on the time since last application. On average for five observations conducted about two weeks after application, the highest rate of Primo MAXX® caused significant reductions in plant height and clipping yield corresponding to 11 and 48 %, respectively (Table 13). On average for four observations conducted four weeks after application, the maximal reductions were only 3 and 14 %, respectively. Fig. 3 illustrates the unstable effect of Primo MAXX®, particularly toward the end of the growing season. However, unlike in the fairway trial at Landvik (Fig.2), clipping yields on sprayed plots were rarely higher than on untreated control plots in the trial at Lepaa.

Table 13. Absolute and relative effects of increasing rates of Primo MAXX® on turfgrass height and dry matter production in turfgrass clippings in fairway trial at Lepaa 2007. Observations conducted 2 weeks (5 observations) and 4 weeks (4 observations) from spraying treatment have been presented separately.

Treatment	Plant height (mm)				Weight of clippings (g DM / m^2 / day)			
Time after treatment	2 weeks	4 weeks	Mean	Rel	2 weeks	4 weeks	Mean	Rel
0 = Control	15.7	16.0	15.8	100	3.2	7.0	4.9	100
0.5 l/ha	15.7	16.0	15.8	100	2.7	6.3	4.3	87
1.0 l/ha	14.9	16.0	15.4	97	2.8	6.6	4.5	92
1.5 l/ha	14.7	15.7	15.1	96	2.3	5.8	3.9	79
2.0 l/ha	14.4	15.6	15.0	95	2.1	6.1	3.9	80
3.0 l/ha	14.0	15.5	14.6	92	1.8	6.0	3.7	75
P%	<0.1	ns	<5	-	<0.1	ns	ns	-
LSD 5%	1.1	-	1.0	-	0.7	-	-	-
CV%	3	4	3	-	13	22	18	

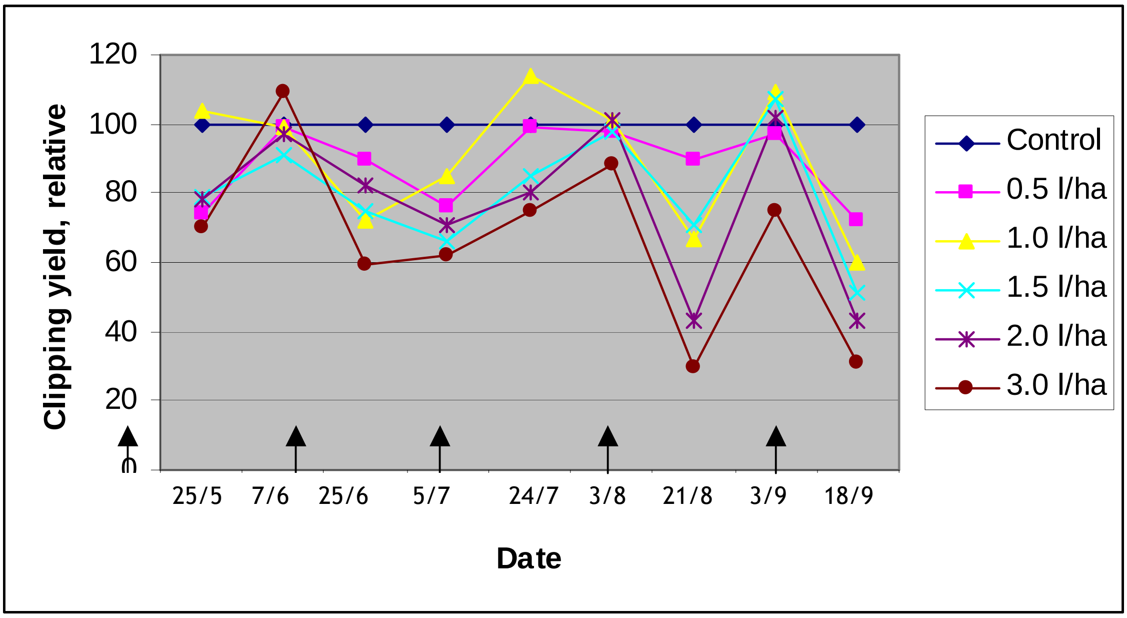


Fig. 3. Relative clipping weights (control = 100) in fairway trial at Lepaa, Finland. Spraying treatments indicated by black arrows were carried out on 11 May, 8 June, 5 July, 3 Aug. and 4 Sep. (The last spraying on 4 Oct. was done primarily to study the effect of Primo MAXX® on overwintering and was not followed by observations in late autumn.)

4.3. Evaluation of Primo MAXX® on a golf course putting green, Lepaa, Finland

On 3 Sep. 2007, a significantly higher tiller density was recorded on green plots sprayed with the highest rate of Primo MAXX® than on unsprayed control plots (data not shown). Otherwise, Primo MAXX® had no significant effect on either general appearance, tiller density or turfgrass colour in the green trial at Lepaa (Table 14). Although the effects on plant height and clipping yields were also not significant, reductions were generally stronger when recorded at two compared with four weeks after application (Table 15, Fig. 4).

Table 14. Turfgrass quality, tiller density and within-season colour (darkness) in green trial at Lepaa as affected by increasing rates of Primo MAXX®, 2007. Means of nine observations (two in spring, i.e. before 10 June, five in summer, i.e. from 10 June to 1 Sep., and two in autumn, i.e. after 1 Sep.). All values are means of four blocks.

Primo MAXX®, rate	Turf quality (general appearance, 1-9)				Tiller density (1-9)	Within season colour (1-9)
	Mean	Spring	Summer	Autumn		
0 = Control	6.4	6.1	6.6	6.3	6.3	6.4
0.2 l/ha	6.3	6.0	6.5	6.0	6.3	6.4
0.4 l/ha	6.3	5.9	6.5	6.1	6.2	6.3
0.6 l/ha	6.3	5.8	6.5	6.4	6.3	6.4
0.8 l/ha	6.2	5.8	6.4	6.3	6.2	6.4
P%	ns	ns	ns	ns	ns	ns
LSD 5%	-	-	-	-	-	-
CV%	3	5	5	7	2	3

Table 15. Absolute and relative effects of increasing rates of Primo MAXX® on turfgrass height and dry matter production in turfgrass clippings in green trial at Lepaa 2007. Observations conducted 2 weeks (5 observations) and 4 weeks (4 observations) from spraying treatment have been presented separately. Plant heights above 3 mm represent one day's growth.

Treatment	Plant height (mm)				Weight of clippings (g DM / m^2 / day)			
Time after treatment	2 weeks	4 weeks	Mean	Rel	2 weeks	4 weeks	Mean	Rel
0 = Control	4.3	3.9	4.1	100	2.60	2.21	2.43	100
0.2 l/ha	4.1	3.8	4.0	96	2.20	2.28	2.23	92
0.4 l/ha	4.0	3.9	3.9	95	1.88	2.28	2.06	85
0.6 l/ha	4.0	3.8	3.9	94	1.72	2.18	1.99	82
0.8 l/ha	3.8	3.9	3.9	93	1.75	2.28	1.92	79
P%	11	ns	ns	-	5	ns	ns	-
LSD 5%	-	-	-	-	0.9	-	-	-
CV%	6	7	8	-	20	14	16	-

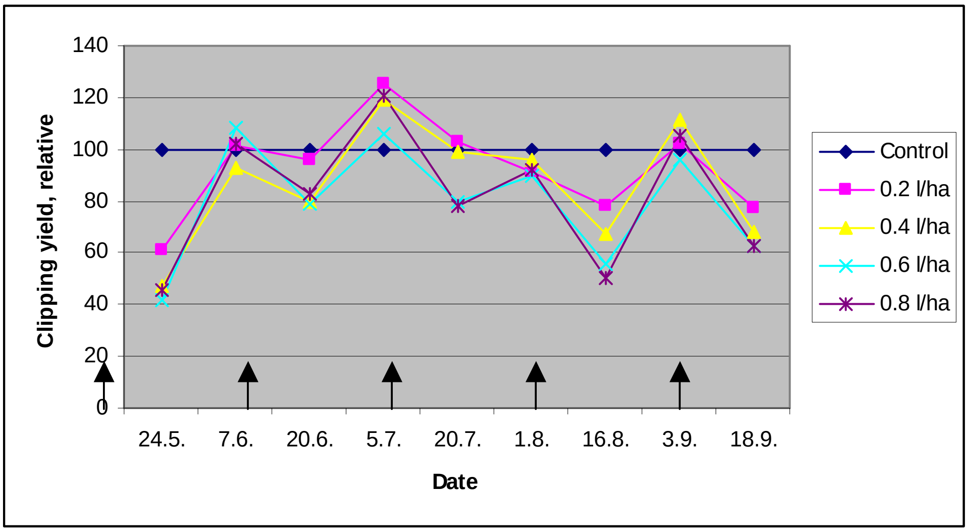


Fig. 4. Relative clipping weights (control = 100) in green trial at Lepaa, Finland. Spraying treatments indicated by black arrows were carried out on 11 May, 8 June, 5 July, 3 Aug. and 4 Sep. (The last spraying on 4 Oct. was done primarily to study the effect of Primo MAXX® on overwintering and was not followed by observations in late autumn.)

4.4. Demonstration trials with Primo MAXX® at Ballerud Golf Course, Oslo, Norway

Green trials

Applications of 0.4 l/ha Primo MAXX® on 5 and 18 June did not affect turf general appearance (Photo 7) or stimpmeter readings on green no. 9 at Ballerud. During the period 14-29 June, clippings were reduced by an average of 32%, but after spraying had been discontinued, there was a rebound effect corresponding to a 26 % increase in clipping yield in the period 12-25 July (data not shown).

Photo 7. Terje Haugen (left) and Lasse Augustsson on green no. 9 at Ballerud Golf Course, 27 June 2007. Photo: Trygve S. Aamlid.

Photo 8. Field day at Ballerud Golf Course 27 Aug. 2007. Photo: Tatsiana Espevig.

Fig. 5 summarizes results from the nursery green trial established on 9 July. In this trial, application of Primo MAXX® about every third week resulted in better colour (not shown), higher green speed (Fig. 5a), and an average reduction in turfgrass clippings of 44 % (Fig. 5b and c). Fig 5b shows that the reduction in clipping yield was most conspicuous during the periods of rapid growth in mid to late July (after only one application of Primo MAXX®) and in late August.

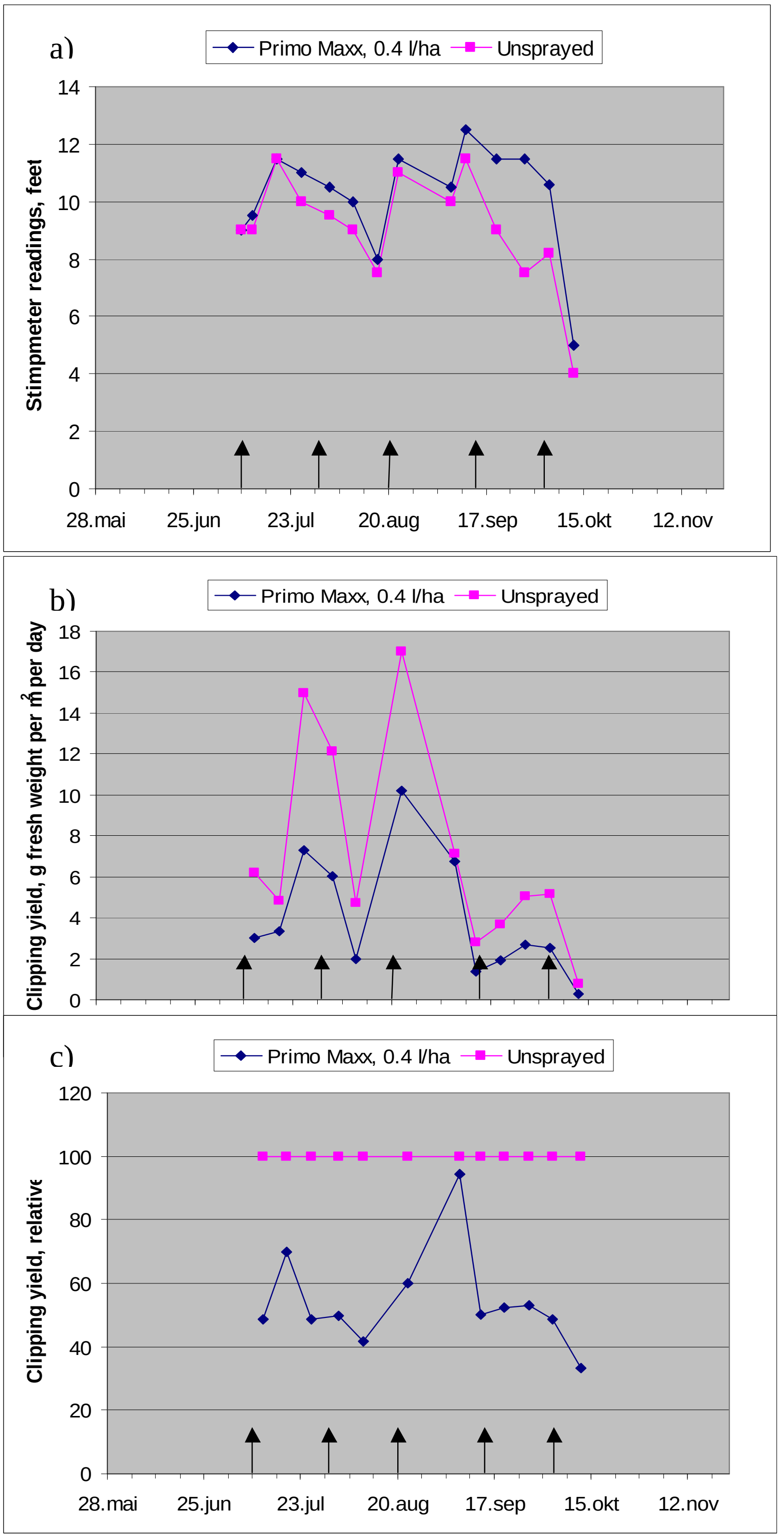


Fig. 5. Effects of spraying Primo MAXX® every three weeks of green speed and absolute and relative clipping yield on nursery green at Ballerud GC, 2007. Black arrows indicate the application dates 9 July, 31 July, 21 Aug., 13 Sep. and 4 Oct.

Fairway trial

As evaluated by the headgreenkeeper, monthly applications of 1.5 l/ha Primo MAXX® (1.5 l/ha) had no negative impact on turf quality in the fairway trial at Ballerud (Fig. 6). Photos 9-11 show, nevertheless, that treated turf was more faded, grayish, and less green than untreated turf. The pronounced colour difference in favour of Primo MAXX® in early September (Fig. 6) was due to less dry spots than the in the control area. While these spots recovered after rainfall on 10 and 17 Sep., the last application of Primo MAXX® on 4 Oct. led to an apparent loss of colour and drop in turf general appearance in late autumn (Photo 11).

On average for 17 clipping, regular application of Primo MAXX® resulted in a 37 % reduction in the fresh weight of turfgrass clippings (Fig. 7). The only time clipping yield was higher on the treated than on the untreated area was at the first clipping nine days after the first application and on 7 Sep. The latter coincided with the observation of less dry spots after use of Primo MAXX®. It may also be interpreted as a rebound effect following growth suppression after application on 31 July.

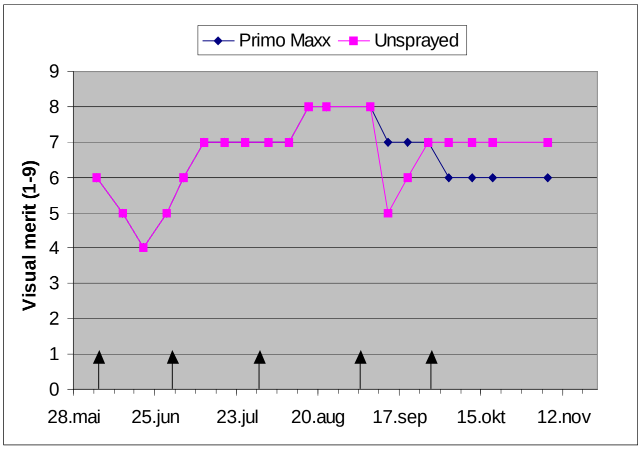


Fig. 6. Effect of Primo MAXX® on turfgrass general appearance in fairway trial at Ballerud GC. Black arrows indicate application dates. (Sprayed an unsprayed plots had identical scores until the beginning of September)

Photo 9. Difference in colour and general appearance of treated and untreated fairway Ballerud GC, 27 June. Photo: Trygve S. Aamlid.

Photo 10. Difference in colour and general appearance of treated and untreated fairway Ballerud GC, 27 Aug. Photo: Tatsiana Espevig.

Photo 11. Difference in colour and general appearance of treated and untreated fairway Ballerud GC, 3 Dec. Photo: Terje Haugen.

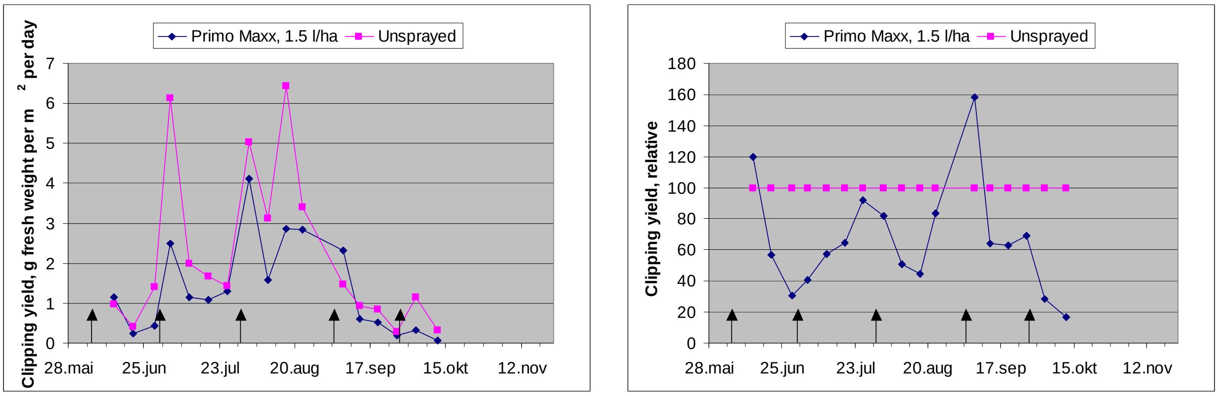


Fig. 7. Absolute (a) and relative (b) reductions in clipping yield resulting form application of Primo MAXX® in fairway trial at Ballerud GC. Arrows indicate application dates.

Spraying 2.2 l/ha of Primo MAXX® at six weeks interval resulted in discoloration and consistent drop in turf quality in the rough trial at Ballerud (Fig. 8, Photos 12 and 13). The effect was most conspicuous in late autumn. Primo MAXX® had less effect on tufts of perennial ryegrass which stood out very markedly in the turf which was otherwise dominated by smooth meadowgrass. Clipping yields were not recorded in this trial.

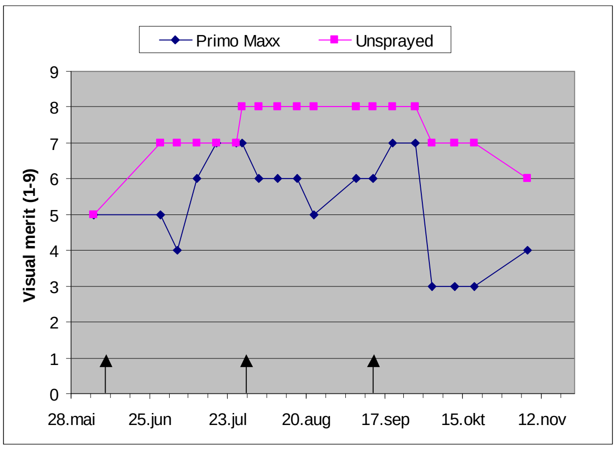


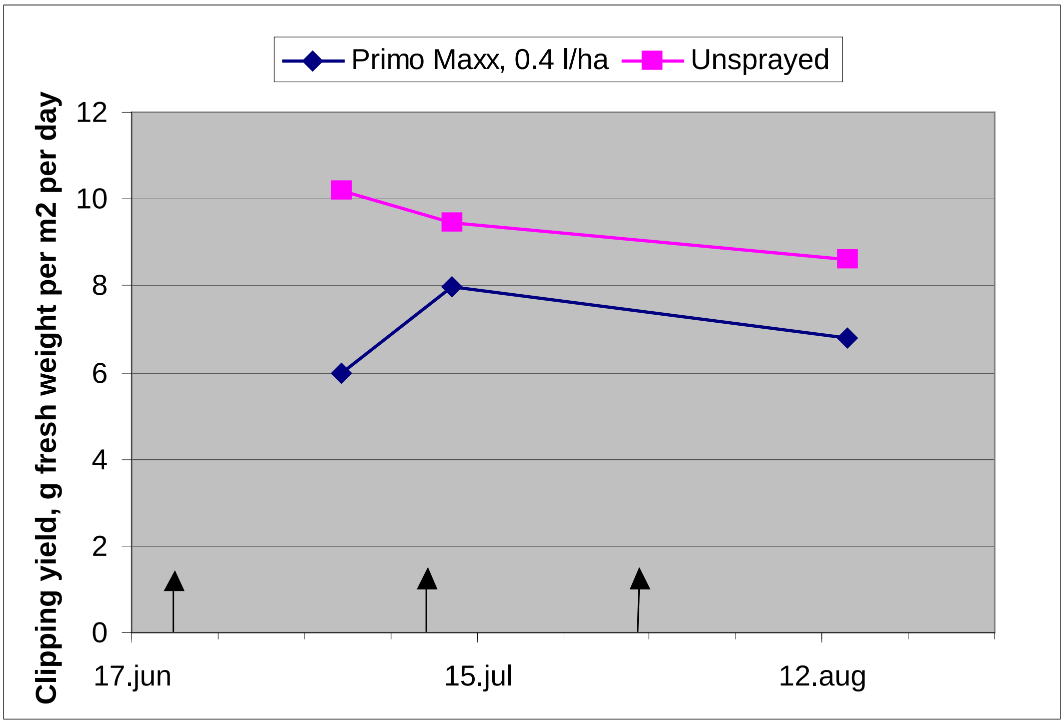
Fig. 8 (upper left). Difference in colour and general appearance of treated and untreated area in rough no 9, Ballerud, 27 June. Photo: Trygve S. Aamlid.

Photo 12 (upper right). Terje Haugen (left) and Lasse Augustsson in rough trial at Ballerud GC, 27 June. Photo: Trygve S. Aamlid.

Photo 13 (lower left). Trygve S. Aamlid inspecting rough trial at Ballerud GC, 27 August 2007. Tufts of ryegrass stand out very markedly on sprayed area.
Photo: Tatsiana Espevig.

4.5. Demonstration trial with Primo MAXX® at Oslo Golf Club, Bogstad, Norway

Application of 0.4 l Primo MAXX® at three week intervals resulted in darker turf but had otherwise no effect on the turfgrass quality of annual meadowgrass at Oslo GC. On average for three registrations, the Primo MAXX led to a 26% reduction in clipping yields (Fig. 9).



5. Discussion and suggestions for 2008

The starting point for evaluating Primo MAXX® in this two-year project was the rates and applications frequencies recommended for the product in Europe (Syngenta 2007, Table 16). Based on our experiences from agricultural crops that the optimal rates may be different in the Nordic countries than countries further south, higher and lower rates were included in the GEP trials both to determine the potential growth inhibition and the risk for discoloration or other phytotoxic effects. All taken together, the results from the first project year confirms that the guidelines in Table 16 are not directly applicable in Scandinavia and that further research is needed to find the optimal way of using the product under Nordic conditions.

Table 16. Dose rates and applications frequencies recommended for Primo MAXX® in the United Kingdom (Syngenta 2007).

	Dose rate		Application
	Primo MAXX®, l/ha	trinexapac-ethyl, g a.i./ha	frequency
Fairways	0.8 – 1.6	90 - 180	Every four to five weeks
Roughs & semi-roughs	1.6-2.4	180 - 240	Every five to eight weeks
Greens	0.4	45	Every two to four weeks

On fairway, the average reduction in clipping yield caused by monthly application of the intermediate Primo MAXX® rate of 1.5 l/ha was 15 and 21 % in the GEP trials at Landvik and Lepaa, respectively. By contrast, monthly application of 1.5 l/ha resulted in a 37 % reduction in clipping yield in the demonstration trial at Ballerud GC, which is closer to the data presented by Syngenta (2007). In agreement with Table 11 showing an increase in turfgrass dry matter percentage (i.e. decreased succulence) after application of Primo MAXX®, one of the reasons for this difference might be that clipping yields were determined on a dry weight basis in the GEP trials but on a fresh weight basis at Ballerud GC and in the data presented by Syngenta (2007). Another, and probably more important explanation, is the difference in species composition among the three trials. While the plant cover at Ballerud was almost 100% by annual meadowgrass, the species composition at Landvik varied with the two blocks showing the least response to Primo MAXX® having a plant cover of 74 % red fescue (Tables 1 and 11). By contrast, smooth meadowgrass dominated over red fescue at Lepaa due to the heavy soil type, use of irrigation, and relatively high nitrogen input. Unfortunately, we have not been able to find many references about the specific effects of Primo MAXX® on red fescue turf, but our results are in partial agreement with Pannacol et al. (2004) who found 40 %, 21 %, and no significant reduction in clipping yield after using trinexapac-ethyl in smooth meadowgrass, chewing fescue and creeping red fescue, respectively.

Perhaps the most conspicuous feature of the present results was the unstable effect of Primo MAXX® on clipping yields due to the postsuppression rebound effect. In the fairway trial at Lepaa, Finland, this resulted in clipping yield reductions being significant only two weeks after application (Table 13), and a similar tendency could be seen also in the green trial (Table 15). In Norway, clipping yields four weeks after spraying were often higher than on unsprayed control plots in the fairway trial at Landvik (Fig. 2), and a strong rebound effect was observed also after spraying treatments had to discontinued at green no. 9, Ballerud GC. The unstable effect in of Primo MAXX® in these trials was probably due to a rapid degradation of trinexapac-ethyl in plant tissue and a higher regrowth potential due to accumulation of carbohydrate reserves and GA_1 precursors during the suppression phase (Lickfeldt et

al. 2001, Branham & Beasley 2007). In North-American experiments, Lickfeldt et al. (2001) reported clipping yields reductions in smooth meadowgrass to be much more consistent when trinexapac-ethyl was applied at four than at six week intervals, but under Nordic long-day conditions, spraying every second, or at least every third week, may well be necessary to stabilize low GA_1 levels, not only on greens, but also on fairways and tees. Although there was a surge effect during the driest period in mid September, the most stable clipping reductions in our trials, on average 44 % on a fresh weight basis, were, indeed, obtained on the nursery green which was sprayed about every third week at Ballerud GC (Fig. 5c). While Branham & Beasley (2007) noted that temperature was the most important factor determining degradation of trinexapac-ethyl in turfgrass tissue, our results suggest that other factors such as light and water availability may also be important for the rebound effect under Nordic conditions. Very clearly, application frequency is a major question that has to be addressed during the continuation of this project.

The potential reductions in mowing costs from using a plant growth regulator will always have to be weighed against the risks for discoloration or other harmful effects on turf quality. In the present trials, reductions in general appearance (visual merit) scores were far more conspicuous in the GEP trial at Landvik than in the GEP trials at Lepaa or the demonstration trials at Ballerud GC. Apart from possible effects of different botanical compositions, this might reflect a subjective human factor, i.e. different backgrounds and attitudes of the observers in the various trials. While the fairway trial at Landvik was evaluated by turfgrass scientists and technicians with long experience from turfgrass variety testing, the trials at Lepaa and Ballerud were evaluated by greenkeepers working on the course. While the observers at Landvik may have paid more attention to turf aesthetic values such as less intense colour, and less vigorous and uniform plots, the observers at Lepaa and Ballerud may well have been more attentive to ball roll and other functional characteristics of the playing surface. The less succulent but significantly darker green turf resulting from high Primo MAXX® rates at Landvik are in agreement with other studies showing higher mesophyll cell densities and chlorophyll concentrations resulting from less elongation of leaf cells (Heckman et al. 2001, Ervin & Zhang 2008). As for tiller density, most literature supports the Finnish rather than the Norwegian results; i.e. enhanced tillering after Primo MAXX® application (Branham & Beasley 2007, Ervin & Zhang 2008).

As compared with the unsprayed control treatment, the strongest negative effect of Primo MAXX® on turfgrass general appearance at Landvik was recorded after the first spraying in early June, in mid July and at the last observation in early November. Each of these observations might be explained by suboptimal conditions causing reduced turfgrass growth. From 6 to 15 June there was a dry and warm and period with maximum temperatures in the range 25-30 ºC that obviously reduced turfgras tillering and aesthetic appearance; until mid July exceptional rainfalls starting on 22 June were not compensated by increase nitrogen inputs, and in autumn, the last application of Primo on 26 September was followed by several nights of frost. Although most studies have failed to document significant interactions between nitrogen and trinexapac-ethyl on turfgrass quality (Steinke & Stier 2001, Goss et al. 2002, McCullogh et al. 2006), it seems reasonable to assume that potential negative effects on Primo MAXX® on turfgrass quality will be most pronounced under suboptimal growing conditions. As in the trials at Landvik (Photo 6) and Ballerud (Photo 11), Beam et al. (2002) reported significant discoloration of trinexapac-ethyl-treated smooth meadowgrass following frost in autumn.

Undoubtedly, the most convincing argument for official approval of Primo MAXX® on Nordic golf courses would be a clear documentation that it improves winter survival. Preliminary results with annual meadowgrass suggested that low rates of trinexapac-ethyl prevented winter injury, whereas high rates had opposite effects due to discoloration during the hardening phase in late autumn (Rossi & Buelow 1997). While trinexapac-ethyl has been shown to increase water soluble carbohydrate contents (Goss et al. 2002) and result in faster spring greenup, Ervin & Zhang (2008) recently called for more detailed investigations into the effect of trinexapac-etyl on freezing tolerance as the research to date has provided scarce information on this aspect. Under Nordic conditions, desiccation if growth resumes when soils are still frozen and irrigation not yet operational in spring, or damage due to unstable winters with ice and water covering the turf, sometimes resulting in suffocation, appear to be more

important that direct freezing injury. In this regard, trineexapac-ethyl may well have a positive effect as it reduces mitochondrial respiration (Ervin & Zhang 2008). In 2008, it will therefore be very interesting to study winter injury and spring green-up and recovery in the on-going trials at Landvik, Lepaa and Ballerud which all had their last application of Primo MAXX® in late September or early October.

Even with winter survival and spring observations included, the amount of data presented in this report is too limited to recommend any listing of Primo MAXX® for turf use in the Nordic countries. Therefore, as stated in the contract between Syngenta and Scandinavian Turfgrass and Environment Research Foundation, there is a need for new GEP trials to be started in spring 2008 and followed until registration of winter survival in spring 2009. For this purpose, a new experimental green was constructed and seeded to creeping bentgrass at Landvik in 2007. In the trial to be established on this green in spring 2008, we suggest to compare Primo MAXX® at three rates (0.15, 0.30 and 0.45 l/ha) and two application frequencies (every 10/11 days and every 21 days), i.e. six combinations plus an unsprayed control treatment. As different grass species seem to vary in their response to Primo MAXX®, similar trials should preferably be carried out on also red fescue/browntop greens and velvet bentgrass greens, although this would require additional funding from Syngenta/STERF.

In Finland, a new GEP trial will be established in spring 2008 on a fairway that is regularly subjected to winter injury. New demonstration trials might be added to the project depending on interest from superintendents and funding from the national golf unions.

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

Results from the first evaluation year 2007

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Finnish team spraying fairway trial at Lepaa Golf Course.
Photo: Oiva Niemelainen

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Summary:
This report presents first year results from a two year project evaluating the plant growth regulator Primo MAXX® (trineexapac-ethyl) on Nordic golf courses.

Sammendrag:
I denne rapporten presenteres første års resultater fra et toårig prosjekt med utprøving av vekstreguleringsmidlet Primo MAXX® (trinexapac-etyl) på golfbaner i Norden.

Approved

Arne Sæbø	Trygve S. Aamlid
Leader, Bioforsk's Section for Urban Greening	Project leader

Contents

1. Abstract

As an inhibitor of the last step in plant synthesis of bioactive gibberellin (GA_1), the plant growth regulator Primo MAXX® (trinexapac-ethyl) offers prospects of reduced energy use for mowing and improved turfgrass quality under Nordic long day conditions. This report presents first year results from 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 possible registration of Primo MAXX®, unreplicated demonstration trials were carried out at Ballerud and Bogstad Golf Courses in Oslo under supervision of Bioforsk and with funding from the Norwegian Golf Federation (NGF).

GEP trials on **fairways** (mowing height 12-18 mm) were carried out at Bioforsk Landvik, Norway (58°34'N, 8°52'E) and at the Lepaa Unit of the HAMK University of Applied Sciences, Finland (61°08'N, 24°20'E). Primo MAXX® was applied at monthly intervals at rates 0.5, 1.0, 1.5, 2.0 and 3.0 l/ha (56.5, 113, 169.5, 226 and 339 g a.i./ha trinexapac-ethyl) in comparison with an unsprayed control treatment. Turfgrass general appearance, tiller density, colour, height growth, and clipping yields were recorded two and four weeks after each application. Primo MAXX® had no effect on turfgrass general appearance but increased density at Lepaa. At Landvik, Primo MAXX® (>= 1.0 l/ha) reduced turfgrass general appearance and density, but resulted in significantly darker green colour. Quality reductions were most apparent during periods with either daily maximum temperatures >25 ºC, extreme rainfall probably causing nitrogen deficiency, or frost at night. Average reductions in clipping yield caused by Primo MAXX® (>= 1.0 l/ha) were 8 % in the GEP trial at Landvik, 18 % in the GEP trial at Lepaa and 37 % in the demonstration trial at Ballerud; to some extent this difference may be due to different botanical composition with red fescue (*Festuca rubra*) and annual meadowgrass (*Poa annua*) being the predominant species at Landvik and Ballerud, respectively. Clipping yield reductions due to Primo MAXX® were unstable, growth suppression two weeks after application often being followed by a rebound effect during the remaining two weeks until next application.

A GEP trial on creeping bentgrass **putting greens** was carried out at Lepaa, Finland, and demonstration trials at Ballerud and Bogstad, Norway. Primo MAXX® was sprayed at rates 0.2, 0.4, 0.6 or 0.8 l/ha at monthly intervals in the GEP trial, and at 0.4 l/ha every three weeks in the demonstration trials. On average for all observations, Primo MAXX® had no effect on turfgrass quality, but clipping yields were reduced by 16, 44 and 26% at Lepaa, Ballerud and Bogstad, respectively. As in the fairway trials, growth suppression at Lepaa was stronger when assessed at two than at four weeks after application. By contrast, Primo MAXX® produced a fairly stable effect when applied at three week intervals in the demonstration trials.

Use of Primo MAXX® on golf course **roughs** was investigated only in a demonstration trial at Ballerud. Application of 2.2 l/ha of Primo MAXX® every seven weeks resulted in discolouration and reduced quality of smooth meadow grass.

In conclusion, the first year of this project has shown that the guidelines for use of Primo MAXX® in other European countries are not directly applicable in Scandinavia. As the present results are too limited to apply for registration of Primo MAXX®, the project will continue in 2008 tentatively with new trials investigating application of Primo MAXX® at lower rates, but higher frequencies. Improved winter stress tolerance would be a convincing argument for registration of Primo MAXX® in the Nordic countries, and the on-going trials will therefore be followed by an assessment of effects of the last Primo MAXX® applications in September or October 2007 on winter survival and spring recovery.

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

2. Introduction

The plant growth regulator trinexapac-ethyl was developed by Syngenta in the 1980s. Since the active ingredient is available in different formulations, the chemical will, in this report, be referred to as Primo MAXX®, which is the product developed by Syngenta specifically for use on turf. Unlike earlier plant growth regulators, Primo MAXX®'s mode of action is highly specific as it blocks the conversion of GA_{20} til GA_1, i.e. the last step in the biosynthesis of gibberellic acid, a plant hormone stimulating cell elongation and thus vertical turf growth.

After its release, Primo MAXX® was rapidly adopted by the US and Canadian turf industries. In North America, there are several independent university studies documenting its positive effects on golf courses, athletic fields, home lawns, and sod production (for a recent review, see Erwin and Zhang 2008). These advantages include reduced leaf elongation and thus reduced mowing costs and energy use, improved tiller production (more lateral growth), darker green colour, and improved resistance to drought and shade.

While other formulations of trinexapac-ethyl have been approved for agricultural use in Europe for about a decade, the experience with Primo MAXX® to European turfgrass areas is relatively limited. During the past three to four years, Primo MAXX® has been approved for turf use in Italy, France and UK, and the evaluation and registration process has been initiated in many other countries.

Being an inhibitor of gibberellin biosynthesis, Primo MAXX® offers special prospects for turfgrass management in the Nordic counties Finland, Sweden, Norway, Iceland, and Denmark. At latitudes ranging form 55 to 71 °N, turfgrasses growing in these countries exposed not only to long photoperiods during most of the growing season, but also to lower photosynthetic flux densities and lower red to farred (R/FR) ratios than in countries further south. The natural turfgrass response to these northern light conditions is to devote more of its resources to shoot elongation (Heide et al. 1985a,b). Since this response is primarily mediated by the gibberellic acid GA_1, any specific growth regulator that controls the biosynthesis of this compound might be useful under Nordic conditions. Nevertheless, our experience from the introduction of trinexapac-ethyl for agricultural use in the Nordic counties suggests that the optimal dose rates and frequencies for application of Primo MAXX® to various types of turf are probably not the same as at lower latitudes. This is also due to different species and cultivars being grown compared with countries further south. Field trials under Nordic conditions are therefore required not only to produce data for the national certification agencies, but also to provide turf managers with recommendations for how to use the product.

This report presents first year preliminary results from a two year project evaluating the use of Primo MAXX® on golf courses in the Nordic countries. The project was funded by Syngenta and the Scandinavian Turfgrass and Environment Research Foundation (STERF) 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' trials needed to provide documentation for possible registrations of Primo MAXX® by the national authorities, a couple of practical demonstration trials were carried out on Norwegian golf courses under supervision from Bioforsk and with funding from the Norwegian Golf Federation (NGF).

3. Methods

3.1. Evaluation of Primo MAXX® under fairway conditions, Bioforsk Landvik, Norway

Experimental site

On 8 May 2007, a field trial was laid out on a fairway established on a sandy loam soil (topsoil: 68 % sand, 27% silt, 5 % clay) at Bioforsk Landvik Research Station (58°34'N, 8°52'E), SE Norway. Soil samples indicated a pH (H_2O) of 5.9, high phosphorus values (P-AL=19) and intermediate to low potassium values (K-AL = 8, K-HNO_3=58). The fairway had been seeded in September 2003 to a mixture of smooth meadowgrass (*Poa pratensis*), chewing fescue (*Festuca rubra* ssp. *commutata*), and browntop bent (*Agrostis capillaris*) (Table 1). Block 1 and 2 were located in one part, and block 3 and 4 in a different part of the fairway. Botanical analyses at the start of experimentation indicated that red fescue was the predominant species in all blocks, but presumably due to slightly less surface drainage, blocks 1 and 2 had a higher percentage of smooth and annual meadowgrass and broadleaved weeds (primarily white clover (*Trifolium repens*)) than blocks 3 and 4 (Table 1).

Table 1. Seed mixture used for fairway establishment in 2003 and botanical composition at the start of the Primo MAXX® trial in spring 2007.

Species	Cultivar	% (w/w) of seed mixture	% cover at initiation of Primo MAXX® trial		
			Block 1 and 2	Block 3 and 4	Mean
Poa pratensis	Conni	25	31	9	20
Poa pratensis	Eva	10			
Poa pratensis	Limousine	10			
Festuca rubra ssp. commutata	Bargreen	25	50	74	62
Festuca rubra ssp. commutata	Calliope	25			
Agrostis capillaris	Tracenta	5	5	15	10
Poa annua			8	2	5
Broadleaved weeds			6	0	3
Sum		100	100	100	100

Experimental plan

The experiment was laid out according to a randomized complete block design with plot size 2m x 3m, four blocks (replicates) and the following treatments:

1. Usprayed control
2. Primo MAXX, 0.5 l/ha (56.5 g a.i./ha) every four weeks
3. Primo MAXX, 1.0 l/ha (113 g a.i./ha) every four weeks
4. Primo MAXX, 1.5 l/ha (169.5 g a.i./ha) every four weeks
5. Primo MAXX, 2.0 l/ha (226 g a.i./ha) every four weeks
6. Primo MAXX, 3.0 l/ha (339 g a.i./ha) every four weeks

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. Actual application rates were recorded by weighing the tank before and after spraying. Table 2 shows actual rates and weather conditions for each spraying event.

Table 2. Weather conditions and actual application rates at the six spraying events.

Application date	Time of day (hours)	Weather conditions at application			Treatment number / application rate (l Primo MAXX® per ha)				
		Air temp. °C	Relative Humidity %	Wind Speed m/s	2. (target 0.5)	3. (target 1.0)	4. (target 1.5)	5. (target 2.0)	6. (target 3.0)
9 May	09-11	14	48	< 1.0	0.47	0.94	1.56	1.90	3.35
5 Jun.	09-11	15	60	< 1.0	0.58	1.06	1.67	1.93	3.19
4 Jul.	13-15	17	70	1.0-2.0	0.61	0.98	1.73	2.19	3.38
31 Jul.	08-10	18	55	1.0-2.0	0.55	1.05	1.66	2.28	3.41
28 Aug.	09-11	19	32	1.0-2.0	0.57	1.03	1.55	2.19	3.52
26 Sep.	09-11	11	69	< 1.0	0.52	1.07	1.55	2.01	3.15
Mean					0.55	1.02	1.62	2.08	3.33

Registrations

At two weeks intervals throughout the experimental period, turfgrass colour, tiller density, and turf general appearance were assessed by turfgrass scientist or technicians using a scale from 1 to 9 where 9 is darkest colour, highest tiller density and best turf quality. The assessments were conducted two and four weeks after application of Primo MAXX®. On the same dates, turfgrass diseases and broadleaf weed (including white clover) invasion were reported as per cent of plot area. Turfgrass height was recorded as the mean of three random measurements with a ordinary ruler in each plot, and the overall growth rate by weighing clippings in the basket of a walk-behind mower used in the 0.56 m x 1.88 m central area of each plot (Photo 1). Both raw weight and dry weight were recorded, the latter after drying for 24 h at 60°C. By the end of the growing season, on 2 Nov., turfgrass dormancy colour was evaluated on a scale 1-9, where 1 is completely faded / brown turf, and 9 is completely green turf.

Photo 1a and b. Tatsiana Espevig collecting clippings in fairway trial at Landvik. Photos: Trygve S. Aamlid

Management

The experiment was mowed at 15 mm two times a week, usually on Monday and Friday. A triplex fairway mower without collection of clippings was used except when clipping weights were to be recorded. Granular fertilizer was applied at approximately monthly intervals as outlined in Table 3. The experiment was not irrigated except for small amounts of water to dissolve fertilizer after application. On 7 Aug., the trial was aerated using a vertidrain with 15 mm solid tines to 15 cm depth. Topdressing was accomplished on 8 Aug. and 5 Nov. at rates 0.75 and 1.5 kg pure sand per m^2, respectively.

The fairway trial at Landvik was not exposed to ordinary play, but it was was subjected to artifical wear from a wear drum one to two times per week.

Table 3. Fertilizer inputs, fairway trial, Landvik.

		Per ha							
Date	Fertilizer type	kg fertilizer	kg N	kg P	kg K	kg Mg	kg S	kg Ca	kg Fe
17 Apr.	Fullgjødsel 22-2-12	40	9	1	5	0	1	0	0
16 May	Fullgjødsel 22-2-12	70	15	1	8	1	2	1	0
12 Jun.	Arena Golf Extra 13-0-15	150	20	0	23	2	21	0	3
23 Jul.	Arena Golf Extra 13-0-15	130	17	0	20	2	18	0	3
9 Aug.	Arena Golf Extra 13-0-15	135	18	0	21	2	18	0	3
5 Sep.	Arena Golf Extra 13-0-15	150	20	0	23	2	21	0	3
SUM			99	2	100	10	80	1	11

Weather data

In SE Norway, the growing season 2007 was characterized by exceptionally high rainfall, especially in July, but also in May, June and August (Table 4). By contrast, September was unusually dry. Precipitation was recorded on 16 out of the 31 days in July; the cloudy summer weather is also reflected by a rather low irradiance during this month. The warmest period, with daily maximum temperatures in the range 23-29 ºC was recorded from 6 to 12 June.

Table 4. Weather data for Landvik meteorological station, about 200 m for experimental field. Normal values for temperature and rainfall are 'official' values for from the period 1961-90, while normal values for irradiance are calculated averages for the period 1994-2006.

	Mean temperature, ˚C		Precipitation, mm		Irradiance, MJ/m^2 (305-2800 nm)	
	2007	30 yr normal	2007	30 yr normal	2007	13 yr average
May	10.2	10.4	107	82	518	540
June	15.9	14.7	109	71	604	600
July	15.5	16.2	213	92	492	632
Aug.	16.2	15.4	132	113	476	476
Sep.	12.0	11.8	59	136	321	262
Mean / sum	14.0	13.7	620	494	2411	2510

3.2. Evaluation of Primo MAXX® on a golf course fairway, Lepaa, Finland

Experimental site

The Finnish fairway trial was laid out on 11 May 2007. The fairway was seeded to a mixture of smooth meadowgrass and chewing fescue (*Festuca rubra* spp. *commutata*) on a heavy clay soil (15% sand, 37% silt, 48% clay) at the Lepaa Unit of HAMK University of Applied Sciences, Finland (61°08'N, 24°20'E). 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. All observations and management of the trial was carried out by the HAMK Lepaa greenkeepers Petteri Lehmuskoski and Tommi Turunen except for the spraying treatments which were carried out by MTT's 'Good Experimental Practice' certified spraying team from Jokioinen (90 km from Lepaa).

Experimental plan and registrations

The experiment was laid out following the same plan and plot size as at Landvik, Norway (previous paragraph). Primo MAXX® was applied in accordance with the Finnish 'Good Experimental Practise' protocol, using a portable, compressed air-powered 'van der Weij' plot sprayer, mounted with a windshield and flat fan nozzles (Hardi 4110-12) and working at 180-250 kPa pressure. The spraying boom had four nozzles spaced 50 cm apart. The spraying volume corresponded to 200 l/ha. Full spray coverage was on the central 1.5m x 2.5 m of each plot. Table 5 shows application dates and weather conditions for each spraying event. The last application on 4 Oct. was conducted especially to evaluate potential effects of Primo MAXX® on turfgrass winter damage.

Table 5. Application dates and weather conditions in fairway and green trials at Lepaa.

Application date	Time of day (hours)	Air temp. °C	Relative humidity %	Wind Speed m/s	% cloud cover
11 May	09-11	11	29	0	25
8 Jun.	09-11	20	56	1.5	1
5 Jul.	13-15	23	47	2.5	70
3 Aug.	09-11	17	78	2.0	90
4 Sep.	09-11	11	90	1.0	90
4 Oct.	13-15	11	92	1.5	100

Photo 2. Austen Sutton, Syngenta (left) and greenkeeper Petteri Lehmuskoski, HAMK Lepaa Unit, in fairway trial at Lepaa, Finland, 29 Aug. 2007.

Photo: Oiva Niemelainen.

Registrations

Registrations were carried out at two-week intervals following the same program as at Landvik (previous section) except that weed occurrence and dormancy colour were not recorded. Plant height at Lepaa was determined using a Turf Check Prism device (Check Signature Inc., Shoreview, MN).

Management and wear

The experiment was mowed with a triplex fairway mower about three times per week. Mowing height ranged from 12 to 18 mm. Granular fertilizer Sportsmaster 26-2-9 was applied at equal rates on 8 May and 12 July, the total input corresponding to 156 kg N, 12 kg P, 54 kg K and 0.9 kg Fe per ha. Information about irrigation is given in Table 6. The trial was aerated or top-dressed in late autumn, after the completion of registrations.

During the growing season period, the trial was exposed to approximately 3.500 rounds of golf.

Weather data

Temperatures at Lepaa were higher the 30 yr normal values throughout the growing season (Table 6). August had the greatest deviation from the long-term average value. July had 49 % more, and August 42 % less rainfall than usual; over the whole experimental season, rainfall was close to the 30 yr normal value.

Table 6. Weather data for Hattula Lepaa weather station and irrigation in fairway and green trial at Lepaa golf course, 2007. Normal values for temperature and rainfall are official values for from the period 1971-2000 (Finnish Meteorological Institute)

	Mean temperature, °C		Rainfall, mm		Irrigation, mm (2007)	
	2007	30 yr normal	2007	30 yr normal	Fairway trial	Green trial
May	10.6	9.8	30	34	*	*
June	15.1	14.5	54	55	26	79
July	16.6	16.4	119	80	5	47
Aug.	16.4	14.6	43	74	7	50
Sep.	9.9	9.4	58	54	0	6
Mean / sum	13.7	12.4	304	297	37	188

* Data are unavailable for the period 1-26 May 2007 due to change of irrigation computer.

3.3. Evaluation of Primo MAXX® on a golf course putting green, Lepaa, Finland

Experimental site

The Finnish green trial was established on 11 May 2007 on a USGA green seeded to creeping bentgrass (*Agrostis stolonifera*, seed blend of 50% 'Penn A-4' and 50% 'Penn G-6') at Lepaa Golf Course.

Experimental plan

The experimental plan comprised five rates of Primo MAXX plus the unsprayed control treatment:

1. Usprayed control
2. Primo MAXX, 0.2 l/ha (22.6 g a.i./ha) every four weeks
3. Primo MAXX, 0.4 l/ha (45.2 g a.i./ha) every four weeks
4. Primo MAXX, 0.6 l/ha (67.8 g a.i./ha) every four weeks
5. Primo MAXX, 0.8 l/ha (90.4 g a.i./ha) every four weeks

The trial had four replicates, and a gross plot size of 2 m x 3 m. It was sprayed on the same dates and following the same GEP procedures as the fairway trial on the same location (Table 5).

Photo 3. Green trial at Lepaa ready for the first treatment on 11 May 2007. Photo: Oiva Niemelainen.

Registrations

Registrations followed the same program as in the Finnish fairway trial (previous section).

Management and wear

The experiment was mowed with a Triplex greens mower for an average of six times per week. Depending on weather and turfgrass density, mowing height was 5–7 mm in May and September and 3-4 mm from June to August. Information about irrigation and fertilizer inputs are given in Tables 6 and 7, respectively.

To avoid thatch accumulation, the trial was aerated with deep slitting knives every second week and with 8 mm needle tines once a month. Verticutting was accomplished every second week and topdressing with 0.1-0.7 mm finely graded sand at a rate of 1 kg per m2 every third week. The sand was brushed/irrigated into the green and the dressing was never done in close proximity to weighing of clippings.

Being located on a practise green, the experiment received wear from about 10.000 rounds of golf over the season. When placing holes on the green, care was taken to create as uniform wear as possible.

Table 7. Fertilizer inputs in green trial at Lepaa.

		Per ha							
Date	Fertilizer type	kg fertilizer	kg N	kg P	kg K	kg Mg	kg S	kg Ca	kg Fe
28.3.2007	Floratine Kevätstartti*	35	5.4	1.2	2.1				
5.4.2007	Floratine Kevätstartti	35	5.4	1.2	2.1				
19.4.2007	Floratine Kevätstartti	35	5.4	1.2	2.1				
26.4.2007	Sierraform Springstart (16-0-13)	250	40	0	32.5				2.50
15.5.2007	Sierraform All Season (18-3-15)	250	45	7.5	37.5	3.0			1.25
30.5.2007	Kemigreen Basic (23-4-14)	40	9	1.6	5.6	0.6	0.8		0.04
5.6.2007	Kemigreen Basic (23-4-14)	40	9	1.6	5.6	0.6	0.8		0.04
11.6.2007	Sierraform All Season (18-3-15)	250	45	7.5	38				
25.6.2007	Osmosol 614R (19-2-10)	40	7.6	0.8	4.0	0.5		1.7	0.04
2.7.2007	Osmosol 614R (19-2-10)	40	7.6	0.8	4.0	0.5		1.7	0.04
13.7.2007	Kemigreen Summer (18-0-17)	40	7.2	0	6.8			2.0	0.40
18.7.2007	Kemigreen Summer (18-0-17)	40	7.2	0	6.8			2.0	0.40
26.7.2007	Sierraform All Season (18-3-15)	250	45	7.5	37.5	3.0			1.25
14.8.2007	Kemigreen Summer (18-0-17)	40	7.2	0	6.8			2.0	0.40
27.8.2007	Greenmaster Autumn (6-2-8)	300	18	6	24	5.4			1.50
30.8.2007	Kemigreen Basic (23-4-14)	40	9	1.6	5.6	0.6	0.8		0.04
11.9.2007	Sierraform Springstart (16-0-13)	200	32	0	39				2.00
SUM			305	39	260	14.0	2.4	9.4	10

* Floratine Kevätstartti (Springstart) is composed of P-48 (10-21-6.6), Per 4 Max (15-0-0), Protesyn (3.5-0.6-1.8), and Plant Marvel (28-3-15).

3.4. Demonstration trials with Primo MAXX® at Ballerud Golf Course, Oslo, Norway

Experimental site and set-up

Ballerud GC is located on an old horticultural farm in a suburban area SW of Oslo. The course has greens with mostly dominated by creeping bentgrass, fairways almost exclusively dominated by annual meadowgrass, and smooth meadowgrass roughs with some tufts of perennial ryegrass (*Lolium perenne*).

Large-scale, unreplicated demonstration trials were laid out on green no. 9, fairway no. 9 and rough no. 9 on 5 June 2007. Plots sizes varied from 80 to 130 m^2. Unsprayed control plots were compared with plots sprayed with Primo MAXX® at rates 0.4, 1.5 and 2.2 l/ha and application intervals of approximately 3, 4 and 7 weeks on green, fairway and rough, respectively. In compliance with the Norwegian Food Authority's rule for complete closure of all sprayed areas for 48 h after each application, the trial on green no. 9 had to be discontinued after the second application on 18 June.

Three weeks later, it was replaced by a new trial laid out on the golf course' nursery green. Actual application dates in the green, fairway and rough trials are given in Table 8. The growth regulator was applied using a battery-operated electric Hardy Defender plot sprayer (Photo 4).

Table 8. Application dates for Primo MAXX in demonstration trials at Ballerud GC.

Green no. 9	Nursery green	Fairway no. 9	Rough no. 9
5 June		5 June	5 June
18 June			
	9 July	2 July	
	31 July	31 July	28 July
	21 Aug.		
	13. Sep.	3 Sep.	11 Sep.
	4 Oct.	28 Sep.	

Photo 4. Sprayer used in demonstrations trials at Ballerud Golf Course.

Photo: Terje Haugen.

Registrations

In all trials at Ballerud, turfgrass general appearance was evaluated by the headgreenkeeper at one to two week intervals throughout the growing season. In the green and fairway trials, turfgrass clipping yields were recorded on a fresh weight basis. Registrations in the green trials also included regular assessments of green speed using a standard stimpmeter.

Maintenance

The green trials at Ballerud were mowed daily at 3.4-3.8 mm and the fairway trial at 20 mm three to four times a week. The rough area was only mowed upon need.

Due to the rich soil from decades of vegetable production, the rough trial was not fertilized in 2007, and the fairway trial only received one application of 200 kg Fullgjødsel® 11-5-18 (22 kg N/ha) on 8 May. The green trials received monthly applications of granuar fertilizer (Gro Power 5-1-1, Anderson 14-0-9, Anderson 8-0-16, and/or Roots 12-2-12), and weekly applications of liquid fertilizers /

biostimulants, mostly Floratine products. Total rates of N, P, K, Mg, Ca, S and Fe over the season were 155, 14, 142, 27, 30, 73 and 14 kg/ha, respectively. The greens were aerated, mostly using Envirojet, six times during the season and top-dressed, also six times, giving a total of 6.3 kg sand per m^2.

Weather data and irrigation

Table 3 shows recordings from Ballerud GC's weather station. Although the rainfall in 2007 was higher than usual, there were periods, especially in May, June and August when the green trials needed irrigation. The fairway and rough trials were never irrigated.

Table 9. Weather recordings and irrigation at Ballerud GC, 2007. Monthly temperatures are means of daily maximum and minimum temperatures.

	Mean monthly temperature, °C	Monthly rainfall, mm	Monthly irrigation, mm (greens only)
May	11.2	94	42
June	17.1	185	52
July	16.9	173	10
Aug.	16.6	83	47
Sep.	11.1	71	21
Mean / sum	14.6	606	172

3.5. Demonstration trial with Primo MAXX® at Oslo Golf Club, Bogstad, Norway

To evaluate the effect of Primo MAXX® on a typical annual meadowgrass green, an unreplicated demonstation trial with plot size 250 m^2 was laid out at Oslo GK on 20 June 2007. Primo MAXX® was sprayed at a rate 0.4 l/ha on 20 June, 10 July and 31 July using the same sprayer as at Ballerud GC, about 10 km from Bogstad (Photo 4). Turfgrass quality (general appearance) and fresh weight clipping yields were determined on 4 July, 13 July and 14 August. Unfortunately, the trial had to be discontinued in mid August due to reconstruction of the green.

3.6. 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 on each plot and on plot values which had been averaged, either over the whole growing season, separately over the spring (before 10 June), summer (10 June – 1 Sep.) and autumn (after 1 Sep.) periods, or for observations conducted two versus four weeks after the last application of Primo MAXX®. The significance levels P%<0.1, P%<1, P%<5 and ns (not significant) have been indicated in the tables along with LSD values for effects significant at P%<5. In a few cases exact P-values have been given for tendencies in the 5-15% probability range. As an indications of the variability for each character, coeffcients of variation, (CV %), have also been given in the tables.

4. Results

4.1. Evaluation of Primo MAXX® under fairway conditions, Bioforsk Landvik, Norway

Turfgrass quality and related characteristics

Table 10 shows results from the visual observations of turfgrass quality and related characters in the fairway trial at Landvik. Both within the three seasons and as a mean value, turfgrass general appearance was significantly lower on plots receiving monthly applications of Primo MAXX® at 1.0 l/ha or higher rates than on unsprayed control plots and plots receiving 0.5 l/ha. Within these two groups, differences in generall appearance were not significant. Separate analyses for blocks 1 and 2 versus 3 and 4 indicated that these responses were practically identical regardless of botanical composition (data not shown).

Individual registrations of turfgrass quality are further depicted in Fig. 1. There was a dramatic decline in quality after the first application on 9 May. After this the turf recovered and there was no significant effect of Primo MAXX® at the two subsequent evaluations. Applications of 1.0 l/ha or higher rates on 4 July lead to new quality reductions in July, August and September (Photo 5); these effects were especially apparent at the last evaluation in early November (Photo 6). By contrast, there tended to be a small quality improvement due to the lowest rate of Primo MAXX® from late August to October. This improvement was reflected also in a significant increase in tiller density on average for the whole growing season (Table 10).

Increasing rates of Primo MAXX® consistently led to darker turf throughout the growing season, but also to earlier growth cessation and a less attractive dormancy colour in late autumn (Table 10). The only visible disease in the trial was a slight attack of red thread (*Laetisaria fuciformis*) during the wet period in July; however, these spots were unaffected by Primo MAXX® which also had no effect on the occurrence of broadleaved weeds, primarily white clover, in the trial.

Table 10. Turfgrass quality, tiller density, within-season colour, dormancy colour and infestation of weeds and red thread (*Laetisaria fuciformis*) in fairway at Landvik as affected by increasing rates of Primo MAXX®, 2007. Visual merit and tiller density are means of twelve observations (two in spring, i.e. before 10 June, six in summer, i.e. from 10 June to 1 Sep., and four in autumn, i.e. after 1 Sep. Within season colour (green darkness) and occurrence weeds and red thread are means of twelve, three (all in July) and two (June and Nov.) observations, respectively. Dormancy colour was evaluated on 2 Nov. All values are means of four blocks.

Primo MAXX®, rate	Turf quality (general appearance, 1-9)				Tiller density (1-9)	Within season colour (1-9)	Dor-mancy colour (1-9)	% of plot area	
	Mean	Spring	Summer	Autumn				Dicot weeds	Red thread
0 = Control	6.2	6.1	6.4	6.0	6.3	5.2	6.8	4	4
0.5 l/ha	6.1	5.6	6.3	6.2	6.5	5.6	6.3	2	3
1.0 l/ha	5.5	4.5	5.9	5.3	6.1	5.8	5.0	5	2
1.5 l/ha	5.3	4.6	5.5	5.4	6.0	5.9	4.1	4	3
2.0 l/ha	5.5	4.6	5.9	5.3	6.1	6.0	4.3	3	2
3.0 l/ha	5.1	4.2	5.5	4.9	6.0	6.2	3.5	4	3
P%	<0.1	<0.1	<1	<0.1	<1	<1	<0.1	ns	ns
LSD 5%	0.3	0.5	0.4	0.4	0.2	0.4	1.2	-	-
CV%	4	7	5	5	3	5	15	-	-

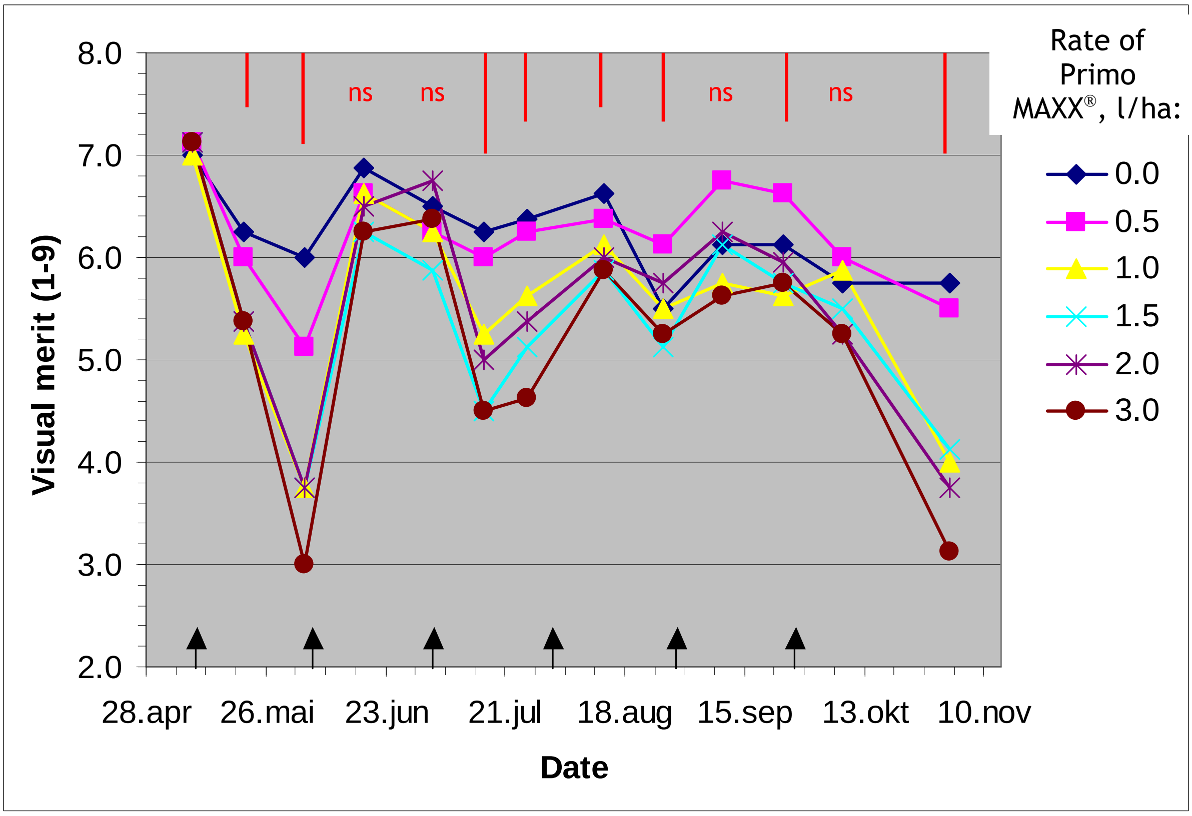


Fig.1. Turfgrass overall quality as affected by increasing rates of Primo MAXX® in fairway trial at Landvik, 2007. Mean of four replicates (blocks). The application dates 9 May, 5 June, 4 July, 31 July, 28 Aug. and 26. Sep. are indicated by black arrows. Red bars indicate LSD 5%.

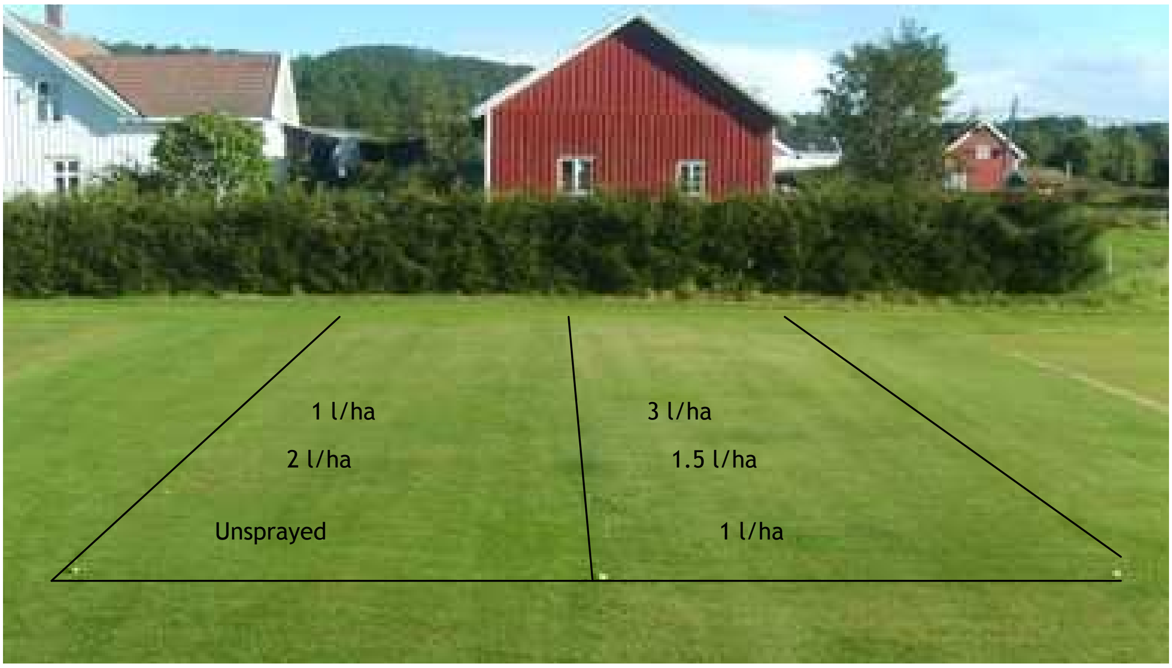


Photo 5. Visual appearance of fairway trial at Landvik, block 1 and 2, on 10 Sept. Within each block, the treatments closest to the photographer have been labeled. High rates of Primo MAXX® resulted in darker, in some cases, almost brown, turf. Photo: Trygve S. Aamlid.

Photo 6.

Turf quality / dormancy colour at growth cessation on 2 Nov. 2007 after application of Primo Maxx at 3.0 l/ha (left) and 0.5 l/ha (right), last application on 26 Sep.

Photo: Trygve S. Aamlid.

Turfgrass height and dry matter production

The average effect of Primo MAXX® on plant height and clipping yields are given in Table 11. In all blocks, the growth regulator caused a significant reduction in plant height even at the lowest rate, but contrary to expectation, this low rate also tended to increase aboveground dry matter production as compared with the unsprayed control treatment. This might reflect a higher tiller density, as also suggested in Table 10. Separate analyses for various parts of trial showed that the average reduction in clipping yield due to Primo MAXX® was stronger in blocks 1 & 2 which had more *Poa* species less red fescue and browntop bent and than blocks 3 & 4. On average for eleven harvests and all replicates, there was a slight tendency for Primo MAXX® to increase the dry matter percentage of turfgrass clippings (P% = 16, Table 11).

Table 11. Absolute and relative effects of increasing rates of Primo MAXX® on turfgrass height, turfgrass dry matter production, and per cent dry matter of clippings in fairway trial at Landvik, 2007. Mean of eleven observations. Plant height above 15 mm represents an average of four days' growth.

Primo MAXX, rate	Plant height, mm		Production of turfgrass clippings, $g/m^2/day$				% dry matter in clippings
	mm	Rel.	Block 1&2	Block 3&4	Mean	Rel.	
0 = Control	21.9	100	1.78	1.62	1.70	100	31.5
0.5 l/ha	20.9	95	1.91	1.93	1.92	113	32.2
1.0 l/ha	20.7	95	1.65	1.72	1.69	99	32.5
1.5 l/ha	20.0	91	1.46	1.46	1.46	86	33.6
2.0 l/ha	20.3	93	1.55	1.61	1.58	93	32.4
3.0 l/ha	19.5	89	1.31	1.70	1.51	88	33.1
P%.	<0.1	-	10	ns	<5	-	16
LSD 5%	0.7	-	-	-	0.29	-	-
CV%	2	-	10	14	12	-	3

In absolute terms, turfgrass clipping yield showed a distinct seasonal pattern with peaks during the warm and sunny periods in early June and late August (Fig. 2a). The low clipping yield on 17 July was probably due to 280 mm rainfall, and thus nutrient leaching, since the last fertilizer application on 12 June (Tables 3 and 4). Separate analyses of variance for each day indicated a significant effect of Primo MAXX® on clipping yield only on 4 June.

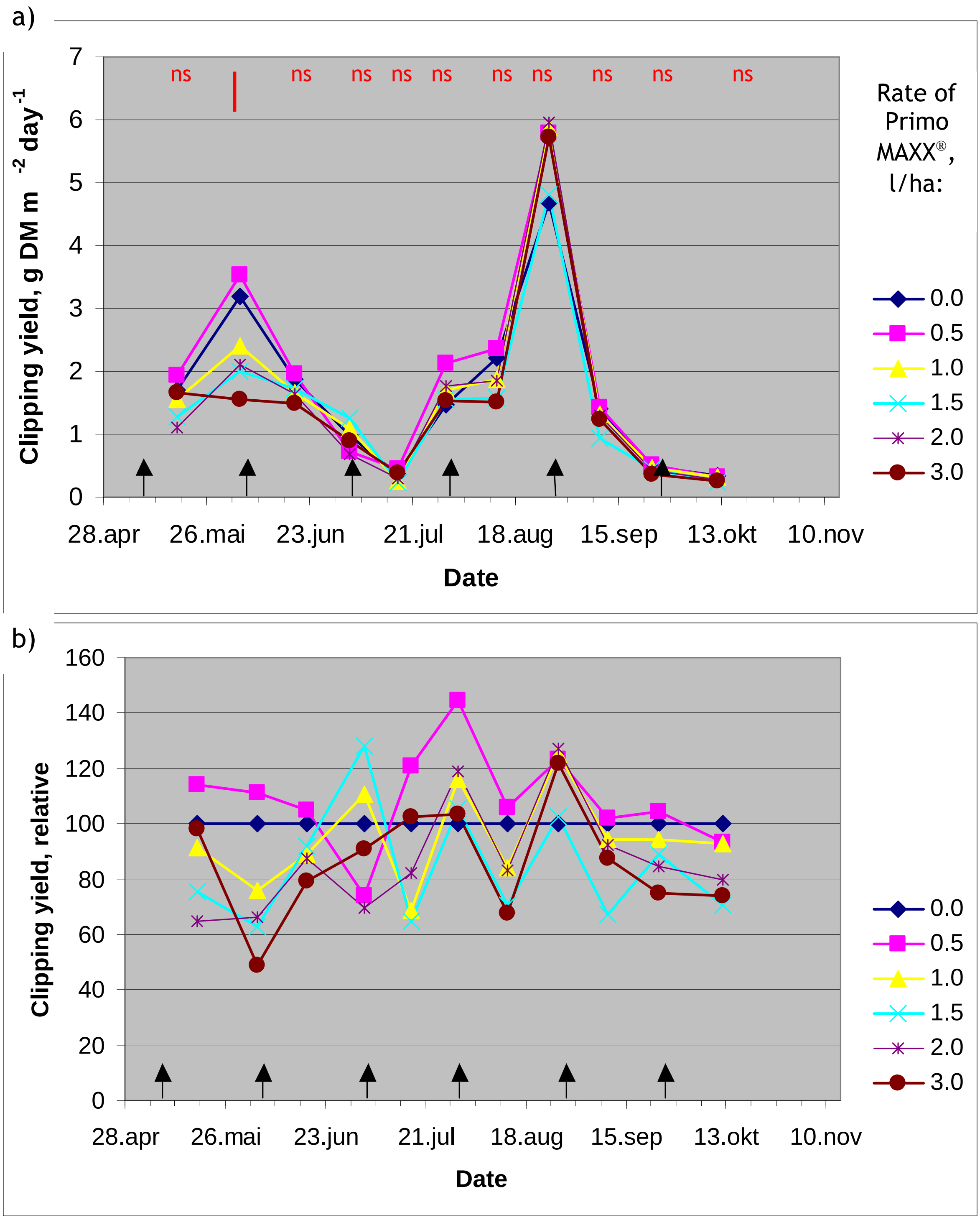


Fig. 2. Absolute (a) and relative (b) reductions in daily dry matter production of turfgrass clippings as affected by increasing rates of Primo MAXX® in fairway trial at Landvik. Red text/bars and black arrows indicate probability / LSD values and application dates 9 May, 5 June, 4 July, 31 July, 28 Aug. and 26 Sep., respectively. In (b), the clipping yield on each date was set to 100 in the unsprayed control treatment.

In relative terms, none of the Primo MAXX® treatments produced clipping yields that were lower than the unsprayed control at all harvests (Fig. 2b). Many of the treatments showed a typical suppression / rebound pattern with clipping yields lower than the control treatment at one harvest, but higher than control treatment at the next harvest.

4.2. Evaluation of Primo MAXX® on a golf course fairway, Lepaa, Finland

On average for two observations in spring, five observations in summer and two observations in autumn, Primo MAXX® had no effect on turfgrass general appearance in the fairway trial at Lepaa. Among the nine observation dates, significant differences were recorded only on 21 August when the plots sprayed with the highest dose (3.0 l/ha) had an average visual merit score of 5.5 as opposed to 6.8 for unsprayed control plots and plots sprayed with the lowest dose (0.5 l/ha).

On average for observations, increasing rates of Primo Max caused an overall increase in tiller density, while turfgrass colour was not significantly affected. No diseases were observed during the growing season.

Table 12. Turfgrass quality (1-9, 9 is best quality), tiller density (1-9, 9 is highest density) and within-season colour (1-9, 9 is darkest green) in fairway trial at Lepaa as affected by increasing rates of Primo MAXX®. Means of nine observations (two in spring, i.e. before 10 June, five in summer, i.e. from 10 June to 1 Sep., and two in autumn, i.e. after 1 Sep.). All values are means of four blocks.

Primo MAXX®, rate	Turf quality (general appearance, 1-9)				Tiller density (1-9)	Within season colour (1-9)
	Mean	Spring	Summer	Autumn		
0 = Control	6.1	5.5	6.1	6.8	5.5	6.1
0.5 l/ha	6.2	5.5	6.1	7.0	5.8	6.2
1.0 l/ha	6.1	5.4	6.1	6.9	5.8	6.1
1.5 l/ha	6.2	5.5	6.2	7.0	6.0	6.3
2.0 l/ha	6.2	5.6	6.1	6.9	6.1	6.3
3.0 l/ha	6.2	5.6	6.1	7.0	6.4	6.2
P%	ns	ns	ns	ns	<0.1	ns
LSD 5%	-	-	-	-	0.4	-
CV%	5	4	8	3	3	4

The effect of Primo MAXX® on turfgrass plant height and clipping yield depended on the time since last application. On average for five observations conducted about two weeks after application, the highest rate of Primo MAXX® caused significant reductions in plant height and clipping yield corresponding to 11 and 48 %, respectively (Table 13). On average for four observations conducted four weeks after application, the maximal reductions were only 3 and 14 %, respectively. Fig. 3 illustrates the unstable effect of Primo MAXX®, particularly toward the end of the growing season. However, unlike in the fairway trial at Landvik (Fig.2), clipping yields on sprayed plots were rarely higher than on untreated control plots in the trial at Lepaa.

Table 13. Absolute and relative effects of increasing rates of Primo MAXX® on turfgrass height and dry matter production in turfgrass clippings in fairway trial at Lepaa 2007. Observations conducted 2 weeks (5 observations) and 4 weeks (4 observations) from spraying treatment have been presented separately.

Treatment	Plant height (mm)				Weight of clippings (g DM / m^2 / day)			
Time after treatment	2 weeks	4 weeks	Mean	Rel	2 weeks	4 weeks	Mean	Rel
0 = Control	15.7	16.0	15.8	100	3.2	7.0	4.9	100
0.5 l/ha	15.7	16.0	15.8	100	2.7	6.3	4.3	87
1.0 l/ha	14.9	16.0	15.4	97	2.8	6.6	4.5	92
1.5 l/ha	14.7	15.7	15.1	96	2.3	5.8	3.9	79
2.0 l/ha	14.4	15.6	15.0	95	2.1	6.1	3.9	80
3.0 l/ha	14.0	15.5	14.6	92	1.8	6.0	3.7	75
P%	<0.1	ns	<5	-	<0.1	ns	ns	-
LSD 5%	1.1	-	1.0	-	0.7	-	-	-
CV%	3	4	3	-	13	22	18	

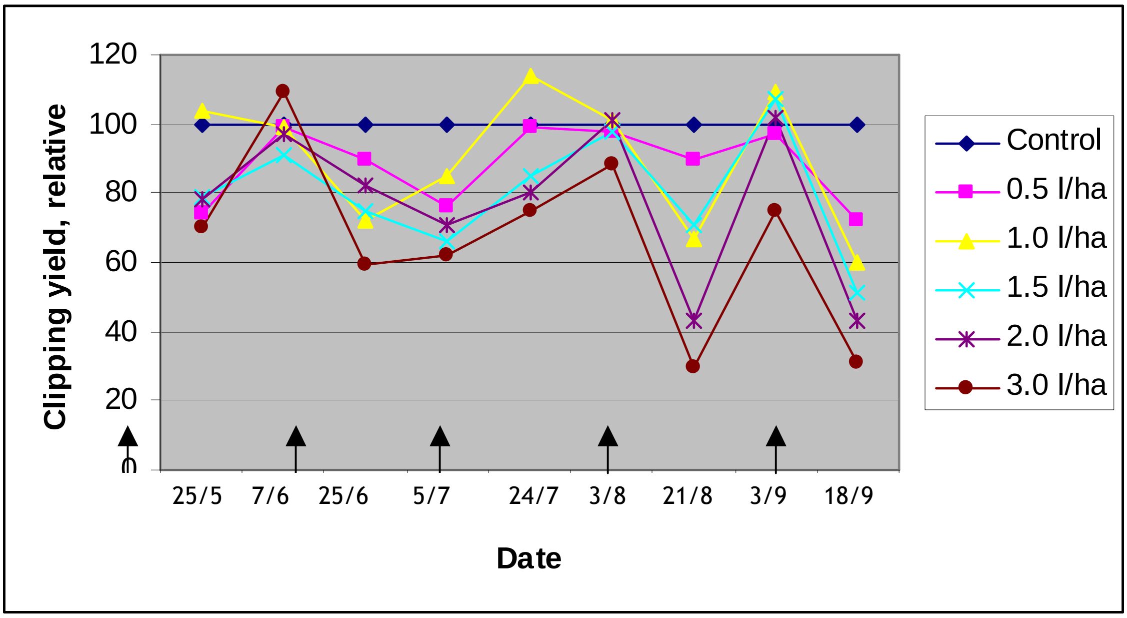


Fig. 3. Relative clipping weights (control = 100) in fairway trial at Lepaa, Finland. Spraying treatments indicated by black arrows were carried out on 11 May, 8 June, 5 July, 3 Aug. and 4 Sep. (The last spraying on 4 Oct. was done primarily to study the effect of Primo MAXX® on overwintering and was not followed by observations in late autumn.)

4.3. Evaluation of Primo MAXX® on a golf course putting green, Lepaa, Finland

On 3 Sep. 2007, a significantly higher tiller density was recorded on green plots sprayed with the highest rate of Primo MAXX® than on unsprayed control plots (data not shown). Otherwise, Primo MAXX® had no significant effect on either general appearance, tiller density or turfgrass colour in the green trial at Lepaa (Table 14). Although the effects on plant height and clipping yields were also not significant, reductions were generally stronger when recorded at two compared with four weeks after application (Table 15, Fig. 4).

Table 14. Turfgrass quality, tiller density and within-season colour (darkness) in green trial at Lepaa as affected by increasing rates of Primo MAXX®, 2007. Means of nine observations (two in spring, i.e. before 10 June, five in summer, i.e. from 10 June to 1 Sep., and two in autumn, i.e. after 1 Sep.). All values are means of four blocks.

Primo MAXX®, rate	Turf quality (general appearance, 1-9)				Tiller density (1-9)	Within season colour (1-9)
	Mean	Spring	Summer	Autumn		
0 = Control	6.4	6.1	6.6	6.3	6.3	6.4
0.2 l/ha	6.3	6.0	6.5	6.0	6.3	6.4
0.4 l/ha	6.3	5.9	6.5	6.1	6.2	6.3
0.6 l/ha	6.3	5.8	6.5	6.4	6.3	6.4
0.8 l/ha	6.2	5.8	6.4	6.3	6.2	6.4
P%	ns	ns	ns	ns	ns	ns
LSD 5%	-	-	-	-	-	-
CV%	3	5	5	7	2	3

Table 15. Absolute and relative effects of increasing rates of Primo MAXX® on turfgrass height and dry matter production in turfgrass clippings in green trial at Lepaa 2007. Observations conducted 2 weeks (5 observations) and 4 weeks (4 observations) from spraying treatment have been presented separately. Plant heights above 3 mm represent one day's growth.

Treatment	Plant height (mm)				Weight of clippings (g DM / m^2 / day)			
Time after treatment	2 weeks	4 weeks	Mean	Rel	2 weeks	4 weeks	Mean	Rel
0 = Control	4.3	3.9	4.1	100	2.60	2.21	2.43	100
0.2 l/ha	4.1	3.8	4.0	96	2.20	2.28	2.23	92
0.4 l/ha	4.0	3.9	3.9	95	1.88	2.28	2.06	85
0.6 l/ha	4.0	3.8	3.9	94	1.72	2.18	1.99	82
0.8 l/ha	3.8	3.9	3.9	93	1.75	2.28	1.92	79
P%	11	ns	ns	-	5	ns	ns	-
LSD 5%	-	-	-	-	0.9	-	-	-
CV%	6	7	8	-	20	14	16	-

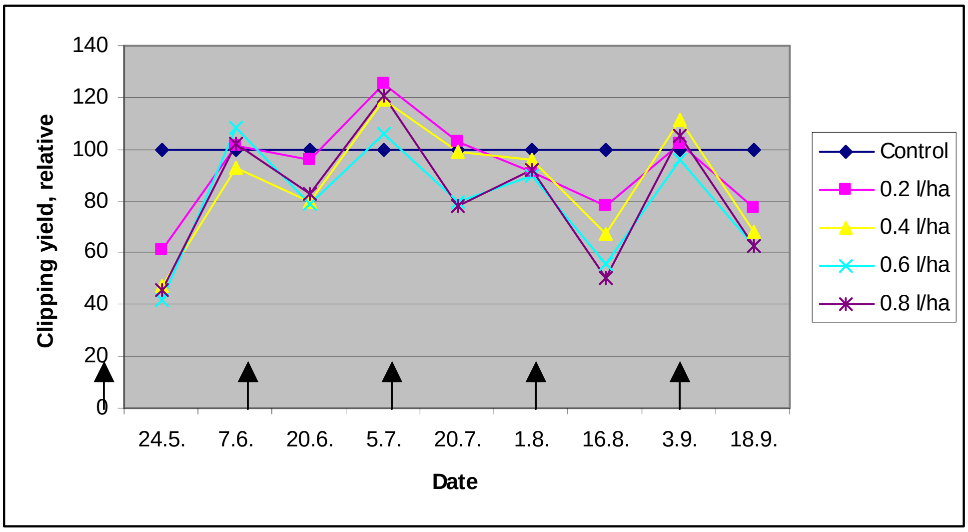


Fig. 4. Relative clipping weights (control = 100) in green trial at Lepaa, Finland. Spraying treatments indicated by black arrows were carried out on 11 May, 8 June, 5 July, 3 Aug. and 4 Sep. (The last spraying on 4 Oct. was done primarily to study the effect of Primo MAXX® on overwintering and was not followed by observations in late autumn.)

4.4. Demonstration trials with Primo MAXX® at Ballerud Golf Course, Oslo, Norway

Green trials

Applications of 0.4 l/ha Primo MAXX® on 5 and 18 June did not affect turf general appearance (Photo 7) or stimpmeter readings on green no. 9 at Ballerud. During the period 14-29 June, clippings were reduced by an average of 32%, but after spraying had been discontinued, there was a rebound effect corresponding to a 26 % increase in clipping yield in the period 12-25 July (data not shown).

Photo 7. Terje Haugen (left) and Lasse Augustsson on green no. 9 at Ballerud Golf Course, 27 June 2007. Photo: Trygve S. Aamlid.

Photo 8. Field day at Ballerud Golf Course 27 Aug. 2007. Photo: Tatsiana Espevig.

Fig. 5 summarizes results from the nursery green trial established on 9 July. In this trial, application of Primo MAXX® about every third week resulted in better colour (not shown), higher green speed (Fig. 5a), and an average reduction in turfgrass clippings of 44 % (Fig. 5b and c). Fig 5b shows that the reduction in clipping yield was most conspicuous during the periods of rapid growth in mid to late July (after only one application of Primo MAXX®) and in late August.

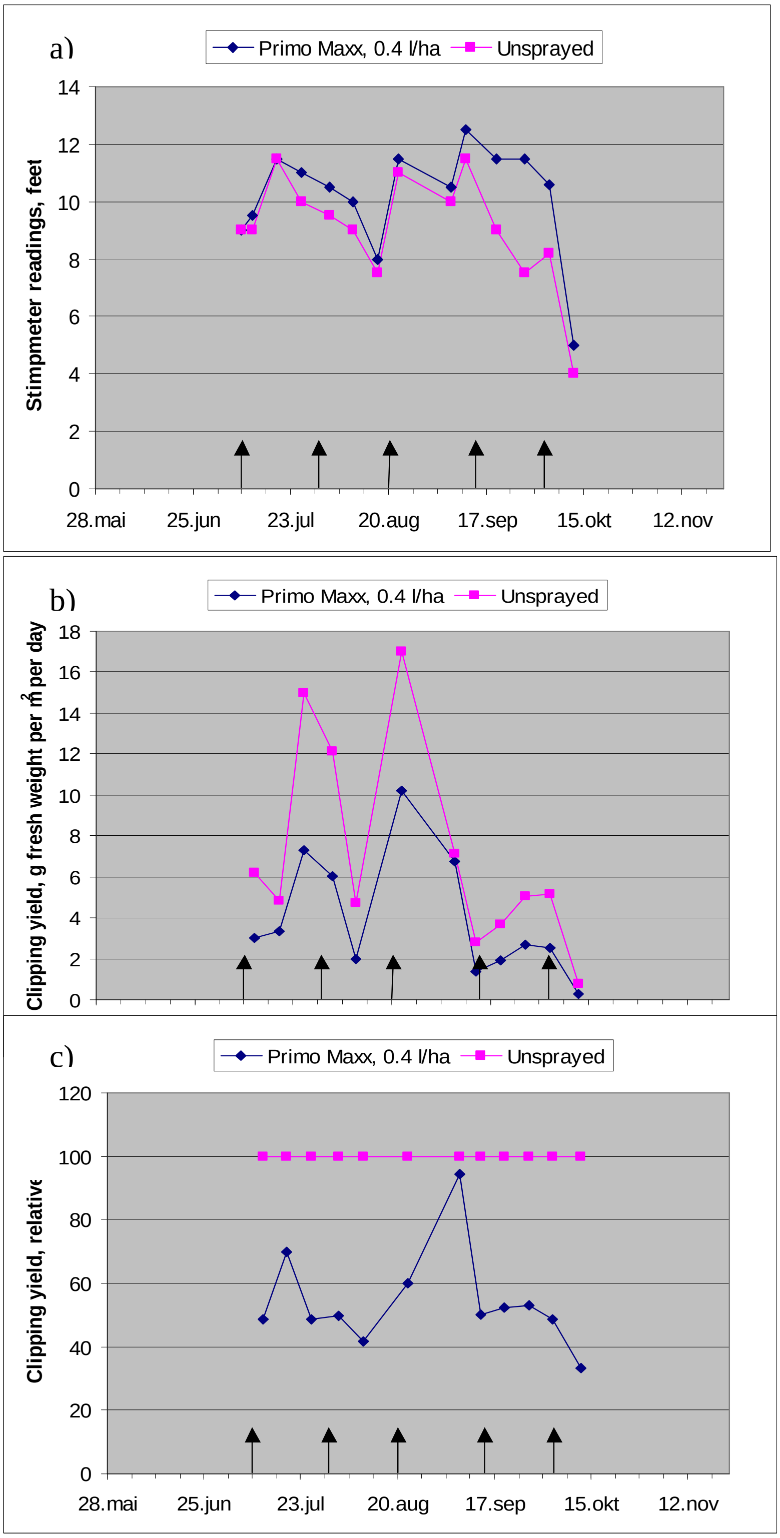


Fig. 5. Effects of spraying Primo MAXX® every three weeks of green speed and absolute and relative clipping yield on nursery green at Ballerud GC, 2007. Black arrows indicate the application dates 9 July, 31 July, 21 Aug., 13 Sep. and 4 Oct.

Fairway trial

As evaluated by the headgreenkeeper, monthly applications of 1.5 l/ha Primo MAXX® (1.5 l/ha) had no negative impact on turf quality in the fairway trial at Ballerud (Fig. 6). Photos 9-11 show, nevertheless, that treated turf was more faded, grayish, and less green than untreated turf. The pronounced colour difference in favour of Primo MAXX® in early September (Fig. 6) was due to less dry spots than the in the control area. While these spots recovered after rainfall on 10 and 17 Sep., the last application of Primo MAXX® on 4 Oct. led to an apparent loss of colour and drop in turf general appearance in late autumn (Photo 11).

On average for 17 clipping, regular application of Primo MAXX® resulted in a 37 % reduction in the fresh weight of turfgrass clippings (Fig. 7). The only time clipping yield was higher on the treated than on the untreated area was at the first clipping nine days after the first application and on 7 Sep. The latter coincided with the observation of less dry spots after use of Primo MAXX®. It may also be interpreted as a rebound effect following growth suppression after application on 31 July.

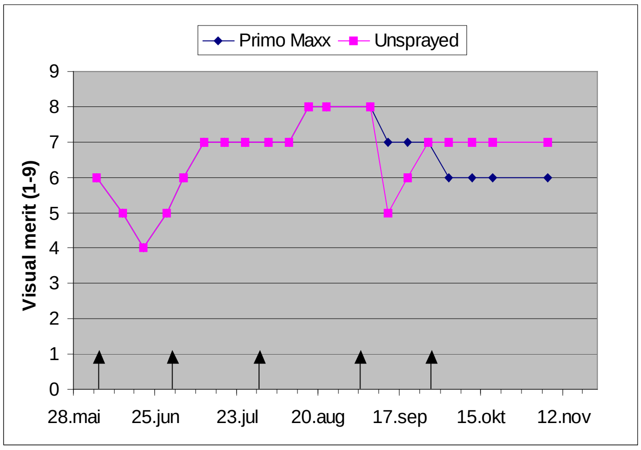
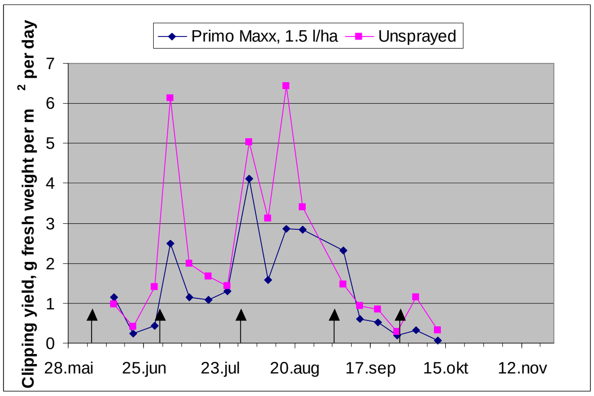


Fig. 6. Effect of Primo MAXX® on turfgrass general appearance in fairway trial at Ballerud GC. Black arrows indicate application dates. (Sprayed an unsprayed plots had identical scores until the beginning of September)

Photo 9. Difference in colour and general appearance of treated and untreated fairway Ballerud GC, 27 June. Photo: Trygve S. Aamlid.

Photo 10. Difference in colour and general appearance of treated and untreated fairway Ballerud GC, 27 Aug. Photo: Tatsiana Espevig.

Photo 11. Difference in colour and general appearance of treated and untreated fairway Ballerud GC, 3 Dec. Photo: Terje Haugen.



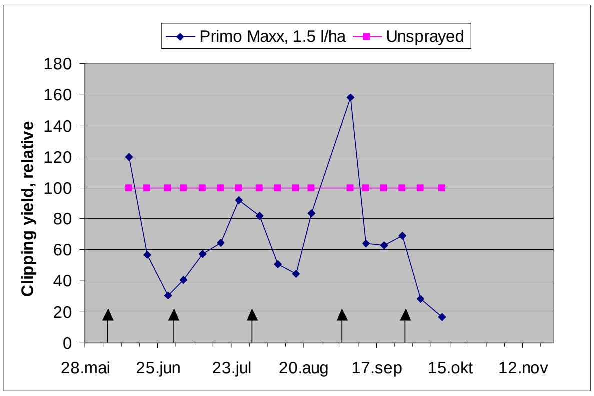


Fig. 7. Absolute (a) and relative (b) reductions in clipping yield resulting form application of Primo MAXX® in fairway trial at Ballerud GC. Arrows indicate application dates.

Spraying 2.2 l/ha of Primo MAXX® at six weeks interval resulted in discoloration and consistent drop in turf quality in the rough trial at Ballerud (Fig. 8, Photos 12 and 13). The effect was most conspicuous in late autumn. Primo MAXX® had less effect on tufts of perennial ryegrass which stood out very markedly in the turf which was otherwise dominated by smooth meadowgrass. Clipping yields were not recorded in this trial.

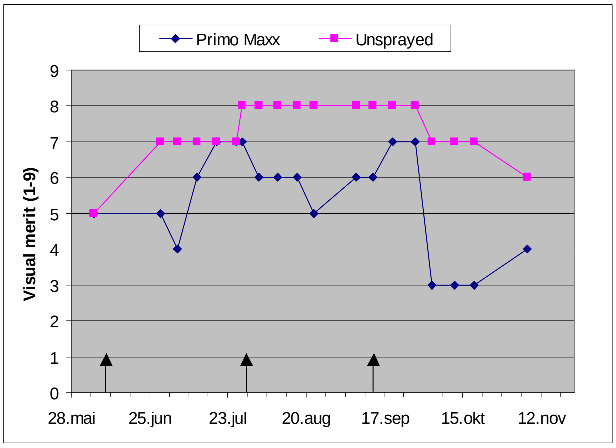


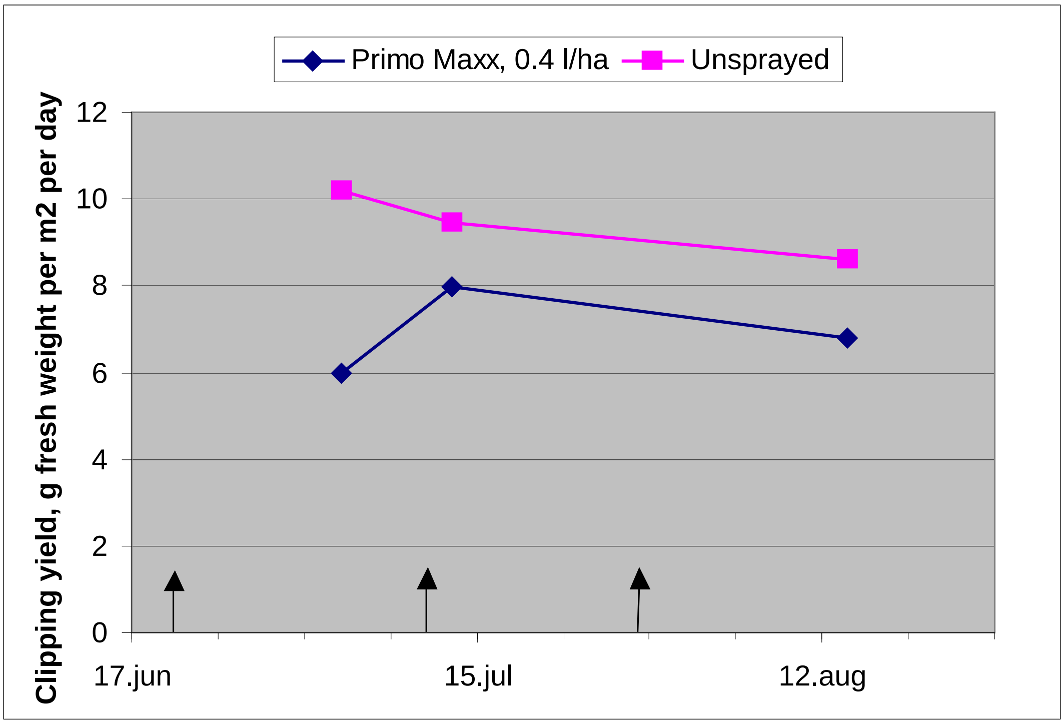
Fig. 8 (upper left). Difference in colour and general appearance of treated and untreated area in rough no 9, Ballerud, 27 June. Photo: Trygve S. Aamlid.

Photo 12 (upper right). Terje Haugen (left) and Lasse Augustsson in rough trial at Ballerud GC, 27 June. Photo: Trygve S. Aamlid.

Photo 13 (lower left). Trygve S. Aamlid inspecting rough trial at Ballerud GC, 27 August 2007. Tufts of ryegrass stand out very markedly on sprayed area.
Photo: Tatsiana Espevig.

4.5. Demonstration trial with Primo MAXX® at Oslo Golf Club, Bogstad, Norway

Application of 0.4 l Primo MAXX® at three week intervals resulted in darker turf but had otherwise no effect on the turfgrass quality of annual meadowgrass at Oslo GC. On average for three registrations, the Primo MAXX led to a 26% reduction in clipping yields (Fig. 9).



5. Discussion and suggestions for 2008

The starting point for evaluating Primo MAXX® in this two-year project was the rates and applications frequencies recommended for the product in Europe (Syngenta 2007, Table 16). Based on our experiences from agricultural crops that the optimal rates may be different in the Nordic countries than countries further south, higher and lower rates were included in the GEP trials both to determine the potential growth inhibition and the risk for discoloration or other phytotoxic effects. All taken together, the results from the first project year confirms that the guidelines in Table 16 are not directly applicable in Scandinavia and that further research is needed to find the optimal way of using the product under Nordic conditions.

Table 16. Dose rates and applications frequencies recommended for Primo MAXX® in the United Kingdom (Syngenta 2007).

	Dose rate		Application
	Primo MAXX®, l/ha	trinexapac-ethyl, g a.i./ha	frequency
Fairways	0.8 – 1.6	90 - 180	Every four to five weeks
Roughs & semi-roughs	1.6-2.4	180 - 240	Every five to eight weeks
Greens	0.4	45	Every two to four weeks

On fairway, the average reduction in clipping yield caused by monthly application of the intermediate Primo MAXX® rate of 1.5 l/ha was 15 and 21 % in the GEP trials at Landvik and Lepaa, respectively. By contrast, monthly application of 1.5 l/ha resulted in a 37 % reduction in clipping yield in the demonstration trial at Ballerud GC, which is closer to the data presented by Syngenta (2007). In agreement with Table 11 showing an increase in turfgrass dry matter percentage (i.e. decreased succulence) after application of Primo MAXX®, one of the reasons for this difference might be that clipping yields were determined on a dry weight basis in the GEP trials but on a fresh weight basis at Ballerud GC and in the data presented by Syngenta (2007). Another, and probably more important explanation, is the difference in species composition among the three trials. While the plant cover at Ballerud was almost 100% by annual meadowgrass, the species composition at Landvik varied with the two blocks showing the least response to Primo MAXX® having a plant cover of 74 % red fescue (Tables 1 and 11). By contrast, smooth meadowgrass dominated over red fescue at Lepaa due to the heavy soil type, use of irrigation, and relatively high nitrogen input. Unfortunately, we have not been able to find many references about the specific effects of Primo MAXX® on red fescue turf, but our results are in partial agreement with Pannacol et al. (2004) who found 40 %, 21 %, and no significant reduction in clipping yield after using trinexapac-ethyl in smooth meadowgrass, chewing fescue and creeping red fescue, respectively.

Perhaps the most conspicuous feature of the present results was the unstable effect of Primo MAXX® on clipping yields due to the postsuppression rebound effect. In the fairway trial at Lepaa, Finland, this resulted in clipping yield reductions being significant only two weeks after application (Table 13), and a similar tendency could be seen also in the green trial (Table 15). In Norway, clipping yields four weeks after spraying were often higher than on unsprayed control plots in the fairway trial at Landvik (Fig. 2), and a strong rebound effect was observed also after spraying treatments had to discontinued at green no. 9, Ballerud GC. The unstable effect in of Primo MAXX® in these trials was probably due to a rapid degradation of trinexapac-ethyl in plant tissue and a higher regrowth potential due to accumulation of carbohydrate reserves and GA_1 precursors during the suppression phase (Lickfeldt et

al. 2001, Branham & Beasley 2007). In North-American experiments, Lickfeldt et al. (2001) reported clipping yields reductions in smooth meadowgrass to be much more consistent when trinexapac-ethyl was applied at four than at six week intervals, but under Nordic long-day conditions, spraying every second, or at least every third week, may well be necessary to stabilize low GA_1 levels, not only on greens, but also on fairways and tees. Although there was a surge effect during the driest period in mid September, the most stable clipping reductions in our trials, on average 44 % on a fresh weight basis, were, indeed, obtained on the nursery green which was sprayed about every third week at Ballerud GC (Fig. 5c). While Branham & Beasley (2007) noted that temperature was the most important factor determining degradation of trinexapac-ethyl in turfgrass tissue, our results suggest that other factors such as light and water availability may also be important for the rebound effect under Nordic conditions. Very clearly, application frequency is a major question that has to be addressed during the continuation of this project.

The potential reductions in mowing costs from using a plant growth regulator will always have to be weighed against the risks for discoloration or other harmful effects on turf quality. In the present trials, reductions in general appearance (visual merit) scores were far more conspicuous in the GEP trial at Landvik than in the GEP trials at Lepaa or the demonstration trials at Ballerud GC. Apart from possible effects of different botanical compositions, this might reflect a subjective human factor, i.e. different backgrounds and attitudes of the observers in the various trials. While the fairway trial at Landvik was evaluated by turfgrass scientists and technicians with long experience from turfgrass variety testing, the trials at Lepaa and Ballerud were evaluated by greenkeepers working on the course. While the observers at Landvik may have paid more attention to turf aesthetic values such as less intense colour, and less vigorous and uniform plots, the observers at Lepaa and Ballerud may well have been more attentive to ball roll and other functional characteristics of the playing surface. The less succulent but significantly darker green turf resulting from high Primo MAXX® rates at Landvik are in agreement with other studies showing higher mesophyll cell densities and chlorophyll concentrations resulting from less elongation of leaf cells (Heckman et al. 2001, Ervin & Zhang 2008). As for tiller density, most literature supports the Finnish rather than the Norwegian results; i.e. enhanced tillering after Primo MAXX® application (Branham & Beasley 2007, Ervin & Zhang 2008).

As compared with the unsprayed control treatment, the strongest negative effect of Primo MAXX® on turfgrass general appearance at Landvik was recorded after the first spraying in early June, in mid July and at the last observation in early November. Each of these observations might be explained by suboptimal conditions causing reduced turfgrass growth. From 6 to 15 June there was a dry and warm and period with maximum temperatures in the range 25-30 ºC that obviously reduced turfgras tillering and aesthetic appearance; until mid July exceptional rainfalls starting on 22 June were not compensated by increase nitrogen inputs, and in autumn, the last application of Primo on 26 September was followed by several nights of frost. Although most studies have failed to document significant interactions between nitrogen and trinexapac-ethyl on turfgrass quality (Steinke & Stier 2001, Goss et al. 2002, McCullogh et al. 2006), it seems reasonable to assume that potential negative effects on Primo MAXX® on turfgrass quality will be most pronounced under suboptimal growing conditions. As in the trials at Landvik (Photo 6) and Ballerud (Photo 11), Beam et al. (2002) reported significant discoloration of trinexapac-ethyl-treated smooth meadowgrass following frost in autumn.

Undoubtedly, the most convincing argument for official approval of Primo MAXX® on Nordic golf courses would be a clear documentation that it improves winter survival. Preliminary results with annual meadowgrass suggested that low rates of trinexapac-ethyl prevented winter injury, whereas high rates had opposite effects due to discoloration during the hardening phase in late autumn (Rossi & Buelow 1997). While trinexapac-ethyl has been shown to increase water soluble carbohydrate contents (Goss et al. 2002) and result in faster spring greenup, Ervin & Zhang (2008) recently called for more detailed investigations into the effect of trinexapac-etyl on freezing tolerance as the research to date has provided scarce information on this aspect. Under Nordic conditions, desiccation if growth resumes when soils are still frozen and irrigation not yet operational in spring, or damage due to unstable winters with ice and water covering the turf, sometimes resulting in suffocation, appear to be more

important that direct freezing injury. In this regard, trineexapac-ethyl may well have a positive effect as it reduces mitochondrial respiration (Ervin & Zhang 2008). In 2008, it will therefore be very interesting to study winter injury and spring green-up and recovery in the on-going trials at Landvik, Lepaa and Ballerud which all had their last application of Primo MAXX® in late September or early October.

Even with winter survival and spring observations included, the amount of data presented in this report is too limited to recommend any listing of Primo MAXX® for turf use in the Nordic countries. Therefore, as stated in the contract between Syngenta and Scandinavian Turfgrass and Environment Research Foundation, there is a need for new GEP trials to be started in spring 2008 and followed until registration of winter survival in spring 2009. For this purpose, a new experimental green was constructed and seeded to creeping bentgrass at Landvik in 2007. In the trial to be established on this green in spring 2008, we suggest to compare Primo MAXX® at three rates (0.15, 0.30 and 0.45 l/ha) and two application frequencies (every 10/11 days and every 21 days), i.e. six combinations plus an unsprayed control treatment. As different grass species seem to vary in their response to Primo MAXX®, similar trials should preferably be carried out on also red fescue/browntop greens and velvet bentgrass greens, although this would require additional funding from Syngenta/STERF.

In Finland, a new GEP trial will be established in spring 2008 on a fairway that is regularly subjected to winter injury. New demonstration trials might be added to the project depending on interest from superintendents and funding from the national golf unions.

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

Results from the first evaluation year 2007

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Finnish team spraying fairway trial at Lepaa Golf Course.
Photo: Oiva Niemelainen

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Summary:

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

Sammendrag:

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

Approved

Arne Sæbø	Trygve S. Aamlid
Leader, Bioforsk's Section for Urban Greening	Project leader

Contents

1. Abstract

As an inhibitor of the last step in plant synthesis of bioactive gibberellin (GA_1), the plant growth regulator Primo MAXX® (trinexapac-ethyl) offers prospects of reduced energy use for mowing and improved turfgrass quality under Nordic long day conditions. This report presents first year results from 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 possible registration of Primo MAXX®, unreplicated demonstration trials were carried out at Ballerud and Bogstad Golf Courses in Oslo under supervision of Bioforsk and with funding from the Norwegian Golf Federation (NGF).

GEP trials on **fairways** (mowing height 12-18 mm) were carried out at Bioforsk Landvik, Norway (58°34'N, 8°52'E) and at the Lepaa Unit of the HAMK University of Applied Sciences, Finland (61°08'N, 24°20'E). Primo MAXX® was applied at monthly intervals at rates 0.5, 1.0, 1.5, 2.0 and 3.0 l/ha (56.5, 113, 169.5, 226 and 339 g a.i./ha trinexapac-ethyl) in comparison with an unsprayed control treatment. Turfgrass general appearance, tiller density, colour, height growth, and clipping yields were recorded two and four weeks after each application. Primo MAXX® had no effect on turfgrass general appearance but increased density at Lepaa. At Landvik, Primo MAXX® (>= 1.0 l/ha) reduced turfgrass general appearance and density, but resulted in significantly darker green colour. Quality reductions were most apparent during periods with either daily maximum temperatures >25 °C, extreme rainfall probably causing nitrogen deficiency, or frost at night. Average reductions in clipping yield caused by Primo MAXX® (>= 1.0 l/ha) were 8 % in the GEP trial at Landvik, 18 % in the GEP trial at Lepaa and 37 % in the demonstration trial at Ballerud; to some extent this difference may be due to different botanical composition with red fescue (*Festuca rubra*) and annual meadowgrass (*Poa annua*) being the predominant species at Landvik and Ballerud, respectively. Clipping yield reductions due to Primo MAXX® were unstable, growth suppression two weeks after application often being followed by a rebound effect during the remaining two weeks until next application.

A GEP trial on creeping bentgrass **putting greens** was carried out at Lepaa, Finland, and demonstration trials at Ballerud and Bogstad, Norway. Primo MAXX® was sprayed at rates 0.2, 0.4, 0.6 or 0.8 l/ha at monthly intervals in the GEP trial, and at 0.4 l/ha every three weeks in the demonstration trials. On average for all observations, Primo MAXX® had no effect on turfgrass quality, but clipping yields were reduced by 16, 44 and 26% at Lepaa, Ballerud and Bogstad, respectively. As in the fairway trials, growth suppression at Lepaa was stronger when assessed at two than at four weeks after application. By contrast, Primo MAXX® produced a fairly stable effect when applied at three week intervals in the demonstration trials.

Use of Primo MAXX® on golf course **roughs** was investigated only in a demonstration trial at Ballerud. Application of 2.2 l/ha of Primo MAXX® every seven weeks resulted in discolouration and reduced quality of smooth meadow grass.

In conclusion, the first year of this project has shown that the guidelines for use of Primo MAXX® in other European countries are not directly applicable in Scandinavia. As the present results are too limited to apply for registration of Primo MAXX®, the project will continue in 2008 tentatively with new trials investigating application of Primo MAXX® at lower rates, but higher frequencies. Improved winter stress tolerance would be a convincing argument for registration of Primo MAXX® in the Nordic countries, and the on-going trials will therefore be followed by an assessment of effects of the last Primo MAXX® applications in September or October 2007 on winter survival and spring recovery.

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

2. Introduction

The plant growth regulator trinexapac-ethyl was developed by Syngenta in the 1980s. Since the active ingredient is available in different formulations, the chemical will, in this report, be referred to as Primo MAXX®, which is the product developed by Syngenta specifically for use on turf. Unlike earlier plant growth regulators, Primo MAXX®'s mode of action is highly specific as it blocks the conversion of GA_{20} til GA_1, i.e. the last step in the biosynthesis of gibberellic acid, a plant hormone stimulating cell elongation and thus vertical turf growth.

After its release, Primo MAXX® was rapidly adopted by the US and Canadian turf industries. In North America, there are several independent university studies documenting its positive effects on golf courses, athletic fields, home lawns, and sod production (for a recent review, see Erwin and Zhang 2008). These advantages include reduced leaf elongation and thus reduced mowing costs and energy use, improved tiller production (more lateral growth), darker green colour, and improved resistance to drought and shade.

While other formulations of trinexapac-ethyl have been approved for agricultural use in Europe for about a decade, the experience with Primo MAXX® to European turfgrass areas is relatively limited. During the past three to four years, Primo MAXX® has been approved for turf use in Italy, France and UK, and the evaluation and registration process has been initiated in many other countries.

Being an inhibitor of gibberellin biosynthesis, Primo MAXX® offers special prospects for turfgrass management in the Nordic counties Finland, Sweden, Norway, Iceland, and Denmark. At latitudes ranging form 55 to 71 °N, turfgrasses growing in these countries exposed not only to long photoperiods during most of the growing season, but also to lower photosynthetic flux densities and lower red to farred (R/FR) ratios than in countries further south. The natural turfgrass response to these northern light conditions is to devote more of its resources to shoot elongation (Heide et al. 1985a,b). Since this response is primarily mediated by the gibberellic acid GA_1, any specific growth regulator that controls the biosynthesis of this compound might be useful under Nordic conditions. Nevertheless, our experience from the introduction of trinexapac-ethyl for agricultural use in the Nordic counties suggests that the optimal dose rates and frequencies for application of Primo MAXX® to various types of turf are probably not the same as at lower latitudes. This is also due to different species and cultivars being grown compared with countries further south. Field trials under Nordic conditions are therefore required not only to produce data for the national certification agencies, but also to provide turf managers with recommendations for how to use the product.

This report presents first year preliminary results from a two year project evaluating the use of Primo MAXX® on golf courses in the Nordic countries. The project was funded by Syngenta and the Scandinavian Turfgrass and Environment Research Foundation (STERF) 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' trials needed to provide documentation for possible registrations of Primo MAXX® by the national authorities, a couple of practical demonstration trials were carried out on Norwegian golf courses under supervision from Bioforsk and with funding from the Norwegian Golf Federation (NGF).

3. Methods

3.1. Evaluation of Primo MAXX® under fairway conditions, Bioforsk Landvik, Norway

Experimental site

On 8 May 2007, a field trial was laid out on a fairway established on a sandy loam soil (topsoil: 68 % sand, 27% silt, 5 % clay) at Bioforsk Landvik Research Station (58°34'N, 8°52'E), SE Norway. Soil samples indicated a pH (H_2O) of 5.9, high phosphorus values (P-AL=19) and intermediate to low potassium values (K-AL = 8, K-HNO_3=58). The fairway had been seeded in September 2003 to a mixture of smooth meadowgrass (*Poa pratensis*), chewing fescue (*Festuca rubra* ssp. *commutata*), and browntop bent (*Agrostis capillaris*) (Table 1). Block 1 and 2 were located in one part, and block 3 and 4 in a different part of the fairway. Botanical analyses at the start of experimentation indicated that red fescue was the predominant species in all blocks, but presumably due to slightly less surface drainage, blocks 1 and 2 had a higher percentage of smooth and annual meadowgrass and broadleaved weeds (primarily white clover (*Trifolium repens*)) than blocks 3 and 4 (Table 1).

Table 1. Seed mixture used for fairway establishment in 2003 and botanical composition at the start of the Primo MAXX® trial in spring 2007.

Species	Cultivar	% (w/w) of seed mixture	% cover at initiation of Primo MAXX® trial		
			Block 1 and 2	Block 3 and 4	Mean
Poa pratensis	Conni	25	31	9	20
Poa pratensis	Eva	10			
Poa pratensis	Limousine	10			
Festuca rubra ssp. commutata	Bargreen	25	50	74	62
Festuca rubra ssp. commutata	Calliope	25			
Agrostis capillaris	Tracenta	5	5	15	10
Poa annua			8	2	5
Broadleaved weeds			6	0	3
Sum		100	100	100	100

Experimental plan

The experiment was laid out according to a randomized complete block design with plot size 2m x 3m, four blocks (replicates) and the following treatments:

1. Usprayed control
2. Primo MAXX, 0.5 l/ha (56.5 g a.i./ha) every four weeks
3. Primo MAXX, 1.0 l/ha (113 g a.i./ha) every four weeks
4. Primo MAXX, 1.5 l/ha (169.5 g a.i./ha) every four weeks
5. Primo MAXX, 2.0 l/ha (226 g a.i./ha) every four weeks
6. Primo MAXX, 3.0 l/ha (339 g a.i./ha) every four weeks

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. Actual application rates were recorded by weighing the tank before and after spraying. Table 2 shows actual rates and weather conditions for each spraying event.

Table 2. Weather conditions and actual application rates at the six spraying events.

Application date	Time of day (hours)	Weather conditions at application			Treatment number / application rate (l Primo MAXX® per ha)				
		Air temp. °C	Relative Humidity %	Wind Speed m/s	2. (target 0.5)	3. (target 1.0)	4. (target 1.5)	5. (target 2.0)	6. (target 3.0)
9 May	09-11	14	48	< 1.0	0.47	0.94	1.56	1.90	3.35
5 Jun.	09-11	15	60	< 1.0	0.58	1.06	1.67	1.93	3.19
4 Jul.	13-15	17	70	1.0-2.0	0.61	0.98	1.73	2.19	3.38
31 Jul.	08-10	18	55	1.0-2.0	0.55	1.05	1.66	2.28	3.41
28 Aug.	09-11	19	32	1.0-2.0	0.57	1.03	1.55	2.19	3.52
26 Sep.	09-11	11	69	< 1.0	0.52	1.07	1.55	2.01	3.15
Mean					0.55	1.02	1.62	2.08	3.33

<u>Registrations</u>

At two weeks intervals throughout the experimental period, turfgrass colour, tiller density, and turf general appearance were assessed by turfgrass scientist or technicians using a scale from 1 to 9 where 9 is darkest colour, highest tiller density and best turf quality. The assessments were conducted two and four weeks after application of Primo MAXX®. On the same dates, turfgrass diseases and broadleaf weed (including white clover) invasion were reported as per cent of plot area. Turfgrass height was recorded as the mean of three random measurements with a ordinary ruler in each plot, and the overall growth rate by weighing clippings in the basket of a walk-behind mower used in the 0.56 m x 1.88 m central area of each plot (Photo 1). Both raw weight and dry weight were recorded, the latter after drying for 24 h at 60ºC. By the end of the growing season, on 2 Nov., turfgrass dormancy colour was evaluated on a scale 1-9, where 1 is completely faded / brown turf, and 9 is completely green turf.

Photo 1a and b. Tatsiana Espevig collecting clippings in fairway trial at Landvik. Photos: Trygve S. Aamlid

Management

The experiment was mowed at 15 mm two times a week, usually on Monday and Friday. A triplex fairway mower without collection of clippings was used except when clipping weights were to be recorded. Granular fertilizer was applied at approximately monthly intervals as outlined in Table 3. The experiment was not irrigated except for small amounts of water to dissolve fertilizer after application. On 7 Aug., the trial was aerated using a vertidrain with 15 mm solid tines to 15 cm depth. Topdressing was accomplished on 8 Aug. and 5 Nov. at rates 0.75 and 1.5 kg pure sand per m^2, respectively.

The fairway trial at Landvik was not exposed to ordinary play, but it was was subjected to artifical wear from a wear drum one to two times per week.

Table 3. Fertilizer inputs, fairway trial, Landvik.

		Per ha							
Date	Fertilizer type	kg fertilizer	kg N	kg P	kg K	kg Mg	kg S	kg Ca	kg Fe
17 Apr.	Fullgjødsel 22-2-12	40	9	1	5	0	1	0	0
16 May	Fullgjødsel 22-2-12	70	15	1	8	1	2	1	0
12 Jun.	Arena Golf Extra 13-0-15	150	20	0	23	2	21	0	3
23 Jul.	Arena Golf Extra 13-0-15	130	17	0	20	2	18	0	3
9 Aug.	Arena Golf Extra 13-0-15	135	18	0	21	2	18	0	3
5 Sep.	Arena Golf Extra 13-0-15	150	20	0	23	2	21	0	3
SUM			99	2	100	10	80	1	11

Weather data

In SE Norway, the growing season 2007 was characterized by exceptionally high rainfall, especially in July, but also in May, June and August (Table 4). By contrast, September was unusually dry. Precipitation was recorded on 16 out of the 31 days in July; the cloudy summer weather is also reflected by a rather low irradiance during this month. The warmest period, with daily maximum temperatures in the range 23-29 ºC was recorded from 6 to 12 June.

Table 4. Weather data for Landvik meteorological station, about 200 m for experimental field. Normal values for temperature and rainfall are 'official' values for from the period 1961-90, while normal values for irradiance are calculated averages for the period 1994-2006.

	Mean temperature, ˚C		Precipitation, mm		Irradiance, MJ/m^2 (305-2800 nm)	
	2007	30 yr normal	2007	30 yr normal	2007	13 yr average
May	10.2	10.4	107	82	518	540
June	15.9	14.7	109	71	604	600
July	15.5	16.2	213	92	492	632
Aug.	16.2	15.4	132	113	476	476
Sep.	12.0	11.8	59	136	321	262
Mean / sum	14.0	13.7	620	494	2411	2510

3.2. Evaluation of Primo MAXX® on a golf course fairway, Lepaa, Finland

Experimental site

The Finnish fairway trial was laid out on 11 May 2007. The fairway was seeded to a mixture of smooth meadowgrass and chewing fescue (*Festuca rubra* spp. *commutata*) on a heavy clay soil (15% sand, 37% silt, 48% clay) at the Lepaa Unit of HAMK University of Applied Sciences, Finland (61°08'N, 24°20'E). 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. All observations and management of the trial was carried out by the HAMK Lepaa greenkeepers Petteri Lehmuskoski and Tommi Turunen except for the spraying treatments which were carried out by MTT's 'Good Experimental Practice' certified spraying team from Jokioinen (90 km from Lepaa).

Experimental plan and registrations

The experiment was laid out following the same plan and plot size as at Landvik, Norway (previous paragraph). Primo MAXX® was applied in accordance with the Finnish 'Good Experimental Practise' protocol, using a portable, compressed air-powered 'van der Weij' plot sprayer, mounted with a windshield and flat fan nozzles (Hardi 4110-12) and working at 180-250 kPa pressure. The spraying boom had four nozzles spaced 50 cm apart. The spraying volume corresponded to 200 l/ha. Full spray coverage was on the central 1.5m x 2.5 m of each plot. Table 5 shows application dates and weather conditions for each spraying event. The last application on 4 Oct. was conducted especially to evaluate potential effects of Primo MAXX® on turfgrass winter damage.

Table 5. Application dates and weather conditions in fairway and green trials at Lepaa.

Application date	Time of day (hours)	Air temp. °C	Relative humidity %	Wind Speed m/s	% cloud cover
11 May	09-11	11	29	0	25
8 Jun.	09-11	20	56	1.5	1
5 Jul.	13-15	23	47	2.5	70
3 Aug.	09-11	17	78	2.0	90
4 Sep.	09-11	11	90	1.0	90
4 Oct.	13-15	11	92	1.5	100

Photo 2. Austen Sutton, Syngenta (left) and greenkeeper Petteri Lehmuskoski, HAMK Lepaa Unit, in fairway trial at Lepaa, Finland, 29 Aug. 2007.

Photo: Oiva Niemelainen.

Registrations

Registrations were carried out at two-week intervals following the same program as at Landvik (previous section) except that weed occurrence and dormancy colour were not recorded. Plant height at Lepaa was determined using a Turf Check Prism device (Check Signature Inc., Shoreview, MN).

Management and wear

The experiment was mowed with a triplex fairway mower about three times per week. Mowing height ranged from 12 to 18 mm. Granular fertilizer Sportsmaster 26-2-9 was applied at equal rates on 8 May and 12 July, the total input corresponding to 156 kg N, 12 kg P, 54 kg K and 0.9 kg Fe per ha. Information about irrigation is given in Table 6. The trial was aerated or top-dressed in late autumn, after the completion of registrations.

During the growing season period, the trial was exposed to approximately 3.500 rounds of golf.

Weather data

Temperatures at Lepaa were higher the 30 yr normal values throughout the growing season (Table 6). August had the greatest deviation from the long-term average value. July had 49 % more, and August 42 % less rainfall than usual; over the whole experimental season, rainfall was close to the 30 yr normal value.

Table 6. Weather data for Hattula Lepaa weather station and irrigation in fairway and green trial at Lepaa golf course, 2007. Normal values for temperature and rainfall are official values for from the period 1971-2000 (Finnish Meteorological Institute)

	Mean temperature, °C		Rainfall, mm		Irrigation, mm (2007)	
	2007	30 yr normal	2007	30 yr normal	Fairway trial	Green trial
May	10.6	9.8	30	34	*	*
June	15.1	14.5	54	55	26	79
July	16.6	16.4	119	80	5	47
Aug.	16.4	14.6	43	74	7	50
Sep.	9.9	9.4	58	54	0	6
Mean / sum	13.7	12.4	304	297	37	188

* Data are unavailable for the period 1-26 May 2007 due to change of irrigation computer.

3.3. Evaluation of Primo MAXX® on a golf course putting green, Lepaa, Finland

Experimental site

The Finnish green trial was established on 11 May 2007 on a USGA green seeded to creeping bentgrass (*Agrostis stolonifera*, seed blend of 50% ‘Penn A-4’ and 50% ‘Penn G-6’) at Lepaa Golf Course.

Experimental plan

The experimental plan comprised five rates of Primo MAXX plus the unsprayed control treatment:

1. Usprayed control
2. Primo MAXX, 0.2 l/ha (22.6 g a.i./ha) every four weeks
3. Primo MAXX, 0.4 l/ha (45.2 g a.i./ha) every four weeks
4. Primo MAXX, 0.6 l/ha (67.8 g a.i./ha) every four weeks
5. Primo MAXX, 0.8 l/ha (90.4 g a.i./ha) every four weeks

The trial had four replicates, and a gross plot size of 2 m x 3 m. It was sprayed on the same dates and following the same GEP procedures as the fairway trial on the same location (Table 5).

Photo 3. Green trial at Lepaa ready for the first treatment on 11 May 2007. Photo: Oiva Niemelainen.

Registrations

Registrations followed the same program as in the Finnish fairway trial (previous section).

Management and wear

The experiment was mowed with a Triplex greens mower for an average of six times per week. Depending on weather and turfgrass density, mowing height was 5–7 mm in May and September and 3-4 mm from June to August. Information about irrigation and fertilizer inputs are given in Tables 6 and 7, respectively.

To avoid thatch accumulation, the trial was aerated with deep slitting knives every second week and with 8 mm needle tines once a month. Verticutting was accomplished every second week and topdressing with 0.1-0.7 mm finely graded sand at a rate of 1 kg per m2 every third week. The sand was brushed/irrigated into the green and the dressing was never done in close proximity to weighing of clippings.

Being located on a practise green, the experiment received wear from about 10.000 rounds of golf over the season. When placing holes on the green, care was taken to create as uniform wear as possible.

Table 7. Fertilizer inputs in green trial at Lepaa.

		Per ha							
Date	Fertilizer type	kg fertilizer	kg N	kg P	kg K	kg Mg	kg S	kg Ca	kg Fe
28.3.2007	Floratine Kevätstartti*	35	5.4	1.2	2.1				
5.4.2007	Floratine Kevätstartti	35	5.4	1.2	2.1				
19.4.2007	Floratine Kevätstartti	35	5.4	1.2	2.1				
26.4.2007	Sierraform Springstart (16-0-13)	250	40	0	32.5				2.50
15.5.2007	Sierraform All Season (18-3-15)	250	45	7.5	37.5	3.0			1.25
30.5.2007	Kemigreen Basic (23-4-14)	40	9	1.6	5.6	0.6	0.8		0.04
5.6.2007	Kemigreen Basic (23-4-14)	40	9	1.6	5.6	0.6	0.8		0.04
11.6.2007	Sierraform All Season (18-3-15)	250	45	7.5	38				
25.6.2007	Osmosol 614R (19-2-10)	40	7.6	0.8	4.0	0.5		1.7	0.04
2.7.2007	Osmosol 614R (19-2-10)	40	7.6	0.8	4.0	0.5		1.7	0.04
13.7.2007	Kemigreen Summer (18-0-17)	40	7.2	0	6.8			2.0	0.40
18.7.2007	Kemigreen Summer (18-0-17)	40	7.2	0	6.8			2.0	0.40
26.7.2007	Sierraform All Season (18-3-15)	250	45	7.5	37.5	3.0			1.25
14.8.2007	Kemigreen Summer (18-0-17)	40	7.2	0	6.8			2.0	0.40
27.8.2007	Greenmaster Autumn (6-2-8)	300	18	6	24	5.4			1.50
30.8.2007	Kemigreen Basic (23-4-14)	40	9	1.6	5.6	0.6	0.8		0.04
11.9.2007	Sierraform Springstart (16-0-13)	200	32	0	39				2.00
SUM			305	39	260	14.0	2.4	9.4	10

* Floratine Kevätstartti (Springstart) is composed of P-48 (10-21-6.6), Per 4 Max (15-0-0), Protesyn (3.5-0.6-1.8), and Plant Marvel (28-3-15).

3.4. Demonstration trials with Primo MAXX® at Ballerud Golf Course, Oslo, Norway

Experimental site and set-up

Ballerud GC is located on an old horticultural farm in a suburban area SW of Oslo. The course has greens with mostly dominated by creeping bentgrass, fairways almost exclusively dominated by annual meadowgrass, and smooth meadowgrass roughs with some tufts of perennial ryegrass (*Lolium perenne*).

Large-scale, unreplicated demonstration trials were laid out on green no. 9, fairway no. 9 and rough no. 9 on 5 June 2007. Plots sizes varied from 80 to 130 m^2. Unsprayed control plots were compared with plots sprayed with Primo MAXX® at rates 0.4, 1.5 and 2.2 l/ha and application intervals of approximately 3, 4 and 7 weeks on green, fairway and rough, respectively. In compliance with the Norwegian Food Authority's rule for complete closure of all sprayed areas for 48 h after each application, the trial on green no. 9 had to be discontinued after the second application on 18 June.

Three weeks later, it was replaced by a new trial laid out on the golf course' nursery green. Actual application dates in the green, fairway and rough trials are given in Table 8. The growth regulator was applied using a battery-operated electric Hardy Defender plot sprayer (Photo 4).

Table 8. Application dates for Primo MAXX in demonstration trials at Ballerud GC.

Green no. 9	Nursery green	Fairway no. 9	Rough no. 9
5 June		5 June	5 June
18 June			
	9 July	2 July	
	31 July	31 July	28 July
	21 Aug.		
	13. Sep.	3 Sep.	11 Sep.
	4 Oct.	28 Sep.	

Photo 4. Sprayer used in demonstrations trials at Ballerud Golf Course.

Photo: Terje Haugen.

Registrations

In all trials at Ballerud, turfgrass general appearance was evaluated by the headgreenkeeper at one to two week intervals throughout the growing season. In the green and fairway trials, turfgrass clipping yields were recorded on a fresh weight basis. Registrations in the green trials also included regular assessments of green speed using a standard stimpmeter.

Maintenance

The green trials at Ballerud were mowed daily at 3.4-3.8 mm and the fairway trial at 20 mm three to four times a week. The rough area was only mowed upon need.

Due to the rich soil from decades of vegetable production, the rough trial was not fertilized in 2007, and the fairway trial only received one application of 200 kg Fullgjødsel® 11-5-18 (22 kg N/ha) on 8 May. The green trials received monthly applications of granuar fertilizer (Gro Power 5-1-1, Anderson 14-0-9, Anderson 8-0-16, and/or Roots 12-2-12), and weekly applications of liquid fertilizers /

biostimulants, mostly Floratine products. Total rates of N, P, K, Mg, Ca, S and Fe over the season were 155, 14, 142, 27, 30, 73 and 14 kg/ha, respectively. The greens were aerated, mostly using Envirojet, six times during the season and top-dressed, also six times, giving a total of 6.3 kg sand per m^2.

Weather data and irrigation

Table 3 shows recordings from Ballerud GC's weather station. Although the rainfall in 2007 was higher than usual, there were periods, especially in May, June and August when the green trials needed irrigation. The fairway and rough trials were never irrigated.

Table 9. Weather recordings and irrigation at Ballerud GC, 2007. Monthly temperatures are means of daily maximum and minimum temperatures.

	Mean monthly temperature, °C	Monthly rainfall, mm	Monthly irrigation, mm (greens only)
May	11.2	94	42
June	17.1	185	52
July	16.9	173	10
Aug.	16.6	83	47
Sep.	11.1	71	21
Mean / sum	14.6	606	172

3.5. Demonstration trial with Primo MAXX® at Oslo Golf Club, Bogstad, Norway

To evaluate the effect of Primo MAXX® on a typical annual meadowgrass green, an unreplicated demonstation trial with plot size 250 m^2 was laid out at Oslo GK on 20 June 2007. Primo MAXX® was sprayed at a rate 0.4 l/ha on 20 June, 10 July and 31 July using the same sprayer as at Ballerud GC, about 10 km from Bogstad (Photo 4). Turfgrass quality (general appearance) and fresh weight clipping yields were determined on 4 July, 13 July and 14 August. Unfortunately, the trial had to be discontinued in mid August due to reconstruction of the green.

3.6. 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 on each plot and on plot values which had been averaged, either over the whole growing season, separately over the spring (before 10 June), summer (10 June – 1 Sep.) and autumn (after 1 Sep.) periods, or for observations conducted two versus four weeks after the last application of Primo MAXX®. The significance levels P%<0.1, P%<1, P%<5 and ns (not significant) have been indicated in the tables along with LSD values for effects significant at P%<5. In a few cases exact P-values have been given for tendencies in the 5-15% probability range. As an indications of the variability for each character, coeffcients of variation, (CV %), have also been given in the tables.

4. Results

4.1. Evaluation of Primo MAXX® under fairway conditions, Bioforsk Landvik, Norway

Turfgrass quality and related characteristics

Table 10 shows results from the visual observations of turfgrass quality and related characters in the fairway trial at Landvik. Both within the three seasons and as a mean value, turfgrass general appearance was significantly lower on plots receiving monthly applications of Primo MAXX® at 1.0 l/ha or higher rates than on unsprayed control plots and plots receiving 0.5 l/ha. Within these two groups, differences in generall appearance were not significant. Separate analyses for blocks 1 and 2 versus 3 and 4 indicated that these responses were practically identical regardless of botanical composition (data not shown).

Individual registrations of turfgrass quality are further depicted in Fig. 1. There was a dramatic decline in quality after the first application on 9 May. After this the turf recovered and there was no significant effect of Primo MAXX® at the two subsequent evaluations. Applications of 1.0 l/ha or higher rates on 4 July lead to new quality reductions in July, August and September (Photo 5); these effects were especially apparent at the last evaluation in early November (Photo 6). By contrast, there tended to be a small quality improvement due to the lowest rate of Primo MAXX® from late August to October. This improvement was reflected also in a significant increase in tiller density on average for the whole growing season (Table 10).

Increasing rates of Primo MAXX® consistently led to darker turf throughout the growing season, but also to earlier growth cessation and a less attractive dormancy colour in late autumn (Table 10). The only visible disease in the trial was a slight attack of red thread (*Laetisaria fuciformis*) during the wet period in July; however, these spots were unaffected by Primo MAXX® which also had no effect on the occurrence of broadleaved weeds, primarily white clover, in the trial.

Table 10. Turfgrass quality, tiller density, within-season colour, dormancy colour and infestation of weeds and red thread (*Laetisaria fuciformis*) in fairway at Landvik as affected by increasing rates of Primo MAXX®, 2007. Visual merit and tiller density are means of twelve observations (two in spring, i.e. before 10 June, six in summer, i.e. from 10 June to 1 Sep., and four in autumn, i.e. after 1 Sep. Within season colour (green darkness) and occurrence weeds and red thread are means of twelve, three (all in July) and two (June and Nov.) observations, respectively. Dormancy colour was evaluated on 2 Nov. All values are means of four blocks.

Primo MAXX®, rate	Turf quality (general appearance, 1-9)				Tiller density (1-9)	Within season colour (1-9)	Dor-mancy colour (1-9)	% of plot area	
	Mean	Spring	Summer	Autumn				Dicot weeds	Red thread
0 = Control	6.2	6.1	6.4	6.0	6.3	5.2	6.8	4	4
0.5 l/ha	6.1	5.6	6.3	6.2	6.5	5.6	6.3	2	3
1.0 l/ha	5.5	4.5	5.9	5.3	6.1	5.8	5.0	5	2
1.5 l/ha	5.3	4.6	5.5	5.4	6.0	5.9	4.1	4	3
2.0 l/ha	5.5	4.6	5.9	5.3	6.1	6.0	4.3	3	2
3.0 l/ha	5.1	4.2	5.5	4.9	6.0	6.2	3.5	4	3
P%	<0.1	<0.1	<1	<0.1	<1	<1	<0.1	ns	ns
LSD 5%	0.3	0.5	0.4	0.4	0.2	0.4	1.2	-	-
CV%	4	7	5	5	3	5	15	-	-

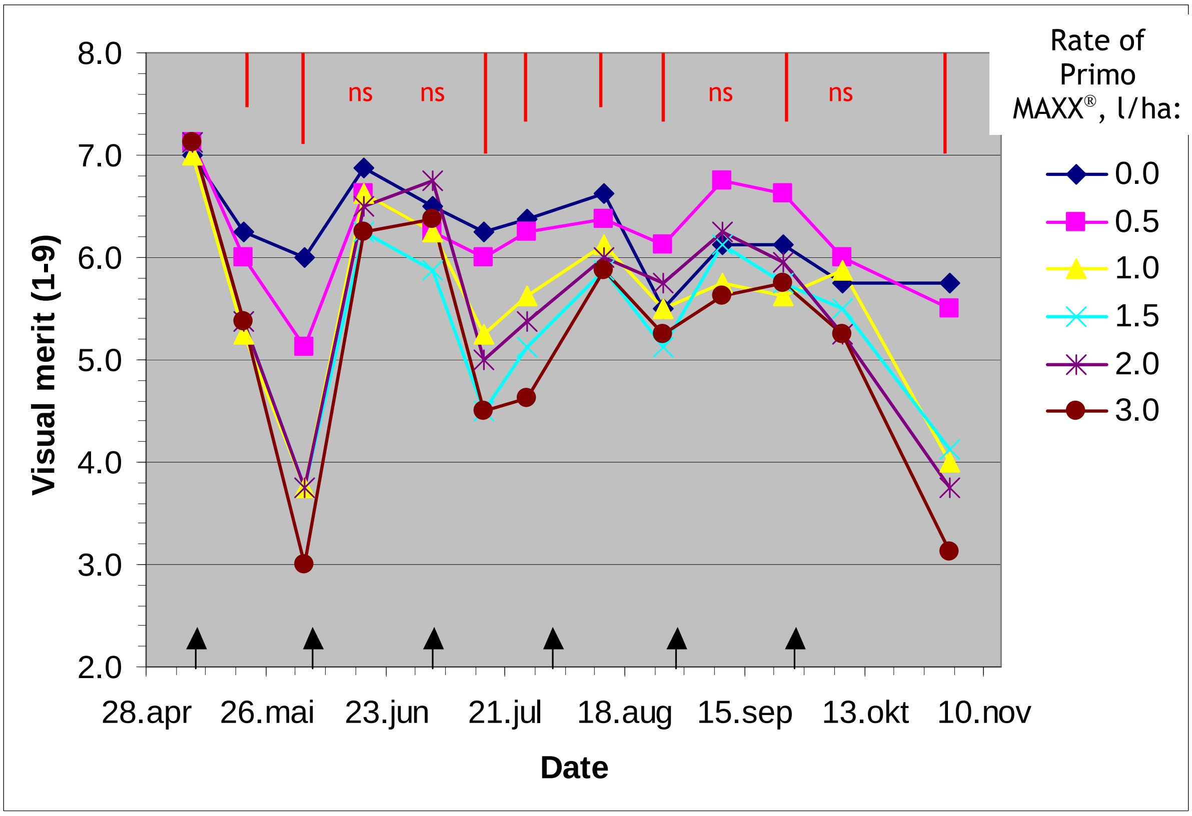


Fig.1. Turfgrass overall quality as affected by increasing rates of Primo MAXX® in fairway trial at Landvik, 2007. Mean of four replicates (blocks). The application dates 9 May, 5 June, 4 July, 31 July, 28 Aug. and 26. Sep. are indicated by black arrows. Red bars indicate LSD 5%.

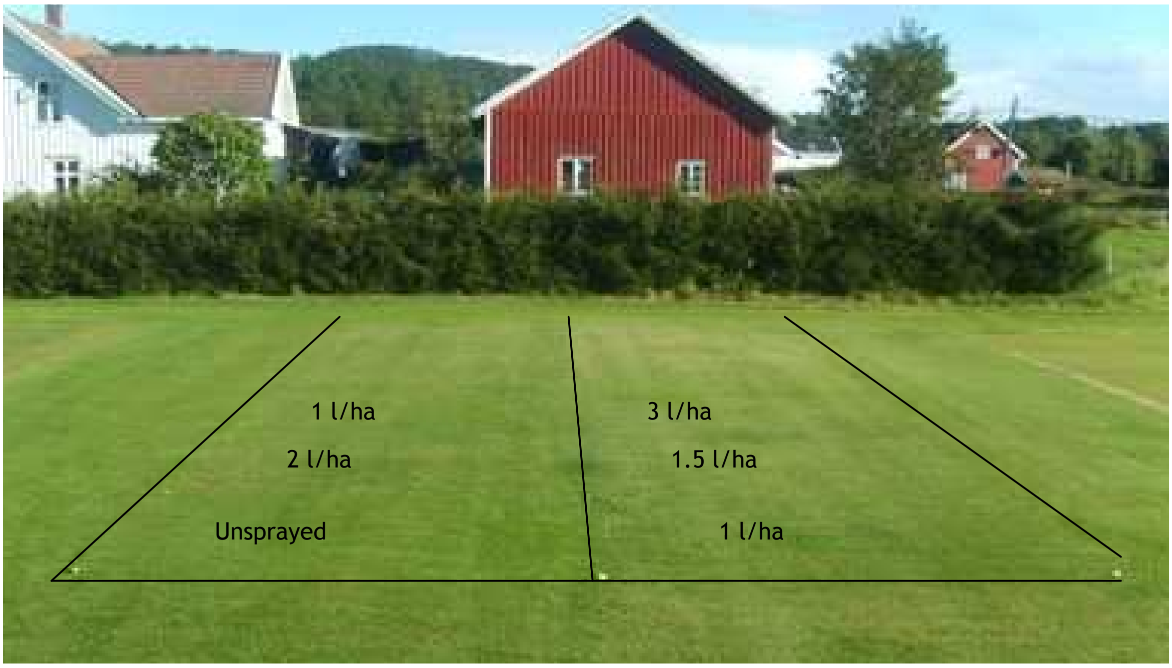


Photo 5. Visual appearance of fairway trial at Landvik, block 1 and 2, on 10 Sept. Within each block, the treatments closest to the photographer have been labeled. High rates of Primo MAXX® resulted in darker, in some cases, almost brown, turf. Photo: Trygve S. Aamlid.

Photo 6.

Turf quality / dormancy colour at growth cessation on 2 Nov. 2007 after application of Primo Maxx at 3.0 l/ha (left) and 0.5 l/ha (right), last application on 26 Sep.

Photo: Trygve S. Aamlid.

Turfgrass height and dry matter production

The average effect of Primo MAXX® on plant height and clipping yields are given in Table 11. In all blocks, the growth regulator caused a significant reduction in plant height even at the lowest rate, but contrary to expectation, this low rate also tended to increase aboveground dry matter production as compared with the unsprayed control treatment. This might reflect a higher tiller density, as also suggested in Table 10. Separate analyses for various parts of trial showed that the average reduction in clipping yield due to Primo MAXX® was stronger in blocks 1 & 2 which had more *Poa* species less red fescue and browntop bent and than blocks 3 & 4. On average for eleven harvests and all replicates, there was a slight tendency for Primo MAXX® to increase the dry matter percentage of turfgrass clippings (P% = 16, Table 11).

Table 11. Absolute and relative effects of increasing rates of Primo MAXX® on turfgrass height, turfgrass dry matter production, and per cent dry matter of clippings in fairway trial at Landvik, 2007. Mean of eleven observations. Plant height above 15 mm represents an average of four days' growth.

Primo MAXX, rate	Plant height, mm		Production of turfgrass clippings, g/m^2/day				% dry matter in clippings
	mm	Rel.	Block 1&2	Block 3&4	Mean	Rel.	
0 = Control	21.9	100	1.78	1.62	1.70	100	31.5
0.5 l/ha	20.9	95	1.91	1.93	1.92	113	32.2
1.0 l/ha	20.7	95	1.65	1.72	1.69	99	32.5
1.5 l/ha	20.0	91	1.46	1.46	1.46	86	33.6
2.0 l/ha	20.3	93	1.55	1.61	1.58	93	32.4
3.0 l/ha	19.5	89	1.31	1.70	1.51	88	33.1
P%.	<0.1	-	10	ns	<5	-	16
LSD 5%	0.7	-	-	-	0.29	-	-
CV%	2	-	10	14	12	-	3

In absolute terms, turfgrass clipping yield showed a distinct seasonal pattern with peaks during the warm and sunny periods in early June and late August (Fig. 2a). The low clipping yield on 17 July was probably due to 280 mm rainfall, and thus nutrient leaching, since the last fertilizer application on 12 June (Tables 3 and 4). Separate analyses of variance for each day indicated a significant effect of Primo MAXX® on clipping yield only on 4 June.

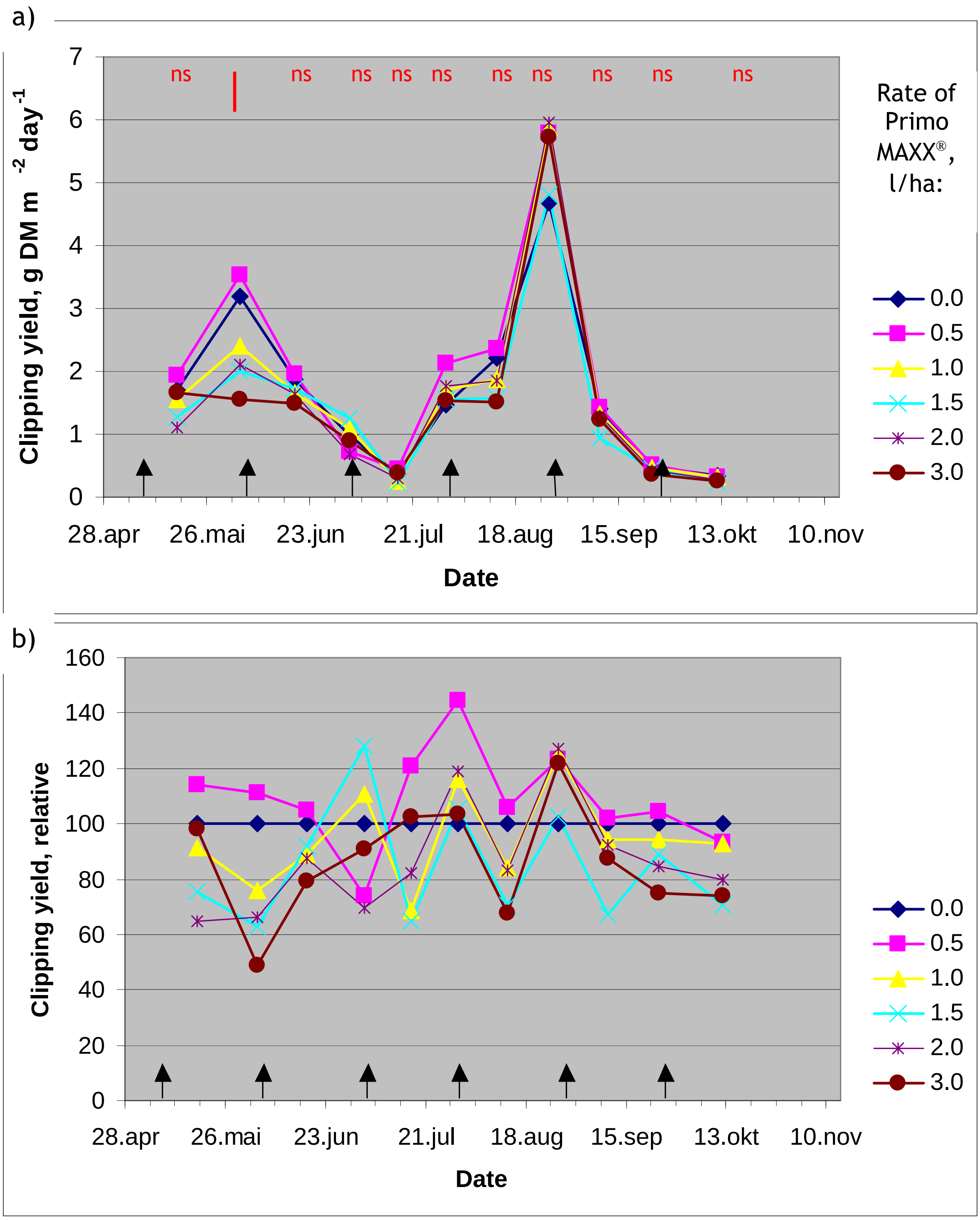


Fig. 2. Absolute (a) and relative (b) reductions in daily dry matter production of turfgrass clippings as affected by increasing rates of Primo MAXX® in fairway trial at Landvik. Red text/bars and black arrows indicate probability / LSD values and application dates 9 May, 5 June, 4 July, 31 July, 28 Aug. and 26 Sep., respectively. In (b), the clipping yield on each date was set to 100 in the unsprayed control treatment.

In relative terms, none of the Primo MAXX® treatments produced clipping yields that were lower than the unsprayed control at all harvests (Fig. 2b). Many of the treatments showed a typical suppression / rebound pattern with clipping yields lower than the control treatment at one harvest, but higher than control treatment at the next harvest.

4.2. Evaluation of Primo MAXX® on a golf course fairway, Lepaa, Finland

On average for two observations in spring, five observations in summer and two observations in autumn, Primo MAXX® had no effect on turfgrass general appearance in the fairway trial at Lepaa. Among the nine observation dates, significant differences were recorded only on 21 August when the plots sprayed with the highest dose (3.0 l/ha) had an average visual merit score of 5.5 as opposed to 6.8 for unsprayed control plots and plots sprayed with the lowest dose (0.5 l/ha).

On average for observations, increasing rates of Primo Max caused an overall increase in tiller density, while turfgrass colour was not significantly affected. No diseases were observed during the growing season.

Table 12. Turfgrass quality (1-9, 9 is best quality), tiller density (1-9, 9 is highest density) and within-season colour (1-9, 9 is darkest green) in fairway trial at Lepaa as affected by increasing rates of Primo MAXX®. Means of nine observations (two in spring, i.e. before 10 June, five in summer, i.e. from 10 June to 1 Sep., and two in autumn, i.e. after 1 Sep.). All values are means of four blocks.

Primo MAXX®, rate	Turf quality (general appearance, 1-9)				Tiller density (1-9)	Within season colour (1-9)
	Mean	Spring	Summer	Autumn		
0 = Control	6.1	5.5	6.1	6.8	5.5	6.1
0.5 l/ha	6.2	5.5	6.1	7.0	5.8	6.2
1.0 l/ha	6.1	5.4	6.1	6.9	5.8	6.1
1.5 l/ha	6.2	5.5	6.2	7.0	6.0	6.3
2.0 l/ha	6.2	5.6	6.1	6.9	6.1	6.3
3.0 l/ha	6.2	5.6	6.1	7.0	6.4	6.2
P%	ns	ns	ns	ns	<0.1	ns
LSD 5%	-	-	-	-	0.4	-
CV%	5	4	8	3	3	4

The effect of Primo MAXX® on turfgrass plant height and clipping yield depended on the time since last application. On average for five observations conducted about two weeks after application, the highest rate of Primo MAXX® caused significant reductions in plant height and clipping yield corresponding to 11 and 48 %, respectively (Table 13). On average for four observations conducted four weeks after application, the maximal reductions were only 3 and 14 %, respectively. Fig. 3 illustrates the unstable effect of Primo MAXX®, particularly toward the end of the growing season. However, unlike in the fairway trial at Landvik (Fig.2), clipping yields on sprayed plots were rarely higher than on untreated control plots in the trial at Lepaa.

Table 13. Absolute and relative effects of increasing rates of Primo MAXX® on turfgrass height and dry matter production in turfgrass clippings in fairway trial at Lepaa 2007. Observations conducted 2 weeks (5 observations) and 4 weeks (4 observations) from spraying treatment have been presented separately.

Treatment	Plant height (mm)				Weight of clippings (g DM / m^2 / day)			
Time after treatment	2 weeks	4 weeks	Mean	Rel	2 weeks	4 weeks	Mean	Rel
0 = Control	15.7	16.0	15.8	100	3.2	7.0	4.9	100
0.5 l/ha	15.7	16.0	15.8	100	2.7	6.3	4.3	87
1.0 l/ha	14.9	16.0	15.4	97	2.8	6.6	4.5	92
1.5 l/ha	14.7	15.7	15.1	96	2.3	5.8	3.9	79
2.0 l/ha	14.4	15.6	15.0	95	2.1	6.1	3.9	80
3.0 l/ha	14.0	15.5	14.6	92	1.8	6.0	3.7	75
P%	<0.1	ns	<5	-	<0.1	ns	ns	-
LSD 5%	1.1	-	1.0	-	0.7	-	-	-
CV%	3	4	3	-	13	22	18	

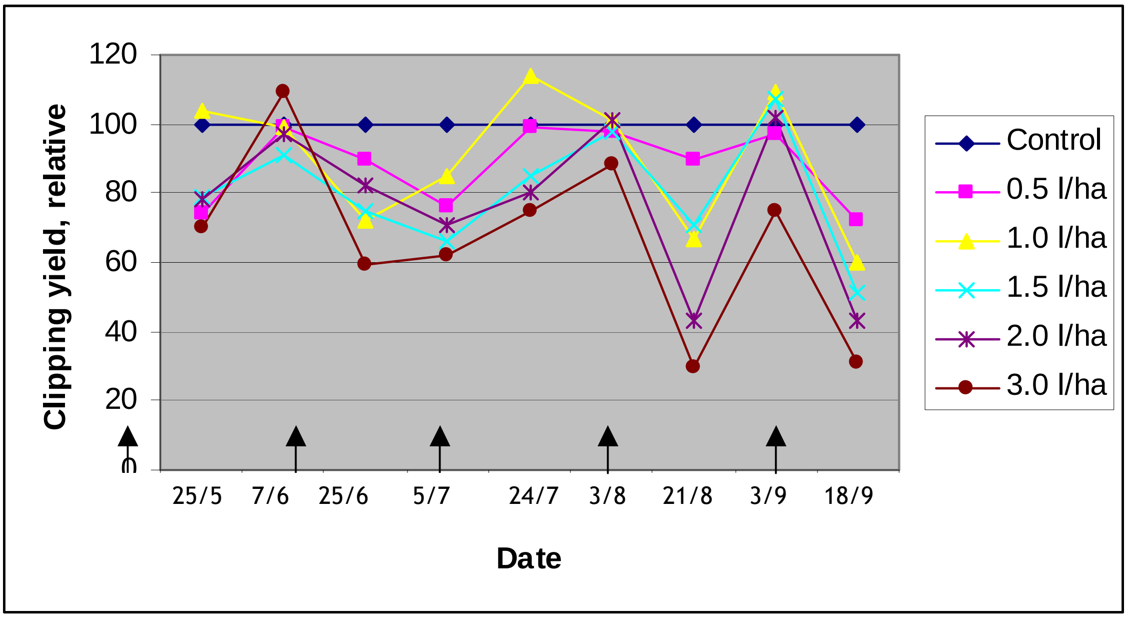


Fig. 3. Relative clipping weights (control = 100) in fairway trial at Lepaa, Finland. Spraying treatments indicated by black arrows were carried out on 11 May, 8 June, 5 July, 3 Aug. and 4 Sep. (The last spraying on 4 Oct. was done primarily to study the effect of Primo MAXX® on overwintering and was not followed by observations in late autumn.)

4.3. Evaluation of Primo MAXX® on a golf course putting green, Lepaa, Finland

On 3 Sep. 2007, a significantly higher tiller density was recorded on green plots sprayed with the highest rate of Primo MAXX® than on unsprayed control plots (data not shown). Otherwise, Primo MAXX® had no significant effect on either general appearance, tiller density or turfgrass colour in the green trial at Lepaa (Table 14). Although the effects on plant height and clipping yields were also not significant, reductions were generally stronger when recorded at two compared with four weeks after application (Table 15, Fig. 4).

Table 14. Turfgrass quality, tiller density and within-season colour (darkness) in green trial at Lepaa as affected by increasing rates of Primo MAXX®, 2007. Means of nine observations (two in spring, i.e. before 10 June, five in summer, i.e. from 10 June to 1 Sep., and two in autumn, i.e. after 1 Sep.). All values are means of four blocks.

Primo MAXX®, rate	Turf quality (general appearance, 1-9)				Tiller density (1-9)	Within season colour (1-9)
	Mean	Spring	Summer	Autumn		
0 = Control	6.4	6.1	6.6	6.3	6.3	6.4
0.2 l/ha	6.3	6.0	6.5	6.0	6.3	6.4
0.4 l/ha	6.3	5.9	6.5	6.1	6.2	6.3
0.6 l/ha	6.3	5.8	6.5	6.4	6.3	6.4
0.8 l/ha	6.2	5.8	6.4	6.3	6.2	6.4
P%	ns	ns	ns	ns	ns	ns
LSD 5%	-	-	-	-	-	-
CV%	3	5	5	7	2	3

Table 15. Absolute and relative effects of increasing rates of Primo MAXX® on turfgrass height and dry matter production in turfgrass clippings in green trial at Lepaa 2007. Observations conducted 2 weeks (5 observations) and 4 weeks (4 observations) from spraying treatment have been presented separately. Plant heights above 3 mm represent one day's growth.

Treatment	Plant height (mm)				Weight of clippings (g DM / m^2 / day)			
Time after treatment	2 weeks	4 weeks	Mean	Rel	2 weeks	4 weeks	Mean	Rel
0 = Control	4.3	3.9	4.1	100	2.60	2.21	2.43	100
0.2 l/ha	4.1	3.8	4.0	96	2.20	2.28	2.23	92
0.4 l/ha	4.0	3.9	3.9	95	1.88	2.28	2.06	85
0.6 l/ha	4.0	3.8	3.9	94	1.72	2.18	1.99	82
0.8 l/ha	3.8	3.9	3.9	93	1.75	2.28	1.92	79
P%	11	ns	ns	-	5	ns	ns	-
LSD 5%	-	-	-	-	0.9	-	-	-
CV%	6	7	8	-	20	14	16	-

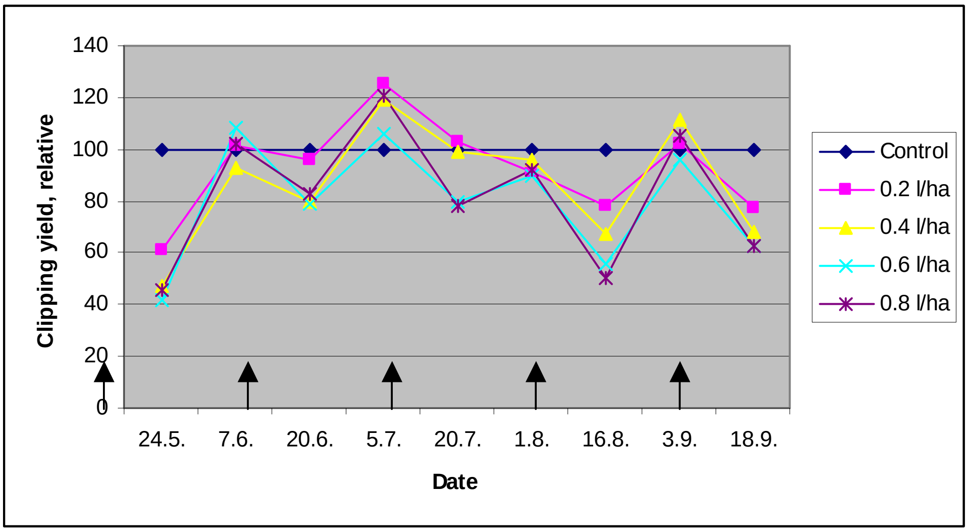


Fig. 4. Relative clipping weights (control = 100) in green trial at Lepaa, Finland. Spraying treatments indicated by black arrows were carried out on 11 May, 8 June, 5 July, 3 Aug. and 4 Sep. (The last spraying on 4 Oct. was done primarily to study the effect of Primo MAXX® on overwintering and was not followed by observations in late autumn.)

4.4. Demonstration trials with Primo MAXX® at Ballerud Golf Course, Oslo, Norway

<u>Green trials</u>

Applications of 0.4 l/ha Primo MAXX® on 5 and 18 June did not affect turf general appearance (Photo 7) or stimpmeter readings on green no. 9 at Ballerud. During the period 14-29 June, clippings were reduced by an average of 32%, but after spraying had been discontinued, there was a rebound effect corresponding to a 26 % increase in clipping yield in the period 12-25 July (data not shown).

Photo 7. Terje Haugen (left) and Lasse Augustsson on green no. 9 at Ballerud Golf Course, 27 June 2007. Photo: Trygve S. Aamlid.

Photo 8. Field day at Ballerud Golf Course 27 Aug. 2007. Photo: Tatsiana Espevig.

Fig. 5 summarizes results from the nursery green trial established on 9 July. In this trial, application of Primo MAXX® about every third week resulted in better colour (not shown), higher green speed (Fig. 5a), and an average reduction in turfgrass clippings of 44 % (Fig. 5b and c). Fig 5b shows that the reduction in clipping yield was most conspicuous during the periods of rapid growth in mid to late July (after only one application of Primo MAXX®) and in late August.

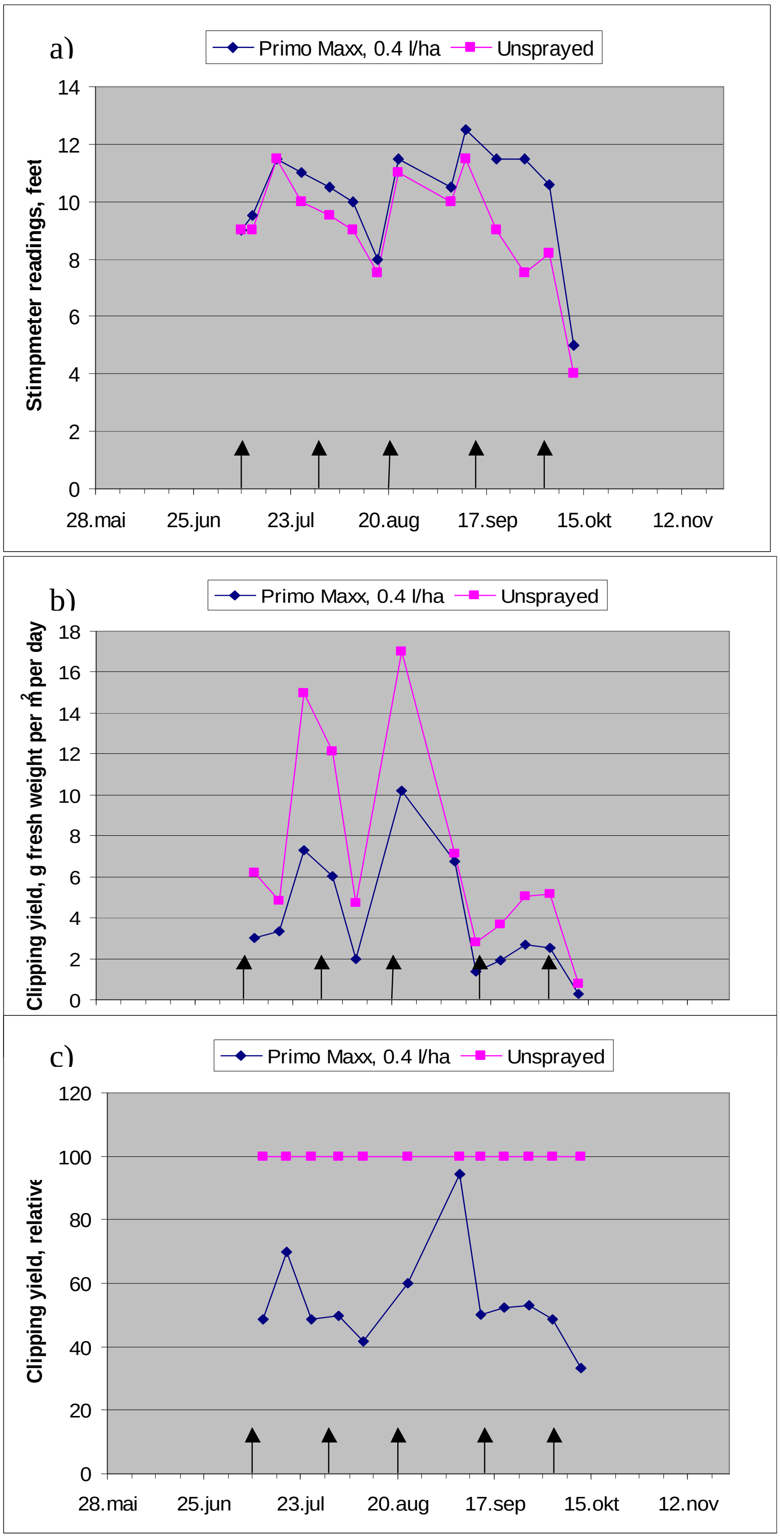


Fig. 5. Effects of spraying Primo MAXX® every three weeks of green speed and absolute and relative clipping yield on nursery green at Ballerud GC, 2007. Black arrows indicate the application dates 9 July, 31 July, 21 Aug., 13 Sep. and 4 Oct.

Fairway trial

As evaluated by the headgreenkeeper, monthly applications of 1.5 l/ha Primo MAXX® (1.5 l/ha) had no negative impact on turf quality in the fairway trial at Ballerud (Fig. 6). Photos 9-11 show, nevertheless, that treated turf was more faded, grayish, and less green than untreated turf. The pronounced colour difference in favour of Primo MAXX® in early September (Fig. 6) was due to less dry spots than the in the control area. While these spots recovered after rainfall on 10 and 17 Sep., the last application of Primo MAXX® on 4 Oct. led to an apparent loss of colour and drop in turf general appearance in late autumn (Photo 11).

On average for 17 clipping, regular application of Primo MAXX® resulted in a 37 % reduction in the fresh weight of turfgrass clippings (Fig. 7). The only time clipping yield was higher on the treated than on the untreated area was at the first clipping nine days after the first application and on 7 Sep. The latter coincided with the observation of less dry spots after use of Primo MAXX®. It may also be interpreted as a rebound effect following growth suppression after application on 31 July.

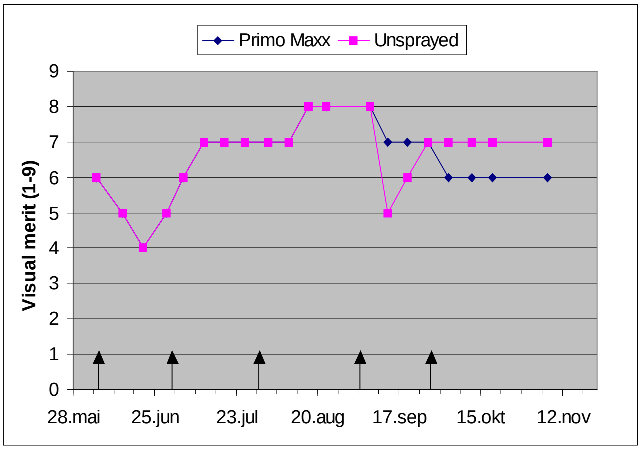
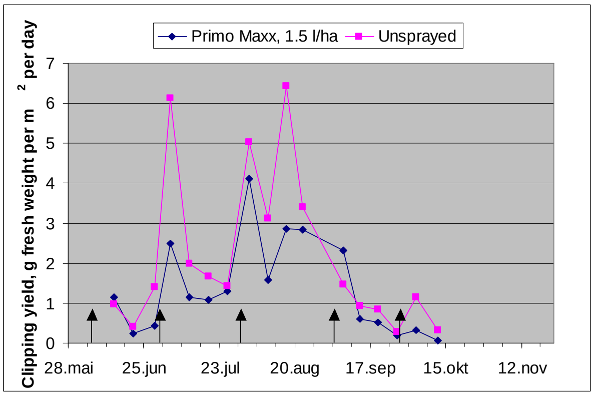


Fig. 6. Effect of Primo MAXX® on turfgrass general appearance in fairway trial at Ballerud GC. Black arrows indicate application dates. (Sprayed an unsprayed plots had identical scores until the beginning of September)

Photo 9. Difference in colour and general appearance of treated and untreated fairway Ballerud GC, 27 June. Photo: Trygve S. Aamlid.

Photo 10. Difference in colour and general appearance of treated and untreated fairway Ballerud GC, 27 Aug. Photo: Tatsiana Espevig.

Photo 11. Difference in colour and general appearance of treated and untreated fairway Ballerud GC, 3 Dec. Photo: Terje Haugen.



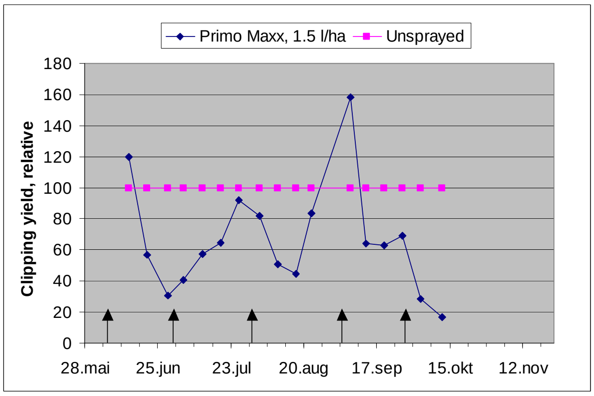


Fig. 7. Absolute (a) and relative (b) reductions in clipping yield resulting form application of Primo MAXX® in fairway trial at Ballerud GC. Arrows indicate application dates.

Spraying 2.2 l/ha of Primo MAXX® at six weeks interval resulted in discoloration and consistent drop in turf quality in the rough trial at Ballerud (Fig. 8, Photos 12 and 13). The effect was most conspicuous in late autumn. Primo MAXX® had less effect on tufts of perennial ryegrass which stood out very markedly in the turf which was otherwise dominated by smooth meadowgrass. Clipping yields were not recorded in this trial.

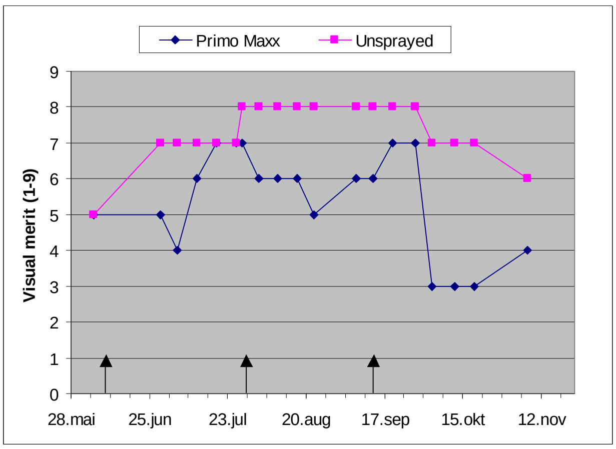


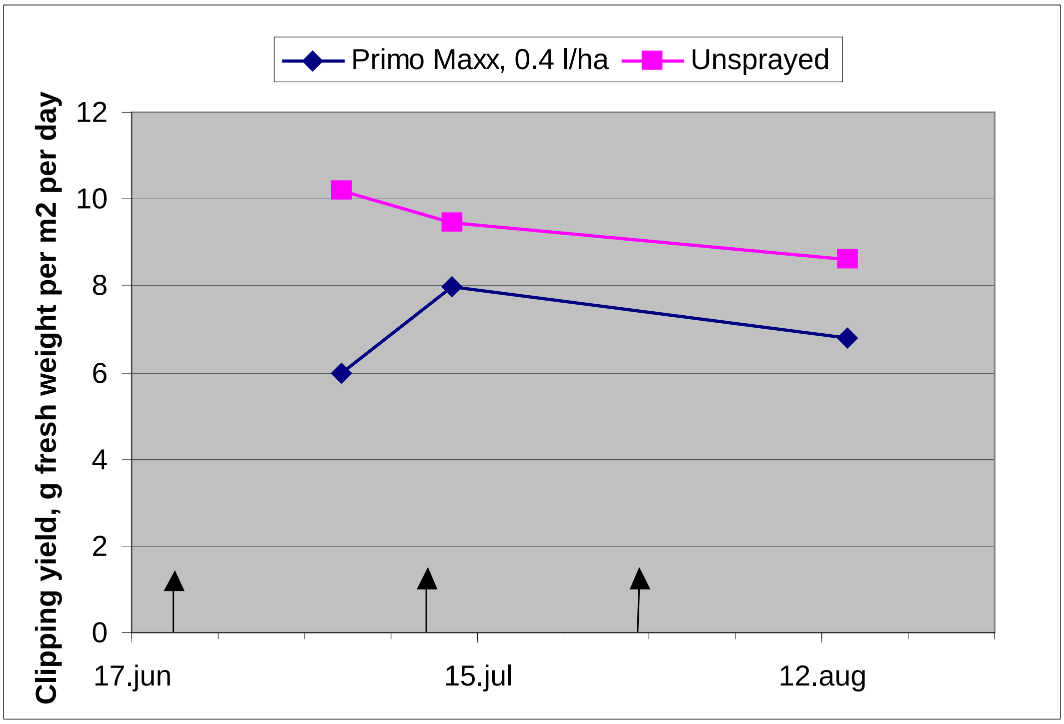
Fig. 8 (upper left). Difference in colour and general appearance of treated and untreated area in rough no 9, Ballerud, 27 June. Photo: Trygve S. Aamlid.

Photo 12 (upper right). Terje Haugen (left) and Lasse Augustsson in rough trial at Ballerud GC, 27 June. Photo: Trygve S. Aamlid.

Photo 13 (lower left). Trygve S. Aamlid inspecting rough trial at Ballerud GC, 27 August 2007. Tufts of ryegrass stand out very markedly on sprayed area.
Photo: Tatsiana Espevig.

4.5. Demonstration trial with Primo MAXX® at Oslo Golf Club, Bogstad, Norway

Application of 0.4 l Primo MAXX® at three week intervals resulted in darker turf but had otherwise no effect on the turfgrass quality of annual meadowgrass at Oslo GC. On average for three registrations, the Primo MAXX led to a 26% reduction in clipping yields (Fig. 9).



5. Discussion and suggestions for 2008

The starting point for evaluating Primo MAXX® in this two-year project was the rates and applications frequencies recommended for the product in Europe (Syngenta 2007, Table 16). Based on our experiences from agricultural crops that the optimal rates may be different in the Nordic countries than countries further south, higher and lower rates were included in the GEP trials both to determine the potential growth inhibition and the risk for discoloration or other phytotoxic effects. All taken together, the results from the first project year confirms that the guidelines in Table 16 are not directly applicable in Scandinavia and that further research is needed to find the optimal way of using the product under Nordic conditions.

Table 16. Dose rates and applications frequencies recommended for Primo MAXX® in the United Kingdom (Syngenta 2007).

	Dose rate		Application
	Primo MAXX®, l/ha	trinexapac-ethyl, g a.i./ha	frequency
Fairways	0.8 – 1.6	90 - 180	Every four to five weeks
Roughs & semi-roughs	1.6-2.4	180 - 240	Every five to eight weeks
Greens	0.4	45	Every two to four weeks

On fairway, the average reduction in clipping yield caused by monthly application of the intermediate Primo MAXX® rate of 1.5 l/ha was 15 and 21 % in the GEP trials at Landvik and Lepaa, respectively. By contrast, monthly application of 1.5 l/ha resulted in a 37 % reduction in clipping yield in the demonstration trial at Ballerud GC, which is closer to the data presented by Syngenta (2007). In agreement with Table 11 showing an increase in turfgrass dry matter percentage (i.e. decreased succulence) after application of Primo MAXX®, one of the reasons for this difference might be that clipping yields were determined on a dry weight basis in the GEP trials but on a fresh weight basis at Ballerud GC and in the data presented by Syngenta (2007). Another, and probably more important explanation, is the difference in species composition among the three trials. While the plant cover at Ballerud was almost 100% by annual meadowgrass, the species composition at Landvik varied with the two blocks showing the least response to Primo MAXX® having a plant cover of 74 % red fescue (Tables 1 and 11). By contrast, smooth meadowgrass dominated over red fescue at Lepaa due to the heavy soil type, use of irrigation, and relatively high nitrogen input. Unfortunately, we have not been able to find many references about the specific effects of Primo MAXX® on red fescue turf, but our results are in partial agreement with Pannacol et al. (2004) who found 40 %, 21 %, and no significant reduction in clipping yield after using trinexapac-ethyl in smooth meadowgrass, chewing fescue and creeping red fescue, respectively.

Perhaps the most conspicuous feature of the present results was the unstable effect of Primo MAXX® on clipping yields due to the postsuppression rebound effect. In the fairway trial at Lepaa, Finland, this resulted in clipping yield reductions being significant only two weeks after application (Table 13), and a similar tendency could be seen also in the green trial (Table 15). In Norway, clipping yields four weeks after spraying were often higher than on unsprayed control plots in the fairway trial at Landvik (Fig. 2), and a strong rebound effect was observed also after spraying treatments had to discontinued at green no. 9, Ballerud GC. The unstable effect in of Primo MAXX® in these trials was probably due to a rapid degradation of trinexapac-ethyl in plant tissue and a higher regrowth potential due to accumulation of carbohydrate reserves and GA_1 precursors during the suppression phase (Lickfeldt et

al. 2001, Branham & Beasley 2007). In North-American experiments, Lickfeldt et al. (2001) reported clipping yields reductions in smooth meadowgrass to be much more consistent when trinexapac-ethyl was applied at four than at six week intervals, but under Nordic long-day conditions, spraying every second, or at least every third week, may well be necessary to stabilize low GA_1 levels, not only on greens, but also on fairways and tees. Although there was a surge effect during the driest period in mid September, the most stable clipping reductions in our trials, on average 44 % on a fresh weight basis, were, indeed, obtained on the nursery green which was sprayed about every third week at Ballerud GC (Fig. 5c). While Branham & Beasley (2007) noted that temperature was the most important factor determining degradation of trinexapac-ethyl in turfgrass tissue, our results suggest that other factors such as light and water availability may also be important for the rebound effect under Nordic conditions. Very clearly, application frequency is a major question that has to be addressed during the continuation of this project.

The potential reductions in mowing costs from using a plant growth regulator will always have to be weighed against the risks for discoloration or other harmful effects on turf quality. In the present trials, reductions in general appearance (visual merit) scores were far more conspicuous in the GEP trial at Landvik than in the GEP trials at Lepaa or the demonstration trials at Ballerud GC. Apart from possible effects of different botanical compositions, this might reflect a subjective human factor, i.e. different backgrounds and attitudes of the observers in the various trials. While the fairway trial at Landvik was evaluated by turfgrass scientists and technicians with long experience from turfgrass variety testing, the trials at Lepaa and Ballerud were evaluated by greenkeepers working on the course. While the observers at Landvik may have paid more attention to turf aesthetic values such as less intense colour, and less vigorous and uniform plots, the observers at Lepaa and Ballerud may well have been more attentive to ball roll and other functional characteristics of the playing surface. The less succulent but significantly darker green turf resulting from high Primo MAXX® rates at Landvik are in agreement with other studies showing higher mesophyll cell densities and chlorophyll concentrations resulting from less elongation of leaf cells (Heckman et al. 2001, Ervin & Zhang 2008). As for tiller density, most literature supports the Finnish rather than the Norwegian results; i.e. enhanced tillering after Primo MAXX® application (Branham & Beasley 2007, Ervin & Zhang 2008).

As compared with the unsprayed control treatment, the strongest negative effect of Primo MAXX® on turfgrass general appearance at Landvik was recorded after the first spraying in early June, in mid July and at the last observation in early November. Each of these observations might be explained by suboptimal conditions causing reduced turfgrass growth. From 6 to 15 June there was a dry and warm and period with maximum temperatures in the range 25-30 ºC that obviously reduced turfgras tillering and aesthetic appearance; until mid July exceptional rainfalls starting on 22 June were not compensated by increase nitrogen inputs, and in autumn, the last application of Primo on 26 September was followed by several nights of frost. Although most studies have failed to document significant interactions between nitrogen and trinexapac-ethyl on turfgrass quality (Steinke & Stier 2001, Goss et al. 2002, McCullogh et al. 2006), it seems reasonable to assume that potential negative effects on Primo MAXX® on turfgrass quality will be most pronounced under suboptimal growing conditions. As in the trials at Landvik (Photo 6) and Ballerud (Photo 11), Beam et al. (2002) reported significant discoloration of trinexapac-ethyl-treated smooth meadowgrass following frost in autumn.

Undoubtedly, the most convincing argument for official approval of Primo MAXX® on Nordic golf courses would be a clear documentation that it improves winter survival. Preliminary results with annual meadowgrass suggested that low rates of trinexapac-ethyl prevented winter injury, whereas high rates had opposite effects due to discoloration during the hardening phase in late autumn (Rossi & Buelow 1997). While trinexapac-ethyl has been shown to increase water soluble carbohydrate contents (Goss et al. 2002) and result in faster spring greenup, Ervin & Zhang (2008) recently called for more detailed investigations into the effect of trinexapac-etyl on freezing tolerance as the research to date has provided scarce information on this aspect. Under Nordic conditions, desiccation if growth resumes when soils are still frozen and irrigation not yet operational in spring, or damage due to unstable winters with ice and water covering the turf, sometimes resulting in suffocation, appear to be more

important that direct freezing injury. In this regard, trineexapac-ethyl may well have a positive effect as it reduces mitochondrial respiration (Ervin & Zhang 2008). In 2008, it will therefore be very interesting to study winter injury and spring green-up and recovery in the on-going trials at Landvik, Lepaa and Ballerud which all had their last application of Primo MAXX® in late September or early October.

Even with winter survival and spring observations included, the amount of data presented in this report is too limited to recommend any listing of Primo MAXX® for turf use in the Nordic countries. Therefore, as stated in the contract between Syngenta and Scandinavian Turfgrass and Environment Research Foundation, there is a need for new GEP trials to be started in spring 2008 and followed until registration of winter survival in spring 2009. For this purpose, a new experimental green was constructed and seeded to creeping bentgrass at Landvik in 2007. In the trial to be established on this green in spring 2008, we suggest to compare Primo MAXX® at three rates (0.15, 0.30 and 0.45 l/ha) and two application frequencies (every 10/11 days and every 21 days), i.e. six combinations plus an unsprayed control treatment. As different grass species seem to vary in their response to Primo MAXX®, similar trials should preferably be carried out on also red fescue/browntop greens and velvet bentgrass greens, although this would require additional funding from Syngenta/STERF.

In Finland, a new GEP trial will be established in spring 2008 on a fairway that is regularly subjected to winter injury. New demonstration trials might be added to the project depending on interest from superintendents and funding from the national golf unions.

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

Results from the first evaluation year 2007

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Finnish team spraying fairway trial at Lepaa Golf Course.
Photo: Oiva Niemelainen

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Summary:

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

Sammendrag:

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

Approved

Arne Sæbø	Trygve S. Aamlid
Leader, Bioforsk's Section for Urban Greening	Project leader

Contents

1. Abstract

As an inhibitor of the last step in plant synthesis of bioactive gibberellin (GA_1), the plant growth regulator Primo MAXX® (trinexapac-ethyl) offers prospects of reduced energy use for mowing and improved turfgrass quality under Nordic long day conditions. This report presents first year results from 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 possible registration of Primo MAXX®, unreplicated demonstration trials were carried out at Ballerud and Bogstad Golf Courses in Oslo under supervision of Bioforsk and with funding from the Norwegian Golf Federation (NGF).

GEP trials on **fairways** (mowing height 12-18 mm) were carried out at Bioforsk Landvik, Norway (58°34'N, 8°52'E) and at the Lepaa Unit of the HAMK University of Applied Sciences, Finland (61°08'N, 24°20'E). Primo MAXX® was applied at monthly intervals at rates 0.5, 1.0, 1.5, 2.0 and 3.0 l/ha (56.5, 113, 169.5, 226 and 339 g a.i./ha trinexapac-ethyl) in comparison with an unsprayed control treatment. Turfgrass general appearance, tiller density, colour, height growth, and clipping yields were recorded two and four weeks after each application. Primo MAXX® had no effect on turfgrass general appearance but increased density at Lepaa. At Landvik, Primo MAXX® (>= 1.0 l/ha) reduced turfgrass general appearance and density, but resulted in significantly darker green colour. Quality reductions were most apparent during periods with either daily maximum temperatures >25 ºC, extreme rainfall probably causing nitrogen deficiency, or frost at night. Average reductions in clipping yield caused by Primo MAXX® (>= 1.0 l/ha) were 8 % in the GEP trial at Landvik, 18 % in the GEP trial at Lepaa and 37 % in the demonstration trial at Ballerud; to some extent this difference may be due to different botanical composition with red fescue (*Festuca rubra*) and annual meadowgrass (*Poa annua*) being the predominant species at Landvik and Ballerud, respectively. Clipping yield reductions due to Primo MAXX® were unstable, growth suppression two weeks after application often being followed by a rebound effect during the remaining two weeks until next application.

A GEP trial on creeping bentgrass **putting greens** was carried out at Lepaa, Finland, and demonstration trials at Ballerud and Bogstad, Norway. Primo MAXX® was sprayed at rates 0.2, 0.4, 0.6 or 0.8 l/ha at monthly intervals in the GEP trial, and at 0.4 l/ha every three weeks in the demonstration trials. On average for all observations, Primo MAXX® had no effect on turfgrass quality, but clipping yields were reduced by 16, 44 and 26% at Lepaa, Ballerud and Bogstad, respectively. As in the fairway trials, growth suppression at Lepaa was stronger when assessed at two than at four weeks after application. By contrast, Primo MAXX® produced a fairly stable effect when applied at three week intervals in the demonstration trials.

Use of Primo MAXX® on golf course **roughs** was investigated only in a demonstration trial at Ballerud. Application of 2.2 l/ha of Primo MAXX® every seven weeks resulted in discolouration and reduced quality of smooth meadow grass.

In conclusion, the first year of this project has shown that the guidelines for use of Primo MAXX® in other European countries are not directly applicable in Scandinavia. As the present results are too limited to apply for registration of Primo MAXX®, the project will continue in 2008 tentatively with new trials investigating application of Primo MAXX® at lower rates, but higher frequencies. Improved winter stress tolerance would be a convincing argument for registration of Primo MAXX® in the Nordic countries, and the on-going trials will therefore be followed by an assessment of effects of the last Primo MAXX® applications in September or October 2007 on winter survival and spring recovery.

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

2. Introduction

The plant growth regulator trinexapac-ethyl was developed by Syngenta in the 1980s. Since the active ingredient is available in different formulations, the chemical will, in this report, be referred to as Primo MAXX®, which is the product developed by Syngenta specifically for use on turf. Unlike earlier plant growth regulators, Primo MAXX®'s mode of action is highly specific as it blocks the conversion of GA_{20} til GA_1, i.e. the last step in the biosynthesis of gibberellic acid, a plant hormone stimulating cell elongation and thus vertical turf growth.

After its release, Primo MAXX® was rapidly adopted by the US and Canadian turf industries. In North America, there are several independent university studies documenting its positive effects on golf courses, athletic fields, home lawns, and sod production (for a recent review, see Erwin and Zhang 2008). These advantages include reduced leaf elongation and thus reduced mowing costs and energy use, improved tiller production (more lateral growth), darker green colour, and improved resistance to drought and shade.

While other formulations of trinexapac-ethyl have been approved for agricultural use in Europe for about a decade, the experience with Primo MAXX® to European turfgrass areas is relatively limited. During the past three to four years, Primo MAXX® has been approved for turf use in Italy, France and UK, and the evaluation and registration process has been initiated in many other countries.

Being an inhibitor of gibberellin biosynthesis, Primo MAXX® offers special prospects for turfgrass management in the Nordic counties Finland, Sweden, Norway, Iceland, and Denmark. At latitudes ranging form 55 to 71 °N, turfgrasses growing in these countries exposed not only to long photoperiods during most of the growing season, but also to lower photosynthetic flux densities and lower red to farred (R/FR) ratios than in countries further south. The natural turfgrass response to these northern light conditions is to devote more of its resources to shoot elongation (Heide et al. 1985a,b). Since this response is primarily mediated by the gibberellic acid GA_1, any specific growth regulator that controls the biosynthesis of this compound might be useful under Nordic conditions. Nevertheless, our experience from the introduction of trinexapac-ethyl for agricultural use in the Nordic counties suggests that the optimal dose rates and frequencies for application of Primo MAXX® to various types of turf are probably not the same as at lower latitudes. This is also due to different species and cultivars being grown compared with countries further south. Field trials under Nordic conditions are therefore required not only to produce data for the national certification agencies, but also to provide turf managers with recommendations for how to use the product.

This report presents first year preliminary results from a two year project evaluating the use of Primo MAXX® on golf courses in the Nordic countries. The project was funded by Syngenta and the Scandinavian Turfgrass and Environment Research Foundation (STERF) 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' trials needed to provide documentation for possible registrations of Primo MAXX® by the national authorities, a couple of practical demonstration trials were carried out on Norwegian golf courses under supervision from Bioforsk and with funding from the Norwegian Golf Federation (NGF).

3. Methods

3.1. Evaluation of Primo MAXX® under fairway conditions, Bioforsk Landvik, Norway

Experimental site

On 8 May 2007, a field trial was laid out on a fairway established on a sandy loam soil (topsoil: 68 % sand, 27% silt, 5 % clay) at Bioforsk Landvik Research Station (58°34'N, 8°52'E), SE Norway. Soil samples indicated a pH (H_2O) of 5.9, high phosphorus values (P-AL=19) and intermediate to low potassium values (K-AL = 8, K-HNO_3=58). The fairway had been seeded in September 2003 to a mixture of smooth meadowgrass (*Poa pratensis*), chewing fescue (*Festuca rubra* ssp. *commutata*), and browntop bent (*Agrostis capillaris*) (Table 1). Block 1 and 2 were located in one part, and block 3 and 4 in a different part of the fairway. Botanical analyses at the start of experimentation indicated that red fescue was the predominant species in all blocks, but presumably due to slightly less surface drainage, blocks 1 and 2 had a higher percentage of smooth and annual meadowgrass and broadleaved weeds (primarily white clover (*Trifolium repens*)) than blocks 3 and 4 (Table 1).

Table 1. Seed mixture used for fairway establishment in 2003 and botanical composition at the start of the Primo MAXX® trial in spring 2007.

Species	Cultivar	% (w/w) of seed mixture	% cover at initiation of Primo MAXX® trial		
			Block 1 and 2	Block 3 and 4	Mean
Poa pratensis	Conni	25	31	9	20
Poa pratensis	Eva	10			
Poa pratensis	Limousine	10			
Festuca rubra ssp. commutata	Bargreen	25	50	74	62
Festuca rubra ssp. commutata	Calliope	25			
Agrostis capillaris	Tracenta	5	5	15	10
Poa annua			8	2	5
Broadleaved weeds			6	0	3
Sum		100	100	100	100

Experimental plan

The experiment was laid out according to a randomized complete block design with plot size 2m x 3m, four blocks (replicates) and the following treatments:

1. Usprayed control
2. Primo MAXX, 0.5 l/ha (56.5 g a.i./ha) every four weeks
3. Primo MAXX, 1.0 l/ha (113 g a.i./ha) every four weeks
4. Primo MAXX, 1.5 l/ha (169.5 g a.i./ha) every four weeks
5. Primo MAXX, 2.0 l/ha (226 g a.i./ha) every four weeks
6. Primo MAXX, 3.0 l/ha (339 g a.i./ha) every four weeks

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. Actual application rates were recorded by weighing the tank before and after spraying. Table 2 shows actual rates and weather conditions for each spraying event.

Table 2. Weather conditions and actual application rates at the six spraying events.

Application date	Time of day (hours)	Weather conditions at application			Treatment number / application rate (l Primo MAXX® per ha)				
		Air temp. °C	Relative Humidity %	Wind Speed m/s	2. (target 0.5)	3. (target 1.0)	4. (target 1.5)	5. (target 2.0)	6. (target 3.0)
9 May	09-11	14	48	< 1.0	0.47	0.94	1.56	1.90	3.35
5 Jun.	09-11	15	60	< 1.0	0.58	1.06	1.67	1.93	3.19
4 Jul.	13-15	17	70	1.0-2.0	0.61	0.98	1.73	2.19	3.38
31 Jul.	08-10	18	55	1.0-2.0	0.55	1.05	1.66	2.28	3.41
28 Aug.	09-11	19	32	1.0-2.0	0.57	1.03	1.55	2.19	3.52
26 Sep.	09-11	11	69	< 1.0	0.52	1.07	1.55	2.01	3.15
Mean					0.55	1.02	1.62	2.08	3.33

Registrations

At two weeks intervals throughout the experimental period, turfgrass colour, tiller density, and turf general appearance were assessed by turfgrass scientist or technicians using a scale from 1 to 9 where 9 is darkest colour, highest tiller density and best turf quality. The assessments were conducted two and four weeks after application of Primo MAXX®. On the same dates, turfgrass diseases and broadleaf weed (including white clover) invasion were reported as per cent of plot area. Turfgrass height was recorded as the mean of three random measurements with a ordinary ruler in each plot, and the overall growth rate by weighing clippings in the basket of a walk-behind mower used in the 0.56 m x 1.88 m central area of each plot (Photo 1). Both raw weight and dry weight were recorded, the latter after drying for 24 h at 60ºC. By the end of the growing season, on 2 Nov., turfgrass dormancy colour was evaluated on a scale 1-9, where 1 is completely faded / brown turf, and 9 is completely green turf.

Photo 1a and b. Tatsiana Espevig collecting clippings in fairway trial at Landvik. Photos: Trygve S. Aamlid

Management

The experiment was mowed at 15 mm two times a week, usually on Monday and Friday. A triplex fairway mower without collection of clippings was used except when clipping weights were to be recorded. Granular fertilizer was applied at approximately monthly intervals as outlined in Table 3. The experiment was not irrigated except for small amounts of water to dissolve fertilizer after application. On 7 Aug., the trial was aerated using a vertidrain with 15 mm solid tines to 15 cm depth. Topdressing was accomplished on 8 Aug. and 5 Nov. at rates 0.75 and 1.5 kg pure sand per m^2, respectively.

The fairway trial at Landvik was not exposed to ordinary play, but it was was subjected to artifical wear from a wear drum one to two times per week.

Table 3. Fertilizer inputs, fairway trial, Landvik.

		Per ha							
Date	Fertilizer type	kg fertilizer	kg N	kg P	kg K	kg Mg	kg S	kg Ca	kg Fe
17 Apr.	Fullgjødsel 22-2-12	40	9	1	5	0	1	0	0
16 May	Fullgjødsel 22-2-12	70	15	1	8	1	2	1	0
12 Jun.	Arena Golf Extra 13-0-15	150	20	0	23	2	21	0	3
23 Jul.	Arena Golf Extra 13-0-15	130	17	0	20	2	18	0	3
9 Aug.	Arena Golf Extra 13-0-15	135	18	0	21	2	18	0	3
5 Sep.	Arena Golf Extra 13-0-15	150	20	0	23	2	21	0	3
SUM			99	2	100	10	80	1	11

Weather data

In SE Norway, the growing season 2007 was characterized by exceptionally high rainfall, especially in July, but also in May, June and August (Table 4). By contrast, September was unusually dry. Precipitation was recorded on 16 out of the 31 days in July; the cloudy summer weather is also reflected by a rather low irradiance during this month. The warmest period, with daily maximum temperatures in the range 23-29 ºC was recorded from 6 to 12 June.

Table 4. Weather data for Landvik meteorological station, about 200 m for experimental field. Normal values for temperature and rainfall are 'official' values for from the period 1961-90, while normal values for irradiance are calculated averages for the period 1994-2006.

	Mean temperature, °C		Precipitation, mm		Irradiance, MJ/m^2 (305-2800 nm)	
	2007	30 yr normal	2007	30 yr normal	2007	13 yr average
May	10.2	10.4	107	82	518	540
June	15.9	14.7	109	71	604	600
July	15.5	16.2	213	92	492	632
Aug.	16.2	15.4	132	113	476	476
Sep.	12.0	11.8	59	136	321	262
Mean / sum	14.0	13.7	620	494	2411	2510

3.2. Evaluation of Primo MAXX® on a golf course fairway, Lepaa, Finland

Experimental site

The Finnish fairway trial was laid out on 11 May 2007. The fairway was seeded to a mixture of smooth meadowgrass and chewing fescue (*Festuca rubra* spp. *commutata*) on a heavy clay soil (15% sand, 37% silt, 48% clay) at the Lepaa Unit of HAMK University of Applied Sciences, Finland (61°08'N, 24°20'E). 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. All observations and management of the trial was carried out by the HAMK Lepaa greenkeepers Petteri Lehmuskoski and Tommi Turunen except for the spraying treatments which were carried out by MTT's 'Good Experimental Practice' certified spraying team from Jokioinen (90 km from Lepaa).

Experimental plan and registrations

The experiment was laid out following the same plan and plot size as at Landvik, Norway (previous paragraph). Primo MAXX® was applied in accordance with the Finnish 'Good Experimental Practise' protocol, using a portable, compressed air-powered 'van der Weij' plot sprayer, mounted with a windshield and flat fan nozzles (Hardi 4110-12) and working at 180-250 kPa pressure. The spraying boom had four nozzles spaced 50 cm apart. The spraying volume corresponded to 200 l/ha. Full spray coverage was on the central 1.5m x 2.5 m of each plot. Table 5 shows application dates and weather conditions for each spraying event. The last application on 4 Oct. was conducted especially to evaluate potential effects of Primo MAXX® on turfgrass winter damage.

Table 5. Application dates and weather conditions in fairway and green trials at Lepaa.

Application date	Time of day (hours)	Air temp. °C	Relative humidity %	Wind Speed m/s	% cloud cover
11 May	09-11	11	29	0	25
8 Jun.	09-11	20	56	1.5	1
5 Jul.	13-15	23	47	2.5	70
3 Aug.	09-11	17	78	2.0	90
4 Sep.	09-11	11	90	1.0	90
4 Oct.	13-15	11	92	1.5	100

Photo 2. Austen Sutton, Syngenta (left) and greenkeeper Petteri Lehmuskoski, HAMK Lepaa Unit, in fairway trial at Lepaa, Finland, 29 Aug. 2007.

Photo: Oiva Niemelainen.

<u>Registrations</u>

Registrations were carried out at two-week intervals following the same program as at Landvik (previous section) except that weed occurrence and dormancy colour were not recorded. Plant height at Lepaa was determined using a Turf Check Prism device (Check Signature Inc., Shoreview, MN).

<u>Management and wear</u>

The experiment was mowed with a triplex fairway mower about three times per week. Mowing height ranged from 12 to 18 mm. Granular fertilizer Sportsmaster 26-2-9 was applied at equal rates on 8 May and 12 July, the total input corresponding to 156 kg N, 12 kg P, 54 kg K and 0.9 kg Fe per ha. Information about irrigation is given in Table 6. The trial was aerated or top-dressed in late autumn, after the completion of registrations.

During the growing season period, the trial was exposed to approximately 3.500 rounds of golf.

<u>Weather data</u>

Temperatures at Lepaa were higher the 30 yr normal values throughout the growing season (Table 6). August had the greatest deviation from the long-term average value. July had 49 % more, and August 42 % less rainfall than usual; over the whole experimental season, rainfall was close to the 30 yr normal value.

Table 6. Weather data for Hattula Lepaa weather station and irrigation in fairway and green trial at Lepaa golf course, 2007. Normal values for temperature and rainfall are official values for from the period 1971-2000 (Finnish Meteorological Institute)

	Mean temperature, °C		Rainfall, mm		Irrigation, mm (2007)	
	2007	30 yr normal	2007	30 yr normal	Fairway trial	Green trial
May	10.6	9.8	30	34	*	*
June	15.1	14.5	54	55	26	79
July	16.6	16.4	119	80	5	47
Aug.	16.4	14.6	43	74	7	50
Sep.	9.9	9.4	58	54	0	6
Mean / sum	13.7	12.4	304	297	37	188

* Data are unavailable for the period 1-26 May 2007 due to change of irrigation computer.

3.3. Evaluation of Primo MAXX® on a golf course putting green, Lepaa, Finland

<u>Experimental site</u>

The Finnish green trial was established on 11 May 2007 on a USGA green seeded to creeping bentgrass (*Agrostis stolonifera*, seed blend of 50% ‘Penn A-4’ and 50% ‘Penn G-6’) at Lepaa Golf Course.

Experimental plan

The experimental plan comprised five rates of Primo MAXX plus the unsprayed control treatment:

1. Usprayed control
2. Primo MAXX, 0.2 l/ha (22.6 g a.i./ha) every four weeks
3. Primo MAXX, 0.4 l/ha (45.2 g a.i./ha) every four weeks
4. Primo MAXX, 0.6 l/ha (67.8 g a.i./ha) every four weeks
5. Primo MAXX, 0.8 l/ha (90.4 g a.i./ha) every four weeks

The trial had four replicates, and a gross plot size of 2 m x 3 m. It was sprayed on the same dates and following the same GEP procedures as the fairway trial on the same location (Table 5).

Photo 3. Green trial at Lepaa ready for the first treatment on 11 May 2007. Photo: Oiva Niemelainen.

Registrations

Registrations followed the same program as in the Finnish fairway trial (previous section).

Management and wear

The experiment was mowed with a Triplex greens mower for an average of six times per week. Depending on weather and turfgrass density, mowing height was 5–7 mm in May and September and 3-4 mm from June to August. Information about irrigation and fertilizer inputs are given in Tables 6 and 7, respectively.

To avoid thatch accumulation, the trial was aerated with deep slitting knives every second week and with 8 mm needle tines once a month. Verticutting was accomplished every second week and topdressing with 0.1-0.7 mm finely graded sand at a rate of 1 kg per m2 every third week. The sand was brushed/irrigated into the green and the dressing was never done in close proximity to weighing of clippings.

Being located on a practise green, the experiment received wear from about 10.000 rounds of golf over the season. When placing holes on the green, care was taken to create as uniform wear as possible.

Table 7. Fertilizer inputs in green trial at Lepaa.

		Per ha							
Date	Fertilizer type	kg fertilizer	kg N	kg P	kg K	kg Mg	kg S	kg Ca	kg Fe
28.3.2007	Floratine Kevätstartti*	35	5.4	1.2	2.1				
5.4.2007	Floratine Kevätstartti	35	5.4	1.2	2.1				
19.4.2007	Floratine Kevätstartti	35	5.4	1.2	2.1				
26.4.2007	Sierraform Springstart (16-0-13)	250	40	0	32.5				2.50
15.5.2007	Sierraform All Season (18-3-15)	250	45	7.5	37.5	3.0			1.25
30.5.2007	Kemigreen Basic (23-4-14)	40	9	1.6	5.6	0.6	0.8		0.04
5.6.2007	Kemigreen Basic (23-4-14)	40	9	1.6	5.6	0.6	0.8		0.04
11.6.2007	Sierraform All Season (18-3-15)	250	45	7.5	38				
25.6.2007	Osmosol 614R (19-2-10)	40	7.6	0.8	4.0	0.5		1.7	0.04
2.7.2007	Osmosol 614R (19-2-10)	40	7.6	0.8	4.0	0.5		1.7	0.04
13.7.2007	Kemigreen Summer (18-0-17)	40	7.2	0	6.8			2.0	0.40
18.7.2007	Kemigreen Summer (18-0-17)	40	7.2	0	6.8			2.0	0.40
26.7.2007	Sierraform All Season (18-3-15)	250	45	7.5	37.5	3.0			1.25
14.8.2007	Kemigreen Summer (18-0-17)	40	7.2	0	6.8			2.0	0.40
27.8.2007	Greenmaster Autumn (6-2-8)	300	18	6	24	5.4			1.50
30.8.2007	Kemigreen Basic (23-4-14)	40	9	1.6	5.6	0.6	0.8		0.04
11.9.2007	Sierraform Springstart (16-0-13)	200	32	0	39				2.00
SUM			305	39	260	14.0	2.4	9.4	10

* Floratine Kevätstartti (Springstart) is composed of P-48 (10-21-6.6), Per 4 Max (15-0-0), Protesyn (3.5-0.6-1.8), and Plant Marvel (28-3-15).

3.4. Demonstration trials with Primo MAXX® at Ballerud Golf Course, Oslo, Norway

Experimental site and set-up

Ballerud GC is located on an old horticultural farm in a suburban area SW of Oslo. The course has greens with mostly dominated by creeping bentgrass, fairways almost exclusively dominated by annual meadowgrass, and smooth meadowgrass roughs with some tufts of perennial ryegrass (*Lolium perenne*).

Large-scale, unreplicated demonstration trials were laid out on green no. 9, fairway no. 9 and rough no. 9 on 5 June 2007. Plots sizes varied from 80 to 130 m^2. Unsprayed control plots were compared with plots sprayed with Primo MAXX® at rates 0.4, 1.5 and 2.2 l/ha and application intervals of approximately 3, 4 and 7 weeks on green, fairway and rough, respectively. In compliance with the Norwegian Food Authority's rule for complete closure of all sprayed areas for 48 h after each application, the trial on green no. 9 had to be discontinued after the second application on 18 June.

Three weeks later, it was replaced by a new trial laid out on the golf course' nursery green. Actual application dates in the green, fairway and rough trials are given in Table 8. The growth regulator was applied using a battery-operated electric Hardy Defender plot sprayer (Photo 4).

Table 8. Application dates for Primo MAXX in demonstration trials at Ballerud GC.

Green no. 9	Nursery green	Fairway no. 9	Rough no. 9
5 June		5 June	5 June
18 June			
	9 July	2 July	
	31 July	31 July	28 July
	21 Aug.		
	13. Sep.	3 Sep.	11 Sep.
	4 Oct.	28 Sep.	

Photo 4. Sprayer used in demonstrations trials at Ballerud Golf Course.

Photo: Terje Haugen.

Registrations

In all trials at Ballerud, turfgrass general appearance was evaluated by the headgreenkeeper at one to two week intervals throughout the growing season. In the green and fairway trials, turfgrass clipping yields were recorded on a fresh weight basis. Registrations in the green trials also included regular assessments of green speed using a standard stimpmeter.

Maintenance

The green trials at Ballerud were mowed daily at 3.4-3.8 mm and the fairway trial at 20 mm three to four times a week. The rough area was only mowed upon need.

Due to the rich soil from decades of vegetable production, the rough trial was not fertilized in 2007, and the fairway trial only received one application of 200 kg Fullgjødsel® 11-5-18 (22 kg N/ha) on 8 May. The green trials received monthly applications of granuar fertilizer (Gro Power 5-1-1, Anderson 14-0-9, Anderson 8-0-16, and/or Roots 12-2-12), and weekly applications of liquid fertilizers /

biostimulants, mostly Floratine products. Total rates of N, P, K, Mg, Ca, S and Fe over the season were 155, 14, 142, 27, 30, 73 and 14 kg/ha, respectively. The greens were aerated, mostly using Envirojet, six times during the season and top-dressed, also six times, giving a total of 6.3 kg sand per m^2.

Weather data and irrigation

Table 3 shows recordings from Ballerud GC's weather station. Although the rainfall in 2007 was higher than usual, there were periods, especially in May, June and August when the green trials needed irrigation. The fairway and rough trials were never irrigated.

Table 9. Weather recordings and irrigation at Ballerud GC, 2007. Monthly temperatures are means of daily maximum and minimum temperatures.

	Mean monthly temperature, °C	Monthly rainfall, mm	Monthly irrigation, mm (greens only)
May	11.2	94	42
June	17.1	185	52
July	16.9	173	10
Aug.	16.6	83	47
Sep.	11.1	71	21
Mean / sum	14.6	606	172

3.5. Demonstration trial with Primo MAXX® at Oslo Golf Club, Bogstad, Norway

To evaluate the effect of Primo MAXX® on a typical annual meadowgrass green, an unreplicated demonstation trial with plot size 250 m^2 was laid out at Oslo GK on 20 June 2007. Primo MAXX® was sprayed at a rate 0.4 l/ha on 20 June, 10 July and 31 July using the same sprayer as at Ballerud GC, about 10 km from Bogstad (Photo 4). Turfgrass quality (general appearance) and fresh weight clipping yields were determined on 4 July, 13 July and 14 August. Unfortunately, the trial had to be discontinued in mid August due to reconstruction of the green.

3.6. 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 on each plot and on plot values which had been averaged, either over the whole growing season, separately over the spring (before 10 June), summer (10 June – 1 Sep.) and autumn (after 1 Sep.) periods, or for observations conducted two versus four weeks after the last application of Primo MAXX®. The significance levels P%<0.1, P%<1, P%<5 and ns (not significant) have been indicated in the tables along with LSD values for effects significant at P%<5. In a few cases exact P-values have been given for tendencies in the 5-15% probability range. As an indications of the variability for each character, coeffcients of variation, (CV %), have also been given in the tables.

4. Results

4.1. Evaluation of Primo MAXX® under fairway conditions, Bioforsk Landvik, Norway

Turfgrass quality and related characteristics

Table 10 shows results from the visual observations of turfgrass quality and related characters in the fairway trial at Landvik. Both within the three seasons and as a mean value, turfgrass general appearance was significantly lower on plots receiving monthly applications of Primo MAXX® at 1.0 l/ha or higher rates than on unsprayed control plots and plots receiving 0.5 l/ha. Within these two groups, differences in generall appearance were not significant. Separate analyses for blocks 1 and 2 versus 3 and 4 indicated that these responses were practically identical regardless of botanical composition (data not shown).

Individual registrations of turfgrass quality are further depicted in Fig. 1. There was a dramatic decline in quality after the first application on 9 May. After this the turf recovered and there was no significant effect of Primo MAXX® at the two subsequent evaluations. Applications of 1.0 l/ha or higher rates on 4 July lead to new quality reductions in July, August and September (Photo 5); these effects were especially apparent at the last evaluation in early November (Photo 6). By contrast, there tended to be a small quality improvement due to the lowest rate of Primo MAXX® from late August to October. This improvement was reflected also in a significant increase in tiller density on average for the whole growing season (Table 10).

Increasing rates of Primo MAXX® consistently led to darker turf throughout the growing season, but also to earlier growth cessation and a less attractive dormancy colour in late autumn (Table 10). The only visible disease in the trial was a slight attack of red thread (*Laetisaria fuciformis*) during the wet period in July; however, these spots were unaffected by Primo MAXX® which also had no effect on the occurrence of broadleaved weeds, primarily white clover, in the trial.

Table 10. Turfgrass quality, tiller density, within-season colour, dormancy colour and infestation of weeds and red thread (*Laetisaria fuciformis*) in fairway at Landvik as affected by increasing rates of Primo MAXX®, 2007. Visual merit and tiller density are means of twelve observations (two in spring, i.e. before 10 June, six in summer, i.e. from 10 June to 1 Sep., and four in autumn, i.e. after 1 Sep. Within season colour (green darkness) and occurrence weeds and red thread are means of twelve, three (all in July) and two (June and Nov.) observations, respectively. Dormancy colour was evaluated on 2 Nov. All values are means of four blocks.

Primo MAXX®, rate	Turf quality (general appearance, 1-9)				Tiller density (1-9)	Within season colour (1-9)	Dor-mancy colour (1-9)	% of plot area	
	Mean	Spring	Summer	Autumn				Dicot weeds	Red thread
0 = Control	6.2	6.1	6.4	6.0	6.3	5.2	6.8	4	4
0.5 l/ha	6.1	5.6	6.3	6.2	6.5	5.6	6.3	2	3
1.0 l/ha	5.5	4.5	5.9	5.3	6.1	5.8	5.0	5	2
1.5 l/ha	5.3	4.6	5.5	5.4	6.0	5.9	4.1	4	3
2.0 l/ha	5.5	4.6	5.9	5.3	6.1	6.0	4.3	3	2
3.0 l/ha	5.1	4.2	5.5	4.9	6.0	6.2	3.5	4	3
P%	<0.1	<0.1	<1	<0.1	<1	<1	<0.1	ns	ns
LSD 5%	0.3	0.5	0.4	0.4	0.2	0.4	1.2	-	-
CV%	4	7	5	5	3	5	15	-	-

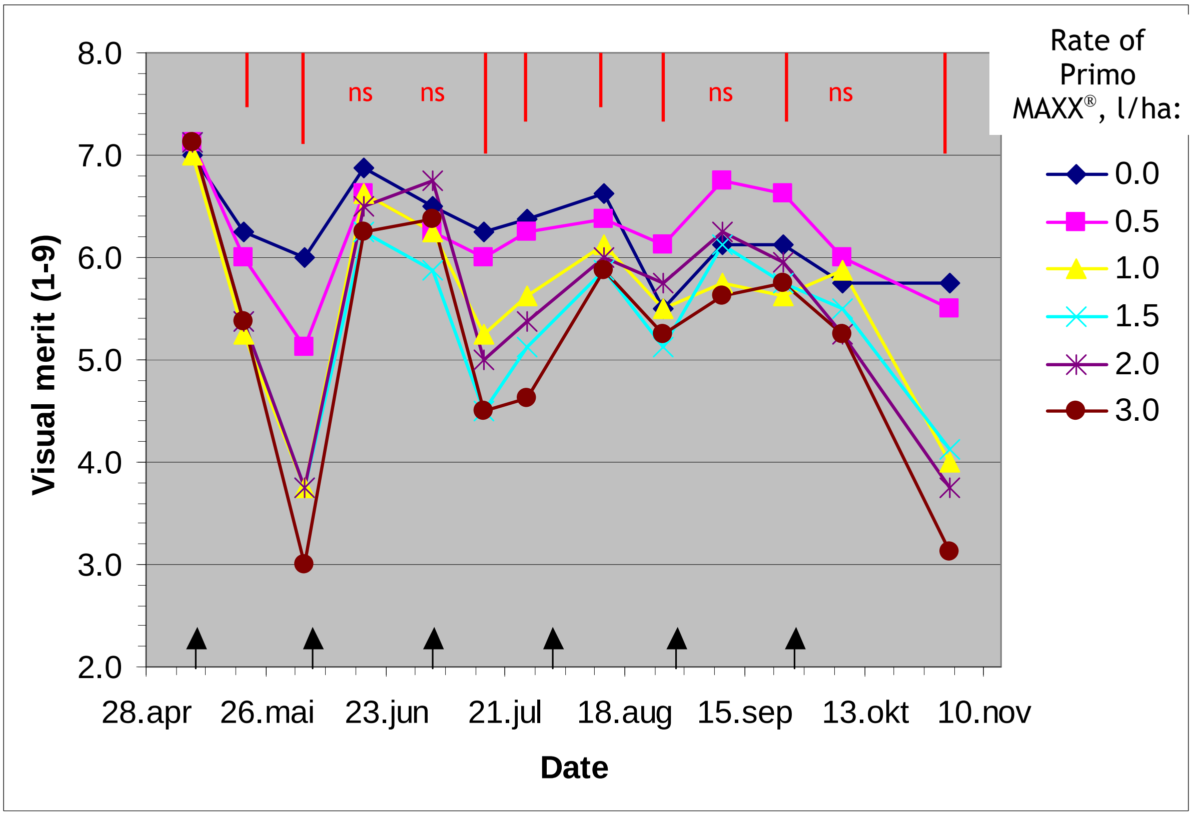


Fig.1. Turfgrass overall quality as affected by increasing rates of Primo MAXX® in fairway trial at Landvik, 2007. Mean of four replicates (blocks). The application dates 9 May, 5 June, 4 July, 31 July, 28 Aug. and 26. Sep. are indicated by black arrows. Red bars indicate LSD 5%.

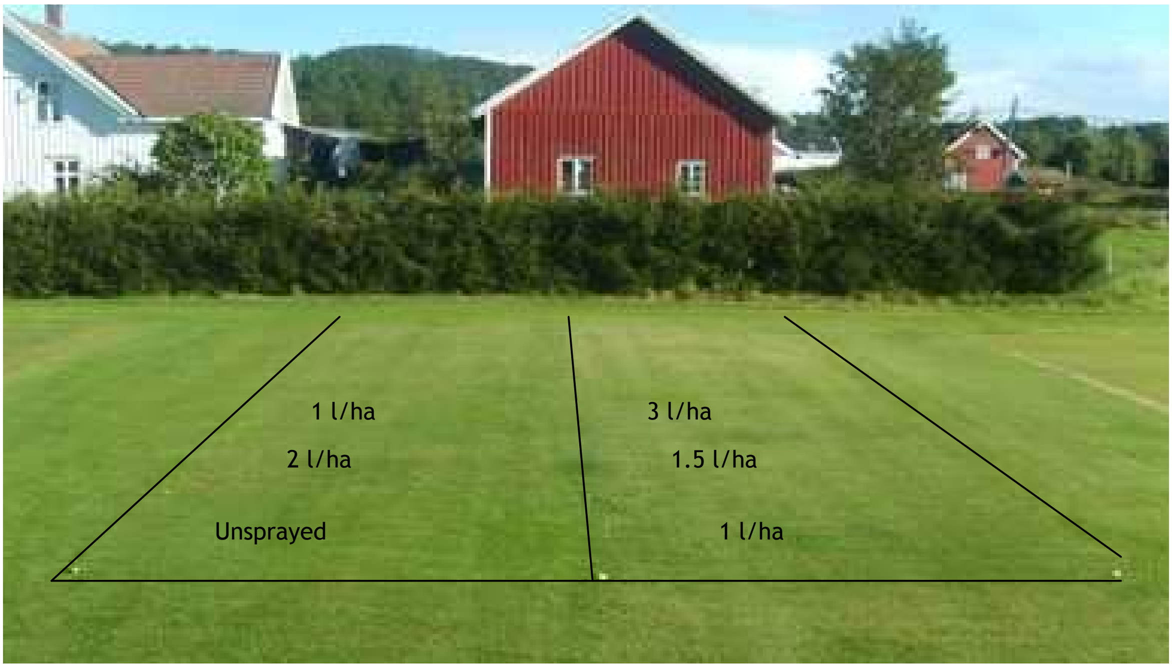


Photo 5. Visual appearance of fairway trial at Landvik, block 1 and 2, on 10 Sept. Within each block, the treatments closest to the photographer have been labeled. High rates of Primo MAXX® resulted in darker, in some cases, almost brown, turf. Photo: Trygve S. Aamlid.

Photo 6.

Turf quality / dormancy colour at growth cessation on 2 Nov. 2007 after application of Primo Maxx at 3.0 l/ha (left) and 0.5 l/ha (right), last application on 26 Sep.

Photo: Trygve S. Aamlid.

Turfgrass height and dry matter production

The average effect of Primo MAXX® on plant height and clipping yields are given in Table 11. In all blocks, the growth regulator caused a significant reduction in plant height even at the lowest rate, but contrary to expectation, this low rate also tended to increase aboveground dry matter production as compared with the unsprayed control treatment. This might reflect a higher tiller density, as also suggested in Table 10. Separate analyses for various parts of trial showed that the average reduction in clipping yield due to Primo MAXX® was stronger in blocks 1 & 2 which had more *Poa* species less red fescue and browntop bent and than blocks 3 & 4. On average for eleven harvests and all replicates, there was a slight tendency for Primo MAXX® to increase the dry matter percentage of turfgrass clippings (P% = 16, Table 11).

Table 11. Absolute and relative effects of increasing rates of Primo MAXX® on turfgrass height, turfgrass dry matter production, and per cent dry matter of clippings in fairway trial at Landvik, 2007. Mean of eleven observations. Plant height above 15 mm represents an average of four days' growth.

Primo MAXX, rate	Plant height, mm		Production of turfgrass clippings, g/m^2/day				% dry matter in clippings
	mm	Rel.	Block 1&2	Block 3&4	Mean	Rel.	
0 = Control	21.9	100	1.78	1.62	1.70	100	31.5
0.5 l/ha	20.9	95	1.91	1.93	1.92	113	32.2
1.0 l/ha	20.7	95	1.65	1.72	1.69	99	32.5
1.5 l/ha	20.0	91	1.46	1.46	1.46	86	33.6
2.0 l/ha	20.3	93	1.55	1.61	1.58	93	32.4
3.0 l/ha	19.5	89	1.31	1.70	1.51	88	33.1
P%.	<0.1	-	10	ns	<5	-	16
LSD 5%	0.7	-	-	-	0.29	-	-
CV%	2	-	10	14	12	-	3

In absolute terms, turfgrass clipping yield showed a distinct seasonal pattern with peaks during the warm and sunny periods in early June and late August (Fig. 2a). The low clipping yield on 17 July was probably due to 280 mm rainfall, and thus nutrient leaching, since the last fertilizer application on 12 June (Tables 3 and 4). Separate analyses of variance for each day indicated a significant effect of Primo MAXX® on clipping yield only on 4 June.

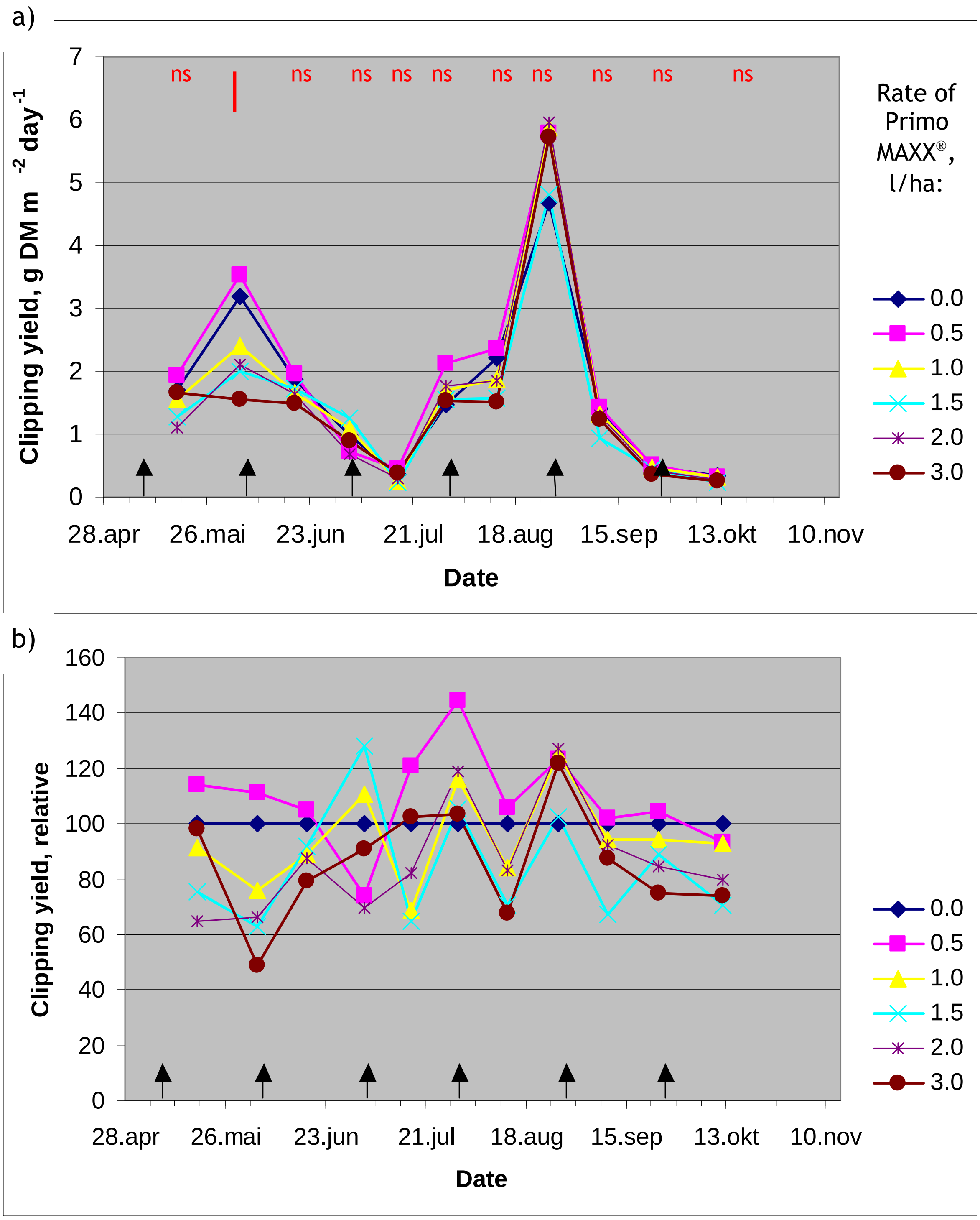


Fig. 2. Absolute (a) and relative (b) reductions in daily dry matter production of turfgrass clippings as affected by increasing rates of Primo MAXX® in fairway trial at Landvik. Red text/bars and black arrows indicate probability / LSD values and application dates 9 May, 5 June, 4 July, 31 July, 28 Aug. and 26 Sep., respectively. In (b), the clipping yield on each date was set to 100 in the unsprayed control treatment.

In relative terms, none of the Primo MAXX® treatments produced clipping yields that were lower than the unsprayed control at all harvests (Fig. 2b). Many of the treatments showed a typical suppression / rebound pattern with clipping yields lower than the control treatment at one harvest, but higher than control treatment at the next harvest.

4.2. Evaluation of Primo MAXX® on a golf course fairway, Lepaa, Finland

On average for two observations in spring, five observations in summer and two observations in autumn, Primo MAXX® had no effect on turfgrass general appearance in the fairway trial at Lepaa. Among the nine observation dates, significant differences were recorded only on 21 August when the plots sprayed with the highest dose (3.0 l/ha) had an average visual merit score of 5.5 as opposed to 6.8 for unsprayed control plots and plots sprayed with the lowest dose (0.5 l/ha).

On average for observations, increasing rates of Primo Max caused an overall increase in tiller density, while turfgrass colour was not significantly affected. No diseases were observed during the growing season.

Table 12. Turfgrass quality (1-9, 9 is best quality), tiller density (1-9, 9 is highest density) and within-season colour (1-9, 9 is darkest green) in fairway trial at Lepaa as affected by increasing rates of Primo MAXX®. Means of nine observations (two in spring, i.e. before 10 June, five in summer, i.e. from 10 June to 1 Sep., and two in autumn, i.e. after 1 Sep.). All values are means of four blocks.

Primo MAXX®, rate	Turf quality (general appearance, 1-9)				Tiller density (1-9)	Within season colour (1-9)
	Mean	Spring	Summer	Autumn		
0 = Control	6.1	5.5	6.1	6.8	5.5	6.1
0.5 l/ha	6.2	5.5	6.1	7.0	5.8	6.2
1.0 l/ha	6.1	5.4	6.1	6.9	5.8	6.1
1.5 l/ha	6.2	5.5	6.2	7.0	6.0	6.3
2.0 l/ha	6.2	5.6	6.1	6.9	6.1	6.3
3.0 l/ha	6.2	5.6	6.1	7.0	6.4	6.2
P%	ns	ns	ns	ns	<0.1	ns
LSD 5%	-	-	-	-	0.4	-
CV%	5	4	8	3	3	4

The effect of Primo MAXX® on turfgrass plant height and clipping yield depended on the time since last application. On average for five observations conducted about two weeks after application, the highest rate of Primo MAXX® caused significant reductions in plant height and clipping yield corresponding to 11 and 48 %, respectively (Table 13). On average for four observations conducted four weeks after application, the maximal reductions were only 3 and 14 %, respectively. Fig. 3 illustrates the unstable effect of Primo MAXX®, particularly toward the end of the growing season. However, unlike in the fairway trial at Landvik (Fig.2), clipping yields on sprayed plots were rarely higher than on untreated control plots in the trial at Lepaa.

Table 13. Absolute and relative effects of increasing rates of Primo MAXX® on turfgrass height and dry matter production in turfgrass clippings in fairway trial at Lepaa 2007. Observations conducted 2 weeks (5 observations) and 4 weeks (4 observations) from spraying treatment have been presented separately.

Treatment	Plant height (mm)				Weight of clippings (g DM / m^2 / day)			
Time after treatment	2 weeks	4 weeks	Mean	Rel	2 weeks	4 weeks	Mean	Rel
0 = Control	15.7	16.0	15.8	100	3.2	7.0	4.9	100
0.5 l/ha	15.7	16.0	15.8	100	2.7	6.3	4.3	87
1.0 l/ha	14.9	16.0	15.4	97	2.8	6.6	4.5	92
1.5 l/ha	14.7	15.7	15.1	96	2.3	5.8	3.9	79
2.0 l/ha	14.4	15.6	15.0	95	2.1	6.1	3.9	80
3.0 l/ha	14.0	15.5	14.6	92	1.8	6.0	3.7	75
P%	<0.1	ns	<5	-	<0.1	ns	ns	-
LSD 5%	1.1	-	1.0	-	0.7	-	-	-
CV%	3	4	3	-	13	22	18	

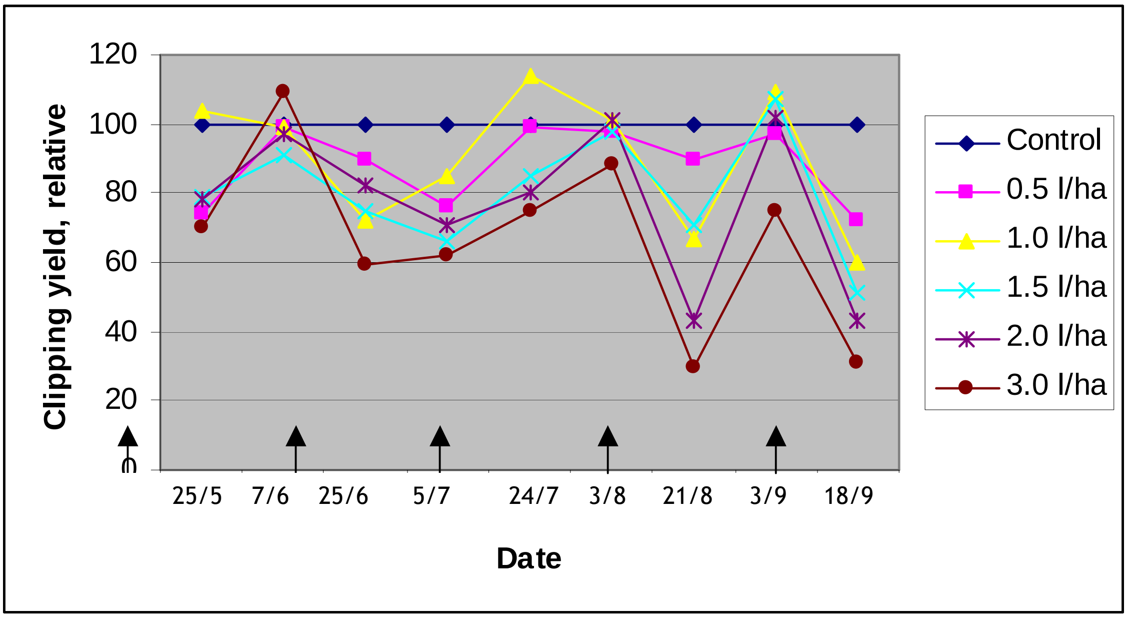


Fig. 3. Relative clipping weights (control = 100) in fairway trial at Lepaa, Finland. Spraying treatments indicated by black arrows were carried out on 11 May, 8 June, 5 July, 3 Aug. and 4 Sep. (The last spraying on 4 Oct. was done primarily to study the effect of Primo MAXX® on overwintering and was not followed by observations in late autumn.)

4.3. Evaluation of Primo MAXX® on a golf course putting green, Lepaa, Finland

On 3 Sep. 2007, a significantly higher tiller density was recorded on green plots sprayed with the highest rate of Primo MAXX® than on unsprayed control plots (data not shown). Otherwise, Primo MAXX® had no significant effect on either general appearance, tiller density or turfgrass colour in the green trial at Lepaa (Table 14). Although the effects on plant height and clipping yields were also not significant, reductions were generally stronger when recorded at two compared with four weeks after application (Table 15, Fig. 4).

Table 14. Turfgrass quality, tiller density and within-season colour (darkness) in green trial at Lepaa as affected by increasing rates of Primo MAXX®, 2007. Means of nine observations (two in spring, i.e. before 10 June, five in summer, i.e. from 10 June to 1 Sep., and two in autumn, i.e. after 1 Sep.). All values are means of four blocks.

Primo MAXX®, rate	Turf quality (general appearance, 1-9)				Tiller density (1-9)	Within season colour (1-9)
	Mean	Spring	Summer	Autumn		
0 = Control	6.4	6.1	6.6	6.3	6.3	6.4
0.2 l/ha	6.3	6.0	6.5	6.0	6.3	6.4
0.4 l/ha	6.3	5.9	6.5	6.1	6.2	6.3
0.6 l/ha	6.3	5.8	6.5	6.4	6.3	6.4
0.8 l/ha	6.2	5.8	6.4	6.3	6.2	6.4
P%	ns	ns	ns	ns	ns	ns
LSD 5%	-	-	-	-	-	-
CV%	3	5	5	7	2	3

Table 15. Absolute and relative effects of increasing rates of Primo MAXX® on turfgrass height and dry matter production in turfgrass clippings in green trial at Lepaa 2007. Observations conducted 2 weeks (5 observations) and 4 weeks (4 observations) from spraying treatment have been presented separately. Plant heights above 3 mm represent one day's growth.

Treatment	Plant height (mm)				Weight of clippings (g DM / m^2 / day)			
Time after treatment	2 weeks	4 weeks	Mean	Rel	2 weeks	4 weeks	Mean	Rel
0 = Control	4.3	3.9	4.1	100	2.60	2.21	2.43	100
0.2 l/ha	4.1	3.8	4.0	96	2.20	2.28	2.23	92
0.4 l/ha	4.0	3.9	3.9	95	1.88	2.28	2.06	85
0.6 l/ha	4.0	3.8	3.9	94	1.72	2.18	1.99	82
0.8 l/ha	3.8	3.9	3.9	93	1.75	2.28	1.92	79
P%	11	ns	ns	-	5	ns	ns	-
LSD 5%	-	-	-	-	0.9	-	-	-
CV%	6	7	8	-	20	14	16	-

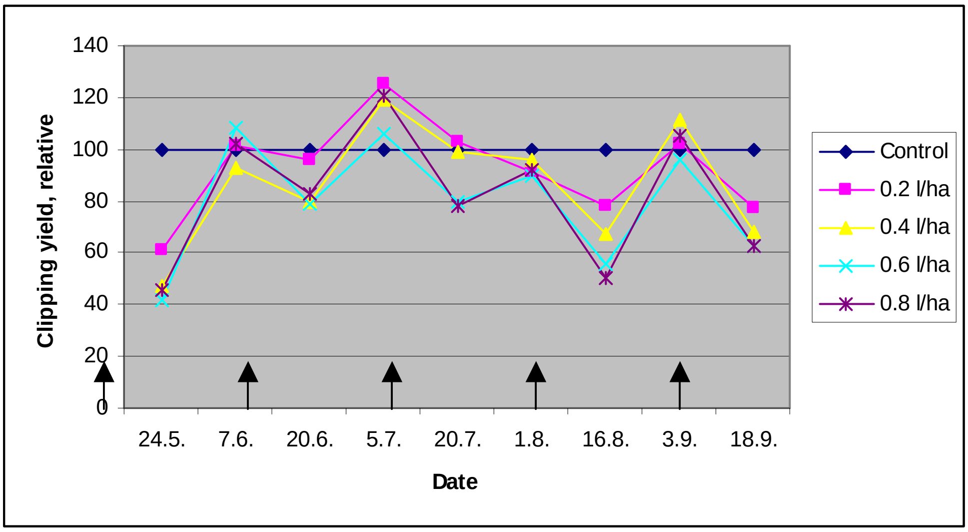


Fig. 4. Relative clipping weights (control = 100) in green trial at Lepaa, Finland. Spraying treatments indicated by black arrows were carried out on 11 May, 8 June, 5 July, 3 Aug. and 4 Sep. (The last spraying on 4 Oct. was done primarily to study the effect of Primo MAXX® on overwintering and was not followed by observations in late autumn.)

4.4. Demonstration trials with Primo MAXX® at Ballerud Golf Course, Oslo, Norway

Green trials

Applications of 0.4 l/ha Primo MAXX® on 5 and 18 June did not affect turf general appearance (Photo 7) or stimpmeter readings on green no. 9 at Ballerud. During the period 14-29 June, clippings were reduced by an average of 32%, but after spraying had been discontinued, there was a rebound effect corresponding to a 26 % increase in clipping yield in the period 12-25 July (data not shown).

Photo 7. Terje Haugen (left) and Lasse Augustsson on green no. 9 at Ballerud Golf Course, 27 June 2007. Photo: Trygve S. Aamlid.

Photo 8. Field day at Ballerud Golf Course 27 Aug. 2007. Photo: Tatsiana Espevig.

Fig. 5 summarizes results from the nursery green trial established on 9 July. In this trial, application of Primo MAXX® about every third week resulted in better colour (not shown), higher green speed (Fig. 5a), and an average reduction in turfgrass clippings of 44 % (Fig. 5b and c). Fig 5b shows that the reduction in clipping yield was most conspicuous during the periods of rapid growth in mid to late July (after only one application of Primo MAXX®) and in late August.

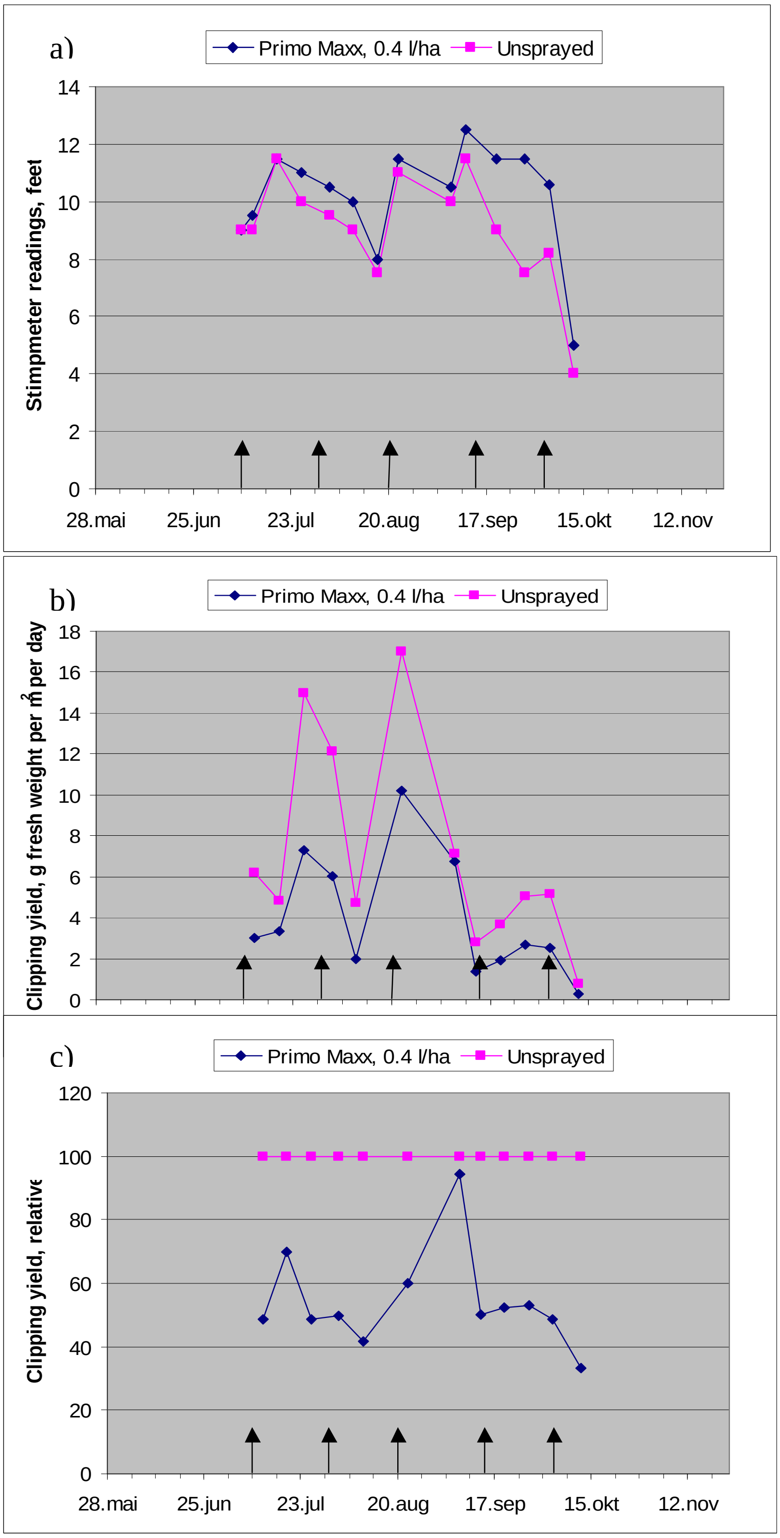


Fig. 5. Effects of spraying Primo MAXX® every three weeks of green speed and absolute and relative clipping yield on nursery green at Ballerud GC, 2007. Black arrows indicate the application dates 9 July, 31 July, 21 Aug., 13 Sep. and 4 Oct.

Fairway trial

As evaluated by the headgreenkeeper, monthly applications of 1.5 l/ha Primo MAXX® (1.5 l/ha) had no negative impact on turf quality in the fairway trial at Ballerud (Fig. 6). Photos 9-11 show, nevertheless, that treated turf was more faded, grayish, and less green than untreated turf. The pronounced colour difference in favour of Primo MAXX® in early September (Fig. 6) was due to less dry spots than the in the control area. While these spots recovered after rainfall on 10 and 17 Sep., the last application of Primo MAXX® on 4 Oct. led to an apparent loss of colour and drop in turf general appearance in late autumn (Photo 11).

On average for 17 clipping, regular application of Primo MAXX® resulted in a 37 % reduction in the fresh weight of turfgrass clippings (Fig. 7). The only time clipping yield was higher on the treated than on the untreated area was at the first clipping nine days after the first application and on 7 Sep. The latter coincided with the observation of less dry spots after use of Primo MAXX®. It may also be interpreted as a rebound effect following growth suppression after application on 31 July.

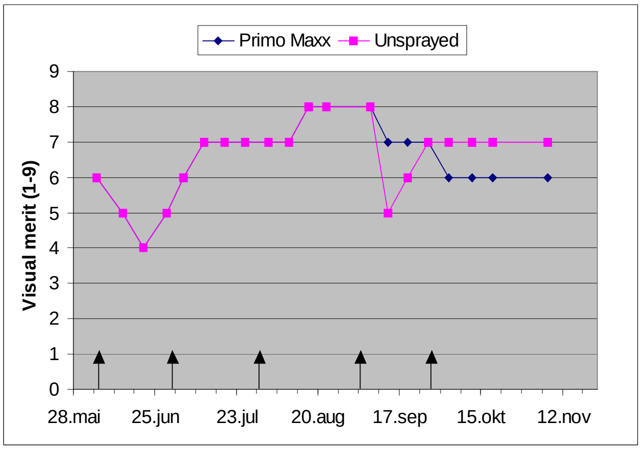
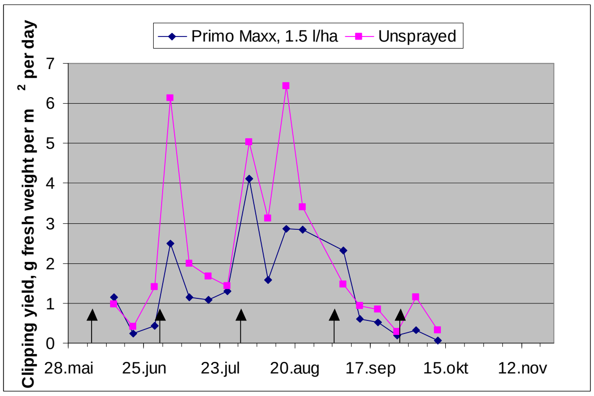


Fig. 6. Effect of Primo MAXX® on turfgrass general appearance in fairway trial at Ballerud GC. Black arrows indicate application dates. (Sprayed an unsprayed plots had identical scores until the beginning of September)

Photo 9. Difference in colour and general appearance of treated and untreated fairway Ballerud GC, 27 June. Photo: Trygve S. Aamlid.

Photo 10. Difference in colour and general appearance of treated and untreated fairway Ballerud GC, 27 Aug. Photo: Tatsiana Espevig.

Photo 11. Difference in colour and general appearance of treated and untreated fairway Ballerud GC, 3 Dec. Photo: Terje Haugen.



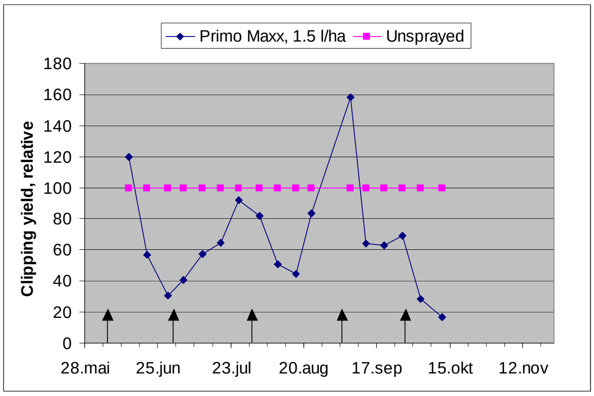


Fig. 7. Absolute (a) and relative (b) reductions in clipping yield resulting form application of Primo MAXX® in fairway trial at Ballerud GC. Arrows indicate application dates.

Spraying 2.2 l/ha of Primo MAXX® at six weeks interval resulted in discoloration and consistent drop in turf quality in the rough trial at Ballerud (Fig. 8, Photos 12 and 13). The effect was most conspicuous in late autumn. Primo MAXX® had less effect on tufts of perennial ryegrass which stood out very markedly in the turf which was otherwise dominated by smooth meadowgrass. Clipping yields were not recorded in this trial.

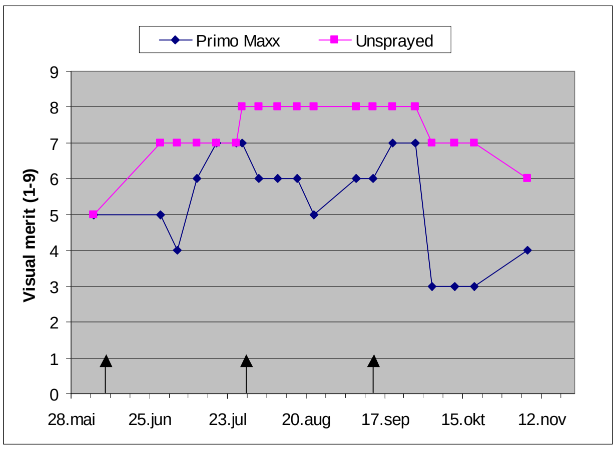


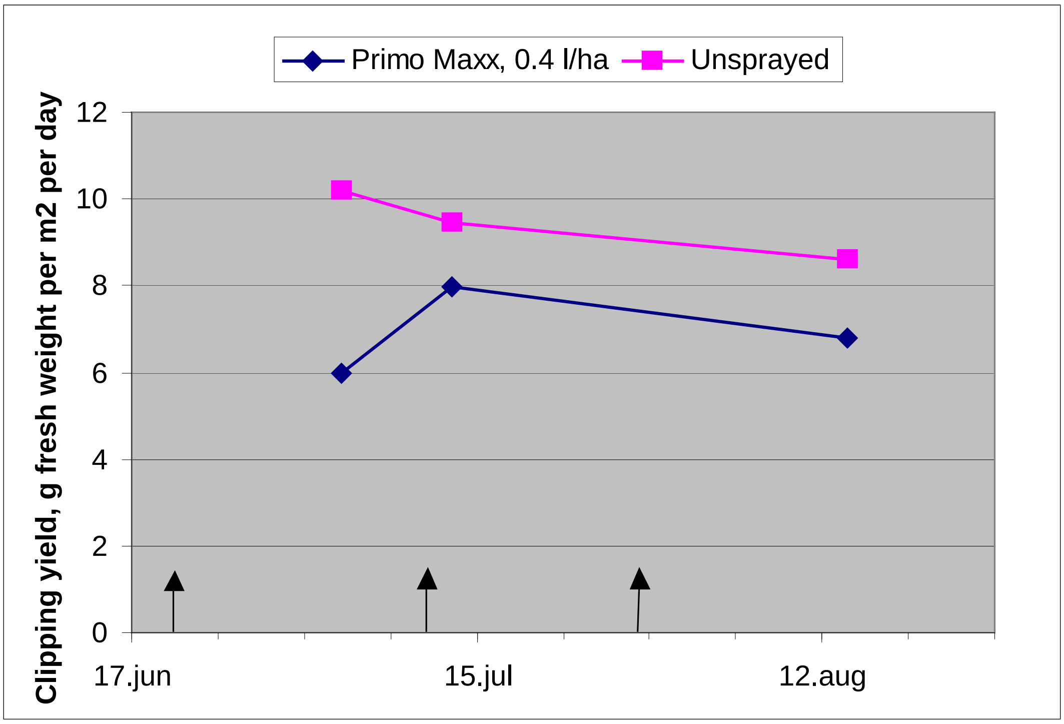
Fig. 8 (upper left). Difference in colour and general appearance of treated and untreated area in rough no 9, Ballerud, 27 June. Photo: Trygve S. Aamlid.

Photo 12 (upper right). Terje Haugen (left) and Lasse Augustsson in rough trial at Ballerud GC, 27 June. Photo: Trygve S. Aamlid.

Photo 13 (lower left). Trygve S. Aamlid inspecting rough trial at Ballerud GC, 27 August 2007. Tufts of ryegrass stand out very markedly on sprayed area.
Photo: Tatsiana Espevig.

4.5. Demonstration trial with Primo MAXX® at Oslo Golf Club, Bogstad, Norway

Application of 0.4 l Primo MAXX® at three week intervals resulted in darker turf but had otherwise no effect on the turfgrass quality of annual meadowgrass at Oslo GC. On average for three registrations, the Primo MAXX led to a 26% reduction in clipping yields (Fig. 9).



5. Discussion and suggestions for 2008

The starting point for evaluating Primo MAXX® in this two-year project was the rates and applications frequencies recommended for the product in Europe (Syngenta 2007, Table 16). Based on our experiences from agricultural crops that the optimal rates may be different in the Nordic countries than countries further south, higher and lower rates were included in the GEP trials both to determine the potential growth inhibition and the risk for discoloration or other phytotoxic effects. All taken together, the results from the first project year confirms that the guidelines in Table 16 are not directly applicable in Scandinavia and that further research is needed to find the optimal way of using the product under Nordic conditions.

Table 16. Dose rates and applications frequencies recommended for Primo MAXX® in the United Kingdom (Syngenta 2007).

	Dose rate		Application
	Primo MAXX®, l/ha	trinexapac-ethyl, g a.i./ha	frequency
Fairways	0.8 – 1.6	90 - 180	Every four to five weeks
Roughs & semi-roughs	1.6-2.4	180 - 240	Every five to eight weeks
Greens	0.4	45	Every two to four weeks

On fairway, the average reduction in clipping yield caused by monthly application of the intermediate Primo MAXX® rate of 1.5 l/ha was 15 and 21 % in the GEP trials at Landvik and Lepaa, respectively. By contrast, monthly application of 1.5 l/ha resulted in a 37 % reduction in clipping yield in the demonstration trial at Ballerud GC, which is closer to the data presented by Syngenta (2007). In agreement with Table 11 showing an increase in turfgrass dry matter percentage (i.e. decreased succulence) after application of Primo MAXX®, one of the reasons for this difference might be that clipping yields were determined on a dry weight basis in the GEP trials but on a fresh weight basis at Ballerud GC and in the data presented by Syngenta (2007). Another, and probably more important explanation, is the difference in species composition among the three trials. While the plant cover at Ballerud was almost 100% by annual meadowgrass, the species composition at Landvik varied with the two blocks showing the least response to Primo MAXX® having a plant cover of 74 % red fescue (Tables 1 and 11). By contrast, smooth meadowgrass dominated over red fescue at Lepaa due to the heavy soil type, use of irrigation, and relatively high nitrogen input. Unfortunately, we have not been able to find many references about the specific effects of Primo MAXX® on red fescue turf, but our results are in partial agreement with Pannacol et al. (2004) who found 40 %, 21 %, and no significant reduction in clipping yield after using trinexapac-ethyl in smooth meadowgrass, chewing fescue and creeping red fescue, respectively.

Perhaps the most conspicuous feature of the present results was the unstable effect of Primo MAXX® on clipping yields due to the postsuppression rebound effect. In the fairway trial at Lepaa, Finland, this resulted in clipping yield reductions being significant only two weeks after application (Table 13), and a similar tendency could be seen also in the green trial (Table 15). In Norway, clipping yields four weeks after spraying were often higher than on unsprayed control plots in the fairway trial at Landvik (Fig. 2), and a strong rebound effect was observed also after spraying treatments had to discontinued at green no. 9, Ballerud GC. The unstable effect in of Primo MAXX® in these trials was probably due to a rapid degradation of trinexapac-ethyl in plant tissue and a higher regrowth potential due to accumulation of carbohydrate reserves and GA_1 precursors during the suppression phase (Lickfeldt et

al. 2001, Branham & Beasley 2007). In North-American experiments, Lickfeldt et al. (2001) reported clipping yields reductions in smooth meadowgrass to be much more consistent when trinexapac-ethyl was applied at four than at six week intervals, but under Nordic long-day conditions, spraying every second, or at least every third week, may well be necessary to stabilize low GA_1 levels, not only on greens, but also on fairways and tees. Although there was a surge effect during the driest period in mid September, the most stable clipping reductions in our trials, on average 44 % on a fresh weight basis, were, indeed, obtained on the nursery green which was sprayed about every third week at Ballerud GC (Fig. 5c). While Branham & Beasley (2007) noted that temperature was the most important factor determining degradation of trinexapac-ethyl in turfgrass tissue, our results suggest that other factors such as light and water availability may also be important for the rebound effect under Nordic conditions. Very clearly, application frequency is a major question that has to be addressed during the continuation of this project.

The potential reductions in mowing costs from using a plant growth regulator will always have to be weighed against the risks for discoloration or other harmful effects on turf quality. In the present trials, reductions in general appearance (visual merit) scores were far more conspicuous in the GEP trial at Landvik than in the GEP trials at Lepaa or the demonstration trials at Ballerud GC. Apart from possible effects of different botanical compositions, this might reflect a subjective human factor, i.e. different backgrounds and attitudes of the observers in the various trials. While the fairway trial at Landvik was evaluated by turfgrass scientists and technicians with long experience from turfgrass variety testing, the trials at Lepaa and Ballerud were evaluated by greenkeepers working on the course. While the observers at Landvik may have paid more attention to turf aesthetic values such as less intense colour, and less vigorous and uniform plots, the observers at Lepaa and Ballerud may well have been more attentive to ball roll and other functional characteristics of the playing surface. The less succulent but significantly darker green turf resulting from high Primo MAXX® rates at Landvik are in agreement with other studies showing higher mesophyll cell densities and chlorophyll concentrations resulting from less elongation of leaf cells (Heckman et al. 2001, Ervin & Zhang 2008). As for tiller density, most literature supports the Finnish rather than the Norwegian results; i.e. enhanced tillering after Primo MAXX® application (Branham & Beasley 2007, Ervin & Zhang 2008).

As compared with the unsprayed control treatment, the strongest negative effect of Primo MAXX® on turfgrass general appearance at Landvik was recorded after the first spraying in early June, in mid July and at the last observation in early November. Each of these observations might be explained by suboptimal conditions causing reduced turfgrass growth. From 6 to 15 June there was a dry and warm and period with maximum temperatures in the range 25-30 ºC that obviously reduced turfgras tillering and aesthetic appearance; until mid July exceptional rainfalls starting on 22 June were not compensated by increase nitrogen inputs, and in autumn, the last application of Primo on 26 September was followed by several nights of frost. Although most studies have failed to document significant interactions between nitrogen and trinexapac-ethyl on turfgrass quality (Steinke & Stier 2001, Goss et al. 2002, McCullogh et al. 2006), it seems reasonable to assume that potential negative effects on Primo MAXX® on turfgrass quality will be most pronounced under suboptimal growing conditions. As in the trials at Landvik (Photo 6) and Ballerud (Photo 11), Beam et al. (2002) reported significant discoloration of trinexapac-ethyl-treated smooth meadowgrass following frost in autumn.

Undoubtedly, the most convincing argument for official approval of Primo MAXX® on Nordic golf courses would be a clear documentation that it improves winter survival. Preliminary results with annual meadowgrass suggested that low rates of trinexapac-ethyl prevented winter injury, whereas high rates had opposite effects due to discoloration during the hardening phase in late autumn (Rossi & Buelow 1997). While trinexapac-ethyl has been shown to increase water soluble carbohydrate contents (Goss et al. 2002) and result in faster spring greenup, Ervin & Zhang (2008) recently called for more detailed investigations into the effect of trinexapac-etyl on freezing tolerance as the research to date has provided scarce information on this aspect. Under Nordic conditions, desiccation if growth resumes when soils are still frozen and irrigation not yet operational in spring, or damage due to unstable winters with ice and water covering the turf, sometimes resulting in suffocation, appear to be more

important that direct freezing injury. In this regard, trineexapac-ethyl may well have a positive effect as it reduces mitochondrial respiration (Ervin & Zhang 2008). In 2008, it will therefore be very interesting to study winter injury and spring green-up and recovery in the on-going trials at Landvik, Lepaa and Ballerud which all had their last application of Primo MAXX® in late September or early October.

Even with winter survival and spring observations included, the amount of data presented in this report is too limited to recommend any listing of Primo MAXX® for turf use in the Nordic countries. Therefore, as stated in the contract between Syngenta and Scandinavian Turfgrass and Environment Research Foundation, there is a need for new GEP trials to be started in spring 2008 and followed until registration of winter survival in spring 2009. For this purpose, a new experimental green was constructed and seeded to creeping bentgrass at Landvik in 2007. In the trial to be established on this green in spring 2008, we suggest to compare Primo MAXX® at three rates (0.15, 0.30 and 0.45 l/ha) and two application frequencies (every 10/11 days and every 21 days), i.e. six combinations plus an unsprayed control treatment. As different grass species seem to vary in their response to Primo MAXX®, similar trials should preferably be carried out on also red fescue/browntop greens and velvet bentgrass greens, although this would require additional funding from Syngenta/STERF.

In Finland, a new GEP trial will be established in spring 2008 on a fairway that is regularly subjected to winter injury. New demonstration trials might be added to the project depending on interest from superintendents and funding from the national golf unions.

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

Results from the first evaluation year 2007

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Finnish team spraying fairway trial at Lepaa Golf Course.
Photo: Oiva Niemelainen

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Summary:

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

Sammendrag:

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

Approved

Arne Sæbø	Trygve S. Aamlid
Leader, Bioforsk's Section for Urban Greening	Project leader

Contents

1. Abstract

As an inhibitor of the last step in plant synthesis of bioactive gibberellin (GA_1), the plant growth regulator Primo MAXX® (trinexapac-ethyl) offers prospects of reduced energy use for mowing and improved turfgrass quality under Nordic long day conditions. This report presents first year results from 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 possible registration of Primo MAXX®, unreplicated demonstration trials were carried out at Ballerud and Bogstad Golf Courses in Oslo under supervision of Bioforsk and with funding from the Norwegian Golf Federation (NGF).

GEP trials on **fairways** (mowing height 12-18 mm) were carried out at Bioforsk Landvik, Norway (58°34'N, 8°52'E) and at the Lepaa Unit of the HAMK University of Applied Sciences, Finland (61°08'N, 24°20'E). Primo MAXX® was applied at monthly intervals at rates 0.5, 1.0, 1.5, 2.0 and 3.0 l/ha (56.5, 113, 169.5, 226 and 339 g a.i./ha trinexapac-ethyl) in comparison with an unsprayed control treatment. Turfgrass general appearance, tiller density, colour, height growth, and clipping yields were recorded two and four weeks after each application. Primo MAXX® had no effect on turfgrass general appearance but increased density at Lepaa. At Landvik, Primo MAXX® (>= 1.0 l/ha) reduced turfgrass general appearance and density, but resulted in significantly darker green colour. Quality reductions were most apparent during periods with either daily maximum temperatures >25 ºC, extreme rainfall probably causing nitrogen deficiency, or frost at night. Average reductions in clipping yield caused by Primo MAXX® (>= 1.0 l/ha) were 8 % in the GEP trial at Landvik, 18 % in the GEP trial at Lepaa and 37 % in the demonstration trial at Ballerud; to some extent this difference may be due to different botanical composition with red fescue (*Festuca rubra*) and annual meadowgrass (*Poa annua*) being the predominant species at Landvik and Ballerud, respectively. Clipping yield reductions due to Primo MAXX® were unstable, growth suppression two weeks after application often being followed by a rebound effect during the remaining two weeks until next application.

A GEP trial on creeping bentgrass **putting greens** was carried out at Lepaa, Finland, and demonstration trials at Ballerud and Bogstad, Norway. Primo MAXX® was sprayed at rates 0.2, 0.4, 0.6 or 0.8 l/ha at monthly intervals in the GEP trial, and at 0.4 l/ha every three weeks in the demonstration trials. On average for all observations, Primo MAXX® had no effect on turfgrass quality, but clipping yields were reduced by 16, 44 and 26% at Lepaa, Ballerud and Bogstad, respectively. As in the fairway trials, growth suppression at Lepaa was stronger when assessed at two than at four weeks after application. By contrast, Primo MAXX® produced a fairly stable effect when applied at three week intervals in the demonstration trials.

Use of Primo MAXX® on golf course **roughs** was investigated only in a demonstration trial at Ballerud. Application of 2.2 l/ha of Primo MAXX® every seven weeks resulted in discolouration and reduced quality of smooth meadow grass.

In conclusion, the first year of this project has shown that the guidelines for use of Primo MAXX® in other European countries are not directly applicable in Scandinavia. As the present results are too limited to apply for registration of Primo MAXX®, the project will continue in 2008 tentatively with new trials investigating application of Primo MAXX® at lower rates, but higher frequencies. Improved winter stress tolerance would be a convincing argument for registration of Primo MAXX® in the Nordic countries, and the on-going trials will therefore be followed by an assessment of effects of the last Primo MAXX® applications in September or October 2007 on winter survival and spring recovery.

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

2. Introduction

The plant growth regulator trinexapac-ethyl was developed by Syngenta in the 1980s. Since the active ingredient is available in different formulations, the chemical will, in this report, be referred to as Primo MAXX®, which is the product developed by Syngenta specifically for use on turf. Unlike earlier plant growth regulators, Primo MAXX®'s mode of action is highly specific as it blocks the conversion of GA_{20} til GA_1, i.e. the last step in the biosynthesis of gibberellic acid, a plant hormone stimulating cell elongation and thus vertical turf growth.

After its release, Primo MAXX® was rapidly adopted by the US and Canadian turf industries. In North America, there are several independent university studies documenting its positive effects on golf courses, athletic fields, home lawns, and sod production (for a recent review, see Erwin and Zhang 2008). These advantages include reduced leaf elongation and thus reduced mowing costs and energy use, improved tiller production (more lateral growth), darker green colour, and improved resistance to drought and shade.

While other formulations of trinexapac-ethyl have been approved for agricultural use in Europe for about a decade, the experience with Primo MAXX® to European turfgrass areas is relatively limited. During the past three to four years, Primo MAXX® has been approved for turf use in Italy, France and UK, and the evaluation and registration process has been initiated in many other countries.

Being an inhibitor of gibberellin biosynthesis, Primo MAXX® offers special prospects for turfgrass management in the Nordic counties Finland, Sweden, Norway, Iceland, and Denmark. At latitudes ranging form 55 to 71 °N, turfgrasses growing in these countries exposed not only to long photoperiods during most of the growing season, but also to lower photosynthetic flux densities and lower red to farred (R/FR) ratios than in countries further south. The natural turfgrass response to these northern light conditions is to devote more of its resources to shoot elongation (Heide et al. 1985a,b). Since this response is primarily mediated by the gibberellic acid GA_1, any specific growth regulator that controls the biosynthesis of this compound might be useful under Nordic conditions. Nevertheless, our experience from the introduction of trinexapac-ethyl for agricultural use in the Nordic counties suggests that the optimal dose rates and frequencies for application of Primo MAXX® to various types of turf are probably not the same as at lower latitudes. This is also due to different species and cultivars being grown compared with countries further south. Field trials under Nordic conditions are therefore required not only to produce data for the national certification agencies, but also to provide turf managers with recommendations for how to use the product.

This report presents first year preliminary results from a two year project evaluating the use of Primo MAXX® on golf courses in the Nordic countries. The project was funded by Syngenta and the Scandinavian Turfgrass and Environment Research Foundation (STERF) 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' trials needed to provide documentation for possible registrations of Primo MAXX® by the national authorities, a couple of practical demonstration trials were carried out on Norwegian golf courses under supervision from Bioforsk and with funding from the Norwegian Golf Federation (NGF).

Bioforsk

3. Methods

3.1. Evaluation of Primo MAXX® under fairway conditions, Bioforsk Landvik, Norway

Experimental site

On 8 May 2007, a field trial was laid out on a fairway established on a sandy loam soil (topsoil: 68 % sand, 27% silt, 5 % clay) at Bioforsk Landvik Research Station (58°34'N, 8°52'E), SE Norway. Soil samples indicated a pH (H_2O) of 5.9, high phosphorus values (P-AL=19) and intermediate to low potassium values (K-AL = 8, K-HNO_3=58). The fairway had been seeded in September 2003 to a mixture of smooth meadowgrass (*Poa pratensis*), chewing fescue (*Festuca rubra* ssp. *commutata*), and browntop bent (*Agrostis capillaris*) (Table 1). Block 1 and 2 were located in one part, and block 3 and 4 in a different part of the fairway. Botanical analyses at the start of experimentation indicated that red fescue was the predominant species in all blocks, but presumably due to slightly less surface drainage, blocks 1 and 2 had a higher percentage of smooth and annual meadowgrass and broadleaved weeds (primarily white clover (*Trifolium repens*)) than blocks 3 and 4 (Table 1).

Table 1. Seed mixture used for fairway establishment in 2003 and botanical composition at the start of the Primo MAXX® trial in spring 2007.

Species	Cultivar	% (w/w) of seed mixture	% cover at initiation of Primo MAXX® trial		
			Block 1 and 2	Block 3 and 4	Mean
Poa pratensis	Conni	25	31	9	20
Poa pratensis	Eva	10			
Poa pratensis	Limousine	10			
Festuca rubra ssp. commutata	Bargreen	25	50	74	62
Festuca rubra ssp. commutata	Calliope	25			
Agrostis capillaris	Tracenta	5	5	15	10
Poa annua			8	2	5
Broadleaved weeds			6	0	3
Sum		100	100	100	100

Experimental plan

The experiment was laid out according to a randomized complete block design with plot size 2m x 3m, four blocks (replicates) and the following treatments:

1. Usprayed control
2. Primo MAXX, 0.5 l/ha (56.5 g a.i./ha) every four weeks
3. Primo MAXX, 1.0 l/ha (113 g a.i./ha) every four weeks
4. Primo MAXX, 1.5 l/ha (169.5 g a.i./ha) every four weeks
5. Primo MAXX, 2.0 l/ha (226 g a.i./ha) every four weeks
6. Primo MAXX, 3.0 l/ha (339 g a.i./ha) every four weeks

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. Actual application rates were recorded by weighing the tank before and after spraying. Table 2 shows actual rates and weather conditions for each spraying event.

Table 2. Weather conditions and actual application rates at the six spraying events.

Application date	Time of day (hours)	Weather conditions at application			Treatment number / application rate (l Primo MAXX® per ha)				
		Air temp. °C	Relative Humidity %	Wind Speed m/s	2. (target 0.5)	3. (target 1.0)	4. (target 1.5)	5. (target 2.0)	6. (target 3.0)
9 May	09-11	14	48	< 1.0	0.47	0.94	1.56	1.90	3.35
5 Jun.	09-11	15	60	< 1.0	0.58	1.06	1.67	1.93	3.19
4 Jul.	13-15	17	70	1.0-2.0	0.61	0.98	1.73	2.19	3.38
31 Jul.	08-10	18	55	1.0-2.0	0.55	1.05	1.66	2.28	3.41
28 Aug.	09-11	19	32	1.0-2.0	0.57	1.03	1.55	2.19	3.52
26 Sep.	09-11	11	69	< 1.0	0.52	1.07	1.55	2.01	3.15
Mean					0.55	1.02	1.62	2.08	3.33

Registrations

At two weeks intervals throughout the experimental period, turfgrass colour, tiller density, and turf general appearance were assessed by turfgrass scientist or technicians using a scale from 1 to 9 where 9 is darkest colour, highest tiller density and best turf quality. The assessments were conducted two and four weeks after application of Primo MAXX®. On the same dates, turfgrass diseases and broadleaf weed (including white clover) invasion were reported as per cent of plot area. Turfgrass height was recorded as the mean of three random measurements with a ordinary ruler in each plot, and the overall growth rate by weighing clippings in the basket of a walk-behind mower used in the 0.56 m x 1.88 m central area of each plot (Photo 1). Both raw weight and dry weight were recorded, the latter after drying for 24 h at 60ºC. By the end of the growing season, on 2 Nov., turfgrass dormancy colour was evaluated on a scale 1-9, where 1 is completely faded / brown turf, and 9 is completely green turf.

Photo 1a and b. Tatsiana Espevig collecting clippings in fairway trial at Landvik. Photos: Trygve S. Aamlid

Management

The experiment was mowed at 15 mm two times a week, usually on Monday and Friday. A triplex fairway mower without collection of clippings was used except when clipping weights were to be recorded. Granular fertilizer was applied at approximately monthly intervals as outlined in Table 3. The experiment was not irrigated except for small amounts of water to dissolve fertilizer after application. On 7 Aug., the trial was aerated using a vertidrain with 15 mm solid tines to 15 cm depth. Topdressing was accomplished on 8 Aug. and 5 Nov. at rates 0.75 and 1.5 kg pure sand per m^2, respectively.

The fairway trial at Landvik was not exposed to ordinary play, but it was was subjected to artifical wear from a wear drum one to two times per week.

Table 3. Fertilizer inputs, fairway trial, Landvik.

		Per ha							
Date	Fertilizer type	kg fertilizer	kg N	kg P	kg K	kg Mg	kg S	kg Ca	kg Fe
17 Apr.	Fullgjødsel 22-2-12	40	9	1	5	0	1	0	0
16 May	Fullgjødsel 22-2-12	70	15	1	8	1	2	1	0
12 Jun.	Arena Golf Extra 13-0-15	150	20	0	23	2	21	0	3
23 Jul.	Arena Golf Extra 13-0-15	130	17	0	20	2	18	0	3
9 Aug.	Arena Golf Extra 13-0-15	135	18	0	21	2	18	0	3
5 Sep.	Arena Golf Extra 13-0-15	150	20	0	23	2	21	0	3
SUM			99	2	100	10	80	1	11

Weather data

In SE Norway, the growing season 2007 was characterized by exceptionally high rainfall, especially in July, but also in May, June and August (Table 4). By contrast, September was unusually dry. Precipitation was recorded on 16 out of the 31 days in July; the cloudy summer weather is also reflected by a rather low irradiance during this month. The warmest period, with daily maximum temperatures in the range 23-29 ºC was recorded from 6 to 12 June.

Table 4. Weather data for Landvik meteorological station, about 200 m for experimental field. Normal values for temperature and rainfall are 'official' values for from the period 1961-90, while normal values for irradiance are calculated averages for the period 1994-2006.

	Mean temperature, °C		Precipitation, mm		Irradiance, MJ/m^2 (305-2800 nm)	
	2007	30 yr normal	2007	30 yr normal	2007	13 yr average
May	10.2	10.4	107	82	518	540
June	15.9	14.7	109	71	604	600
July	15.5	16.2	213	92	492	632
Aug.	16.2	15.4	132	113	476	476
Sep.	12.0	11.8	59	136	321	262
Mean / sum	14.0	13.7	620	494	2411	2510

3.2. Evaluation of Primo MAXX® on a golf course fairway, Lepaa, Finland

Experimental site

The Finnish fairway trial was laid out on 11 May 2007. The fairway was seeded to a mixture of smooth meadowgrass and chewing fescue (*Festuca rubra* spp. *commutata*) on a heavy clay soil (15% sand, 37% silt, 48% clay) at the Lepaa Unit of HAMK University of Applied Sciences, Finland (61°08'N, 24°20'E). 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. All observations and management of the trial was carried out by the HAMK Lepaa greenkeepers Petteri Lehmuskoski and Tommi Turunen except for the spraying treatments which were carried out by MTT's 'Good Experimental Practice' certified spraying team from Jokioinen (90 km from Lepaa).

Experimental plan and registrations

The experiment was laid out following the same plan and plot size as at Landvik, Norway (previous paragraph). Primo MAXX® was applied in accordance with the Finnish 'Good Experimental Practise' protocol, using a portable, compressed air-powered 'van der Weij' plot sprayer, mounted with a windshield and flat fan nozzles (Hardi 4110-12) and working at 180-250 kPa pressure. The spraying boom had four nozzles spaced 50 cm apart. The spraying volume corresponded to 200 l/ha. Full spray coverage was on the central 1.5m x 2.5 m of each plot. Table 5 shows application dates and weather conditions for each spraying event. The last application on 4 Oct. was conducted especially to evaluate potential effects of Primo MAXX® on turfgrass winter damage.

Table 5. Application dates and weather conditions in fairway and green trials at Lepaa.

Application date	Time of day (hours)	Air temp. °C	Relative humidity %	Wind Speed m/s	% cloud cover
11 May	09-11	11	29	0	25
8 Jun.	09-11	20	56	1.5	1
5 Jul.	13-15	23	47	2.5	70
3 Aug.	09-11	17	78	2.0	90
4 Sep.	09-11	11	90	1.0	90
4 Oct.	13-15	11	92	1.5	100

Photo 2. Austen Sutton, Syngenta (left) and greenkeeper Petteri Lehmuskoski, HAMK Lepaa Unit, in fairway trial at Lepaa, Finland, 29 Aug. 2007.

Photo: Oiva Niemelainen.

Registrations

Registrations were carried out at two-week intervals following the same program as at Landvik (previous section) except that weed occurrence and dormancy colour were not recorded. Plant height at Lepaa was determined using a Turf Check Prism device (Check Signature Inc., Shoreview, MN).

Management and wear

The experiment was mowed with a triplex fairway mower about three times per week. Mowing height ranged from 12 to 18 mm. Granular fertilizer Sportsmaster 26-2-9 was applied at equal rates on 8 May and 12 July, the total input corresponding to 156 kg N, 12 kg P, 54 kg K and 0.9 kg Fe per ha. Information about irrigation is given in Table 6. The trial was aerated or top-dressed in late autumn, after the completion of registrations.

During the growing season period, the trial was exposed to approximately 3.500 rounds of golf.

Weather data

Temperatures at Lepaa were higher the 30 yr normal values throughout the growing season (Table 6). August had the greatest deviation from the long-term average value. July had 49 % more, and August 42 % less rainfall than usual; over the whole experimental season, rainfall was close to the 30 yr normal value.

Table 6. Weather data for Hattula Lepaa weather station and irrigation in fairway and green trial at Lepaa golf course, 2007. Normal values for temperature and rainfall are official values for from the period 1971-2000 (Finnish Meteorological Institute)

	Mean temperature, °C		Rainfall, mm		Irrigation, mm (2007)	
	2007	30 yr normal	2007	30 yr normal	Fairway trial	Green trial
May	10.6	9.8	30	34	*	*
June	15.1	14.5	54	55	26	79
July	16.6	16.4	119	80	5	47
Aug.	16.4	14.6	43	74	7	50
Sep.	9.9	9.4	58	54	0	6
Mean / sum	13.7	12.4	304	297	37	188

* Data are unavailable for the period 1-26 May 2007 due to change of irrigation computer.

3.3. Evaluation of Primo MAXX® on a golf course putting green, Lepaa, Finland

Experimental site

The Finnish green trial was established on 11 May 2007 on a USGA green seeded to creeping bentgrass (*Agrostis stolonifera*, seed blend of 50% ‘Penn A-4’ and 50% ‘Penn G-6’) at Lepaa Golf Course.

Experimental plan

The experimental plan comprised five rates of Primo MAXX plus the unsprayed control treatment:

1. Usprayed control
2. Primo MAXX, 0.2 l/ha (22.6 g a.i./ha) every four weeks
3. Primo MAXX, 0.4 l/ha (45.2 g a.i./ha) every four weeks
4. Primo MAXX, 0.6 l/ha (67.8 g a.i./ha) every four weeks
5. Primo MAXX, 0.8 l/ha (90.4 g a.i./ha) every four weeks

The trial had four replicates, and a gross plot size of 2 m x 3 m. It was sprayed on the same dates and following the same GEP procedures as the fairway trial on the same location (Table 5).

Photo 3. Green trial at Lepaa ready for the first treatment on 11 May 2007. Photo: Oiva Niemelainen.

Registrations

Registrations followed the same program as in the Finnish fairway trial (previous section).

Management and wear

The experiment was mowed with a Triplex greens mower for an average of six times per week. Depending on weather and turfgrass density, mowing height was 5–7 mm in May and September and 3-4 mm from June to August. Information about irrigation and fertilizer inputs are given in Tables 6 and 7, respectively.

To avoid thatch accumulation, the trial was aerated with deep slitting knives every second week and with 8 mm needle tines once a month. Verticutting was accomplished every second week and topdressing with 0.1-0.7 mm finely graded sand at a rate of 1 kg per m2 every third week. The sand was brushed/irrigated into the green and the dressing was never done in close proximity to weighing of clippings.

Being located on a practise green, the experiment received wear from about 10.000 rounds of golf over the season. When placing holes on the green, care was taken to create as uniform wear as possible.

Table 7. Fertilizer inputs in green trial at Lepaa.

		Per ha							
Date	Fertilizer type	kg fertilizer	kg N	kg P	kg K	kg Mg	kg S	kg Ca	kg Fe
28.3.2007	Floratine Kevätstartti*	35	5.4	1.2	2.1				
5.4.2007	Floratine Kevätstartti	35	5.4	1.2	2.1				
19.4.2007	Floratine Kevätstartti	35	5.4	1.2	2.1				
26.4.2007	Sierraform Springstart (16-0-13)	250	40	0	32.5				2.50
15.5.2007	Sierraform All Season (18-3-15)	250	45	7.5	37.5	3.0			1.25
30.5.2007	Kemigreen Basic (23-4-14)	40	9	1.6	5.6	0.6	0.8		0.04
5.6.2007	Kemigreen Basic (23-4-14)	40	9	1.6	5.6	0.6	0.8		0.04
11.6.2007	Sierraform All Season (18-3-15)	250	45	7.5	38				
25.6.2007	Osmosol 614R (19-2-10)	40	7.6	0.8	4.0	0.5		1.7	0.04
2.7.2007	Osmosol 614R (19-2-10)	40	7.6	0.8	4.0	0.5		1.7	0.04
13.7.2007	Kemigreen Summer (18-0-17)	40	7.2	0	6.8			2.0	0.40
18.7.2007	Kemigreen Summer (18-0-17)	40	7.2	0	6.8			2.0	0.40
26.7.2007	Sierraform All Season (18-3-15)	250	45	7.5	37.5	3.0			1.25
14.8.2007	Kemigreen Summer (18-0-17)	40	7.2	0	6.8			2.0	0.40
27.8.2007	Greenmaster Autumn (6-2-8)	300	18	6	24	5.4			1.50
30.8.2007	Kemigreen Basic (23-4-14)	40	9	1.6	5.6	0.6	0.8		0.04
11.9.2007	Sierraform Springstart (16-0-13)	200	32	0	39				2.00
SUM			305	39	260	14.0	2.4	9.4	10

* Floratine Kevätstartti (Springstart) is composed of P-48 (10-21-6.6), Per 4 Max (15-0-0), Protesyn (3.5-0.6-1.8), and Plant Marvel (28-3-15).

3.4. Demonstration trials with Primo MAXX® at Ballerud Golf Course, Oslo, Norway

Experimental site and set-up

Ballerud GC is located on an old horticultural farm in a suburban area SW of Oslo. The course has greens with mostly dominated by creeping bentgrass, fairways almost exclusively dominated by annual meadowgrass, and smooth meadowgrass roughs with some tufts of perennial ryegrass (*Lolium perenne*).

Large-scale, unreplicated demonstration trials were laid out on green no. 9, fairway no. 9 and rough no. 9 on 5 June 2007. Plots sizes varied from 80 to 130 m^2. Unsprayed control plots were compared with plots sprayed with Primo MAXX® at rates 0.4, 1.5 and 2.2 l/ha and application intervals of approximately 3, 4 and 7 weeks on green, fairway and rough, respectively. In compliance with the Norwegian Food Authority's rule for complete closure of all sprayed areas for 48 h after each application, the trial on green no. 9 had to be discontinued after the second application on 18 June.

Three weeks later, it was replaced by a new trial laid out on the golf course' nursery green. Actual application dates in the green, fairway and rough trials are given in Table 8. The growth regulator was applied using a battery-operated electric Hardy Defender plot sprayer (Photo 4).

Table 8. Application dates for Primo MAXX in demonstration trials at Ballerud GC.

Green no. 9	Nursery green	Fairway no. 9	Rough no. 9
5 June		5 June	5 June
18 June			
	9 July	2 July	
	31 July	31 July	28 July
	21 Aug.		
	13. Sep.	3 Sep.	11 Sep.
	4 Oct.	28 Sep.	

Photo 4. Sprayer used in demonstrations trials at Ballerud Golf Course.

Photo: Terje Haugen.

Registrations

In all trials at Ballerud, turfgrass general appearance was evaluated by the headgreenkeeper at one to two week intervals throughout the growing season. In the green and fairway trials, turfgrass clipping yields were recorded on a fresh weight basis. Registrations in the green trials also included regular assessments of green speed using a standard stimpmeter.

Maintenance

The green trials at Ballerud were mowed daily at 3.4-3.8 mm and the fairway trial at 20 mm three to four times a week. The rough area was only mowed upon need.

Due to the rich soil from decades of vegetable production, the rough trial was not fertilized in 2007, and the fairway trial only received one application of 200 kg Fullgjødsel® 11-5-18 (22 kg N/ha) on 8 May. The green trials received monthly applications of granuar fertilizer (Gro Power 5-1-1, Anderson 14-0-9, Anderson 8-0-16, and/or Roots 12-2-12), and weekly applications of liquid fertilizers /

biostimulants, mostly Floratine products. Total rates of N, P, K, Mg, Ca, S and Fe over the season were 155, 14, 142, 27, 30, 73 and 14 kg/ha, respectively. The greens were aerated, mostly using Envirojet, six times during the season and top-dressed, also six times, giving a total of 6.3 kg sand per m^2.

Weather data and irrigation

Table 3 shows recordings from Ballerud GC's weather station. Although the rainfall in 2007 was higher than usual, there were periods, especially in May, June and August when the green trials needed irrigation. The fairway and rough trials were never irrigated.

Table 9. Weather recordings and irrigation at Ballerud GC, 2007. Monthly temperatures are means of daily maximum and minimum temperatures.

	Mean monthly temperature, °C	Monthly rainfall, mm	Monthly irrigation, mm (greens only)
May	11.2	94	42
June	17.1	185	52
July	16.9	173	10
Aug.	16.6	83	47
Sep.	11.1	71	21
Mean / sum	14.6	606	172

3.5. Demonstration trial with Primo MAXX® at Oslo Golf Club, Bogstad, Norway

To evaluate the effect of Primo MAXX® on a typical annual meadowgrass green, an unreplicated demonstation trial with plot size 250 m^2 was laid out at Oslo GK on 20 June 2007. Primo MAXX® was sprayed at a rate 0.4 l/ha on 20 June, 10 July and 31 July using the same sprayer as at Ballerud GC, about 10 km from Bogstad (Photo 4). Turfgrass quality (general appearance) and fresh weight clipping yields were determined on 4 July, 13 July and 14 August. Unfortunately, the trial had to be discontinued in mid August due to reconstruction of the green.

3.6. 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 on each plot and on plot values which had been averaged, either over the whole growing season, separately over the spring (before 10 June), summer (10 June – 1 Sep.) and autumn (after 1 Sep.) periods, or for observations conducted two versus four weeks after the last application of Primo MAXX®. The significance levels P%<0.1, P%<1, P%<5 and ns (not significant) have been indicated in the tables along with LSD values for effects significant at P%<5. In a few cases exact P-values have been given for tendencies in the 5-15% probability range. As an indications of the variability for each character, coeffcients of variation, (CV %), have also been given in the tables.

4. Results

4.1. Evaluation of Primo MAXX® under fairway conditions, Bioforsk Landvik, Norway

Turfgrass quality and related characteristics

Table 10 shows results from the visual observations of turfgrass quality and related characters in the fairway trial at Landvik. Both within the three seasons and as a mean value, turfgrass general appearance was significantly lower on plots receiving monthly applications of Primo MAXX® at 1.0 l/ha or higher rates than on unsprayed control plots and plots receiving 0.5 l/ha. Within these two groups, differences in generall appearance were not significant. Separate analyses for blocks 1 and 2 versus 3 and 4 indicated that these responses were practically identical regardless of botanical composition (data not shown).

Individual registrations of turfgrass quality are further depicted in Fig. 1. There was a dramatic decline in quality after the first application on 9 May. After this the turf recovered and there was no significant effect of Primo MAXX® at the two subsequent evaluations. Applications of 1.0 l/ha or higher rates on 4 July lead to new quality reductions in July, August and September (Photo 5); these effects were especially apparent at the last evaluation in early November (Photo 6). By contrast, there tended to be a small quality improvement due to the lowest rate of Primo MAXX® from late August to October. This improvement was reflected also in a significant increase in tiller density on average for the whole growing season (Table 10).

Increasing rates of Primo MAXX® consistently led to darker turf throughout the growing season, but also to earlier growth cessation and a less attractive dormancy colour in late autumn (Table 10). The only visible disease in the trial was a slight attack of red thread (*Laetisaria fuciformis*) during the wet period in July; however, these spots were unaffected by Primo MAXX® which also had no effect on the occurrence of broadleaved weeds, primarily white clover, in the trial.

Table 10. Turfgrass quality, tiller density, within-season colour, dormancy colour and infestation of weeds and red thread (*Laetisaria fuciformis*) in fairway at Landvik as affected by increasing rates of Primo MAXX®, 2007. Visual merit and tiller density are means of twelve observations (two in spring, i.e. before 10 June, six in summer, i.e. from 10 June to 1 Sep., and four in autumn, i.e. after 1 Sep. Within season colour (green darkness) and occurrence weeds and red thread are means of twelve, three (all in July) and two (June and Nov.) observations, respectively. Dormancy colour was evaluated on 2 Nov. All values are means of four blocks.

Primo MAXX®, rate	Turf quality (general appearance, 1-9)				Tiller density (1-9)	Within season colour (1-9)	Dor-mancy colour (1-9)	% of plot area	
	Mean	Spring	Summer	Autumn				Dicot weeds	Red thread
0 = Control	6.2	6.1	6.4	6.0	6.3	5.2	6.8	4	4
0.5 l/ha	6.1	5.6	6.3	6.2	6.5	5.6	6.3	2	3
1.0 l/ha	5.5	4.5	5.9	5.3	6.1	5.8	5.0	5	2
1.5 l/ha	5.3	4.6	5.5	5.4	6.0	5.9	4.1	4	3
2.0 l/ha	5.5	4.6	5.9	5.3	6.1	6.0	4.3	3	2
3.0 l/ha	5.1	4.2	5.5	4.9	6.0	6.2	3.5	4	3
P%	<0.1	<0.1	<1	<0.1	<1	<1	<0.1	ns	ns
LSD 5%	0.3	0.5	0.4	0.4	0.2	0.4	1.2	-	-
CV%	4	7	5	5	3	5	15	-	-

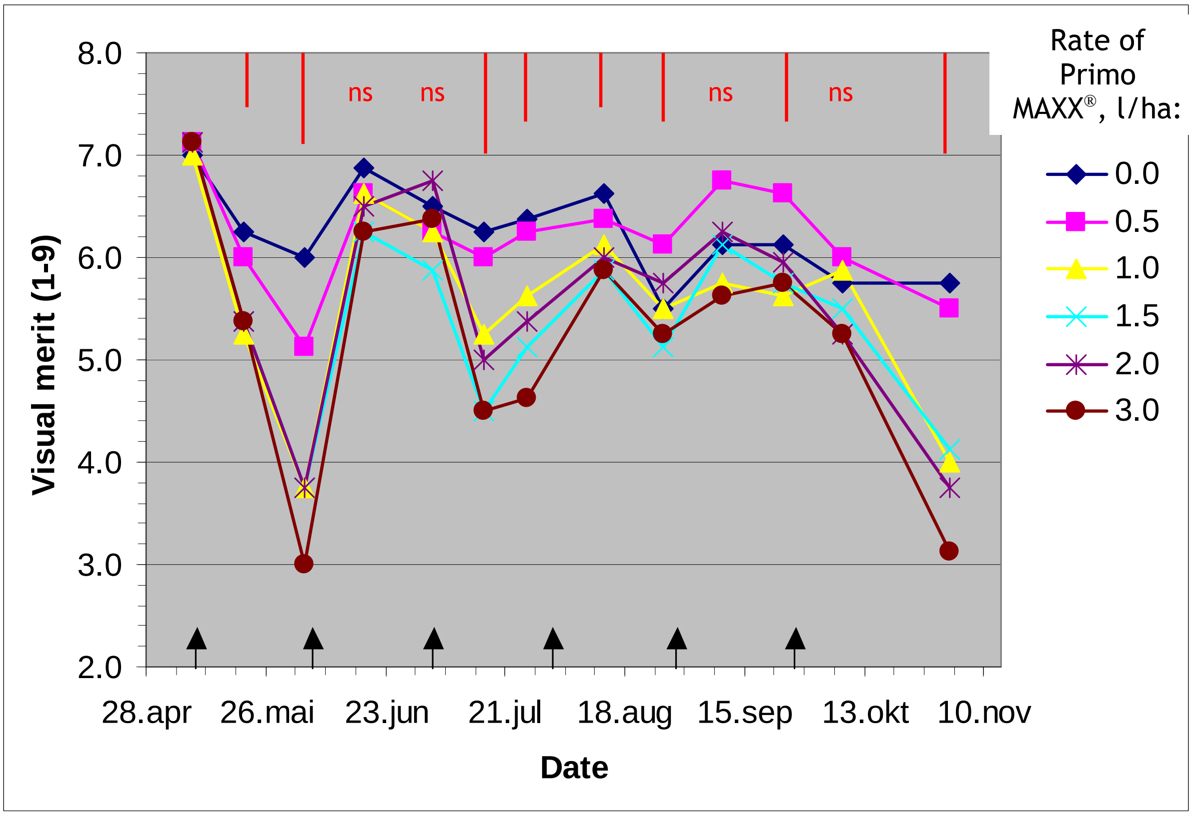


Fig.1. Turfgrass overall quality as affected by increasing rates of Primo MAXX® in fairway trial at Landvik, 2007. Mean of four replicates (blocks). The application dates 9 May, 5 June, 4 July, 31 July, 28 Aug. and 26. Sep. are indicated by black arrows. Red bars indicate LSD 5%.

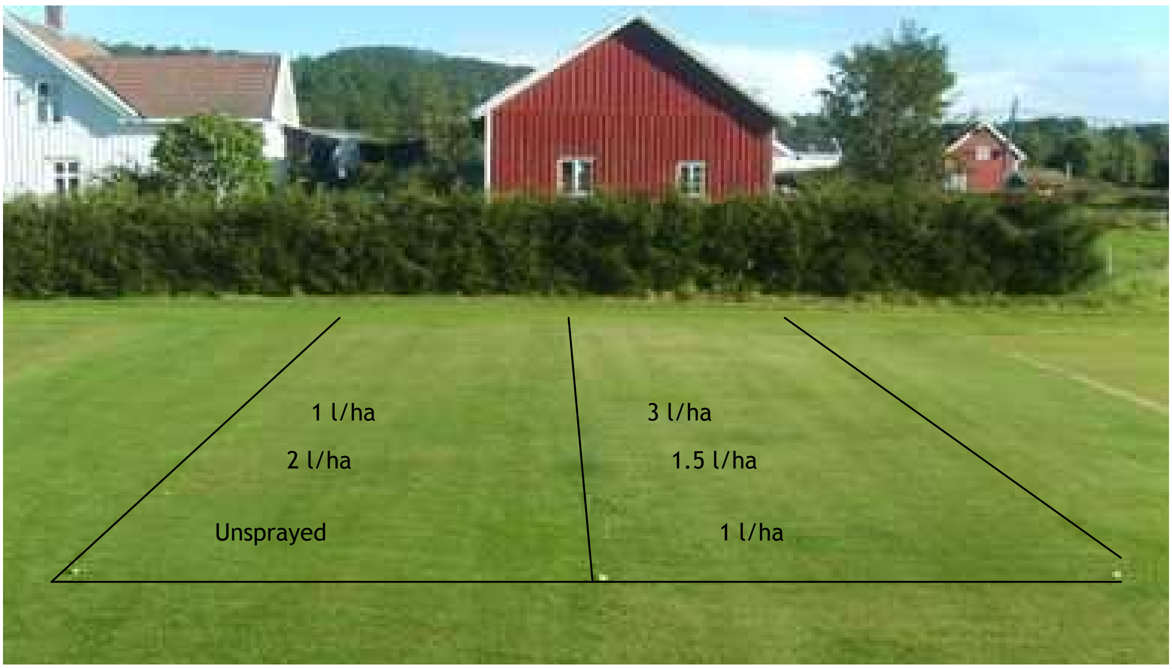


Photo 5. Visual appearance of fairway trial at Landvik, block 1 and 2, on 10 Sept. Within each block, the treatments closest to the photographer have been labeled. High rates of Primo MAXX® resulted in darker, in some cases, almost brown, turf. Photo: Trygve S. Aamlid.

Photo 6.

Turf quality / dormancy colour at growth cessation on 2 Nov. 2007 after application of Primo Maxx at 3.0 l/ha (left) and 0.5 l/ha (right), last application on 26 Sep.

Photo: Trygve S. Aamlid.

Turfgrass height and dry matter production

The average effect of Primo MAXX® on plant height and clipping yields are given in Table 11. In all blocks, the growth regulator caused a significant reduction in plant height even at the lowest rate, but contrary to expectation, this low rate also tended to increase aboveground dry matter production as compared with the unsprayed control treatment. This might reflect a higher tiller density, as also suggested in Table 10. Separate analyses for various parts of trial showed that the average reduction in clipping yield due to Primo MAXX® was stronger in blocks 1 & 2 which had more *Poa* species less red fescue and browntop bent and than blocks 3 & 4. On average for eleven harvests and all replicates, there was a slight tendency for Primo MAXX® to increase the dry matter percentage of turfgrass clippings (P% = 16, Table 11).

Table 11. Absolute and relative effects of increasing rates of Primo MAXX® on turfgrass height, turfgrass dry matter production, and per cent dry matter of clippings in fairway trial at Landvik, 2007. Mean of eleven observations. Plant height above 15 mm represents an average of four days' growth.

Primo MAXX, rate	Plant height, mm		Production of turfgrass clippings, g/m^2/day				% dry matter in clippings
	mm	Rel.	Block 1&2	Block 3&4	Mean	Rel.	
0 = Control	21.9	100	1.78	1.62	1.70	100	31.5
0.5 l/ha	20.9	95	1.91	1.93	1.92	113	32.2
1.0 l/ha	20.7	95	1.65	1.72	1.69	99	32.5
1.5 l/ha	20.0	91	1.46	1.46	1.46	86	33.6
2.0 l/ha	20.3	93	1.55	1.61	1.58	93	32.4
3.0 l/ha	19.5	89	1.31	1.70	1.51	88	33.1
P%.	<0.1	-	10	ns	<5	-	16
LSD 5%	0.7	-	-	-	0.29	-	-
CV%	2	-	10	14	12	-	3

In absolute terms, turfgrass clipping yield showed a distinct seasonal pattern with peaks during the warm and sunny periods in early June and late August (Fig. 2a). The low clipping yield on 17 July was probably due to 280 mm rainfall, and thus nutrient leaching, since the last fertilizer application on 12 June (Tables 3 and 4). Separate analyses of variance for each day indicated a significant effect of Primo MAXX® on clipping yield only on 4 June.

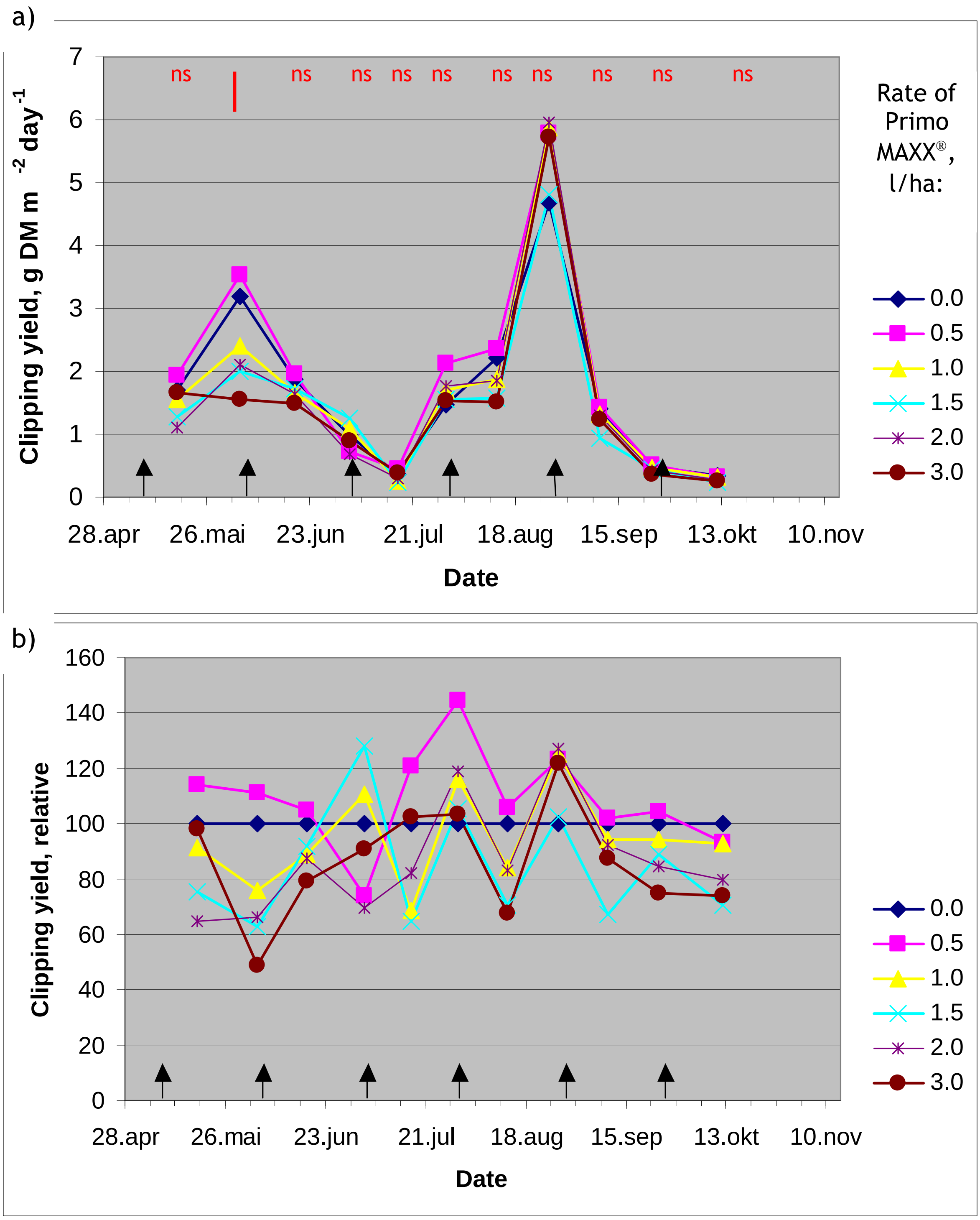


Fig. 2. Absolute (a) and relative (b) reductions in daily dry matter production of turfgrass clippings as affected by increasing rates of Primo MAXX® in fairway trial at Landvik. Red text/bars and black arrows indicate probability / LSD values and application dates 9 May, 5 June, 4 July, 31 July, 28 Aug. and 26 Sep., respectively. In (b), the clipping yield on each date was set to 100 in the unsprayed control treatment.

In relative terms, none of the Primo MAXX® treatments produced clipping yields that were lower than the unsprayed control at all harvests (Fig. 2b). Many of the treatments showed a typical suppression / rebound pattern with clipping yields lower than the control treatment at one harvest, but higher than control treatment at the next harvest.

4.2. Evaluation of Primo MAXX® on a golf course fairway, Lepaa, Finland

On average for two observations in spring, five observations in summer and two observations in autumn, Primo MAXX® had no effect on turfgrass general appearance in the fairway trial at Lepaa. Among the nine observation dates, significant differences were recorded only on 21 August when the plots sprayed with the highest dose (3.0 l/ha) had an average visual merit score of 5.5 as opposed to 6.8 for unsprayed control plots and plots sprayed with the lowest dose (0.5 l/ha).

On average for observations, increasing rates of Primo Max caused an overall increase in tiller density, while turfgrass colour was not significantly affected. No diseases were observed during the growing season.

Table 12. Turfgrass quality (1-9, 9 is best quality), tiller density (1-9, 9 is highest density) and within-season colour (1-9, 9 is darkest green) in fairway trial at Lepaa as affected by increasing rates of Primo MAXX®. Means of nine observations (two in spring, i.e. before 10 June, five in summer, i.e. from 10 June to 1 Sep., and two in autumn, i.e. after 1 Sep.). All values are means of four blocks.

Primo MAXX®, rate	Turf quality (general appearance, 1-9)				Tiller density (1-9)	Within season colour (1-9)
	Mean	Spring	Summer	Autumn		
0 = Control	6.1	5.5	6.1	6.8	5.5	6.1
0.5 l/ha	6.2	5.5	6.1	7.0	5.8	6.2
1.0 l/ha	6.1	5.4	6.1	6.9	5.8	6.1
1.5 l/ha	6.2	5.5	6.2	7.0	6.0	6.3
2.0 l/ha	6.2	5.6	6.1	6.9	6.1	6.3
3.0 l/ha	6.2	5.6	6.1	7.0	6.4	6.2
P%	ns	ns	ns	ns	<0.1	ns
LSD 5%	-	-	-	-	0.4	-
CV%	5	4	8	3	3	4

The effect of Primo MAXX® on turfgrass plant height and clipping yield depended on the time since last application. On average for five observations conducted about two weeks after application, the highest rate of Primo MAXX® caused significant reductions in plant height and clipping yield corresponding to 11 and 48 %, respectively (Table 13). On average for four observations conducted four weeks after application, the maximal reductions were only 3 and 14 %, respectively. Fig. 3 illustrates the unstable effect of Primo MAXX®, particularly toward the end of the growing season. However, unlike in the fairway trial at Landvik (Fig.2), clipping yields on sprayed plots were rarely higher than on untreated control plots in the trial at Lepaa.

Table 13. Absolute and relative effects of increasing rates of Primo MAXX® on turfgrass height and dry matter production in turfgrass clippings in fairway trial at Lepaa 2007. Observations conducted 2 weeks (5 observations) and 4 weeks (4 observations) from spraying treatment have been presented separately.

Treatment	Plant height (mm)				Weight of clippings (g DM / m^2 / day)			
Time after treatment	2 weeks	4 weeks	Mean	Rel	2 weeks	4 weeks	Mean	Rel
0 = Control	15.7	16.0	15.8	100	3.2	7.0	4.9	100
0.5 l/ha	15.7	16.0	15.8	100	2.7	6.3	4.3	87
1.0 l/ha	14.9	16.0	15.4	97	2.8	6.6	4.5	92
1.5 l/ha	14.7	15.7	15.1	96	2.3	5.8	3.9	79
2.0 l/ha	14.4	15.6	15.0	95	2.1	6.1	3.9	80
3.0 l/ha	14.0	15.5	14.6	92	1.8	6.0	3.7	75
P%	<0.1	ns	<5	-	<0.1	ns	ns	-
LSD 5%	1.1	-	1.0	-	0.7	-	-	-
CV%	3	4	3	-	13	22	18	

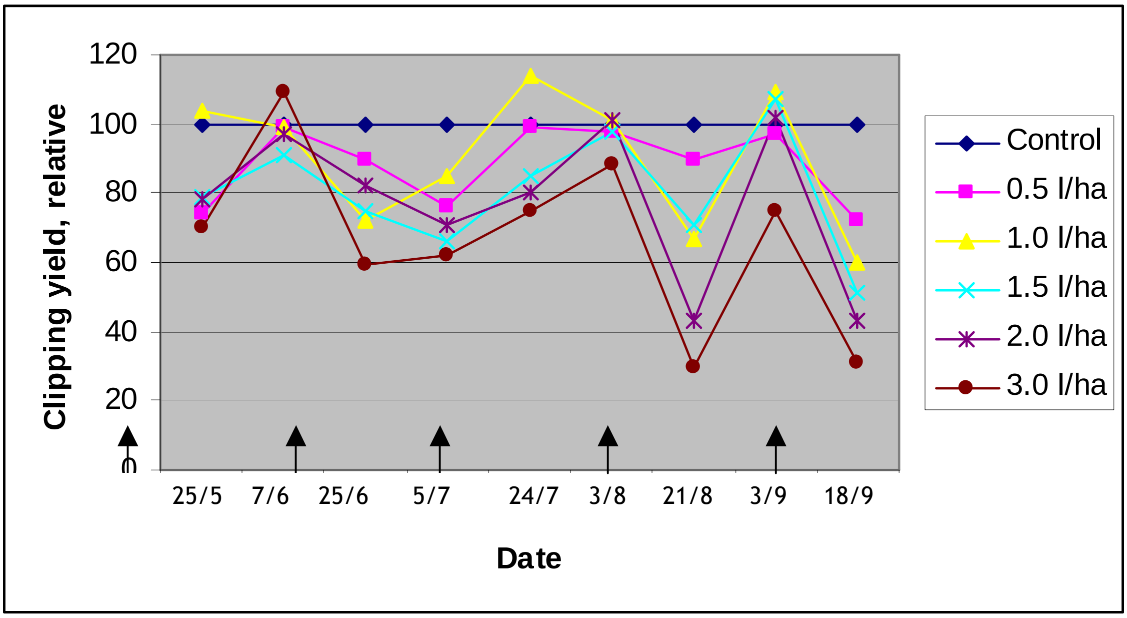


Fig. 3. Relative clipping weights (control = 100) in fairway trial at Lepaa, Finland. Spraying treatments indicated by black arrows were carried out on 11 May, 8 June, 5 July, 3 Aug. and 4 Sep. (The last spraying on 4 Oct. was done primarily to study the effect of Primo MAXX® on overwintering and was not followed by observations in late autumn.)

4.3. Evaluation of Primo MAXX® on a golf course putting green, Lepaa, Finland

On 3 Sep. 2007, a significantly higher tiller density was recorded on green plots sprayed with the highest rate of Primo MAXX® than on unsprayed control plots (data not shown). Otherwise, Primo MAXX® had no significant effect on either general appearance, tiller density or turfgrass colour in the green trial at Lepaa (Table 14). Although the effects on plant height and clipping yields were also not significant, reductions were generally stronger when recorded at two compared with four weeks after application (Table 15, Fig. 4).

Table 14. Turfgrass quality, tiller density and within-season colour (darkness) in green trial at Lepaa as affected by increasing rates of Primo MAXX®, 2007. Means of nine observations (two in spring, i.e. before 10 June, five in summer, i.e. from 10 June to 1 Sep., and two in autumn, i.e. after 1 Sep.). All values are means of four blocks.

Primo MAXX®, rate	Turf quality (general appearance, 1-9)				Tiller density (1-9)	Within season colour (1-9)
	Mean	Spring	Summer	Autumn		
0 = Control	6.4	6.1	6.6	6.3	6.3	6.4
0.2 l/ha	6.3	6.0	6.5	6.0	6.3	6.4
0.4 l/ha	6.3	5.9	6.5	6.1	6.2	6.3
0.6 l/ha	6.3	5.8	6.5	6.4	6.3	6.4
0.8 l/ha	6.2	5.8	6.4	6.3	6.2	6.4
P%	ns	ns	ns	ns	ns	ns
LSD 5%	-	-	-	-	-	-
CV%	3	5	5	7	2	3

Table 15. Absolute and relative effects of increasing rates of Primo MAXX® on turfgrass height and dry matter production in turfgrass clippings in green trial at Lepaa 2007. Observations conducted 2 weeks (5 observations) and 4 weeks (4 observations) from spraying treatment have been presented separately. Plant heights above 3 mm represent one day's growth.

Treatment	Plant height (mm)				Weight of clippings (g DM / m^2 / day)			
Time after treatment	2 weeks	4 weeks	Mean	Rel	2 weeks	4 weeks	Mean	Rel
0 = Control	4.3	3.9	4.1	100	2.60	2.21	2.43	100
0.2 l/ha	4.1	3.8	4.0	96	2.20	2.28	2.23	92
0.4 l/ha	4.0	3.9	3.9	95	1.88	2.28	2.06	85
0.6 l/ha	4.0	3.8	3.9	94	1.72	2.18	1.99	82
0.8 l/ha	3.8	3.9	3.9	93	1.75	2.28	1.92	79
P%	11	ns	ns	-	5	ns	ns	-
LSD 5%	-	-	-	-	0.9	-	-	-
CV%	6	7	8	-	20	14	16	-

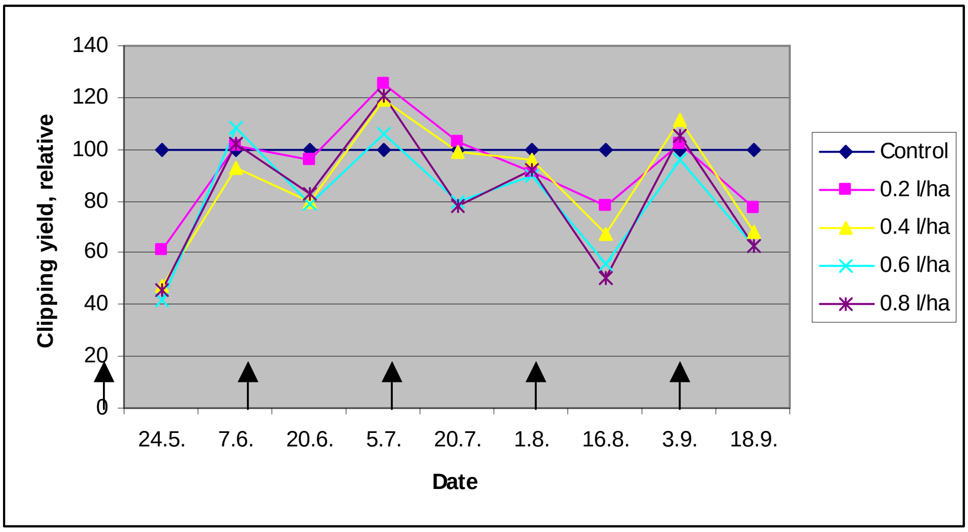


Fig. 4. Relative clipping weights (control = 100) in green trial at Lepaa, Finland. Spraying treatments indicated by black arrows were carried out on 11 May, 8 June, 5 July, 3 Aug. and 4 Sep. (The last spraying on 4 Oct. was done primarily to study the effect of Primo MAXX® on overwintering and was not followed by observations in late autumn.)

4.4. Demonstration trials with Primo MAXX® at Ballerud Golf Course, Oslo, Norway

Green trials

Applications of 0.4 l/ha Primo MAXX® on 5 and 18 June did not affect turf general appearance (Photo 7) or stimpmeter readings on green no. 9 at Ballerud. During the period 14-29 June, clippings were reduced by an average of 32%, but after spraying had been discontinued, there was a rebound effect corresponding to a 26 % increase in clipping yield in the period 12-25 July (data not shown).

Photo 7. Terje Haugen (left) and Lasse Augustsson on green no. 9 at Ballerud Golf Course, 27 June 2007. Photo: Trygve S. Aamlid.

Photo 8. Field day at Ballerud Golf Course 27 Aug. 2007. Photo: Tatsiana Espevig.

Fig. 5 summarizes results from the nursery green trial established on 9 July. In this trial, application of Primo MAXX® about every third week resulted in better colour (not shown), higher green speed (Fig. 5a), and an average reduction in turfgrass clippings of 44 % (Fig. 5b and c). Fig 5b shows that the reduction in clipping yield was most conspicuous during the periods of rapid growth in mid to late July (after only one application of Primo MAXX®) and in late August.

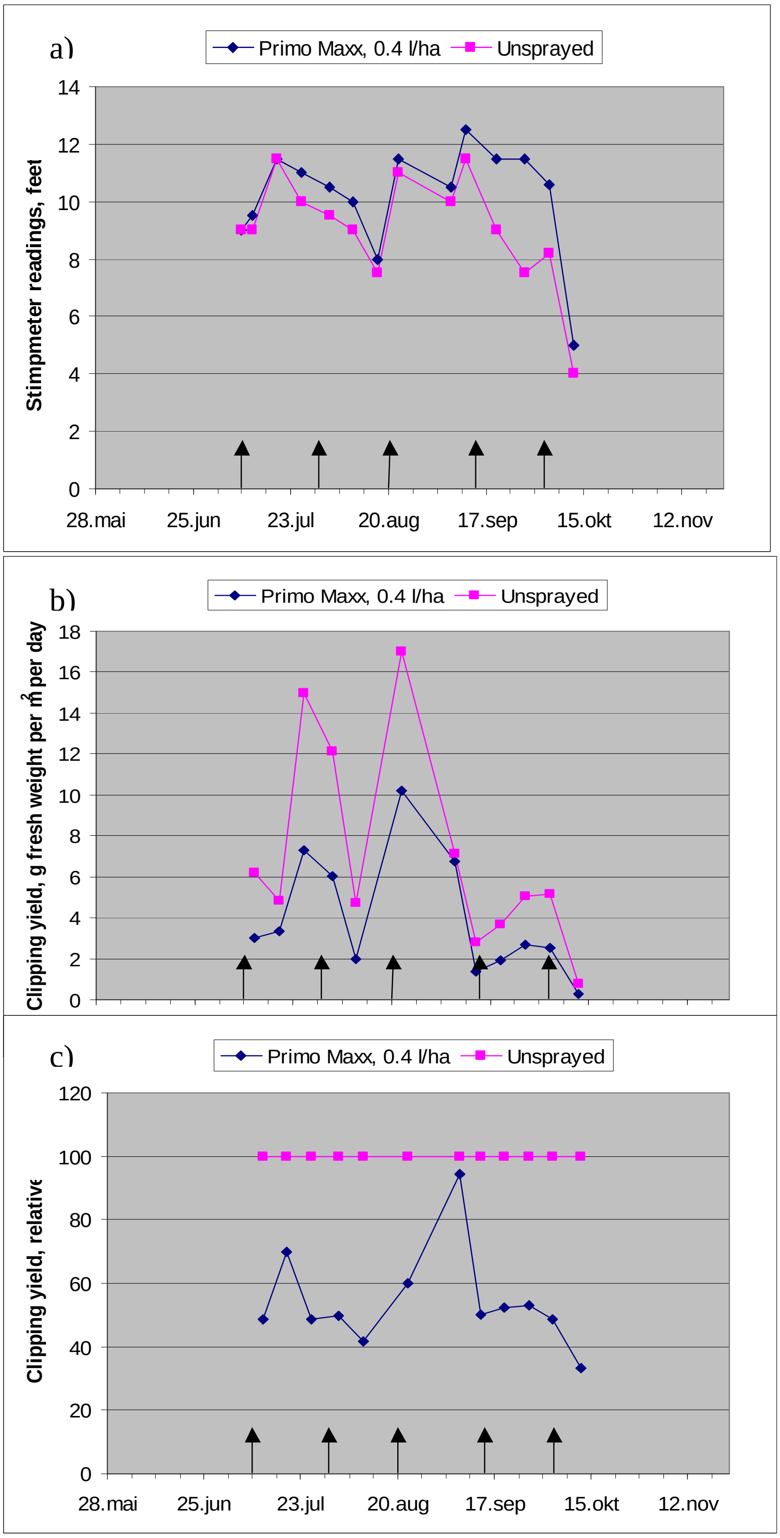


Fig. 5. Effects of spraying Primo MAXX® every three weeks of green speed and absolute and relative clipping yield on nursery green at Ballerud GC, 2007. Black arrows indicate the application dates 9 July, 31 July, 21 Aug., 13 Sep. and 4 Oct.

Fairway trial

As evaluated by the headgreenkeeper, monthly applications of 1.5 l/ha Primo MAXX® (1.5 l/ha) had no negative impact on turf quality in the fairway trial at Ballerud (Fig. 6). Photos 9-11 show, nevertheless, that treated turf was more faded, grayish, and less green than untreated turf. The pronounced colour difference in favour of Primo MAXX® in early September (Fig. 6) was due to less dry spots than the in the control area. While these spots recovered after rainfall on 10 and 17 Sep., the last application of Primo MAXX® on 4 Oct. led to an apparent loss of colour and drop in turf general appearance in late autumn (Photo 11).

On average for 17 clipping, regular application of Primo MAXX® resulted in a 37 % reduction in the fresh weight of turfgrass clippings (Fig. 7). The only time clipping yield was higher on the treated than on the untreated area was at the first clipping nine days after the first application and on 7 Sep. The latter coincided with the observation of less dry spots after use of Primo MAXX®. It may also be interpreted as a rebound effect following growth suppression after application on 31 July.

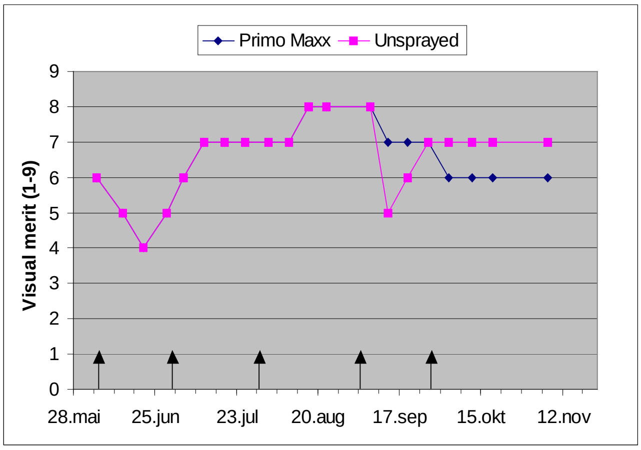


Fig. 6. Effect of Primo MAXX® on turfgrass general appearance in fairway trial at Ballerud GC. Black arrows indicate application dates. (Sprayed an unsprayed plots had identical scores until the beginning of September)

Photo 9. Difference in colour and general appearance of treated and untreated fairway Ballerud GC, 27 June. Photo: Trygve S. Aamlid.

Photo 10. Difference in colour and general appearance of treated and untreated fairway Ballerud GC, 27 Aug. Photo: Tatsiana Espevig.

Photo 11. Difference in colour and general appearance of treated and untreated fairway Ballerud GC, 3 Dec. Photo: Terje Haugen.

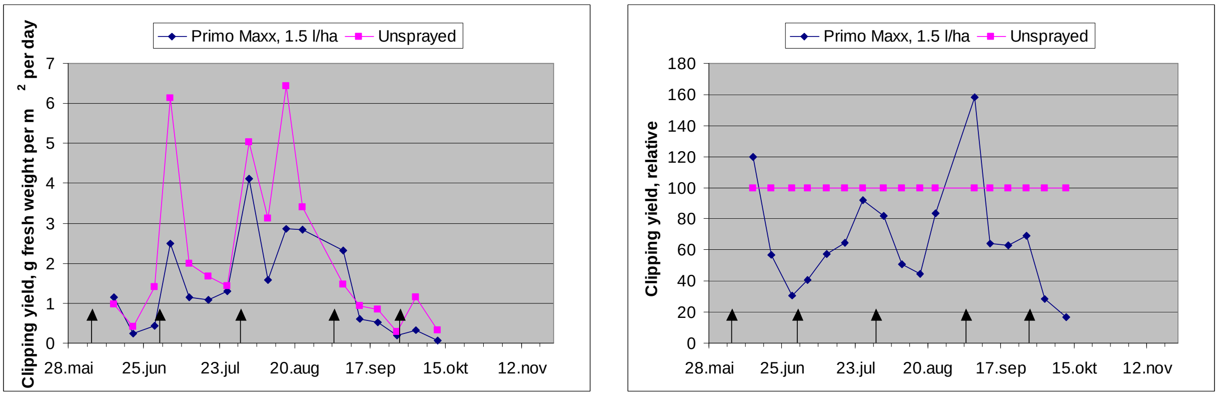


Fig. 7. Absolute (a) and relative (b) reductions in clipping yield resulting form application of Primo MAXX® in fairway trial at Ballerud GC. Arrows indicate application dates.

Spraying 2.2 l/ha of Primo MAXX® at six weeks interval resulted in discoloration and consistent drop in turf quality in the rough trial at Ballerud (Fig. 8, Photos 12 and 13). The effect was most conspicuous in late autumn. Primo MAXX® had less effect on tufts of perennial ryegrass which stood out very markedly in the turf which was otherwise dominated by smooth meadowgrass. Clipping yields were not recorded in this trial.

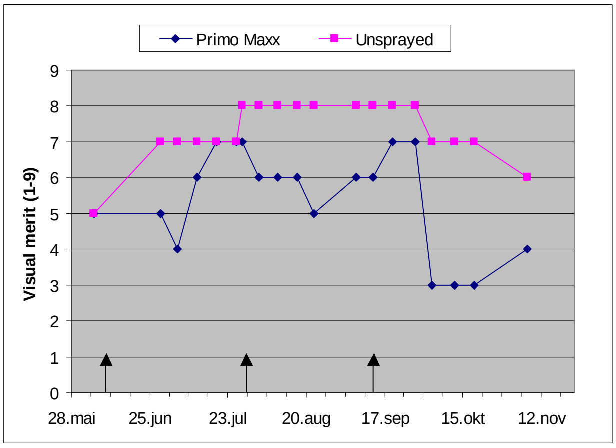


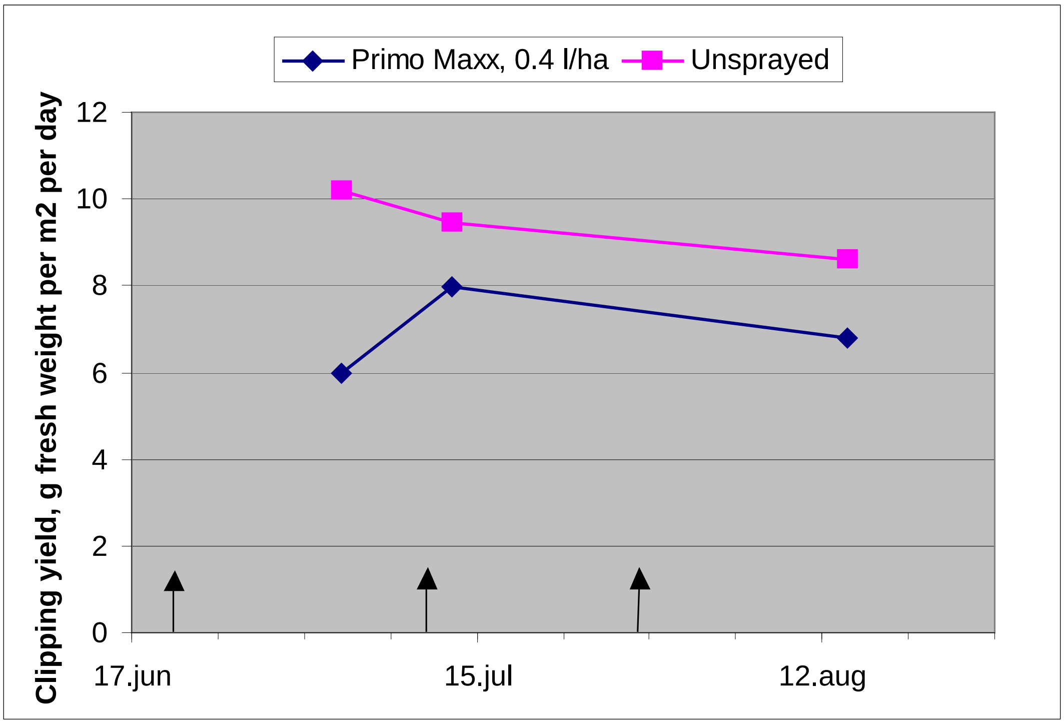
Fig. 8 (upper left). Difference in colour and general appearance of treated and untreated area in rough no 9, Ballerud, 27 June. Photo: Trygve S. Aamlid.

Photo 12 (upper right). Terje Haugen (left) and Lasse Augustsson in rough trial at Ballerud GC, 27 June. Photo: Trygve S. Aamlid.

Photo 13 (lower left). Trygve S. Aamlid inspecting rough trial at Ballerud GC, 27 August 2007. Tufts of ryegrass stand out very markedly on sprayed area.
Photo: Tatsiana Espevig.

4.5. Demonstration trial with Primo MAXX® at Oslo Golf Club, Bogstad, Norway

Application of 0.4 l Primo MAXX® at three week intervals resulted in darker turf but had otherwise no effect on the turfgrass quality of annual meadowgrass at Oslo GC. On average for three registrations, the Primo MAXX led to a 26% reduction in clipping yields (Fig. 9).



5. Discussion and suggestions for 2008

The starting point for evaluating Primo MAXX® in this two-year project was the rates and applications frequencies recommended for the product in Europe (Syngenta 2007, Table 16). Based on our experiences from agricultural crops that the optimal rates may be different in the Nordic countries than countries further south, higher and lower rates were included in the GEP trials both to determine the potential growth inhibition and the risk for discoloration or other phytotoxic effects. All taken together, the results from the first project year confirms that the guidelines in Table 16 are not directly applicable in Scandinavia and that further research is needed to find the optimal way of using the product under Nordic conditions.

Table 16. Dose rates and applications frequencies recommended for Primo MAXX® in the United Kingdom (Syngenta 2007).

	Dose rate		Application frequency
	Primo MAXX®, l/ha	trinexapac-ethyl, g a.i./ha	
Fairways	0.8 – 1.6	90 - 180	Every four to five weeks
Roughs & semi-roughs	1.6-2.4	180 - 240	Every five to eight weeks
Greens	0.4	45	Every two to four weeks

On fairway, the average reduction in clipping yield caused by monthly application of the intermediate Primo MAXX® rate of 1.5 l/ha was 15 and 21 % in the GEP trials at Landvik and Lepaa, respectively. By contrast, monthly application of 1.5 l/ha resulted in a 37 % reduction in clipping yield in the demonstration trial at Ballerud GC, which is closer to the data presented by Syngenta (2007). In agreement with Table 11 showing an increase in turfgrass dry matter percentage (i.e. decreased succulence) after application of Primo MAXX®, one of the reasons for this difference might be that clipping yields were determined on a dry weight basis in the GEP trials but on a fresh weight basis at Ballerud GC and in the data presented by Syngenta (2007). Another, and probably more important explanation, is the difference in species composition among the three trials. While the plant cover at Ballerud was almost 100% by annual meadowgrass, the species composition at Landvik varied with the two blocks showing the least response to Primo MAXX® having a plant cover of 74 % red fescue (Tables 1 and 11). By contrast, smooth meadowgrass dominated over red fescue at Lepaa due to the heavy soil type, use of irrigation, and relatively high nitrogen input. Unfortunately, we have not been able to find many references about the specific effects of Primo MAXX® on red fescue turf, but our results are in partial agreement with Pannacol et al. (2004) who found 40 %, 21 %, and no significant reduction in clipping yield after using trinexapac-ethyl in smooth meadowgrass, chewing fescue and creeping red fescue, respectively.

Perhaps the most conspicuous feature of the present results was the unstable effect of Primo MAXX® on clipping yields due to the postsuppression rebound effect. In the fairway trial at Lepaa, Finland, this resulted in clipping yield reductions being significant only two weeks after application (Table 13), and a similar tendency could be seen also in the green trial (Table 15). In Norway, clipping yields four weeks after spraying were often higher than on unsprayed control plots in the fairway trial at Landvik (Fig. 2), and a strong rebound effect was observed also after spraying treatments had to discontinued at green no. 9, Ballerud GC. The unstable effect in of Primo MAXX® in these trials was probably due to a rapid degradation of trinexapac-ethyl in plant tissue and a higher regrowth potential due to accumulation of carbohydrate reserves and GA_1 precursors during the suppression phase (Lickfeldt et

al. 2001, Branham & Beasley 2007). In North-American experiments, Lickfeldt et al. (2001) reported clipping yields reductions in smooth meadowgrass to be much more consistent when trinexapac-ethyl was applied at four than at six week intervals, but under Nordic long-day conditions, spraying every second, or at least every third week, may well be necessary to stabilize low GA_1 levels, not only on greens, but also on fairways and tees. Although there was a surge effect during the driest period in mid September, the most stable clipping reductions in our trials, on average 44 % on a fresh weight basis, were, indeed, obtained on the nursery green which was sprayed about every third week at Ballerud GC (Fig. 5c). While Branham & Beasley (2007) noted that temperature was the most important factor determining degradation of trinexapac-ethyl in turfgrass tissue, our results suggest that other factors such as light and water availability may also be important for the rebound effect under Nordic conditions. Very clearly, application frequency is a major question that has to be addressed during the continuation of this project.

The potential reductions in mowing costs from using a plant growth regulator will always have to be weighed against the risks for discoloration or other harmful effects on turf quality. In the present trials, reductions in general appearance (visual merit) scores were far more conspicuous in the GEP trial at Landvik than in the GEP trials at Lepaa or the demonstration trials at Ballerud GC. Apart from possible effects of different botanical compositions, this might reflect a subjective human factor, i.e. different backgrounds and attitudes of the observers in the various trials. While the fairway trial at Landvik was evaluated by turfgrass scientists and technicians with long experience from turfgrass variety testing, the trials at Lepaa and Ballerud were evaluated by greenkeepers working on the course. While the observers at Landvik may have paid more attention to turf aesthetic values such as less intense colour, and less vigorous and uniform plots, the observers at Lepaa and Ballerud may well have been more attentive to ball roll and other functional characteristics of the playing surface. The less succulent but significantly darker green turf resulting from high Primo MAXX® rates at Landvik are in agreement with other studies showing higher mesophyll cell densities and chlorophyll concentrations resulting from less elongation of leaf cells (Heckman et al. 2001, Ervin & Zhang 2008). As for tiller density, most literature supports the Finnish rather than the Norwegian results; i.e. enhanced tillering after Primo MAXX® application (Branham & Beasley 2007, Ervin & Zhang 2008).

As compared with the unsprayed control treatment, the strongest negative effect of Primo MAXX® on turfgrass general appearance at Landvik was recorded after the first spraying in early June, in mid July and at the last observation in early November. Each of these observations might be explained by suboptimal conditions causing reduced turfgrass growth. From 6 to 15 June there was a dry and warm and period with maximum temperatures in the range 25-30 ºC that obviously reduced turfgras tillering and aesthetic appearance; until mid July exceptional rainfalls starting on 22 June were not compensated by increase nitrogen inputs, and in autumn, the last application of Primo on 26 September was followed by several nights of frost. Although most studies have failed to document significant interactions between nitrogen and trinexapac-ethyl on turfgrass quality (Steinke & Stier 2001, Goss et al. 2002, McCullogh et al. 2006), it seems reasonable to assume that potential negative effects on Primo MAXX® on turfgrass quality will be most pronounced under suboptimal growing conditions. As in the trials at Landvik (Photo 6) and Ballerud (Photo 11), Beam et al. (2002) reported significant discoloration of trinexapac-ethyl-treated smooth meadowgrass following frost in autumn.

Undoubtedly, the most convincing argument for official approval of Primo MAXX® on Nordic golf courses would be a clear documentation that it improves winter survival. Preliminary results with annual meadowgrass suggested that low rates of trinexapac-ethyl prevented winter injury, whereas high rates had opposite effects due to discoloration during the hardening phase in late autumn (Rossi & Buelow 1997). While trinexapac-ethyl has been shown to increase water soluble carbohydrate contents (Goss et al. 2002) and result in faster spring greenup, Ervin & Zhang (2008) recently called for more detailed investigations into the effect of trinexapac-etyl on freezing tolerance as the research to date has provided scarce information on this aspect. Under Nordic conditions, desiccation if growth resumes when soils are still frozen and irrigation not yet operational in spring, or damage due to unstable winters with ice and water covering the turf, sometimes resulting in suffocation, appear to be more

important that direct freezing injury. In this regard, trineexapac-ethyl may well have a positive effect as it reduces mitochondrial respiration (Ervin & Zhang 2008). In 2008, it will therefore be very interesting to study winter injury and spring green-up and recovery in the on-going trials at Landvik, Lepaa and Ballerud which all had their last application of Primo MAXX® in late September or early October.

Even with winter survival and spring observations included, the amount of data presented in this report is too limited to recommend any listing of Primo MAXX® for turf use in the Nordic countries. Therefore, as stated in the contract between Syngenta and Scandinavian Turfgrass and Environment Research Foundation, there is a need for new GEP trials to be started in spring 2008 and followed until registration of winter survival in spring 2009. For this purpose, a new experimental green was constructed and seeded to creeping bentgrass at Landvik in 2007. In the trial to be established on this green in spring 2008, we suggest to compare Primo MAXX® at three rates (0.15, 0.30 and 0.45 l/ha) and two application frequencies (every 10/11 days and every 21 days), i.e. six combinations plus an unsprayed control treatment. As different grass species seem to vary in their response to Primo MAXX®, similar trials should preferably be carried out on also red fescue/browntop greens and velvet bentgrass greens, although this would require additional funding from Syngenta/STERF.

In Finland, a new GEP trial will be established in spring 2008 on a fairway that is regularly subjected to winter injury. New demonstration trials might be added to the project depending on interest from superintendents and funding from the national golf unions.

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

Results from the first evaluation year 2007

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SCANDINAVIAN TURFGRASS AND ENVIRONMENT RESEARCH FOUNDATION

Finnish team spraying fairway trial at Lepaa Golf Course.
Photo: Oiva Niemelainen

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Summary:

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

Sammendrag:

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

Approved

Arne Sæbø	Trygve S. Aamlid
Leader, Bioforsk's Section for Urban Greening	Project leader

Contents

1. Abstract

As an inhibitor of the last step in plant synthesis of bioactive gibberellin (GA_1), the plant growth regulator Primo MAXX® (trinexapac-ethyl) offers prospects of reduced energy use for mowing and improved turfgrass quality under Nordic long day conditions. This report presents first year results from 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 possible registration of Primo MAXX®, unreplicated demonstration trials were carried out at Ballerud and Bogstad Golf Courses in Oslo under supervision of Bioforsk and with funding from the Norwegian Golf Federation (NGF).

GEP trials on **fairways** (mowing height 12-18 mm) were carried out at Bioforsk Landvik, Norway (58°34'N, 8°52'E) and at the Lepaa Unit of the HAMK University of Applied Sciences, Finland (61°08'N, 24°20'E). Primo MAXX® was applied at monthly intervals at rates 0.5, 1.0, 1.5, 2.0 and 3.0 l/ha (56.5, 113, 169.5, 226 and 339 g a.i./ha trinexapac-ethyl) in comparison with an unsprayed control treatment. Turfgrass general appearance, tiller density, colour, height growth, and clipping yields were recorded two and four weeks after each application. Primo MAXX® had no effect on turfgrass general appearance but increased density at Lepaa. At Landvik, Primo MAXX® (>= 1.0 l/ha) reduced turfgrass general appearance and density, but resulted in significantly darker green colour. Quality reductions were most apparent during periods with either daily maximum temperatures >25 ºC, extreme rainfall probably causing nitrogen deficiency, or frost at night. Average reductions in clipping yield caused by Primo MAXX® (>= 1.0 l/ha) were 8 % in the GEP trial at Landvik, 18 % in the GEP trial at Lepaa and 37 % in the demonstration trial at Ballerud; to some extent this difference may be due to different botanical composition with red fescue (*Festuca rubra*) and annual meadowgrass (*Poa annua*) being the predominant species at Landvik and Ballerud, respectively. Clipping yield reductions due to Primo MAXX® were unstable, growth suppression two weeks after application often being followed by a rebound effect during the remaining two weeks until next application.

A GEP trial on creeping bentgrass **putting greens** was carried out at Lepaa, Finland, and demonstration trials at Ballerud and Bogstad, Norway. Primo MAXX® was sprayed at rates 0.2, 0.4, 0.6 or 0.8 l/ha at monthly intervals in the GEP trial, and at 0.4 l/ha every three weeks in the demonstration trials. On average for all observations, Primo MAXX® had no effect on turfgrass quality, but clipping yields were reduced by 16, 44 and 26% at Lepaa, Ballerud and Bogstad, respectively. As in the fairway trials, growth suppression at Lepaa was stronger when assessed at two than at four weeks after application. By contrast, Primo MAXX® produced a fairly stable effect when applied at three week intervals in the demonstration trials.

Use of Primo MAXX® on golf course **roughs** was investigated only in a demonstration trial at Ballerud. Application of 2.2 l/ha of Primo MAXX® every seven weeks resulted in discolouration and reduced quality of smooth meadow grass.

In conclusion, the first year of this project has shown that the guidelines for use of Primo MAXX® in other European countries are not directly applicable in Scandinavia. As the present results are too limited to apply for registration of Primo MAXX®, the project will continue in 2008 tentatively with new trials investigating application of Primo MAXX® at lower rates, but higher frequencies. Improved winter stress tolerance would be a convincing argument for registration of Primo MAXX® in the Nordic countries, and the on-going trials will therefore be followed by an assessment of effects of the last Primo MAXX® applications in September or October 2007 on winter survival and spring recovery.

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

2. Introduction

The plant growth regulator trinexapac-ethyl was developed by Syngenta in the 1980s. Since the active ingredient is available in different formulations, the chemical will, in this report, be referred to as Primo MAXX®, which is the product developed by Syngenta specifically for use on turf. Unlike earlier plant growth regulators, Primo MAXX®'s mode of action is highly specific as it blocks the conversion of GA_{20} til GA_1, i.e. the last step in the biosynthesis of gibberellic acid, a plant hormone stimulating cell elongation and thus vertical turf growth.

After its release, Primo MAXX® was rapidly adopted by the US and Canadian turf industries. In North America, there are several independent university studies documenting its positive effects on golf courses, athletic fields, home lawns, and sod production (for a recent review, see Erwin and Zhang 2008). These advantages include reduced leaf elongation and thus reduced mowing costs and energy use, improved tiller production (more lateral growth), darker green colour, and improved resistance to drought and shade.

While other formulations of trinexapac-ethyl have been approved for agricultural use in Europe for about a decade, the experience with Primo MAXX® to European turfgrass areas is relatively limited. During the past three to four years, Primo MAXX® has been approved for turf use in Italy, France and UK, and the evaluation and registration process has been initiated in many other countries.

Being an inhibitor of gibberellin biosynthesis, Primo MAXX® offers special prospects for turfgrass management in the Nordic counties Finland, Sweden, Norway, Iceland, and Denmark. At latitudes ranging form 55 to 71 °N, turfgrasses growing in these countries exposed not only to long photoperiods during most of the growing season, but also to lower photosynthetic flux densities and lower red to farred (R/FR) ratios than in countries further south. The natural turfgrass response to these northern light conditions is to devote more of its resources to shoot elongation (Heide et al. 1985a,b). Since this response is primarily mediated by the gibberellic acid GA_1, any specific growth regulator that controls the biosynthesis of this compound might be useful under Nordic conditions. Nevertheless, our experience from the introduction of trinexapac-ethyl for agricultural use in the Nordic counties suggests that the optimal dose rates and frequencies for application of Primo MAXX® to various types of turf are probably not the same as at lower latitudes. This is also due to different species and cultivars being grown compared with countries further south. Field trials under Nordic conditions are therefore required not only to produce data for the national certification agencies, but also to provide turf managers with recommendations for how to use the product.

This report presents first year preliminary results from a two year project evaluating the use of Primo MAXX® on golf courses in the Nordic countries. The project was funded by Syngenta and the Scandinavian Turfgrass and Environment Research Foundation (STERF) 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' trials needed to provide documentation for possible registrations of Primo MAXX® by the national authorities, a couple of practical demonstration trials were carried out on Norwegian golf courses under supervision from Bioforsk and with funding from the Norwegian Golf Federation (NGF).

3. Methods

3.1. Evaluation of Primo MAXX® under fairway conditions, Bioforsk Landvik, Norway

Experimental site

On 8 May 2007, a field trial was laid out on a fairway established on a sandy loam soil (topsoil: 68 % sand, 27% silt, 5 % clay) at Bioforsk Landvik Research Station (58°34'N, 8°52'E), SE Norway. Soil samples indicated a pH (H_2O) of 5.9, high phosphorus values (P-AL=19) and intermediate to low potassium values (K-AL = 8, K-HNO_3=58). The fairway had been seeded in September 2003 to a mixture of smooth meadowgrass (*Poa pratensis*), chewing fescue (*Festuca rubra* ssp. *commutata*), and browntop bent (*Agrostis capillaris*) (Table 1). Block 1 and 2 were located in one part, and block 3 and 4 in a different part of the fairway. Botanical analyses at the start of experimentation indicated that red fescue was the predominant species in all blocks, but presumably due to slightly less surface drainage, blocks 1 and 2 had a higher percentage of smooth and annual meadowgrass and broadleaved weeds (primarily white clover (*Trifolium repens*)) than blocks 3 and 4 (Table 1).

Table 1. Seed mixture used for fairway establishment in 2003 and botanical composition at the start of the Primo MAXX® trial in spring 2007.

Species	Cultivar	% (w/w) of seed mixture	% cover at initiation of Primo MAXX® trial		
			Block 1 and 2	Block 3 and 4	Mean
Poa pratensis	Conni	25	31	9	20
Poa pratensis	Eva	10			
Poa pratensis	Limousine	10			
Festuca rubra ssp. commutata	Bargreen	25	50	74	62
Festuca rubra ssp. commutata	Calliope	25			
Agrostis capillaris	Tracenta	5	5	15	10
Poa annua			8	2	5
Broadleaved weeds			6	0	3
Sum		100	100	100	100

Experimental plan

The experiment was laid out according to a randomized complete block design with plot size 2m x 3m, four blocks (replicates) and the following treatments:

1. Usprayed control
2. Primo MAXX, 0.5 l/ha (56.5 g a.i./ha) every four weeks
3. Primo MAXX, 1.0 l/ha (113 g a.i./ha) every four weeks
4. Primo MAXX, 1.5 l/ha (169.5 g a.i./ha) every four weeks
5. Primo MAXX, 2.0 l/ha (226 g a.i./ha) every four weeks
6. Primo MAXX, 3.0 l/ha (339 g a.i./ha) every four weeks

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. Actual application rates were recorded by weighing the tank before and after spraying. Table 2 shows actual rates and weather conditions for each spraying event.

Table 2. Weather conditions and actual application rates at the six spraying events.

Application date	Time of day (hours)	Weather conditions at application			Treatment number / application rate (l Primo MAXX® per ha)				
		Air temp. °C	Relative Humidity %	Wind Speed m/s	2. (target 0.5)	3. (target 1.0)	4. (target 1.5)	5. (target 2.0)	6. (target 3.0)
9 May	09-11	14	48	< 1.0	0.47	0.94	1.56	1.90	3.35
5 Jun.	09-11	15	60	< 1.0	0.58	1.06	1.67	1.93	3.19
4 Jul.	13-15	17	70	1.0-2.0	0.61	0.98	1.73	2.19	3.38
31 Jul.	08-10	18	55	1.0-2.0	0.55	1.05	1.66	2.28	3.41
28 Aug.	09-11	19	32	1.0-2.0	0.57	1.03	1.55	2.19	3.52
26 Sep.	09-11	11	69	< 1.0	0.52	1.07	1.55	2.01	3.15
Mean					0.55	1.02	1.62	2.08	3.33

Registrations

At two weeks intervals throughout the experimental period, turfgrass colour, tiller density, and turf general appearance were assessed by turfgrass scientist or technicians using a scale from 1 to 9 where 9 is darkest colour, highest tiller density and best turf quality. The assessments were conducted two and four weeks after application of Primo MAXX®. On the same dates, turfgrass diseases and broadleaf weed (including white clover) invasion were reported as per cent of plot area. Turfgrass height was recorded as the mean of three random measurements with a ordinary ruler in each plot, and the overall growth rate by weighing clippings in the basket of a walk-behind mower used in the 0.56 m x 1.88 m central area of each plot (Photo 1). Both raw weight and dry weight were recorded, the latter after drying for 24 h at 60ºC. By the end of the growing season, on 2 Nov., turfgrass dormancy colour was evaluated on a scale 1-9, where 1 is completely faded / brown turf, and 9 is completely green turf.

Photo 1a and b. Tatsiana Espevig collecting clippings in fairway trial at Landvik. Photos: Trygve S. Aamlid

Management

The experiment was mowed at 15 mm two times a week, usually on Monday and Friday. A triplex fairway mower without collection of clippings was used except when clipping weights were to be recorded. Granular fertilizer was applied at approximately monthly intervals as outlined in Table 3. The experiment was not irrigated except for small amounts of water to dissolve fertilizer after application. On 7 Aug., the trial was aerated using a vertidrain with 15 mm solid tines to 15 cm depth. Topdressing was accomplished on 8 Aug. and 5 Nov. at rates 0.75 and 1.5 kg pure sand per m^2, respectively.

The fairway trial at Landvik was not exposed to ordinary play, but it was was subjected to artifical wear from a wear drum one to two times per week.

Table 3. Fertilizer inputs, fairway trial, Landvik.

		Per ha							
Date	Fertilizer type	kg fertilizer	kg N	kg P	kg K	kg Mg	kg S	kg Ca	kg Fe
17 Apr.	Fullgjødsel 22-2-12	40	9	1	5	0	1	0	0
16 May	Fullgjødsel 22-2-12	70	15	1	8	1	2	1	0
12 Jun.	Arena Golf Extra 13-0-15	150	20	0	23	2	21	0	3
23 Jul.	Arena Golf Extra 13-0-15	130	17	0	20	2	18	0	3
9 Aug.	Arena Golf Extra 13-0-15	135	18	0	21	2	18	0	3
5 Sep.	Arena Golf Extra 13-0-15	150	20	0	23	2	21	0	3
SUM			99	2	100	10	80	1	11

Weather data

In SE Norway, the growing season 2007 was characterized by exceptionally high rainfall, especially in July, but also in May, June and August (Table 4). By contrast, September was unusually dry. Precipitation was recorded on 16 out of the 31 days in July; the cloudy summer weather is also reflected by a rather low irradiance during this month. The warmest period, with daily maximum temperatures in the range 23-29 ºC was recorded from 6 to 12 June.

Table 4. Weather data for Landvik meteorological station, about 200 m for experimental field. Normal values for temperature and rainfall are 'official' values for from the period 1961-90, while normal values for irradiance are calculated averages for the period 1994-2006.

	Mean temperature, ˚C		Precipitation, mm		Irradiance, MJ/m^2 (305-2800 nm)	
	2007	30 yr normal	2007	30 yr normal	2007	13 yr average
May	10.2	10.4	107	82	518	540
June	15.9	14.7	109	71	604	600
July	15.5	16.2	213	92	492	632
Aug.	16.2	15.4	132	113	476	476
Sep.	12.0	11.8	59	136	321	262
Mean / sum	14.0	13.7	620	494	2411	2510

3.2. Evaluation of Primo MAXX® on a golf course fairway, Lepaa, Finland

Experimental site

The Finnish fairway trial was laid out on 11 May 2007. The fairway was seeded to a mixture of smooth meadowgrass and chewing fescue (*Festuca rubra* spp. *commutata*) on a heavy clay soil (15% sand, 37% silt, 48% clay) at the Lepaa Unit of HAMK University of Applied Sciences, Finland (61°08'N, 24°20'E). 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. All observations and management of the trial was carried out by the HAMK Lepaa greenkeepers Petteri Lehmuskoski and Tommi Turunen except for the spraying treatments which were carried out by MTT's 'Good Experimental Practice' certified spraying team from Jokioinen (90 km from Lepaa).

Experimental plan and registrations

The experiment was laid out following the same plan and plot size as at Landvik, Norway (previous paragraph). Primo MAXX® was applied in accordance with the Finnish 'Good Experimental Practise' protocol, using a portable, compressed air-powered 'van der Weij' plot sprayer, mounted with a windshield and flat fan nozzles (Hardi 4110-12) and working at 180-250 kPa pressure. The spraying boom had four nozzles spaced 50 cm apart. The spraying volume corresponded to 200 l/ha. Full spray coverage was on the central 1.5m x 2.5 m of each plot. Table 5 shows application dates and weather conditions for each spraying event. The last application on 4 Oct. was conducted especially to evaluate potential effects of Primo MAXX® on turfgrass winter damage.

Table 5. Application dates and weather conditions in fairway and green trials at Lepaa.

Application date	Time of day (hours)	Air temp. °C	Relative humidity %	Wind Speed m/s	% cloud cover
11 May	09-11	11	29	0	25
8 Jun.	09-11	20	56	1.5	1
5 Jul.	13-15	23	47	2.5	70
3 Aug.	09-11	17	78	2.0	90
4 Sep.	09-11	11	90	1.0	90
4 Oct.	13-15	11	92	1.5	100

Photo 2. Austen Sutton, Syngenta (left) and greenkeeper Petteri Lehmuskoski, HAMK Lepaa Unit, in fairway trial at Lepaa, Finland, 29 Aug. 2007.

Photo: Oiva Niemelainen.

Registrations

Registrations were carried out at two-week intervals following the same program as at Landvik (previous section) except that weed occurrence and dormancy colour were not recorded. Plant height at Lepaa was determined using a Turf Check Prism device (Check Signature Inc., Shoreview, MN).

Management and wear

The experiment was mowed with a triplex fairway mower about three times per week. Mowing height ranged from 12 to 18 mm. Granular fertilizer Sportsmaster 26-2-9 was applied at equal rates on 8 May and 12 July, the total input corresponding to 156 kg N, 12 kg P, 54 kg K and 0.9 kg Fe per ha. Information about irrigation is given in Table 6. The trial was aerated or top-dressed in late autumn, after the completion of registrations.

During the growing season period, the trial was exposed to approximately 3.500 rounds of golf.

Weather data

Temperatures at Lepaa were higher the 30 yr normal values throughout the growing season (Table 6). August had the greatest deviation from the long-term average value. July had 49 % more, and August 42 % less rainfall than usual; over the whole experimental season, rainfall was close to the 30 yr normal value.

Table 6. Weather data for Hattula Lepaa weather station and irrigation in fairway and green trial at Lepaa golf course, 2007. Normal values for temperature and rainfall are official values for from the period 1971-2000 (Finnish Meteorological Institute)

	Mean temperature, °C		Rainfall, mm		Irrigation, mm (2007)	
	2007	30 yr normal	2007	30 yr normal	Fairway trial	Green trial
May	10.6	9.8	30	34	*	*
June	15.1	14.5	54	55	26	79
July	16.6	16.4	119	80	5	47
Aug.	16.4	14.6	43	74	7	50
Sep.	9.9	9.4	58	54	0	6
Mean / sum	13.7	12.4	304	297	37	188

* Data are unavailable for the period 1-26 May 2007 due to change of irrigation computer.

3.3. Evaluation of Primo MAXX® on a golf course putting green, Lepaa, Finland

Experimental site

The Finnish green trial was established on 11 May 2007 on a USGA green seeded to creeping bentgrass (*Agrostis stolonifera*, seed blend of 50% 'Penn A-4' and 50% 'Penn G-6') at Lepaa Golf Course.

Experimental plan

The experimental plan comprised five rates of Primo MAXX plus the unsprayed control treatment:

1. Usprayed control
2. Primo MAXX, 0.2 l/ha (22.6 g a.i./ha) every four weeks
3. Primo MAXX, 0.4 l/ha (45.2 g a.i./ha) every four weeks
4. Primo MAXX, 0.6 l/ha (67.8 g a.i./ha) every four weeks
5. Primo MAXX, 0.8 l/ha (90.4 g a.i./ha) every four weeks

The trial had four replicates, and a gross plot size of 2 m x 3 m. It was sprayed on the same dates and following the same GEP procedures as the fairway trial on the same location (Table 5).

Photo 3. Green trial at Lepaa ready for the first treatment on 11 May 2007. Photo: Oiva Niemelainen.

Registrations

Registrations followed the same program as in the Finnish fairway trial (previous section).

Management and wear

The experiment was mowed with a Triplex greens mower for an average of six times per week. Depending on weather and turfgrass density, mowing height was 5–7 mm in May and September and 3-4 mm from June to August. Information about irrigation and fertilizer inputs are given in Tables 6 and 7, respectively.

To avoid thatch accumulation, the trial was aerated with deep slitting knives every second week and with 8 mm needle tines once a month. Verticutting was accomplished every second week and topdressing with 0.1-0.7 mm finely graded sand at a rate of 1 kg per m2 every third week. The sand was brushed/irrigated into the green and the dressing was never done in close proximity to weighing of clippings.

Being located on a practise green, the experiment received wear from about 10.000 rounds of golf over the season. When placing holes on the green, care was taken to create as uniform wear as possible.

Table 7. Fertilizer inputs in green trial at Lepaa.

		Per ha							
Date	Fertilizer type	kg fertilizer	kg N	kg P	kg K	kg Mg	kg S	kg Ca	kg Fe
28.3.2007	Floratine Kevätstartti*	35	5.4	1.2	2.1				
5.4.2007	Floratine Kevätstartti	35	5.4	1.2	2.1				
19.4.2007	Floratine Kevätstartti	35	5.4	1.2	2.1				
26.4.2007	Sierraform Springstart (16-0-13)	250	40	0	32.5				2.50
15.5.2007	Sierraform All Season (18-3-15)	250	45	7.5	37.5	3.0			1.25
30.5.2007	Kemigreen Basic (23-4-14)	40	9	1.6	5.6	0.6	0.8		0.04
5.6.2007	Kemigreen Basic (23-4-14)	40	9	1.6	5.6	0.6	0.8		0.04
11.6.2007	Sierraform All Season (18-3-15)	250	45	7.5	38				
25.6.2007	Osmosol 614R (19-2-10)	40	7.6	0.8	4.0	0.5		1.7	0.04
2.7.2007	Osmosol 614R (19-2-10)	40	7.6	0.8	4.0	0.5		1.7	0.04
13.7.2007	Kemigreen Summer (18-0-17)	40	7.2	0	6.8			2.0	0.40
18.7.2007	Kemigreen Summer (18-0-17)	40	7.2	0	6.8			2.0	0.40
26.7.2007	Sierraform All Season (18-3-15)	250	45	7.5	37.5	3.0			1.25
14.8.2007	Kemigreen Summer (18-0-17)	40	7.2	0	6.8			2.0	0.40
27.8.2007	Greenmaster Autumn (6-2-8)	300	18	6	24	5.4			1.50
30.8.2007	Kemigreen Basic (23-4-14)	40	9	1.6	5.6	0.6	0.8		0.04
11.9.2007	Sierraform Springstart (16-0-13)	200	32	0	39				2.00
SUM			305	39	260	14.0	2.4	9.4	10

* Floratine Kevätstartti (Springstart) is composed of P-48 (10-21-6.6), Per 4 Max (15-0-0), Protesyn (3.5-0.6-1.8), and Plant Marvel (28-3-15).

3.4. Demonstration trials with Primo MAXX® at Ballerud Golf Course, Oslo, Norway

Experimental site and set-up

Ballerud GC is located on an old horticultural farm in a suburban area SW of Oslo. The course has greens with mostly dominated by creeping bentgrass, fairways almost exclusively dominated by annual meadowgrass, and smooth meadowgrass roughs with some tufts of perennial ryegrass (*Lolium perenne*).

Large-scale, unreplicated demonstration trials were laid out on green no. 9, fairway no. 9 and rough no. 9 on 5 June 2007. Plots sizes varied from 80 to 130 m^2. Unsprayed control plots were compared with plots sprayed with Primo MAXX® at rates 0.4, 1.5 and 2.2 l/ha and application intervals of approximately 3, 4 and 7 weeks on green, fairway and rough, respectively. In compliance with the Norwegian Food Authority's rule for complete closure of all sprayed areas for 48 h after each application, the trial on green no. 9 had to be discontinued after the second application on 18 June.

Three weeks later, it was replaced by a new trial laid out on the golf course' nursery green. Actual application dates in the green, fairway and rough trials are given in Table 8. The growth regulator was applied using a battery-operated electric Hardy Defender plot sprayer (Photo 4).

Table 8. Application dates for Primo MAXX in demonstration trials at Ballerud GC.

Green no. 9	Nursery green	Fairway no. 9	Rough no. 9
5 June		5 June	5 June
18 June			
	9 July	2 July	
	31 July	31 July	28 July
	21 Aug.		
	13. Sep.	3 Sep.	11 Sep.
	4 Oct.	28 Sep.	

Photo 4. Sprayer used in demonstrations trials at Ballerud Golf Course.

Photo: Terje Haugen.

Registrations

In all trials at Ballerud, turfgrass general appearance was evaluated by the headgreenkeeper at one to two week intervals throughout the growing season. In the green and fairway trials, turfgrass clipping yields were recorded on a fresh weight basis. Registrations in the green trials also included regular assessments of green speed using a standard stimpmeter.

Maintenance

The green trials at Ballerud were mowed daily at 3.4-3.8 mm and the fairway trial at 20 mm three to four times a week. The rough area was only mowed upon need.

Due to the rich soil from decades of vegetable production, the rough trial was not fertilized in 2007, and the fairway trial only received one application of 200 kg Fullgjødsel® 11-5-18 (22 kg N/ha) on 8 May. The green trials received monthly applications of granuar fertilizer (Gro Power 5-1-1, Anderson 14-0-9, Anderson 8-0-16, and/or Roots 12-2-12), and weekly applications of liquid fertilizers /

biostimulants, mostly Floratine products. Total rates of N, P, K, Mg, Ca, S and Fe over the season were 155, 14, 142, 27, 30, 73 and 14 kg/ha, respectively. The greens were aerated, mostly using Envirojet, six times during the season and top-dressed, also six times, giving a total of 6.3 kg sand per m^2.

Weather data and irrigation

Table 3 shows recordings from Ballerud GC's weather station. Although the rainfall in 2007 was higher than usual, there were periods, especially in May, June and August when the green trials needed irrigation. The fairway and rough trials were never irrigated.

Table 9. Weather recordings and irrigation at Ballerud GC, 2007. Monthly temperatures are means of daily maximum and minimum temperatures.

	Mean monthly temperature, °C	Monthly rainfall, mm	Monthly irrigation, mm (greens only)
May	11.2	94	42
June	17.1	185	52
July	16.9	173	10
Aug.	16.6	83	47
Sep.	11.1	71	21
Mean / sum	14.6	606	172

3.5. Demonstration trial with Primo MAXX® at Oslo Golf Club, Bogstad, Norway

To evaluate the effect of Primo MAXX® on a typical annual meadowgrass green, an unreplicated demonstation trial with plot size 250 m^2 was laid out at Oslo GK on 20 June 2007. Primo MAXX® was sprayed at a rate 0.4 l/ha on 20 June, 10 July and 31 July using the same sprayer as at Ballerud GC, about 10 km from Bogstad (Photo 4). Turfgrass quality (general appearance) and fresh weight clipping yields were determined on 4 July, 13 July and 14 August. Unfortunately, the trial had to be discontinued in mid August due to reconstruction of the green.

3.6. 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 on each plot and on plot values which had been averaged, either over the whole growing season, separately over the spring (before 10 June), summer (10 June – 1 Sep.) and autumn (after 1 Sep.) periods, or for observations conducted two versus four weeks after the last application of Primo MAXX®. The significance levels P%<0.1, P%<1, P%<5 and ns (not significant) have been indicated in the tables along with LSD values for effects significant at P%<5. In a few cases exact P-values have been given for tendencies in the 5-15% probability range. As an indications of the variability for each character, coeffcients of variation, (CV %), have also been given in the tables.

4. Results

4.1. Evaluation of Primo MAXX® under fairway conditions, Bioforsk Landvik, Norway

Turfgrass quality and related characteristics

Table 10 shows results from the visual observations of turfgrass quality and related characters in the fairway trial at Landvik. Both within the three seasons and as a mean value, turfgrass general appearance was significantly lower on plots receiving monthly applications of Primo MAXX® at 1.0 l/ha or higher rates than on unsprayed control plots and plots receiving 0.5 l/ha. Within these two groups, differences in generall appearance were not significant. Separate analyses for blocks 1 and 2 versus 3 and 4 indicated that these responses were practically identical regardless of botanical composition (data not shown).

Individual registrations of turfgrass quality are further depicted in Fig. 1. There was a dramatic decline in quality after the first application on 9 May. After this the turf recovered and there was no significant effect of Primo MAXX® at the two subsequent evaluations. Applications of 1.0 l/ha or higher rates on 4 July lead to new quality reductions in July, August and September (Photo 5); these effects were especially apparent at the last evaluation in early November (Photo 6). By contrast, there tended to be a small quality improvement due to the lowest rate of Primo MAXX® from late August to October. This improvement was reflected also in a significant increase in tiller density on average for the whole growing season (Table 10).

Increasing rates of Primo MAXX® consistently led to darker turf throughout the growing season, but also to earlier growth cessation and a less attractive dormancy colour in late autumn (Table 10). The only visible disease in the trial was a slight attack of red thread (*Laetisaria fuciformis*) during the wet period in July; however, these spots were unaffected by Primo MAXX® which also had no effect on the occurrence of broadleaved weeds, primarily white clover, in the trial.

Table 10. Turfgrass quality, tiller density, within-season colour, dormancy colour and infestation of weeds and red thread (*Laetisaria fuciformis*) in fairway at Landvik as affected by increasing rates of Primo MAXX®, 2007. Visual merit and tiller density are means of twelve observations (two in spring, i.e. before 10 June, six in summer, i.e. from 10 June to 1 Sep., and four in autumn, i.e. after 1 Sep. Within season colour (green darkness) and occurrence weeds and red thread are means of twelve, three (all in July) and two (June and Nov.) observations, respectively. Dormancy colour was evaluated on 2 Nov. All values are means of four blocks.

Primo MAXX®, rate	Turf quality (general appearance, 1-9)				Tiller density (1-9)	Within season colour (1-9)	Dor-mancy colour (1-9)	% of plot area	
	Mean	Spring	Summer	Autumn				Dicot weeds	Red thread
0 = Control	6.2	6.1	6.4	6.0	6.3	5.2	6.8	4	4
0.5 l/ha	6.1	5.6	6.3	6.2	6.5	5.6	6.3	2	3
1.0 l/ha	5.5	4.5	5.9	5.3	6.1	5.8	5.0	5	2
1.5 l/ha	5.3	4.6	5.5	5.4	6.0	5.9	4.1	4	3
2.0 l/ha	5.5	4.6	5.9	5.3	6.1	6.0	4.3	3	2
3.0 l/ha	5.1	4.2	5.5	4.9	6.0	6.2	3.5	4	3
P%	<0.1	<0.1	<1	<0.1	<1	<1	<0.1	ns	ns
LSD 5%	0.3	0.5	0.4	0.4	0.2	0.4	1.2	-	-
CV%	4	7	5	5	3	5	15	-	-

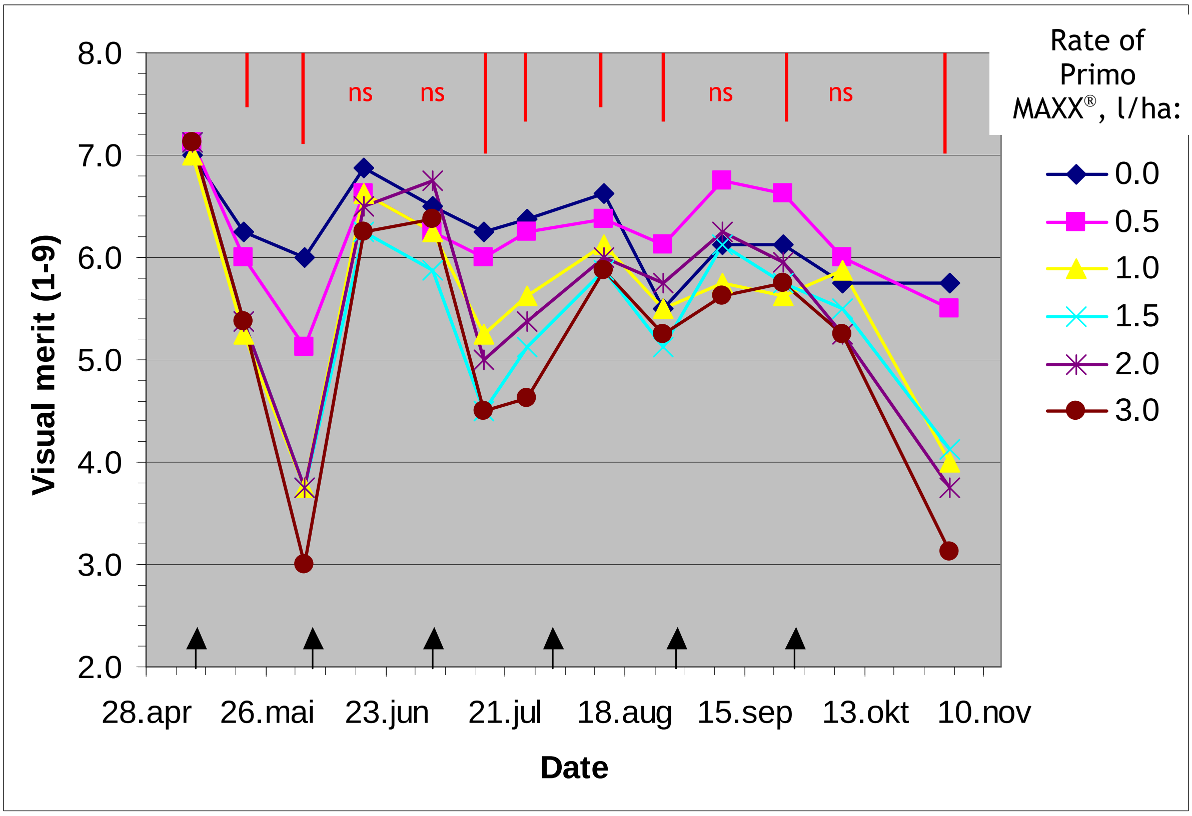


Fig.1. Turfgrass overall quality as affected by increasing rates of Primo MAXX® in fairway trial at Landvik, 2007. Mean of four replicates (blocks). The application dates 9 May, 5 June, 4 July, 31 July, 28 Aug. and 26. Sep. are indicated by black arrows. Red bars indicate LSD 5%.

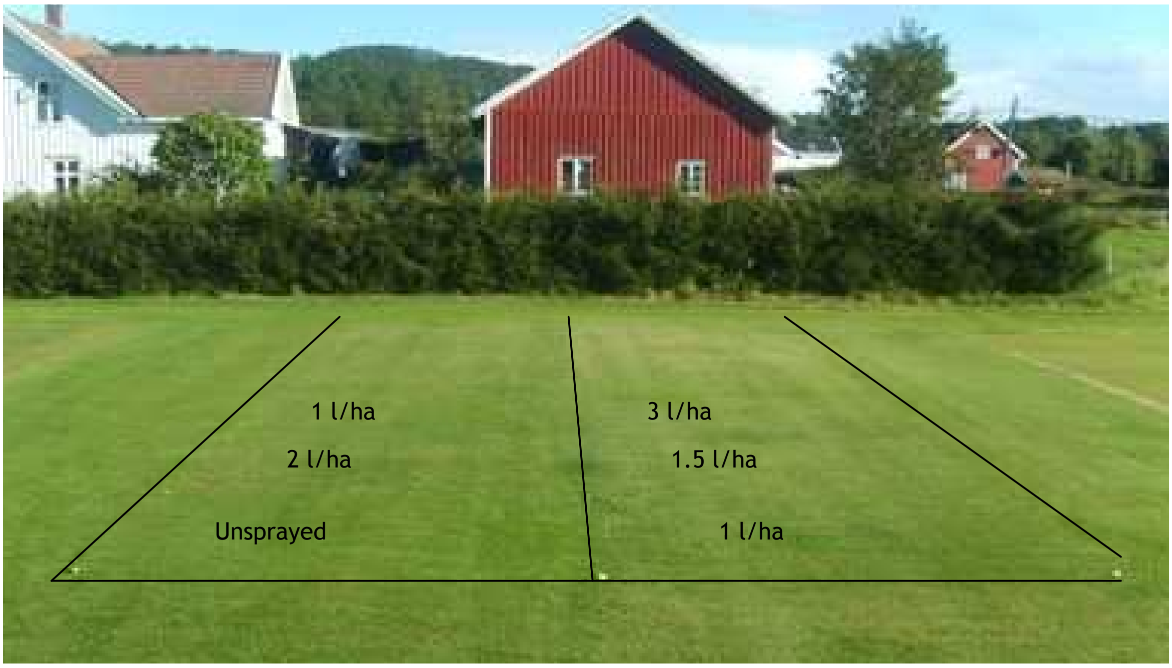


Photo 5. Visual appearance of fairway trial at Landvik, block 1 and 2, on 10 Sept. Within each block, the treatments closest to the photographer have been labeled. High rates of Primo MAXX® resulted in darker, in some cases, almost brown, turf. Photo: Trygve S. Aamlid.

Photo 6.

Turf quality / dormancy colour at growth cessation on 2 Nov. 2007 after application of Primo Maxx at 3.0 l/ha (left) and 0.5 l/ha (right), last application on 26 Sep.

Photo: Trygve S. Aamlid.

Turfgrass height and dry matter production

The average effect of Primo MAXX® on plant height and clipping yields are given in Table 11. In all blocks, the growth regulator caused a significant reduction in plant height even at the lowest rate, but contrary to expectation, this low rate also tended to increase aboveground dry matter production as compared with the unsprayed control treatment. This might reflect a higher tiller density, as also suggested in Table 10. Separate analyses for various parts of trial showed that the average reduction in clipping yield due to Primo MAXX® was stronger in blocks 1 & 2 which had more *Poa* species less red fescue and browntop bent and than blocks 3 & 4. On average for eleven harvests and all replicates, there was a slight tendency for Primo MAXX® to increase the dry matter percentage of turfgrass clippings (P% = 16, Table 11).

Table 11. Absolute and relative effects of increasing rates of Primo MAXX® on turfgrass height, turfgrass dry matter production, and per cent dry matter of clippings in fairway trial at Landvik, 2007. Mean of eleven observations. Plant height above 15 mm represents an average of four days' growth.

Primo MAXX, rate	Plant height, mm		Production of turfgrass clippings, g/m^2/day				% dry matter in clippings
	mm	Rel.	Block 1&2	Block 3&4	Mean	Rel.	
0 = Control	21.9	100	1.78	1.62	1.70	100	31.5
0.5 l/ha	20.9	95	1.91	1.93	1.92	113	32.2
1.0 l/ha	20.7	95	1.65	1.72	1.69	99	32.5
1.5 l/ha	20.0	91	1.46	1.46	1.46	86	33.6
2.0 l/ha	20.3	93	1.55	1.61	1.58	93	32.4
3.0 l/ha	19.5	89	1.31	1.70	1.51	88	33.1
P%.	<0.1	-	10	ns	<5	-	16
LSD 5%	0.7	-	-	-	0.29	-	-
CV%	2	-	10	14	12	-	3

In absolute terms, turfgrass clipping yield showed a distinct seasonal pattern with peaks during the warm and sunny periods in early June and late August (Fig. 2a). The low clipping yield on 17 July was probably due to 280 mm rainfall, and thus nutrient leaching, since the last fertilizer application on 12 June (Tables 3 and 4). Separate analyses of variance for each day indicated a significant effect of Primo MAXX® on clipping yield only on 4 June.

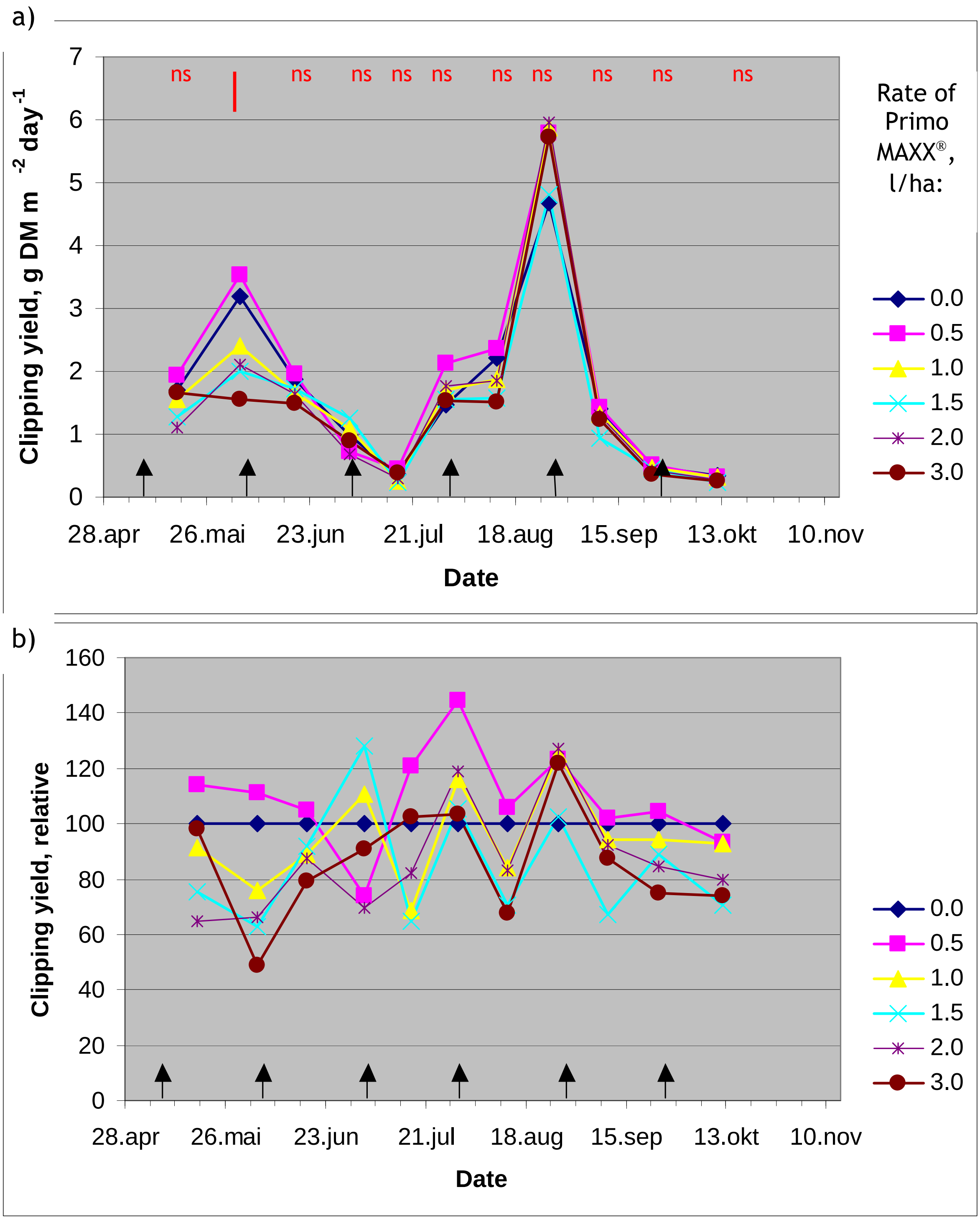


Fig. 2. Absolute (a) and relative (b) reductions in daily dry matter production of turfgrass clippings as affected by increasing rates of Primo MAXX® in fairway trial at Landvik. Red text/bars and black arrows indicate probability / LSD values and application dates 9 May, 5 June, 4 July, 31 July, 28 Aug. and 26 Sep., respectively. In (b), the clipping yield on each date was set to 100 in the unsprayed control treatment.

In relative terms, none of the Primo MAXX® treatments produced clipping yields that were lower than the unsprayed control at all harvests (Fig. 2b). Many of the treatments showed a typical suppression / rebound pattern with clipping yields lower than the control treatment at one harvest, but higher than control treatment at the next harvest.

4.2. Evaluation of Primo MAXX® on a golf course fairway, Lepaa, Finland

On average for two observations in spring, five observations in summer and two observations in autumn, Primo MAXX® had no effect on turfgrass general appearance in the fairway trial at Lepaa. Among the nine observation dates, significant differences were recorded only on 21 August when the plots sprayed with the highest dose (3.0 l/ha) had an average visual merit score of 5.5 as opposed to 6.8 for unsprayed control plots and plots sprayed with the lowest dose (0.5 l/ha).

On average for observations, increasing rates of Primo Max caused an overall increase in tiller density, while turfgrass colour was not significantly affected. No diseases were observed during the growing season.

Table 12. Turfgrass quality (1-9, 9 is best quality), tiller density (1-9, 9 is highest density) and within-season colour (1-9, 9 is darkest green) in fairway trial at Lepaa as affected by increasing rates of Primo MAXX®. Means of nine observations (two in spring, i.e. before 10 June, five in summer, i.e. from 10 June to 1 Sep., and two in autumn, i.e. after 1 Sep.). All values are means of four blocks.

Primo MAXX®, rate	Turf quality (general appearance, 1-9)				Tiller density (1-9)	Within season colour (1-9)
	Mean	Spring	Summer	Autumn		
0 = Control	6.1	5.5	6.1	6.8	5.5	6.1
0.5 l/ha	6.2	5.5	6.1	7.0	5.8	6.2
1.0 l/ha	6.1	5.4	6.1	6.9	5.8	6.1
1.5 l/ha	6.2	5.5	6.2	7.0	6.0	6.3
2.0 l/ha	6.2	5.6	6.1	6.9	6.1	6.3
3.0 l/ha	6.2	5.6	6.1	7.0	6.4	6.2
P%	ns	ns	ns	ns	<0.1	ns
LSD 5%	-	-	-	-	0.4	-
CV%	5	4	8	3	3	4

The effect of Primo MAXX® on turfgrass plant height and clipping yield depended on the time since last application. On average for five observations conducted about two weeks after application, the highest rate of Primo MAXX® caused significant reductions in plant height and clipping yield corresponding to 11 and 48 %, respectively (Table 13). On average for four observations conducted four weeks after application, the maximal reductions were only 3 and 14 %, respectively. Fig. 3 illustrates the unstable effect of Primo MAXX®, particularly toward the end of the growing season. However, unlike in the fairway trial at Landvik (Fig.2), clipping yields on sprayed plots were rarely higher than on untreated control plots in the trial at Lepaa.

Table 13. Absolute and relative effects of increasing rates of Primo MAXX® on turfgrass height and dry matter production in turfgrass clippings in fairway trial at Lepaa 2007. Observations conducted 2 weeks (5 observations) and 4 weeks (4 observations) from spraying treatment have been presented separately.

Treatment	Plant height (mm)				Weight of clippings (g DM / m^2 / day)			
Time after treatment	2 weeks	4 weeks	Mean	Rel	2 weeks	4 weeks	Mean	Rel
0 = Control	15.7	16.0	15.8	100	3.2	7.0	4.9	100
0.5 l/ha	15.7	16.0	15.8	100	2.7	6.3	4.3	87
1.0 l/ha	14.9	16.0	15.4	97	2.8	6.6	4.5	92
1.5 l/ha	14.7	15.7	15.1	96	2.3	5.8	3.9	79
2.0 l/ha	14.4	15.6	15.0	95	2.1	6.1	3.9	80
3.0 l/ha	14.0	15.5	14.6	92	1.8	6.0	3.7	75
P%	<0.1	ns	<5	-	<0.1	ns	ns	-
LSD 5%	1.1	-	1.0	-	0.7	-	-	-
CV%	3	4	3	-	13	22	18	

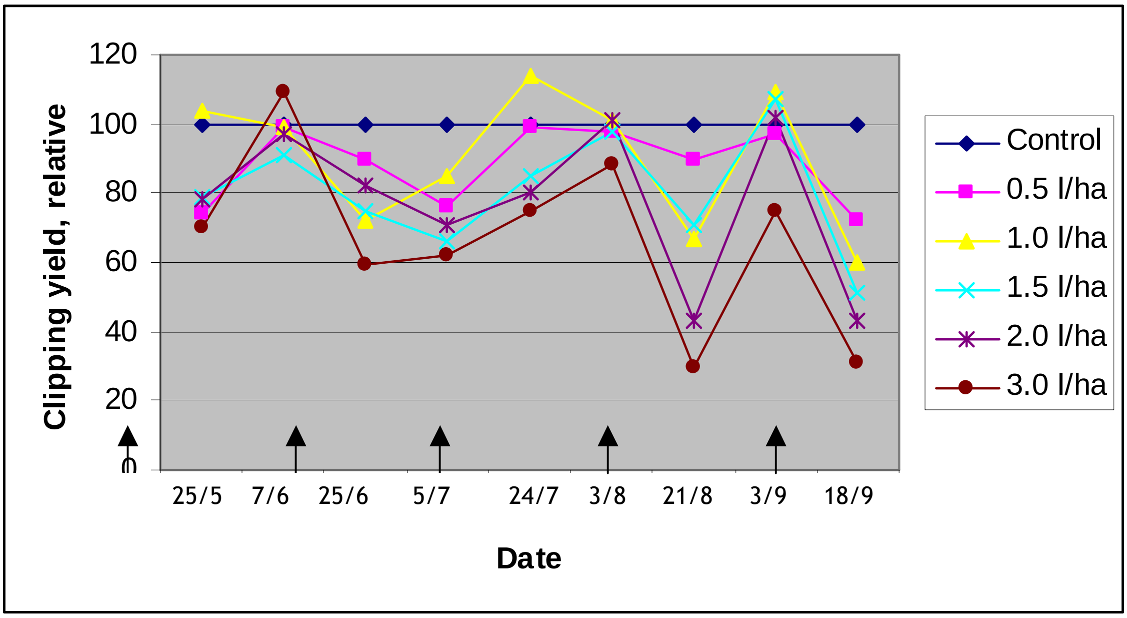


Fig. 3. Relative clipping weights (control = 100) in fairway trial at Lepaa, Finland. Spraying treatments indicated by black arrows were carried out on 11 May, 8 June, 5 July, 3 Aug. and 4 Sep. (The last spraying on 4 Oct. was done primarily to study the effect of Primo MAXX® on overwintering and was not followed by observations in late autumn.)

4.3. Evaluation of Primo MAXX® on a golf course putting green, Lepaa, Finland

On 3 Sep. 2007, a significantly higher tiller density was recorded on green plots sprayed with the highest rate of Primo MAXX® than on unsprayed control plots (data not shown). Otherwise, Primo MAXX® had no significant effect on either general appearance, tiller density or turfgrass colour in the green trial at Lepaa (Table 14). Although the effects on plant height and clipping yields were also not significant, reductions were generally stronger when recorded at two compared with four weeks after application (Table 15, Fig. 4).

Table 14. Turfgrass quality, tiller density and within-season colour (darkness) in green trial at Lepaa as affected by increasing rates of Primo MAXX®, 2007. Means of nine observations (two in spring, i.e. before 10 June, five in summer, i.e. from 10 June to 1 Sep., and two in autumn, i.e. after 1 Sep.). All values are means of four blocks.

Primo MAXX®, rate	Turf quality (general appearance, 1-9)				Tiller density (1-9)	Within season colour (1-9)
	Mean	Spring	Summer	Autumn		
0 = Control	6.4	6.1	6.6	6.3	6.3	6.4
0.2 l/ha	6.3	6.0	6.5	6.0	6.3	6.4
0.4 l/ha	6.3	5.9	6.5	6.1	6.2	6.3
0.6 l/ha	6.3	5.8	6.5	6.4	6.3	6.4
0.8 l/ha	6.2	5.8	6.4	6.3	6.2	6.4
P%	ns	ns	ns	ns	ns	ns
LSD 5%	-	-	-	-	-	-
CV%	3	5	5	7	2	3

Table 15. Absolute and relative effects of increasing rates of Primo MAXX® on turfgrass height and dry matter production in turfgrass clippings in green trial at Lepaa 2007. Observations conducted 2 weeks (5 observations) and 4 weeks (4 observations) from spraying treatment have been presented separately. Plant heights above 3 mm represent one day's growth.

Treatment	Plant height (mm)				Weight of clippings (g DM / m^2 / day)			
Time after treatment	2 weeks	4 weeks	Mean	Rel	2 weeks	4 weeks	Mean	Rel
0 = Control	4.3	3.9	4.1	100	2.60	2.21	2.43	100
0.2 l/ha	4.1	3.8	4.0	96	2.20	2.28	2.23	92
0.4 l/ha	4.0	3.9	3.9	95	1.88	2.28	2.06	85
0.6 l/ha	4.0	3.8	3.9	94	1.72	2.18	1.99	82
0.8 l/ha	3.8	3.9	3.9	93	1.75	2.28	1.92	79
P%	11	ns	ns	-	5	ns	ns	-
LSD 5%	-	-	-	-	0.9	-	-	-
CV%	6	7	8	-	20	14	16	-

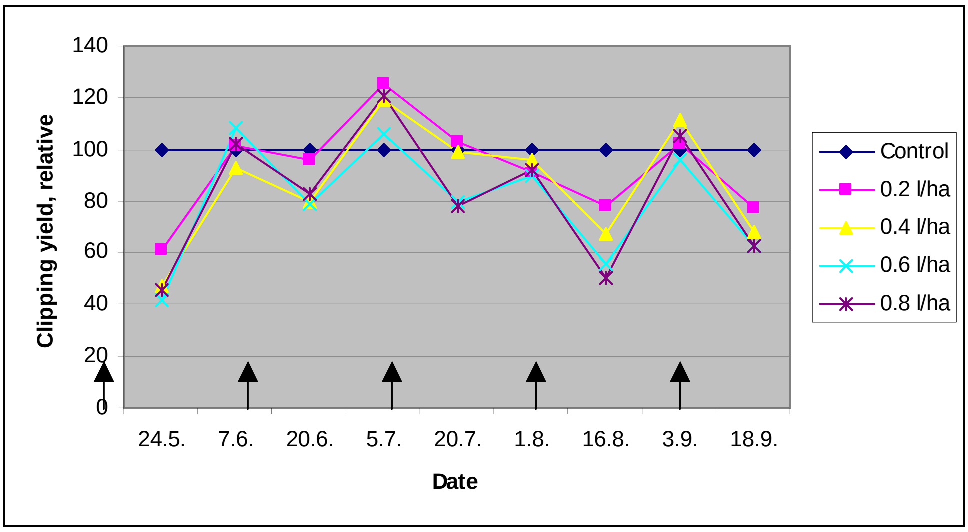


Fig. 4. Relative clipping weights (control = 100) in green trial at Lepaa, Finland. Spraying treatments indicated by black arrows were carried out on 11 May, 8 June, 5 July, 3 Aug. and 4 Sep. (The last spraying on 4 Oct. was done primarily to study the effect of Primo MAXX® on overwintering and was not followed by observations in late autumn.)

4.4. Demonstration trials with Primo MAXX® at Ballerud Golf Course, Oslo, Norway

Green trials

Applications of 0.4 l/ha Primo MAXX® on 5 and 18 June did not affect turf general appearance (Photo 7) or stimpmeter readings on green no. 9 at Ballerud. During the period 14-29 June, clippings were reduced by an average of 32%, but after spraying had been discontinued, there was a rebound effect corresponding to a 26 % increase in clipping yield in the period 12-25 July (data not shown).

Photo 7. Terje Haugen (left) and Lasse Augustsson on green no. 9 at Ballerud Golf Course, 27 June 2007. Photo: Trygve S. Aamlid.

Photo 8. Field day at Ballerud Golf Course 27 Aug. 2007. Photo: Tatsiana Espevig.

Fig. 5 summarizes results from the nursery green trial established on 9 July. In this trial, application of Primo MAXX® about every third week resulted in better colour (not shown), higher green speed (Fig. 5a), and an average reduction in turfgrass clippings of 44 % (Fig. 5b and c). Fig 5b shows that the reduction in clipping yield was most conspicuous during the periods of rapid growth in mid to late July (after only one application of Primo MAXX®) and in late August.

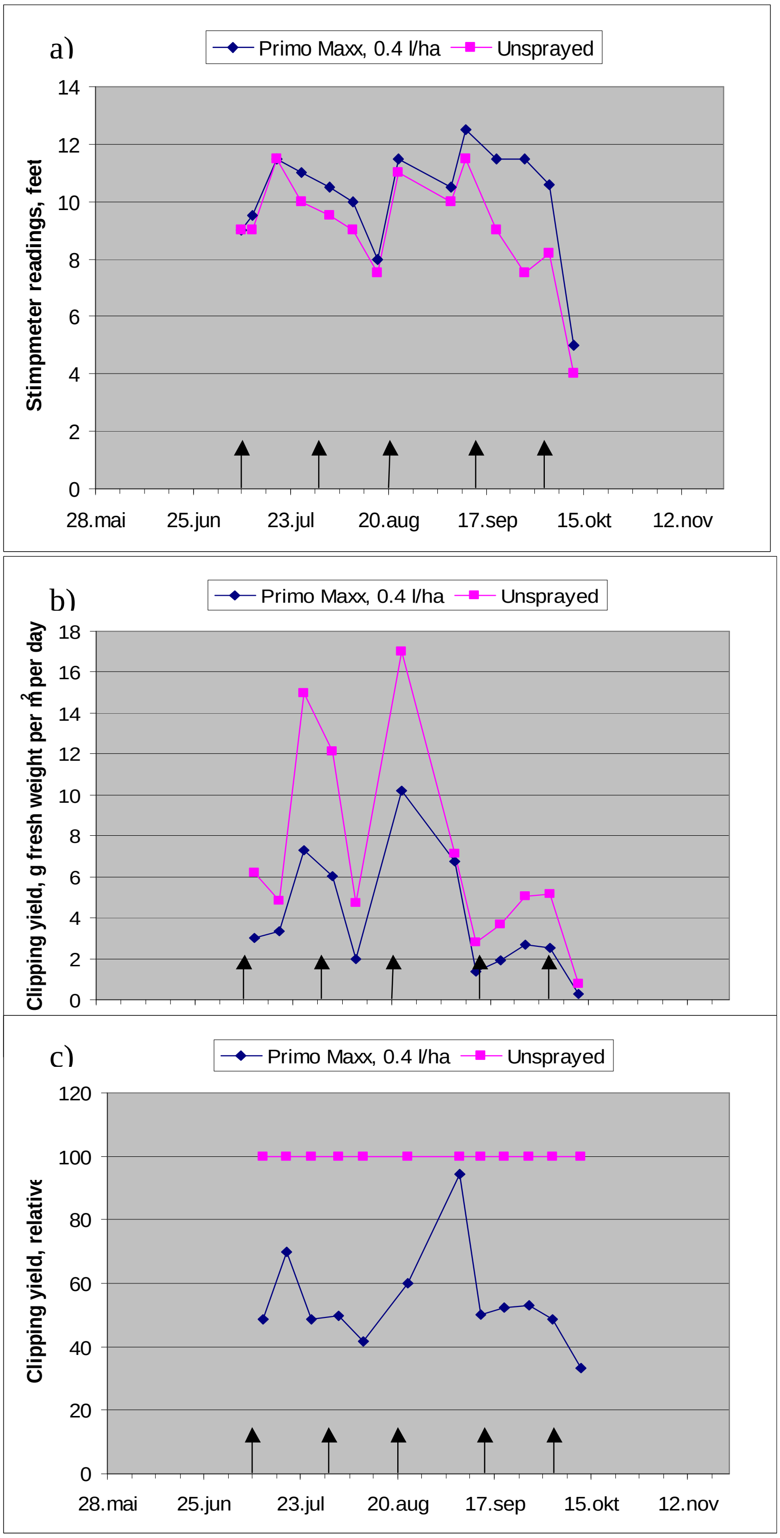


Fig. 5. Effects of spraying Primo MAXX® every three weeks of green speed and absolute and relative clipping yield on nursery green at Ballerud GC, 2007. Black arrows indicate the application dates 9 July, 31 July, 21 Aug., 13 Sep. and 4 Oct.

Fairway trial

As evaluated by the headgreenkeeper, monthly applications of 1.5 l/ha Primo MAXX® (1.5 l/ha) had no negative impact on turf quality in the fairway trial at Ballerud (Fig. 6). Photos 9-11 show, nevertheless, that treated turf was more faded, grayish, and less green than untreated turf. The pronounced colour difference in favour of Primo MAXX® in early September (Fig. 6) was due to less dry spots than the in the control area. While these spots recovered after rainfall on 10 and 17 Sep., the last application of Primo MAXX® on 4 Oct. led to an apparent loss of colour and drop in turf general appearance in late autumn (Photo 11).

On average for 17 clipping, regular application of Primo MAXX® resulted in a 37 % reduction in the fresh weight of turfgrass clippings (Fig. 7). The only time clipping yield was higher on the treated than on the untreated area was at the first clipping nine days after the first application and on 7 Sep. The latter coincided with the observation of less dry spots after use of Primo MAXX®. It may also be interpreted as a rebound effect following growth suppression after application on 31 July.

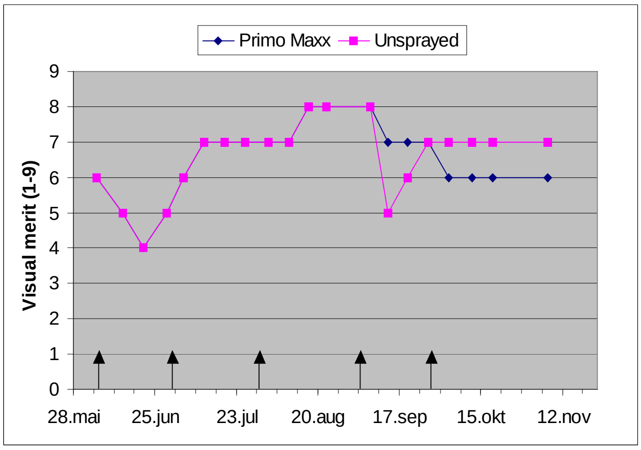
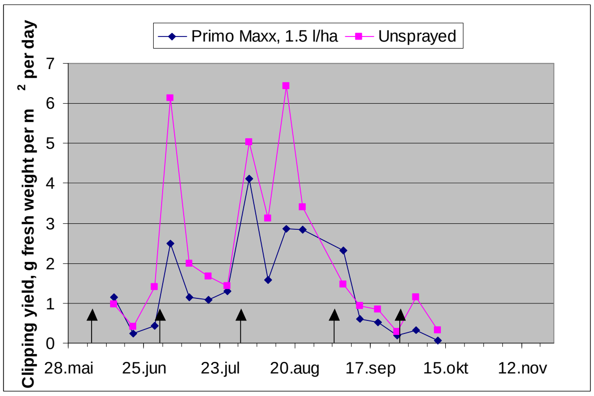


Fig. 6. Effect of Primo MAXX® on turfgrass general appearance in fairway trial at Ballerud GC. Black arrows indicate application dates. (Sprayed an unsprayed plots had identical scores until the beginning of September)

Photo 9. Difference in colour and general appearance of treated and untreated fairway Ballerud GC, 27 June. Photo: Trygve S. Aamlid.

Photo 10. Difference in colour and general appearance of treated and untreated fairway Ballerud GC, 27 Aug. Photo: Tatsiana Espevig.

Photo 11. Difference in colour and general appearance of treated and untreated fairway Ballerud GC, 3 Dec. Photo: Terje Haugen.



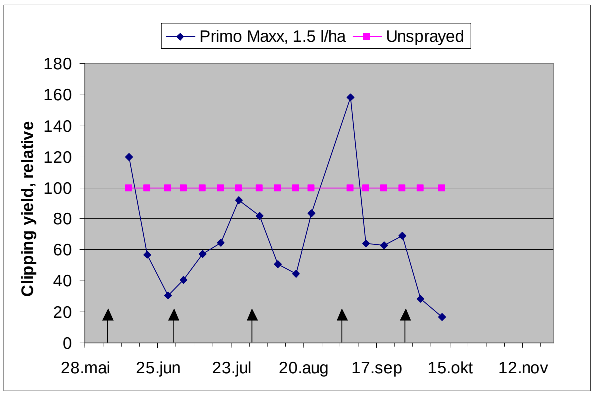


Fig. 7. Absolute (a) and relative (b) reductions in clipping yield resulting form application of Primo MAXX® in fairway trial at Ballerud GC. Arrows indicate application dates.

Spraying 2.2 l/ha of Primo MAXX® at six weeks interval resulted in discoloration and consistent drop in turf quality in the rough trial at Ballerud (Fig. 8, Photos 12 and 13). The effect was most conspicuous in late autumn. Primo MAXX® had less effect on tufts of perennial ryegrass which stood out very markedly in the turf which was otherwise dominated by smooth meadowgrass. Clipping yields were not recorded in this trial.

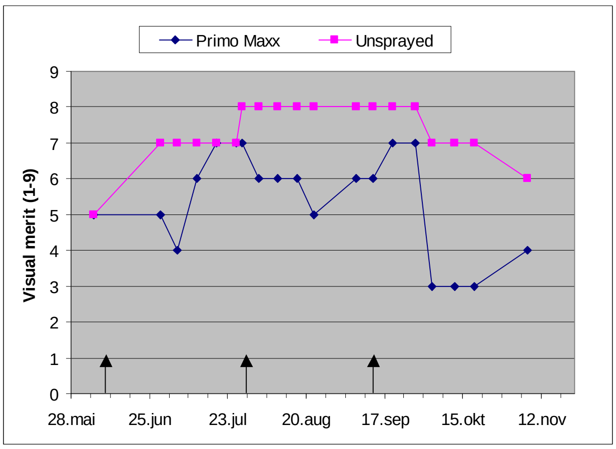


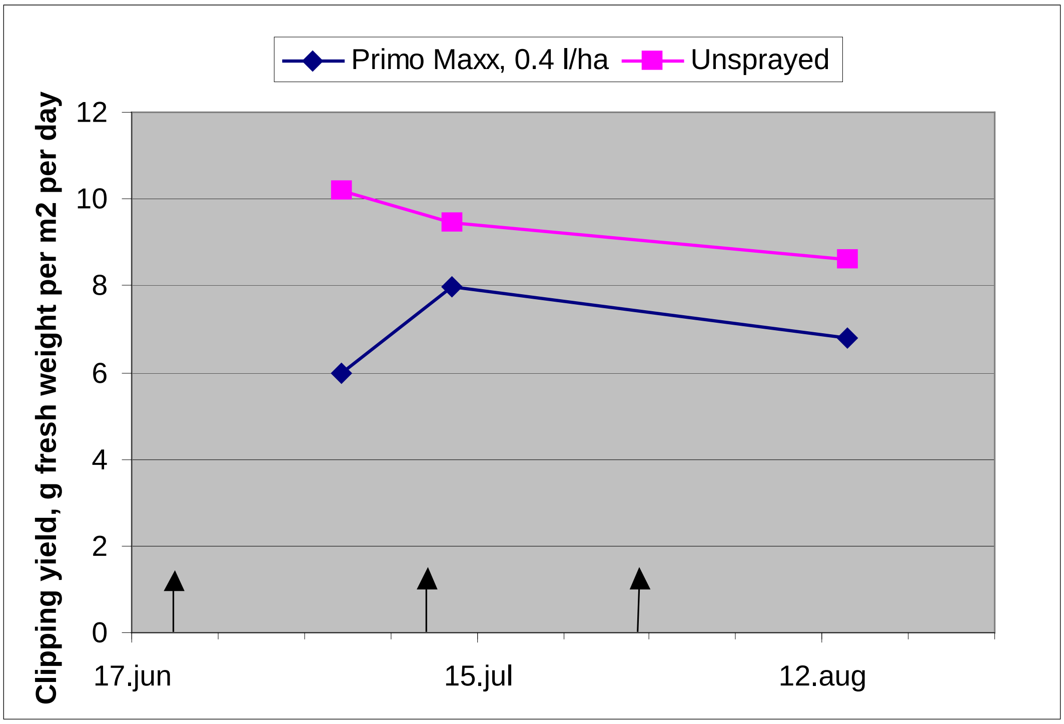
Fig. 8 (upper left). Difference in colour and general appearance of treated and untreated area in rough no 9, Ballerud, 27 June. Photo: Trygve S. Aamlid.

Photo 12 (upper right). Terje Haugen (left) and Lasse Augustsson in rough trial at Ballerud GC, 27 June. Photo: Trygve S. Aamlid.

Photo 13 (lower left). Trygve S. Aamlid inspecting rough trial at Ballerud GC, 27 August 2007. Tufts of ryegrass stand out very markedly on sprayed area.
Photo: Tatsiana Espevig.

4.5. Demonstration trial with Primo MAXX® at Oslo Golf Club, Bogstad, Norway

Application of 0.4 l Primo MAXX® at three week intervals resulted in darker turf but had otherwise no effect on the turfgrass quality of annual meadowgrass at Oslo GC. On average for three registrations, the Primo MAXX led to a 26% reduction in clipping yields (Fig. 9).



5. Discussion and suggestions for 2008

The starting point for evaluating Primo MAXX® in this two-year project was the rates and applications frequencies recommended for the product in Europe (Syngenta 2007, Table 16). Based on our experiences from agricultural crops that the optimal rates may be different in the Nordic countries than countries further south, higher and lower rates were included in the GEP trials both to determine the potential growth inhibition and the risk for discoloration or other phytotoxic effects. All taken together, the results from the first project year confirms that the guidelines in Table 16 are not directly applicable in Scandinavia and that further research is needed to find the optimal way of using the product under Nordic conditions.

Table 16. Dose rates and applications frequencies recommended for Primo MAXX® in the United Kingdom (Syngenta 2007).

	Dose rate		Application
	Primo MAXX®, l/ha	trinexapac-ethyl, g a.i./ha	frequency
Fairways	0.8 – 1.6	90 - 180	Every four to five weeks
Roughs & semi-roughs	1.6-2.4	180 - 240	Every five to eight weeks
Greens	0.4	45	Every two to four weeks

On fairway, the average reduction in clipping yield caused by monthly application of the intermediate Primo MAXX® rate of 1.5 l/ha was 15 and 21 % in the GEP trials at Landvik and Lepaa, respectively. By contrast, monthly application of 1.5 l/ha resulted in a 37 % reduction in clipping yield in the demonstration trial at Ballerud GC, which is closer to the data presented by Syngenta (2007). In agreement with Table 11 showing an increase in turfgrass dry matter percentage (i.e. decreased succulence) after application of Primo MAXX®, one of the reasons for this difference might be that clipping yields were determined on a dry weight basis in the GEP trials but on a fresh weight basis at Ballerud GC and in the data presented by Syngenta (2007). Another, and probably more important explanation, is the difference in species composition among the three trials. While the plant cover at Ballerud was almost 100% by annual meadowgrass, the species composition at Landvik varied with the two blocks showing the least response to Primo MAXX® having a plant cover of 74 % red fescue (Tables 1 and 11). By contrast, smooth meadowgrass dominated over red fescue at Lepaa due to the heavy soil type, use of irrigation, and relatively high nitrogen input. Unfortunately, we have not been able to find many references about the specific effects of Primo MAXX® on red fescue turf, but our results are in partial agreement with Pannacol et al. (2004) who found 40 %, 21 %, and no significant reduction in clipping yield after using trinexapac-ethyl in smooth meadowgrass, chewing fescue and creeping red fescue, respectively.

Perhaps the most conspicuous feature of the present results was the unstable effect of Primo MAXX® on clipping yields due to the postsuppression rebound effect. In the fairway trial at Lepaa, Finland, this resulted in clipping yield reductions being significant only two weeks after application (Table 13), and a similar tendency could be seen also in the green trial (Table 15). In Norway, clipping yields four weeks after spraying were often higher than on unsprayed control plots in the fairway trial at Landvik (Fig. 2), and a strong rebound effect was observed also after spraying treatments had to discontinued at green no. 9, Ballerud GC. The unstable effect in of Primo MAXX® in these trials was probably due to a rapid degradation of trinexapac-ethyl in plant tissue and a higher regrowth potential due to accumulation of carbohydrate reserves and GA_1 precursors during the suppression phase (Lickfeldt et

al. 2001, Branham & Beasley 2007). In North-American experiments, Lickfeldt et al. (2001) reported clipping yields reductions in smooth meadowgrass to be much more consistent when trinexapac-ethyl was applied at four than at six week intervals, but under Nordic long-day conditions, spraying every second, or at least every third week, may well be necessary to stabilize low GA_1 levels, not only on greens, but also on fairways and tees. Although there was a surge effect during the driest period in mid September, the most stable clipping reductions in our trials, on average 44 % on a fresh weight basis, were, indeed, obtained on the nursery green which was sprayed about every third week at Ballerud GC (Fig. 5c). While Branham & Beasley (2007) noted that temperature was the most important factor determining degradation of trinexapac-ethyl in turfgrass tissue, our results suggest that other factors such as light and water availability may also be important for the rebound effect under Nordic conditions. Very clearly, application frequency is a major question that has to be addressed during the continuation of this project.

The potential reductions in mowing costs from using a plant growth regulator will always have to be weighed against the risks for discoloration or other harmful effects on turf quality. In the present trials, reductions in general appearance (visual merit) scores were far more conspicuous in the GEP trial at Landvik than in the GEP trials at Lepaa or the demonstration trials at Ballerud GC. Apart from possible effects of different botanical compositions, this might reflect a subjective human factor, i.e. different backgrounds and attitudes of the observers in the various trials. While the fairway trial at Landvik was evaluated by turfgrass scientists and technicians with long experience from turfgrass variety testing, the trials at Lepaa and Ballerud were evaluated by greenkeepers working on the course. While the observers at Landvik may have paid more attention to turf aesthetic values such as less intense colour, and less vigorous and uniform plots, the observers at Lepaa and Ballerud may well have been more attentive to ball roll and other functional characteristics of the playing surface. The less succulent but significantly darker green turf resulting from high Primo MAXX® rates at Landvik are in agreement with other studies showing higher mesophyll cell densities and chlorophyll concentrations resulting from less elongation of leaf cells (Heckman et al. 2001, Ervin & Zhang 2008). As for tiller density, most literature supports the Finnish rather than the Norwegian results; i.e. enhanced tillering after Primo MAXX® application (Branham & Beasley 2007, Ervin & Zhang 2008).

As compared with the unsprayed control treatment, the strongest negative effect of Primo MAXX® on turfgrass general appearance at Landvik was recorded after the first spraying in early June, in mid July and at the last observation in early November. Each of these observations might be explained by suboptimal conditions causing reduced turfgrass growth. From 6 to 15 June there was a dry and warm and period with maximum temperatures in the range 25-30 ºC that obviously reduced turfgras tillering and aesthetic appearance; until mid July exceptional rainfalls starting on 22 June were not compensated by increase nitrogen inputs, and in autumn, the last application of Primo on 26 September was followed by several nights of frost. Although most studies have failed to document significant interactions between nitrogen and trinexapac-ethyl on turfgrass quality (Steinke & Stier 2001, Goss et al. 2002, McCullogh et al. 2006), it seems reasonable to assume that potential negative effects on Primo MAXX® on turfgrass quality will be most pronounced under suboptimal growing conditions. As in the trials at Landvik (Photo 6) and Ballerud (Photo 11), Beam et al. (2002) reported significant discoloration of trinexapac-ethyl-treated smooth meadowgrass following frost in autumn.

Undoubtedly, the most convincing argument for official approval of Primo MAXX® on Nordic golf courses would be a clear documentation that it improves winter survival. Preliminary results with annual meadowgrass suggested that low rates of trinexapac-ethyl prevented winter injury, whereas high rates had opposite effects due to discoloration during the hardening phase in late autumn (Rossi & Buelow 1997). While trinexapac-ethyl has been shown to increase water soluble carbohydrate contents (Goss et al. 2002) and result in faster spring greenup, Ervin & Zhang (2008) recently called for more detailed investigations into the effect of trinexapac-etyl on freezing tolerance as the research to date has provided scarce information on this aspect. Under Nordic conditions, desiccation if growth resumes when soils are still frozen and irrigation not yet operational in spring, or damage due to unstable winters with ice and water covering the turf, sometimes resulting in suffocation, appear to be more

important that direct freezing injury. In this regard, trineexapac-ethyl may well have a positive effect as it reduces mitochondrial respiration (Ervin & Zhang 2008). In 2008, it will therefore be very interesting to study winter injury and spring green-up and recovery in the on-going trials at Landvik, Lepaa and Ballerud which all had their last application of Primo MAXX® in late September or early October.

Even with winter survival and spring observations included, the amount of data presented in this report is too limited to recommend any listing of Primo MAXX® for turf use in the Nordic countries. Therefore, as stated in the contract between Syngenta and Scandinavian Turfgrass and Environment Research Foundation, there is a need for new GEP trials to be started in spring 2008 and followed until registration of winter survival in spring 2009. For this purpose, a new experimental green was constructed and seeded to creeping bentgrass at Landvik in 2007. In the trial to be established on this green in spring 2008, we suggest to compare Primo MAXX® at three rates (0.15, 0.30 and 0.45 l/ha) and two application frequencies (every 10/11 days and every 21 days), i.e. six combinations plus an unsprayed control treatment. As different grass species seem to vary in their response to Primo MAXX®, similar trials should preferably be carried out on also red fescue/browntop greens and velvet bentgrass greens, although this would require additional funding from Syngenta/STERF.

In Finland, a new GEP trial will be established in spring 2008 on a fairway that is regularly subjected to winter injury. New demonstration trials might be added to the project depending on interest from superintendents and funding from the national golf unions.

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

Results from the first evaluation year 2007

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Finnish team spraying fairway trial at Lepaa Golf Course.
Photo: Oiva Niemelainen

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Summary:

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

Sammendrag:

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

Approved

Arne Sæbø	Trygve S. Aamlid
Leader, Bioforsk's Section for Urban Greening	Project leader

Contents

1. Abstract

As an inhibitor of the last step in plant synthesis of bioactive gibberellin (GA_1), the plant growth regulator Primo MAXX® (trinexapac-ethyl) offers prospects of reduced energy use for mowing and improved turfgrass quality under Nordic long day conditions. This report presents first year results from 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 possible registration of Primo MAXX®, unreplicated demonstration trials were carried out at Ballerud and Bogstad Golf Courses in Oslo under supervision of Bioforsk and with funding from the Norwegian Golf Federation (NGF).

GEP trials on **fairways** (mowing height 12-18 mm) were carried out at Bioforsk Landvik, Norway (58°34'N, 8°52'E) and at the Lepaa Unit of the HAMK University of Applied Sciences, Finland (61°08'N, 24°20'E). Primo MAXX® was applied at monthly intervals at rates 0.5, 1.0, 1.5, 2.0 and 3.0 l/ha (56.5, 113, 169.5, 226 and 339 g a.i./ha trinexapac-ethyl) in comparison with an unsprayed control treatment. Turfgrass general appearance, tiller density, colour, height growth, and clipping yields were recorded two and four weeks after each application. Primo MAXX® had no effect on turfgrass general appearance but increased density at Lepaa. At Landvik, Primo MAXX® (>= 1.0 l/ha) reduced turfgrass general appearance and density, but resulted in significantly darker green colour. Quality reductions were most apparent during periods with either daily maximum temperatures >25 ºC, extreme rainfall probably causing nitrogen deficiency, or frost at night. Average reductions in clipping yield caused by Primo MAXX® (>= 1.0 l/ha) were 8 % in the GEP trial at Landvik, 18 % in the GEP trial at Lepaa and 37 % in the demonstration trial at Ballerud; to some extent this difference may be due to different botanical composition with red fescue (*Festuca rubra*) and annual meadowgrass (*Poa annua*) being the predominant species at Landvik and Ballerud, respectively. Clipping yield reductions due to Primo MAXX® were unstable, growth suppression two weeks after application often being followed by a rebound effect during the remaining two weeks until next application.

A GEP trial on creeping bentgrass **putting greens** was carried out at Lepaa, Finland, and demonstration trials at Ballerud and Bogstad, Norway. Primo MAXX® was sprayed at rates 0.2, 0.4, 0.6 or 0.8 l/ha at monthly intervals in the GEP trial, and at 0.4 l/ha every three weeks in the demonstration trials. On average for all observations, Primo MAXX® had no effect on turfgrass quality, but clipping yields were reduced by 16, 44 and 26% at Lepaa, Ballerud and Bogstad, respectively. As in the fairway trials, growth suppression at Lepaa was stronger when assessed at two than at four weeks after application. By contrast, Primo MAXX® produced a fairly stable effect when applied at three week intervals in the demonstration trials.

Use of Primo MAXX® on golf course **roughs** was investigated only in a demonstration trial at Ballerud. Application of 2.2 l/ha of Primo MAXX® every seven weeks resulted in discolouration and reduced quality of smooth meadow grass.

In conclusion, the first year of this project has shown that the guidelines for use of Primo MAXX® in other European countries are not directly applicable in Scandinavia. As the present results are too limited to apply for registration of Primo MAXX®, the project will continue in 2008 tentatively with new trials investigating application of Primo MAXX® at lower rates, but higher frequencies. Improved winter stress tolerance would be a convincing argument for registration of Primo MAXX® in the Nordic countries, and the on-going trials will therefore be followed by an assessment of effects of the last Primo MAXX® applications in September or October 2007 on winter survival and spring recovery.

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

2. Introduction

The plant growth regulator trinexapac-ethyl was developed by Syngenta in the 1980s. Since the active ingredient is available in different formulations, the chemical will, in this report, be referred to as Primo MAXX®, which is the product developed by Syngenta specifically for use on turf. Unlike earlier plant growth regulators, Primo MAXX®'s mode of action is highly specific as it blocks the conversion of GA_{20} til GA_1, i.e. the last step in the biosynthesis of gibberellic acid, a plant hormone stimulating cell elongation and thus vertical turf growth.

After its release, Primo MAXX® was rapidly adopted by the US and Canadian turf industries. In North America, there are several independent university studies documenting its positive effects on golf courses, athletic fields, home lawns, and sod production (for a recent review, see Erwin and Zhang 2008). These advantages include reduced leaf elongation and thus reduced mowing costs and energy use, improved tiller production (more lateral growth), darker green colour, and improved resistance to drought and shade.

While other formulations of trinexapac-ethyl have been approved for agricultural use in Europe for about a decade, the experience with Primo MAXX® to European turfgrass areas is relatively limited. During the past three to four years, Primo MAXX® has been approved for turf use in Italy, France and UK, and the evaluation and registration process has been initiated in many other countries.

Being an inhibitor of gibberellin biosynthesis, Primo MAXX® offers special prospects for turfgrass management in the Nordic counties Finland, Sweden, Norway, Iceland, and Denmark. At latitudes ranging form 55 to 71 °N, turfgrasses growing in these countries exposed not only to long photoperiods during most of the growing season, but also to lower photosynthetic flux densities and lower red to farred (R/FR) ratios than in countries further south. The natural turfgrass response to these northern light conditions is to devote more of its resources to shoot elongation (Heide et al. 1985a,b). Since this response is primarily mediated by the gibberellic acid GA_1, any specific growth regulator that controls the biosynthesis of this compound might be useful under Nordic conditions. Nevertheless, our experience from the introduction of trinexapac-ethyl for agricultural use in the Nordic counties suggests that the optimal dose rates and frequencies for application of Primo MAXX® to various types of turf are probably not the same as at lower latitudes. This is also due to different species and cultivars being grown compared with countries further south. Field trials under Nordic conditions are therefore required not only to produce data for the national certification agencies, but also to provide turf managers with recommendations for how to use the product.

This report presents first year preliminary results from a two year project evaluating the use of Primo MAXX® on golf courses in the Nordic countries. The project was funded by Syngenta and the Scandinavian Turfgrass and Environment Research Foundation (STERF) 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' trials needed to provide documentation for possible registrations of Primo MAXX® by the national authorities, a couple of practical demonstration trials were carried out on Norwegian golf courses under supervision from Bioforsk and with funding from the Norwegian Golf Federation (NGF).

3. Methods

3.1. Evaluation of Primo MAXX® under fairway conditions, Bioforsk Landvik, Norway

Experimental site

On 8 May 2007, a field trial was laid out on a fairway established on a sandy loam soil (topsoil: 68 % sand, 27% silt, 5 % clay) at Bioforsk Landvik Research Station (58°34'N, 8°52'E), SE Norway. Soil samples indicated a pH (H_2O) of 5.9, high phosphorus values (P-AL=19) and intermediate to low potassium values (K-AL = 8, K-HNO_3=58). The fairway had been seeded in September 2003 to a mixture of smooth meadowgrass (*Poa pratensis*), chewing fescue (*Festuca rubra* ssp. *commutata*), and browntop bent (*Agrostis capillaris*) (Table 1). Block 1 and 2 were located in one part, and block 3 and 4 in a different part of the fairway. Botanical analyses at the start of experimentation indicated that red fescue was the predominant species in all blocks, but presumably due to slightly less surface drainage, blocks 1 and 2 had a higher percentage of smooth and annual meadowgrass and broadleaved weeds (primarily white clover (*Trifolium repens*)) than blocks 3 and 4 (Table 1).

Table 1. Seed mixture used for fairway establishment in 2003 and botanical composition at the start of the Primo MAXX® trial in spring 2007.

Species	Cultivar	% (w/w) of seed mixture	% cover at initiation of Primo MAXX® trial		
			Block 1 and 2	Block 3 and 4	Mean
Poa pratensis	Conni	25	31	9	20
Poa pratensis	Eva	10			
Poa pratensis	Limousine	10			
Festuca rubra ssp. commutata	Bargreen	25	50	74	62
Festuca rubra ssp. commutata	Calliope	25			
Agrostis capillaris	Tracenta	5	5	15	10
Poa annua			8	2	5
Broadleaved weeds			6	0	3
Sum		100	100	100	100

Experimental plan

The experiment was laid out according to a randomized complete block design with plot size 2m x 3m, four blocks (replicates) and the following treatments:

1. Usprayed control
2. Primo MAXX, 0.5 l/ha (56.5 g a.i./ha) every four weeks
3. Primo MAXX, 1.0 l/ha (113 g a.i./ha) every four weeks
4. Primo MAXX, 1.5 l/ha (169.5 g a.i./ha) every four weeks
5. Primo MAXX, 2.0 l/ha (226 g a.i./ha) every four weeks
6. Primo MAXX, 3.0 l/ha (339 g a.i./ha) every four weeks

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. Actual application rates were recorded by weighing the tank before and after spraying. Table 2 shows actual rates and weather conditions for each spraying event.

Table 2. Weather conditions and actual application rates at the six spraying events.

Application date	Time of day (hours)	Weather conditions at application			Treatment number / application rate (l Primo MAXX® per ha)				
		Air temp. °C	Relative Humidity %	Wind Speed m/s	2. (target 0.5)	3. (target 1.0)	4. (target 1.5)	5. (target 2.0)	6. (target 3.0)
9 May	09-11	14	48	< 1.0	0.47	0.94	1.56	1.90	3.35
5 Jun.	09-11	15	60	< 1.0	0.58	1.06	1.67	1.93	3.19
4 Jul.	13-15	17	70	1.0-2.0	0.61	0.98	1.73	2.19	3.38
31 Jul.	08-10	18	55	1.0-2.0	0.55	1.05	1.66	2.28	3.41
28 Aug.	09-11	19	32	1.0-2.0	0.57	1.03	1.55	2.19	3.52
26 Sep.	09-11	11	69	< 1.0	0.52	1.07	1.55	2.01	3.15
Mean					0.55	1.02	1.62	2.08	3.33

Registrations

At two weeks intervals throughout the experimental period, turfgrass colour, tiller density, and turf general appearance were assessed by turfgrass scientist or technicians using a scale from 1 to 9 where 9 is darkest colour, highest tiller density and best turf quality. The assessments were conducted two and four weeks after application of Primo MAXX®. On the same dates, turfgrass diseases and broadleaf weed (including white clover) invasion were reported as per cent of plot area. Turfgrass height was recorded as the mean of three random measurements with a ordinary ruler in each plot, and the overall growth rate by weighing clippings in the basket of a walk-behind mower used in the 0.56 m x 1.88 m central area of each plot (Photo 1). Both raw weight and dry weight were recorded, the latter after drying for 24 h at 60ºC. By the end of the growing season, on 2 Nov., turfgrass dormancy colour was evaluated on a scale 1-9, where 1 is completely faded / brown turf, and 9 is completely green turf.

Photo 1a and b. Tatsiana Espevig collecting clippings in fairway trial at Landvik. Photos: Trygve S. Aamlid

Management

The experiment was mowed at 15 mm two times a week, usually on Monday and Friday. A triplex fairway mower without collection of clippings was used except when clipping weights were to be recorded. Granular fertilizer was applied at approximately monthly intervals as outlined in Table 3. The experiment was not irrigated except for small amounts of water to dissolve fertilizer after application. On 7 Aug., the trial was aerated using a vertidrain with 15 mm solid tines to 15 cm depth. Topdressing was accomplished on 8 Aug. and 5 Nov. at rates 0.75 and 1.5 kg pure sand per m^2, respectively.

The fairway trial at Landvik was not exposed to ordinary play, but it was was subjected to artifical wear from a wear drum one to two times per week.

Table 3. Fertilizer inputs, fairway trial, Landvik.

		Per ha							
Date	Fertilizer type	kg fertilizer	kg N	kg P	kg K	kg Mg	kg S	kg Ca	kg Fe
17 Apr.	Fullgjødsel 22-2-12	40	9	1	5	0	1	0	0
16 May	Fullgjødsel 22-2-12	70	15	1	8	1	2	1	0
12 Jun.	Arena Golf Extra 13-0-15	150	20	0	23	2	21	0	3
23 Jul.	Arena Golf Extra 13-0-15	130	17	0	20	2	18	0	3
9 Aug.	Arena Golf Extra 13-0-15	135	18	0	21	2	18	0	3
5 Sep.	Arena Golf Extra 13-0-15	150	20	0	23	2	21	0	3
SUM			99	2	100	10	80	1	11

Weather data

In SE Norway, the growing season 2007 was characterized by exceptionally high rainfall, especially in July, but also in May, June and August (Table 4). By contrast, September was unusually dry. Precipitation was recorded on 16 out of the 31 days in July; the cloudy summer weather is also reflected by a rather low irradiance during this month. The warmest period, with daily maximum temperatures in the range 23-29 ºC was recorded from 6 to 12 June.

Table 4. Weather data for Landvik meteorological station, about 200 m for experimental field. Normal values for temperature and rainfall are 'official' values for from the period 1961-90, while normal values for irradiance are calculated averages for the period 1994-2006.

	Mean temperature, °C		Precipitation, mm		Irradiance, MJ/m^2 (305-2800 nm)	
	2007	30 yr normal	2007	30 yr normal	2007	13 yr average
May	10.2	10.4	107	82	518	540
June	15.9	14.7	109	71	604	600
July	15.5	16.2	213	92	492	632
Aug.	16.2	15.4	132	113	476	476
Sep.	12.0	11.8	59	136	321	262
Mean / sum	14.0	13.7	620	494	2411	2510

3.2. Evaluation of Primo MAXX® on a golf course fairway, Lepaa, Finland

Experimental site

The Finnish fairway trial was laid out on 11 May 2007. The fairway was seeded to a mixture of smooth meadowgrass and chewing fescue (*Festuca rubra* spp. *commutata*) on a heavy clay soil (15% sand, 37% silt, 48% clay) at the Lepaa Unit of HAMK University of Applied Sciences, Finland (61°08'N, 24°20'E). 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. All observations and management of the trial was carried out by the HAMK Lepaa greenkeepers Petteri Lehmuskoski and Tommi Turunen except for the spraying treatments which were carried out by MTT's 'Good Experimental Practice' certified spraying team from Jokioinen (90 km from Lepaa).

Experimental plan and registrations

The experiment was laid out following the same plan and plot size as at Landvik, Norway (previous paragraph). Primo MAXX® was applied in accordance with the Finnish 'Good Experimental Practise' protocol, using a portable, compressed air-powered 'van der Weij' plot sprayer, mounted with a windshield and flat fan nozzles (Hardi 4110-12) and working at 180-250 kPa pressure. The spraying boom had four nozzles spaced 50 cm apart. The spraying volume corresponded to 200 l/ha. Full spray coverage was on the central 1.5m x 2.5 m of each plot. Table 5 shows application dates and weather conditions for each spraying event. The last application on 4 Oct. was conducted especially to evaluate potential effects of Primo MAXX® on turfgrass winter damage.

Table 5. Application dates and weather conditions in fairway and green trials at Lepaa.

Application date	Time of day (hours)	Air temp. °C	Relative humidity %	Wind Speed m/s	% cloud cover
11 May	09-11	11	29	0	25
8 Jun.	09-11	20	56	1.5	1
5 Jul.	13-15	23	47	2.5	70
3 Aug.	09-11	17	78	2.0	90
4 Sep.	09-11	11	90	1.0	90
4 Oct.	13-15	11	92	1.5	100

Photo 2. Austen Sutton, Syngenta (left) and greenkeeper Petteri Lehmuskoski, HAMK Lepaa Unit, in fairway trial at Lepaa, Finland, 29 Aug. 2007.

Photo: Oiva Niemelainen.

Registrations

Registrations were carried out at two-week intervals following the same program as at Landvik (previous section) except that weed occurrence and dormancy colour were not recorded. Plant height at Lepaa was determined using a Turf Check Prism device (Check Signature Inc., Shoreview, MN).

Management and wear

The experiment was mowed with a triplex fairway mower about three times per week. Mowing height ranged from 12 to 18 mm. Granular fertilizer Sportsmaster 26-2-9 was applied at equal rates on 8 May and 12 July, the total input corresponding to 156 kg N, 12 kg P, 54 kg K and 0.9 kg Fe per ha. Information about irrigation is given in Table 6. The trial was aerated or top-dressed in late autumn, after the completion of registrations.

During the growing season period, the trial was exposed to approximately 3.500 rounds of golf.

Weather data

Temperatures at Lepaa were higher the 30 yr normal values throughout the growing season (Table 6). August had the greatest deviation from the long-term average value. July had 49 % more, and August 42 % less rainfall than usual; over the whole experimental season, rainfall was close to the 30 yr normal value.

Table 6. Weather data for Hattula Lepaa weather station and irrigation in fairway and green trial at Lepaa golf course, 2007. Normal values for temperature and rainfall are official values for from the period 1971-2000 (Finnish Meteorological Institute)

	Mean temperature, °C		Rainfall, mm		Irrigation, mm (2007)	
	2007	30 yr normal	2007	30 yr normal	Fairway trial	Green trial
May	10.6	9.8	30	34	*	*
June	15.1	14.5	54	55	26	79
July	16.6	16.4	119	80	5	47
Aug.	16.4	14.6	43	74	7	50
Sep.	9.9	9.4	58	54	0	6
Mean / sum	13.7	12.4	304	297	37	188

* Data are unavailable for the period 1-26 May 2007 due to change of irrigation computer.

3.3. Evaluation of Primo MAXX® on a golf course putting green, Lepaa, Finland

Experimental site

The Finnish green trial was established on 11 May 2007 on a USGA green seeded to creeping bentgrass (*Agrostis stolonifera*, seed blend of 50% 'Penn A-4' and 50% 'Penn G-6') at Lepaa Golf Course.

Experimental plan

The experimental plan comprised five rates of Primo MAXX plus the unsprayed control treatment:

1. Usprayed control
2. Primo MAXX, 0.2 l/ha (22.6 g a.i./ha) every four weeks
3. Primo MAXX, 0.4 l/ha (45.2 g a.i./ha) every four weeks
4. Primo MAXX, 0.6 l/ha (67.8 g a.i./ha) every four weeks
5. Primo MAXX, 0.8 l/ha (90.4 g a.i./ha) every four weeks

The trial had four replicates, and a gross plot size of 2 m x 3 m. It was sprayed on the same dates and following the same GEP procedures as the fairway trial on the same location (Table 5).

Photo 3. Green trial at Lepaa ready for the first treatment on 11 May 2007. Photo: Oiva Niemelainen.

Registrations

Registrations followed the same program as in the Finnish fairway trial (previous section).

Management and wear

The experiment was mowed with a Triplex greens mower for an average of six times per week. Depending on weather and turfgrass density, mowing height was 5–7 mm in May and September and 3-4 mm from June to August. Information about irrigation and fertilizer inputs are given in Tables 6 and 7, respectively.

To avoid thatch accumulation, the trial was aerated with deep slitting knives every second week and with 8 mm needle tines once a month. Verticutting was accomplished every second week and topdressing with 0.1-0.7 mm finely graded sand at a rate of 1 kg per m2 every third week. The sand was brushed/irrigated into the green and the dressing was never done in close proximity to weighing of clippings.

Being located on a practise green, the experiment received wear from about 10.000 rounds of golf over the season. When placing holes on the green, care was taken to create as uniform wear as possible.

Table 7. Fertilizer inputs in green trial at Lepaa.

		Per ha							
Date	Fertilizer type	kg fertilizer	kg N	kg P	kg K	kg Mg	kg S	kg Ca	kg Fe
28.3.2007	Floratine Kevätstartti*	35	5.4	1.2	2.1				
5.4.2007	Floratine Kevätstartti	35	5.4	1.2	2.1				
19.4.2007	Floratine Kevätstartti	35	5.4	1.2	2.1				
26.4.2007	Sierraform Springstart (16-0-13)	250	40	0	32.5				2.50
15.5.2007	Sierraform All Season (18-3-15)	250	45	7.5	37.5	3.0			1.25
30.5.2007	Kemigreen Basic (23-4-14)	40	9	1.6	5.6	0.6	0.8		0.04
5.6.2007	Kemigreen Basic (23-4-14)	40	9	1.6	5.6	0.6	0.8		0.04
11.6.2007	Sierraform All Season (18-3-15)	250	45	7.5	38				
25.6.2007	Osmosol 614R (19-2-10)	40	7.6	0.8	4.0	0.5		1.7	0.04
2.7.2007	Osmosol 614R (19-2-10)	40	7.6	0.8	4.0	0.5		1.7	0.04
13.7.2007	Kemigreen Summer (18-0-17)	40	7.2	0	6.8			2.0	0.40
18.7.2007	Kemigreen Summer (18-0-17)	40	7.2	0	6.8			2.0	0.40
26.7.2007	Sierraform All Season (18-3-15)	250	45	7.5	37.5	3.0			1.25
14.8.2007	Kemigreen Summer (18-0-17)	40	7.2	0	6.8			2.0	0.40
27.8.2007	Greenmaster Autumn (6-2-8)	300	18	6	24	5.4			1.50
30.8.2007	Kemigreen Basic (23-4-14)	40	9	1.6	5.6	0.6	0.8		0.04
11.9.2007	Sierraform Springstart (16-0-13)	200	32	0	39				2.00
SUM			305	39	260	14.0	2.4	9.4	10

* Floratine Kevätstartti (Springstart) is composed of P-48 (10-21-6.6), Per 4 Max (15-0-0), Protesyn (3.5-0.6-1.8), and Plant Marvel (28-3-15).

3.4. Demonstration trials with Primo MAXX® at Ballerud Golf Course, Oslo, Norway

Experimental site and set-up

Ballerud GC is located on an old horticultural farm in a suburban area SW of Oslo. The course has greens with mostly dominated by creeping bentgrass, fairways almost exclusively dominated by annual meadowgrass, and smooth meadowgrass roughs with some tufts of perennial ryegrass (*Lolium perenne*).

Large-scale, unreplicated demonstration trials were laid out on green no. 9, fairway no. 9 and rough no. 9 on 5 June 2007. Plots sizes varied from 80 to 130 m^2. Unsprayed control plots were compared with plots sprayed with Primo MAXX® at rates 0.4, 1.5 and 2.2 l/ha and application intervals of approximately 3, 4 and 7 weeks on green, fairway and rough, respectively. In compliance with the Norwegian Food Authority's rule for complete closure of all sprayed areas for 48 h after each application, the trial on green no. 9 had to be discontinued after the second application on 18 June.

Three weeks later, it was replaced by a new trial laid out on the golf course' nursery green. Actual application dates in the green, fairway and rough trials are given in Table 8. The growth regulator was applied using a battery-operated electric Hardy Defender plot sprayer (Photo 4).

Table 8. Application dates for Primo MAXX in demonstration trials at Ballerud GC.

Green no. 9	Nursery green	Fairway no. 9	Rough no. 9
5 June		5 June	5 June
18 June			
	9 July	2 July	
	31 July	31 July	28 July
	21 Aug.		
	13. Sep.	3 Sep.	11 Sep.
	4 Oct.	28 Sep.	

Photo 4. Sprayer used in demonstrations trials at Ballerud Golf Course.

Photo: Terje Haugen.

Registrations

In all trials at Ballerud, turfgrass general appearance was evaluated by the headgreenkeeper at one to two week intervals throughout the growing season. In the green and fairway trials, turfgrass clipping yields were recorded on a fresh weight basis. Registrations in the green trials also included regular assessments of green speed using a standard stimpmeter.

Maintenance

The green trials at Ballerud were mowed daily at 3.4-3.8 mm and the fairway trial at 20 mm three to four times a week. The rough area was only mowed upon need.

Due to the rich soil from decades of vegetable production, the rough trial was not fertilized in 2007, and the fairway trial only received one application of 200 kg Fullgjødsel® 11-5-18 (22 kg N/ha) on 8 May. The green trials received monthly applications of granuar fertilizer (Gro Power 5-1-1, Anderson 14-0-9, Anderson 8-0-16, and/or Roots 12-2-12), and weekly applications of liquid fertilizers /

biostimulants, mostly Floratine products. Total rates of N, P, K, Mg, Ca, S and Fe over the season were 155, 14, 142, 27, 30, 73 and 14 kg/ha, respectively. The greens were aerated, mostly using Envirojet, six times during the season and top-dressed, also six times, giving a total of 6.3 kg sand per m^2.

Weather data and irrigation

Table 3 shows recordings from Ballerud GC's weather station. Although the rainfall in 2007 was higher than usual, there were periods, especially in May, June and August when the green trials needed irrigation. The fairway and rough trials were never irrigated.

Table 9. Weather recordings and irrigation at Ballerud GC, 2007. Monthly temperatures are means of daily maximum and minimum temperatures.

	Mean monthly temperature, °C	Monthly rainfall, mm	Monthly irrigation, mm (greens only)
May	11.2	94	42
June	17.1	185	52
July	16.9	173	10
Aug.	16.6	83	47
Sep.	11.1	71	21
Mean / sum	14.6	606	172

3.5. Demonstration trial with Primo MAXX® at Oslo Golf Club, Bogstad, Norway

To evaluate the effect of Primo MAXX® on a typical annual meadowgrass green, an unreplicated demonstation trial with plot size 250 m^2 was laid out at Oslo GK on 20 June 2007. Primo MAXX® was sprayed at a rate 0.4 l/ha on 20 June, 10 July and 31 July using the same sprayer as at Ballerud GC, about 10 km from Bogstad (Photo 4). Turfgrass quality (general appearance) and fresh weight clipping yields were determined on 4 July, 13 July and 14 August. Unfortunately, the trial had to be discontinued in mid August due to reconstruction of the green.

3.6. 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 on each plot and on plot values which had been averaged, either over the whole growing season, separately over the spring (before 10 June), summer (10 June – 1 Sep.) and autumn (after 1 Sep.) periods, or for observations conducted two versus four weeks after the last application of Primo MAXX®. The significance levels P%<0.1, P%<1, P%<5 and ns (not significant) have been indicated in the tables along with LSD values for effects significant at P%<5. In a few cases exact P-values have been given for tendencies in the 5-15% probability range. As an indications of the variability for each character, coeffcients of variation, (CV %), have also been given in the tables.

4. Results

4.1. Evaluation of Primo MAXX® under fairway conditions, Bioforsk Landvik, Norway

Turfgrass quality and related characteristics

Table 10 shows results from the visual observations of turfgrass quality and related characters in the fairway trial at Landvik. Both within the three seasons and as a mean value, turfgrass general appearance was significantly lower on plots receiving monthly applications of Primo MAXX® at 1.0 l/ha or higher rates than on unsprayed control plots and plots receiving 0.5 l/ha. Within these two groups, differences in generall appearance were not significant. Separate analyses for blocks 1 and 2 versus 3 and 4 indicated that these responses were practically identical regardless of botanical composition (data not shown).

Individual registrations of turfgrass quality are further depicted in Fig. 1. There was a dramatic decline in quality after the first application on 9 May. After this the turf recovered and there was no significant effect of Primo MAXX® at the two subsequent evaluations. Applications of 1.0 l/ha or higher rates on 4 July lead to new quality reductions in July, August and September (Photo 5); these effects were especially apparent at the last evaluation in early November (Photo 6). By contrast, there tended to be a small quality improvement due to the lowest rate of Primo MAXX® from late August to October. This improvement was reflected also in a significant increase in tiller density on average for the whole growing season (Table 10).

Increasing rates of Primo MAXX® consistently led to darker turf throughout the growing season, but also to earlier growth cessation and a less attractive dormancy colour in late autumn (Table 10). The only visible disease in the trial was a slight attack of red thread (*Laetisaria fuciformis*) during the wet period in July; however, these spots were unaffected by Primo MAXX® which also had no effect on the occurrence of broadleaved weeds, primarily white clover, in the trial.

Table 10. Turfgrass quality, tiller density, within-season colour, dormancy colour and infestation of weeds and red thread (*Laetisaria fuciformis*) in fairway at Landvik as affected by increasing rates of Primo MAXX®, 2007. Visual merit and tiller density are means of twelve observations (two in spring, i.e. before 10 June, six in summer, i.e. from 10 June to 1 Sep., and four in autumn, i.e. after 1 Sep. Within season colour (green darkness) and occurrence weeds and red thread are means of twelve, three (all in July) and two (June and Nov.) observations, respectively. Dormancy colour was evaluated on 2 Nov. All values are means of four blocks.

Primo MAXX®, rate	Turf quality (general appearance, 1-9)				Tiller density (1-9)	Within season colour (1-9)	Dor-mancy colour (1-9)	% of plot area	
	Mean	Spring	Summer	Autumn				Dicot weeds	Red thread
0 = Control	6.2	6.1	6.4	6.0	6.3	5.2	6.8	4	4
0.5 l/ha	6.1	5.6	6.3	6.2	6.5	5.6	6.3	2	3
1.0 l/ha	5.5	4.5	5.9	5.3	6.1	5.8	5.0	5	2
1.5 l/ha	5.3	4.6	5.5	5.4	6.0	5.9	4.1	4	3
2.0 l/ha	5.5	4.6	5.9	5.3	6.1	6.0	4.3	3	2
3.0 l/ha	5.1	4.2	5.5	4.9	6.0	6.2	3.5	4	3
P%	<0.1	<0.1	<1	<0.1	<1	<1	<0.1	ns	ns
LSD 5%	0.3	0.5	0.4	0.4	0.2	0.4	1.2	-	-
CV%	4	7	5	5	3	5	15	-	-

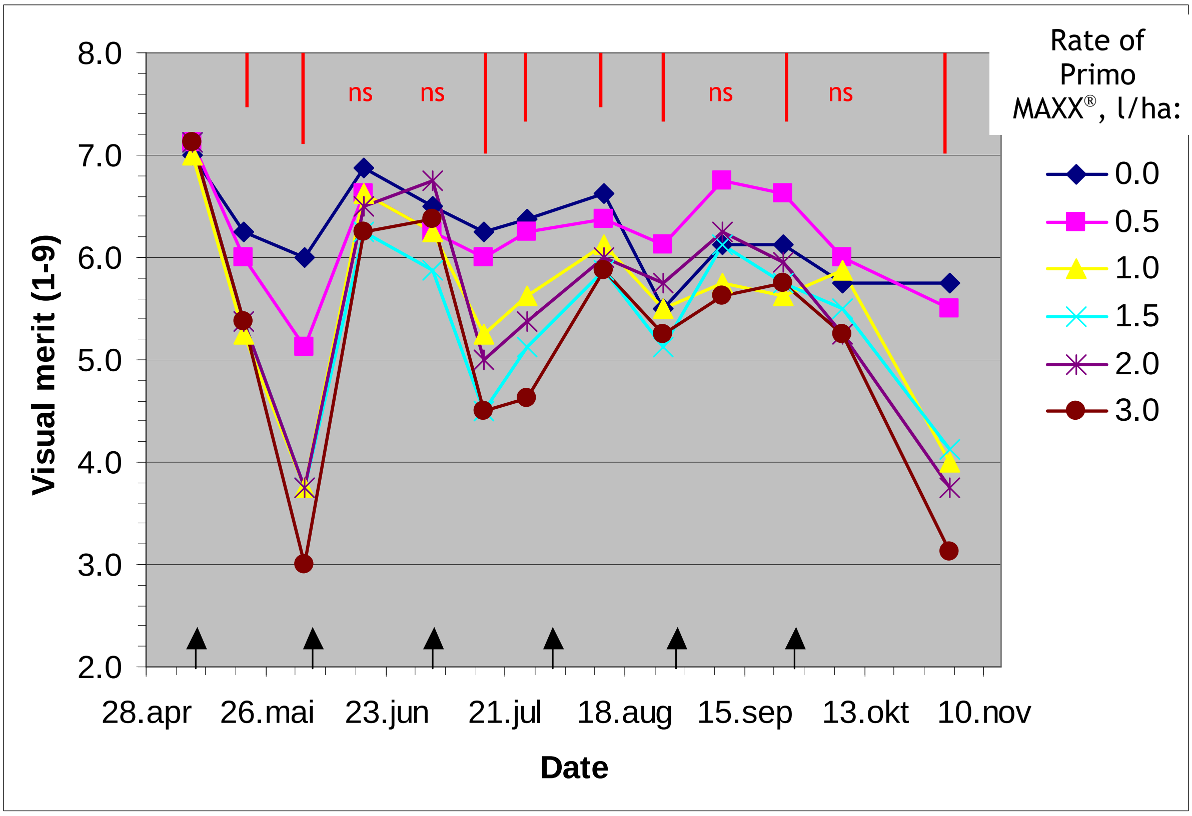


Fig.1. Turfgrass overall quality as affected by increasing rates of Primo MAXX® in fairway trial at Landvik, 2007. Mean of four replicates (blocks). The application dates 9 May, 5 June, 4 July, 31 July, 28 Aug. and 26. Sep. are indicated by black arrows. Red bars indicate LSD 5%.

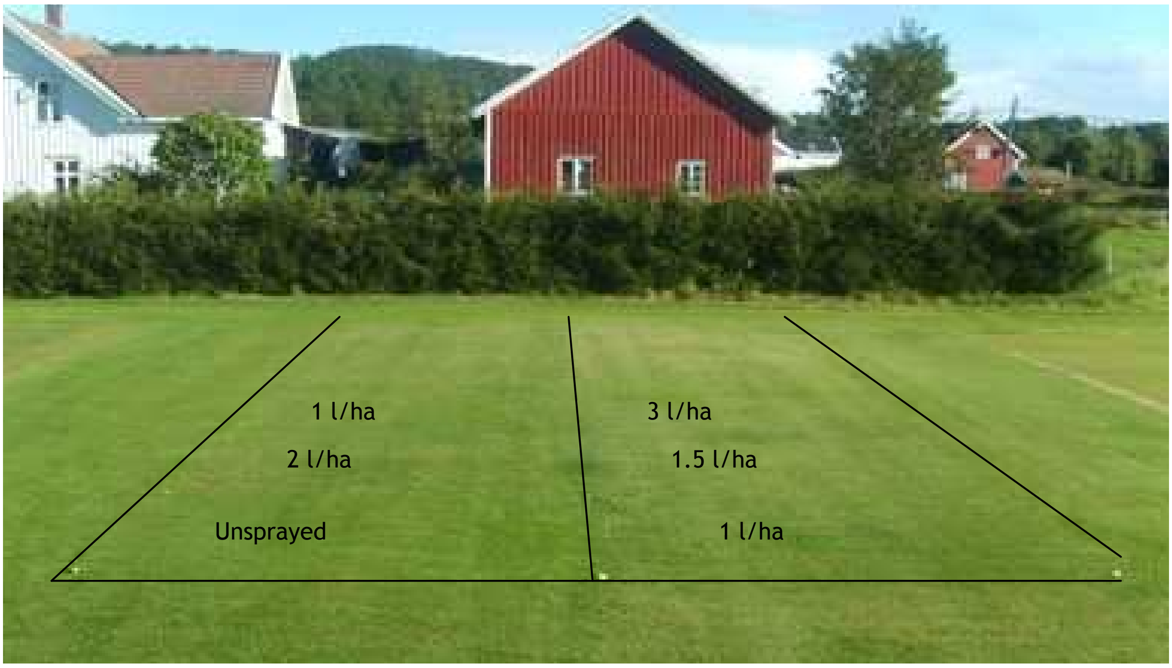


Photo 5. Visual appearance of fairway trial at Landvik, block 1 and 2, on 10 Sept. Within each block, the treatments closest to the photographer have been labeled. High rates of Primo MAXX® resulted in darker, in some cases, almost brown, turf. Photo: Trygve S. Aamlid.

Photo 6.

Turf quality / dormancy colour at growth cessation on 2 Nov. 2007 after application of Primo Maxx at 3.0 l/ha (left) and 0.5 l/ha (right), last application on 26 Sep.

Photo: Trygve S. Aamlid.

Turfgrass height and dry matter production

The average effect of Primo MAXX® on plant height and clipping yields are given in Table 11. In all blocks, the growth regulator caused a significant reduction in plant height even at the lowest rate, but contrary to expectation, this low rate also tended to increase aboveground dry matter production as compared with the unsprayed control treatment. This might reflect a higher tiller density, as also suggested in Table 10. Separate analyses for various parts of trial showed that the average reduction in clipping yield due to Primo MAXX® was stronger in blocks 1 & 2 which had more *Poa* species less red fescue and browntop bent and than blocks 3 & 4. On average for eleven harvests and all replicates, there was a slight tendency for Primo MAXX® to increase the dry matter percentage of turfgrass clippings (P% = 16, Table 11).

Table 11. Absolute and relative effects of increasing rates of Primo MAXX® on turfgrass height, turfgrass dry matter production, and per cent dry matter of clippings in fairway trial at Landvik, 2007. Mean of eleven observations. Plant height above 15 mm represents an average of four days' growth.

Primo MAXX, rate	Plant height, mm		Production of turfgrass clippings, g/m^2/day				% dry matter in clippings
	mm	Rel.	Block 1&2	Block 3&4	Mean	Rel.	
0 = Control	21.9	100	1.78	1.62	1.70	100	31.5
0.5 l/ha	20.9	95	1.91	1.93	1.92	113	32.2
1.0 l/ha	20.7	95	1.65	1.72	1.69	99	32.5
1.5 l/ha	20.0	91	1.46	1.46	1.46	86	33.6
2.0 l/ha	20.3	93	1.55	1.61	1.58	93	32.4
3.0 l/ha	19.5	89	1.31	1.70	1.51	88	33.1
P%.	<0.1	-	10	ns	<5	-	16
LSD 5%	0.7	-	-	-	0.29	-	-
CV%	2	-	10	14	12	-	3

In absolute terms, turfgrass clipping yield showed a distinct seasonal pattern with peaks during the warm and sunny periods in early June and late August (Fig. 2a). The low clipping yield on 17 July was probably due to 280 mm rainfall, and thus nutrient leaching, since the last fertilizer application on 12 June (Tables 3 and 4). Separate analyses of variance for each day indicated a significant effect of Primo MAXX® on clipping yield only on 4 June.

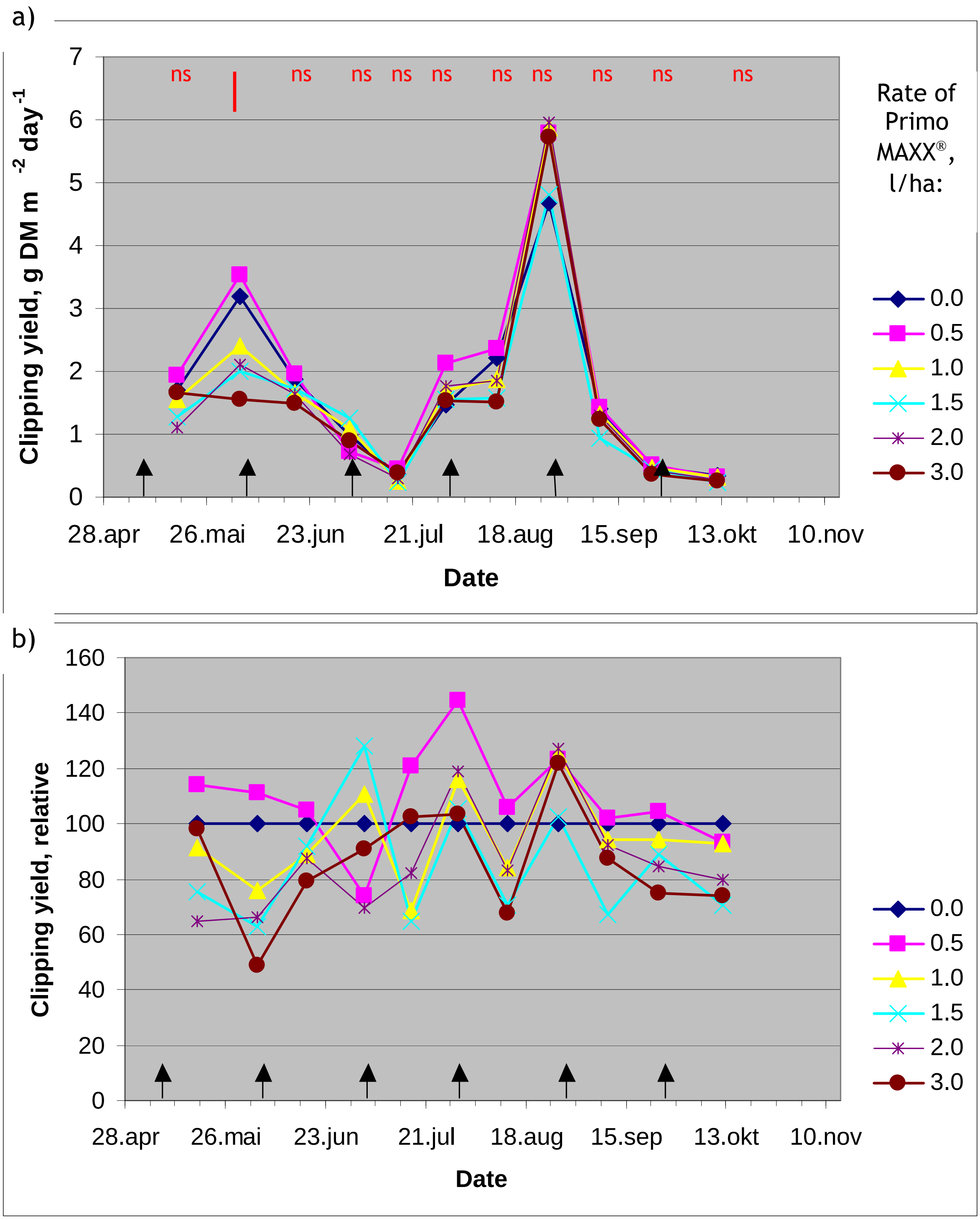


Fig. 2. Absolute (a) and relative (b) reductions in daily dry matter production of turfgrass clippings as affected by increasing rates of Primo MAXX® in fairway trial at Landvik. Red text/bars and black arrows indicate probability / LSD values and application dates 9 May, 5 June, 4 July, 31 July, 28 Aug. and 26 Sep., respectively. In (b), the clipping yield on each date was set to 100 in the unsprayed control treatment.

In relative terms, none of the Primo MAXX® treatments produced clipping yields that were lower than the unsprayed control at all harvests (Fig. 2b). Many of the treatments showed a typical suppression / rebound pattern with clipping yields lower than the control treatment at one harvest, but higher than control treatment at the next harvest.

4.2. Evaluation of Primo MAXX® on a golf course fairway, Lepaa, Finland

On average for two observations in spring, five observations in summer and two observations in autumn, Primo MAXX® had no effect on turfgrass general appearance in the fairway trial at Lepaa. Among the nine observation dates, significant differences were recorded only on 21 August when the plots sprayed with the highest dose (3.0 l/ha) had an average visual merit score of 5.5 as opposed to 6.8 for unsprayed control plots and plots sprayed with the lowest dose (0.5 l/ha).

On average for observations, increasing rates of Primo Max caused an overall increase in tiller density, while turfgrass colour was not significantly affected. No diseases were observed during the growing season.

Table 12. Turfgrass quality (1-9, 9 is best quality), tiller density (1-9, 9 is highest density) and within-season colour (1-9, 9 is darkest green) in fairway trial at Lepaa as affected by increasing rates of Primo MAXX®. Means of nine observations (two in spring, i.e. before 10 June, five in summer, i.e. from 10 June to 1 Sep., and two in autumn, i.e. after 1 Sep.). All values are means of four blocks.

Primo MAXX®, rate	Turf quality (general appearance, 1-9)				Tiller density (1-9)	Within season colour (1-9)
	Mean	Spring	Summer	Autumn		
0 = Control	6.1	5.5	6.1	6.8	5.5	6.1
0.5 l/ha	6.2	5.5	6.1	7.0	5.8	6.2
1.0 l/ha	6.1	5.4	6.1	6.9	5.8	6.1
1.5 l/ha	6.2	5.5	6.2	7.0	6.0	6.3
2.0 l/ha	6.2	5.6	6.1	6.9	6.1	6.3
3.0 l/ha	6.2	5.6	6.1	7.0	6.4	6.2
P%	ns	ns	ns	ns	<0.1	ns
LSD 5%	-	-	-	-	0.4	-
CV%	5	4	8	3	3	4

The effect of Primo MAXX® on turfgrass plant height and clipping yield depended on the time since last application. On average for five observations conducted about two weeks after application, the highest rate of Primo MAXX® caused significant reductions in plant height and clipping yield corresponding to 11 and 48 %, respectively (Table 13). On average for four observations conducted four weeks after application, the maximal reductions were only 3 and 14 %, respectively. Fig. 3 illustrates the unstable effect of Primo MAXX®, particularly toward the end of the growing season. However, unlike in the fairway trial at Landvik (Fig.2), clipping yields on sprayed plots were rarely higher than on untreated control plots in the trial at Lepaa.

Table 13. Absolute and relative effects of increasing rates of Primo MAXX® on turfgrass height and dry matter production in turfgrass clippings in fairway trial at Lepaa 2007. Observations conducted 2 weeks (5 observations) and 4 weeks (4 observations) from spraying treatment have been presented separately.

Treatment	Plant height (mm)				Weight of clippings (g DM / m^2 / day)			
Time after treatment	2 weeks	4 weeks	Mean	Rel	2 weeks	4 weeks	Mean	Rel
0 = Control	15.7	16.0	15.8	100	3.2	7.0	4.9	100
0.5 l/ha	15.7	16.0	15.8	100	2.7	6.3	4.3	87
1.0 l/ha	14.9	16.0	15.4	97	2.8	6.6	4.5	92
1.5 l/ha	14.7	15.7	15.1	96	2.3	5.8	3.9	79
2.0 l/ha	14.4	15.6	15.0	95	2.1	6.1	3.9	80
3.0 l/ha	14.0	15.5	14.6	92	1.8	6.0	3.7	75
P%	<0.1	ns	<5	-	<0.1	ns	ns	-
LSD 5%	1.1	-	1.0	-	0.7	-	-	-
CV%	3	4	3	-	13	22	18	

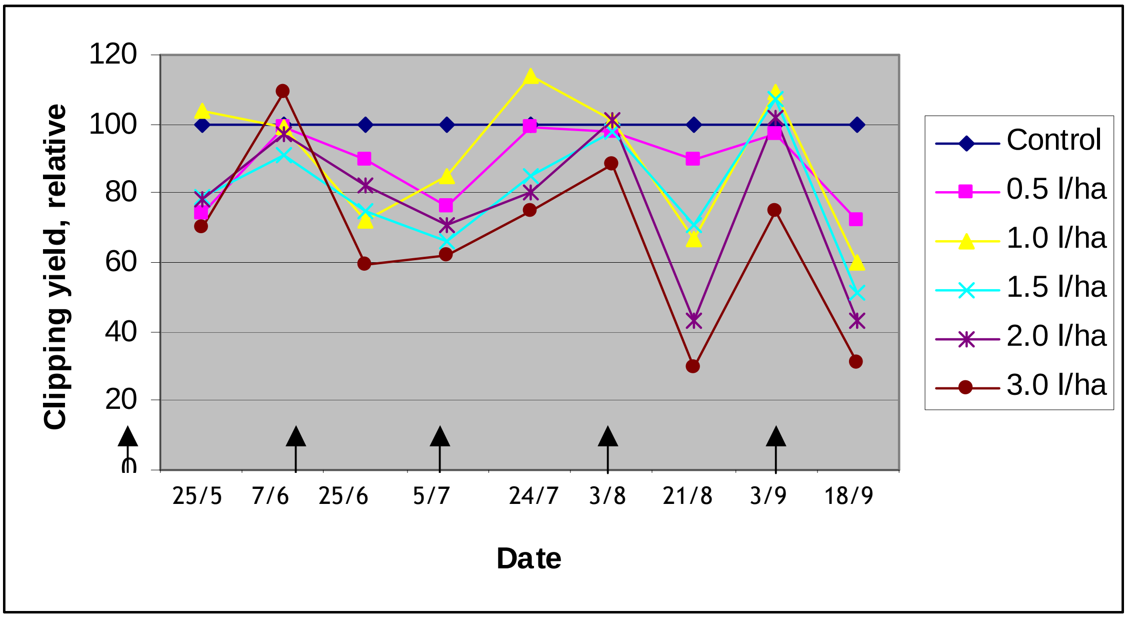


Fig. 3. Relative clipping weights (control = 100) in fairway trial at Lepaa, Finland. Spraying treatments indicated by black arrows were carried out on 11 May, 8 June, 5 July, 3 Aug. and 4 Sep. (The last spraying on 4 Oct. was done primarily to study the effect of Primo MAXX® on overwintering and was not followed by observations in late autumn.)

4.3. Evaluation of Primo MAXX® on a golf course putting green, Lepaa, Finland

On 3 Sep. 2007, a significantly higher tiller density was recorded on green plots sprayed with the highest rate of Primo MAXX® than on unsprayed control plots (data not shown). Otherwise, Primo MAXX® had no significant effect on either general appearance, tiller density or turfgrass colour in the green trial at Lepaa (Table 14). Although the effects on plant height and clipping yields were also not significant, reductions were generally stronger when recorded at two compared with four weeks after application (Table 15, Fig. 4).

Table 14. Turfgrass quality, tiller density and within-season colour (darkness) in green trial at Lepaa as affected by increasing rates of Primo MAXX®, 2007. Means of nine observations (two in spring, i.e. before 10 June, five in summer, i.e. from 10 June to 1 Sep., and two in autumn, i.e. after 1 Sep.). All values are means of four blocks.

Primo MAXX®, rate	Turf quality (general appearance, 1-9)				Tiller density (1-9)	Within season colour (1-9)
	Mean	Spring	Summer	Autumn		
0 = Control	6.4	6.1	6.6	6.3	6.3	6.4
0.2 l/ha	6.3	6.0	6.5	6.0	6.3	6.4
0.4 l/ha	6.3	5.9	6.5	6.1	6.2	6.3
0.6 l/ha	6.3	5.8	6.5	6.4	6.3	6.4
0.8 l/ha	6.2	5.8	6.4	6.3	6.2	6.4
P%	ns	ns	ns	ns	ns	ns
LSD 5%	-	-	-	-	-	-
CV%	3	5	5	7	2	3

Table 15. Absolute and relative effects of increasing rates of Primo MAXX® on turfgrass height and dry matter production in turfgrass clippings in green trial at Lepaa 2007. Observations conducted 2 weeks (5 observations) and 4 weeks (4 observations) from spraying treatment have been presented separately. Plant heights above 3 mm represent one day's growth.

Treatment	Plant height (mm)				Weight of clippings (g DM / m^2 / day)			
Time after treatment	2 weeks	4 weeks	Mean	Rel	2 weeks	4 weeks	Mean	Rel
0 = Control	4.3	3.9	4.1	100	2.60	2.21	2.43	100
0.2 l/ha	4.1	3.8	4.0	96	2.20	2.28	2.23	92
0.4 l/ha	4.0	3.9	3.9	95	1.88	2.28	2.06	85
0.6 l/ha	4.0	3.8	3.9	94	1.72	2.18	1.99	82
0.8 l/ha	3.8	3.9	3.9	93	1.75	2.28	1.92	79
P%	11	ns	ns	-	5	ns	ns	-
LSD 5%	-	-	-	-	0.9	-	-	-
CV%	6	7	8	-	20	14	16	-

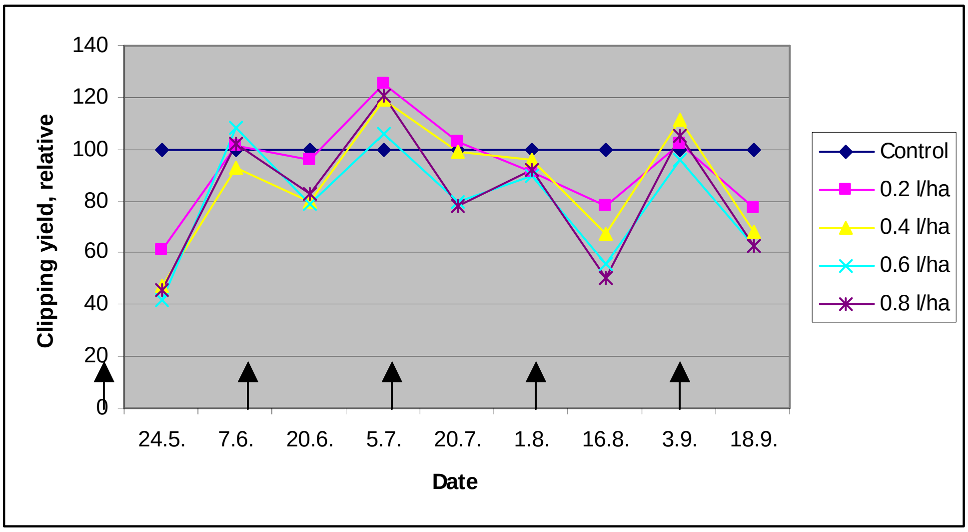


Fig. 4. Relative clipping weights (control = 100) in green trial at Lepaa, Finland. Spraying treatments indicated by black arrows were carried out on 11 May, 8 June, 5 July, 3 Aug. and 4 Sep. (The last spraying on 4 Oct. was done primarily to study the effect of Primo MAXX® on overwintering and was not followed by observations in late autumn.)

4.4. Demonstration trials with Primo MAXX® at Ballerud Golf Course, Oslo, Norway

<u>Green trials</u>

Applications of 0.4 l/ha Primo MAXX® on 5 and 18 June did not affect turf general appearance (Photo 7) or stimpmeter readings on green no. 9 at Ballerud. During the period 14-29 June, clippings were reduced by an average of 32%, but after spraying had been discontinued, there was a rebound effect corresponding to a 26 % increase in clipping yield in the period 12-25 July (data not shown).

Photo 7. Terje Haugen (left) and Lasse Augustsson on green no. 9 at Ballerud Golf Course, 27 June 2007. Photo: Trygve S. Aamlid.

Photo 8. Field day at Ballerud Golf Course 27 Aug. 2007. Photo: Tatsiana Espevig.

Fig. 5 summarizes results from the nursery green trial established on 9 July. In this trial, application of Primo MAXX® about every third week resulted in better colour (not shown), higher green speed (Fig. 5a), and an average reduction in turfgrass clippings of 44 % (Fig. 5b and c). Fig 5b shows that the reduction in clipping yield was most conspicuous during the periods of rapid growth in mid to late July (after only one application of Primo MAXX®) and in late August.

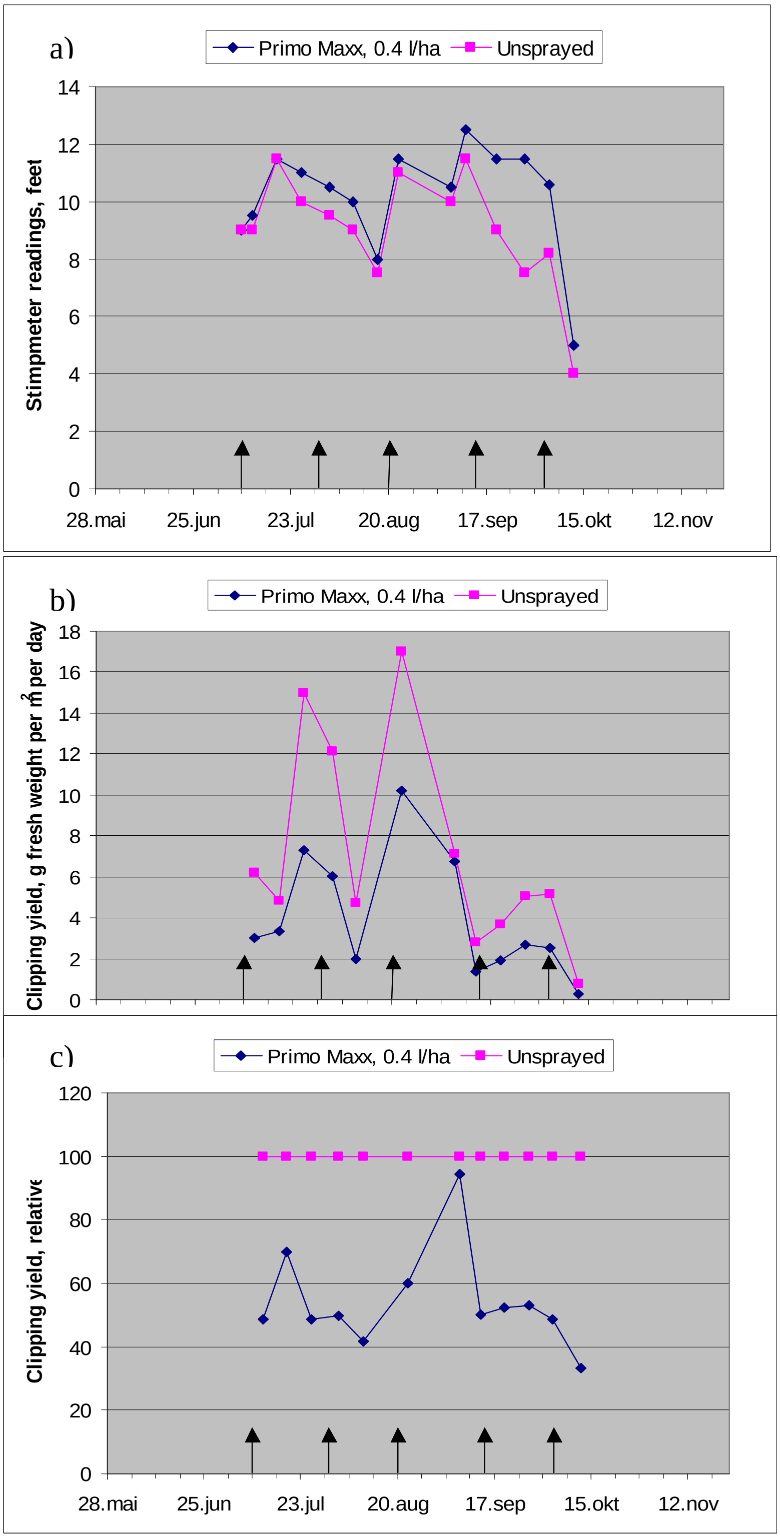


Fig. 5. Effects of spraying Primo MAXX® every three weeks of green speed and absolute and relative clipping yield on nursery green at Ballerud GC, 2007. Black arrows indicate the application dates 9 July, 31 July, 21 Aug., 13 Sep. and 4 Oct.

<u>Fairway trial</u>

As evaluated by the headgreenkeeper, monthly applications of 1.5 l/ha Primo MAXX® (1.5 l/ha) had no negative impact on turf quality in the fairway trial at Ballerud (Fig. 6). Photos 9-11 show, nevertheless, that treated turf was more faded, grayish, and less green than untreated turf. The pronounced colour difference in favour of Primo MAXX® in early September (Fig. 6) was due to less dry spots than the in the control area. While these spots recovered after rainfall on 10 and 17 Sep., the last application of Primo MAXX® on 4 Oct. led to an apparent loss of colour and drop in turf general appearance in late autumn (Photo 11).

On average for 17 clipping, regular application of Primo MAXX® resulted in a 37 % reduction in the fresh weight of turfgrass clippings (Fig. 7). The only time clipping yield was higher on the treated than on the untreated area was at the first clipping nine days after the first application and on 7 Sep. The latter coincided with the observation of less dry spots after use of Primo MAXX®. It may also be interpreted as a rebound effect following growth suppression after application on 31 July.

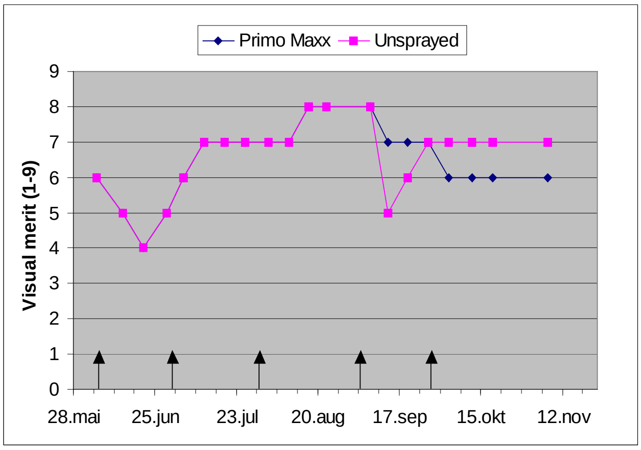


Fig. 6. Effect of Primo MAXX® on turfgrass general appearance in fairway trial at Ballerud GC. Black arrows indicate application dates. (Sprayed an unsprayed plots had identical scores until the beginning of September)

Photo 9. Difference in colour and general appearance of treated and untreated fairway Ballerud GC, 27 June. Photo: Trygve S. Aamlid.

Photo 10. Difference in colour and general appearance of treated and untreated fairway Ballerud GC, 27 Aug. Photo: Tatsiana Espevig.

Photo 11. Difference in colour and general appearance of treated and untreated fairway Ballerud GC, 3 Dec. Photo: Terje Haugen.

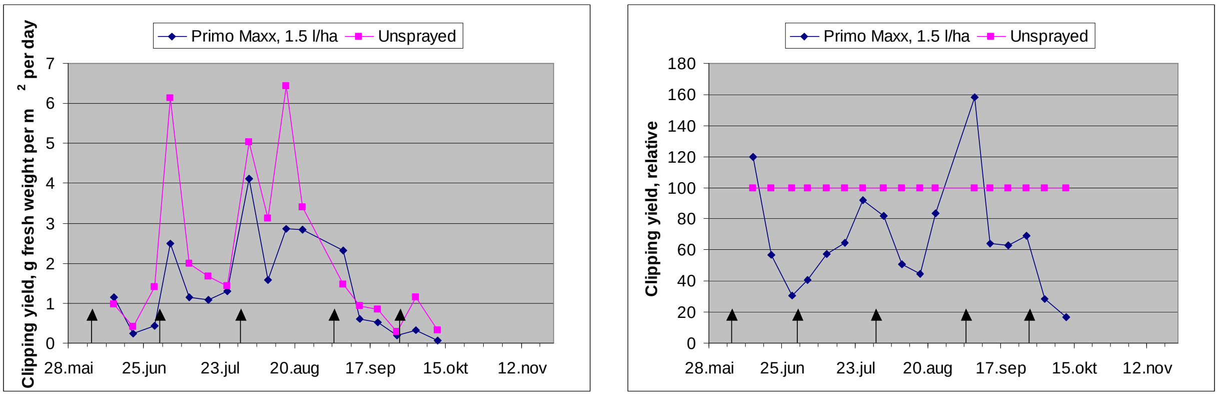


Fig. 7. Absolute (a) and relative (b) reductions in clipping yield resulting form application of Primo MAXX® in fairway trial at Ballerud GC. Arrows indicate application dates.

Spraying 2.2 l/ha of Primo MAXX® at six weeks interval resulted in discoloration and consistent drop in turf quality in the rough trial at Ballerud (Fig. 8, Photos 12 and 13). The effect was most conspicuous in late autumn. Primo MAXX® had less effect on tufts of perennial ryegrass which stood out very markedly in the turf which was otherwise dominated by smooth meadowgrass. Clipping yields were not recorded in this trial.

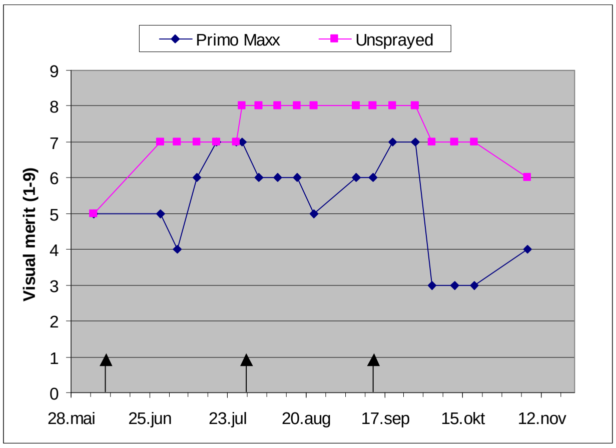


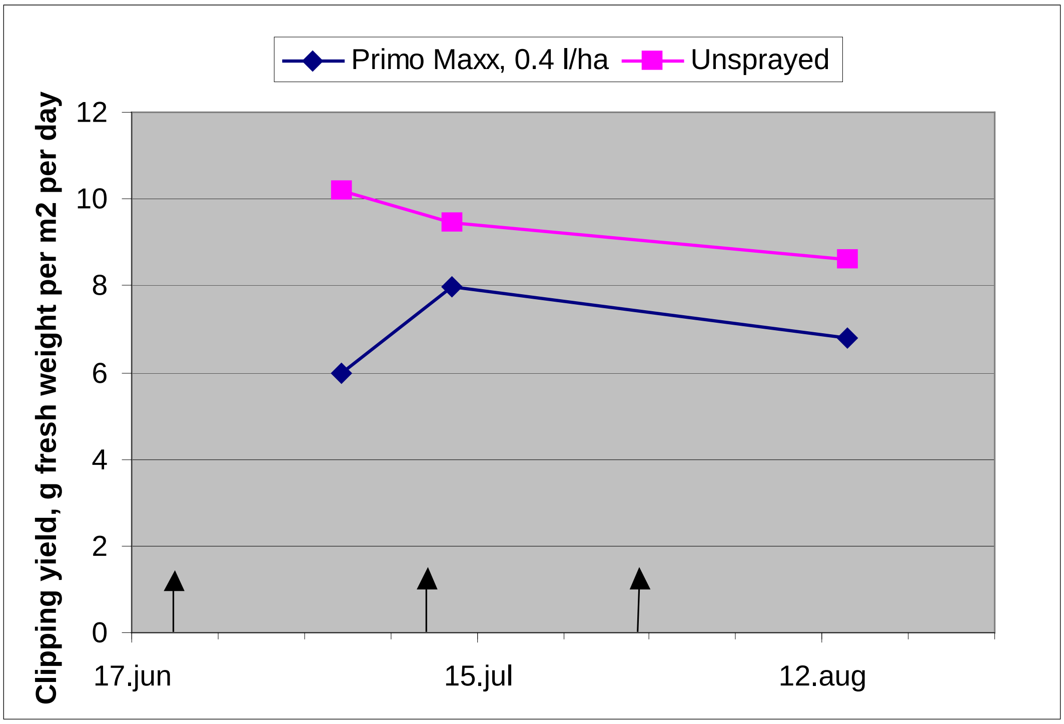
Fig. 8 (upper left). Difference in colour and general appearance of treated and untreated area in rough no 9, Ballerud, 27 June. Photo: Trygve S. Aamlid.

Photo 12 (upper right). Terje Haugen (left) and Lasse Augustsson in rough trial at Ballerud GC, 27 June. Photo: Trygve S. Aamlid.

Photo 13 (lower left). Trygve S. Aamlid inspecting rough trial at Ballerud GC, 27 August 2007. Tufts of ryegrass stand out very markedly on sprayed area.
Photo: Tatsiana Espevig.

4.5. Demonstration trial with Primo MAXX® at Oslo Golf Club, Bogstad, Norway

Application of 0.4 l Primo MAXX® at three week intervals resulted in darker turf but had otherwise no effect on the turfgrass quality of annual meadowgrass at Oslo GC. On average for three registrations, the Primo MAXX led to a 26% reduction in clipping yields (Fig. 9).



5. Discussion and suggestions for 2008

The starting point for evaluating Primo MAXX® in this two-year project was the rates and applications frequencies recommended for the product in Europe (Syngenta 2007, Table 16). Based on our experiences from agricultural crops that the optimal rates may be different in the Nordic countries than countries further south, higher and lower rates were included in the GEP trials both to determine the potential growth inhibition and the risk for discoloration or other phytotoxic effects. All taken together, the results from the first project year confirms that the guidelines in Table 16 are not directly applicable in Scandinavia and that further research is needed to find the optimal way of using the product under Nordic conditions.

Table 16. Dose rates and applications frequencies recommended for Primo MAXX® in the United Kingdom (Syngenta 2007).

	Dose rate		Application
	Primo MAXX®, l/ha	trinexapac-ethyl, g a.i./ha	frequency
Fairways	0.8 – 1.6	90 - 180	Every four to five weeks
Roughs & semi-roughs	1.6-2.4	180 - 240	Every five to eight weeks
Greens	0.4	45	Every two to four weeks

On fairway, the average reduction in clipping yield caused by monthly application of the intermediate Primo MAXX® rate of 1.5 l/ha was 15 and 21 % in the GEP trials at Landvik and Lepaa, respectively. By contrast, monthly application of 1.5 l/ha resulted in a 37 % reduction in clipping yield in the demonstration trial at Ballerud GC, which is closer to the data presented by Syngenta (2007). In agreement with Table 11 showing an increase in turfgrass dry matter percentage (i.e. decreased succulence) after application of Primo MAXX®, one of the reasons for this difference might be that clipping yields were determined on a dry weight basis in the GEP trials but on a fresh weight basis at Ballerud GC and in the data presented by Syngenta (2007). Another, and probably more important explanation, is the difference in species composition among the three trials. While the plant cover at Ballerud was almost 100% by annual meadowgrass, the species composition at Landvik varied with the two blocks showing the least response to Primo MAXX® having a plant cover of 74 % red fescue (Tables 1 and 11). By contrast, smooth meadowgrass dominated over red fescue at Lepaa due to the heavy soil type, use of irrigation, and relatively high nitrogen input. Unfortunately, we have not been able to find many references about the specific effects of Primo MAXX® on red fescue turf, but our results are in partial agreement with Pannacol et al. (2004) who found 40 %, 21 %, and no significant reduction in clipping yield after using trinexapac-ethyl in smooth meadowgrass, chewing fescue and creeping red fescue, respectively.

Perhaps the most conspicuous feature of the present results was the unstable effect of Primo MAXX® on clipping yields due to the postsuppression rebound effect. In the fairway trial at Lepaa, Finland, this resulted in clipping yield reductions being significant only two weeks after application (Table 13), and a similar tendency could be seen also in the green trial (Table 15). In Norway, clipping yields four weeks after spraying were often higher than on unsprayed control plots in the fairway trial at Landvik (Fig. 2), and a strong rebound effect was observed also after spraying treatments had to discontinued at green no. 9, Ballerud GC. The unstable effect in of Primo MAXX® in these trials was probably due to a rapid degradation of trinexapac-ethyl in plant tissue and a higher regrowth potential due to accumulation of carbohydrate reserves and GA_1 precursors during the suppression phase (Lickfeldt et

al. 2001, Branham & Beasley 2007). In North-American experiments, Lickfeldt et al. (2001) reported clipping yields reductions in smooth meadowgrass to be much more consistent when trinexapac-ethyl was applied at four than at six week intervals, but under Nordic long-day conditions, spraying every second, or at least every third week, may well be necessary to stabilize low GA_1 levels, not only on greens, but also on fairways and tees. Although there was a surge effect during the driest period in mid September, the most stable clipping reductions in our trials, on average 44 % on a fresh weight basis, were, indeed, obtained on the nursery green which was sprayed about every third week at Ballerud GC (Fig. 5c). While Branham & Beasley (2007) noted that temperature was the most important factor determining degradation of trinexapac-ethyl in turfgrass tissue, our results suggest that other factors such as light and water availability may also be important for the rebound effect under Nordic conditions. Very clearly, application frequency is a major question that has to be addressed during the continuation of this project.

The potential reductions in mowing costs from using a plant growth regulator will always have to be weighed against the risks for discoloration or other harmful effects on turf quality. In the present trials, reductions in general appearance (visual merit) scores were far more conspicuous in the GEP trial at Landvik than in the GEP trials at Lepaa or the demonstration trials at Ballerud GC. Apart from possible effects of different botanical compositions, this might reflect a subjective human factor, i.e. different backgrounds and attitudes of the observers in the various trials. While the fairway trial at Landvik was evaluated by turfgrass scientists and technicians with long experience from turfgrass variety testing, the trials at Lepaa and Ballerud were evaluated by greenkeepers working on the course. While the observers at Landvik may have paid more attention to turf aesthetic values such as less intense colour, and less vigorous and uniform plots, the observers at Lepaa and Ballerud may well have been more attentive to ball roll and other functional characteristics of the playing surface. The less succulent but significantly darker green turf resulting from high Primo MAXX® rates at Landvik are in agreement with other studies showing higher mesophyll cell densities and chlorophyll concentrations resulting from less elongation of leaf cells (Heckman et al. 2001, Ervin & Zhang 2008). As for tiller density, most literature supports the Finnish rather than the Norwegian results; i.e. enhanced tillering after Primo MAXX® application (Branham & Beasley 2007, Ervin & Zhang 2008).

As compared with the unsprayed control treatment, the strongest negative effect of Primo MAXX® on turfgrass general appearance at Landvik was recorded after the first spraying in early June, in mid July and at the last observation in early November. Each of these observations might be explained by suboptimal conditions causing reduced turfgrass growth. From 6 to 15 June there was a dry and warm and period with maximum temperatures in the range 25-30 ºC that obviously reduced turfgras tillering and aesthetic appearance; until mid July exceptional rainfalls starting on 22 June were not compensated by increase nitrogen inputs, and in autumn, the last application of Primo on 26 September was followed by several nights of frost. Although most studies have failed to document significant interactions between nitrogen and trinexapac-ethyl on turfgrass quality (Steinke & Stier 2001, Goss et al. 2002, McCullogh et al. 2006), it seems reasonable to assume that potential negative effects on Primo MAXX® on turfgrass quality will be most pronounced under suboptimal growing conditions. As in the trials at Landvik (Photo 6) and Ballerud (Photo 11), Beam et al. (2002) reported significant discoloration of trinexapac-ethyl-treated smooth meadowgrass following frost in autumn.

Undoubtedly, the most convincing argument for official approval of Primo MAXX® on Nordic golf courses would be a clear documentation that it improves winter survival. Preliminary results with annual meadowgrass suggested that low rates of trinexapac-ethyl prevented winter injury, whereas high rates had opposite effects due to discoloration during the hardening phase in late autumn (Rossi & Buelow 1997). While trinexapac-ethyl has been shown to increase water soluble carbohydrate contents (Goss et al. 2002) and result in faster spring greenup, Ervin & Zhang (2008) recently called for more detailed investigations into the effect of trinexapac-etyl on freezing tolerance as the research to date has provided scarce information on this aspect. Under Nordic conditions, desiccation if growth resumes when soils are still frozen and irrigation not yet operational in spring, or damage due to unstable winters with ice and water covering the turf, sometimes resulting in suffocation, appear to be more

important that direct freezing injury. In this regard, trineexapac-ethyl may well have a positive effect as it reduces mitochondrial respiration (Ervin & Zhang 2008). In 2008, it will therefore be very interesting to study winter injury and spring green-up and recovery in the on-going trials at Landvik, Lepaa and Ballerud which all had their last application of Primo MAXX® in late September or early October.

Even with winter survival and spring observations included, the amount of data presented in this report is too limited to recommend any listing of Primo MAXX® for turf use in the Nordic countries. Therefore, as stated in the contract between Syngenta and Scandinavian Turfgrass and Environment Research Foundation, there is a need for new GEP trials to be started in spring 2008 and followed until registration of winter survival in spring 2009. For this purpose, a new experimental green was constructed and seeded to creeping bentgrass at Landvik in 2007. In the trial to be established on this green in spring 2008, we suggest to compare Primo MAXX® at three rates (0.15, 0.30 and 0.45 l/ha) and two application frequencies (every 10/11 days and every 21 days), i.e. six combinations plus an unsprayed control treatment. As different grass species seem to vary in their response to Primo MAXX®, similar trials should preferably be carried out on also red fescue/browntop greens and velvet bentgrass greens, although this would require additional funding from Syngenta/STERF.

In Finland, a new GEP trial will be established in spring 2008 on a fairway that is regularly subjected to winter injury. New demonstration trials might be added to the project depending on interest from superintendents and funding from the national golf unions.

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

Results from the first evaluation year 2007

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Finnish team spraying fairway trial at Lepaa Golf Course.
Photo: Oiva Niemelainen

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Summary:

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

Sammendrag:

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

Approved

Arne Sæbø	Trygve S. Aamlid
Leader, Bioforsk's Section for Urban Greening	Project leader

Contents

1. Abstract

As an inhibitor of the last step in plant synthesis of bioactive gibberellin (GA_1), the plant growth regulator Primo MAXX® (trinexapac-ethyl) offers prospects of reduced energy use for mowing and improved turfgrass quality under Nordic long day conditions. This report presents first year results from 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 possible registration of Primo MAXX®, unreplicated demonstration trials were carried out at Ballerud and Bogstad Golf Courses in Oslo under supervision of Bioforsk and with funding from the Norwegian Golf Federation (NGF).

GEP trials on **fairways** (mowing height 12-18 mm) were carried out at Bioforsk Landvik, Norway (58°34'N, 8°52'E) and at the Lepaa Unit of the HAMK University of Applied Sciences, Finland (61°08'N, 24°20'E). Primo MAXX® was applied at monthly intervals at rates 0.5, 1.0, 1.5, 2.0 and 3.0 l/ha (56.5, 113, 169.5, 226 and 339 g a.i./ha trinexapac-ethyl) in comparison with an unsprayed control treatment. Turfgrass general appearance, tiller density, colour, height growth, and clipping yields were recorded two and four weeks after each application. Primo MAXX® had no effect on turfgrass general appearance but increased density at Lepaa. At Landvik, Primo MAXX® (>= 1.0 l/ha) reduced turfgrass general appearance and density, but resulted in significantly darker green colour. Quality reductions were most apparent during periods with either daily maximum temperatures >25 ºC, extreme rainfall probably causing nitrogen deficiency, or frost at night. Average reductions in clipping yield caused by Primo MAXX® (>= 1.0 l/ha) were 8 % in the GEP trial at Landvik, 18 % in the GEP trial at Lepaa and 37 % in the demonstration trial at Ballerud; to some extent this difference may be due to different botanical composition with red fescue (*Festuca rubra*) and annual meadowgrass (*Poa annua*) being the predominant species at Landvik and Ballerud, respectively. Clipping yield reductions due to Primo MAXX® were unstable, growth suppression two weeks after application often being followed by a rebound effect during the remaining two weeks until next application.

A GEP trial on creeping bentgrass **putting greens** was carried out at Lepaa, Finland, and demonstration trials at Ballerud and Bogstad, Norway. Primo MAXX® was sprayed at rates 0.2, 0.4, 0.6 or 0.8 l/ha at monthly intervals in the GEP trial, and at 0.4 l/ha every three weeks in the demonstration trials. On average for all observations, Primo MAXX® had no effect on turfgrass quality, but clipping yields were reduced by 16, 44 and 26% at Lepaa, Ballerud and Bogstad, respectively. As in the fairway trials, growth suppression at Lepaa was stronger when assessed at two than at four weeks after application. By contrast, Primo MAXX® produced a fairly stable effect when applied at three week intervals in the demonstration trials.

Use of Primo MAXX® on golf course **roughs** was investigated only in a demonstration trial at Ballerud. Application of 2.2 l/ha of Primo MAXX® every seven weeks resulted in discolouration and reduced quality of smooth meadow grass.

In conclusion, the first year of this project has shown that the guidelines for use of Primo MAXX® in other European countries are not directly applicable in Scandinavia. As the present results are too limited to apply for registration of Primo MAXX®, the project will continue in 2008 tentatively with new trials investigating application of Primo MAXX® at lower rates, but higher frequencies. Improved winter stress tolerance would be a convincing argument for registration of Primo MAXX® in the Nordic countries, and the on-going trials will therefore be followed by an assessment of effects of the last Primo MAXX® applications in September or October 2007 on winter survival and spring recovery.

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

2. Introduction

The plant growth regulator trinexapac-ethyl was developed by Syngenta in the 1980s. Since the active ingredient is available in different formulations, the chemical will, in this report, be referred to as Primo MAXX®, which is the product developed by Syngenta specifically for use on turf. Unlike earlier plant growth regulators, Primo MAXX®'s mode of action is highly specific as it blocks the conversion of GA_{20} til GA_1, i.e. the last step in the biosynthesis of gibberellic acid, a plant hormone stimulating cell elongation and thus vertical turf growth.

After its release, Primo MAXX® was rapidly adopted by the US and Canadian turf industries. In North America, there are several independent university studies documenting its positive effects on golf courses, athletic fields, home lawns, and sod production (for a recent review, see Erwin and Zhang 2008). These advantages include reduced leaf elongation and thus reduced mowing costs and energy use, improved tiller production (more lateral growth), darker green colour, and improved resistance to drought and shade.

While other formulations of trinexapac-ethyl have been approved for agricultural use in Europe for about a decade, the experience with Primo MAXX® to European turfgrass areas is relatively limited. During the past three to four years, Primo MAXX® has been approved for turf use in Italy, France and UK, and the evaluation and registration process has been initiated in many other countries.

Being an inhibitor of gibberellin biosynthesis, Primo MAXX® offers special prospects for turfgrass management in the Nordic counties Finland, Sweden, Norway, Iceland, and Denmark. At latitudes ranging form 55 to 71 °N, turfgrasses growing in these countries exposed not only to long photoperiods during most of the growing season, but also to lower photosynthetic flux densities and lower red to farred (R/FR) ratios than in countries further south. The natural turfgrass response to these northern light conditions is to devote more of its resources to shoot elongation (Heide et al. 1985a,b). Since this response is primarily mediated by the gibberellic acid GA_1, any specific growth regulator that controls the biosynthesis of this compound might be useful under Nordic conditions. Nevertheless, our experience from the introduction of trinexapac-ethyl for agricultural use in the Nordic counties suggests that the optimal dose rates and frequencies for application of Primo MAXX® to various types of turf are probably not the same as at lower latitudes. This is also due to different species and cultivars being grown compared with countries further south. Field trials under Nordic conditions are therefore required not only to produce data for the national certification agencies, but also to provide turf managers with recommendations for how to use the product.

This report presents first year preliminary results from a two year project evaluating the use of Primo MAXX® on golf courses in the Nordic countries. The project was funded by Syngenta and the Scandinavian Turfgrass and Environment Research Foundation (STERF) 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' trials needed to provide documentation for possible registrations of Primo MAXX® by the national authorities, a couple of practical demonstration trials were carried out on Norwegian golf courses under supervision from Bioforsk and with funding from the Norwegian Golf Federation (NGF).

3. Methods

3.1. Evaluation of Primo MAXX® under fairway conditions, Bioforsk Landvik, Norway

Experimental site

On 8 May 2007, a field trial was laid out on a fairway established on a sandy loam soil (topsoil: 68 % sand, 27% silt, 5 % clay) at Bioforsk Landvik Research Station (58°34'N, 8°52'E), SE Norway. Soil samples indicated a pH (H_2O) of 5.9, high phosphorus values (P-AL=19) and intermediate to low potassium values (K-AL = 8, K-HNO_3=58). The fairway had been seeded in September 2003 to a mixture of smooth meadowgrass (*Poa pratensis*), chewing fescue (*Festuca rubra* ssp. *commutata*), and browntop bent (*Agrostis capillaris*) (Table 1). Block 1 and 2 were located in one part, and block 3 and 4 in a different part of the fairway. Botanical analyses at the start of experimentation indicated that red fescue was the predominant species in all blocks, but presumably due to slightly less surface drainage, blocks 1 and 2 had a higher percentage of smooth and annual meadowgrass and broadleaved weeds (primarily white clover (*Trifolium repens*)) than blocks 3 and 4 (Table 1).

Table 1. Seed mixture used for fairway establishment in 2003 and botanical composition at the start of the Primo MAXX® trial in spring 2007.

Species	Cultivar	% (w/w) of seed mixture	% cover at initiation of Primo MAXX® trial		
			Block 1 and 2	Block 3 and 4	Mean
Poa pratensis	Conni	25	31	9	20
Poa pratensis	Eva	10			
Poa pratensis	Limousine	10			
Festuca rubra ssp. commutata	Bargreen	25	50	74	62
Festuca rubra ssp. commutata	Calliope	25			
Agrostis capillaris	Tracenta	5	5	15	10
Poa annua			8	2	5
Broadleaved weeds			6	0	3
Sum		100	100	100	100

Experimental plan

The experiment was laid out according to a randomized complete block design with plot size 2m x 3m, four blocks (replicates) and the following treatments:

1. Usprayed control
2. Primo MAXX, 0.5 l/ha (56.5 g a.i./ha) every four weeks
3. Primo MAXX, 1.0 l/ha (113 g a.i./ha) every four weeks
4. Primo MAXX, 1.5 l/ha (169.5 g a.i./ha) every four weeks
5. Primo MAXX, 2.0 l/ha (226 g a.i./ha) every four weeks
6. Primo MAXX, 3.0 l/ha (339 g a.i./ha) every four weeks

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. Actual application rates were recorded by weighing the tank before and after spraying. Table 2 shows actual rates and weather conditions for each spraying event.

Table 2. Weather conditions and actual application rates at the six spraying events.

Application date	Time of day (hours)	Weather conditions at application			Treatment number / application rate (l Primo MAXX® per ha)				
		Air temp. °C	Relative Humidity %	Wind Speed m/s	2. (target 0.5)	3. (target 1.0)	4. (target 1.5)	5. (target 2.0)	6. (target 3.0)
9 May	09-11	14	48	< 1.0	0.47	0.94	1.56	1.90	3.35
5 Jun.	09-11	15	60	< 1.0	0.58	1.06	1.67	1.93	3.19
4 Jul.	13-15	17	70	1.0-2.0	0.61	0.98	1.73	2.19	3.38
31 Jul.	08-10	18	55	1.0-2.0	0.55	1.05	1.66	2.28	3.41
28 Aug.	09-11	19	32	1.0-2.0	0.57	1.03	1.55	2.19	3.52
26 Sep.	09-11	11	69	< 1.0	0.52	1.07	1.55	2.01	3.15
Mean					0.55	1.02	1.62	2.08	3.33

Registrations

At two weeks intervals throughout the experimental period, turfgrass colour, tiller density, and turf general appearance were assessed by turfgrass scientist or technicians using a scale from 1 to 9 where 9 is darkest colour, highest tiller density and best turf quality. The assessments were conducted two and four weeks after application of Primo MAXX®. On the same dates, turfgrass diseases and broadleaf weed (including white clover) invasion were reported as per cent of plot area. Turfgrass height was recorded as the mean of three random measurements with a ordinary ruler in each plot, and the overall growth rate by weighing clippings in the basket of a walk-behind mower used in the 0.56 m x 1.88 m central area of each plot (Photo 1). Both raw weight and dry weight were recorded, the latter after drying for 24 h at 60ºC. By the end of the growing season, on 2 Nov., turfgrass dormancy colour was evaluated on a scale 1-9, where 1 is completely faded / brown turf, and 9 is completely green turf.

Photo 1a and b. Tatsiana Espevig collecting clippings in fairway trial at Landvik. Photos: Trygve S. Aamlid

Management

The experiment was mowed at 15 mm two times a week, usually on Monday and Friday. A triplex fairway mower without collection of clippings was used except when clipping weights were to be recorded. Granular fertilizer was applied at approximately monthly intervals as outlined in Table 3. The experiment was not irrigated except for small amounts of water to dissolve fertilizer after application. On 7 Aug., the trial was aerated using a vertidrain with 15 mm solid tines to 15 cm depth. Topdressing was accomplished on 8 Aug. and 5 Nov. at rates 0.75 and 1.5 kg pure sand per m^2, respectively.

The fairway trial at Landvik was not exposed to ordinary play, but it was was subjected to artifical wear from a wear drum one to two times per week.

Table 3. Fertilizer inputs, fairway trial, Landvik.

		Per ha							
Date	Fertilizer type	kg fertilizer	kg N	kg P	kg K	kg Mg	kg S	kg Ca	kg Fe
17 Apr.	Fullgjødsel 22-2-12	40	9	1	5	0	1	0	0
16 May	Fullgjødsel 22-2-12	70	15	1	8	1	2	1	0
12 Jun.	Arena Golf Extra 13-0-15	150	20	0	23	2	21	0	3
23 Jul.	Arena Golf Extra 13-0-15	130	17	0	20	2	18	0	3
9 Aug.	Arena Golf Extra 13-0-15	135	18	0	21	2	18	0	3
5 Sep.	Arena Golf Extra 13-0-15	150	20	0	23	2	21	0	3
SUM			99	2	100	10	80	1	11

Weather data

In SE Norway, the growing season 2007 was characterized by exceptionally high rainfall, especially in July, but also in May, June and August (Table 4). By contrast, September was unusually dry. Precipitation was recorded on 16 out of the 31 days in July; the cloudy summer weather is also reflected by a rather low irradiance during this month. The warmest period, with daily maximum temperatures in the range 23-29 ºC was recorded from 6 to 12 June.

Table 4. Weather data for Landvik meteorological station, about 200 m for experimental field. Normal values for temperature and rainfall are 'official' values for from the period 1961-90, while normal values for irradiance are calculated averages for the period 1994-2006.

	Mean temperature, °C		Precipitation, mm		Irradiance, MJ/m^2 (305-2800 nm)	
	2007	30 yr normal	2007	30 yr normal	2007	13 yr average
May	10.2	10.4	107	82	518	540
June	15.9	14.7	109	71	604	600
July	15.5	16.2	213	92	492	632
Aug.	16.2	15.4	132	113	476	476
Sep.	12.0	11.8	59	136	321	262
Mean / sum	14.0	13.7	620	494	2411	2510

3.2. Evaluation of Primo MAXX® on a golf course fairway, Lepaa, Finland

Experimental site

The Finnish fairway trial was laid out on 11 May 2007. The fairway was seeded to a mixture of smooth meadowgrass and chewing fescue (*Festuca rubra* spp. *commutata*) on a heavy clay soil (15% sand, 37% silt, 48% clay) at the Lepaa Unit of HAMK University of Applied Sciences, Finland (61°08'N, 24°20'E). 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. All observations and management of the trial was carried out by the HAMK Lepaa greenkeepers Petteri Lehmuskoski and Tommi Turunen except for the spraying treatments which were carried out by MTT's 'Good Experimental Practice' certified spraying team from Jokioinen (90 km from Lepaa).

Experimental plan and registrations

The experiment was laid out following the same plan and plot size as at Landvik, Norway (previous paragraph). Primo MAXX® was applied in accordance with the Finnish 'Good Experimental Practise' protocol, using a portable, compressed air-powered 'van der Weij' plot sprayer, mounted with a windshield and flat fan nozzles (Hardi 4110-12) and working at 180-250 kPa pressure. The spraying boom had four nozzles spaced 50 cm apart. The spraying volume corresponded to 200 l/ha. Full spray coverage was on the central 1.5m x 2.5 m of each plot. Table 5 shows application dates and weather conditions for each spraying event. The last application on 4 Oct. was conducted especially to evaluate potential effects of Primo MAXX® on turfgrass winter damage.

Table 5. Application dates and weather conditions in fairway and green trials at Lepaa.

Application date	Time of day (hours)	Air temp. °C	Relative humidity %	Wind Speed m/s	% cloud cover
11 May	09-11	11	29	0	25
8 Jun.	09-11	20	56	1.5	1
5 Jul.	13-15	23	47	2.5	70
3 Aug.	09-11	17	78	2.0	90
4 Sep.	09-11	11	90	1.0	90
4 Oct.	13-15	11	92	1.5	100

Photo 2. Austen Sutton, Syngenta (left) and greenkeeper Petteri Lehmuskoski, HAMK Lepaa Unit, in fairway trial at Lepaa, Finland, 29 Aug. 2007.

Photo: Oiva Niemelainen.

Registrations

Registrations were carried out at two-week intervals following the same program as at Landvik (previous section) except that weed occurrence and dormancy colour were not recorded. Plant height at Lepaa was determined using a Turf Check Prism device (Check Signature Inc., Shoreview, MN).

Management and wear

The experiment was mowed with a triplex fairway mower about three times per week. Mowing height ranged from 12 to 18 mm. Granular fertilizer Sportsmaster 26-2-9 was applied at equal rates on 8 May and 12 July, the total input corresponding to 156 kg N, 12 kg P, 54 kg K and 0.9 kg Fe per ha. Information about irrigation is given in Table 6. The trial was aerated or top-dressed in late autumn, after the completion of registrations.

During the growing season period, the trial was exposed to approximately 3.500 rounds of golf.

Weather data

Temperatures at Lepaa were higher the 30 yr normal values throughout the growing season (Table 6). August had the greatest deviation from the long-term average value. July had 49 % more, and August 42 % less rainfall than usual; over the whole experimental season, rainfall was close to the 30 yr normal value.

Table 6. Weather data for Hattula Lepaa weather station and irrigation in fairway and green trial at Lepaa golf course, 2007. Normal values for temperature and rainfall are official values for from the period 1971-2000 (Finnish Meteorological Institute)

	Mean temperature, °C		Rainfall, mm		Irrigation, mm (2007)	
	2007	30 yr normal	2007	30 yr normal	Fairway trial	Green trial
May	10.6	9.8	30	34	*	*
June	15.1	14.5	54	55	26	79
July	16.6	16.4	119	80	5	47
Aug.	16.4	14.6	43	74	7	50
Sep.	9.9	9.4	58	54	0	6
Mean / sum	13.7	12.4	304	297	37	188

* Data are unavailable for the period 1-26 May 2007 due to change of irrigation computer.

3.3. Evaluation of Primo MAXX® on a golf course putting green, Lepaa, Finland

Experimental site

The Finnish green trial was established on 11 May 2007 on a USGA green seeded to creeping bentgrass (*Agrostis stolonifera*, seed blend of 50% 'Penn A-4' and 50% 'Penn G-6') at Lepaa Golf Course.

Experimental plan

The experimental plan comprised five rates of Primo MAXX plus the unsprayed control treatment:

1. Usprayed control
2. Primo MAXX, 0.2 l/ha (22.6 g a.i./ha) every four weeks
3. Primo MAXX, 0.4 l/ha (45.2 g a.i./ha) every four weeks
4. Primo MAXX, 0.6 l/ha (67.8 g a.i./ha) every four weeks
5. Primo MAXX, 0.8 l/ha (90.4 g a.i./ha) every four weeks

The trial had four replicates, and a gross plot size of 2 m x 3 m. It was sprayed on the same dates and following the same GEP procedures as the fairway trial on the same location (Table 5).

Photo 3. Green trial at Lepaa ready for the first treatment on 11 May 2007. Photo: Oiva Niemelainen.

Registrations

Registrations followed the same program as in the Finnish fairway trial (previous section).

Management and wear

The experiment was mowed with a Triplex greens mower for an average of six times per week. Depending on weather and turfgrass density, mowing height was 5–7 mm in May and September and 3-4 mm from June to August. Information about irrigation and fertilizer inputs are given in Tables 6 and 7, respectively.

To avoid thatch accumulation, the trial was aerated with deep slitting knives every second week and with 8 mm needle tines once a month. Verticutting was accomplished every second week and topdressing with 0.1-0.7 mm finely graded sand at a rate of 1 kg per m2 every third week. The sand was brushed/irrigated into the green and the dressing was never done in close proximity to weighing of clippings.

Being located on a practise green, the experiment received wear from about 10.000 rounds of golf over the season. When placing holes on the green, care was taken to create as uniform wear as possible.

Table 7. Fertilizer inputs in green trial at Lepaa.

		Per ha							
Date	Fertilizer type	kg fertilizer	kg N	kg P	kg K	kg Mg	kg S	kg Ca	kg Fe
28.3.2007	Floratine Kevätstartti*	35	5.4	1.2	2.1				
5.4.2007	Floratine Kevätstartti	35	5.4	1.2	2.1				
19.4.2007	Floratine Kevätstartti	35	5.4	1.2	2.1				
26.4.2007	Sierraform Springstart (16-0-13)	250	40	0	32.5				2.50
15.5.2007	Sierraform All Season (18-3-15)	250	45	7.5	37.5	3.0			1.25
30.5.2007	Kemigreen Basic (23-4-14)	40	9	1.6	5.6	0.6	0.8		0.04
5.6.2007	Kemigreen Basic (23-4-14)	40	9	1.6	5.6	0.6	0.8		0.04
11.6.2007	Sierraform All Season (18-3-15)	250	45	7.5	38				
25.6.2007	Osmosol 614R (19-2-10)	40	7.6	0.8	4.0	0.5		1.7	0.04
2.7.2007	Osmosol 614R (19-2-10)	40	7.6	0.8	4.0	0.5		1.7	0.04
13.7.2007	Kemigreen Summer (18-0-17)	40	7.2	0	6.8			2.0	0.40
18.7.2007	Kemigreen Summer (18-0-17)	40	7.2	0	6.8			2.0	0.40
26.7.2007	Sierraform All Season (18-3-15)	250	45	7.5	37.5	3.0			1.25
14.8.2007	Kemigreen Summer (18-0-17)	40	7.2	0	6.8			2.0	0.40
27.8.2007	Greenmaster Autumn (6-2-8)	300	18	6	24	5.4			1.50
30.8.2007	Kemigreen Basic (23-4-14)	40	9	1.6	5.6	0.6	0.8		0.04
11.9.2007	Sierraform Springstart (16-0-13)	200	32	0	39				2.00
SUM			305	39	260	14.0	2.4	9.4	10

* Floratine Kevätstartti (Springstart) is composed of P-48 (10-21-6.6), Per 4 Max (15-0-0), Protesyn (3.5-0.6-1.8), and Plant Marvel (28-3-15).

3.4. Demonstration trials with Primo MAXX® at Ballerud Golf Course, Oslo, Norway

Experimental site and set-up

Ballerud GC is located on an old horticultural farm in a suburban area SW of Oslo. The course has greens with mostly dominated by creeping bentgrass, fairways almost exclusively dominated by annual meadowgrass, and smooth meadowgrass roughs with some tufts of perennial ryegrass (*Lolium perenne*).

Large-scale, unreplicated demonstration trials were laid out on green no. 9, fairway no. 9 and rough no. 9 on 5 June 2007. Plots sizes varied from 80 to 130 m^2. Unsprayed control plots were compared with plots sprayed with Primo MAXX® at rates 0.4, 1.5 and 2.2 l/ha and application intervals of approximately 3, 4 and 7 weeks on green, fairway and rough, respectively. In compliance with the Norwegian Food Authority's rule for complete closure of all sprayed areas for 48 h after each application, the trial on green no. 9 had to be discontinued after the second application on 18 June.

Three weeks later, it was replaced by a new trial laid out on the golf course' nursery green. Actual application dates in the green, fairway and rough trials are given in Table 8. The growth regulator was applied using a battery-operated electric Hardy Defender plot sprayer (Photo 4).

Table 8. Application dates for Primo MAXX in demonstration trials at Ballerud GC.

Green no. 9	Nursery green	Fairway no. 9	Rough no. 9
5 June		5 June	5 June
18 June			
	9 July	2 July	
	31 July	31 July	28 July
	21 Aug.		
	13. Sep.	3 Sep.	11 Sep.
	4 Oct.	28 Sep.	

Photo 4. Sprayer used in demonstrations trials at Ballerud Golf Course.

Photo: Terje Haugen.

Registrations

In all trials at Ballerud, turfgrass general appearance was evaluated by the headgreenkeeper at one to two week intervals throughout the growing season. In the green and fairway trials, turfgrass clipping yields were recorded on a fresh weight basis. Registrations in the green trials also included regular assessments of green speed using a standard stimpmeter.

Maintenance

The green trials at Ballerud were mowed daily at 3.4-3.8 mm and the fairway trial at 20 mm three to four times a week. The rough area was only mowed upon need.

Due to the rich soil from decades of vegetable production, the rough trial was not fertilized in 2007, and the fairway trial only received one application of 200 kg Fullgjødsel® 11-5-18 (22 kg N/ha) on 8 May. The green trials received monthly applications of granuar fertilizer (Gro Power 5-1-1, Anderson 14-0-9, Anderson 8-0-16, and/or Roots 12-2-12), and weekly applications of liquid fertilizers /

biostimulants, mostly Floratine products. Total rates of N, P, K, Mg, Ca, S and Fe over the season were 155, 14, 142, 27, 30, 73 and 14 kg/ha, respectively. The greens were aerated, mostly using Envirojet, six times during the season and top-dressed, also six times, giving a total of 6.3 kg sand per m^2.

Weather data and irrigation

Table 3 shows recordings from Ballerud GC's weather station. Although the rainfall in 2007 was higher than usual, there were periods, especially in May, June and August when the green trials needed irrigation. The fairway and rough trials were never irrigated.

Table 9. Weather recordings and irrigation at Ballerud GC, 2007. Monthly temperatures are means of daily maximum and minimum temperatures.

	Mean monthly temperature, °C	Monthly rainfall, mm	Monthly irrigation, mm (greens only)
May	11.2	94	42
June	17.1	185	52
July	16.9	173	10
Aug.	16.6	83	47
Sep.	11.1	71	21
Mean / sum	14.6	606	172

3.5. Demonstration trial with Primo MAXX® at Oslo Golf Club, Bogstad, Norway

To evaluate the effect of Primo MAXX® on a typical annual meadowgrass green, an unreplicated demonstation trial with plot size 250 m^2 was laid out at Oslo GK on 20 June 2007. Primo MAXX® was sprayed at a rate 0.4 l/ha on 20 June, 10 July and 31 July using the same sprayer as at Ballerud GC, about 10 km from Bogstad (Photo 4). Turfgrass quality (general appearance) and fresh weight clipping yields were determined on 4 July, 13 July and 14 August. Unfortunately, the trial had to be discontinued in mid August due to reconstruction of the green.

3.6. 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 on each plot and on plot values which had been averaged, either over the whole growing season, separately over the spring (before 10 June), summer (10 June – 1 Sep.) and autumn (after 1 Sep.) periods, or for observations conducted two versus four weeks after the last application of Primo MAXX®. The significance levels P%<0.1, P%<1, P%<5 and ns (not significant) have been indicated in the tables along with LSD values for effects significant at P%<5. In a few cases exact P-values have been given for tendencies in the 5-15% probability range. As an indications of the variability for each character, coeffcients of variation, (CV %), have also been given in the tables.

4. Results

4.1. Evaluation of Primo MAXX® under fairway conditions, Bioforsk Landvik, Norway

Turfgrass quality and related characteristics

Table 10 shows results from the visual observations of turfgrass quality and related characters in the fairway trial at Landvik. Both within the three seasons and as a mean value, turfgrass general appearance was significantly lower on plots receiving monthly applications of Primo MAXX® at 1.0 l/ha or higher rates than on unsprayed control plots and plots receiving 0.5 l/ha. Within these two groups, differences in generall appearance were not significant. Separate analyses for blocks 1 and 2 versus 3 and 4 indicated that these responses were practically identical regardless of botanical composition (data not shown).

Individual registrations of turfgrass quality are further depicted in Fig. 1. There was a dramatic decline in quality after the first application on 9 May. After this the turf recovered and there was no significant effect of Primo MAXX® at the two subsequent evaluations. Applications of 1.0 l/ha or higher rates on 4 July lead to new quality reductions in July, August and September (Photo 5); these effects were especially apparent at the last evaluation in early November (Photo 6). By contrast, there tended to be a small quality improvement due to the lowest rate of Primo MAXX® from late August to October. This improvement was reflected also in a significant increase in tiller density on average for the whole growing season (Table 10).

Increasing rates of Primo MAXX® consistently led to darker turf throughout the growing season, but also to earlier growth cessation and a less attractive dormancy colour in late autumn (Table 10). The only visible disease in the trial was a slight attack of red thread (*Laetisaria fuciformis*) during the wet period in July; however, these spots were unaffected by Primo MAXX® which also had no effect on the occurrence of broadleaved weeds, primarily white clover, in the trial.

Table 10. Turfgrass quality, tiller density, within-season colour, dormancy colour and infestation of weeds and red thread (*Laetisaria fuciformis*) in fairway at Landvik as affected by increasing rates of Primo MAXX®, 2007. Visual merit and tiller density are means of twelve observations (two in spring, i.e. before 10 June, six in summer, i.e. from 10 June to 1 Sep., and four in autumn, i.e. after 1 Sep. Within season colour (green darkness) and occurrence weeds and red thread are means of twelve, three (all in July) and two (June and Nov.) observations, respectively. Dormancy colour was evaluated on 2 Nov. All values are means of four blocks.

Primo MAXX®, rate	Turf quality (general appearance, 1-9)				Tiller density (1-9)	Within season colour (1-9)	Dor-mancy colour (1-9)	% of plot area	
	Mean	Spring	Summer	Autumn				Dicot weeds	Red thread
0 = Control	6.2	6.1	6.4	6.0	6.3	5.2	6.8	4	4
0.5 l/ha	6.1	5.6	6.3	6.2	6.5	5.6	6.3	2	3
1.0 l/ha	5.5	4.5	5.9	5.3	6.1	5.8	5.0	5	2
1.5 l/ha	5.3	4.6	5.5	5.4	6.0	5.9	4.1	4	3
2.0 l/ha	5.5	4.6	5.9	5.3	6.1	6.0	4.3	3	2
3.0 l/ha	5.1	4.2	5.5	4.9	6.0	6.2	3.5	4	3
P%	<0.1	<0.1	<1	<0.1	<1	<1	<0.1	ns	ns
LSD 5%	0.3	0.5	0.4	0.4	0.2	0.4	1.2	-	-
CV%	4	7	5	5	3	5	15	-	-

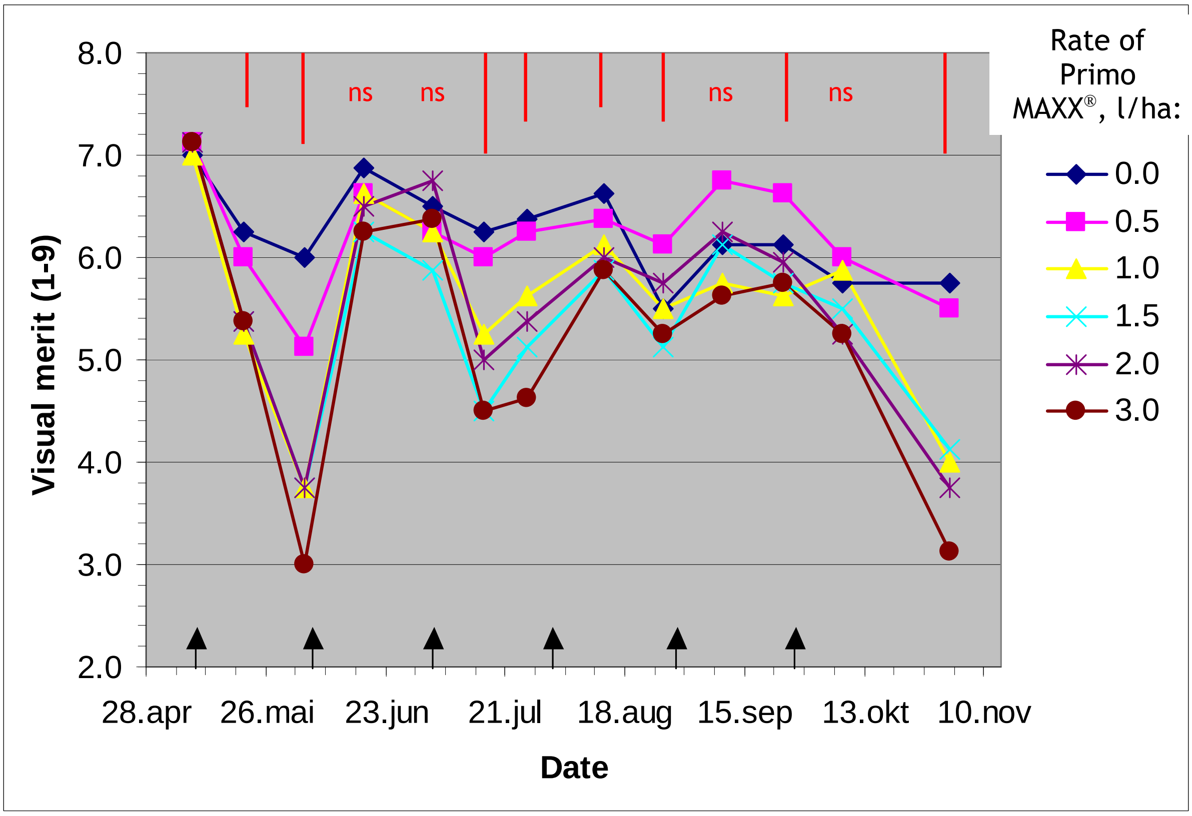


Fig.1. Turfgrass overall quality as affected by increasing rates of Primo MAXX® in fairway trial at Landvik, 2007. Mean of four replicates (blocks). The application dates 9 May, 5 June, 4 July, 31 July, 28 Aug. and 26. Sep. are indicated by black arrows. Red bars indicate LSD 5%.

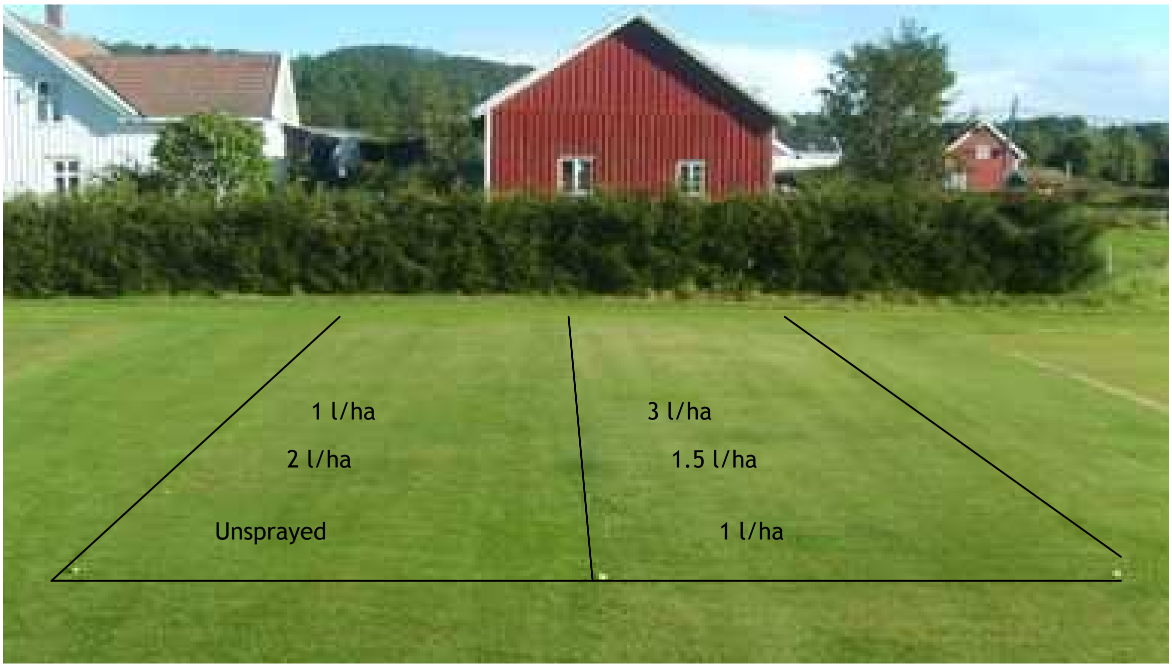


Photo 5. Visual appearance of fairway trial at Landvik, block 1 and 2, on 10 Sept. Within each block, the treatments closest to the photographer have been labeled. High rates of Primo MAXX® resulted in darker, in some cases, almost brown, turf. Photo: Trygve S. Aamlid.

Photo 6.

Turf quality / dormancy colour at growth cessation on 2 Nov. 2007 after application of Primo Maxx at 3.0 l/ha (left) and 0.5 l/ha (right), last application on 26 Sep.

Photo: Trygve S. Aamlid.

<u>Turfgrass height and dry matter production</u>

The average effect of Primo MAXX® on plant height and clipping yields are given in Table 11. In all blocks, the growth regulator caused a significant reduction in plant height even at the lowest rate, but contrary to expectation, this low rate also tended to increase aboveground dry matter production as compared with the unsprayed control treatment. This might reflect a higher tiller density, as also suggested in Table 10. Separate analyses for various parts of trial showed that the average reduction in clipping yield due to Primo MAXX® was stronger in blocks 1 & 2 which had more *Poa* species less red fescue and browntop bent and than blocks 3 & 4. On average for eleven harvests and all replicates, there was a slight tendency for Primo MAXX® to increase the dry matter percentage of turfgrass clippings (P% = 16, Table 11).

Table 11. Absolute and relative effects of increasing rates of Primo MAXX® on turfgrass height, turfgrass dry matter production, and per cent dry matter of clippings in fairway trial at Landvik, 2007. Mean of eleven observations. Plant height above 15 mm represents an average of four days' growth.

Primo MAXX, rate	Plant height, mm		Production of turfgrass clippings, g/m^2/day				% dry matter in clippings
	mm	Rel.	Block 1&2	Block 3&4	Mean	Rel.	
0 = Control	21.9	100	1.78	1.62	1.70	100	31.5
0.5 l/ha	20.9	95	1.91	1.93	1.92	113	32.2
1.0 l/ha	20.7	95	1.65	1.72	1.69	99	32.5
1.5 l/ha	20.0	91	1.46	1.46	1.46	86	33.6
2.0 l/ha	20.3	93	1.55	1.61	1.58	93	32.4
3.0 l/ha	19.5	89	1.31	1.70	1.51	88	33.1
P%.	<0.1	-	10	ns	<5	-	16
LSD 5%	0.7	-	-	-	0.29	-	-
CV%	2	-	10	14	12	-	3

In absolute terms, turfgrass clipping yield showed a distinct seasonal pattern with peaks during the warm and sunny periods in early June and late August (Fig. 2a). The low clipping yield on 17 July was probably due to 280 mm rainfall, and thus nutrient leaching, since the last fertilizer application on 12 June (Tables 3 and 4). Separate analyses of variance for each day indicated a significant effect of Primo MAXX® on clipping yield only on 4 June.

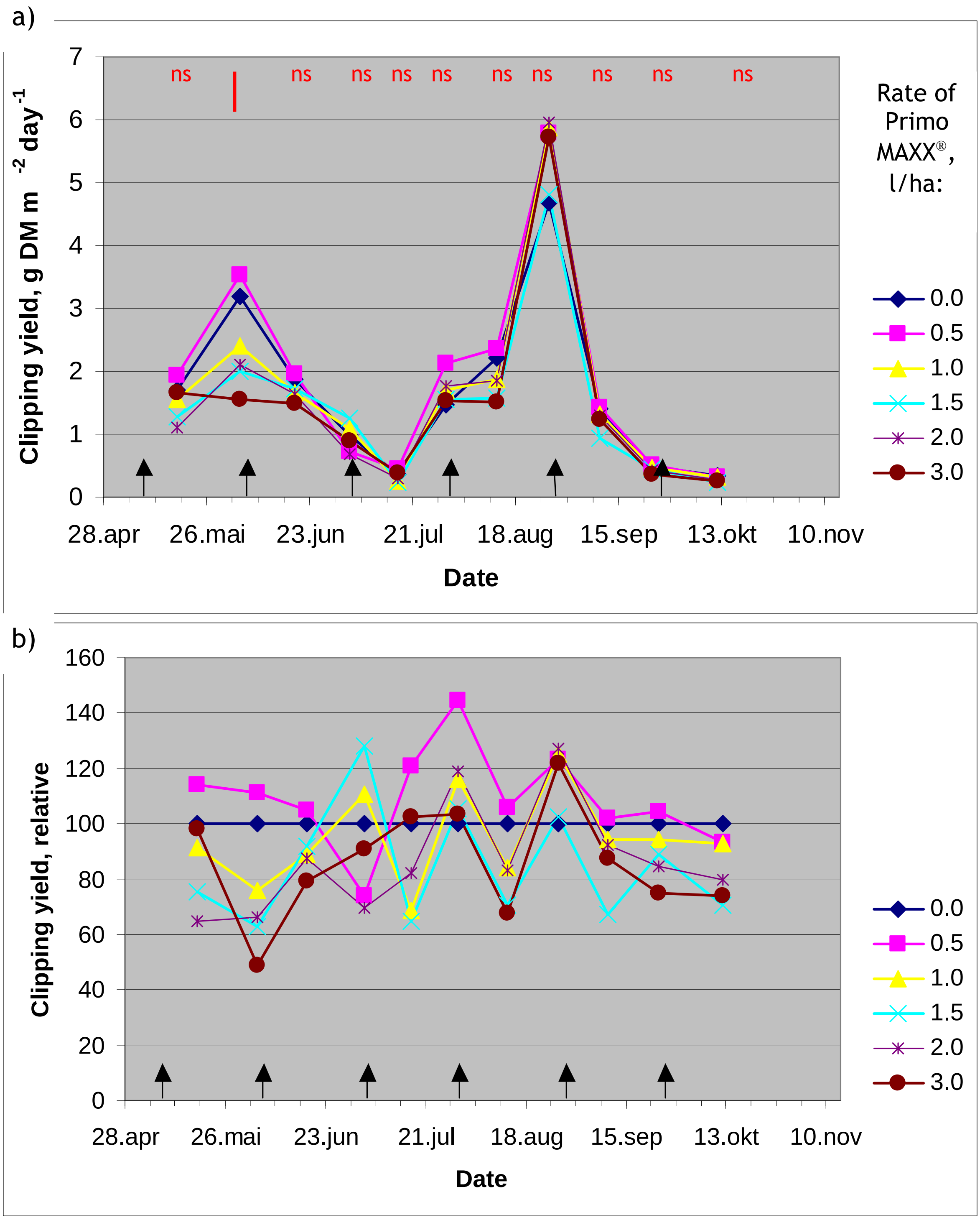


Fig. 2. Absolute (a) and relative (b) reductions in daily dry matter production of turfgrass clippings as affected by increasing rates of Primo MAXX® in fairway trial at Landvik. Red text/bars and black arrows indicate probability / LSD values and application dates 9 May, 5 June, 4 July, 31 July, 28 Aug. and 26 Sep., respectively. In (b), the clipping yield on each date was set to 100 in the unsprayed control treatment.

In relative terms, none of the Primo MAXX® treatments produced clipping yields that were lower than the unsprayed control at all harvests (Fig. 2b). Many of the treatments showed a typical suppression / rebound pattern with clipping yields lower than the control treatment at one harvest, but higher than control treatment at the next harvest.

4.2. Evaluation of Primo MAXX® on a golf course fairway, Lepaa, Finland

On average for two observations in spring, five observations in summer and two observations in autumn, Primo MAXX® had no effect on turfgrass general appearance in the fairway trial at Lepaa. Among the nine observation dates, significant differences were recorded only on 21 August when the plots sprayed with the highest dose (3.0 l/ha) had an average visual merit score of 5.5 as opposed to 6.8 for unsprayed control plots and plots sprayed with the lowest dose (0.5 l/ha).

On average for observations, increasing rates of Primo Max caused an overall increase in tiller density, while turfgrass colour was not significantly affected. No diseases were observed during the growing season.

Table 12. Turfgrass quality (1-9, 9 is best quality), tiller density (1-9, 9 is highest density) and within-season colour (1-9, 9 is darkest green) in fairway trial at Lepaa as affected by increasing rates of Primo MAXX®. Means of nine observations (two in spring, i.e. before 10 June, five in summer, i.e. from 10 June to 1 Sep., and two in autumn, i.e. after 1 Sep.). All values are means of four blocks.

Primo MAXX®, rate	Turf quality (general appearance, 1-9)				Tiller density (1-9)	Within season colour (1-9)
	Mean	Spring	Summer	Autumn		
0 = Control	6.1	5.5	6.1	6.8	5.5	6.1
0.5 l/ha	6.2	5.5	6.1	7.0	5.8	6.2
1.0 l/ha	6.1	5.4	6.1	6.9	5.8	6.1
1.5 l/ha	6.2	5.5	6.2	7.0	6.0	6.3
2.0 l/ha	6.2	5.6	6.1	6.9	6.1	6.3
3.0 l/ha	6.2	5.6	6.1	7.0	6.4	6.2
P%	ns	ns	ns	ns	<0.1	ns
LSD 5%	-	-	-	-	0.4	-
CV%	5	4	8	3	3	4

The effect of Primo MAXX® on turfgrass plant height and clipping yield depended on the time since last application. On average for five observations conducted about two weeks after application, the highest rate of Primo MAXX® caused significant reductions in plant height and clipping yield corresponding to 11 and 48 %, respectively (Table 13). On average for four observations conducted four weeks after application, the maximal reductions were only 3 and 14 %, respectively. Fig. 3 illustrates the unstable effect of Primo MAXX®, particularly toward the end of the growing season. However, unlike in the fairway trial at Landvik (Fig.2), clipping yields on sprayed plots were rarely higher than on untreated control plots in the trial at Lepaa.

Table 13. Absolute and relative effects of increasing rates of Primo MAXX® on turfgrass height and dry matter production in turfgrass clippings in fairway trial at Lepaa 2007. Observations conducted 2 weeks (5 observations) and 4 weeks (4 observations) from spraying treatment have been presented separately.

Treatment	Plant height (mm)				Weight of clippings (g DM / m^2 / day)			
Time after treatment	2 weeks	4 weeks	Mean	Rel	2 weeks	4 weeks	Mean	Rel
0 = Control	15.7	16.0	15.8	100	3.2	7.0	4.9	100
0.5 l/ha	15.7	16.0	15.8	100	2.7	6.3	4.3	87
1.0 l/ha	14.9	16.0	15.4	97	2.8	6.6	4.5	92
1.5 l/ha	14.7	15.7	15.1	96	2.3	5.8	3.9	79
2.0 l/ha	14.4	15.6	15.0	95	2.1	6.1	3.9	80
3.0 l/ha	14.0	15.5	14.6	92	1.8	6.0	3.7	75
P%	<0.1	ns	<5	-	<0.1	ns	ns	-
LSD 5%	1.1	-	1.0	-	0.7	-	-	-
CV%	3	4	3	-	13	22	18	

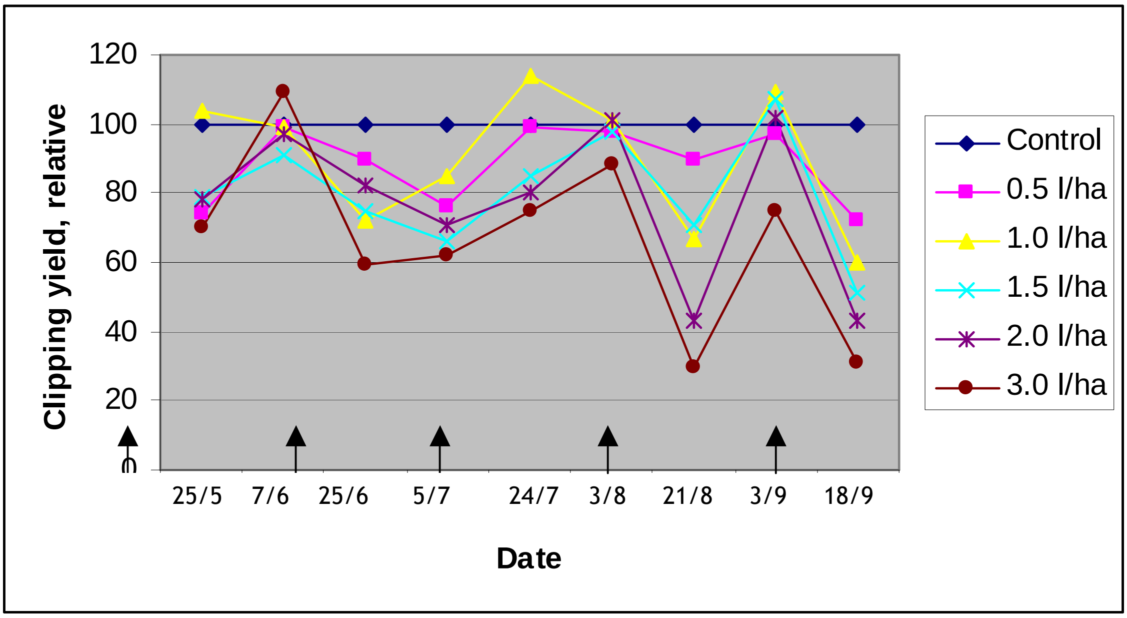


Fig. 3. Relative clipping weights (control = 100) in fairway trial at Lepaa, Finland. Spraying treatments indicated by black arrows were carried out on 11 May, 8 June, 5 July, 3 Aug. and 4 Sep. (The last spraying on 4 Oct. was done primarily to study the effect of Primo MAXX® on overwintering and was not followed by observations in late autumn.)

4.3. Evaluation of Primo MAXX® on a golf course putting green, Lepaa, Finland

On 3 Sep. 2007, a significantly higher tiller density was recorded on green plots sprayed with the highest rate of Primo MAXX® than on unsprayed control plots (data not shown). Otherwise, Primo MAXX® had no significant effect on either general appearance, tiller density or turfgrass colour in the green trial at Lepaa (Table 14). Although the effects on plant height and clipping yields were also not significant, reductions were generally stronger when recorded at two compared with four weeks after application (Table 15, Fig. 4).

Table 14. Turfgrass quality, tiller density and within-season colour (darkness) in green trial at Lepaa as affected by increasing rates of Primo MAXX®, 2007. Means of nine observations (two in spring, i.e. before 10 June, five in summer, i.e. from 10 June to 1 Sep., and two in autumn, i.e. after 1 Sep.). All values are means of four blocks.

Primo MAXX®, rate	Turf quality (general appearance, 1-9)				Tiller density (1-9)	Within season colour (1-9)
	Mean	Spring	Summer	Autumn		
0 = Control	6.4	6.1	6.6	6.3	6.3	6.4
0.2 l/ha	6.3	6.0	6.5	6.0	6.3	6.4
0.4 l/ha	6.3	5.9	6.5	6.1	6.2	6.3
0.6 l/ha	6.3	5.8	6.5	6.4	6.3	6.4
0.8 l/ha	6.2	5.8	6.4	6.3	6.2	6.4
P%	ns	ns	ns	ns	ns	ns
LSD 5%	-	-	-	-	-	-
CV%	3	5	5	7	2	3

Table 15. Absolute and relative effects of increasing rates of Primo MAXX® on turfgrass height and dry matter production in turfgrass clippings in green trial at Lepaa 2007. Observations conducted 2 weeks (5 observations) and 4 weeks (4 observations) from spraying treatment have been presented separately. Plant heights above 3 mm represent one day's growth.

Treatment	Plant height (mm)				Weight of clippings (g DM / m^2 / day)			
Time after treatment	2 weeks	4 weeks	Mean	Rel	2 weeks	4 weeks	Mean	Rel
0 = Control	4.3	3.9	4.1	100	2.60	2.21	2.43	100
0.2 l/ha	4.1	3.8	4.0	96	2.20	2.28	2.23	92
0.4 l/ha	4.0	3.9	3.9	95	1.88	2.28	2.06	85
0.6 l/ha	4.0	3.8	3.9	94	1.72	2.18	1.99	82
0.8 l/ha	3.8	3.9	3.9	93	1.75	2.28	1.92	79
P%	11	ns	ns	-	5	ns	ns	-
LSD 5%	-	-	-	-	0.9	-	-	-
CV%	6	7	8	-	20	14	16	-

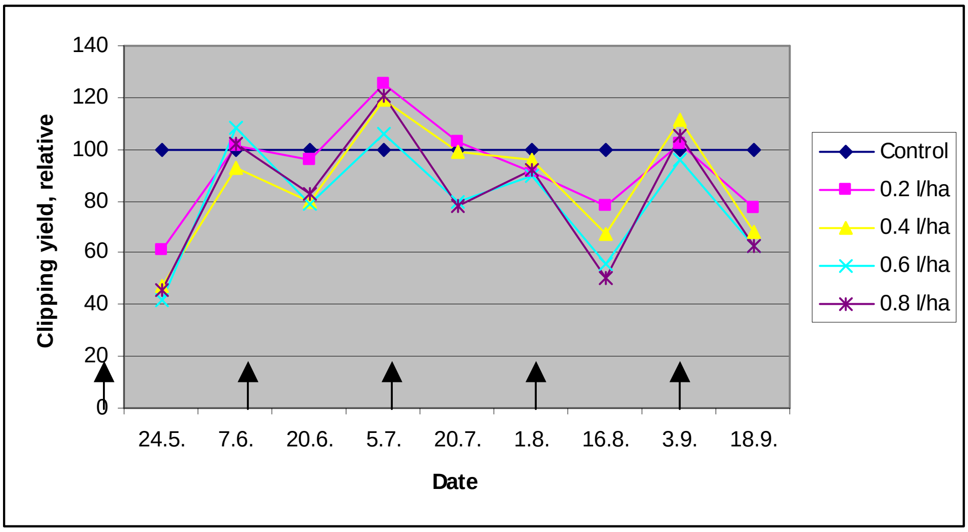


Fig. 4. Relative clipping weights (control = 100) in green trial at Lepaa, Finland. Spraying treatments indicated by black arrows were carried out on 11 May, 8 June, 5 July, 3 Aug. and 4 Sep. (The last spraying on 4 Oct. was done primarily to study the effect of Primo MAXX® on overwintering and was not followed by observations in late autumn.)

4.4. Demonstration trials with Primo MAXX® at Ballerud Golf Course, Oslo, Norway

Green trials

Applications of 0.4 l/ha Primo MAXX® on 5 and 18 June did not affect turf general appearance (Photo 7) or stimpmeter readings on green no. 9 at Ballerud. During the period 14-29 June, clippings were reduced by an average of 32%, but after spraying had been discontinued, there was a rebound effect corresponding to a 26 % increase in clipping yield in the period 12-25 July (data not shown).

Photo 7. Terje Haugen (left) and Lasse Augustsson on green no. 9 at Ballerud Golf Course, 27 June 2007. Photo: Trygve S. Aamlid.

Photo 8. Field day at Ballerud Golf Course 27 Aug. 2007. Photo: Tatsiana Espevig.

Fig. 5 summarizes results from the nursery green trial established on 9 July. In this trial, application of Primo MAXX® about every third week resulted in better colour (not shown), higher green speed (Fig. 5a), and an average reduction in turfgrass clippings of 44 % (Fig. 5b and c). Fig 5b shows that the reduction in clipping yield was most conspicuous during the periods of rapid growth in mid to late July (after only one application of Primo MAXX®) and in late August.

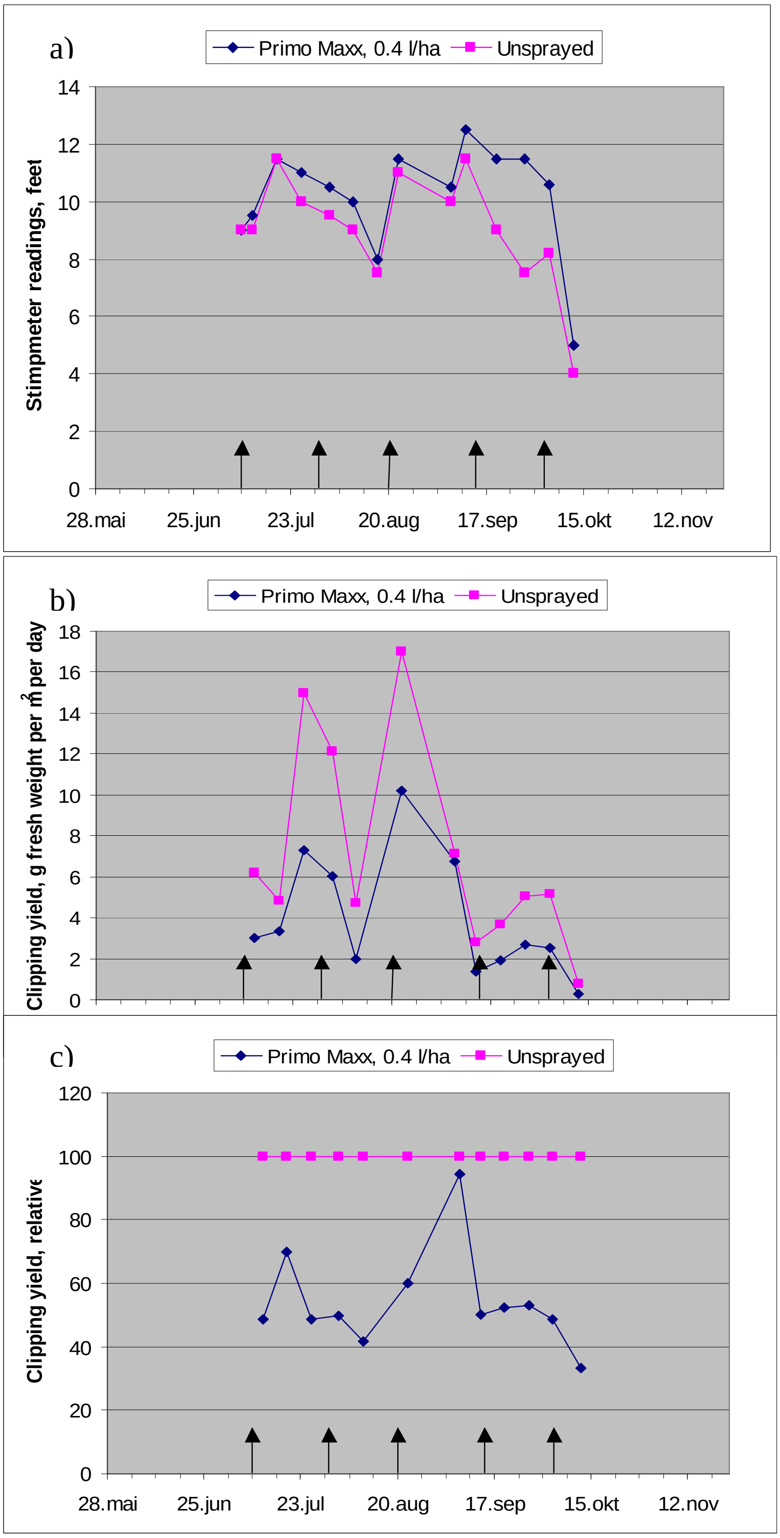


Fig. 5. Effects of spraying Primo MAXX® every three weeks of green speed and absolute and relative clipping yield on nursery green at Ballerud GC, 2007. Black arrows indicate the application dates 9 July, 31 July, 21 Aug., 13 Sep. and 4 Oct.

Fairway trial

As evaluated by the headgreenkeeper, monthly applications of 1.5 l/ha Primo MAXX® (1.5 l/ha) had no negative impact on turf quality in the fairway trial at Ballerud (Fig. 6). Photos 9-11 show, nevertheless, that treated turf was more faded, grayish, and less green than untreated turf. The pronounced colour difference in favour of Primo MAXX® in early September (Fig. 6) was due to less dry spots than the in the control area. While these spots recovered after rainfall on 10 and 17 Sep., the last application of Primo MAXX® on 4 Oct. led to an apparent loss of colour and drop in turf general appearance in late autumn (Photo 11).

On average for 17 clipping, regular application of Primo MAXX® resulted in a 37 % reduction in the fresh weight of turfgrass clippings (Fig. 7). The only time clipping yield was higher on the treated than on the untreated area was at the first clipping nine days after the first application and on 7 Sep. The latter coincided with the observation of less dry spots after use of Primo MAXX®. It may also be interpreted as a rebound effect following growth suppression after application on 31 July.

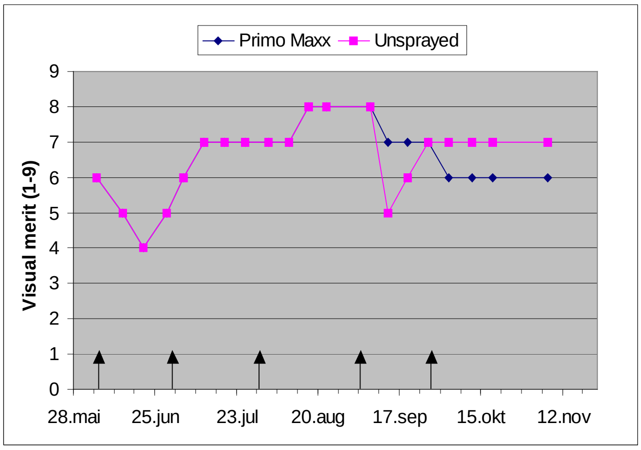


Fig. 6. Effect of Primo MAXX® on turfgrass general appearance in fairway trial at Ballerud GC. Black arrows indicate application dates. (Sprayed an unsprayed plots had identical scores until the beginning of September)

Photo 9. Difference in colour and general appearance of treated and untreated fairway Ballerud GC, 27 June. Photo: Trygve S. Aamlid.

Photo 10. Difference in colour and general appearance of treated and untreated fairway Ballerud GC, 27 Aug. Photo: Tatsiana Espevig.

Photo 11. Difference in colour and general appearance of treated and untreated fairway Ballerud GC, 3 Dec. Photo: Terje Haugen.

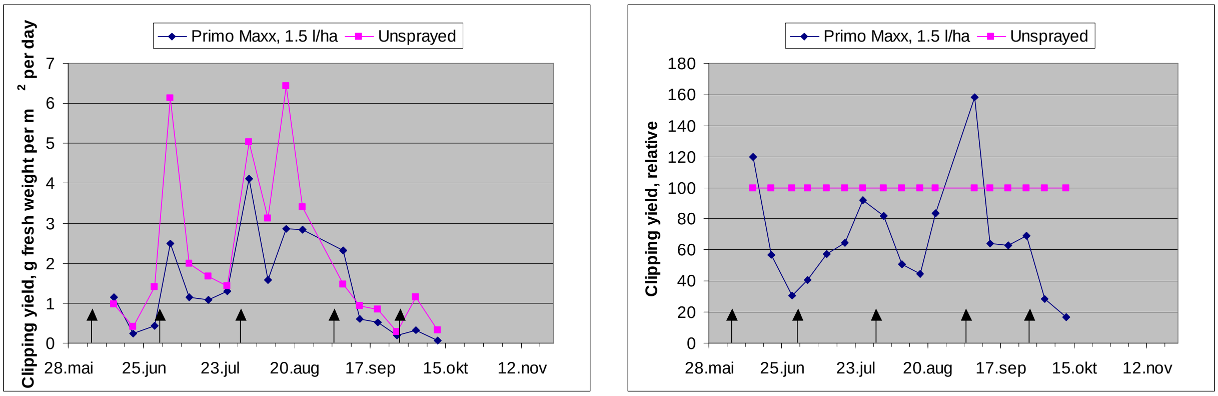


Fig. 7. Absolute (a) and relative (b) reductions in clipping yield resulting form application of Primo MAXX® in fairway trial at Ballerud GC. Arrows indicate application dates.

Spraying 2.2 l/ha of Primo MAXX® at six weeks interval resulted in discoloration and consistent drop in turf quality in the rough trial at Ballerud (Fig. 8, Photos 12 and 13). The effect was most conspicuous in late autumn. Primo MAXX® had less effect on tufts of perennial ryegrass which stood out very markedly in the turf which was otherwise dominated by smooth meadowgrass. Clipping yields were not recorded in this trial.

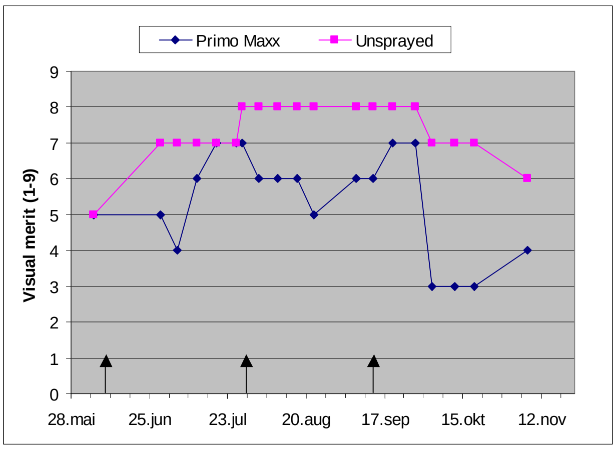


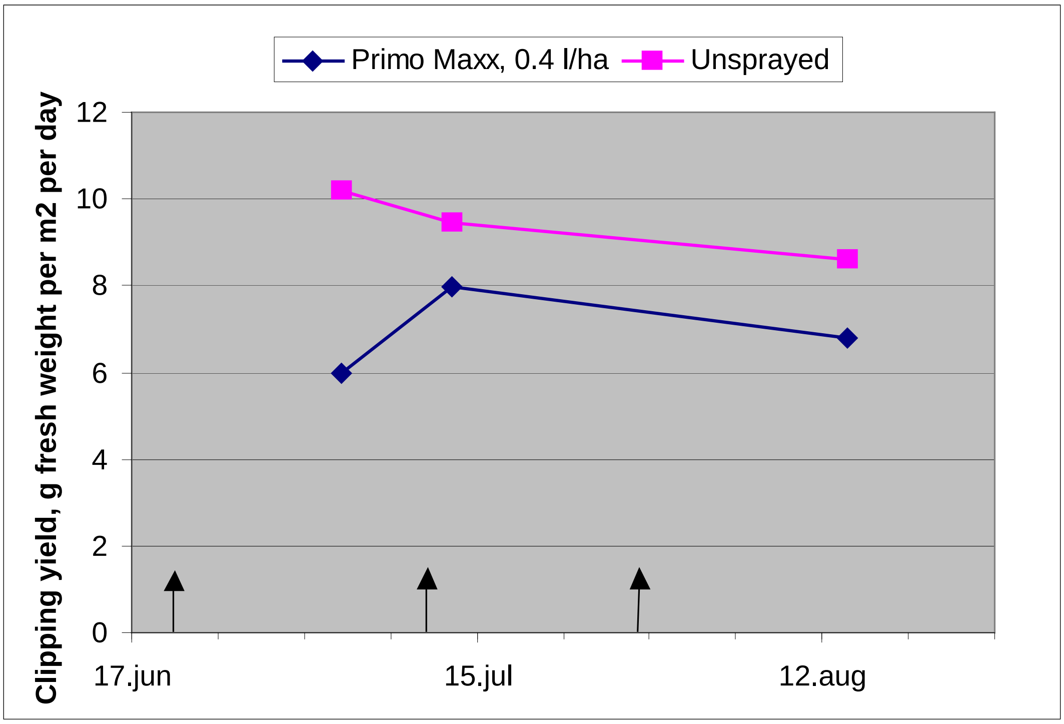
Fig. 8 (upper left). Difference in colour and general appearance of treated and untreated area in rough no 9, Ballerud, 27 June. Photo: Trygve S. Aamlid.

Photo 12 (upper right). Terje Haugen (left) and Lasse Augustsson in rough trial at Ballerud GC, 27 June. Photo: Trygve S. Aamlid.

Photo 13 (lower left). Trygve S. Aamlid inspecting rough trial at Ballerud GC, 27 August 2007. Tufts of ryegrass stand out very markedly on sprayed area.
Photo: Tatsiana Espevig.

4.5. Demonstration trial with Primo MAXX® at Oslo Golf Club, Bogstad, Norway

Application of 0.4 l Primo MAXX® at three week intervals resulted in darker turf but had otherwise no effect on the turfgrass quality of annual meadowgrass at Oslo GC. On average for three registrations, the Primo MAXX led to a 26% reduction in clipping yields (Fig. 9).



5. Discussion and suggestions for 2008

The starting point for evaluating Primo MAXX® in this two-year project was the rates and applications frequencies recommended for the product in Europe (Syngenta 2007, Table 16). Based on our experiences from agricultural crops that the optimal rates may be different in the Nordic countries than countries further south, higher and lower rates were included in the GEP trials both to determine the potential growth inhibition and the risk for discoloration or other phytotoxic effects. All taken together, the results from the first project year confirms that the guidelines in Table 16 are not directly applicable in Scandinavia and that further research is needed to find the optimal way of using the product under Nordic conditions.

Table 16. Dose rates and applications frequencies recommended for Primo MAXX® in the United Kingdom (Syngenta 2007).

	Dose rate		Application frequency
	Primo MAXX®, l/ha	trinexapac-ethyl, g a.i./ha	
Fairways	0.8 – 1.6	90 - 180	Every four to five weeks
Roughs & semi-roughs	1.6-2.4	180 - 240	Every five to eight weeks
Greens	0.4	45	Every two to four weeks

On fairway, the average reduction in clipping yield caused by monthly application of the intermediate Primo MAXX® rate of 1.5 l/ha was 15 and 21 % in the GEP trials at Landvik and Lepaa, respectively. By contrast, monthly application of 1.5 l/ha resulted in a 37 % reduction in clipping yield in the demonstration trial at Ballerud GC, which is closer to the data presented by Syngenta (2007). In agreement with Table 11 showing an increase in turfgrass dry matter percentage (i.e. decreased succulence) after application of Primo MAXX®, one of the reasons for this difference might be that clipping yields were determined on a dry weight basis in the GEP trials but on a fresh weight basis at Ballerud GC and in the data presented by Syngenta (2007). Another, and probably more important explanation, is the difference in species composition among the three trials. While the plant cover at Ballerud was almost 100% by annual meadowgrass, the species composition at Landvik varied with the two blocks showing the least response to Primo MAXX® having a plant cover of 74 % red fescue (Tables 1 and 11). By contrast, smooth meadowgrass dominated over red fescue at Lepaa due to the heavy soil type, use of irrigation, and relatively high nitrogen input. Unfortunately, we have not been able to find many references about the specific effects of Primo MAXX® on red fescue turf, but our results are in partial agreement with Pannacol et al. (2004) who found 40 %, 21 %, and no significant reduction in clipping yield after using trinexapac-ethyl in smooth meadowgrass, chewing fescue and creeping red fescue, respectively.

Perhaps the most conspicuous feature of the present results was the unstable effect of Primo MAXX® on clipping yields due to the postsuppression rebound effect. In the fairway trial at Lepaa, Finland, this resulted in clipping yield reductions being significant only two weeks after application (Table 13), and a similar tendency could be seen also in the green trial (Table 15). In Norway, clipping yields four weeks after spraying were often higher than on unsprayed control plots in the fairway trial at Landvik (Fig. 2), and a strong rebound effect was observed also after spraying treatments had to discontinued at green no. 9, Ballerud GC. The unstable effect in of Primo MAXX® in these trials was probably due to a rapid degradation of trinexapac-ethyl in plant tissue and a higher regrowth potential due to accumulation of carbohydrate reserves and GA_1 precursors during the suppression phase (Lickfeldt et

al. 2001, Branham & Beasley 2007). In North-American experiments, Lickfeldt et al. (2001) reported clipping yields reductions in smooth meadowgrass to be much more consistent when trinexapac-ethyl was applied at four than at six week intervals, but under Nordic long-day conditions, spraying every second, or at least every third week, may well be necessary to stabilize low GA_1 levels, not only on greens, but also on fairways and tees. Although there was a surge effect during the driest period in mid September, the most stable clipping reductions in our trials, on average 44 % on a fresh weight basis, were, indeed, obtained on the nursery green which was sprayed about every third week at Ballerud GC (Fig. 5c). While Branham & Beasley (2007) noted that temperature was the most important factor determining degradation of trinexapac-ethyl in turfgrass tissue, our results suggest that other factors such as light and water availability may also be important for the rebound effect under Nordic conditions. Very clearly, application frequency is a major question that has to be addressed during the continuation of this project.

The potential reductions in mowing costs from using a plant growth regulator will always have to be weighed against the risks for discoloration or other harmful effects on turf quality. In the present trials, reductions in general appearance (visual merit) scores were far more conspicuous in the GEP trial at Landvik than in the GEP trials at Lepaa or the demonstration trials at Ballerud GC. Apart from possible effects of different botanical compositions, this might reflect a subjective human factor, i.e. different backgrounds and attitudes of the observers in the various trials. While the fairway trial at Landvik was evaluated by turfgrass scientists and technicians with long experience from turfgrass variety testing, the trials at Lepaa and Ballerud were evaluated by greenkeepers working on the course. While the observers at Landvik may have paid more attention to turf aesthetic values such as less intense colour, and less vigorous and uniform plots, the observers at Lepaa and Ballerud may well have been more attentive to ball roll and other functional characteristics of the playing surface. The less succulent but significantly darker green turf resulting from high Primo MAXX® rates at Landvik are in agreement with other studies showing higher mesophyll cell densities and chlorophyll concentrations resulting from less elongation of leaf cells (Heckman et al. 2001, Ervin & Zhang 2008). As for tiller density, most literature supports the Finnish rather than the Norwegian results; i.e. enhanced tillering after Primo MAXX® application (Branham & Beasley 2007, Ervin & Zhang 2008).

As compared with the unsprayed control treatment, the strongest negative effect of Primo MAXX® on turfgrass general appearance at Landvik was recorded after the first spraying in early June, in mid July and at the last observation in early November. Each of these observations might be explained by suboptimal conditions causing reduced turfgrass growth. From 6 to 15 June there was a dry and warm and period with maximum temperatures in the range 25-30 ºC that obviously reduced turfgras tillering and aesthetic appearance; until mid July exceptional rainfalls starting on 22 June were not compensated by increase nitrogen inputs, and in autumn, the last application of Primo on 26 September was followed by several nights of frost. Although most studies have failed to document significant interactions between nitrogen and trinexapac-ethyl on turfgrass quality (Steinke & Stier 2001, Goss et al. 2002, McCullogh et al. 2006), it seems reasonable to assume that potential negative effects on Primo MAXX® on turfgrass quality will be most pronounced under suboptimal growing conditions. As in the trials at Landvik (Photo 6) and Ballerud (Photo 11), Beam et al. (2002) reported significant discoloration of trinexapac-ethyl-treated smooth meadowgrass following frost in autumn.

Undoubtedly, the most convincing argument for official approval of Primo MAXX® on Nordic golf courses would be a clear documentation that it improves winter survival. Preliminary results with annual meadowgrass suggested that low rates of trinexapac-ethyl prevented winter injury, whereas high rates had opposite effects due to discoloration during the hardening phase in late autumn (Rossi & Buelow 1997). While trinexapac-ethyl has been shown to increase water soluble carbohydrate contents (Goss et al. 2002) and result in faster spring greenup, Ervin & Zhang (2008) recently called for more detailed investigations into the effect of trinexapac-etyl on freezing tolerance as the research to date has provided scarce information on this aspect. Under Nordic conditions, desiccation if growth resumes when soils are still frozen and irrigation not yet operational in spring, or damage due to unstable winters with ice and water covering the turf, sometimes resulting in suffocation, appear to be more

important that direct freezing injury. In this regard, trineexapac-ethyl may well have a positive effect as it reduces mitochondrial respiration (Ervin & Zhang 2008). In 2008, it will therefore be very interesting to study winter injury and spring green-up and recovery in the on-going trials at Landvik, Lepaa and Ballerud which all had their last application of Primo MAXX® in late September or early October.

Even with winter survival and spring observations included, the amount of data presented in this report is too limited to recommend any listing of Primo MAXX® for turf use in the Nordic countries. Therefore, as stated in the contract between Syngenta and Scandinavian Turfgrass and Environment Research Foundation, there is a need for new GEP trials to be started in spring 2008 and followed until registration of winter survival in spring 2009. For this purpose, a new experimental green was constructed and seeded to creeping bentgrass at Landvik in 2007. In the trial to be established on this green in spring 2008, we suggest to compare Primo MAXX® at three rates (0.15, 0.30 and 0.45 l/ha) and two application frequencies (every 10/11 days and every 21 days), i.e. six combinations plus an unsprayed control treatment. As different grass species seem to vary in their response to Primo MAXX®, similar trials should preferably be carried out on also red fescue/browntop greens and velvet bentgrass greens, although this would require additional funding from Syngenta/STERF.

In Finland, a new GEP trial will be established in spring 2008 on a fairway that is regularly subjected to winter injury. New demonstration trials might be added to the project depending on interest from superintendents and funding from the national golf unions.

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

Results from the first evaluation year 2007

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Finnish team spraying fairway trial at Lepaa Golf Course.
Photo: Oiva Niemelainen

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Evaluation of the plant growth regulator Primo®MAXX® (trinexapac-ethyl) on Nordic golf courses. Results from the first evaluation year 2007

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Summary:

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

Sammendrag:

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

Approved

Arne Sæbø	Trygve S. Aamlid
Leader, Bioforsk's Section for Urban Greening	Project leader

Contents

1. Abstract

As an inhibitor of the last step in plant synthesis of bioactive gibberellin (GA_1), the plant growth regulator Primo MAXX® (trinexapac-ethyl) offers prospects of reduced energy use for mowing and improved turfgrass quality under Nordic long day conditions. This report presents first year results from 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 possible registration of Primo MAXX®, unreplicated demonstration trials were carried out at Ballerud and Bogstad Golf Courses in Oslo under supervision of Bioforsk and with funding from the Norwegian Golf Federation (NGF).

GEP trials on **fairways** (mowing height 12-18 mm) were carried out at Bioforsk Landvik, Norway (58°34'N, 8°52'E) and at the Lepaa Unit of the HAMK University of Applied Sciences, Finland (61°08'N, 24°20'E). Primo MAXX® was applied at monthly intervals at rates 0.5, 1.0, 1.5, 2.0 and 3.0 l/ha (56.5, 113, 169.5, 226 and 339 g a.i./ha trinexapac-ethyl) in comparison with an unsprayed control treatment. Turfgrass general appearance, tiller density, colour, height growth, and clipping yields were recorded two and four weeks after each application. Primo MAXX® had no effect on turfgrass general appearance but increased density at Lepaa. At Landvik, Primo MAXX® (>= 1.0 l/ha) reduced turfgrass general appearance and density, but resulted in significantly darker green colour. Quality reductions were most apparent during periods with either daily maximum temperatures >25 ºC, extreme rainfall probably causing nitrogen deficiency, or frost at night. Average reductions in clipping yield caused by Primo MAXX® (>= 1.0 l/ha) were 8 % in the GEP trial at Landvik, 18 % in the GEP trial at Lepaa and 37 % in the demonstration trial at Ballerud; to some extent this difference may be due to different botanical composition with red fescue (*Festuca rubra*) and annual meadowgrass (*Poa annua*) being the predominant species at Landvik and Ballerud, respectively. Clipping yield reductions due to Primo MAXX® were unstable, growth suppression two weeks after application often being followed by a rebound effect during the remaining two weeks until next application.

A GEP trial on creeping bentgrass **putting greens** was carried out at Lepaa, Finland, and demonstration trials at Ballerud and Bogstad, Norway. Primo MAXX® was sprayed at rates 0.2, 0.4, 0.6 or 0.8 l/ha at monthly intervals in the GEP trial, and at 0.4 l/ha every three weeks in the demonstration trials. On average for all observations, Primo MAXX® had no effect on turfgrass quality, but clipping yields were reduced by 16, 44 and 26% at Lepaa, Ballerud and Bogstad, respectively. As in the fairway trials, growth suppression at Lepaa was stronger when assessed at two than at four weeks after application. By contrast, Primo MAXX® produced a fairly stable effect when applied at three week intervals in the demonstration trials.

Use of Primo MAXX® on golf course **roughs** was investigated only in a demonstration trial at Ballerud. Application of 2.2 l/ha of Primo MAXX® every seven weeks resulted in discolouration and reduced quality of smooth meadow grass.

In conclusion, the first year of this project has shown that the guidelines for use of Primo MAXX® in other European countries are not directly applicable in Scandinavia. As the present results are too limited to apply for registration of Primo MAXX®, the project will continue in 2008 tentatively with new trials investigating application of Primo MAXX® at lower rates, but higher frequencies. Improved winter stress tolerance would be a convincing argument for registration of Primo MAXX® in the Nordic countries, and the on-going trials will therefore be followed by an assessment of effects of the last Primo MAXX® applications in September or October 2007 on winter survival and spring recovery.

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

2. Introduction

The plant growth regulator trinexapac-ethyl was developed by Syngenta in the 1980s. Since the active ingredient is available in different formulations, the chemical will, in this report, be referred to as Primo MAXX®, which is the product developed by Syngenta specifically for use on turf. Unlike earlier plant growth regulators, Primo MAXX®'s mode of action is highly specific as it blocks the conversion of GA_{20} til GA_1, i.e. the last step in the biosynthesis of gibberellic acid, a plant hormone stimulating cell elongation and thus vertical turf growth.

After its release, Primo MAXX® was rapidly adopted by the US and Canadian turf industries. In North America, there are several independent university studies documenting its positive effects on golf courses, athletic fields, home lawns, and sod production (for a recent review, see Erwin and Zhang 2008). These advantages include reduced leaf elongation and thus reduced mowing costs and energy use, improved tiller production (more lateral growth), darker green colour, and improved resistance to drought and shade.

While other formulations of trinexapac-ethyl have been approved for agricultural use in Europe for about a decade, the experience with Primo MAXX® to European turfgrass areas is relatively limited. During the past three to four years, Primo MAXX® has been approved for turf use in Italy, France and UK, and the evaluation and registration process has been initiated in many other countries.

Being an inhibitor of gibberellin biosynthesis, Primo MAXX® offers special prospects for turfgrass management in the Nordic counties Finland, Sweden, Norway, Iceland, and Denmark. At latitudes ranging form 55 to 71 °N, turfgrasses growing in these countries exposed not only to long photoperiods during most of the growing season, but also to lower photosynthetic flux densities and lower red to farred (R/FR) ratios than in countries further south. The natural turfgrass response to these northern light conditions is to devote more of its resources to shoot elongation (Heide et al. 1985a,b). Since this response is primarily mediated by the gibberellic acid GA_1, any specific growth regulator that controls the biosynthesis of this compound might be useful under Nordic conditions. Nevertheless, our experience from the introduction of trinexapac-ethyl for agricultural use in the Nordic counties suggests that the optimal dose rates and frequencies for application of Primo MAXX® to various types of turf are probably not the same as at lower latitudes. This is also due to different species and cultivars being grown compared with countries further south. Field trials under Nordic conditions are therefore required not only to produce data for the national certification agencies, but also to provide turf managers with recommendations for how to use the product.

This report presents first year preliminary results from a two year project evaluating the use of Primo MAXX® on golf courses in the Nordic countries. The project was funded by Syngenta and the Scandinavian Turfgrass and Environment Research Foundation (STERF) 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' trials needed to provide documentation for possible registrations of Primo MAXX® by the national authorities, a couple of practical demonstration trials were carried out on Norwegian golf courses under supervision from Bioforsk and with funding from the Norwegian Golf Federation (NGF).

3. Methods

3.1. Evaluation of Primo MAXX® under fairway conditions, Bioforsk Landvik, Norway

Experimental site

On 8 May 2007, a field trial was laid out on a fairway established on a sandy loam soil (topsoil: 68 % sand, 27% silt, 5 % clay) at Bioforsk Landvik Research Station (58°34'N, 8°52'E), SE Norway. Soil samples indicated a pH (H_2O) of 5.9, high phosphorus values (P-AL=19) and intermediate to low potassium values (K-AL = 8, K-HNO_3=58). The fairway had been seeded in September 2003 to a mixture of smooth meadowgrass (*Poa pratensis*), chewing fescue (*Festuca rubra* ssp. *commutata*), and browntop bent (*Agrostis capillaris*) (Table 1). Block 1 and 2 were located in one part, and block 3 and 4 in a different part of the fairway. Botanical analyses at the start of experimentation indicated that red fescue was the predominant species in all blocks, but presumably due to slightly less surface drainage, blocks 1 and 2 had a higher percentage of smooth and annual meadowgrass and broadleaved weeds (primarily white clover (*Trifolium repens*)) than blocks 3 and 4 (Table 1).

Table 1. Seed mixture used for fairway establishment in 2003 and botanical composition at the start of the Primo MAXX® trial in spring 2007.

Species	Cultivar	% (w/w) of seed mixture	% cover at initiation of Primo MAXX® trial		
			Block 1 and 2	Block 3 and 4	Mean
Poa pratensis	Conni	25	31	9	20
Poa pratensis	Eva	10			
Poa pratensis	Limousine	10			
Festuca rubra ssp. commutata	Bargreen	25	50	74	62
Festuca rubra ssp. commutata	Calliope	25			
Agrostis capillaris	Tracenta	5	5	15	10
Poa annua			8	2	5
Broadleaved weeds			6	0	3
Sum		100	100	100	100

Experimental plan

The experiment was laid out according to a randomized complete block design with plot size 2m x 3m, four blocks (replicates) and the following treatments:

1. Usprayed control
2. Primo MAXX, 0.5 l/ha (56.5 g a.i./ha) every four weeks
3. Primo MAXX, 1.0 l/ha (113 g a.i./ha) every four weeks
4. Primo MAXX, 1.5 l/ha (169.5 g a.i./ha) every four weeks
5. Primo MAXX, 2.0 l/ha (226 g a.i./ha) every four weeks
6. Primo MAXX, 3.0 l/ha (339 g a.i./ha) every four weeks

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. Actual application rates were recorded by weighing the tank before and after spraying. Table 2 shows actual rates and weather conditions for each spraying event.

Table 2. Weather conditions and actual application rates at the six spraying events.

Application date	Time of day (hours)	Weather conditions at application			Treatment number / application rate (l Primo MAXX® per ha)				
		Air temp. °C	Relative Humidity %	Wind Speed m/s	2. (target 0.5)	3. (target 1.0)	4. (target 1.5)	5. (target 2.0)	6. (target 3.0)
9 May	09-11	14	48	< 1.0	0.47	0.94	1.56	1.90	3.35
5 Jun.	09-11	15	60	< 1.0	0.58	1.06	1.67	1.93	3.19
4 Jul.	13-15	17	70	1.0-2.0	0.61	0.98	1.73	2.19	3.38
31 Jul.	08-10	18	55	1.0-2.0	0.55	1.05	1.66	2.28	3.41
28 Aug.	09-11	19	32	1.0-2.0	0.57	1.03	1.55	2.19	3.52
26 Sep.	09-11	11	69	< 1.0	0.52	1.07	1.55	2.01	3.15
Mean					0.55	1.02	1.62	2.08	3.33

Registrations

At two weeks intervals throughout the experimental period, turfgrass colour, tiller density, and turf general appearance were assessed by turfgrass scientist or technicians using a scale from 1 to 9 where 9 is darkest colour, highest tiller density and best turf quality. The assessments were conducted two and four weeks after application of Primo MAXX®. On the same dates, turfgrass diseases and broadleaf weed (including white clover) invasion were reported as per cent of plot area. Turfgrass height was recorded as the mean of three random measurements with a ordinary ruler in each plot, and the overall growth rate by weighing clippings in the basket of a walk-behind mower used in the 0.56 m x 1.88 m central area of each plot (Photo 1). Both raw weight and dry weight were recorded, the latter after drying for 24 h at 60ºC. By the end of the growing season, on 2 Nov., turfgrass dormancy colour was evaluated on a scale 1-9, where 1 is completely faded / brown turf, and 9 is completely green turf.

Photo 1a and b. Tatsiana Espevig collecting clippings in fairway trial at Landvik. Photos: Trygve S. Aamlid

Bioforsk

Management

The experiment was mowed at 15 mm two times a week, usually on Monday and Friday. A triplex fairway mower without collection of clippings was used except when clipping weights were to be recorded. Granular fertilizer was applied at approximately monthly intervals as outlined in Table 3. The experiment was not irrigated except for small amounts of water to dissolve fertilizer after application. On 7 Aug., the trial was aerated using a vertidrain with 15 mm solid tines to 15 cm depth. Topdressing was accomplished on 8 Aug. and 5 Nov. at rates 0.75 and 1.5 kg pure sand per m^2, respectively.

The fairway trial at Landvik was not exposed to ordinary play, but it was was subjected to artifical wear from a wear drum one to two times per week.

Table 3. Fertilizer inputs, fairway trial, Landvik.

		Per ha							
Date	Fertilizer type	kg fertilizer	kg N	kg P	kg K	kg Mg	kg S	kg Ca	kg Fe
17 Apr.	Fullgjødsel 22-2-12	40	9	1	5	0	1	0	0
16 May	Fullgjødsel 22-2-12	70	15	1	8	1	2	1	0
12 Jun.	Arena Golf Extra 13-0-15	150	20	0	23	2	21	0	3
23 Jul.	Arena Golf Extra 13-0-15	130	17	0	20	2	18	0	3
9 Aug.	Arena Golf Extra 13-0-15	135	18	0	21	2	18	0	3
5 Sep.	Arena Golf Extra 13-0-15	150	20	0	23	2	21	0	3
SUM			99	2	100	10	80	1	11

Weather data

In SE Norway, the growing season 2007 was characterized by exceptionally high rainfall, especially in July, but also in May, June and August (Table 4). By contrast, September was unusually dry. Precipitation was recorded on 16 out of the 31 days in July; the cloudy summer weather is also reflected by a rather low irradiance during this month. The warmest period, with daily maximum temperatures in the range 23-29 ºC was recorded from 6 to 12 June.

Table 4. Weather data for Landvik meteorological station, about 200 m for experimental field. Normal values for temperature and rainfall are 'official' values for from the period 1961-90, while normal values for irradiance are calculated averages for the period 1994-2006.

	Mean temperature, ˚C		Precipitation, mm		Irradiance, MJ/m^2 (305-2800 nm)	
	2007	30 yr normal	2007	30 yr normal	2007	13 yr average
May	10.2	10.4	107	82	518	540
June	15.9	14.7	109	71	604	600
July	15.5	16.2	213	92	492	632
Aug.	16.2	15.4	132	113	476	476
Sep.	12.0	11.8	59	136	321	262
Mean / sum	14.0	13.7	620	494	2411	2510

3.2. Evaluation of Primo MAXX® on a golf course fairway, Lepaa, Finland

Experimental site

The Finnish fairway trial was laid out on 11 May 2007. The fairway was seeded to a mixture of smooth meadowgrass and chewing fescue (*Festuca rubra* spp. *commutata*) on a heavy clay soil (15% sand, 37% silt, 48% clay) at the Lepaa Unit of HAMK University of Applied Sciences, Finland (61°08'N, 24°20'E). 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. All observations and management of the trial was carried out by the HAMK Lepaa greenkeepers Petteri Lehmuskoski and Tommi Turunen except for the spraying treatments which were carried out by MTT's 'Good Experimental Practice' certified spraying team from Jokioinen (90 km from Lepaa).

Experimental plan and registrations

The experiment was laid out following the same plan and plot size as at Landvik, Norway (previous paragraph). Primo MAXX® was applied in accordance with the Finnish 'Good Experimental Practise' protocol, using a portable, compressed air-powered 'van der Weij' plot sprayer, mounted with a windshield and flat fan nozzles (Hardi 4110-12) and working at 180-250 kPa pressure. The spraying boom had four nozzles spaced 50 cm apart. The spraying volume corresponded to 200 l/ha. Full spray coverage was on the central 1.5m x 2.5 m of each plot. Table 5 shows application dates and weather conditions for each spraying event. The last application on 4 Oct. was conducted especially to evaluate potential effects of Primo MAXX® on turfgrass winter damage.

Table 5. Application dates and weather conditions in fairway and green trials at Lepaa.

Application date	Time of day (hours)	Air temp. °C	Relative humidity %	Wind Speed m/s	% cloud cover
11 May	09-11	11	29	0	25
8 Jun.	09-11	20	56	1.5	1
5 Jul.	13-15	23	47	2.5	70
3 Aug.	09-11	17	78	2.0	90
4 Sep.	09-11	11	90	1.0	90
4 Oct.	13-15	11	92	1.5	100

Photo 2. Austen Sutton, Syngenta (left) and greenkeeper Petteri Lehmuskoski, HAMK Lepaa Unit, in fairway trial at Lepaa, Finland, 29 Aug. 2007.

Photo: Oiva Niemelainen.

Registrations

Registrations were carried out at two-week intervals following the same program as at Landvik (previous section) except that weed occurrence and dormancy colour were not recorded. Plant height at Lepaa was determined using a Turf Check Prism device (Check Signature Inc., Shoreview, MN).

Management and wear

The experiment was mowed with a triplex fairway mower about three times per week. Mowing height ranged from 12 to 18 mm. Granular fertilizer Sportsmaster 26-2-9 was applied at equal rates on 8 May and 12 July, the total input corresponding to 156 kg N, 12 kg P, 54 kg K and 0.9 kg Fe per ha. Information about irrigation is given in Table 6. The trial was aerated or top-dressed in late autumn, after the completion of registrations.

During the growing season period, the trial was exposed to approximately 3.500 rounds of golf.

Weather data

Temperatures at Lepaa were higher the 30 yr normal values throughout the growing season (Table 6). August had the greatest deviation from the long-term average value. July had 49 % more, and August 42 % less rainfall than usual; over the whole experimental season, rainfall was close to the 30 yr normal value.

Table 6. Weather data for Hattula Lepaa weather station and irrigation in fairway and green trial at Lepaa golf course, 2007. Normal values for temperature and rainfall are official values for from the period 1971-2000 (Finnish Meteorological Institute)

	Mean temperature, °C		Rainfall, mm		Irrigation, mm (2007)	
	2007	30 yr normal	2007	30 yr normal	Fairway trial	Green trial
May	10.6	9.8	30	34	*	*
June	15.1	14.5	54	55	26	79
July	16.6	16.4	119	80	5	47
Aug.	16.4	14.6	43	74	7	50
Sep.	9.9	9.4	58	54	0	6
Mean / sum	13.7	12.4	304	297	37	188

* Data are unavailable for the period 1-26 May 2007 due to change of irrigation computer.

3.3. Evaluation of Primo MAXX® on a golf course putting green, Lepaa, Finland

Experimental site

The Finnish green trial was established on 11 May 2007 on a USGA green seeded to creeping bentgrass (*Agrostis stolonifera*, seed blend of 50% 'Penn A-4' and 50% 'Penn G-6') at Lepaa Golf Course.

Experimental plan

The experimental plan comprised five rates of Primo MAXX plus the unsprayed control treatment:

1. Usprayed control
2. Primo MAXX, 0.2 l/ha (22.6 g a.i./ha) every four weeks
3. Primo MAXX, 0.4 l/ha (45.2 g a.i./ha) every four weeks
4. Primo MAXX, 0.6 l/ha (67.8 g a.i./ha) every four weeks
5. Primo MAXX, 0.8 l/ha (90.4 g a.i./ha) every four weeks

The trial had four replicates, and a gross plot size of 2 m x 3 m. It was sprayed on the same dates and following the same GEP procedures as the fairway trial on the same location (Table 5).

Photo 3. Green trial at Lepaa ready for the first treatment on 11 May 2007. Photo: Oiva Niemelainen.

Registrations

Registrations followed the same program as in the Finnish fairway trial (previous section).

Management and wear

The experiment was mowed with a Triplex greens mower for an average of six times per week. Depending on weather and turfgrass density, mowing height was 5–7 mm in May and September and 3-4 mm from June to August. Information about irrigation and fertilizer inputs are given in Tables 6 and 7, respectively.

To avoid thatch accumulation, the trial was aerated with deep slitting knives every second week and with 8 mm needle tines once a month. Verticutting was accomplished every second week and topdressing with 0.1-0.7 mm finely graded sand at a rate of 1 kg per m2 every third week. The sand was brushed/irrigated into the green and the dressing was never done in close proximity to weighing of clippings.

Being located on a practise green, the experiment received wear from about 10.000 rounds of golf over the season. When placing holes on the green, care was taken to create as uniform wear as possible.

Table 7. Fertilizer inputs in green trial at Lepaa.

		Per ha							
Date	Fertilizer type	kg fertilizer	kg N	kg P	kg K	kg Mg	kg S	kg Ca	kg Fe
28.3.2007	Floratine Kevätstartti*	35	5.4	1.2	2.1				
5.4.2007	Floratine Kevätstartti	35	5.4	1.2	2.1				
19.4.2007	Floratine Kevätstartti	35	5.4	1.2	2.1				
26.4.2007	Sierraform Springstart (16-0-13)	250	40	0	32.5				2.50
15.5.2007	Sierraform All Season (18-3-15)	250	45	7.5	37.5	3.0			1.25
30.5.2007	Kemigreen Basic (23-4-14)	40	9	1.6	5.6	0.6	0.8		0.04
5.6.2007	Kemigreen Basic (23-4-14)	40	9	1.6	5.6	0.6	0.8		0.04
11.6.2007	Sierraform All Season (18-3-15)	250	45	7.5	38				
25.6.2007	Osmosol 614R (19-2-10)	40	7.6	0.8	4.0	0.5		1.7	0.04
2.7.2007	Osmosol 614R (19-2-10)	40	7.6	0.8	4.0	0.5		1.7	0.04
13.7.2007	Kemigreen Summer (18-0-17)	40	7.2	0	6.8			2.0	0.40
18.7.2007	Kemigreen Summer (18-0-17)	40	7.2	0	6.8			2.0	0.40
26.7.2007	Sierraform All Season (18-3-15)	250	45	7.5	37.5	3.0			1.25
14.8.2007	Kemigreen Summer (18-0-17)	40	7.2	0	6.8			2.0	0.40
27.8.2007	Greenmaster Autumn (6-2-8)	300	18	6	24	5.4			1.50
30.8.2007	Kemigreen Basic (23-4-14)	40	9	1.6	5.6	0.6	0.8		0.04
11.9.2007	Sierraform Springstart (16-0-13)	200	32	0	39				2.00
SUM			305	39	260	14.0	2.4	9.4	10

* Floratine Kevätstartti (Springstart) is composed of P-48 (10-21-6.6), Per 4 Max (15-0-0), Protesyn (3.5-0.6-1.8), and Plant Marvel (28-3-15).

3.4. Demonstration trials with Primo MAXX® at Ballerud Golf Course, Oslo, Norway

Experimental site and set-up

Ballerud GC is located on an old horticultural farm in a suburban area SW of Oslo. The course has greens with mostly dominated by creeping bentgrass, fairways almost exclusively dominated by annual meadowgrass, and smooth meadowgrass roughs with some tufts of perennial ryegrass (*Lolium perenne*).

Large-scale, unreplicated demonstration trials were laid out on green no. 9, fairway no. 9 and rough no. 9 on 5 June 2007. Plots sizes varied from 80 to 130 m^2. Unsprayed control plots were compared with plots sprayed with Primo MAXX® at rates 0.4, 1.5 and 2.2 l/ha and application intervals of approximately 3, 4 and 7 weeks on green, fairway and rough, respectively. In compliance with the Norwegian Food Authority's rule for complete closure of all sprayed areas for 48 h after each application, the trial on green no. 9 had to be discontinued after the second application on 18 June.

Three weeks later, it was replaced by a new trial laid out on the golf course' nursery green. Actual application dates in the green, fairway and rough trials are given in Table 8. The growth regulator was applied using a battery-operated electric Hardy Defender plot sprayer (Photo 4).

Table 8. Application dates for Primo MAXX in demonstration trials at Ballerud GC.

Green no. 9	Nursery green	Fairway no. 9	Rough no. 9
5 June		5 June	5 June
18 June			
	9 July	2 July	
	31 July	31 July	28 July
	21 Aug.		
	13. Sep.	3 Sep.	11 Sep.
	4 Oct.	28 Sep.	

Photo 4. Sprayer used in demonstrations trials at Ballerud Golf Course.

Photo: Terje Haugen.

Registrations

In all trials at Ballerud, turfgrass general appearance was evaluated by the headgreenkeeper at one to two week intervals throughout the growing season. In the green and fairway trials, turfgrass clipping yields were recorded on a fresh weight basis. Registrations in the green trials also included regular assessments of green speed using a standard stimpmeter.

Maintenance

The green trials at Ballerud were mowed daily at 3.4-3.8 mm and the fairway trial at 20 mm three to four times a week. The rough area was only mowed upon need.

Due to the rich soil from decades of vegetable production, the rough trial was not fertilized in 2007, and the fairway trial only received one application of 200 kg Fullgjødsel® 11-5-18 (22 kg N/ha) on 8 May. The green trials received monthly applications of granuar fertilizer (Gro Power 5-1-1, Anderson 14-0-9, Anderson 8-0-16, and/or Roots 12-2-12), and weekly applications of liquid fertilizers /

biostimulants, mostly Floratine products. Total rates of N, P, K, Mg, Ca, S and Fe over the season were 155, 14, 142, 27, 30, 73 and 14 kg/ha, respectively. The greens were aerated, mostly using Envirojet, six times during the season and top-dressed, also six times, giving a total of 6.3 kg sand per m^2.

Weather data and irrigation

Table 3 shows recordings from Ballerud GC's weather station. Although the rainfall in 2007 was higher than usual, there were periods, especially in May, June and August when the green trials needed irrigation. The fairway and rough trials were never irrigated.

Table 9. Weather recordings and irrigation at Ballerud GC, 2007. Monthly temperatures are means of daily maximum and minimum temperatures.

	Mean monthly temperature, °C	Monthly rainfall, mm	Monthly irrigation, mm (greens only)
May	11.2	94	42
June	17.1	185	52
July	16.9	173	10
Aug.	16.6	83	47
Sep.	11.1	71	21
Mean / sum	14.6	606	172

3.5. Demonstration trial with Primo MAXX® at Oslo Golf Club, Bogstad, Norway

To evaluate the effect of Primo MAXX® on a typical annual meadowgrass green, an unreplicated demonstation trial with plot size 250 m^2 was laid out at Oslo GK on 20 June 2007. Primo MAXX® was sprayed at a rate 0.4 l/ha on 20 June, 10 July and 31 July using the same sprayer as at Ballerud GC, about 10 km from Bogstad (Photo 4). Turfgrass quality (general appearance) and fresh weight clipping yields were determined on 4 July, 13 July and 14 August. Unfortunately, the trial had to be discontinued in mid August due to reconstruction of the green.

3.6. 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 on each plot and on plot values which had been averaged, either over the whole growing season, separately over the spring (before 10 June), summer (10 June – 1 Sep.) and autumn (after 1 Sep.) periods, or for observations conducted two versus four weeks after the last application of Primo MAXX®. The significance levels P%<0.1, P%<1, P%<5 and ns (not significant) have been indicated in the tables along with LSD values for effects significant at P%<5. In a few cases exact P-values have been given for tendencies in the 5-15% probability range. As an indications of the variability for each character, coeffcients of variation, (CV %), have also been given in the tables.

4. Results

4.1. Evaluation of Primo MAXX® under fairway conditions, Bioforsk Landvik, Norway

Turfgrass quality and related characteristics

Table 10 shows results from the visual observations of turfgrass quality and related characters in the fairway trial at Landvik. Both within the three seasons and as a mean value, turfgrass general appearance was significantly lower on plots receiving monthly applications of Primo MAXX® at 1.0 l/ha or higher rates than on unsprayed control plots and plots receiving 0.5 l/ha. Within these two groups, differences in generall appearance were not significant. Separate analyses for blocks 1 and 2 versus 3 and 4 indicated that these responses were practically identical regardless of botanical composition (data not shown).

Individual registrations of turfgrass quality are further depicted in Fig. 1. There was a dramatic decline in quality after the first application on 9 May. After this the turf recovered and there was no significant effect of Primo MAXX® at the two subsequent evaluations. Applications of 1.0 l/ha or higher rates on 4 July lead to new quality reductions in July, August and September (Photo 5); these effects were especially apparent at the last evaluation in early November (Photo 6). By contrast, there tended to be a small quality improvement due to the lowest rate of Primo MAXX® from late August to October. This improvement was reflected also in a significant increase in tiller density on average for the whole growing season (Table 10).

Increasing rates of Primo MAXX® consistently led to darker turf throughout the growing season, but also to earlier growth cessation and a less attractive dormancy colour in late autumn (Table 10). The only visible disease in the trial was a slight attack of red thread (*Laetisaria fuciformis*) during the wet period in July; however, these spots were unaffected by Primo MAXX® which also had no effect on the occurrence of broadleaved weeds, primarily white clover, in the trial.

Table 10. Turfgrass quality, tiller density, within-season colour, dormancy colour and infestation of weeds and red thread (*Laetisaria fuciformis*) in fairway at Landvik as affected by increasing rates of Primo MAXX®, 2007. Visual merit and tiller density are means of twelve observations (two in spring, i.e. before 10 June, six in summer, i.e. from 10 June to 1 Sep., and four in autumn, i.e. after 1 Sep. Within season colour (green darkness) and occurrence weeds and red thread are means of twelve, three (all in July) and two (June and Nov.) observations, respectively. Dormancy colour was evaluated on 2 Nov. All values are means of four blocks.

Primo MAXX®, rate	Turf quality (general appearance, 1-9)				Tiller density (1-9)	Within season colour (1-9)	Dor-mancy colour (1-9)	% of plot area	
	Mean	Spring	Summer	Autumn				Dicot weeds	Red thread
0 = Control	6.2	6.1	6.4	6.0	6.3	5.2	6.8	4	4
0.5 l/ha	6.1	5.6	6.3	6.2	6.5	5.6	6.3	2	3
1.0 l/ha	5.5	4.5	5.9	5.3	6.1	5.8	5.0	5	2
1.5 l/ha	5.3	4.6	5.5	5.4	6.0	5.9	4.1	4	3
2.0 l/ha	5.5	4.6	5.9	5.3	6.1	6.0	4.3	3	2
3.0 l/ha	5.1	4.2	5.5	4.9	6.0	6.2	3.5	4	3
P%	<0.1	<0.1	<1	<0.1	<1	<1	<0.1	ns	ns
LSD 5%	0.3	0.5	0.4	0.4	0.2	0.4	1.2	-	-
CV%	4	7	5	5	3	5	15	-	-

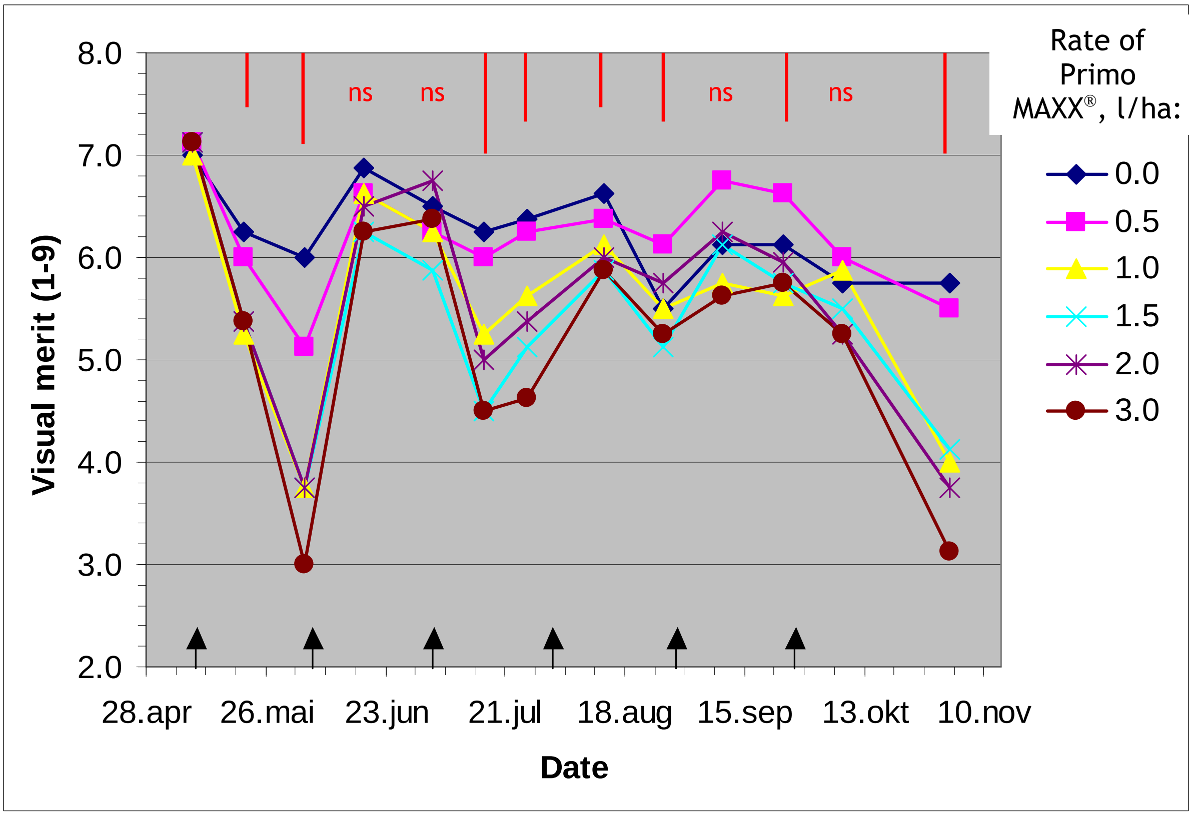


Fig.1. Turfgrass overall quality as affected by increasing rates of Primo MAXX® in fairway trial at Landvik, 2007. Mean of four replicates (blocks). The application dates 9 May, 5 June, 4 July, 31 July, 28 Aug. and 26. Sep. are indicated by black arrows. Red bars indicate LSD 5%.

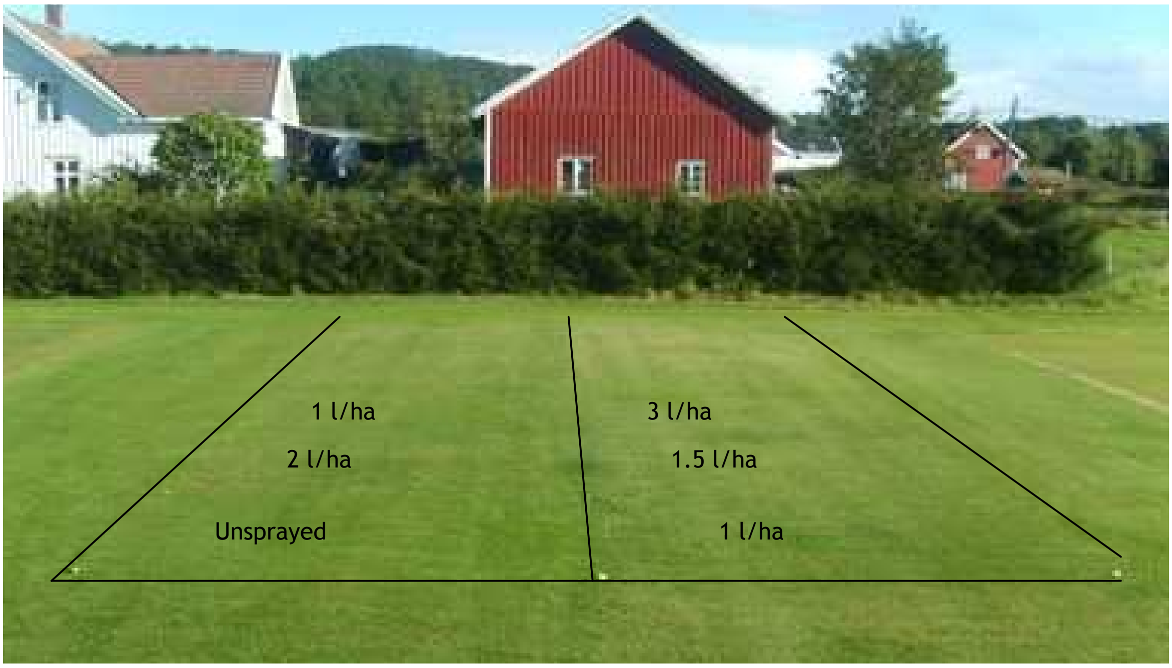


Photo 5. Visual appearance of fairway trial at Landvik, block 1 and 2, on 10 Sept. Within each block, the treatments closest to the photographer have been labeled. High rates of Primo MAXX® resulted in darker, in some cases, almost brown, turf. Photo: Trygve S. Aamlid.

Photo 6.

Turf quality / dormancy colour at growth cessation on 2 Nov. 2007 after application of Primo Maxx at 3.0 l/ha (left) and 0.5 l/ha (right), last application on 26 Sep.

Photo: Trygve S. Aamlid.

Turfgrass height and dry matter production

The average effect of Primo MAXX® on plant height and clipping yields are given in Table 11. In all blocks, the growth regulator caused a significant reduction in plant height even at the lowest rate, but contrary to expectation, this low rate also tended to increase aboveground dry matter production as compared with the unsprayed control treatment. This might reflect a higher tiller density, as also suggested in Table 10. Separate analyses for various parts of trial showed that the average reduction in clipping yield due to Primo MAXX® was stronger in blocks 1 & 2 which had more *Poa* species less red fescue and browntop bent and than blocks 3 & 4. On average for eleven harvests and all replicates, there was a slight tendency for Primo MAXX® to increase the dry matter percentage of turfgrass clippings (P% = 16, Table 11).

Table 11. Absolute and relative effects of increasing rates of Primo MAXX® on turfgrass height, turfgrass dry matter production, and per cent dry matter of clippings in fairway trial at Landvik, 2007. Mean of eleven observations. Plant height above 15 mm represents an average of four days' growth.

Primo MAXX, rate	Plant height, mm		Production of turfgrass clippings, g/m^2/day				% dry matter in clippings
	mm	Rel.	Block 1&2	Block 3&4	Mean	Rel.	
0 = Control	21.9	100	1.78	1.62	1.70	100	31.5
0.5 l/ha	20.9	95	1.91	1.93	1.92	113	32.2
1.0 l/ha	20.7	95	1.65	1.72	1.69	99	32.5
1.5 l/ha	20.0	91	1.46	1.46	1.46	86	33.6
2.0 l/ha	20.3	93	1.55	1.61	1.58	93	32.4
3.0 l/ha	19.5	89	1.31	1.70	1.51	88	33.1
P%.	<0.1	-	10	ns	<5	-	16
LSD 5%	0.7	-	-	-	0.29	-	-
CV%	2	-	10	14	12	-	3

In absolute terms, turfgrass clipping yield showed a distinct seasonal pattern with peaks during the warm and sunny periods in early June and late August (Fig. 2a). The low clipping yield on 17 July was probably due to 280 mm rainfall, and thus nutrient leaching, since the last fertilizer application on 12 June (Tables 3 and 4). Separate analyses of variance for each day indicated a significant effect of Primo MAXX® on clipping yield only on 4 June.

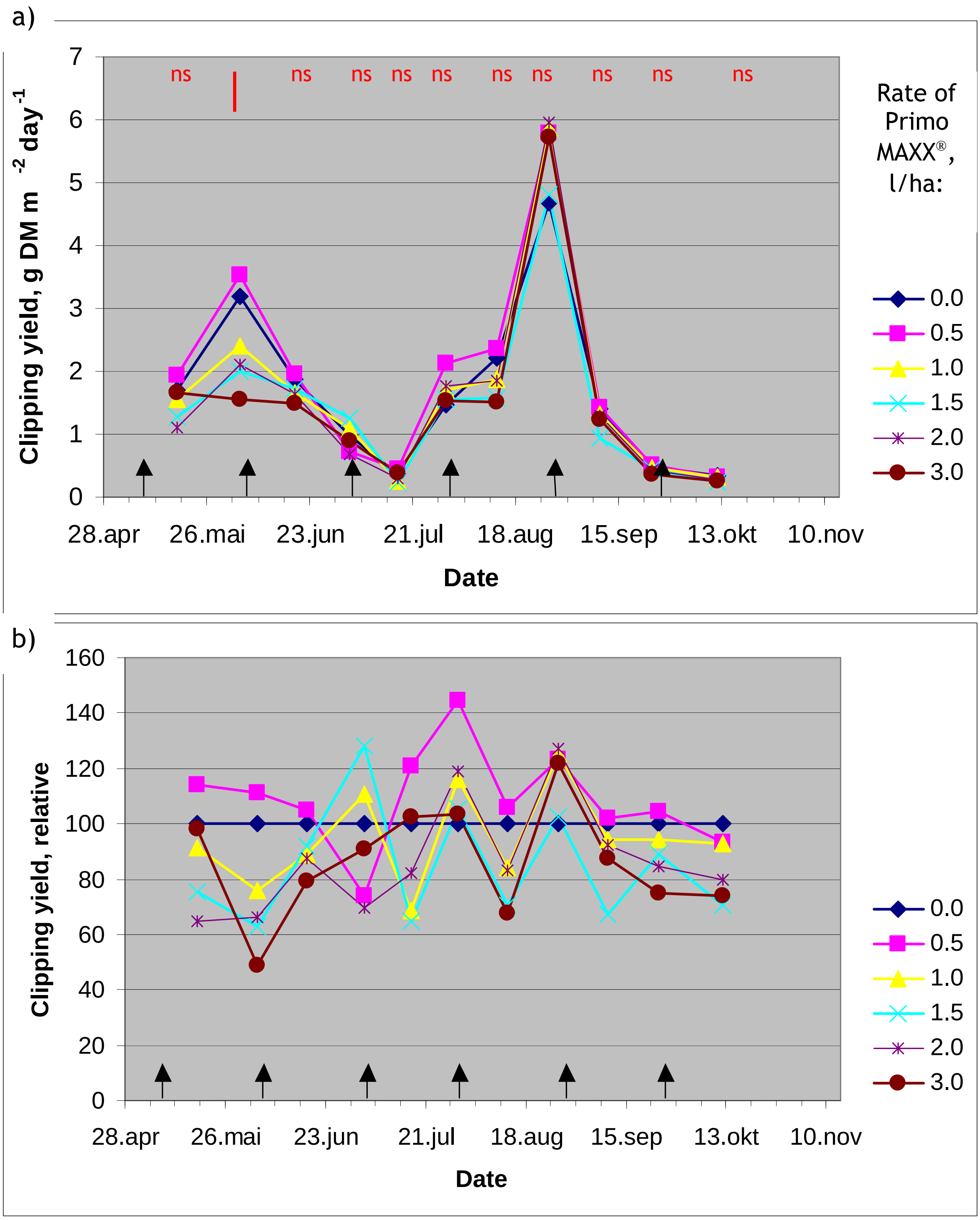


Fig. 2. Absolute (a) and relative (b) reductions in daily dry matter production of turfgrass clippings as affected by increasing rates of Primo MAXX® in fairway trial at Landvik. Red text/bars and black arrows indicate probability / LSD values and application dates 9 May, 5 June, 4 July, 31 July, 28 Aug. and 26 Sep., respectively. In (b), the clipping yield on each date was set to 100 in the unsprayed control treatment.

In relative terms, none of the Primo MAXX® treatments produced clipping yields that were lower than the unsprayed control at all harvests (Fig. 2b). Many of the treatments showed a typical suppression / rebound pattern with clipping yields lower than the control treatment at one harvest, but higher than control treatment at the next harvest.

4.2. Evaluation of Primo MAXX® on a golf course fairway, Lepaa, Finland

On average for two observations in spring, five observations in summer and two observations in autumn, Primo MAXX® had no effect on turfgrass general appearance in the fairway trial at Lepaa. Among the nine observation dates, significant differences were recorded only on 21 August when the plots sprayed with the highest dose (3.0 l/ha) had an average visual merit score of 5.5 as opposed to 6.8 for unsprayed control plots and plots sprayed with the lowest dose (0.5 l/ha).

On average for observations, increasing rates of Primo Max caused an overall increase in tiller density, while turfgrass colour was not significantly affected. No diseases were observed during the growing season.

Table 12. Turfgrass quality (1-9, 9 is best quality), tiller density (1-9, 9 is highest density) and within-season colour (1-9, 9 is darkest green) in fairway trial at Lepaa as affected by increasing rates of Primo MAXX®. Means of nine observations (two in spring, i.e. before 10 June, five in summer, i.e. from 10 June to 1 Sep., and two in autumn, i.e. after 1 Sep.). All values are means of four blocks.

Primo MAXX®, rate	Turf quality (general appearance, 1-9)				Tiller density (1-9)	Within season colour (1-9)
	Mean	Spring	Summer	Autumn		
0 = Control	6.1	5.5	6.1	6.8	5.5	6.1
0.5 l/ha	6.2	5.5	6.1	7.0	5.8	6.2
1.0 l/ha	6.1	5.4	6.1	6.9	5.8	6.1
1.5 l/ha	6.2	5.5	6.2	7.0	6.0	6.3
2.0 l/ha	6.2	5.6	6.1	6.9	6.1	6.3
3.0 l/ha	6.2	5.6	6.1	7.0	6.4	6.2
P%	ns	ns	ns	ns	<0.1	ns
LSD 5%	-	-	-	-	0.4	-
CV%	5	4	8	3	3	4

The effect of Primo MAXX® on turfgrass plant height and clipping yield depended on the time since last application. On average for five observations conducted about two weeks after application, the highest rate of Primo MAXX® caused significant reductions in plant height and clipping yield corresponding to 11 and 48 %, respectively (Table 13). On average for four observations conducted four weeks after application, the maximal reductions were only 3 and 14 %, respectively. Fig. 3 illustrates the unstable effect of Primo MAXX®, particularly toward the end of the growing season. However, unlike in the fairway trial at Landvik (Fig.2), clipping yields on sprayed plots were rarely higher than on untreated control plots in the trial at Lepaa.

Table 13. Absolute and relative effects of increasing rates of Primo MAXX® on turfgrass height and dry matter production in turfgrass clippings in fairway trial at Lepaa 2007. Observations conducted 2 weeks (5 observations) and 4 weeks (4 observations) from spraying treatment have been presented separately.

Treatment	Plant height (mm)				Weight of clippings (g DM / m^2 / day)			
Time after treatment	2 weeks	4 weeks	Mean	Rel	2 weeks	4 weeks	Mean	Rel
0 = Control	15.7	16.0	15.8	100	3.2	7.0	4.9	100
0.5 l/ha	15.7	16.0	15.8	100	2.7	6.3	4.3	87
1.0 l/ha	14.9	16.0	15.4	97	2.8	6.6	4.5	92
1.5 l/ha	14.7	15.7	15.1	96	2.3	5.8	3.9	79
2.0 l/ha	14.4	15.6	15.0	95	2.1	6.1	3.9	80
3.0 l/ha	14.0	15.5	14.6	92	1.8	6.0	3.7	75
P%	<0.1	ns	<5	-	<0.1	ns	ns	-
LSD 5%	1.1	-	1.0	-	0.7	-	-	-
CV%	3	4	3	-	13	22	18	

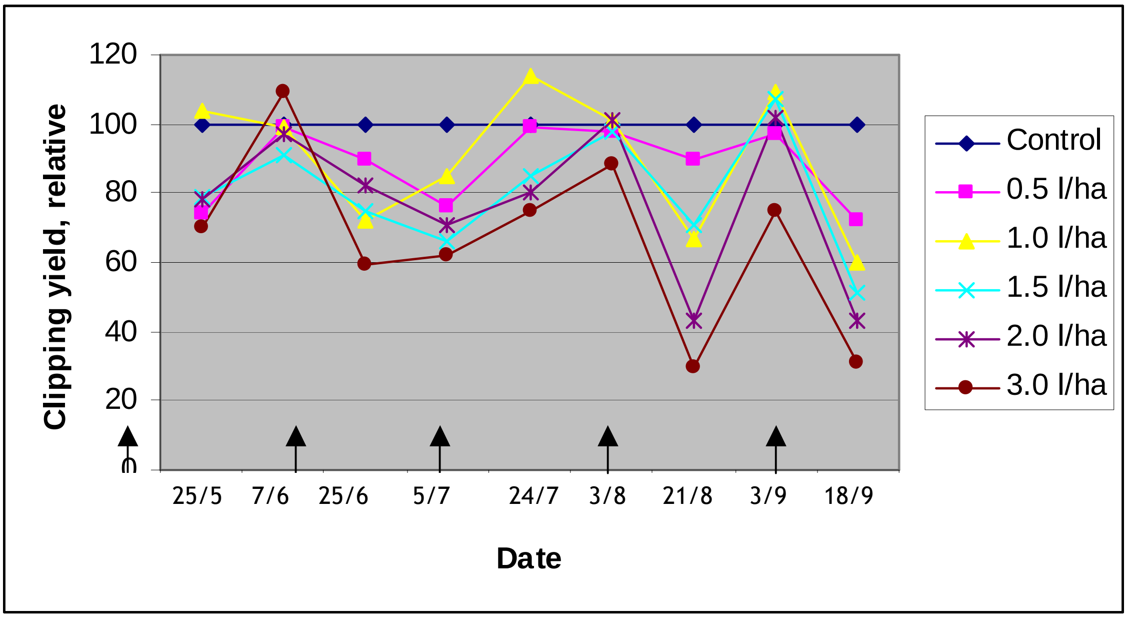


Fig. 3. Relative clipping weights (control = 100) in fairway trial at Lepaa, Finland. Spraying treatments indicated by black arrows were carried out on 11 May, 8 June, 5 July, 3 Aug. and 4 Sep. (The last spraying on 4 Oct. was done primarily to study the effect of Primo MAXX® on overwintering and was not followed by observations in late autumn.)

4.3. Evaluation of Primo MAXX® on a golf course putting green, Lepaa, Finland

On 3 Sep. 2007, a significantly higher tiller density was recorded on green plots sprayed with the highest rate of Primo MAXX® than on unsprayed control plots (data not shown). Otherwise, Primo MAXX® had no significant effect on either general appearance, tiller density or turfgrass colour in the green trial at Lepaa (Table 14). Although the effects on plant height and clipping yields were also not significant, reductions were generally stronger when recorded at two compared with four weeks after application (Table 15, Fig. 4).

Table 14. Turfgrass quality, tiller density and within-season colour (darkness) in green trial at Lepaa as affected by increasing rates of Primo MAXX®, 2007. Means of nine observations (two in spring, i.e. before 10 June, five in summer, i.e. from 10 June to 1 Sep., and two in autumn, i.e. after 1 Sep.). All values are means of four blocks.

Primo MAXX®, rate	Turf quality (general appearance, 1-9)				Tiller density (1-9)	Within season colour (1-9)
	Mean	Spring	Summer	Autumn		
0 = Control	6.4	6.1	6.6	6.3	6.3	6.4
0.2 l/ha	6.3	6.0	6.5	6.0	6.3	6.4
0.4 l/ha	6.3	5.9	6.5	6.1	6.2	6.3
0.6 l/ha	6.3	5.8	6.5	6.4	6.3	6.4
0.8 l/ha	6.2	5.8	6.4	6.3	6.2	6.4
P%	ns	ns	ns	ns	ns	ns
LSD 5%	-	-	-	-	-	-
CV%	3	5	5	7	2	3

Table 15. Absolute and relative effects of increasing rates of Primo MAXX® on turfgrass height and dry matter production in turfgrass clippings in green trial at Lepaa 2007. Observations conducted 2 weeks (5 observations) and 4 weeks (4 observations) from spraying treatment have been presented separately. Plant heights above 3 mm represent one day's growth.

Treatment	Plant height (mm)				Weight of clippings (g DM / m^2 / day)			
Time after treatment	2 weeks	4 weeks	Mean	Rel	2 weeks	4 weeks	Mean	Rel
0 = Control	4.3	3.9	4.1	100	2.60	2.21	2.43	100
0.2 l/ha	4.1	3.8	4.0	96	2.20	2.28	2.23	92
0.4 l/ha	4.0	3.9	3.9	95	1.88	2.28	2.06	85
0.6 l/ha	4.0	3.8	3.9	94	1.72	2.18	1.99	82
0.8 l/ha	3.8	3.9	3.9	93	1.75	2.28	1.92	79
P%	11	ns	ns	-	5	ns	ns	-
LSD 5%	-	-	-	-	0.9	-	-	-
CV%	6	7	8	-	20	14	16	-

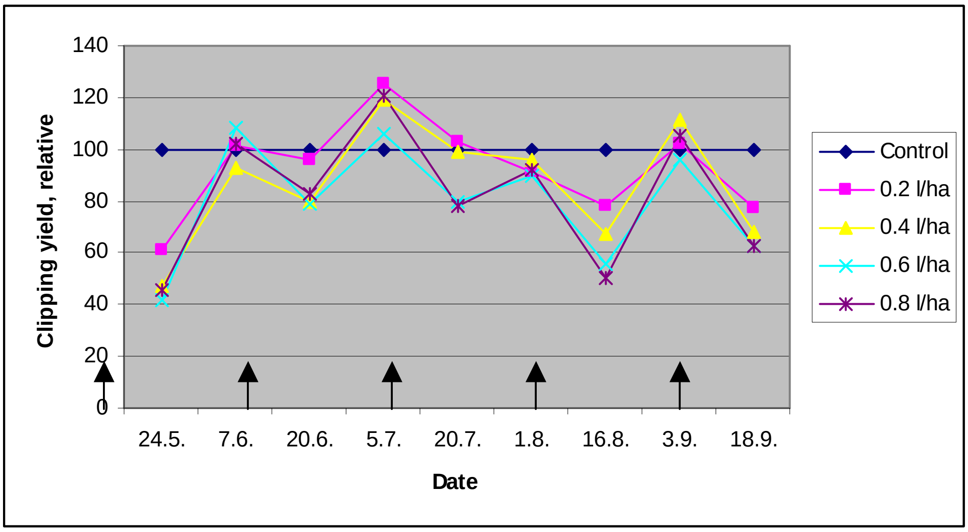


Fig. 4. Relative clipping weights (control = 100) in green trial at Lepaa, Finland. Spraying treatments indicated by black arrows were carried out on 11 May, 8 June, 5 July, 3 Aug. and 4 Sep. (The last spraying on 4 Oct. was done primarily to study the effect of Primo MAXX® on overwintering and was not followed by observations in late autumn.)

4.4. Demonstration trials with Primo MAXX® at Ballerud Golf Course, Oslo, Norway

Green trials

Applications of 0.4 l/ha Primo MAXX® on 5 and 18 June did not affect turf general appearance (Photo 7) or stimpmeter readings on green no. 9 at Ballerud. During the period 14-29 June, clippings were reduced by an average of 32%, but after spraying had been discontinued, there was a rebound effect corresponding to a 26 % increase in clipping yield in the period 12-25 July (data not shown).

Photo 7. Terje Haugen (left) and Lasse Augustsson on green no. 9 at Ballerud Golf Course, 27 June 2007. Photo: Trygve S. Aamlid.

Photo 8. Field day at Ballerud Golf Course 27 Aug. 2007. Photo: Tatsiana Espevig.

Fig. 5 summarizes results from the nursery green trial established on 9 July. In this trial, application of Primo MAXX® about every third week resulted in better colour (not shown), higher green speed (Fig. 5a), and an average reduction in turfgrass clippings of 44 % (Fig. 5b and c). Fig 5b shows that the reduction in clipping yield was most conspicuous during the periods of rapid growth in mid to late July (after only one application of Primo MAXX®) and in late August.

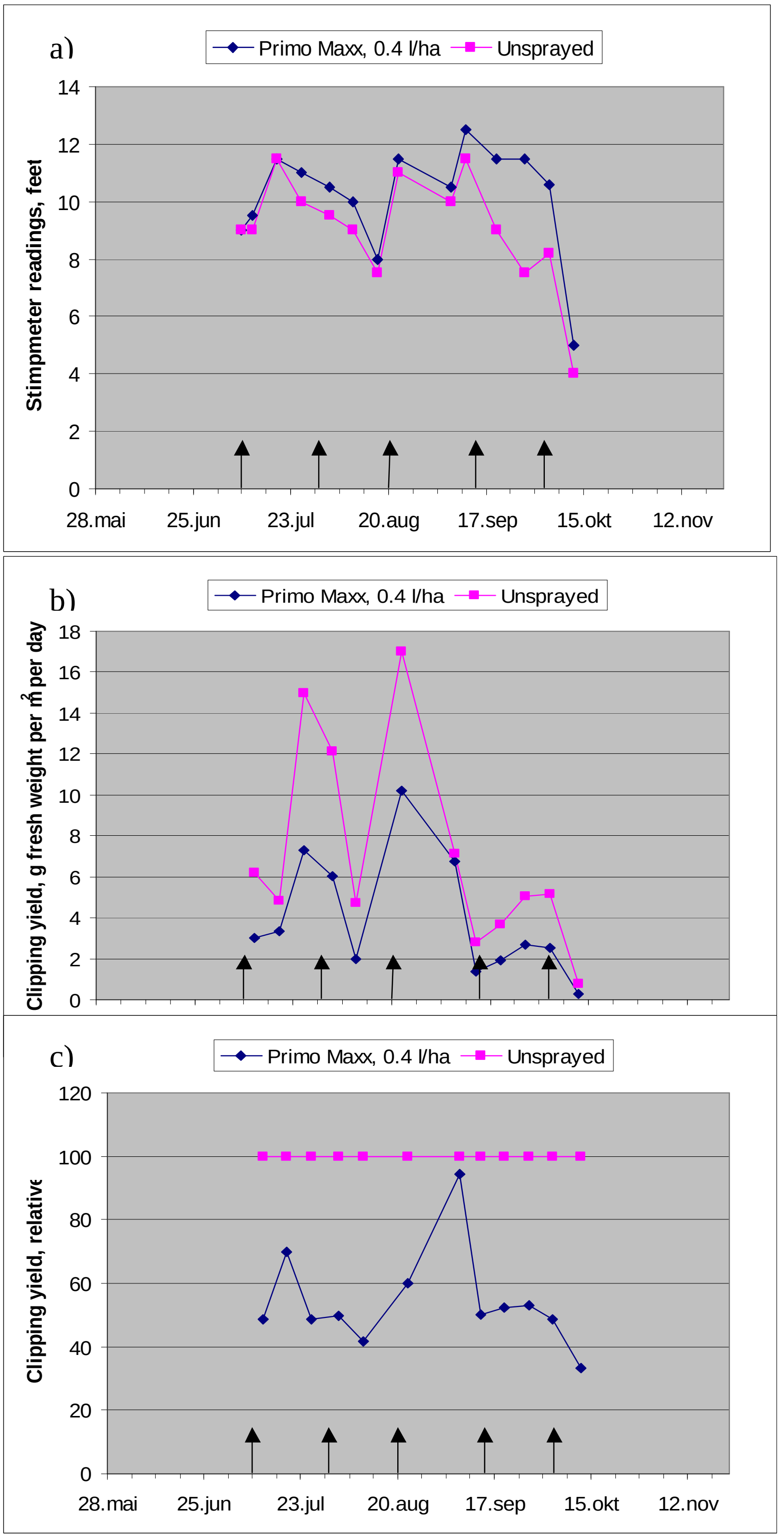


Fig. 5. Effects of spraying Primo MAXX® every three weeks of green speed and absolute and relative clipping yield on nursery green at Ballerud GC, 2007. Black arrows indicate the application dates 9 July, 31 July, 21 Aug., 13 Sep. and 4 Oct.

Fairway trial

As evaluated by the headgreenkeeper, monthly applications of 1.5 l/ha Primo MAXX® (1.5 l/ha) had no negative impact on turf quality in the fairway trial at Ballerud (Fig. 6). Photos 9-11 show, nevertheless, that treated turf was more faded, grayish, and less green than untreated turf. The pronounced colour difference in favour of Primo MAXX® in early September (Fig. 6) was due to less dry spots than the in the control area. While these spots recovered after rainfall on 10 and 17 Sep., the last application of Primo MAXX® on 4 Oct. led to an apparent loss of colour and drop in turf general appearance in late autumn (Photo 11).

On average for 17 clipping, regular application of Primo MAXX® resulted in a 37 % reduction in the fresh weight of turfgrass clippings (Fig. 7). The only time clipping yield was higher on the treated than on the untreated area was at the first clipping nine days after the first application and on 7 Sep. The latter coincided with the observation of less dry spots after use of Primo MAXX®. It may also be interpreted as a rebound effect following growth suppression after application on 31 July.

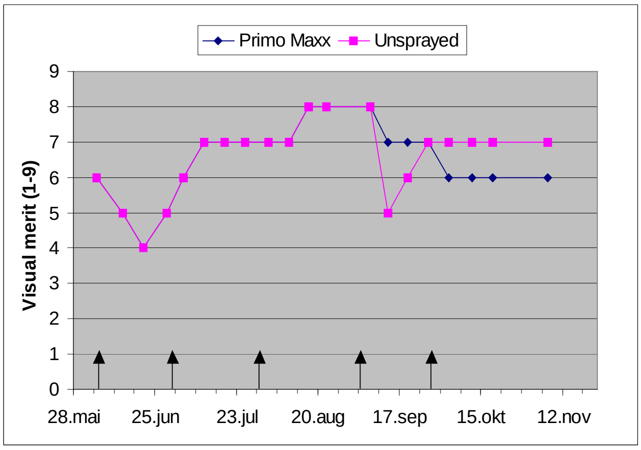


Fig. 6. Effect of Primo MAXX® on turfgrass general appearance in fairway trial at Ballerud GC. Black arrows indicate application dates. (Sprayed an unsprayed plots had identical scores until the beginning of September)

Photo 9. Difference in colour and general appearance of treated and untreated fairway Ballerud GC, 27 June. Photo: Trygve S. Aamlid.

Photo 10. Difference in colour and general appearance of treated and untreated fairway Ballerud GC, 27 Aug. Photo: Tatsiana Espevig.

Photo 11. Difference in colour and general appearance of treated and untreated fairway Ballerud GC, 3 Dec. Photo: Terje Haugen.

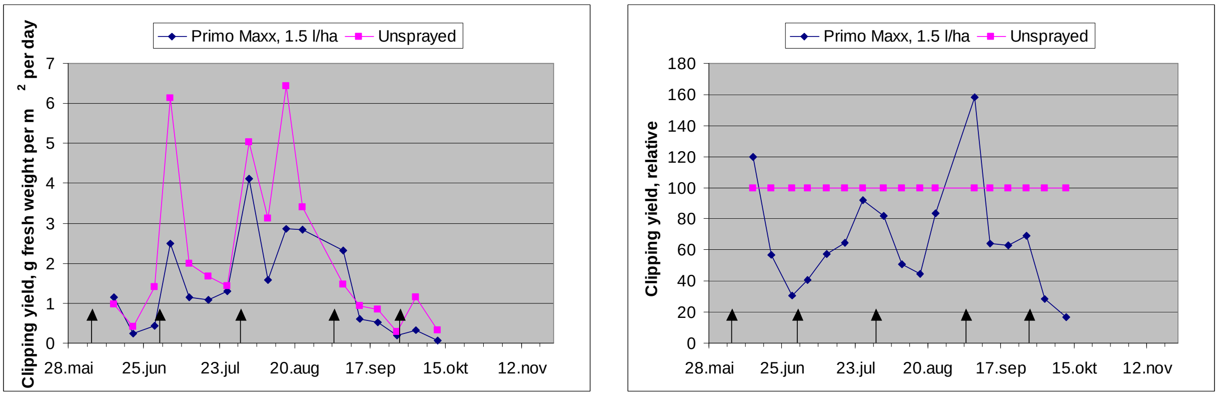


Fig. 7. Absolute (a) and relative (b) reductions in clipping yield resulting form application of Primo MAXX® in fairway trial at Ballerud GC. Arrows indicate application dates.

Spraying 2.2 l/ha of Primo MAXX® at six weeks interval resulted in discoloration and consistent drop in turf quality in the rough trial at Ballerud (Fig. 8, Photos 12 and 13). The effect was most conspicuous in late autumn. Primo MAXX® had less effect on tufts of perennial ryegrass which stood out very markedly in the turf which was otherwise dominated by smooth meadowgrass. Clipping yields were not recorded in this trial.

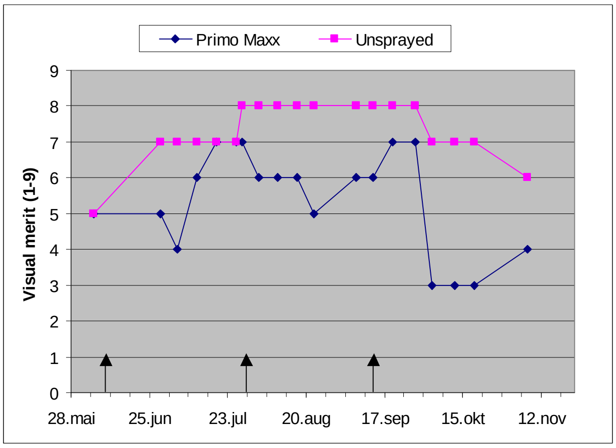


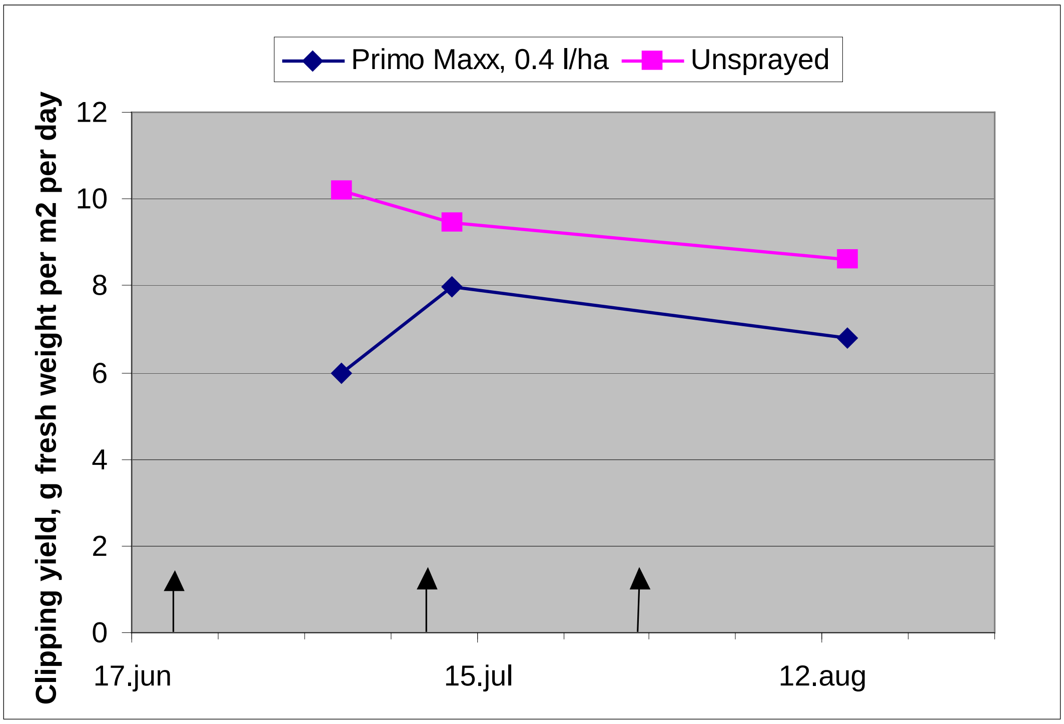
Fig. 8 (upper left). Difference in colour and general appearance of treated and untreated area in rough no 9, Ballerud, 27 June. Photo: Trygve S. Aamlid.

Photo 12 (upper right). Terje Haugen (left) and Lasse Augustsson in rough trial at Ballerud GC, 27 June. Photo: Trygve S. Aamlid.

Photo 13 (lower left). Trygve S. Aamlid inspecting rough trial at Ballerud GC, 27 August 2007. Tufts of ryegrass stand out very markedly on sprayed area. Photo: Tatsiana Espevig.

4.5. Demonstration trial with Primo MAXX® at Oslo Golf Club, Bogstad, Norway

Application of 0.4 l Primo MAXX® at three week intervals resulted in darker turf but had otherwise no effect on the turfgrass quality of annual meadowgrass at Oslo GC. On average for three registrations, the Primo MAXX led to a 26% reduction in clipping yields (Fig. 9).



5. Discussion and suggestions for 2008

The starting point for evaluating Primo MAXX® in this two-year project was the rates and applications frequencies recommended for the product in Europe (Syngenta 2007, Table 16). Based on our experiences from agricultural crops that the optimal rates may be different in the Nordic countries than countries further south, higher and lower rates were included in the GEP trials both to determine the potential growth inhibition and the risk for discoloration or other phytotoxic effects. All taken together, the results from the first project year confirms that the guidelines in Table 16 are not directly applicable in Scandinavia and that further research is needed to find the optimal way of using the product under Nordic conditions.

Table 16. Dose rates and applications frequencies recommended for Primo MAXX® in the United Kingdom (Syngenta 2007).

	Dose rate		Application
	Primo MAXX®, l/ha	trinexapac-ethyl, g a.i./ha	frequency
Fairways	0.8 – 1.6	90 - 180	Every four to five weeks
Roughs & semi-roughs	1.6-2.4	180 - 240	Every five to eight weeks
Greens	0.4	45	Every two to four weeks

On fairway, the average reduction in clipping yield caused by monthly application of the intermediate Primo MAXX® rate of 1.5 l/ha was 15 and 21 % in the GEP trials at Landvik and Lepaa, respectively. By contrast, monthly application of 1.5 l/ha resulted in a 37 % reduction in clipping yield in the demonstration trial at Ballerud GC, which is closer to the data presented by Syngenta (2007). In agreement with Table 11 showing an increase in turfgrass dry matter percentage (i.e. decreased succulence) after application of Primo MAXX®, one of the reasons for this difference might be that clipping yields were determined on a dry weight basis in the GEP trials but on a fresh weight basis at Ballerud GC and in the data presented by Syngenta (2007). Another, and probably more important explanation, is the difference in species composition among the three trials. While the plant cover at Ballerud was almost 100% by annual meadowgrass, the species composition at Landvik varied with the two blocks showing the least response to Primo MAXX® having a plant cover of 74 % red fescue (Tables 1 and 11). By contrast, smooth meadowgrass dominated over red fescue at Lepaa due to the heavy soil type, use of irrigation, and relatively high nitrogen input. Unfortunately, we have not been able to find many references about the specific effects of Primo MAXX® on red fescue turf, but our results are in partial agreement with Pannacol et al. (2004) who found 40 %, 21 %, and no significant reduction in clipping yield after using trinexapac-ethyl in smooth meadowgrass, chewing fescue and creeping red fescue, respectively.

Perhaps the most conspicuous feature of the present results was the unstable effect of Primo MAXX® on clipping yields due to the postsuppression rebound effect. In the fairway trial at Lepaa, Finland, this resulted in clipping yield reductions being significant only two weeks after application (Table 13), and a similar tendency could be seen also in the green trial (Table 15). In Norway, clipping yields four weeks after spraying were often higher than on unsprayed control plots in the fairway trial at Landvik (Fig. 2), and a strong rebound effect was observed also after spraying treatments had to discontinued at green no. 9, Ballerud GC. The unstable effect in of Primo MAXX® in these trials was probably due to a rapid degradation of trinexapac-ethyl in plant tissue and a higher regrowth potential due to accumulation of carbohydrate reserves and GA_1 precursors during the suppression phase (Lickfeldt et

al. 2001, Branham & Beasley 2007). In North-American experiments, Lickfeldt et al. (2001) reported clipping yields reductions in smooth meadowgrass to be much more consistent when trinexapac-ethyl was applied at four than at six week intervals, but under Nordic long-day conditions, spraying every second, or at least every third week, may well be necessary to stabilize low GA_1 levels, not only on greens, but also on fairways and tees. Although there was a surge effect during the driest period in mid September, the most stable clipping reductions in our trials, on average 44 % on a fresh weight basis, were, indeed, obtained on the nursery green which was sprayed about every third week at Ballerud GC (Fig. 5c). While Branham & Beasley (2007) noted that temperature was the most important factor determining degradation of trinexapac-ethyl in turfgrass tissue, our results suggest that other factors such as light and water availability may also be important for the rebound effect under Nordic conditions. Very clearly, application frequency is a major question that has to be addressed during the continuation of this project.

The potential reductions in mowing costs from using a plant growth regulator will always have to be weighed against the risks for discoloration or other harmful effects on turf quality. In the present trials, reductions in general appearance (visual merit) scores were far more conspicuous in the GEP trial at Landvik than in the GEP trials at Lepaa or the demonstration trials at Ballerud GC. Apart from possible effects of different botanical compositions, this might reflect a subjective human factor, i.e. different backgrounds and attitudes of the observers in the various trials. While the fairway trial at Landvik was evaluated by turfgrass scientists and technicians with long experience from turfgrass variety testing, the trials at Lepaa and Ballerud were evaluated by greenkeepers working on the course. While the observers at Landvik may have paid more attention to turf aesthetic values such as less intense colour, and less vigorous and uniform plots, the observers at Lepaa and Ballerud may well have been more attentive to ball roll and other functional characteristics of the playing surface. The less succulent but significantly darker green turf resulting from high Primo MAXX® rates at Landvik are in agreement with other studies showing higher mesophyll cell densities and chlorophyll concentrations resulting from less elongation of leaf cells (Heckman et al. 2001, Ervin & Zhang 2008). As for tiller density, most literature supports the Finnish rather than the Norwegian results; i.e. enhanced tillering after Primo MAXX® application (Branham & Beasley 2007, Ervin & Zhang 2008).

As compared with the unsprayed control treatment, the strongest negative effect of Primo MAXX® on turfgrass general appearance at Landvik was recorded after the first spraying in early June, in mid July and at the last observation in early November. Each of these observations might be explained by suboptimal conditions causing reduced turfgrass growth. From 6 to 15 June there was a dry and warm and period with maximum temperatures in the range 25-30 ºC that obviously reduced turfgras tillering and aesthetic appearance; until mid July exceptional rainfalls starting on 22 June were not compensated by increase nitrogen inputs, and in autumn, the last application of Primo on 26 September was followed by several nights of frost. Although most studies have failed to document significant interactions between nitrogen and trinexapac-ethyl on turfgrass quality (Steinke & Stier 2001, Goss et al. 2002, McCullogh et al. 2006), it seems reasonable to assume that potential negative effects on Primo MAXX® on turfgrass quality will be most pronounced under suboptimal growing conditions. As in the trials at Landvik (Photo 6) and Ballerud (Photo 11), Beam et al. (2002) reported significant discoloration of trinexapac-ethyl-treated smooth meadowgrass following frost in autumn.

Undoubtedly, the most convincing argument for official approval of Primo MAXX® on Nordic golf courses would be a clear documentation that it improves winter survival. Preliminary results with annual meadowgrass suggested that low rates of trinexapac-ethyl prevented winter injury, whereas high rates had opposite effects due to discoloration during the hardening phase in late autumn (Rossi & Buelow 1997). While trinexapac-ethyl has been shown to increase water soluble carbohydrate contents (Goss et al. 2002) and result in faster spring greenup, Ervin & Zhang (2008) recently called for more detailed investigations into the effect of trinexapac-etyl on freezing tolerance as the research to date has provided scarce information on this aspect. Under Nordic conditions, desiccation if growth resumes when soils are still frozen and irrigation not yet operational in spring, or damage due to unstable winters with ice and water covering the turf, sometimes resulting in suffocation, appear to be more

important that direct freezing injury. In this regard, trineexapac-ethyl may well have a positive effect as it reduces mitochondrial respiration (Ervin & Zhang 2008). In 2008, it will therefore be very interesting to study winter injury and spring green-up and recovery in the on-going trials at Landvik, Lepaa and Ballerud which all had their last application of Primo MAXX® in late September or early October.

Even with winter survival and spring observations included, the amount of data presented in this report is too limited to recommend any listing of Primo MAXX® for turf use in the Nordic countries. Therefore, as stated in the contract between Syngenta and Scandinavian Turfgrass and Environment Research Foundation, there is a need for new GEP trials to be started in spring 2008 and followed until registration of winter survival in spring 2009. For this purpose, a new experimental green was constructed and seeded to creeping bentgrass at Landvik in 2007. In the trial to be established on this green in spring 2008, we suggest to compare Primo MAXX® at three rates (0.15, 0.30 and 0.45 l/ha) and two application frequencies (every 10/11 days and every 21 days), i.e. six combinations plus an unsprayed control treatment. As different grass species seem to vary in their response to Primo MAXX®, similar trials should preferably be carried out on also red fescue/browntop greens and velvet bentgrass greens, although this would require additional funding from Syngenta/STERF.

In Finland, a new GEP trial will be established in spring 2008 on a fairway that is regularly subjected to winter injury. New demonstration trials might be added to the project depending on interest from superintendents and funding from the national golf unions.

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

Results from the first evaluation year 2007

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Finnish team spraying fairway trial at Lepaa Golf Course.
Photo: Oiva Niemelainen

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Summary:

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

Sammendrag:

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

Approved

Arne Sæbø	Trygve S. Aamlid
Leader, Bioforsk's Section for Urban Greening	Project leader

Contents

1. Abstract

As an inhibitor of the last step in plant synthesis of bioactive gibberellin (GA_1), the plant growth regulator Primo MAXX® (trinexapac-ethyl) offers prospects of reduced energy use for mowing and improved turfgrass quality under Nordic long day conditions. This report presents first year results from 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 possible registration of Primo MAXX®, unreplicated demonstration trials were carried out at Ballerud and Bogstad Golf Courses in Oslo under supervision of Bioforsk and with funding from the Norwegian Golf Federation (NGF).

GEP trials on **fairways** (mowing height 12-18 mm) were carried out at Bioforsk Landvik, Norway (58°34'N, 8°52'E) and at the Lepaa Unit of the HAMK University of Applied Sciences, Finland (61°08'N, 24°20'E). Primo MAXX® was applied at monthly intervals at rates 0.5, 1.0, 1.5, 2.0 and 3.0 l/ha (56.5, 113, 169.5, 226 and 339 g a.i./ha trinexapac-ethyl) in comparison with an unsprayed control treatment. Turfgrass general appearance, tiller density, colour, height growth, and clipping yields were recorded two and four weeks after each application. Primo MAXX® had no effect on turfgrass general appearance but increased density at Lepaa. At Landvik, Primo MAXX® (>= 1.0 l/ha) reduced turfgrass general appearance and density, but resulted in significantly darker green colour. Quality reductions were most apparent during periods with either daily maximum temperatures >25 °C, extreme rainfall probably causing nitrogen deficiency, or frost at night. Average reductions in clipping yield caused by Primo MAXX® (>= 1.0 l/ha) were 8 % in the GEP trial at Landvik, 18 % in the GEP trial at Lepaa and 37 % in the demonstration trial at Ballerud; to some extent this difference may be due to different botanical composition with red fescue (*Festuca rubra*) and annual meadowgrass (*Poa annua*) being the predominant species at Landvik and Ballerud, respectively. Clipping yield reductions due to Primo MAXX® were unstable, growth suppression two weeks after application often being followed by a rebound effect during the remaining two weeks until next application.

A GEP trial on creeping bentgrass **putting greens** was carried out at Lepaa, Finland, and demonstration trials at Ballerud and Bogstad, Norway. Primo MAXX® was sprayed at rates 0.2, 0.4, 0.6 or 0.8 l/ha at monthly intervals in the GEP trial, and at 0.4 l/ha every three weeks in the demonstration trials. On average for all observations, Primo MAXX® had no effect on turfgrass quality, but clipping yields were reduced by 16, 44 and 26% at Lepaa, Ballerud and Bogstad, respectively. As in the fairway trials, growth suppression at Lepaa was stronger when assessed at two than at four weeks after application. By contrast, Primo MAXX® produced a fairly stable effect when applied at three week intervals in the demonstration trials.

Use of Primo MAXX® on golf course **roughs** was investigated only in a demonstration trial at Ballerud. Application of 2.2 l/ha of Primo MAXX® every seven weeks resulted in discolouration and reduced quality of smooth meadow grass.

In conclusion, the first year of this project has shown that the guidelines for use of Primo MAXX® in other European countries are not directly applicable in Scandinavia. As the present results are too limited to apply for registration of Primo MAXX®, the project will continue in 2008 tentatively with new trials investigating application of Primo MAXX® at lower rates, but higher frequencies. Improved winter stress tolerance would be a convincing argument for registration of Primo MAXX® in the Nordic countries, and the on-going trials will therefore be followed by an assessment of effects of the last Primo MAXX® applications in September or October 2007 on winter survival and spring recovery.

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

2. Introduction

The plant growth regulator trinexapac-ethyl was developed by Syngenta in the 1980s. Since the active ingredient is available in different formulations, the chemical will, in this report, be referred to as Primo MAXX®, which is the product developed by Syngenta specifically for use on turf. Unlike earlier plant growth regulators, Primo MAXX®'s mode of action is highly specific as it blocks the conversion of GA_{20} til GA_1, i.e. the last step in the biosynthesis of gibberellic acid, a plant hormone stimulating cell elongation and thus vertical turf growth.

After its release, Primo MAXX® was rapidly adopted by the US and Canadian turf industries. In North America, there are several independent university studies documenting its positive effects on golf courses, athletic fields, home lawns, and sod production (for a recent review, see Erwin and Zhang 2008). These advantages include reduced leaf elongation and thus reduced mowing costs and energy use, improved tiller production (more lateral growth), darker green colour, and improved resistance to drought and shade.

While other formulations of trinexapac-ethyl have been approved for agricultural use in Europe for about a decade, the experience with Primo MAXX® to European turfgrass areas is relatively limited. During the past three to four years, Primo MAXX® has been approved for turf use in Italy, France and UK, and the evaluation and registration process has been initiated in many other countries.

Being an inhibitor of gibberellin biosynthesis, Primo MAXX® offers special prospects for turfgrass management in the Nordic counties Finland, Sweden, Norway, Iceland, and Denmark. At latitudes ranging form 55 to 71 °N, turfgrasses growing in these countries exposed not only to long photoperiods during most of the growing season, but also to lower photosynthetic flux densities and lower red to farred (R/FR) ratios than in countries further south. The natural turfgrass response to these northern light conditions is to devote more of its resources to shoot elongation (Heide et al. 1985a,b). Since this response is primarily mediated by the gibberellic acid GA_1, any specific growth regulator that controls the biosynthesis of this compound might be useful under Nordic conditions. Nevertheless, our experience from the introduction of trinexapac-ethyl for agricultural use in the Nordic counties suggests that the optimal dose rates and frequencies for application of Primo MAXX® to various types of turf are probably not the same as at lower latitudes. This is also due to different species and cultivars being grown compared with countries further south. Field trials under Nordic conditions are therefore required not only to produce data for the national certification agencies, but also to provide turf managers with recommendations for how to use the product.

This report presents first year preliminary results from a two year project evaluating the use of Primo MAXX® on golf courses in the Nordic countries. The project was funded by Syngenta and the Scandinavian Turfgrass and Environment Research Foundation (STERF) 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' trials needed to provide documentation for possible registrations of Primo MAXX® by the national authorities, a couple of practical demonstration trials were carried out on Norwegian golf courses under supervision from Bioforsk and with funding from the Norwegian Golf Federation (NGF).

3. Methods

3.1. Evaluation of Primo MAXX® under fairway conditions, Bioforsk Landvik, Norway

Experimental site

On 8 May 2007, a field trial was laid out on a fairway established on a sandy loam soil (topsoil: 68 % sand, 27% silt, 5 % clay) at Bioforsk Landvik Research Station (58°34'N, 8°52'E), SE Norway. Soil samples indicated a pH (H_2O) of 5.9, high phosphorus values (P-AL=19) and intermediate to low potassium values (K-AL = 8, K-HNO_3=58). The fairway had been seeded in September 2003 to a mixture of smooth meadowgrass (*Poa pratensis*), chewing fescue (*Festuca rubra* ssp. *commutata*), and browntop bent (*Agrostis capillaris*) (Table 1). Block 1 and 2 were located in one part, and block 3 and 4 in a different part of the fairway. Botanical analyses at the start of experimentation indicated that red fescue was the predominant species in all blocks, but presumably due to slightly less surface drainage, blocks 1 and 2 had a higher percentage of smooth and annual meadowgrass and broadleaved weeds (primarily white clover (*Trifolium repens*)) than blocks 3 and 4 (Table 1).

Table 1. Seed mixture used for fairway establishment in 2003 and botanical composition at the start of the Primo MAXX® trial in spring 2007.

Species	Cultivar	% (w/w) of seed mixture	% cover at initiation of Primo MAXX® trial		
			Block 1 and 2	Block 3 and 4	Mean
Poa pratensis	Conni	25	31	9	20
Poa pratensis	Eva	10			
Poa pratensis	Limousine	10			
Festuca rubra ssp. commutata	Bargreen	25	50	74	62
Festuca rubra ssp. commutata	Calliope	25			
Agrostis capillaris	Tracenta	5	5	15	10
Poa annua			8	2	5
Broadleaved weeds			6	0	3
Sum		100	100	100	100

Experimental plan

The experiment was laid out according to a randomized complete block design with plot size 2m x 3m, four blocks (replicates) and the following treatments:

1. Usprayed control
2. Primo MAXX, 0.5 l/ha (56.5 g a.i./ha) every four weeks
3. Primo MAXX, 1.0 l/ha (113 g a.i./ha) every four weeks
4. Primo MAXX, 1.5 l/ha (169.5 g a.i./ha) every four weeks
5. Primo MAXX, 2.0 l/ha (226 g a.i./ha) every four weeks
6. Primo MAXX, 3.0 l/ha (339 g a.i./ha) every four weeks

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. Actual application rates were recorded by weighing the tank before and after spraying. Table 2 shows actual rates and weather conditions for each spraying event.

Table 2. Weather conditions and actual application rates at the six spraying events.

Application date	Time of day (hours)	Weather conditions at application			Treatment number / application rate (l Primo MAXX® per ha)				
		Air temp. °C	Relative Humidity %	Wind Speed m/s	2. (target 0.5)	3. (target 1.0)	4. (target 1.5)	5. (target 2.0)	6. (target 3.0)
9 May	09-11	14	48	< 1.0	0.47	0.94	1.56	1.90	3.35
5 Jun.	09-11	15	60	< 1.0	0.58	1.06	1.67	1.93	3.19
4 Jul.	13-15	17	70	1.0-2.0	0.61	0.98	1.73	2.19	3.38
31 Jul.	08-10	18	55	1.0-2.0	0.55	1.05	1.66	2.28	3.41
28 Aug.	09-11	19	32	1.0-2.0	0.57	1.03	1.55	2.19	3.52
26 Sep.	09-11	11	69	< 1.0	0.52	1.07	1.55	2.01	3.15
Mean					0.55	1.02	1.62	2.08	3.33

Registrations

At two weeks intervals throughout the experimental period, turfgrass colour, tiller density, and turf general appearance were assessed by turfgrass scientist or technicians using a scale from 1 to 9 where 9 is darkest colour, highest tiller density and best turf quality. The assessments were conducted two and four weeks after application of Primo MAXX®. On the same dates, turfgrass diseases and broadleaf weed (including white clover) invasion were reported as per cent of plot area. Turfgrass height was recorded as the mean of three random measurements with a ordinary ruler in each plot, and the overall growth rate by weighing clippings in the basket of a walk-behind mower used in the 0.56 m x 1.88 m central area of each plot (Photo 1). Both raw weight and dry weight were recorded, the latter after drying for 24 h at 60°C. By the end of the growing season, on 2 Nov., turfgrass dormancy colour was evaluated on a scale 1-9, where 1 is completely faded / brown turf, and 9 is completely green turf.

Photo 1a and b. Tatsiana Espevig collecting clippings in fairway trial at Landvik. Photos: Trygve S. Aamlid

Management

The experiment was mowed at 15 mm two times a week, usually on Monday and Friday. A triplex fairway mower without collection of clippings was used except when clipping weights were to be recorded. Granular fertilizer was applied at approximately monthly intervals as outlined in Table 3. The experiment was not irrigated except for small amounts of water to dissolve fertilizer after application. On 7 Aug., the trial was aerated using a vertidrain with 15 mm solid tines to 15 cm depth. Topdressing was accomplished on 8 Aug. and 5 Nov. at rates 0.75 and 1.5 kg pure sand per m^2, respectively.

The fairway trial at Landvik was not exposed to ordinary play, but it was was subjected to artifical wear from a wear drum one to two times per week.

Table 3. Fertilizer inputs, fairway trial, Landvik.

		Per ha							
Date	Fertilizer type	kg fertilizer	kg N	kg P	kg K	kg Mg	kg S	kg Ca	kg Fe
17 Apr.	Fullgjødsel 22-2-12	40	9	1	5	0	1	0	0
16 May	Fullgjødsel 22-2-12	70	15	1	8	1	2	1	0
12 Jun.	Arena Golf Extra 13-0-15	150	20	0	23	2	21	0	3
23 Jul.	Arena Golf Extra 13-0-15	130	17	0	20	2	18	0	3
9 Aug.	Arena Golf Extra 13-0-15	135	18	0	21	2	18	0	3
5 Sep.	Arena Golf Extra 13-0-15	150	20	0	23	2	21	0	3
SUM			99	2	100	10	80	1	11

Weather data

In SE Norway, the growing season 2007 was characterized by exceptionally high rainfall, especially in July, but also in May, June and August (Table 4). By contrast, September was unusually dry. Precipitation was recorded on 16 out of the 31 days in July; the cloudy summer weather is also reflected by a rather low irradiance during this month. The warmest period, with daily maximum temperatures in the range 23-29 ºC was recorded from 6 to 12 June.

Table 4. Weather data for Landvik meteorological station, about 200 m for experimental field. Normal values for temperature and rainfall are 'official' values for from the period 1961-90, while normal values for irradiance are calculated averages for the period 1994-2006.

	Mean temperature, °C		Precipitation, mm		Irradiance, MJ/m^2 (305-2800 nm)	
	2007	30 yr normal	2007	30 yr normal	2007	13 yr average
May	10.2	10.4	107	82	518	540
June	15.9	14.7	109	71	604	600
July	15.5	16.2	213	92	492	632
Aug.	16.2	15.4	132	113	476	476
Sep.	12.0	11.8	59	136	321	262
Mean / sum	14.0	13.7	620	494	2411	2510

3.2. Evaluation of Primo MAXX® on a golf course fairway, Lepaa, Finland

Experimental site

The Finnish fairway trial was laid out on 11 May 2007. The fairway was seeded to a mixture of smooth meadowgrass and chewing fescue (*Festuca rubra* spp. *commutata*) on a heavy clay soil (15% sand, 37% silt, 48% clay) at the Lepaa Unit of HAMK University of Applied Sciences, Finland (61°08'N, 24°20'E). 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. All observations and management of the trial was carried out by the HAMK Lepaa greenkeepers Petteri Lehmuskoski and Tommi Turunen except for the spraying treatments which were carried out by MTT's 'Good Experimental Practice' certified spraying team from Jokioinen (90 km from Lepaa).

Experimental plan and registrations

The experiment was laid out following the same plan and plot size as at Landvik, Norway (previous paragraph). Primo MAXX® was applied in accordance with the Finnish 'Good Experimental Practise' protocol, using a portable, compressed air-powered 'van der Weij' plot sprayer, mounted with a windshield and flat fan nozzles (Hardi 4110-12) and working at 180-250 kPa pressure. The spraying boom had four nozzles spaced 50 cm apart. The spraying volume corresponded to 200 l/ha. Full spray coverage was on the central 1.5m x 2.5 m of each plot. Table 5 shows application dates and weather conditions for each spraying event. The last application on 4 Oct. was conducted especially to evaluate potential effects of Primo MAXX® on turfgrass winter damage.

Table 5. Application dates and weather conditions in fairway and green trials at Lepaa.

Application date	Time of day (hours)	Air temp. °C	Relative humidity %	Wind Speed m/s	% cloud cover
11 May	09-11	11	29	0	25
8 Jun.	09-11	20	56	1.5	1
5 Jul.	13-15	23	47	2.5	70
3 Aug.	09-11	17	78	2.0	90
4 Sep.	09-11	11	90	1.0	90
4 Oct.	13-15	11	92	1.5	100

Photo 2. Austen Sutton, Syngenta (left) and greenkeeper Petteri Lehmuskoski, HAMK Lepaa Unit, in fairway trial at Lepaa, Finland, 29 Aug. 2007.

Photo: Oiva Niemelainen.

Registrations

Registrations were carried out at two-week intervals following the same program as at Landvik (previous section) except that weed occurrence and dormancy colour were not recorded. Plant height at Lepaa was determined using a Turf Check Prism device (Check Signature Inc., Shoreview, MN).

Management and wear

The experiment was mowed with a triplex fairway mower about three times per week. Mowing height ranged from 12 to 18 mm. Granular fertilizer Sportsmaster 26-2-9 was applied at equal rates on 8 May and 12 July, the total input corresponding to 156 kg N, 12 kg P, 54 kg K and 0.9 kg Fe per ha. Information about irrigation is given in Table 6. The trial was aerated or top-dressed in late autumn, after the completion of registrations.

During the growing season period, the trial was exposed to approximately 3.500 rounds of golf.

Weather data

Temperatures at Lepaa were higher the 30 yr normal values throughout the growing season (Table 6). August had the greatest deviation from the long-term average value. July had 49 % more, and August 42 % less rainfall than usual; over the whole experimental season, rainfall was close to the 30 yr normal value.

Table 6. Weather data for Hattula Lepaa weather station and irrigation in fairway and green trial at Lepaa golf course, 2007. Normal values for temperature and rainfall are official values for from the period 1971-2000 (Finnish Meteorological Institute)

	Mean temperature, °C		Rainfall, mm		Irrigation, mm (2007)	
	2007	30 yr normal	2007	30 yr normal	Fairway trial	Green trial
May	10.6	9.8	30	34	*	*
June	15.1	14.5	54	55	26	79
July	16.6	16.4	119	80	5	47
Aug.	16.4	14.6	43	74	7	50
Sep.	9.9	9.4	58	54	0	6
Mean / sum	13.7	12.4	304	297	37	188

* Data are unavailable for the period 1-26 May 2007 due to change of irrigation computer.

3.3. Evaluation of Primo MAXX® on a golf course putting green, Lepaa, Finland

Experimental site

The Finnish green trial was established on 11 May 2007 on a USGA green seeded to creeping bentgrass (*Agrostis stolonifera*, seed blend of 50% ‘Penn A-4’ and 50% ‘Penn G-6’) at Lepaa Golf Course.

Experimental plan

The experimental plan comprised five rates of Primo MAXX plus the unsprayed control treatment:

1. Usprayed control
2. Primo MAXX, 0.2 l/ha (22.6 g a.i./ha) every four weeks
3. Primo MAXX, 0.4 l/ha (45.2 g a.i./ha) every four weeks
4. Primo MAXX, 0.6 l/ha (67.8 g a.i./ha) every four weeks
5. Primo MAXX, 0.8 l/ha (90.4 g a.i./ha) every four weeks

The trial had four replicates, and a gross plot size of 2 m x 3 m. It was sprayed on the same dates and following the same GEP procedures as the fairway trial on the same location (Table 5).

Photo 3. Green trial at Lepaa ready for the first treatment on 11 May 2007. Photo: Oiva Niemelainen.

Registrations

Registrations followed the same program as in the Finnish fairway trial (previous section).

Management and wear

The experiment was mowed with a Triplex greens mower for an average of six times per week. Depending on weather and turfgrass density, mowing height was 5–7 mm in May and September and 3-4 mm from June to August. Information about irrigation and fertilizer inputs are given in Tables 6 and 7, respectively.

To avoid thatch accumulation, the trial was aerated with deep slitting knives every second week and with 8 mm needle tines once a month. Verticutting was accomplished every second week and topdressing with 0.1-0.7 mm finely graded sand at a rate of 1 kg per m2 every third week. The sand was brushed/irrigated into the green and the dressing was never done in close proximity to weighing of clippings.

Being located on a practise green, the experiment received wear from about 10.000 rounds of golf over the season. When placing holes on the green, care was taken to create as uniform wear as possible.

Table 7. Fertilizer inputs in green trial at Lepaa.

		Per ha							
Date	Fertilizer type	kg fertilizer	kg N	kg P	kg K	kg Mg	kg S	kg Ca	kg Fe
28.3.2007	Floratine Kevätstartti*	35	5.4	1.2	2.1				
5.4.2007	Floratine Kevätstartti	35	5.4	1.2	2.1				
19.4.2007	Floratine Kevätstartti	35	5.4	1.2	2.1				
26.4.2007	Sierraform Springstart (16-0-13)	250	40	0	32.5				2.50
15.5.2007	Sierraform All Season (18-3-15)	250	45	7.5	37.5	3.0			1.25
30.5.2007	Kemigreen Basic (23-4-14)	40	9	1.6	5.6	0.6	0.8		0.04
5.6.2007	Kemigreen Basic (23-4-14)	40	9	1.6	5.6	0.6	0.8		0.04
11.6.2007	Sierraform All Season (18-3-15)	250	45	7.5	38				
25.6.2007	Osmosol 614R (19-2-10)	40	7.6	0.8	4.0	0.5		1.7	0.04
2.7.2007	Osmosol 614R (19-2-10)	40	7.6	0.8	4.0	0.5		1.7	0.04
13.7.2007	Kemigreen Summer (18-0-17)	40	7.2	0	6.8			2.0	0.40
18.7.2007	Kemigreen Summer (18-0-17)	40	7.2	0	6.8			2.0	0.40
26.7.2007	Sierraform All Season (18-3-15)	250	45	7.5	37.5	3.0			1.25
14.8.2007	Kemigreen Summer (18-0-17)	40	7.2	0	6.8			2.0	0.40
27.8.2007	Greenmaster Autumn (6-2-8)	300	18	6	24	5.4			1.50
30.8.2007	Kemigreen Basic (23-4-14)	40	9	1.6	5.6	0.6	0.8		0.04
11.9.2007	Sierraform Springstart (16-0-13)	200	32	0	39				2.00
SUM			305	39	260	14.0	2.4	9.4	10

* Floratine Kevätstartti (Springstart) is composed of P-48 (10-21-6.6), Per 4 Max (15-0-0), Protesyn (3.5-0.6-1.8), and Plant Marvel (28-3-15).

3.4. Demonstration trials with Primo MAXX® at Ballerud Golf Course, Oslo, Norway

Experimental site and set-up

Ballerud GC is located on an old horticultural farm in a suburban area SW of Oslo. The course has greens with mostly dominated by creeping bentgrass, fairways almost exclusively dominated by annual meadowgrass, and smooth meadowgrass roughs with some tufts of perennial ryegrass (*Lolium perenne*).

Large-scale, unreplicated demonstration trials were laid out on green no. 9, fairway no. 9 and rough no. 9 on 5 June 2007. Plots sizes varied from 80 to 130 m^2. Unsprayed control plots were compared with plots sprayed with Primo MAXX® at rates 0.4, 1.5 and 2.2 l/ha and application intervals of approximately 3, 4 and 7 weeks on green, fairway and rough, respectively. In compliance with the Norwegian Food Authority's rule for complete closure of all sprayed areas for 48 h after each application, the trial on green no. 9 had to be discontinued after the second application on 18 June.

Three weeks later, it was replaced by a new trial laid out on the golf course' nursery green. Actual application dates in the green, fairway and rough trials are given in Table 8. The growth regulator was applied using a battery-operated electric Hardy Defender plot sprayer (Photo 4).

Table 8. Application dates for Primo MAXX in demonstration trials at Ballerud GC.

Green no. 9	Nursery green	Fairway no. 9	Rough no. 9
5 June		5 June	5 June
18 June			
	9 July	2 July	
	31 July	31 July	28 July
	21 Aug.		
	13. Sep.	3 Sep.	11 Sep.
	4 Oct.	28 Sep.	

Photo 4. Sprayer used in demonstrations trials at Ballerud Golf Course.

Photo: Terje Haugen.

Registrations

In all trials at Ballerud, turfgrass general appearance was evaluated by the headgreenkeeper at one to two week intervals throughout the growing season. In the green and fairway trials, turfgrass clipping yields were recorded on a fresh weight basis. Registrations in the green trials also included regular assessments of green speed using a standard stimpmeter.

Maintenance

The green trials at Ballerud were mowed daily at 3.4-3.8 mm and the fairway trial at 20 mm three to four times a week. The rough area was only mowed upon need.

Due to the rich soil from decades of vegetable production, the rough trial was not fertilized in 2007, and the fairway trial only received one application of 200 kg Fullgjødsel® 11-5-18 (22 kg N/ha) on 8 May. The green trials received monthly applications of granuar fertilizer (Gro Power 5-1-1, Anderson 14-0-9, Anderson 8-0-16, and/or Roots 12-2-12), and weekly applications of liquid fertilizers /

biostimulants, mostly Floratine products. Total rates of N, P, K, Mg, Ca, S and Fe over the season were 155, 14, 142, 27, 30, 73 and 14 kg/ha, respectively. The greens were aerated, mostly using Envirojet, six times during the season and top-dressed, also six times, giving a total of 6.3 kg sand per m^2.

Weather data and irrigation

Table 3 shows recordings from Ballerud GC's weather station. Although the rainfall in 2007 was higher than usual, there were periods, especially in May, June and August when the green trials needed irrigation. The fairway and rough trials were never irrigated.

Table 9. Weather recordings and irrigation at Ballerud GC, 2007. Monthly temperatures are means of daily maximum and minimum temperatures.

	Mean monthly temperature, °C	Monthly rainfall, mm	Monthly irrigation, mm (greens only)
May	11.2	94	42
June	17.1	185	52
July	16.9	173	10
Aug.	16.6	83	47
Sep.	11.1	71	21
Mean / sum	14.6	606	172

3.5. Demonstration trial with Primo MAXX® at Oslo Golf Club, Bogstad, Norway

To evaluate the effect of Primo MAXX® on a typical annual meadowgrass green, an unreplicated demonstation trial with plot size 250 m^2 was laid out at Oslo GK on 20 June 2007. Primo MAXX® was sprayed at a rate 0.4 l/ha on 20 June, 10 July and 31 July using the same sprayer as at Ballerud GC, about 10 km from Bogstad (Photo 4). Turfgrass quality (general appearance) and fresh weight clipping yields were determined on 4 July, 13 July and 14 August. Unfortunately, the trial had to be discontinued in mid August due to reconstruction of the green.

3.6. 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 on each plot and on plot values which had been averaged, either over the whole growing season, separately over the spring (before 10 June), summer (10 June – 1 Sep.) and autumn (after 1 Sep.) periods, or for observations conducted two versus four weeks after the last application of Primo MAXX®. The significance levels P%<0.1, P%<1, P%<5 and ns (not significant) have been indicated in the tables along with LSD values for effects significant at P%<5. In a few cases exact P-values have been given for tendencies in the 5-15% probability range. As an indications of the variability for each character, coeffcients of variation, (CV %), have also been given in the tables.

4. Results

4.1. Evaluation of Primo MAXX® under fairway conditions, Bioforsk Landvik, Norway

Turfgrass quality and related characteristics

Table 10 shows results from the visual observations of turfgrass quality and related characters in the fairway trial at Landvik. Both within the three seasons and as a mean value, turfgrass general appearance was significantly lower on plots receiving monthly applications of Primo MAXX® at 1.0 l/ha or higher rates than on unsprayed control plots and plots receiving 0.5 l/ha. Within these two groups, differences in generall appearance were not significant. Separate analyses for blocks 1 and 2 versus 3 and 4 indicated that these responses were practically identical regardless of botanical composition (data not shown).

Individual registrations of turfgrass quality are further depicted in Fig. 1. There was a dramatic decline in quality after the first application on 9 May. After this the turf recovered and there was no significant effect of Primo MAXX® at the two subsequent evaluations. Applications of 1.0 l/ha or higher rates on 4 July lead to new quality reductions in July, August and September (Photo 5); these effects were especially apparent at the last evaluation in early November (Photo 6). By contrast, there tended to be a small quality improvement due to the lowest rate of Primo MAXX® from late August to October. This improvement was reflected also in a significant increase in tiller density on average for the whole growing season (Table 10).

Increasing rates of Primo MAXX® consistently led to darker turf throughout the growing season, but also to earlier growth cessation and a less attractive dormancy colour in late autumn (Table 10). The only visible disease in the trial was a slight attack of red thread (*Laetisaria fuciformis*) during the wet period in July; however, these spots were unaffected by Primo MAXX® which also had no effect on the occurrence of broadleaved weeds, primarily white clover, in the trial.

Table 10. Turfgrass quality, tiller density, within-season colour, dormancy colour and infestation of weeds and red thread (*Laetisaria fuciformis*) in fairway at Landvik as affected by increasing rates of Primo MAXX®, 2007. Visual merit and tiller density are means of twelve observations (two in spring, i.e. before 10 June, six in summer, i.e. from 10 June to 1 Sep., and four in autumn, i.e. after 1 Sep. Within season colour (green darkness) and occurrence weeds and red thread are means of twelve, three (all in July) and two (June and Nov.) observations, respectively. Dormancy colour was evaluated on 2 Nov. All values are means of four blocks.

Primo MAXX®, rate	Turf quality (general appearance, 1-9)				Tiller density (1-9)	Within season colour (1-9)	Dor-mancy colour (1-9)	% of plot area	
	Mean	Spring	Summer	Autumn				Dicot weeds	Red thread
0 = Control	6.2	6.1	6.4	6.0	6.3	5.2	6.8	4	4
0.5 l/ha	6.1	5.6	6.3	6.2	6.5	5.6	6.3	2	3
1.0 l/ha	5.5	4.5	5.9	5.3	6.1	5.8	5.0	5	2
1.5 l/ha	5.3	4.6	5.5	5.4	6.0	5.9	4.1	4	3
2.0 l/ha	5.5	4.6	5.9	5.3	6.1	6.0	4.3	3	2
3.0 l/ha	5.1	4.2	5.5	4.9	6.0	6.2	3.5	4	3
P%	<0.1	<0.1	<1	<0.1	<1	<1	<0.1	ns	ns
LSD 5%	0.3	0.5	0.4	0.4	0.2	0.4	1.2	-	-
CV%	4	7	5	5	3	5	15	-	-

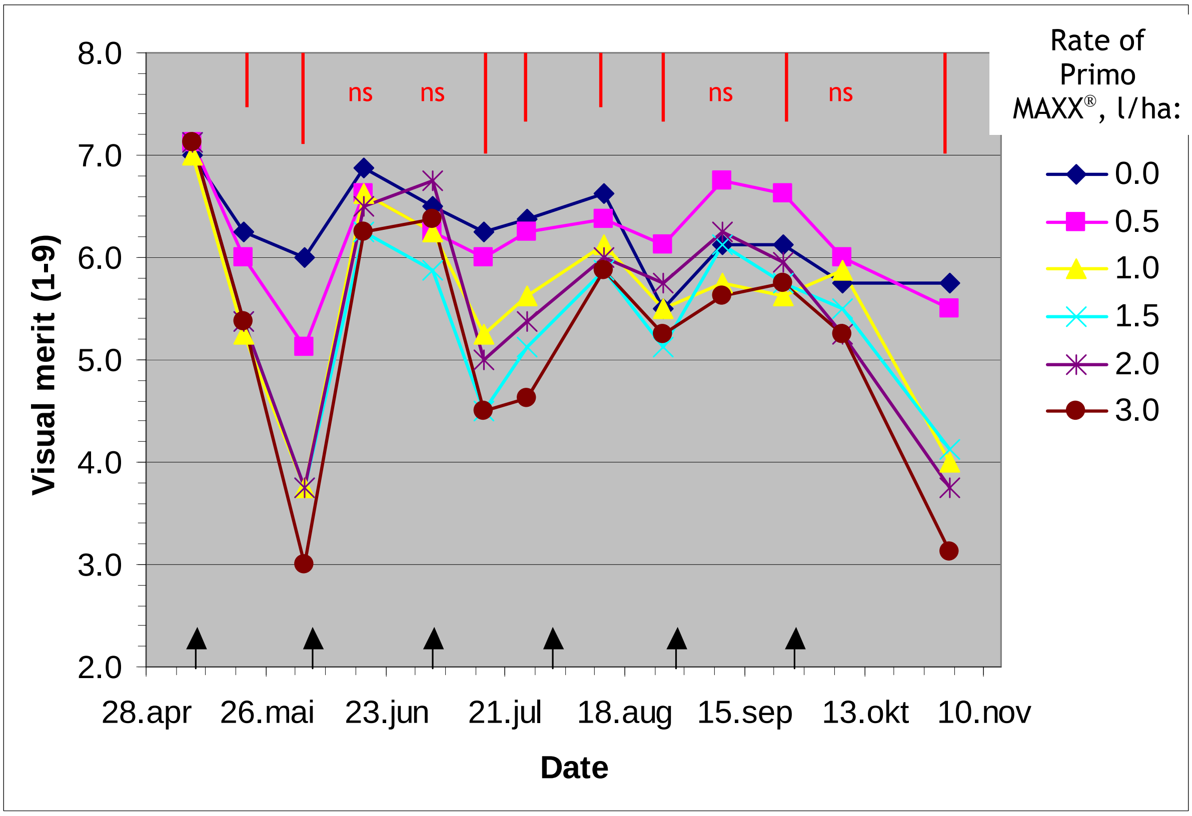


Fig.1. Turfgrass overall quality as affected by increasing rates of Primo MAXX® in fairway trial at Landvik, 2007. Mean of four replicates (blocks). The application dates 9 May, 5 June, 4 July, 31 July, 28 Aug. and 26. Sep. are indicated by black arrows. Red bars indicate LSD 5%.

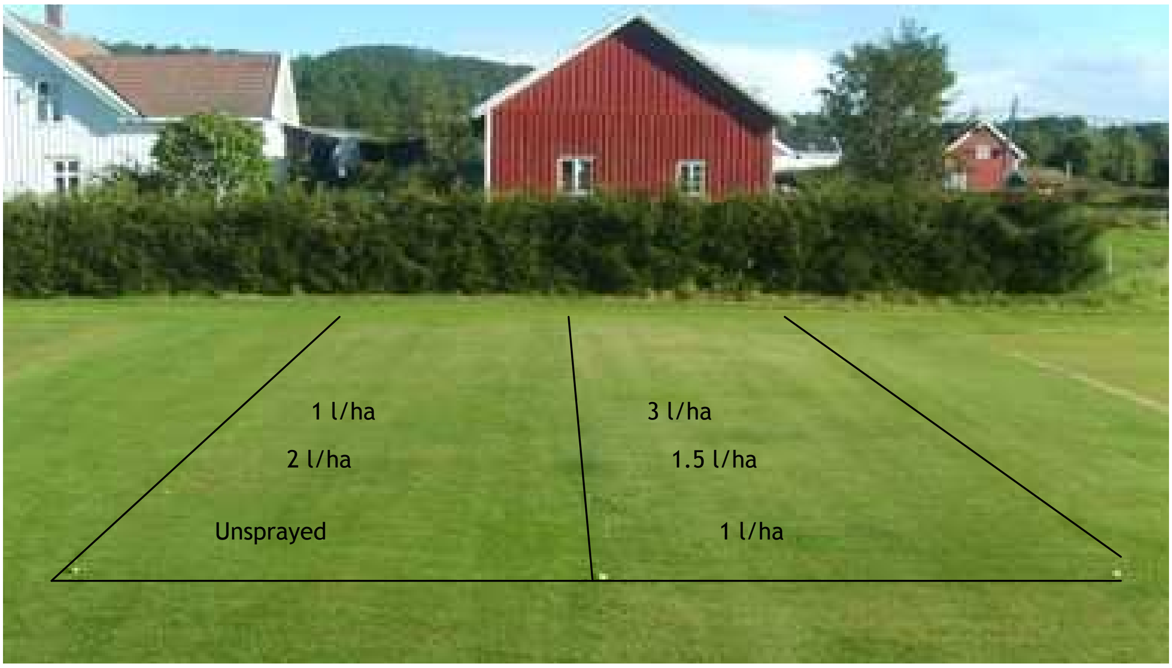


Photo 5. Visual appearance of fairway trial at Landvik, block 1 and 2, on 10 Sept. Within each block, the treatments closest to the photographer have been labeled. High rates of Primo MAXX® resulted in darker, in some cases, almost brown, turf. Photo: Trygve S. Aamlid.

Photo 6.

Turf quality / dormancy colour at growth cessation on 2 Nov. 2007 after application of Primo Maxx at 3.0 l/ha (left) and 0.5 l/ha (right), last application on 26 Sep.

Photo: Trygve S. Aamlid.

Turfgrass height and dry matter production

The average effect of Primo MAXX® on plant height and clipping yields are given in Table 11. In all blocks, the growth regulator caused a significant reduction in plant height even at the lowest rate, but contrary to expectation, this low rate also tended to increase aboveground dry matter production as compared with the unsprayed control treatment. This might reflect a higher tiller density, as also suggested in Table 10. Separate analyses for various parts of trial showed that the average reduction in clipping yield due to Primo MAXX® was stronger in blocks 1 & 2 which had more *Poa* species less red fescue and browntop bent and than blocks 3 & 4. On average for eleven harvests and all replicates, there was a slight tendency for Primo MAXX® to increase the dry matter percentage of turfgrass clippings (P% = 16, Table 11).

Table 11. Absolute and relative effects of increasing rates of Primo MAXX® on turfgrass height, turfgrass dry matter production, and per cent dry matter of clippings in fairway trial at Landvik, 2007. Mean of eleven observations. Plant height above 15 mm represents an average of four days' growth.

Primo MAXX, rate	Plant height, mm		Production of turfgrass clippings, g/m^2/day				% dry matter in clippings
	mm	Rel.	Block 1&2	Block 3&4	Mean	Rel.	
0 = Control	21.9	100	1.78	1.62	1.70	100	31.5
0.5 l/ha	20.9	95	1.91	1.93	1.92	113	32.2
1.0 l/ha	20.7	95	1.65	1.72	1.69	99	32.5
1.5 l/ha	20.0	91	1.46	1.46	1.46	86	33.6
2.0 l/ha	20.3	93	1.55	1.61	1.58	93	32.4
3.0 l/ha	19.5	89	1.31	1.70	1.51	88	33.1
P%.	<0.1	-	10	ns	<5	-	16
LSD 5%	0.7	-	-	-	0.29	-	-
CV%	2	-	10	14	12	-	3

In absolute terms, turfgrass clipping yield showed a distinct seasonal pattern with peaks during the warm and sunny periods in early June and late August (Fig. 2a). The low clipping yield on 17 July was probably due to 280 mm rainfall, and thus nutrient leaching, since the last fertilizer application on 12 June (Tables 3 and 4). Separate analyses of variance for each day indicated a significant effect of Primo MAXX® on clipping yield only on 4 June.

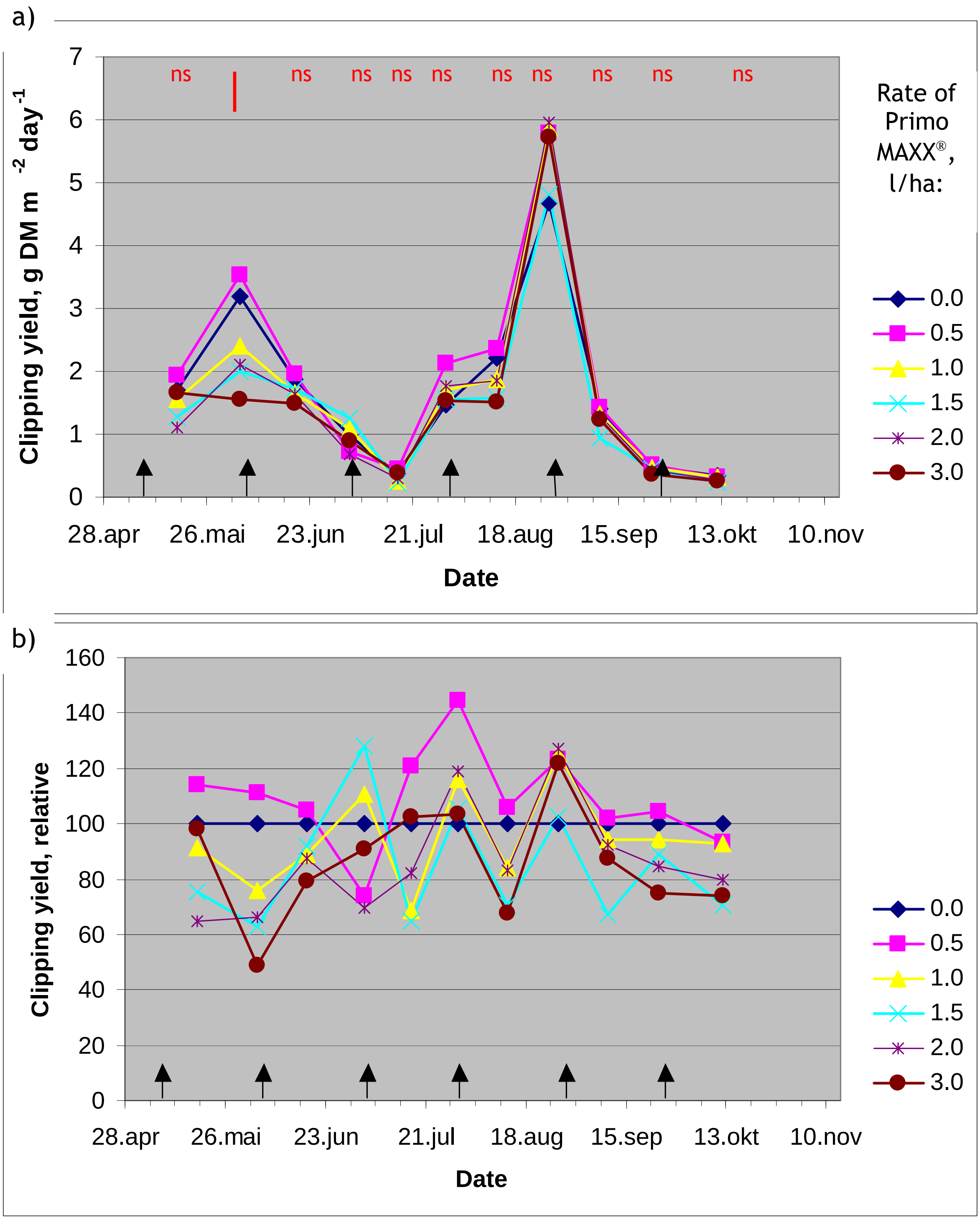


Fig. 2. Absolute (a) and relative (b) reductions in daily dry matter production of turfgrass clippings as affected by increasing rates of Primo MAXX® in fairway trial at Landvik. Red text/bars and black arrows indicate probability / LSD values and application dates 9 May, 5 June, 4 July, 31 July, 28 Aug. and 26 Sep., respectively. In (b), the clipping yield on each date was set to 100 in the unsprayed control treatment.

In relative terms, none of the Primo MAXX® treatments produced clipping yields that were lower than the unsprayed control at all harvests (Fig. 2b). Many of the treatments showed a typical suppression / rebound pattern with clipping yields lower than the control treatment at one harvest, but higher than control treatment at the next harvest.

4.2. Evaluation of Primo MAXX® on a golf course fairway, Lepaa, Finland

On average for two observations in spring, five observations in summer and two observations in autumn, Primo MAXX® had no effect on turfgrass general appearance in the fairway trial at Lepaa. Among the nine observation dates, significant differences were recorded only on 21 August when the plots sprayed with the highest dose (3.0 l/ha) had an average visual merit score of 5.5 as opposed to 6.8 for unsprayed control plots and plots sprayed with the lowest dose (0.5 l/ha).

On average for observations, increasing rates of Primo Max caused an overall increase in tiller density, while turfgrass colour was not significantly affected. No diseases were observed during the growing season.

Table 12. Turfgrass quality (1-9, 9 is best quality), tiller density (1-9, 9 is highest density) and within-season colour (1-9, 9 is darkest green) in fairway trial at Lepaa as affected by increasing rates of Primo MAXX®. Means of nine observations (two in spring, i.e. before 10 June, five in summer, i.e. from 10 June to 1 Sep., and two in autumn, i.e. after 1 Sep.). All values are means of four blocks.

Primo MAXX®, rate	Turf quality (general appearance, 1-9)				Tiller density (1-9)	Within season colour (1-9)
	Mean	Spring	Summer	Autumn		
0 = Control	6.1	5.5	6.1	6.8	5.5	6.1
0.5 l/ha	6.2	5.5	6.1	7.0	5.8	6.2
1.0 l/ha	6.1	5.4	6.1	6.9	5.8	6.1
1.5 l/ha	6.2	5.5	6.2	7.0	6.0	6.3
2.0 l/ha	6.2	5.6	6.1	6.9	6.1	6.3
3.0 l/ha	6.2	5.6	6.1	7.0	6.4	6.2
P%	ns	ns	ns	ns	<0.1	ns
LSD 5%	-	-	-	-	0.4	-
CV%	5	4	8	3	3	4

The effect of Primo MAXX® on turfgrass plant height and clipping yield depended on the time since last application. On average for five observations conducted about two weeks after application, the highest rate of Primo MAXX® caused significant reductions in plant height and clipping yield corresponding to 11 and 48 %, respectively (Table 13). On average for four observations conducted four weeks after application, the maximal reductions were only 3 and 14 %, respectively. Fig. 3 illustrates the unstable effect of Primo MAXX®, particularly toward the end of the growing season. However, unlike in the fairway trial at Landvik (Fig.2), clipping yields on sprayed plots were rarely higher than on untreated control plots in the trial at Lepaa.

Table 13. Absolute and relative effects of increasing rates of Primo MAXX® on turfgrass height and dry matter production in turfgrass clippings in fairway trial at Lepaa 2007. Observations conducted 2 weeks (5 observations) and 4 weeks (4 observations) from spraying treatment have been presented separately.

Treatment	Plant height (mm)				Weight of clippings (g DM / m^2 / day)			
Time after treatment	2 weeks	4 weeks	Mean	Rel	2 weeks	4 weeks	Mean	Rel
0 = Control	15.7	16.0	15.8	100	3.2	7.0	4.9	100
0.5 l/ha	15.7	16.0	15.8	100	2.7	6.3	4.3	87
1.0 l/ha	14.9	16.0	15.4	97	2.8	6.6	4.5	92
1.5 l/ha	14.7	15.7	15.1	96	2.3	5.8	3.9	79
2.0 l/ha	14.4	15.6	15.0	95	2.1	6.1	3.9	80
3.0 l/ha	14.0	15.5	14.6	92	1.8	6.0	3.7	75
P%	<0.1	ns	<5	-	<0.1	ns	ns	-
LSD 5%	1.1	-	1.0	-	0.7	-	-	-
CV%	3	4	3	-	13	22	18	

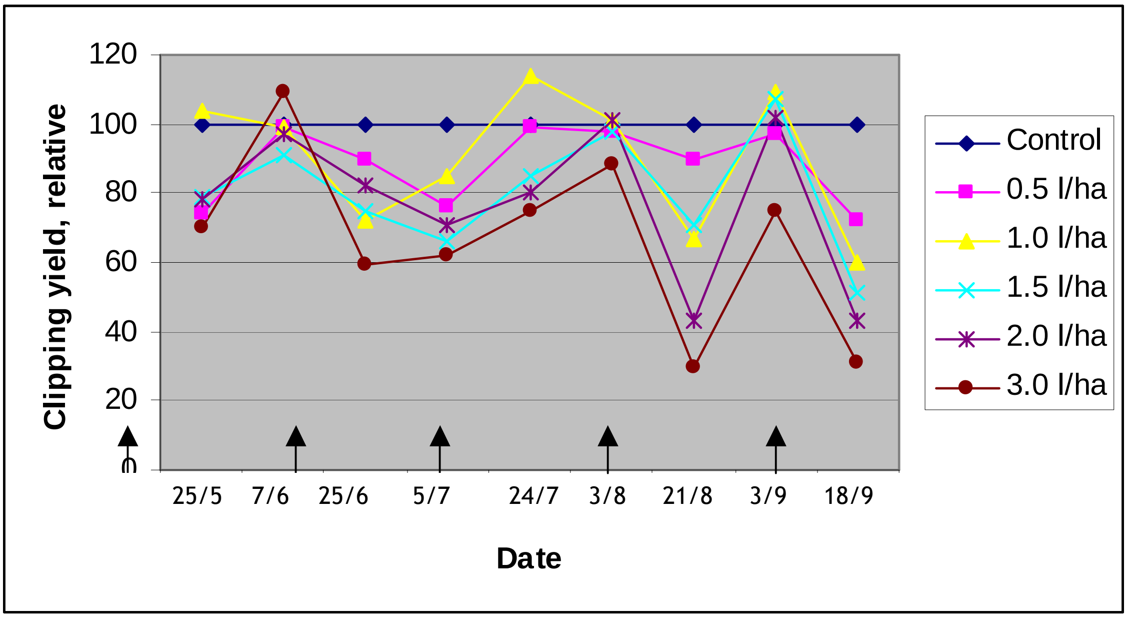


Fig. 3. Relative clipping weights (control = 100) in fairway trial at Lepaa, Finland. Spraying treatments indicated by black arrows were carried out on 11 May, 8 June, 5 July, 3 Aug. and 4 Sep. (The last spraying on 4 Oct. was done primarily to study the effect of Primo MAXX® on overwintering and was not followed by observations in late autumn.)

4.3. Evaluation of Primo MAXX® on a golf course putting green, Lepaa, Finland

On 3 Sep. 2007, a significantly higher tiller density was recorded on green plots sprayed with the highest rate of Primo MAXX® than on unsprayed control plots (data not shown). Otherwise, Primo MAXX® had no significant effect on either general appearance, tiller density or turfgrass colour in the green trial at Lepaa (Table 14). Although the effects on plant height and clipping yields were also not significant, reductions were generally stronger when recorded at two compared with four weeks after application (Table 15, Fig. 4).

Table 14. Turfgrass quality, tiller density and within-season colour (darkness) in green trial at Lepaa as affected by increasing rates of Primo MAXX®, 2007. Means of nine observations (two in spring, i.e. before 10 June, five in summer, i.e. from 10 June to 1 Sep., and two in autumn, i.e. after 1 Sep.). All values are means of four blocks.

Primo MAXX®, rate	Turf quality (general appearance, 1-9)				Tiller density (1-9)	Within season colour (1-9)
	Mean	Spring	Summer	Autumn		
0 = Control	6.4	6.1	6.6	6.3	6.3	6.4
0.2 l/ha	6.3	6.0	6.5	6.0	6.3	6.4
0.4 l/ha	6.3	5.9	6.5	6.1	6.2	6.3
0.6 l/ha	6.3	5.8	6.5	6.4	6.3	6.4
0.8 l/ha	6.2	5.8	6.4	6.3	6.2	6.4
P%	ns	ns	ns	ns	ns	ns
LSD 5%	-	-	-	-	-	-
CV%	3	5	5	7	2	3

Table 15. Absolute and relative effects of increasing rates of Primo MAXX® on turfgrass height and dry matter production in turfgrass clippings in green trial at Lepaa 2007. Observations conducted 2 weeks (5 observations) and 4 weeks (4 observations) from spraying treatment have been presented separately. Plant heights above 3 mm represent one day's growth.

Treatment	Plant height (mm)				Weight of clippings (g DM / m^2 / day)			
Time after treatment	2 weeks	4 weeks	Mean	Rel	2 weeks	4 weeks	Mean	Rel
0 = Control	4.3	3.9	4.1	100	2.60	2.21	2.43	100
0.2 l/ha	4.1	3.8	4.0	96	2.20	2.28	2.23	92
0.4 l/ha	4.0	3.9	3.9	95	1.88	2.28	2.06	85
0.6 l/ha	4.0	3.8	3.9	94	1.72	2.18	1.99	82
0.8 l/ha	3.8	3.9	3.9	93	1.75	2.28	1.92	79
P%	11	ns	ns	-	5	ns	ns	-
LSD 5%	-	-	-	-	0.9	-	-	-
CV%	6	7	8	-	20	14	16	-

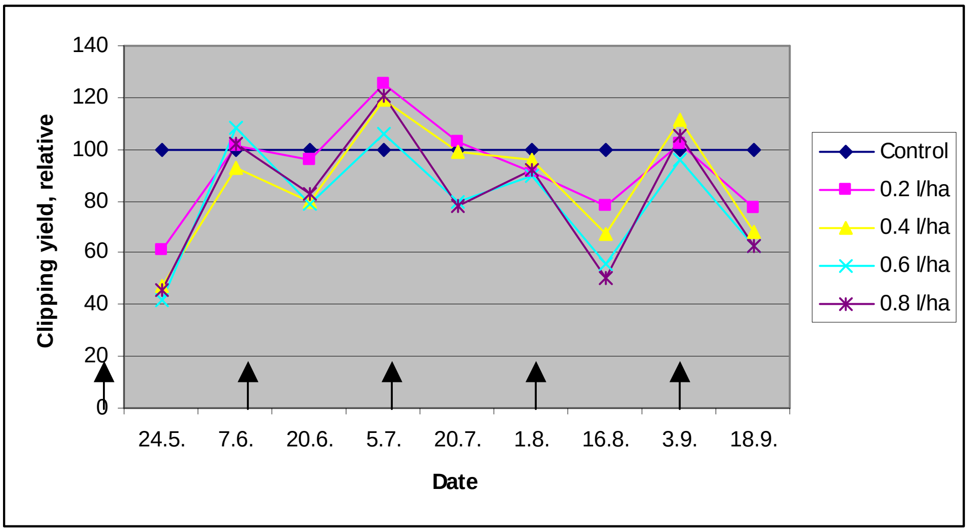


Fig. 4. Relative clipping weights (control = 100) in green trial at Lepaa, Finland. Spraying treatments indicated by black arrows were carried out on 11 May, 8 June, 5 July, 3 Aug. and 4 Sep. (The last spraying on 4 Oct. was done primarily to study the effect of Primo MAXX® on overwintering and was not followed by observations in late autumn.)

4.4. Demonstration trials with Primo MAXX® at Ballerud Golf Course, Oslo, Norway

Green trials

Applications of 0.4 l/ha Primo MAXX® on 5 and 18 June did not affect turf general appearance (Photo 7) or stimpmeter readings on green no. 9 at Ballerud. During the period 14-29 June, clippings were reduced by an average of 32%, but after spraying had been discontinued, there was a rebound effect corresponding to a 26 % increase in clipping yield in the period 12-25 July (data not shown).

Photo 7. Terje Haugen (left) and Lasse Augustsson on green no. 9 at Ballerud Golf Course, 27 June 2007. Photo: Trygve S. Aamlid.

Photo 8. Field day at Ballerud Golf Course 27 Aug. 2007. Photo: Tatsiana Espevig.

Fig. 5 summarizes results from the nursery green trial established on 9 July. In this trial, application of Primo MAXX® about every third week resulted in better colour (not shown), higher green speed (Fig. 5a), and an average reduction in turfgrass clippings of 44 % (Fig. 5b and c). Fig 5b shows that the reduction in clipping yield was most conspicuous during the periods of rapid growth in mid to late July (after only one application of Primo MAXX®) and in late August.

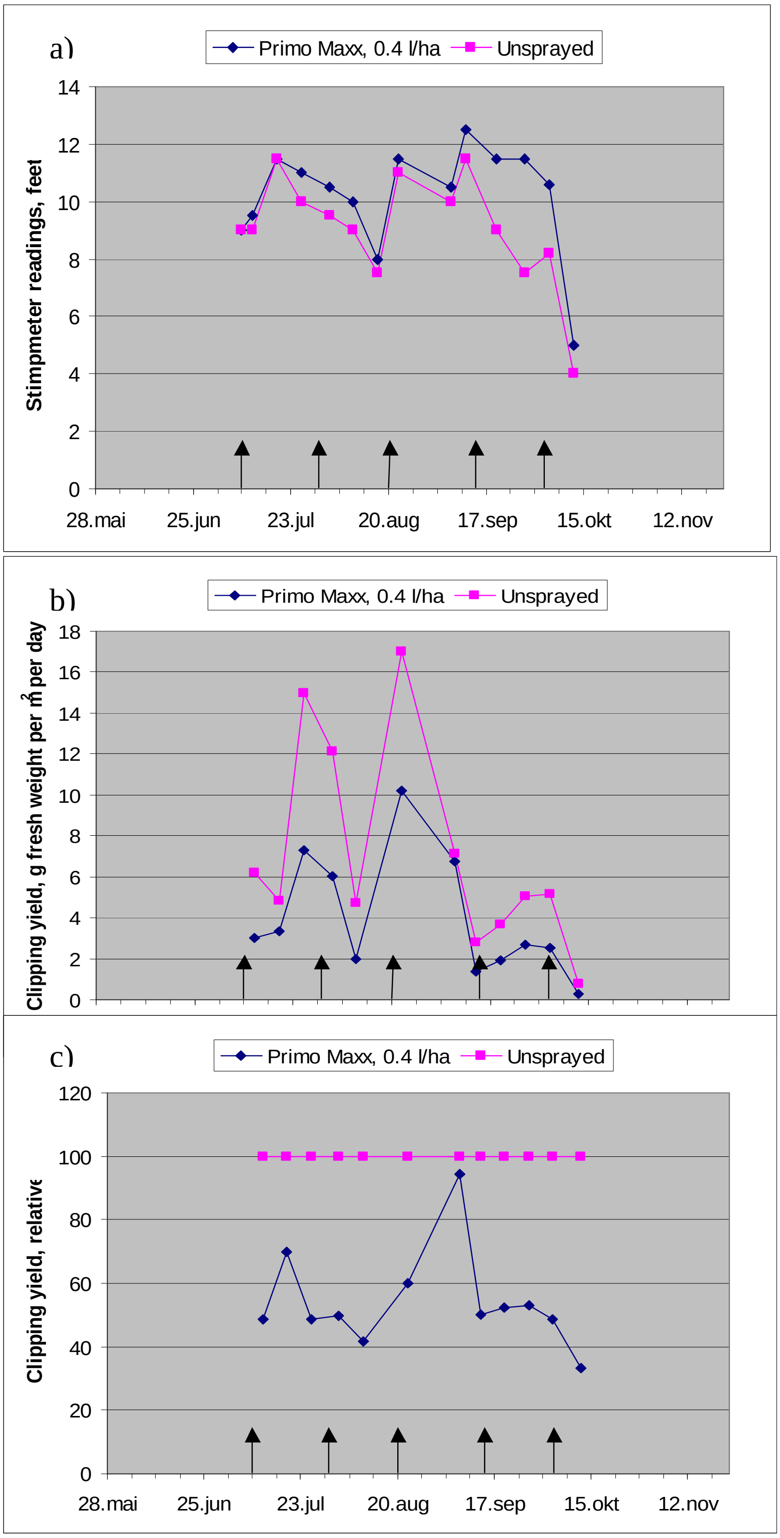


Fig. 5. Effects of spraying Primo MAXX® every three weeks of green speed and absolute and relative clipping yield on nursery green at Ballerud GC, 2007. Black arrows indicate the application dates 9 July, 31 July, 21 Aug., 13 Sep. and 4 Oct.

<u>Fairway trial</u>

As evaluated by the headgreenkeeper, monthly applications of 1.5 l/ha Primo MAXX® (1.5 l/ha) had no negative impact on turf quality in the fairway trial at Ballerud (Fig. 6). Photos 9-11 show, nevertheless, that treated turf was more faded, grayish, and less green than untreated turf. The pronounced colour difference in favour of Primo MAXX® in early September (Fig. 6) was due to less dry spots than the in the control area. While these spots recovered after rainfall on 10 and 17 Sep., the last application of Primo MAXX® on 4 Oct. led to an apparent loss of colour and drop in turf general appearance in late autumn (Photo 11).

On average for 17 clipping, regular application of Primo MAXX® resulted in a 37 % reduction in the fresh weight of turfgrass clippings (Fig. 7). The only time clipping yield was higher on the treated than on the untreated area was at the first clipping nine days after the first application and on 7 Sep. The latter coincided with the observation of less dry spots after use of Primo MAXX®. It may also be interpreted as a rebound effect following growth suppression after application on 31 July.

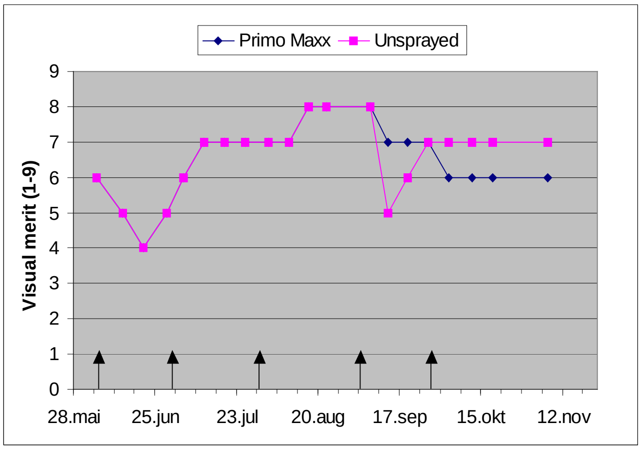


Fig. 6. Effect of Primo MAXX® on turfgrass general appearance in fairway trial at Ballerud GC. Black arrows indicate application dates. (Sprayed an unsprayed plots had identical scores until the beginning of September)

Photo 9. Difference in colour and general appearance of treated and untreated fairway Ballerud GC, 27 June. Photo: Trygve S. Aamlid.

Photo 10. Difference in colour and general appearance of treated and untreated fairway Ballerud GC, 27 Aug. Photo: Tatsiana Espevig.

Photo 11. Difference in colour and general appearance of treated and untreated fairway Ballerud GC, 3 Dec. Photo: Terje Haugen.

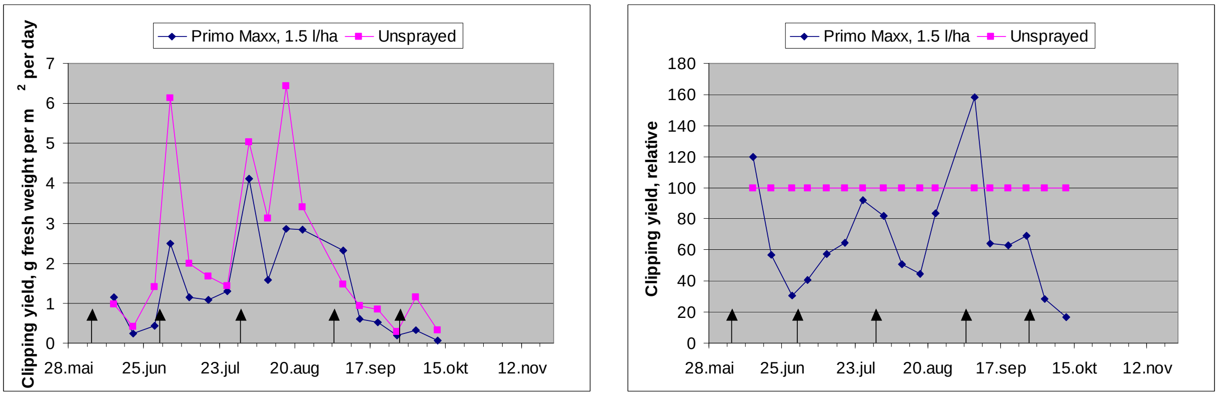


Fig. 7. Absolute (a) and relative (b) reductions in clipping yield resulting form application of Primo MAXX® in fairway trial at Ballerud GC. Arrows indicate application dates.

Spraying 2.2 l/ha of Primo MAXX® at six weeks interval resulted in discoloration and consistent drop in turf quality in the rough trial at Ballerud (Fig. 8, Photos 12 and 13). The effect was most conspicuous in late autumn. Primo MAXX® had less effect on tufts of perennial ryegrass which stood out very markedly in the turf which was otherwise dominated by smooth meadowgrass. Clipping yields were not recorded in this trial.

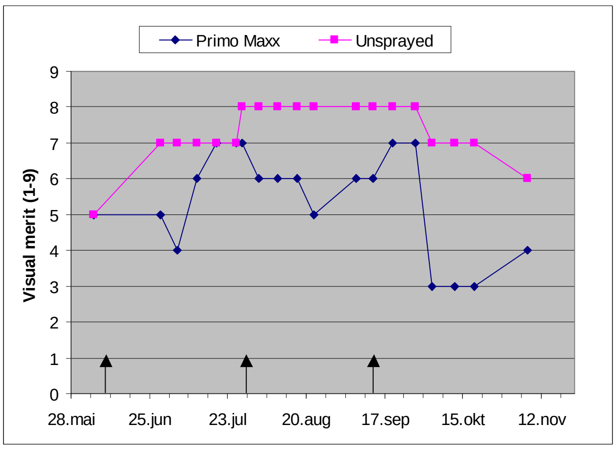


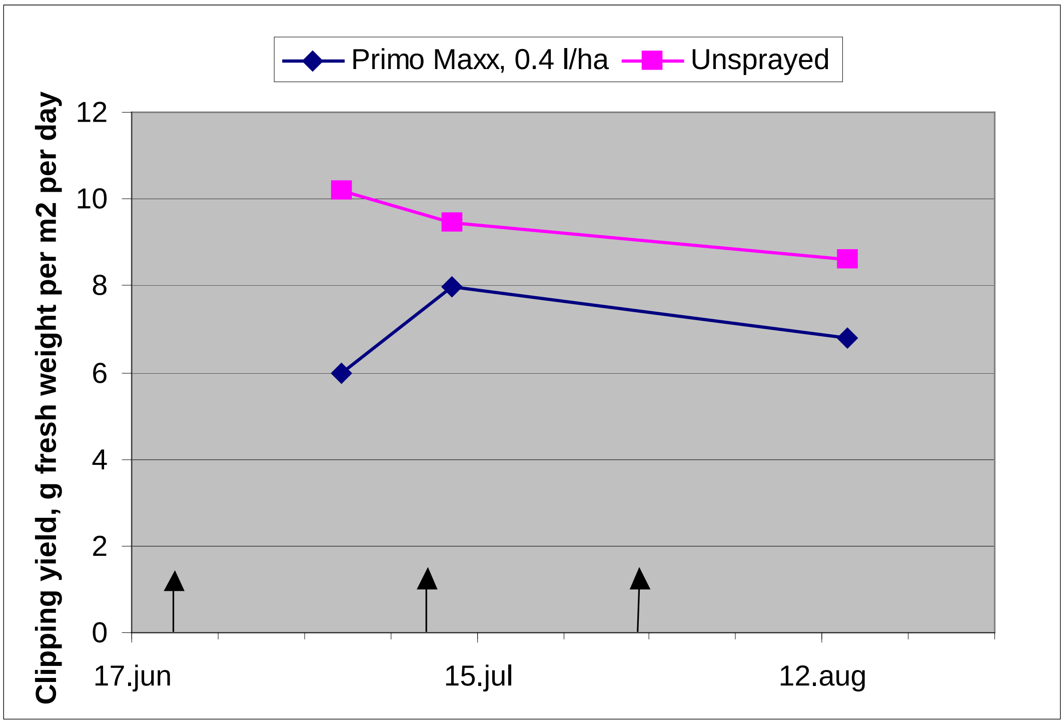
Fig. 8 (upper left). Difference in colour and general appearance of treated and untreated area in rough no 9, Ballerud, 27 June. Photo: Trygve S. Aamlid.

Photo 12 (upper right). Terje Haugen (left) and Lasse Augustsson in rough trial at Ballerud GC, 27 June. Photo: Trygve S. Aamlid.

Photo 13 (lower left). Trygve S. Aamlid inspecting rough trial at Ballerud GC, 27 August 2007. Tufts of ryegrass stand out very markedly on sprayed area.
Photo: Tatsiana Espevig.

4.5. Demonstration trial with Primo MAXX® at Oslo Golf Club, Bogstad, Norway

Application of 0.4 l Primo MAXX® at three week intervals resulted in darker turf but had otherwise no effect on the turfgrass quality of annual meadowgrass at Oslo GC. On average for three registrations, the Primo MAXX led to a 26% reduction in clipping yields (Fig. 9).



5. Discussion and suggestions for 2008

The starting point for evaluating Primo MAXX® in this two-year project was the rates and applications frequencies recommended for the product in Europe (Syngenta 2007, Table 16). Based on our experiences from agricultural crops that the optimal rates may be different in the Nordic countries than countries further south, higher and lower rates were included in the GEP trials both to determine the potential growth inhibition and the risk for discoloration or other phytotoxic effects. All taken together, the results from the first project year confirms that the guidelines in Table 16 are not directly applicable in Scandinavia and that further research is needed to find the optimal way of using the product under Nordic conditions.

Table 16. Dose rates and applications frequencies recommended for Primo MAXX® in the United Kingdom (Syngenta 2007).

	Dose rate		Application frequency
	Primo MAXX®, l/ha	trinexapac-ethyl, g a.i./ha	
Fairways	0.8 – 1.6	90 - 180	Every four to five weeks
Roughs & semi-roughs	1.6-2.4	180 - 240	Every five to eight weeks
Greens	0.4	45	Every two to four weeks

On fairway, the average reduction in clipping yield caused by monthly application of the intermediate Primo MAXX® rate of 1.5 l/ha was 15 and 21 % in the GEP trials at Landvik and Lepaa, respectively. By contrast, monthly application of 1.5 l/ha resulted in a 37 % reduction in clipping yield in the demonstration trial at Ballerud GC, which is closer to the data presented by Syngenta (2007). In agreement with Table 11 showing an increase in turfgrass dry matter percentage (i.e. decreased succulence) after application of Primo MAXX®, one of the reasons for this difference might be that clipping yields were determined on a dry weight basis in the GEP trials but on a fresh weight basis at Ballerud GC and in the data presented by Syngenta (2007). Another, and probably more important explanation, is the difference in species composition among the three trials. While the plant cover at Ballerud was almost 100% by annual meadowgrass, the species composition at Landvik varied with the two blocks showing the least response to Primo MAXX® having a plant cover of 74 % red fescue (Tables 1 and 11). By contrast, smooth meadowgrass dominated over red fescue at Lepaa due to the heavy soil type, use of irrigation, and relatively high nitrogen input. Unfortunately, we have not been able to find many references about the specific effects of Primo MAXX® on red fescue turf, but our results are in partial agreement with Pannacol et al. (2004) who found 40 %, 21 %, and no significant reduction in clipping yield after using trinexapac-ethyl in smooth meadowgrass, chewing fescue and creeping red fescue, respectively.

Perhaps the most conspicuous feature of the present results was the unstable effect of Primo MAXX® on clipping yields due to the postsuppression rebound effect. In the fairway trial at Lepaa, Finland, this resulted in clipping yield reductions being significant only two weeks after application (Table 13), and a similar tendency could be seen also in the green trial (Table 15). In Norway, clipping yields four weeks after spraying were often higher than on unsprayed control plots in the fairway trial at Landvik (Fig. 2), and a strong rebound effect was observed also after spraying treatments had to discontinued at green no. 9, Ballerud GC. The unstable effect in of Primo MAXX® in these trials was probably due to a rapid degradation of trinexapac-ethyl in plant tissue and a higher regrowth potential due to accumulation of carbohydrate reserves and GA_1 precursors during the suppression phase (Lickfeldt et

al. 2001, Branham & Beasley 2007). In North-American experiments, Lickfeldt et al. (2001) reported clipping yields reductions in smooth meadowgrass to be much more consistent when trinexapac-ethyl was applied at four than at six week intervals, but under Nordic long-day conditions, spraying every second, or at least every third week, may well be necessary to stabilize low GA_1 levels, not only on greens, but also on fairways and tees. Although there was a surge effect during the driest period in mid September, the most stable clipping reductions in our trials, on average 44 % on a fresh weight basis, were, indeed, obtained on the nursery green which was sprayed about every third week at Ballerud GC (Fig. 5c). While Branham & Beasley (2007) noted that temperature was the most important factor determining degradation of trinexapac-ethyl in turfgrass tissue, our results suggest that other factors such as light and water availability may also be important for the rebound effect under Nordic conditions. Very clearly, application frequency is a major question that has to be addressed during the continuation of this project.

The potential reductions in mowing costs from using a plant growth regulator will always have to be weighed against the risks for discoloration or other harmful effects on turf quality. In the present trials, reductions in general appearance (visual merit) scores were far more conspicuous in the GEP trial at Landvik than in the GEP trials at Lepaa or the demonstration trials at Ballerud GC. Apart from possible effects of different botanical compositions, this might reflect a subjective human factor, i.e. different backgrounds and attitudes of the observers in the various trials. While the fairway trial at Landvik was evaluated by turfgrass scientists and technicians with long experience from turfgrass variety testing, the trials at Lepaa and Ballerud were evaluated by greenkeepers working on the course. While the observers at Landvik may have paid more attention to turf aesthetic values such as less intense colour, and less vigorous and uniform plots, the observers at Lepaa and Ballerud may well have been more attentive to ball roll and other functional characteristics of the playing surface. The less succulent but significantly darker green turf resulting from high Primo MAXX® rates at Landvik are in agreement with other studies showing higher mesophyll cell densities and chlorophyll concentrations resulting from less elongation of leaf cells (Heckman et al. 2001, Ervin & Zhang 2008). As for tiller density, most literature supports the Finnish rather than the Norwegian results; i.e. enhanced tillering after Primo MAXX® application (Branham & Beasley 2007, Ervin & Zhang 2008).

As compared with the unsprayed control treatment, the strongest negative effect of Primo MAXX® on turfgrass general appearance at Landvik was recorded after the first spraying in early June, in mid July and at the last observation in early November. Each of these observations might be explained by suboptimal conditions causing reduced turfgrass growth. From 6 to 15 June there was a dry and warm and period with maximum temperatures in the range 25-30 ºC that obviously reduced turfgras tillering and aesthetic appearance; until mid July exceptional rainfalls starting on 22 June were not compensated by increase nitrogen inputs, and in autumn, the last application of Primo on 26 September was followed by several nights of frost. Although most studies have failed to document significant interactions between nitrogen and trinexapac-ethyl on turfgrass quality (Steinke & Stier 2001, Goss et al. 2002, McCullogh et al. 2006), it seems reasonable to assume that potential negative effects on Primo MAXX® on turfgrass quality will be most pronounced under suboptimal growing conditions. As in the trials at Landvik (Photo 6) and Ballerud (Photo 11), Beam et al. (2002) reported significant discoloration of trinexapac-ethyl-treated smooth meadowgrass following frost in autumn.

Undoubtedly, the most convincing argument for official approval of Primo MAXX® on Nordic golf courses would be a clear documentation that it improves winter survival. Preliminary results with annual meadowgrass suggested that low rates of trinexapac-ethyl prevented winter injury, whereas high rates had opposite effects due to discoloration during the hardening phase in late autumn (Rossi & Buelow 1997). While trinexapac-ethyl has been shown to increase water soluble carbohydrate contents (Goss et al. 2002) and result in faster spring greenup, Ervin & Zhang (2008) recently called for more detailed investigations into the effect of trinexapac-etyl on freezing tolerance as the research to date has provided scarce information on this aspect. Under Nordic conditions, desiccation if growth resumes when soils are still frozen and irrigation not yet operational in spring, or damage due to unstable winters with ice and water covering the turf, sometimes resulting in suffocation, appear to be more

important that direct freezing injury. In this regard, trineexapac-ethyl may well have a positive effect as it reduces mitochondrial respiration (Ervin & Zhang 2008). In 2008, it will therefore be very interesting to study winter injury and spring green-up and recovery in the on-going trials at Landvik, Lepaa and Ballerud which all had their last application of Primo MAXX® in late September or early October.

Even with winter survival and spring observations included, the amount of data presented in this report is too limited to recommend any listing of Primo MAXX® for turf use in the Nordic countries. Therefore, as stated in the contract between Syngenta and Scandinavian Turfgrass and Environment Research Foundation, there is a need for new GEP trials to be started in spring 2008 and followed until registration of winter survival in spring 2009. For this purpose, a new experimental green was constructed and seeded to creeping bentgrass at Landvik in 2007. In the trial to be established on this green in spring 2008, we suggest to compare Primo MAXX® at three rates (0.15, 0.30 and 0.45 l/ha) and two application frequencies (every 10/11 days and every 21 days), i.e. six combinations plus an unsprayed control treatment. As different grass species seem to vary in their response to Primo MAXX®, similar trials should preferably be carried out on also red fescue/browntop greens and velvet bentgrass greens, although this would require additional funding from Syngenta/STERF.

In Finland, a new GEP trial will be established in spring 2008 on a fairway that is regularly subjected to winter injury. New demonstration trials might be added to the project depending on interest from superintendents and funding from the national golf unions.

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

Results from the first evaluation year 2007

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Finnish team spraying fairway trial at Lepaa Golf Course.
Photo: Oiva Niemelainen

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Summary:

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

Sammendrag:

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

Approved

Arne Sæbø	Trygve S. Aamlid
Leader, Bioforsk's Section for Urban Greening	Project leader

Contents

1. Abstract

As an inhibitor of the last step in plant synthesis of bioactive gibberellin (GA_1), the plant growth regulator Primo MAXX® (trinexapac-ethyl) offers prospects of reduced energy use for mowing and improved turfgrass quality under Nordic long day conditions. This report presents first year results from 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 possible registration of Primo MAXX®, unreplicated demonstration trials were carried out at Ballerud and Bogstad Golf Courses in Oslo under supervision of Bioforsk and with funding from the Norwegian Golf Federation (NGF).

GEP trials on **fairways** (mowing height 12-18 mm) were carried out at Bioforsk Landvik, Norway (58°34'N, 8°52'E) and at the Lepaa Unit of the HAMK University of Applied Sciences, Finland (61°08'N, 24°20'E). Primo MAXX® was applied at monthly intervals at rates 0.5, 1.0, 1.5, 2.0 and 3.0 l/ha (56.5, 113, 169.5, 226 and 339 g a.i./ha trinexapac-ethyl) in comparison with an unsprayed control treatment. Turfgrass general appearance, tiller density, colour, height growth, and clipping yields were recorded two and four weeks after each application. Primo MAXX® had no effect on turfgrass general appearance but increased density at Lepaa. At Landvik, Primo MAXX® (>= 1.0 l/ha) reduced turfgrass general appearance and density, but resulted in significantly darker green colour. Quality reductions were most apparent during periods with either daily maximum temperatures >25 °C, extreme rainfall probably causing nitrogen deficiency, or frost at night. Average reductions in clipping yield caused by Primo MAXX® (>= 1.0 l/ha) were 8 % in the GEP trial at Landvik, 18 % in the GEP trial at Lepaa and 37 % in the demonstration trial at Ballerud; to some extent this difference may be due to different botanical composition with red fescue (*Festuca rubra*) and annual meadowgrass (*Poa annua*) being the predominant species at Landvik and Ballerud, respectively. Clipping yield reductions due to Primo MAXX® were unstable, growth suppression two weeks after application often being followed by a rebound effect during the remaining two weeks until next application.

A GEP trial on creeping bentgrass **putting greens** was carried out at Lepaa, Finland, and demonstration trials at Ballerud and Bogstad, Norway. Primo MAXX® was sprayed at rates 0.2, 0.4, 0.6 or 0.8 l/ha at monthly intervals in the GEP trial, and at 0.4 l/ha every three weeks in the demonstration trials. On average for all observations, Primo MAXX® had no effect on turfgrass quality, but clipping yields were reduced by 16, 44 and 26% at Lepaa, Ballerud and Bogstad, respectively. As in the fairway trials, growth suppression at Lepaa was stronger when assessed at two than at four weeks after application. By contrast, Primo MAXX® produced a fairly stable effect when applied at three week intervals in the demonstration trials.

Use of Primo MAXX® on golf course **roughs** was investigated only in a demonstration trial at Ballerud. Application of 2.2 l/ha of Primo MAXX® every seven weeks resulted in discolouration and reduced quality of smooth meadow grass.

In conclusion, the first year of this project has shown that the guidelines for use of Primo MAXX® in other European countries are not directly applicable in Scandinavia. As the present results are too limited to apply for registration of Primo MAXX®, the project will continue in 2008 tentatively with new trials investigating application of Primo MAXX® at lower rates, but higher frequencies. Improved winter stress tolerance would be a convincing argument for registration of Primo MAXX® in the Nordic countries, and the on-going trials will therefore be followed by an assessment of effects of the last Primo MAXX® applications in September or October 2007 on winter survival and spring recovery.

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

2. Introduction

The plant growth regulator trinexapac-ethyl was developed by Syngenta in the 1980s. Since the active ingredient is available in different formulations, the chemical will, in this report, be referred to as Primo MAXX®, which is the product developed by Syngenta specifically for use on turf. Unlike earlier plant growth regulators, Primo MAXX®'s mode of action is highly specific as it blocks the conversion of GA_{20} til GA_1, i.e. the last step in the biosynthesis of gibberellic acid, a plant hormone stimulating cell elongation and thus vertical turf growth.

After its release, Primo MAXX® was rapidly adopted by the US and Canadian turf industries. In North America, there are several independent university studies documenting its positive effects on golf courses, athletic fields, home lawns, and sod production (for a recent review, see Erwin and Zhang 2008). These advantages include reduced leaf elongation and thus reduced mowing costs and energy use, improved tiller production (more lateral growth), darker green colour, and improved resistance to drought and shade.

While other formulations of trinexapac-ethyl have been approved for agricultural use in Europe for about a decade, the experience with Primo MAXX® to European turfgrass areas is relatively limited. During the past three to four years, Primo MAXX® has been approved for turf use in Italy, France and UK, and the evaluation and registration process has been initiated in many other countries.

Being an inhibitor of gibberellin biosynthesis, Primo MAXX® offers special prospects for turfgrass management in the Nordic counties Finland, Sweden, Norway, Iceland, and Denmark. At latitudes ranging form 55 to 71 °N, turfgrasses growing in these countries exposed not only to long photoperiods during most of the growing season, but also to lower photosynthetic flux densities and lower red to farred (R/FR) ratios than in countries further south. The natural turfgrass response to these northern light conditions is to devote more of its resources to shoot elongation (Heide et al. 1985a,b). Since this response is primarily mediated by the gibberellic acid GA_1, any specific growth regulator that controls the biosynthesis of this compound might be useful under Nordic conditions. Nevertheless, our experience from the introduction of trinexapac-ethyl for agricultural use in the Nordic counties suggests that the optimal dose rates and frequencies for application of Primo MAXX® to various types of turf are probably not the same as at lower latitudes. This is also due to different species and cultivars being grown compared with countries further south. Field trials under Nordic conditions are therefore required not only to produce data for the national certification agencies, but also to provide turf managers with recommendations for how to use the product.

This report presents first year preliminary results from a two year project evaluating the use of Primo MAXX® on golf courses in the Nordic countries. The project was funded by Syngenta and the Scandinavian Turfgrass and Environment Research Foundation (STERF) 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' trials needed to provide documentation for possible registrations of Primo MAXX® by the national authorities, a couple of practical demonstration trials were carried out on Norwegian golf courses under supervision from Bioforsk and with funding from the Norwegian Golf Federation (NGF).

3. Methods

3.1. Evaluation of Primo MAXX® under fairway conditions, Bioforsk Landvik, Norway

Experimental site

On 8 May 2007, a field trial was laid out on a fairway established on a sandy loam soil (topsoil: 68 % sand, 27% silt, 5 % clay) at Bioforsk Landvik Research Station (58°34'N, 8°52'E), SE Norway. Soil samples indicated a pH (H_2O) of 5.9, high phosphorus values (P-AL=19) and intermediate to low potassium values (K-AL = 8, K-HNO_3=58). The fairway had been seeded in September 2003 to a mixture of smooth meadowgrass (*Poa pratensis*), chewing fescue (*Festuca rubra* ssp. *commutata*), and browntop bent (*Agrostis capillaris*) (Table 1). Block 1 and 2 were located in one part, and block 3 and 4 in a different part of the fairway. Botanical analyses at the start of experimentation indicated that red fescue was the predominant species in all blocks, but presumably due to slightly less surface drainage, blocks 1 and 2 had a higher percentage of smooth and annual meadowgrass and broadleaved weeds (primarily white clover (*Trifolium repens*)) than blocks 3 and 4 (Table 1).

Table 1. Seed mixture used for fairway establishment in 2003 and botanical composition at the start of the Primo MAXX® trial in spring 2007.

Species	Cultivar	% (w/w) of seed mixture	% cover at initiation of Primo MAXX® trial		
			Block 1 and 2	Block 3 and 4	Mean
Poa pratensis	Conni	25	31	9	20
Poa pratensis	Eva	10			
Poa pratensis	Limousine	10			
Festuca rubra ssp. commutata	Bargreen	25	50	74	62
Festuca rubra ssp. commutata	Calliope	25			
Agrostis capillaris	Tracenta	5	5	15	10
Poa annua			8	2	5
Broadleaved weeds			6	0	3
Sum		100	100	100	100

Experimental plan

The experiment was laid out according to a randomized complete block design with plot size 2m x 3m, four blocks (replicates) and the following treatments:

1. Usprayed control
2. Primo MAXX, 0.5 l/ha (56.5 g a.i./ha) every four weeks
3. Primo MAXX, 1.0 l/ha (113 g a.i./ha) every four weeks
4. Primo MAXX, 1.5 l/ha (169.5 g a.i./ha) every four weeks
5. Primo MAXX, 2.0 l/ha (226 g a.i./ha) every four weeks
6. Primo MAXX, 3.0 l/ha (339 g a.i./ha) every four weeks

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. Actual application rates were recorded by weighing the tank before and after spraying. Table 2 shows actual rates and weather conditions for each spraying event.

Table 2. Weather conditions and actual application rates at the six spraying events.

Application date	Time of day (hours)	Weather conditions at application			Treatment number / application rate (l Primo MAXX® per ha)				
		Air temp. °C	Relative Humidity %	Wind Speed m/s	2. (target 0.5)	3. (target 1.0)	4. (target 1.5)	5. (target 2.0)	6. (target 3.0)
9 May	09-11	14	48	< 1.0	0.47	0.94	1.56	1.90	3.35
5 Jun.	09-11	15	60	< 1.0	0.58	1.06	1.67	1.93	3.19
4 Jul.	13-15	17	70	1.0-2.0	0.61	0.98	1.73	2.19	3.38
31 Jul.	08-10	18	55	1.0-2.0	0.55	1.05	1.66	2.28	3.41
28 Aug.	09-11	19	32	1.0-2.0	0.57	1.03	1.55	2.19	3.52
26 Sep.	09-11	11	69	< 1.0	0.52	1.07	1.55	2.01	3.15
Mean					0.55	1.02	1.62	2.08	3.33

Registrations

At two weeks intervals throughout the experimental period, turfgrass colour, tiller density, and turf general appearance were assessed by turfgrass scientist or technicians using a scale from 1 to 9 where 9 is darkest colour, highest tiller density and best turf quality. The assessments were conducted two and four weeks after application of Primo MAXX®. On the same dates, turfgrass diseases and broadleaf weed (including white clover) invasion were reported as per cent of plot area. Turfgrass height was recorded as the mean of three random measurements with a ordinary ruler in each plot, and the overall growth rate by weighing clippings in the basket of a walk-behind mower used in the 0.56 m x 1.88 m central area of each plot (Photo 1). Both raw weight and dry weight were recorded, the latter after drying for 24 h at 60°C. By the end of the growing season, on 2 Nov., turfgrass dormancy colour was evaluated on a scale 1-9, where 1 is completely faded / brown turf, and 9 is completely green turf.

Photo 1a and b. Tatsiana Espevig collecting clippings in fairway trial at Landvik. Photos: Trygve S. Aamlid

Management

The experiment was mowed at 15 mm two times a week, usually on Monday and Friday. A triplex fairway mower without collection of clippings was used except when clipping weights were to be recorded. Granular fertilizer was applied at approximately monthly intervals as outlined in Table 3. The experiment was not irrigated except for small amounts of water to dissolve fertilizer after application. On 7 Aug., the trial was aerated using a vertidrain with 15 mm solid tines to 15 cm depth. Topdressing was accomplished on 8 Aug. and 5 Nov. at rates 0.75 and 1.5 kg pure sand per m^2, respectively.

The fairway trial at Landvik was not exposed to ordinary play, but it was was subjected to artifical wear from a wear drum one to two times per week.

Table 3. Fertilizer inputs, fairway trial, Landvik.

		Per ha							
Date	Fertilizer type	kg fertilizer	kg N	kg P	kg K	kg Mg	kg S	kg Ca	kg Fe
17 Apr.	Fullgjødsel 22-2-12	40	9	1	5	0	1	0	0
16 May	Fullgjødsel 22-2-12	70	15	1	8	1	2	1	0
12 Jun.	Arena Golf Extra 13-0-15	150	20	0	23	2	21	0	3
23 Jul.	Arena Golf Extra 13-0-15	130	17	0	20	2	18	0	3
9 Aug.	Arena Golf Extra 13-0-15	135	18	0	21	2	18	0	3
5 Sep.	Arena Golf Extra 13-0-15	150	20	0	23	2	21	0	3
SUM			99	2	100	10	80	1	11

Weather data

In SE Norway, the growing season 2007 was characterized by exceptionally high rainfall, especially in July, but also in May, June and August (Table 4). By contrast, September was unusually dry. Precipitation was recorded on 16 out of the 31 days in July; the cloudy summer weather is also reflected by a rather low irradiance during this month. The warmest period, with daily maximum temperatures in the range 23-29 ºC was recorded from 6 to 12 June.

Table 4. Weather data for Landvik meteorological station, about 200 m for experimental field. Normal values for temperature and rainfall are 'official' values for from the period 1961-90, while normal values for irradiance are calculated averages for the period 1994-2006.

	Mean temperature, °C		Precipitation, mm		Irradiance, MJ/m^2 (305-2800 nm)	
	2007	30 yr normal	2007	30 yr normal	2007	13 yr average
May	10.2	10.4	107	82	518	540
June	15.9	14.7	109	71	604	600
July	15.5	16.2	213	92	492	632
Aug.	16.2	15.4	132	113	476	476
Sep.	12.0	11.8	59	136	321	262
Mean / sum	14.0	13.7	620	494	2411	2510

3.2. Evaluation of Primo MAXX® on a golf course fairway, Lepaa, Finland

Experimental site

The Finnish fairway trial was laid out on 11 May 2007. The fairway was seeded to a mixture of smooth meadowgrass and chewing fescue (*Festuca rubra* spp. *commutata*) on a heavy clay soil (15% sand, 37% silt, 48% clay) at the Lepaa Unit of HAMK University of Applied Sciences, Finland (61°08'N, 24°20'E). 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. All observations and management of the trial was carried out by the HAMK Lepaa greenkeepers Petteri Lehmuskoski and Tommi Turunen except for the spraying treatments which were carried out by MTT's 'Good Experimental Practice' certified spraying team from Jokioinen (90 km from Lepaa).

Experimental plan and registrations

The experiment was laid out following the same plan and plot size as at Landvik, Norway (previous paragraph). Primo MAXX® was applied in accordance with the Finnish 'Good Experimental Practise' protocol, using a portable, compressed air-powered 'van der Weij' plot sprayer, mounted with a windshield and flat fan nozzles (Hardi 4110-12) and working at 180-250 kPa pressure. The spraying boom had four nozzles spaced 50 cm apart. The spraying volume corresponded to 200 l/ha. Full spray coverage was on the central 1.5m x 2.5 m of each plot. Table 5 shows application dates and weather conditions for each spraying event. The last application on 4 Oct. was conducted especially to evaluate potential effects of Primo MAXX® on turfgrass winter damage.

Table 5. Application dates and weather conditions in fairway and green trials at Lepaa.

Application date	Time of day (hours)	Air temp. °C	Relative humidity %	Wind Speed m/s	% cloud cover
11 May	09-11	11	29	0	25
8 Jun.	09-11	20	56	1.5	1
5 Jul.	13-15	23	47	2.5	70
3 Aug.	09-11	17	78	2.0	90
4 Sep.	09-11	11	90	1.0	90
4 Oct.	13-15	11	92	1.5	100

Photo 2. Austen Sutton, Syngenta (left) and greenkeeper Petteri Lehmuskoski, HAMK Lepaa Unit, in fairway trial at Lepaa, Finland, 29 Aug. 2007.

Photo: Oiva Niemelainen.

Registrations

Registrations were carried out at two-week intervals following the same program as at Landvik (previous section) except that weed occurrence and dormancy colour were not recorded. Plant height at Lepaa was determined using a Turf Check Prism device (Check Signature Inc., Shoreview, MN).

Management and wear

The experiment was mowed with a triplex fairway mower about three times per week. Mowing height ranged from 12 to 18 mm. Granular fertilizer Sportsmaster 26-2-9 was applied at equal rates on 8 May and 12 July, the total input corresponding to 156 kg N, 12 kg P, 54 kg K and 0.9 kg Fe per ha. Information about irrigation is given in Table 6. The trial was aerated or top-dressed in late autumn, after the completion of registrations.

During the growing season period, the trial was exposed to approximately 3.500 rounds of golf.

Weather data

Temperatures at Lepaa were higher the 30 yr normal values throughout the growing season (Table 6). August had the greatest deviation from the long-term average value. July had 49 % more, and August 42 % less rainfall than usual; over the whole experimental season, rainfall was close to the 30 yr normal value.

Table 6. Weather data for Hattula Lepaa weather station and irrigation in fairway and green trial at Lepaa golf course, 2007. Normal values for temperature and rainfall are official values for from the period 1971-2000 (Finnish Meteorological Institute)

	Mean temperature,°C		Rainfall, mm		Irrigation, mm (2007)	
	2007	30 yr normal	2007	30 yr normal	Fairway trial	Green trial
May	10.6	9.8	30	34	*	*
June	15.1	14.5	54	55	26	79
July	16.6	16.4	119	80	5	47
Aug.	16.4	14.6	43	74	7	50
Sep.	9.9	9.4	58	54	0	6
Mean / sum	13.7	12.4	304	297	37	188

* Data are unavailable for the period 1-26 May 2007 due to change of irrigation computer.

3.3. Evaluation of Primo MAXX® on a golf course putting green, Lepaa, Finland

Experimental site

The Finnish green trial was established on 11 May 2007 on a USGA green seeded to creeping bentgrass (*Agrostis stolonifera*, seed blend of 50% 'Penn A-4' and 50% 'Penn G-6') at Lepaa Golf Course.

Experimental plan

The experimental plan comprised five rates of Primo MAXX plus the unsprayed control treatment:

1. Usprayed control
2. Primo MAXX, 0.2 l/ha (22.6 g a.i./ha) every four weeks
3. Primo MAXX, 0.4 l/ha (45.2 g a.i./ha) every four weeks
4. Primo MAXX, 0.6 l/ha (67.8 g a.i./ha) every four weeks
5. Primo MAXX, 0.8 l/ha (90.4 g a.i./ha) every four weeks

The trial had four replicates, and a gross plot size of 2 m x 3 m. It was sprayed on the same dates and following the same GEP procedures as the fairway trial on the same location (Table 5).

Photo 3. Green trial at Lepaa ready for the first treatment on 11 May 2007. Photo: Oiva Niemelainen.

Registrations

Registrations followed the same program as in the Finnish fairway trial (previous section).

Management and wear

The experiment was mowed with a Triplex greens mower for an average of six times per week. Depending on weather and turfgrass density, mowing height was 5–7 mm in May and September and 3-4 mm from June to August. Information about irrigation and fertilizer inputs are given in Tables 6 and 7, respectively.

To avoid thatch accumulation, the trial was aerated with deep slitting knives every second week and with 8 mm needle tines once a month. Verticutting was accomplished every second week and topdressing with 0.1-0.7 mm finely graded sand at a rate of 1 kg per m2 every third week. The sand was brushed/irrigated into the green and the dressing was never done in close proximity to weighing of clippings.

Being located on a practise green, the experiment received wear from about 10.000 rounds of golf over the season. When placing holes on the green, care was taken to create as uniform wear as possible.

Table 7. Fertilizer inputs in green trial at Lepaa.

		Per ha							
Date	Fertilizer type	kg fertilizer	kg N	kg P	kg K	kg Mg	kg S	kg Ca	kg Fe
28.3.2007	Floratine Kevätstartti*	35	5.4	1.2	2.1				
5.4.2007	Floratine Kevätstartti	35	5.4	1.2	2.1				
19.4.2007	Floratine Kevätstartti	35	5.4	1.2	2.1				
26.4.2007	Sierraform Springstart (16-0-13)	250	40	0	32.5				2.50
15.5.2007	Sierraform All Season (18-3-15)	250	45	7.5	37.5	3.0			1.25
30.5.2007	Kemigreen Basic (23-4-14)	40	9	1.6	5.6	0.6	0.8		0.04
5.6.2007	Kemigreen Basic (23-4-14)	40	9	1.6	5.6	0.6	0.8		0.04
11.6.2007	Sierraform All Season (18-3-15)	250	45	7.5	38				
25.6.2007	Osmosol 614R (19-2-10)	40	7.6	0.8	4.0	0.5		1.7	0.04
2.7.2007	Osmosol 614R (19-2-10)	40	7.6	0.8	4.0	0.5		1.7	0.04
13.7.2007	Kemigreen Summer (18-0-17)	40	7.2	0	6.8			2.0	0.40
18.7.2007	Kemigreen Summer (18-0-17)	40	7.2	0	6.8			2.0	0.40
26.7.2007	Sierraform All Season (18-3-15)	250	45	7.5	37.5	3.0			1.25
14.8.2007	Kemigreen Summer (18-0-17)	40	7.2	0	6.8			2.0	0.40
27.8.2007	Greenmaster Autumn (6-2-8)	300	18	6	24	5.4			1.50
30.8.2007	Kemigreen Basic (23-4-14)	40	9	1.6	5.6	0.6	0.8		0.04
11.9.2007	Sierraform Springstart (16-0-13)	200	32	0	39				2.00
SUM			305	39	260	14.0	2.4	9.4	10

* Floratine Kevätstartti (Springstart) is composed of P-48 (10-21-6.6), Per 4 Max (15-0-0), Protesyn (3.5-0.6-1.8), and Plant Marvel (28-3-15).

3.4. Demonstration trials with Primo MAXX® at Ballerud Golf Course, Oslo, Norway

Experimental site and set-up

Ballerud GC is located on an old horticultural farm in a suburban area SW of Oslo. The course has greens with mostly dominated by creeping bentgrass, fairways almost exclusively dominated by annual meadowgrass, and smooth meadowgrass roughs with some tufts of perennial ryegrass (*Lolium perenne*).

Large-scale, unreplicated demonstration trials were laid out on green no. 9, fairway no. 9 and rough no. 9 on 5 June 2007. Plots sizes varied from 80 to 130 m^2. Unsprayed control plots were compared with plots sprayed with Primo MAXX® at rates 0.4, 1.5 and 2.2 l/ha and application intervals of approximately 3, 4 and 7 weeks on green, fairway and rough, respectively. In compliance with the Norwegian Food Authority's rule for complete closure of all sprayed areas for 48 h after each application, the trial on green no. 9 had to be discontinued after the second application on 18 June.

Three weeks later, it was replaced by a new trial laid out on the golf course' nursery green. Actual application dates in the green, fairway and rough trials are given in Table 8. The growth regulator was applied using a battery-operated electric Hardy Defender plot sprayer (Photo 4).

Table 8. Application dates for Primo MAXX in demonstration trials at Ballerud GC.

Green no. 9	Nursery green	Fairway no. 9	Rough no. 9
5 June		5 June	5 June
18 June			
	9 July	2 July	
	31 July	31 July	28 July
	21 Aug.		
	13. Sep.	3 Sep.	11 Sep.
	4 Oct.	28 Sep.	

Photo 4. Sprayer used in demonstrations trials at Ballerud Golf Course.

Photo: Terje Haugen.

Registrations

In all trials at Ballerud, turfgrass general appearance was evaluated by the headgreenkeeper at one to two week intervals throughout the growing season. In the green and fairway trials, turfgrass clipping yields were recorded on a fresh weight basis. Registrations in the green trials also included regular assessments of green speed using a standard stimpmeter.

Maintenance

The green trials at Ballerud were mowed daily at 3.4-3.8 mm and the fairway trial at 20 mm three to four times a week. The rough area was only mowed upon need.

Due to the rich soil from decades of vegetable production, the rough trial was not fertilized in 2007, and the fairway trial only received one application of 200 kg Fullgjødsel® 11-5-18 (22 kg N/ha) on 8 May. The green trials received monthly applications of granuar fertilizer (Gro Power 5-1-1, Anderson 14-0-9, Anderson 8-0-16, and/or Roots 12-2-12), and weekly applications of liquid fertilizers /

biostimulants, mostly Floratine products. Total rates of N, P, K, Mg, Ca, S and Fe over the season were 155, 14, 142, 27, 30, 73 and 14 kg/ha, respectively. The greens were aerated, mostly using Envirojet, six times during the season and top-dressed, also six times, giving a total of 6.3 kg sand per m^2.

Weather data and irrigation

Table 3 shows recordings from Ballerud GC's weather station. Although the rainfall in 2007 was higher than usual, there were periods, especially in May, June and August when the green trials needed irrigation. The fairway and rough trials were never irrigated.

Table 9. Weather recordings and irrigation at Ballerud GC, 2007. Monthly temperatures are means of daily maximum and minimum temperatures.

	Mean monthly temperature, °C	Monthly rainfall, mm	Monthly irrigation, mm (greens only)
May	11.2	94	42
June	17.1	185	52
July	16.9	173	10
Aug.	16.6	83	47
Sep.	11.1	71	21
Mean / sum	14.6	606	172

3.5. Demonstration trial with Primo MAXX® at Oslo Golf Club, Bogstad, Norway

To evaluate the effect of Primo MAXX® on a typical annual meadowgrass green, an unreplicated demonstation trial with plot size 250 m^2 was laid out at Oslo GK on 20 June 2007. Primo MAXX® was sprayed at a rate 0.4 l/ha on 20 June, 10 July and 31 July using the same sprayer as at Ballerud GC, about 10 km from Bogstad (Photo 4). Turfgrass quality (general appearance) and fresh weight clipping yields were determined on 4 July, 13 July and 14 August. Unfortunately, the trial had to be discontinued in mid August due to reconstruction of the green.

3.6. 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 on each plot and on plot values which had been averaged, either over the whole growing season, separately over the spring (before 10 June), summer (10 June – 1 Sep.) and autumn (after 1 Sep.) periods, or for observations conducted two versus four weeks after the last application of Primo MAXX®. The significance levels P%<0.1, P%<1, P%<5 and ns (not significant) have been indicated in the tables along with LSD values for effects significant at P%<5. In a few cases exact P-values have been given for tendencies in the 5-15% probability range. As an indications of the variability for each character, coeffcients of variation, (CV %), have also been given in the tables.

4. Results

4.1. Evaluation of Primo MAXX® under fairway conditions, Bioforsk Landvik, Norway

Turfgrass quality and related characteristics

Table 10 shows results from the visual observations of turfgrass quality and related characters in the fairway trial at Landvik. Both within the three seasons and as a mean value, turfgrass general appearance was significantly lower on plots receiving monthly applications of Primo MAXX® at 1.0 l/ha or higher rates than on unsprayed control plots and plots receiving 0.5 l/ha. Within these two groups, differences in generall appearance were not significant. Separate analyses for blocks 1 and 2 versus 3 and 4 indicated that these responses were practically identical regardless of botanical composition (data not shown).

Individual registrations of turfgrass quality are further depicted in Fig. 1. There was a dramatic decline in quality after the first application on 9 May. After this the turf recovered and there was no significant effect of Primo MAXX® at the two subsequent evaluations. Applications of 1.0 l/ha or higher rates on 4 July lead to new quality reductions in July, August and September (Photo 5); these effects were especially apparent at the last evaluation in early November (Photo 6). By contrast, there tended to be a small quality improvement due to the lowest rate of Primo MAXX® from late August to October. This improvement was reflected also in a significant increase in tiller density on average for the whole growing season (Table 10).

Increasing rates of Primo MAXX® consistently led to darker turf throughout the growing season, but also to earlier growth cessation and a less attractive dormancy colour in late autumn (Table 10). The only visible disease in the trial was a slight attack of red thread (*Laetisaria fuciformis*) during the wet period in July; however, these spots were unaffected by Primo MAXX® which also had no effect on the occurrence of broadleaved weeds, primarily white clover, in the trial.

Table 10. Turfgrass quality, tiller density, within-season colour, dormancy colour and infestation of weeds and red thread (*Laetisaria fuciformis*) in fairway at Landvik as affected by increasing rates of Primo MAXX®, 2007. Visual merit and tiller density are means of twelve observations (two in spring, i.e. before 10 June, six in summer, i.e. from 10 June to 1 Sep., and four in autumn, i.e. after 1 Sep. Within season colour (green darkness) and occurrence weeds and red thread are means of twelve, three (all in July) and two (June and Nov.) observations, respectively. Dormancy colour was evaluated on 2 Nov. All values are means of four blocks.

Primo MAXX®, rate	Turf quality (general appearance, 1-9)				Tiller density (1-9)	Within season colour (1-9)	Dor-mancy colour (1-9)	% of plot area	
	Mean	Spring	Summer	Autumn				Dicot weeds	Red thread
0 = Control	6.2	6.1	6.4	6.0	6.3	5.2	6.8	4	4
0.5 l/ha	6.1	5.6	6.3	6.2	6.5	5.6	6.3	2	3
1.0 l/ha	5.5	4.5	5.9	5.3	6.1	5.8	5.0	5	2
1.5 l/ha	5.3	4.6	5.5	5.4	6.0	5.9	4.1	4	3
2.0 l/ha	5.5	4.6	5.9	5.3	6.1	6.0	4.3	3	2
3.0 l/ha	5.1	4.2	5.5	4.9	6.0	6.2	3.5	4	3
P%	<0.1	<0.1	<1	<0.1	<1	<1	<0.1	ns	ns
LSD 5%	0.3	0.5	0.4	0.4	0.2	0.4	1.2	-	-
CV%	4	7	5	5	3	5	15	-	-

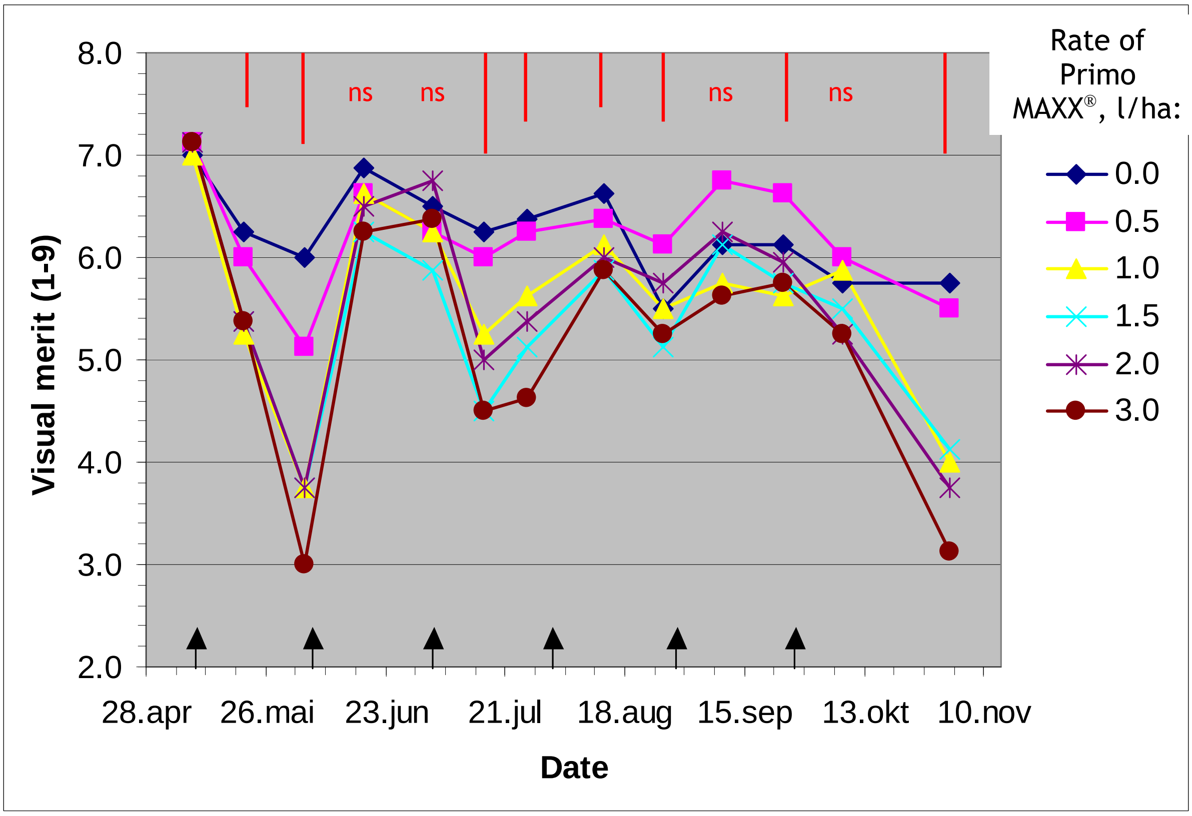


Fig.1. Turfgrass overall quality as affected by increasing rates of Primo MAXX® in fairway trial at Landvik, 2007. Mean of four replicates (blocks). The application dates 9 May, 5 June, 4 July, 31 July, 28 Aug. and 26. Sep. are indicated by black arrows. Red bars indicate LSD 5%.

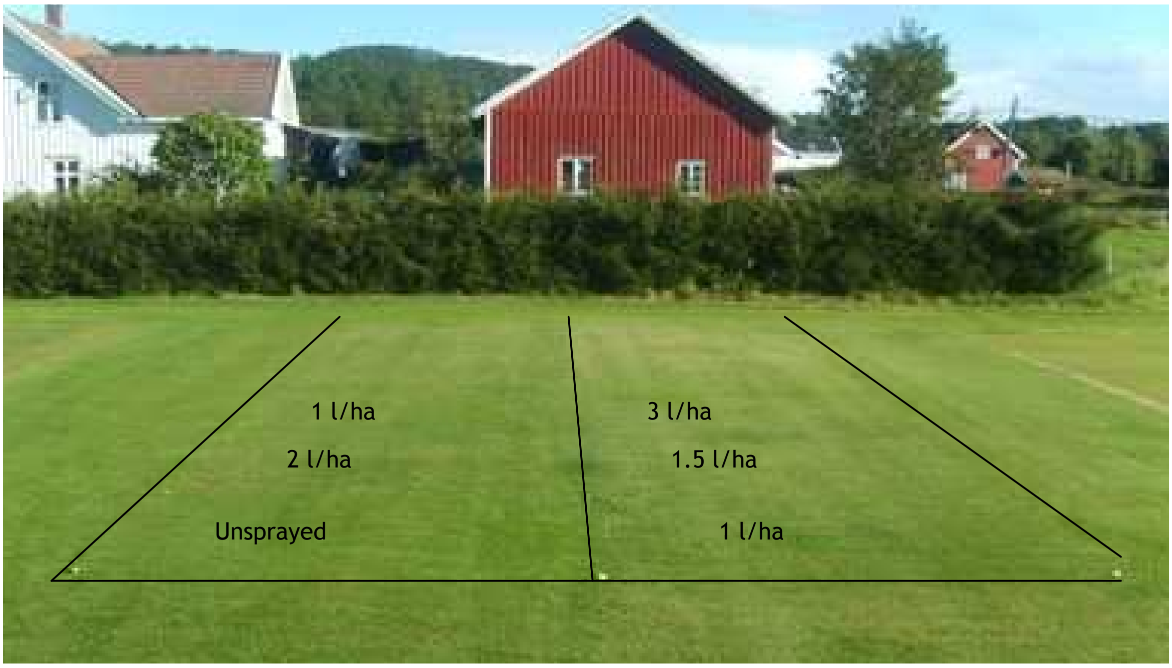


Photo 5. Visual appearance of fairway trial at Landvik, block 1 and 2, on 10 Sept. Within each block, the treatments closest to the photographer have been labeled. High rates of Primo MAXX® resulted in darker, in some cases, almost brown, turf. Photo: Trygve S. Aamlid.

Photo 6.

Turf quality / dormancy colour at growth cessation on 2 Nov. 2007 after application of Primo Maxx at 3.0 l/ha (left) and 0.5 l/ha (right), last application on 26 Sep.

Photo: Trygve S. Aamlid.

Turfgrass height and dry matter production

The average effect of Primo MAXX® on plant height and clipping yields are given in Table 11. In all blocks, the growth regulator caused a significant reduction in plant height even at the lowest rate, but contrary to expectation, this low rate also tended to increase aboveground dry matter production as compared with the unsprayed control treatment. This might reflect a higher tiller density, as also suggested in Table 10. Separate analyses for various parts of trial showed that the average reduction in clipping yield due to Primo MAXX® was stronger in blocks 1 & 2 which had more *Poa* species less red fescue and browntop bent and than blocks 3 & 4. On average for eleven harvests and all replicates, there was a slight tendency for Primo MAXX® to increase the dry matter percentage of turfgrass clippings (P% = 16, Table 11).

Table 11. Absolute and relative effects of increasing rates of Primo MAXX® on turfgrass height, turfgrass dry matter production, and per cent dry matter of clippings in fairway trial at Landvik, 2007. Mean of eleven observations. Plant height above 15 mm represents an average of four days' growth.

Primo MAXX, rate	Plant height, mm		Production of turfgrass clippings, g/m^2/day				% dry matter in clippings
	mm	Rel.	Block 1&2	Block 3&4	Mean	Rel.	
0 = Control	21.9	100	1.78	1.62	1.70	100	31.5
0.5 l/ha	20.9	95	1.91	1.93	1.92	113	32.2
1.0 l/ha	20.7	95	1.65	1.72	1.69	99	32.5
1.5 l/ha	20.0	91	1.46	1.46	1.46	86	33.6
2.0 l/ha	20.3	93	1.55	1.61	1.58	93	32.4
3.0 l/ha	19.5	89	1.31	1.70	1.51	88	33.1
P%.	<0.1	-	10	ns	<5	-	16
LSD 5%	0.7	-	-	-	0.29	-	-
CV%	2	-	10	14	12	-	3

In absolute terms, turfgrass clipping yield showed a distinct seasonal pattern with peaks during the warm and sunny periods in early June and late August (Fig. 2a). The low clipping yield on 17 July was probably due to 280 mm rainfall, and thus nutrient leaching, since the last fertilizer application on 12 June (Tables 3 and 4). Separate analyses of variance for each day indicated a significant effect of Primo MAXX® on clipping yield only on 4 June.

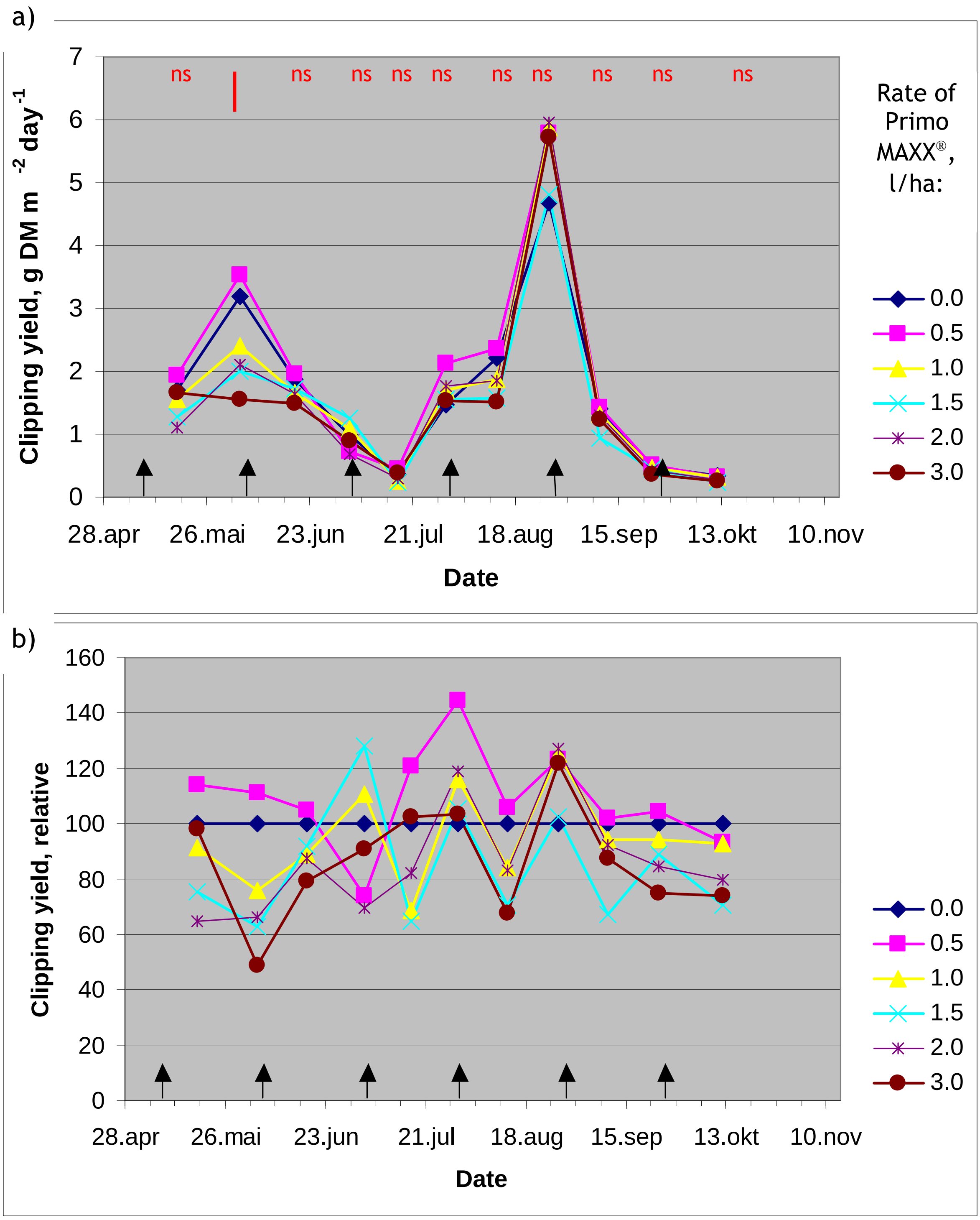


Fig. 2. Absolute (a) and relative (b) reductions in daily dry matter production of turfgrass clippings as affected by increasing rates of Primo MAXX® in fairway trial at Landvik. Red text/bars and black arrows indicate probability / LSD values and application dates 9 May, 5 June, 4 July, 31 July, 28 Aug. and 26 Sep., respectively. In (b), the clipping yield on each date was set to 100 in the unsprayed control treatment.

In relative terms, none of the Primo MAXX® treatments produced clipping yields that were lower than the unsprayed control at all harvests (Fig. 2b). Many of the treatments showed a typical suppression / rebound pattern with clipping yields lower than the control treatment at one harvest, but higher than control treatment at the next harvest.

4.2. Evaluation of Primo MAXX® on a golf course fairway, Lepaa, Finland

On average for two observations in spring, five observations in summer and two observations in autumn, Primo MAXX® had no effect on turfgrass general appearance in the fairway trial at Lepaa. Among the nine observation dates, significant differences were recorded only on 21 August when the plots sprayed with the highest dose (3.0 l/ha) had an average visual merit score of 5.5 as opposed to 6.8 for unsprayed control plots and plots sprayed with the lowest dose (0.5 l/ha).

On average for observations, increasing rates of Primo Max caused an overall increase in tiller density, while turfgrass colour was not significantly affected. No diseases were observed during the growing season.

Table 12. Turfgrass quality (1-9, 9 is best quality), tiller density (1-9, 9 is highest density) and within-season colour (1-9, 9 is darkest green) in fairway trial at Lepaa as affected by increasing rates of Primo MAXX®. Means of nine observations (two in spring, i.e. before 10 June, five in summer, i.e. from 10 June to 1 Sep., and two in autumn, i.e. after 1 Sep.). All values are means of four blocks.

Primo MAXX®, rate	Turf quality (general appearance, 1-9)				Tiller density (1-9)	Within season colour (1-9)
	Mean	Spring	Summer	Autumn		
0 = Control	6.1	5.5	6.1	6.8	5.5	6.1
0.5 l/ha	6.2	5.5	6.1	7.0	5.8	6.2
1.0 l/ha	6.1	5.4	6.1	6.9	5.8	6.1
1.5 l/ha	6.2	5.5	6.2	7.0	6.0	6.3
2.0 l/ha	6.2	5.6	6.1	6.9	6.1	6.3
3.0 l/ha	6.2	5.6	6.1	7.0	6.4	6.2
P%	ns	ns	ns	ns	<0.1	ns
LSD 5%	-	-	-	-	0.4	-
CV%	5	4	8	3	3	4

The effect of Primo MAXX® on turfgrass plant height and clipping yield depended on the time since last application. On average for five observations conducted about two weeks after application, the highest rate of Primo MAXX® caused significant reductions in plant height and clipping yield corresponding to 11 and 48 %, respectively (Table 13). On average for four observations conducted four weeks after application, the maximal reductions were only 3 and 14 %, respectively. Fig. 3 illustrates the unstable effect of Primo MAXX®, particularly toward the end of the growing season. However, unlike in the fairway trial at Landvik (Fig.2), clipping yields on sprayed plots were rarely higher than on untreated control plots in the trial at Lepaa.

Table 13. Absolute and relative effects of increasing rates of Primo MAXX® on turfgrass height and dry matter production in turfgrass clippings in fairway trial at Lepaa 2007. Observations conducted 2 weeks (5 observations) and 4 weeks (4 observations) from spraying treatment have been presented separately.

Treatment	Plant height (mm)				Weight of clippings (g DM / m^2 / day)			
Time after treatment	2 weeks	4 weeks	Mean	Rel	2 weeks	4 weeks	Mean	Rel
0 = Control	15.7	16.0	15.8	100	3.2	7.0	4.9	100
0.5 l/ha	15.7	16.0	15.8	100	2.7	6.3	4.3	87
1.0 l/ha	14.9	16.0	15.4	97	2.8	6.6	4.5	92
1.5 l/ha	14.7	15.7	15.1	96	2.3	5.8	3.9	79
2.0 l/ha	14.4	15.6	15.0	95	2.1	6.1	3.9	80
3.0 l/ha	14.0	15.5	14.6	92	1.8	6.0	3.7	75
P%	<0.1	ns	<5	-	<0.1	ns	ns	-
LSD 5%	1.1	-	1.0	-	0.7	-	-	-
CV%	3	4	3	-	13	22	18	

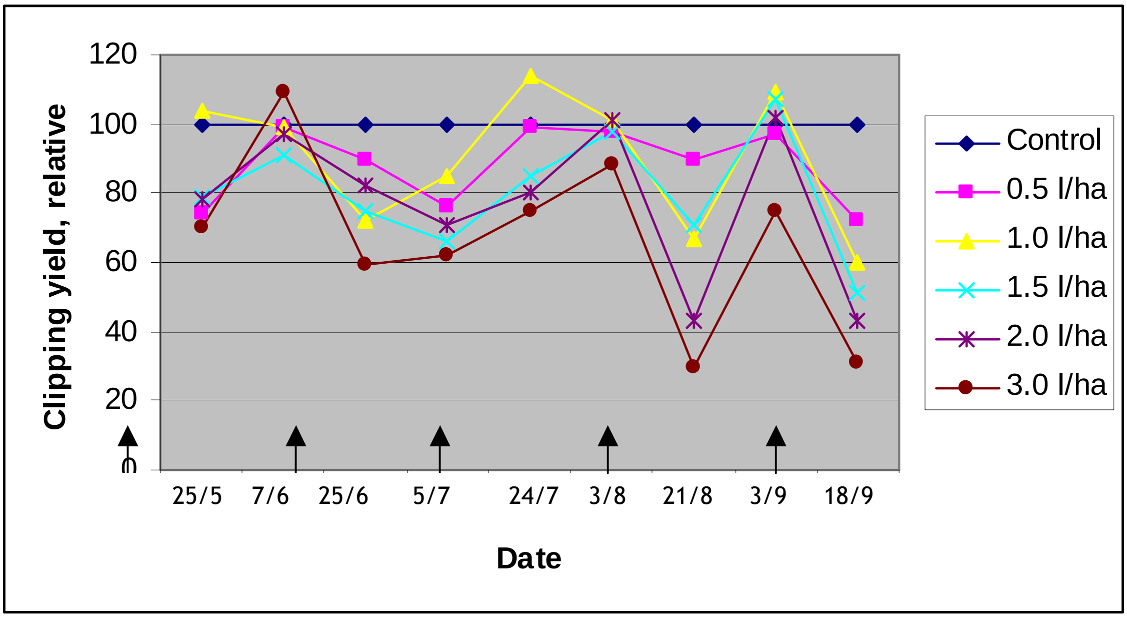


Fig. 3. Relative clipping weights (control = 100) in fairway trial at Lepaa, Finland. Spraying treatments indicated by black arrows were carried out on 11 May, 8 June, 5 July, 3 Aug. and 4 Sep. (The last spraying on 4 Oct. was done primarily to study the effect of Primo MAXX® on overwintering and was not followed by observations in late autumn.)

4.3. Evaluation of Primo MAXX® on a golf course putting green, Lepaa, Finland

On 3 Sep. 2007, a significantly higher tiller density was recorded on green plots sprayed with the highest rate of Primo MAXX® than on unsprayed control plots (data not shown). Otherwise, Primo MAXX® had no significant effect on either general appearance, tiller density or turfgrass colour in the green trial at Lepaa (Table 14). Although the effects on plant height and clipping yields were also not significant, reductions were generally stronger when recorded at two compared with four weeks after application (Table 15, Fig. 4).

Table 14. Turfgrass quality, tiller density and within-season colour (darkness) in green trial at Lepaa as affected by increasing rates of Primo MAXX®, 2007. Means of nine observations (two in spring, i.e. before 10 June, five in summer, i.e. from 10 June to 1 Sep., and two in autumn, i.e. after 1 Sep.). All values are means of four blocks.

Primo MAXX®, rate	Turf quality (general appearance, 1-9)				Tiller density (1-9)	Within season colour (1-9)
	Mean	Spring	Summer	Autumn		
0 = Control	6.4	6.1	6.6	6.3	6.3	6.4
0.2 l/ha	6.3	6.0	6.5	6.0	6.3	6.4
0.4 l/ha	6.3	5.9	6.5	6.1	6.2	6.3
0.6 l/ha	6.3	5.8	6.5	6.4	6.3	6.4
0.8 l/ha	6.2	5.8	6.4	6.3	6.2	6.4
P%	ns	ns	ns	ns	ns	ns
LSD 5%	-	-	-	-	-	-
CV%	3	5	5	7	2	3

Table 15. Absolute and relative effects of increasing rates of Primo MAXX® on turfgrass height and dry matter production in turfgrass clippings in green trial at Lepaa 2007. Observations conducted 2 weeks (5 observations) and 4 weeks (4 observations) from spraying treatment have been presented separately. Plant heights above 3 mm represent one day's growth.

Treatment	Plant height (mm)				Weight of clippings (g DM / m^2 / day)			
Time after treatment	2 weeks	4 weeks	Mean	Rel	2 weeks	4 weeks	Mean	Rel
0 = Control	4.3	3.9	4.1	100	2.60	2.21	2.43	100
0.2 l/ha	4.1	3.8	4.0	96	2.20	2.28	2.23	92
0.4 l/ha	4.0	3.9	3.9	95	1.88	2.28	2.06	85
0.6 l/ha	4.0	3.8	3.9	94	1.72	2.18	1.99	82
0.8 l/ha	3.8	3.9	3.9	93	1.75	2.28	1.92	79
P%	11	ns	ns	-	5	ns	ns	-
LSD 5%	-	-	-	-	0.9	-	-	-
CV%	6	7	8	-	20	14	16	-

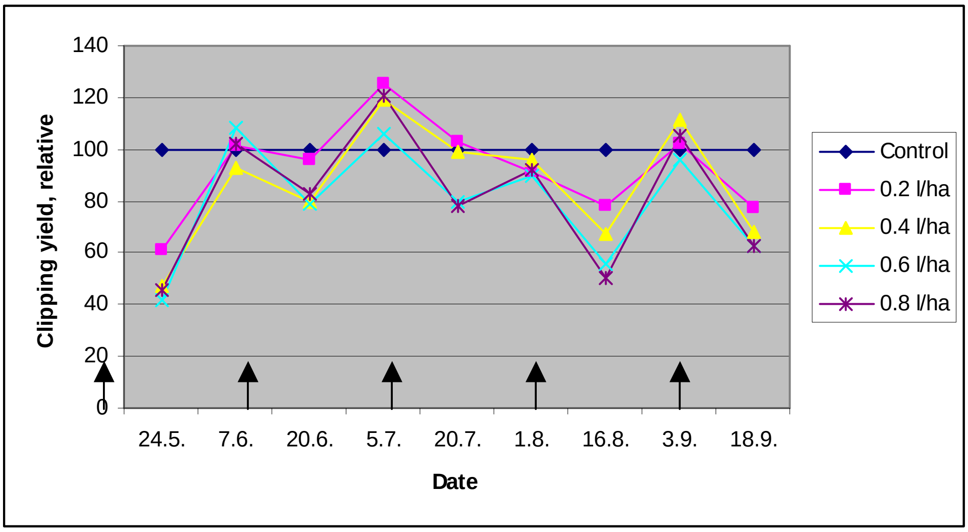


Fig. 4. Relative clipping weights (control = 100) in green trial at Lepaa, Finland. Spraying treatments indicated by black arrows were carried out on 11 May, 8 June, 5 July, 3 Aug. and 4 Sep. (The last spraying on 4 Oct. was done primarily to study the effect of Primo MAXX® on overwintering and was not followed by observations in late autumn.)

4.4. Demonstration trials with Primo MAXX® at Ballerud Golf Course, Oslo, Norway

<u>Green trials</u>

Applications of 0.4 l/ha Primo MAXX® on 5 and 18 June did not affect turf general appearance (Photo 7) or stimpmeter readings on green no. 9 at Ballerud. During the period 14-29 June, clippings were reduced by an average of 32%, but after spraying had been discontinued, there was a rebound effect corresponding to a 26 % increase in clipping yield in the period 12-25 July (data not shown).

Photo 7. Terje Haugen (left) and Lasse Augustsson on green no. 9 at Ballerud Golf Course, 27 June 2007. Photo: Trygve S. Aamlid.

Photo 8. Field day at Ballerud Golf Course 27 Aug. 2007. Photo: Tatsiana Espevig.

Fig. 5 summarizes results from the nursery green trial established on 9 July. In this trial, application of Primo MAXX® about every third week resulted in better colour (not shown), higher green speed (Fig. 5a), and an average reduction in turfgrass clippings of 44 % (Fig. 5b and c). Fig 5b shows that the reduction in clipping yield was most conspicuous during the periods of rapid growth in mid to late July (after only one application of Primo MAXX®) and in late August.

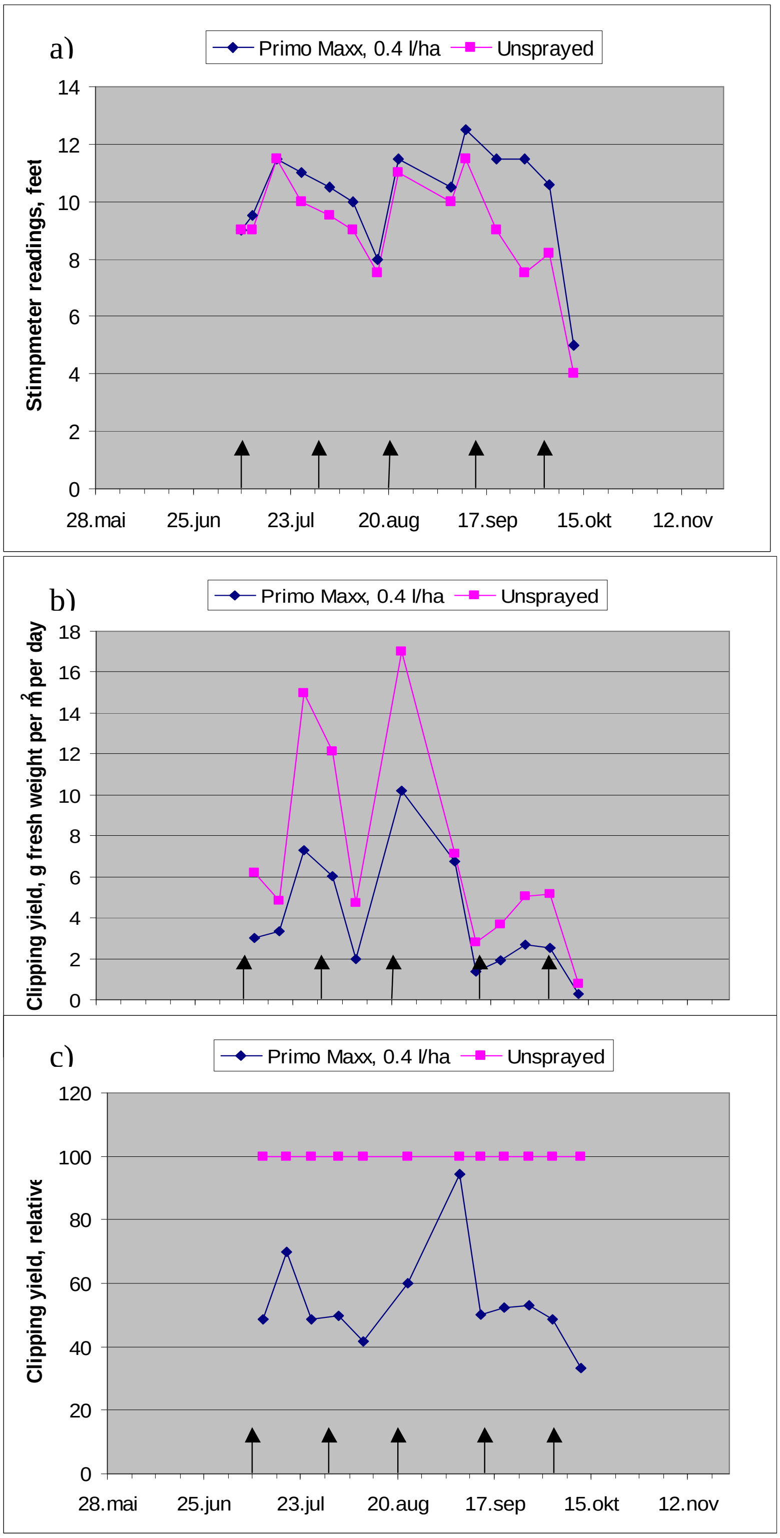


Fig. 5. Effects of spraying Primo MAXX® every three weeks of green speed and absolute and relative clipping yield on nursery green at Ballerud GC, 2007. Black arrows indicate the application dates 9 July, 31 July, 21 Aug., 13 Sep. and 4 Oct.

<u>Fairway trial</u>

As evaluated by the headgreenkeeper, monthly applications of 1.5 l/ha Primo MAXX® (1.5 l/ha) had no negative impact on turf quality in the fairway trial at Ballerud (Fig. 6). Photos 9-11 show, nevertheless, that treated turf was more faded, grayish, and less green than untreated turf. The pronounced colour difference in favour of Primo MAXX® in early September (Fig. 6) was due to less dry spots than the in the control area. While these spots recovered after rainfall on 10 and 17 Sep., the last application of Primo MAXX® on 4 Oct. led to an apparent loss of colour and drop in turf general appearance in late autumn (Photo 11).

On average for 17 clipping, regular application of Primo MAXX® resulted in a 37 % reduction in the fresh weight of turfgrass clippings (Fig. 7). The only time clipping yield was higher on the treated than on the untreated area was at the first clipping nine days after the first application and on 7 Sep. The latter coincided with the observation of less dry spots after use of Primo MAXX®. It may also be interpreted as a rebound effect following growth suppression after application on 31 July.

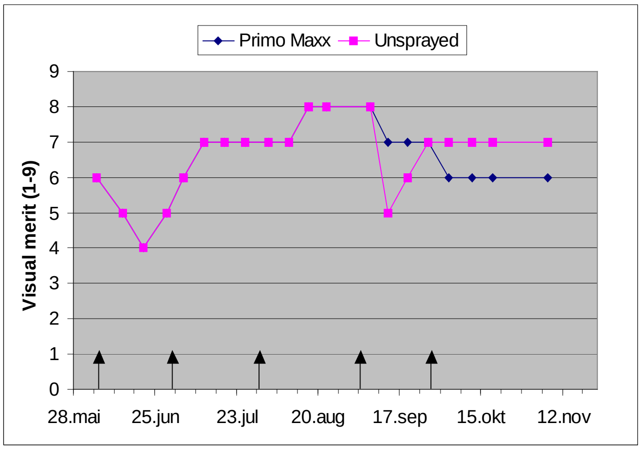
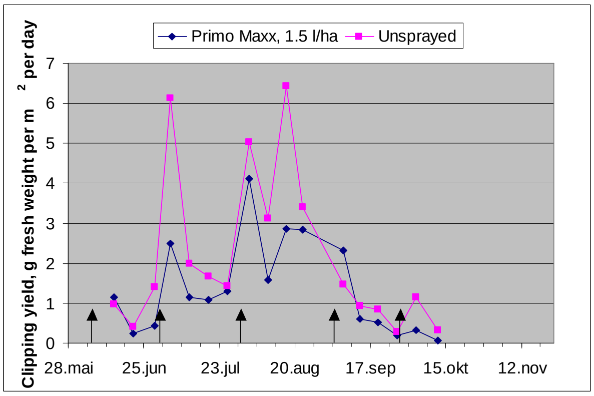


Fig. 6. Effect of Primo MAXX® on turfgrass general appearance in fairway trial at Ballerud GC. Black arrows indicate application dates. (Sprayed an unsprayed plots had identical scores until the beginning of September)

Photo 9. Difference in colour and general appearance of treated and untreated fairway Ballerud GC, 27 June. Photo: Trygve S. Aamlid.

Photo 10. Difference in colour and general appearance of treated and untreated fairway Ballerud GC, 27 Aug. Photo: Tatsiana Espevig.

Photo 11. Difference in colour and general appearance of treated and untreated fairway Ballerud GC, 3 Dec. Photo: Terje Haugen.



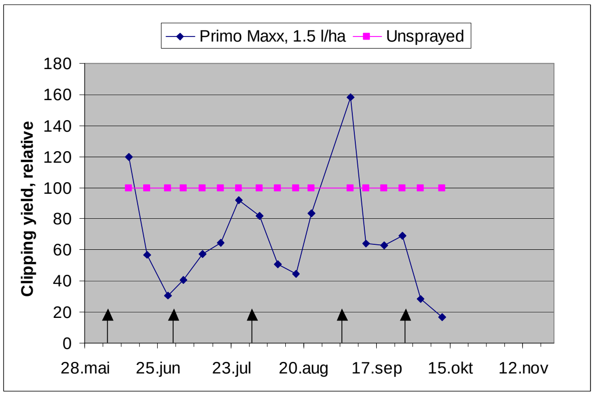


Fig. 7. Absolute (a) and relative (b) reductions in clipping yield resulting form application of Primo MAXX® in fairway trial at Ballerud GC. Arrows indicate application dates.

Spraying 2.2 l/ha of Primo MAXX® at six weeks interval resulted in discoloration and consistent drop in turf quality in the rough trial at Ballerud (Fig. 8, Photos 12 and 13). The effect was most conspicuous in late autumn. Primo MAXX® had less effect on tufts of perennial ryegrass which stood out very markedly in the turf which was otherwise dominated by smooth meadowgrass. Clipping yields were not recorded in this trial.

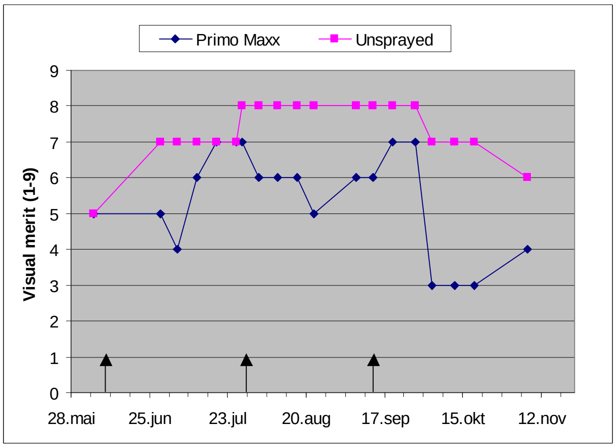


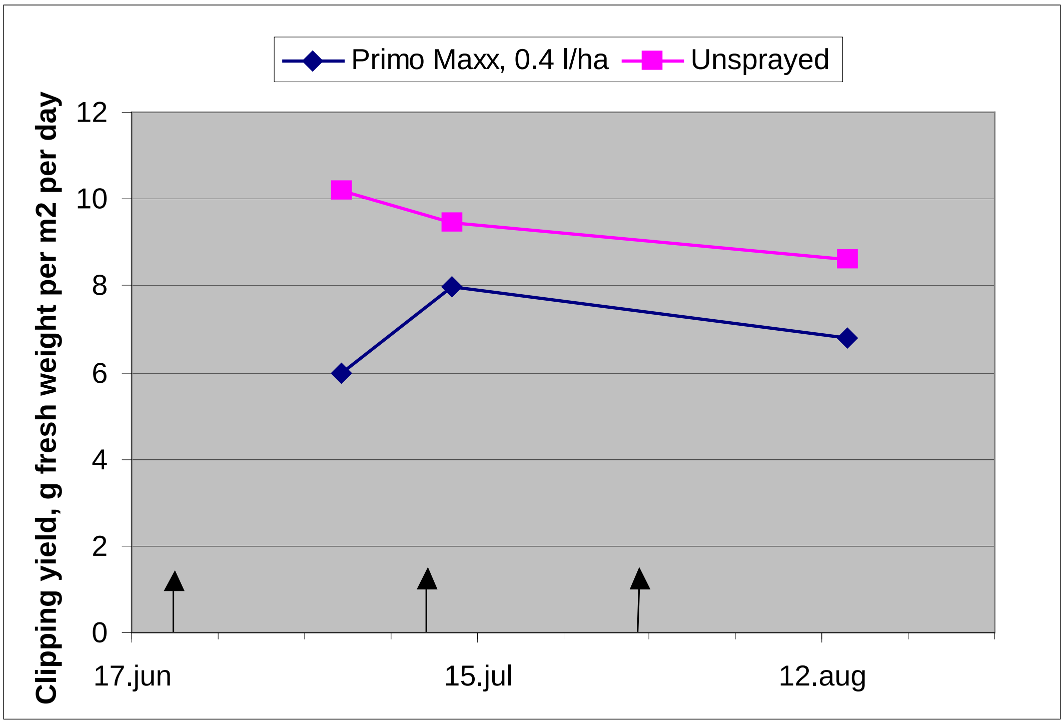
Fig. 8 (upper left). Difference in colour and general appearance of treated and untreated area in rough no 9, Ballerud, 27 June. Photo: Trygve S. Aamlid.

Photo 12 (upper right). Terje Haugen (left) and Lasse Augustsson in rough trial at Ballerud GC, 27 June. Photo: Trygve S. Aamlid.

Photo 13 (lower left). Trygve S. Aamlid inspecting rough trial at Ballerud GC, 27 August 2007. Tufts of ryegrass stand out very markedly on sprayed area.
Photo: Tatsiana Espevig.

4.5. Demonstration trial with Primo MAXX® at Oslo Golf Club, Bogstad, Norway

Application of 0.4 l Primo MAXX® at three week intervals resulted in darker turf but had otherwise no effect on the turfgrass quality of annual meadowgrass at Oslo GC. On average for three registrations, the Primo MAXX led to a 26% reduction in clipping yields (Fig. 9).



5. Discussion and suggestions for 2008

The starting point for evaluating Primo MAXX® in this two-year project was the rates and applications frequencies recommended for the product in Europe (Syngenta 2007, Table 16). Based on our experiences from agricultural crops that the optimal rates may be different in the Nordic countries than countries further south, higher and lower rates were included in the GEP trials both to determine the potential growth inhibition and the risk for discoloration or other phytotoxic effects. All taken together, the results from the first project year confirms that the guidelines in Table 16 are not directly applicable in Scandinavia and that further research is needed to find the optimal way of using the product under Nordic conditions.

Table 16. Dose rates and applications frequencies recommended for Primo MAXX® in the United Kingdom (Syngenta 2007).

	Dose rate		Application
	Primo MAXX®, l/ha	trinexapac-ethyl, g a.i./ha	frequency
Fairways	0.8 – 1.6	90 - 180	Every four to five weeks
Roughs & semi-roughs	1.6-2.4	180 - 240	Every five to eight weeks
Greens	0.4	45	Every two to four weeks

On fairway, the average reduction in clipping yield caused by monthly application of the intermediate Primo MAXX® rate of 1.5 l/ha was 15 and 21 % in the GEP trials at Landvik and Lepaa, respectively. By contrast, monthly application of 1.5 l/ha resulted in a 37 % reduction in clipping yield in the demonstration trial at Ballerud GC, which is closer to the data presented by Syngenta (2007). In agreement with Table 11 showing an increase in turfgrass dry matter percentage (i.e. decreased succulence) after application of Primo MAXX®, one of the reasons for this difference might be that clipping yields were determined on a dry weight basis in the GEP trials but on a fresh weight basis at Ballerud GC and in the data presented by Syngenta (2007). Another, and probably more important explanation, is the difference in species composition among the three trials. While the plant cover at Ballerud was almost 100% by annual meadowgrass, the species composition at Landvik varied with the two blocks showing the least response to Primo MAXX® having a plant cover of 74 % red fescue (Tables 1 and 11). By contrast, smooth meadowgrass dominated over red fescue at Lepaa due to the heavy soil type, use of irrigation, and relatively high nitrogen input. Unfortunately, we have not been able to find many references about the specific effects of Primo MAXX® on red fescue turf, but our results are in partial agreement with Pannacol et al. (2004) who found 40 %, 21 %, and no significant reduction in clipping yield after using trinexapac-ethyl in smooth meadowgrass, chewing fescue and creeping red fescue, respectively.

Perhaps the most conspicuous feature of the present results was the unstable effect of Primo MAXX® on clipping yields due to the postsuppression rebound effect. In the fairway trial at Lepaa, Finland, this resulted in clipping yield reductions being significant only two weeks after application (Table 13), and a similar tendency could be seen also in the green trial (Table 15). In Norway, clipping yields four weeks after spraying were often higher than on unsprayed control plots in the fairway trial at Landvik (Fig. 2), and a strong rebound effect was observed also after spraying treatments had to discontinued at green no. 9, Ballerud GC. The unstable effect in of Primo MAXX® in these trials was probably due to a rapid degradation of trinexapac-ethyl in plant tissue and a higher regrowth potential due to accumulation of carbohydrate reserves and GA_1 precursors during the suppression phase (Lickfeldt et

al. 2001, Branham & Beasley 2007). In North-American experiments, Lickfeldt et al. (2001) reported clipping yields reductions in smooth meadowgrass to be much more consistent when trinexapac-ethyl was applied at four than at six week intervals, but under Nordic long-day conditions, spraying every second, or at least every third week, may well be necessary to stabilize low GA_1 levels, not only on greens, but also on fairways and tees. Although there was a surge effect during the driest period in mid September, the most stable clipping reductions in our trials, on average 44 % on a fresh weight basis, were, indeed, obtained on the nursery green which was sprayed about every third week at Ballerud GC (Fig. 5c). While Branham & Beasley (2007) noted that temperature was the most important factor determining degradation of trinexapac-ethyl in turfgrass tissue, our results suggest that other factors such as light and water availability may also be important for the rebound effect under Nordic conditions. Very clearly, application frequency is a major question that has to be addressed during the continuation of this project.

The potential reductions in mowing costs from using a plant growth regulator will always have to be weighed against the risks for discoloration or other harmful effects on turf quality. In the present trials, reductions in general appearance (visual merit) scores were far more conspicuous in the GEP trial at Landvik than in the GEP trials at Lepaa or the demonstration trials at Ballerud GC. Apart from possible effects of different botanical compositions, this might reflect a subjective human factor, i.e. different backgrounds and attitudes of the observers in the various trials. While the fairway trial at Landvik was evaluated by turfgrass scientists and technicians with long experience from turfgrass variety testing, the trials at Lepaa and Ballerud were evaluated by greenkeepers working on the course. While the observers at Landvik may have paid more attention to turf aesthetic values such as less intense colour, and less vigorous and uniform plots, the observers at Lepaa and Ballerud may well have been more attentive to ball roll and other functional characteristics of the playing surface. The less succulent but significantly darker green turf resulting from high Primo MAXX® rates at Landvik are in agreement with other studies showing higher mesophyll cell densities and chlorophyll concentrations resulting from less elongation of leaf cells (Heckman et al. 2001, Ervin & Zhang 2008). As for tiller density, most literature supports the Finnish rather than the Norwegian results; i.e. enhanced tillering after Primo MAXX® application (Branham & Beasley 2007, Ervin & Zhang 2008).

As compared with the unsprayed control treatment, the strongest negative effect of Primo MAXX® on turfgrass general appearance at Landvik was recorded after the first spraying in early June, in mid July and at the last observation in early November. Each of these observations might be explained by suboptimal conditions causing reduced turfgrass growth. From 6 to 15 June there was a dry and warm and period with maximum temperatures in the range 25-30 ºC that obviously reduced turfgras tillering and aesthetic appearance; until mid July exceptional rainfalls starting on 22 June were not compensated by increase nitrogen inputs, and in autumn, the last application of Primo on 26 September was followed by several nights of frost. Although most studies have failed to document significant interactions between nitrogen and trinexapac-ethyl on turfgrass quality (Steinke & Stier 2001, Goss et al. 2002, McCullogh et al. 2006), it seems reasonable to assume that potential negative effects on Primo MAXX® on turfgrass quality will be most pronounced under suboptimal growing conditions. As in the trials at Landvik (Photo 6) and Ballerud (Photo 11), Beam et al. (2002) reported significant discoloration of trinexapac-ethyl-treated smooth meadowgrass following frost in autumn.

Undoubtedly, the most convincing argument for official approval of Primo MAXX® on Nordic golf courses would be a clear documentation that it improves winter survival. Preliminary results with annual meadowgrass suggested that low rates of trinexapac-ethyl prevented winter injury, whereas high rates had opposite effects due to discoloration during the hardening phase in late autumn (Rossi & Buelow 1997). While trinexapac-ethyl has been shown to increase water soluble carbohydrate contents (Goss et al. 2002) and result in faster spring greenup, Ervin & Zhang (2008) recently called for more detailed investigations into the effect of trinexapac-etyl on freezing tolerance as the research to date has provided scarce information on this aspect. Under Nordic conditions, desiccation if growth resumes when soils are still frozen and irrigation not yet operational in spring, or damage due to unstable winters with ice and water covering the turf, sometimes resulting in suffocation, appear to be more

important that direct freezing injury. In this regard, trineexapac-ethyl may well have a positive effect as it reduces mitochondrial respiration (Ervin & Zhang 2008). In 2008, it will therefore be very interesting to study winter injury and spring green-up and recovery in the on-going trials at Landvik, Lepaa and Ballerud which all had their last application of Primo MAXX® in late September or early October.

Even with winter survival and spring observations included, the amount of data presented in this report is too limited to recommend any listing of Primo MAXX® for turf use in the Nordic countries. Therefore, as stated in the contract between Syngenta and Scandinavian Turfgrass and Environment Research Foundation, there is a need for new GEP trials to be started in spring 2008 and followed until registration of winter survival in spring 2009. For this purpose, a new experimental green was constructed and seeded to creeping bentgrass at Landvik in 2007. In the trial to be established on this green in spring 2008, we suggest to compare Primo MAXX® at three rates (0.15, 0.30 and 0.45 l/ha) and two application frequencies (every 10/11 days and every 21 days), i.e. six combinations plus an unsprayed control treatment. As different grass species seem to vary in their response to Primo MAXX®, similar trials should preferably be carried out on also red fescue/browntop greens and velvet bentgrass greens, although this would require additional funding from Syngenta/STERF.

In Finland, a new GEP trial will be established in spring 2008 on a fairway that is regularly subjected to winter injury. New demonstration trials might be added to the project depending on interest from superintendents and funding from the national golf unions.

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

Results from the first evaluation year 2007

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SCANDINAVIAN TURFGRASS AND ENVIRONMENT RESEARCH FOUNDATION

Finnish team spraying fairway trial at Lepaa Golf Course.
Photo: Oiva Niemelainen

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Summary:
This report presents first year results from a two year project evaluating the plant growth regulator Primo MAXX® (trineexapac-ethyl) on Nordic golf courses.

Sammendrag:
I denne rapporten presenteres første års resultater fra et toårig prosjekt med utprøving av vekstreguleringsmidlet Primo MAXX® (trinexapac-etyl) på golfbaner i Norden.

Approved

Arne Sæbø	Trygve S. Aamlid
Leader, Bioforsk's Section for Urban Greening	Project leader

Contents

1. Abstract

As an inhibitor of the last step in plant synthesis of bioactive gibberellin (GA_1), the plant growth regulator Primo MAXX® (trinexapac-ethyl) offers prospects of reduced energy use for mowing and improved turfgrass quality under Nordic long day conditions. This report presents first year results from 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 possible registration of Primo MAXX®, unreplicated demonstration trials were carried out at Ballerud and Bogstad Golf Courses in Oslo under supervision of Bioforsk and with funding from the Norwegian Golf Federation (NGF).

GEP trials on **fairways** (mowing height 12-18 mm) were carried out at Bioforsk Landvik, Norway (58°34'N, 8°52'E) and at the Lepaa Unit of the HAMK University of Applied Sciences, Finland (61°08'N, 24°20'E). Primo MAXX® was applied at monthly intervals at rates 0.5, 1.0, 1.5, 2.0 and 3.0 l/ha (56.5, 113, 169.5, 226 and 339 g a.i./ha trinexapac-ethyl) in comparison with an unsprayed control treatment. Turfgrass general appearance, tiller density, colour, height growth, and clipping yields were recorded two and four weeks after each application. Primo MAXX® had no effect on turfgrass general appearance but increased density at Lepaa. At Landvik, Primo MAXX® (>= 1.0 l/ha) reduced turfgrass general appearance and density, but resulted in significantly darker green colour. Quality reductions were most apparent during periods with either daily maximum temperatures >25 ºC, extreme rainfall probably causing nitrogen deficiency, or frost at night. Average reductions in clipping yield caused by Primo MAXX® (>= 1.0 l/ha) were 8 % in the GEP trial at Landvik, 18 % in the GEP trial at Lepaa and 37 % in the demonstration trial at Ballerud; to some extent this difference may be due to different botanical composition with red fescue (*Festuca rubra*) and annual meadowgrass (*Poa annua*) being the predominant species at Landvik and Ballerud, respectively. Clipping yield reductions due to Primo MAXX® were unstable, growth suppression two weeks after application often being followed by a rebound effect during the remaining two weeks until next application.

A GEP trial on creeping bentgrass **putting greens** was carried out at Lepaa, Finland, and demonstration trials at Ballerud and Bogstad, Norway. Primo MAXX® was sprayed at rates 0.2, 0.4, 0.6 or 0.8 l/ha at monthly intervals in the GEP trial, and at 0.4 l/ha every three weeks in the demonstration trials. On average for all observations, Primo MAXX® had no effect on turfgrass quality, but clipping yields were reduced by 16, 44 and 26% at Lepaa, Ballerud and Bogstad, respectively. As in the fairway trials, growth suppression at Lepaa was stronger when assessed at two than at four weeks after application. By contrast, Primo MAXX® produced a fairly stable effect when applied at three week intervals in the demonstration trials.

Use of Primo MAXX® on golf course **roughs** was investigated only in a demonstration trial at Ballerud. Application of 2.2 l/ha of Primo MAXX® every seven weeks resulted in discolouration and reduced quality of smooth meadow grass.

In conclusion, the first year of this project has shown that the guidelines for use of Primo MAXX® in other European countries are not directly applicable in Scandinavia. As the present results are too limited to apply for registration of Primo MAXX®, the project will continue in 2008 tentatively with new trials investigating application of Primo MAXX® at lower rates, but higher frequencies. Improved winter stress tolerance would be a convincing argument for registration of Primo MAXX® in the Nordic countries, and the on-going trials will therefore be followed by an assessment of effects of the last Primo MAXX® applications in September or October 2007 on winter survival and spring recovery.

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

2. Introduction

The plant growth regulator trinexapac-ethyl was developed by Syngenta in the 1980s. Since the active ingredient is available in different formulations, the chemical will, in this report, be referred to as Primo MAXX®, which is the product developed by Syngenta specifically for use on turf. Unlike earlier plant growth regulators, Primo MAXX®'s mode of action is highly specific as it blocks the conversion of GA_{20} til GA_1, i.e. the last step in the biosynthesis of gibberellic acid, a plant hormone stimulating cell elongation and thus vertical turf growth.

After its release, Primo MAXX® was rapidly adopted by the US and Canadian turf industries. In North America, there are several independent university studies documenting its positive effects on golf courses, athletic fields, home lawns, and sod production (for a recent review, see Erwin and Zhang 2008). These advantages include reduced leaf elongation and thus reduced mowing costs and energy use, improved tiller production (more lateral growth), darker green colour, and improved resistance to drought and shade.

While other formulations of trinexapac-ethyl have been approved for agricultural use in Europe for about a decade, the experience with Primo MAXX® to European turfgrass areas is relatively limited. During the past three to four years, Primo MAXX® has been approved for turf use in Italy, France and UK, and the evaluation and registration process has been initiated in many other countries.

Being an inhibitor of gibberellin biosynthesis, Primo MAXX® offers special prospects for turfgrass management in the Nordic counties Finland, Sweden, Norway, Iceland, and Denmark. At latitudes ranging form 55 to 71 °N, turfgrasses growing in these countries exposed not only to long photoperiods during most of the growing season, but also to lower photosynthetic flux densities and lower red to farred (R/FR) ratios than in countries further south. The natural turfgrass response to these northern light conditions is to devote more of its resources to shoot elongation (Heide et al. 1985a,b). Since this response is primarily mediated by the gibberellic acid GA_1, any specific growth regulator that controls the biosynthesis of this compound might be useful under Nordic conditions. Nevertheless, our experience from the introduction of trinexapac-ethyl for agricultural use in the Nordic counties suggests that the optimal dose rates and frequencies for application of Primo MAXX® to various types of turf are probably not the same as at lower latitudes. This is also due to different species and cultivars being grown compared with countries further south. Field trials under Nordic conditions are therefore required not only to produce data for the national certification agencies, but also to provide turf managers with recommendations for how to use the product.

This report presents first year preliminary results from a two year project evaluating the use of Primo MAXX® on golf courses in the Nordic countries. The project was funded by Syngenta and the Scandinavian Turfgrass and Environment Research Foundation (STERF) 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' trials needed to provide documentation for possible registrations of Primo MAXX® by the national authorities, a couple of practical demonstration trials were carried out on Norwegian golf courses under supervision from Bioforsk and with funding from the Norwegian Golf Federation (NGF).

3. Methods

3.1. Evaluation of Primo MAXX® under fairway conditions, Bioforsk Landvik, Norway

Experimental site

On 8 May 2007, a field trial was laid out on a fairway established on a sandy loam soil (topsoil: 68 % sand, 27% silt, 5 % clay) at Bioforsk Landvik Research Station (58°34'N, 8°52'E), SE Norway. Soil samples indicated a pH (H_2O) of 5.9, high phosphorus values (P-AL=19) and intermediate to low potassium values (K-AL = 8, K-HNO_3=58). The fairway had been seeded in September 2003 to a mixture of smooth meadowgrass (*Poa pratensis*), chewing fescue (*Festuca rubra* ssp. *commutata*), and browntop bent (*Agrostis capillaris*) (Table 1). Block 1 and 2 were located in one part, and block 3 and 4 in a different part of the fairway. Botanical analyses at the start of experimentation indicated that red fescue was the predominant species in all blocks, but presumably due to slightly less surface drainage, blocks 1 and 2 had a higher percentage of smooth and annual meadowgrass and broadleaved weeds (primarily white clover (*Trifolium repens*)) than blocks 3 and 4 (Table 1).

Table 1. Seed mixture used for fairway establishment in 2003 and botanical composition at the start of the Primo MAXX® trial in spring 2007.

Species	Cultivar	% (w/w) of seed mixture	% cover at initiation of Primo MAXX® trial		
			Block 1 and 2	Block 3 and 4	Mean
Poa pratensis	Conni	25	31	9	20
Poa pratensis	Eva	10			
Poa pratensis	Limousine	10			
Festuca rubra ssp. commutata	Bargreen	25	50	74	62
Festuca rubra ssp. commutata	Calliope	25			
Agrostis capillaris	Tracenta	5	5	15	10
Poa annua			8	2	5
Broadleaved weeds			6	0	3
Sum		100	100	100	100

Experimental plan

The experiment was laid out according to a randomized complete block design with plot size 2m x 3m, four blocks (replicates) and the following treatments:

1. Usprayed control
2. Primo MAXX, 0.5 l/ha (56.5 g a.i./ha) every four weeks
3. Primo MAXX, 1.0 l/ha (113 g a.i./ha) every four weeks
4. Primo MAXX, 1.5 l/ha (169.5 g a.i./ha) every four weeks
5. Primo MAXX, 2.0 l/ha (226 g a.i./ha) every four weeks
6. Primo MAXX, 3.0 l/ha (339 g a.i./ha) every four weeks

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. Actual application rates were recorded by weighing the tank before and after spraying. Table 2 shows actual rates and weather conditions for each spraying event.

Table 2. Weather conditions and actual application rates at the six spraying events.

Application date	Time of day (hours)	Weather conditions at application			Treatment number / application rate (l Primo MAXX® per ha)				
		Air temp. °C	Relative Humidity %	Wind Speed m/s	2. (target 0.5)	3. (target 1.0)	4. (target 1.5)	5. (target 2.0)	6. (target 3.0)
9 May	09-11	14	48	< 1.0	0.47	0.94	1.56	1.90	3.35
5 Jun.	09-11	15	60	< 1.0	0.58	1.06	1.67	1.93	3.19
4 Jul.	13-15	17	70	1.0-2.0	0.61	0.98	1.73	2.19	3.38
31 Jul.	08-10	18	55	1.0-2.0	0.55	1.05	1.66	2.28	3.41
28 Aug.	09-11	19	32	1.0-2.0	0.57	1.03	1.55	2.19	3.52
26 Sep.	09-11	11	69	< 1.0	0.52	1.07	1.55	2.01	3.15
Mean					0.55	1.02	1.62	2.08	3.33

Registrations

At two weeks intervals throughout the experimental period, turfgrass colour, tiller density, and turf general appearance were assessed by turfgrass scientist or technicians using a scale from 1 to 9 where 9 is darkest colour, highest tiller density and best turf quality. The assessments were conducted two and four weeks after application of Primo MAXX®. On the same dates, turfgrass diseases and broadleaf weed (including white clover) invasion were reported as per cent of plot area. Turfgrass height was recorded as the mean of three random measurements with a ordinary ruler in each plot, and the overall growth rate by weighing clippings in the basket of a walk-behind mower used in the 0.56 m x 1.88 m central area of each plot (Photo 1). Both raw weight and dry weight were recorded, the latter after drying for 24 h at 60ºC. By the end of the growing season, on 2 Nov., turfgrass dormancy colour was evaluated on a scale 1-9, where 1 is completely faded / brown turf, and 9 is completely green turf.

Photo 1a and b. Tatsiana Espevig collecting clippings in fairway trial at Landvik. Photos: Trygve S. Aamlid

Management

The experiment was mowed at 15 mm two times a week, usually on Monday and Friday. A triplex fairway mower without collection of clippings was used except when clipping weights were to be recorded. Granular fertilizer was applied at approximately monthly intervals as outlined in Table 3. The experiment was not irrigated except for small amounts of water to dissolve fertilizer after application. On 7 Aug., the trial was aerated using a vertidrain with 15 mm solid tines to 15 cm depth. Topdressing was accomplished on 8 Aug. and 5 Nov. at rates 0.75 and 1.5 kg pure sand per m^2, respectively.

The fairway trial at Landvik was not exposed to ordinary play, but it was was subjected to artifical wear from a wear drum one to two times per week.

Table 3. Fertilizer inputs, fairway trial, Landvik.

		Per ha							
Date	Fertilizer type	kg fertilizer	kg N	kg P	kg K	kg Mg	kg S	kg Ca	kg Fe
17 Apr.	Fullgjødsel 22-2-12	40	9	1	5	0	1	0	0
16 May	Fullgjødsel 22-2-12	70	15	1	8	1	2	1	0
12 Jun.	Arena Golf Extra 13-0-15	150	20	0	23	2	21	0	3
23 Jul.	Arena Golf Extra 13-0-15	130	17	0	20	2	18	0	3
9 Aug.	Arena Golf Extra 13-0-15	135	18	0	21	2	18	0	3
5 Sep.	Arena Golf Extra 13-0-15	150	20	0	23	2	21	0	3
SUM			99	2	100	10	80	1	11

Weather data

In SE Norway, the growing season 2007 was characterized by exceptionally high rainfall, especially in July, but also in May, June and August (Table 4). By contrast, September was unusually dry. Precipitation was recorded on 16 out of the 31 days in July; the cloudy summer weather is also reflected by a rather low irradiance during this month. The warmest period, with daily maximum temperatures in the range 23-29 ºC was recorded from 6 to 12 June.

Table 4. Weather data for Landvik meteorological station, about 200 m for experimental field. Normal values for temperature and rainfall are 'official' values for from the period 1961-90, while normal values for irradiance are calculated averages for the period 1994-2006.

	Mean temperature, ˚C		Precipitation, mm		Irradiance, MJ/m^2 (305-2800 nm)	
	2007	30 yr normal	2007	30 yr normal	2007	13 yr average
May	10.2	10.4	107	82	518	540
June	15.9	14.7	109	71	604	600
July	15.5	16.2	213	92	492	632
Aug.	16.2	15.4	132	113	476	476
Sep.	12.0	11.8	59	136	321	262
Mean / sum	14.0	13.7	620	494	2411	2510

3.2. Evaluation of Primo MAXX® on a golf course fairway, Lepaa, Finland

Experimental site

The Finnish fairway trial was laid out on 11 May 2007. The fairway was seeded to a mixture of smooth meadowgrass and chewing fescue (*Festuca rubra* spp. *commutata*) on a heavy clay soil (15% sand, 37% silt, 48% clay) at the Lepaa Unit of HAMK University of Applied Sciences, Finland (61°08'N, 24°20'E). 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. All observations and management of the trial was carried out by the HAMK Lepaa greenkeepers Petteri Lehmuskoski and Tommi Turunen except for the spraying treatments which were carried out by MTT's 'Good Experimental Practice' certified spraying team from Jokioinen (90 km from Lepaa).

Experimental plan and registrations

The experiment was laid out following the same plan and plot size as at Landvik, Norway (previous paragraph). Primo MAXX® was applied in accordance with the Finnish 'Good Experimental Practise' protocol, using a portable, compressed air-powered 'van der Weij' plot sprayer, mounted with a windshield and flat fan nozzles (Hardi 4110-12) and working at 180-250 kPa pressure. The spraying boom had four nozzles spaced 50 cm apart. The spraying volume corresponded to 200 l/ha. Full spray coverage was on the central 1.5m x 2.5 m of each plot. Table 5 shows application dates and weather conditions for each spraying event. The last application on 4 Oct. was conducted especially to evaluate potential effects of Primo MAXX® on turfgrass winter damage.

Table 5. Application dates and weather conditions in fairway and green trials at Lepaa.

Application date	Time of day (hours)	Air temp. °C	Relative humidity %	Wind Speed m/s	% cloud cover
11 May	09-11	11	29	0	25
8 Jun.	09-11	20	56	1.5	1
5 Jul.	13-15	23	47	2.5	70
3 Aug.	09-11	17	78	2.0	90
4 Sep.	09-11	11	90	1.0	90
4 Oct.	13-15	11	92	1.5	100

Photo 2. Austen Sutton, Syngenta (left) and greenkeeper Petteri Lehmuskoski, HAMK Lepaa Unit, in fairway trial at Lepaa, Finland, 29 Aug. 2007.

Photo: Oiva Niemelainen.

Registrations

Registrations were carried out at two-week intervals following the same program as at Landvik (previous section) except that weed occurrence and dormancy colour were not recorded. Plant height at Lepaa was determined using a Turf Check Prism device (Check Signature Inc., Shoreview, MN).

Management and wear

The experiment was mowed with a triplex fairway mower about three times per week. Mowing height ranged from 12 to 18 mm. Granular fertilizer Sportsmaster 26-2-9 was applied at equal rates on 8 May and 12 July, the total input corresponding to 156 kg N, 12 kg P, 54 kg K and 0.9 kg Fe per ha. Information about irrigation is given in Table 6. The trial was aerated or top-dressed in late autumn, after the completion of registrations.

During the growing season period, the trial was exposed to approximately 3.500 rounds of golf.

Weather data

Temperatures at Lepaa were higher the 30 yr normal values throughout the growing season (Table 6). August had the greatest deviation from the long-term average value. July had 49 % more, and August 42 % less rainfall than usual; over the whole experimental season, rainfall was close to the 30 yr normal value.

Table 6. Weather data for Hattula Lepaa weather station and irrigation in fairway and green trial at Lepaa golf course, 2007. Normal values for temperature and rainfall are official values for from the period 1971-2000 (Finnish Meteorological Institute)

	Mean temperature, °C		Rainfall, mm		Irrigation, mm (2007)	
	2007	30 yr normal	2007	30 yr normal	Fairway trial	Green trial
May	10.6	9.8	30	34	*	*
June	15.1	14.5	54	55	26	79
July	16.6	16.4	119	80	5	47
Aug.	16.4	14.6	43	74	7	50
Sep.	9.9	9.4	58	54	0	6
Mean / sum	13.7	12.4	304	297	37	188

* Data are unavailable for the period 1-26 May 2007 due to change of irrigation computer.

3.3. Evaluation of Primo MAXX® on a golf course putting green, Lepaa, Finland

Experimental site

The Finnish green trial was established on 11 May 2007 on a USGA green seeded to creeping bentgrass (*Agrostis stolonifera*, seed blend of 50% 'Penn A-4' and 50% 'Penn G-6') at Lepaa Golf Course.

Experimental plan

The experimental plan comprised five rates of Primo MAXX plus the unsprayed control treatment:

1. Usprayed control
2. Primo MAXX, 0.2 l/ha (22.6 g a.i./ha) every four weeks
3. Primo MAXX, 0.4 l/ha (45.2 g a.i./ha) every four weeks
4. Primo MAXX, 0.6 l/ha (67.8 g a.i./ha) every four weeks
5. Primo MAXX, 0.8 l/ha (90.4 g a.i./ha) every four weeks

The trial had four replicates, and a gross plot size of 2 m x 3 m. It was sprayed on the same dates and following the same GEP procedures as the fairway trial on the same location (Table 5).

Photo 3. Green trial at Lepaa ready for the first treatment on 11 May 2007. Photo: Oiva Niemelainen.

Registrations

Registrations followed the same program as in the Finnish fairway trial (previous section).

Management and wear

The experiment was mowed with a Triplex greens mower for an average of six times per week. Depending on weather and turfgrass density, mowing height was 5–7 mm in May and September and 3-4 mm from June to August. Information about irrigation and fertilizer inputs are given in Tables 6 and 7, respectively.

To avoid thatch accumulation, the trial was aerated with deep slitting knives every second week and with 8 mm needle tines once a month. Verticutting was accomplished every second week and topdressing with 0.1-0.7 mm finely graded sand at a rate of 1 kg per m2 every third week. The sand was brushed/irrigated into the green and the dressing was never done in close proximity to weighing of clippings.

Being located on a practise green, the experiment received wear from about 10.000 rounds of golf over the season. When placing holes on the green, care was taken to create as uniform wear as possible.

Table 7. Fertilizer inputs in green trial at Lepaa.

		Per ha							
Date	Fertilizer type	kg fertilizer	kg N	kg P	kg K	kg Mg	kg S	kg Ca	kg Fe
28.3.2007	Floratine Kevätstartti*	35	5.4	1.2	2.1				
5.4.2007	Floratine Kevätstartti	35	5.4	1.2	2.1				
19.4.2007	Floratine Kevätstartti	35	5.4	1.2	2.1				
26.4.2007	Sierraform Springstart (16-0-13)	250	40	0	32.5				2.50
15.5.2007	Sierraform All Season (18-3-15)	250	45	7.5	37.5	3.0			1.25
30.5.2007	Kemigreen Basic (23-4-14)	40	9	1.6	5.6	0.6	0.8		0.04
5.6.2007	Kemigreen Basic (23-4-14)	40	9	1.6	5.6	0.6	0.8		0.04
11.6.2007	Sierraform All Season (18-3-15)	250	45	7.5	38				
25.6.2007	Osmosol 614R (19-2-10)	40	7.6	0.8	4.0	0.5		1.7	0.04
2.7.2007	Osmosol 614R (19-2-10)	40	7.6	0.8	4.0	0.5		1.7	0.04
13.7.2007	Kemigreen Summer (18-0-17)	40	7.2	0	6.8			2.0	0.40
18.7.2007	Kemigreen Summer (18-0-17)	40	7.2	0	6.8			2.0	0.40
26.7.2007	Sierraform All Season (18-3-15)	250	45	7.5	37.5	3.0			1.25
14.8.2007	Kemigreen Summer (18-0-17)	40	7.2	0	6.8			2.0	0.40
27.8.2007	Greenmaster Autumn (6-2-8)	300	18	6	24	5.4			1.50
30.8.2007	Kemigreen Basic (23-4-14)	40	9	1.6	5.6	0.6	0.8		0.04
11.9.2007	Sierraform Springstart (16-0-13)	200	32	0	39				2.00
SUM			305	39	260	14.0	2.4	9.4	10

* Floratine Kevätstartti (Springstart) is composed of P-48 (10-21-6.6), Per 4 Max (15-0-0), Protesyn (3.5-0.6-1.8), and Plant Marvel (28-3-15).

3.4. Demonstration trials with Primo MAXX® at Ballerud Golf Course, Oslo, Norway

Experimental site and set-up

Ballerud GC is located on an old horticultural farm in a suburban area SW of Oslo. The course has greens with mostly dominated by creeping bentgrass, fairways almost exclusively dominated by annual meadowgrass, and smooth meadowgrass roughs with some tufts of perennial ryegrass (*Lolium perenne*).

Large-scale, unreplicated demonstration trials were laid out on green no. 9, fairway no. 9 and rough no. 9 on 5 June 2007. Plots sizes varied from 80 to 130 m^2. Unsprayed control plots were compared with plots sprayed with Primo MAXX® at rates 0.4, 1.5 and 2.2 l/ha and application intervals of approximately 3, 4 and 7 weeks on green, fairway and rough, respectively. In compliance with the Norwegian Food Authority's rule for complete closure of all sprayed areas for 48 h after each application, the trial on green no. 9 had to be discontinued after the second application on 18 June.

Three weeks later, it was replaced by a new trial laid out on the golf course' nursery green. Actual application dates in the green, fairway and rough trials are given in Table 8. The growth regulator was applied using a battery-operated electric Hardy Defender plot sprayer (Photo 4).

Table 8. Application dates for Primo MAXX in demonstration trials at Ballerud GC.

Green no. 9	Nursery green	Fairway no. 9	Rough no. 9
5 June		5 June	5 June
18 June			
	9 July	2 July	
	31 July	31 July	28 July
	21 Aug.		
	13. Sep.	3 Sep.	11 Sep.
	4 Oct.	28 Sep.	

Photo 4. Sprayer used in demonstrations trials at Ballerud Golf Course.

Photo: Terje Haugen.

Registrations

In all trials at Ballerud, turfgrass general appearance was evaluated by the headgreenkeeper at one to two week intervals throughout the growing season. In the green and fairway trials, turfgrass clipping yields were recorded on a fresh weight basis. Registrations in the green trials also included regular assessments of green speed using a standard stimpmeter.

Maintenance

The green trials at Ballerud were mowed daily at 3.4-3.8 mm and the fairway trial at 20 mm three to four times a week. The rough area was only mowed upon need.

Due to the rich soil from decades of vegetable production, the rough trial was not fertilized in 2007, and the fairway trial only received one application of 200 kg Fullgjødsel® 11-5-18 (22 kg N/ha) on 8 May. The green trials received monthly applications of granuar fertilizer (Gro Power 5-1-1, Anderson 14-0-9, Anderson 8-0-16, and/or Roots 12-2-12), and weekly applications of liquid fertilizers /

biostimulants, mostly Floratine products. Total rates of N, P, K, Mg, Ca, S and Fe over the season were 155, 14, 142, 27, 30, 73 and 14 kg/ha, respectively. The greens were aerated, mostly using Envirojet, six times during the season and top-dressed, also six times, giving a total of 6.3 kg sand per m^2.

Weather data and irrigation

Table 3 shows recordings from Ballerud GC's weather station. Although the rainfall in 2007 was higher than usual, there were periods, especially in May, June and August when the green trials needed irrigation. The fairway and rough trials were never irrigated.

Table 9. Weather recordings and irrigation at Ballerud GC, 2007. Monthly temperatures are means of daily maximum and minimum temperatures.

	Mean monthly temperature, °C	Monthly rainfall, mm	Monthly irrigation, mm (greens only)
May	11.2	94	42
June	17.1	185	52
July	16.9	173	10
Aug.	16.6	83	47
Sep.	11.1	71	21
Mean / sum	14.6	606	172

3.5. Demonstration trial with Primo MAXX® at Oslo Golf Club, Bogstad, Norway

To evaluate the effect of Primo MAXX® on a typical annual meadowgrass green, an unreplicated demonstation trial with plot size 250 m^2 was laid out at Oslo GK on 20 June 2007. Primo MAXX® was sprayed at a rate 0.4 l/ha on 20 June, 10 July and 31 July using the same sprayer as at Ballerud GC, about 10 km from Bogstad (Photo 4). Turfgrass quality (general appearance) and fresh weight clipping yields were determined on 4 July, 13 July and 14 August. Unfortunately, the trial had to be discontinued in mid August due to reconstruction of the green.

3.6. 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 on each plot and on plot values which had been averaged, either over the whole growing season, separately over the spring (before 10 June), summer (10 June – 1 Sep.) and autumn (after 1 Sep.) periods, or for observations conducted two versus four weeks after the last application of Primo MAXX®. The significance levels P%<0.1, P%<1, P%<5 and ns (not significant) have been indicated in the tables along with LSD values for effects significant at P%<5. In a few cases exact P-values have been given for tendencies in the 5-15% probability range. As an indications of the variability for each character, coeffcients of variation, (CV %), have also been given in the tables.

4. Results

4.1. Evaluation of Primo MAXX® under fairway conditions, Bioforsk Landvik, Norway

Turfgrass quality and related characteristics

Table 10 shows results from the visual observations of turfgrass quality and related characters in the fairway trial at Landvik. Both within the three seasons and as a mean value, turfgrass general appearance was significantly lower on plots receiving monthly applications of Primo MAXX® at 1.0 l/ha or higher rates than on unsprayed control plots and plots receiving 0.5 l/ha. Within these two groups, differences in generall appearance were not significant. Separate analyses for blocks 1 and 2 versus 3 and 4 indicated that these responses were practically identical regardless of botanical composition (data not shown).

Individual registrations of turfgrass quality are further depicted in Fig. 1. There was a dramatic decline in quality after the first application on 9 May. After this the turf recovered and there was no significant effect of Primo MAXX® at the two subsequent evaluations. Applications of 1.0 l/ha or higher rates on 4 July lead to new quality reductions in July, August and September (Photo 5); these effects were especially apparent at the last evaluation in early November (Photo 6). By contrast, there tended to be a small quality improvement due to the lowest rate of Primo MAXX® from late August to October. This improvement was reflected also in a significant increase in tiller density on average for the whole growing season (Table 10).

Increasing rates of Primo MAXX® consistently led to darker turf throughout the growing season, but also to earlier growth cessation and a less attractive dormancy colour in late autumn (Table 10). The only visible disease in the trial was a slight attack of red thread (*Laetisaria fuciformis*) during the wet period in July; however, these spots were unaffected by Primo MAXX® which also had no effect on the occurrence of broadleaved weeds, primarily white clover, in the trial.

Table 10. Turfgrass quality, tiller density, within-season colour, dormancy colour and infestation of weeds and red thread (*Laetisaria fuciformis*) in fairway at Landvik as affected by increasing rates of Primo MAXX®, 2007. Visual merit and tiller density are means of twelve observations (two in spring, i.e. before 10 June, six in summer, i.e. from 10 June to 1 Sep., and four in autumn, i.e. after 1 Sep. Within season colour (green darkness) and occurrence weeds and red thread are means of twelve, three (all in July) and two (June and Nov.) observations, respectively. Dormancy colour was evaluated on 2 Nov. All values are means of four blocks.

Primo MAXX®, rate	Turf quality (general appearance, 1-9)				Tiller density (1-9)	Within season colour (1-9)	Dor-mancy colour (1-9)	% of plot area	
	Mean	Spring	Summer	Autumn				Dicot weeds	Red thread
0 = Control	6.2	6.1	6.4	6.0	6.3	5.2	6.8	4	4
0.5 l/ha	6.1	5.6	6.3	6.2	6.5	5.6	6.3	2	3
1.0 l/ha	5.5	4.5	5.9	5.3	6.1	5.8	5.0	5	2
1.5 l/ha	5.3	4.6	5.5	5.4	6.0	5.9	4.1	4	3
2.0 l/ha	5.5	4.6	5.9	5.3	6.1	6.0	4.3	3	2
3.0 l/ha	5.1	4.2	5.5	4.9	6.0	6.2	3.5	4	3
P%	<0.1	<0.1	<1	<0.1	<1	<1	<0.1	ns	ns
LSD 5%	0.3	0.5	0.4	0.4	0.2	0.4	1.2	-	-
CV%	4	7	5	5	3	5	15	-	-

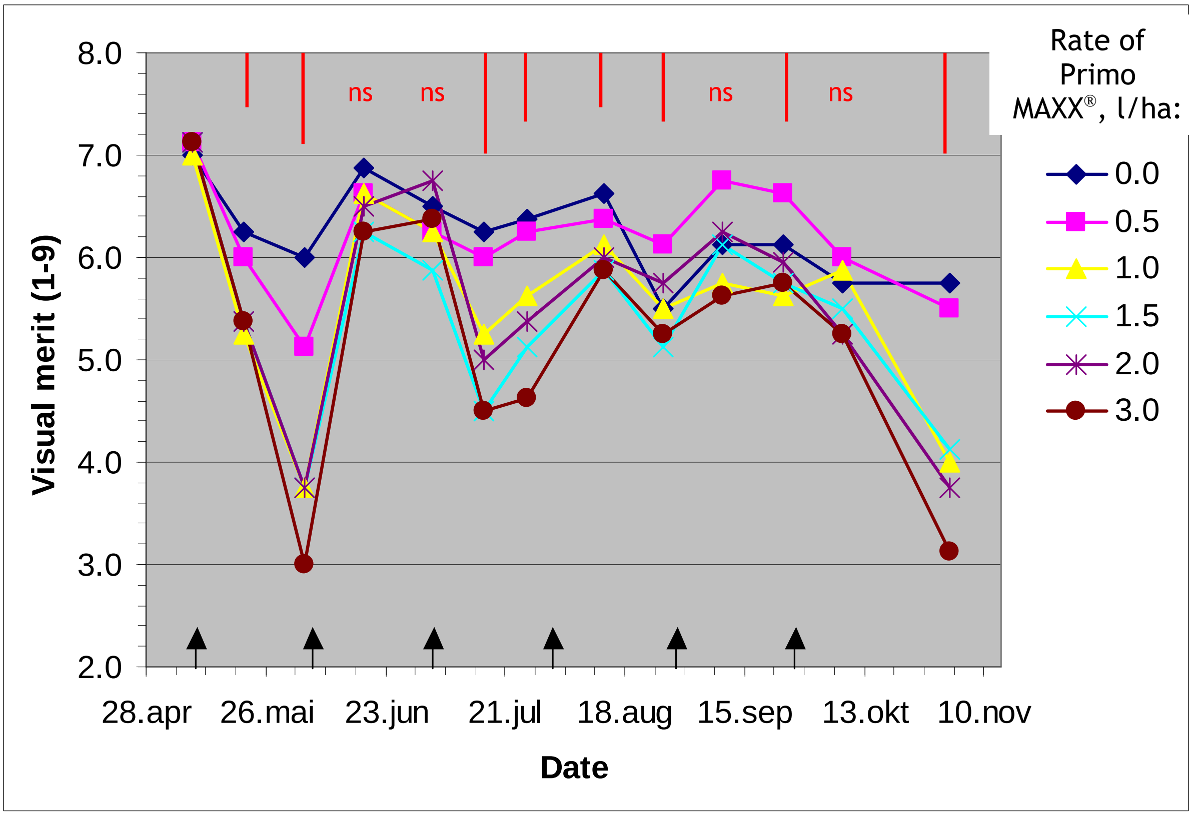


Fig.1. Turfgrass overall quality as affected by increasing rates of Primo MAXX® in fairway trial at Landvik, 2007. Mean of four replicates (blocks). The application dates 9 May, 5 June, 4 July, 31 July, 28 Aug. and 26. Sep. are indicated by black arrows. Red bars indicate LSD 5%.

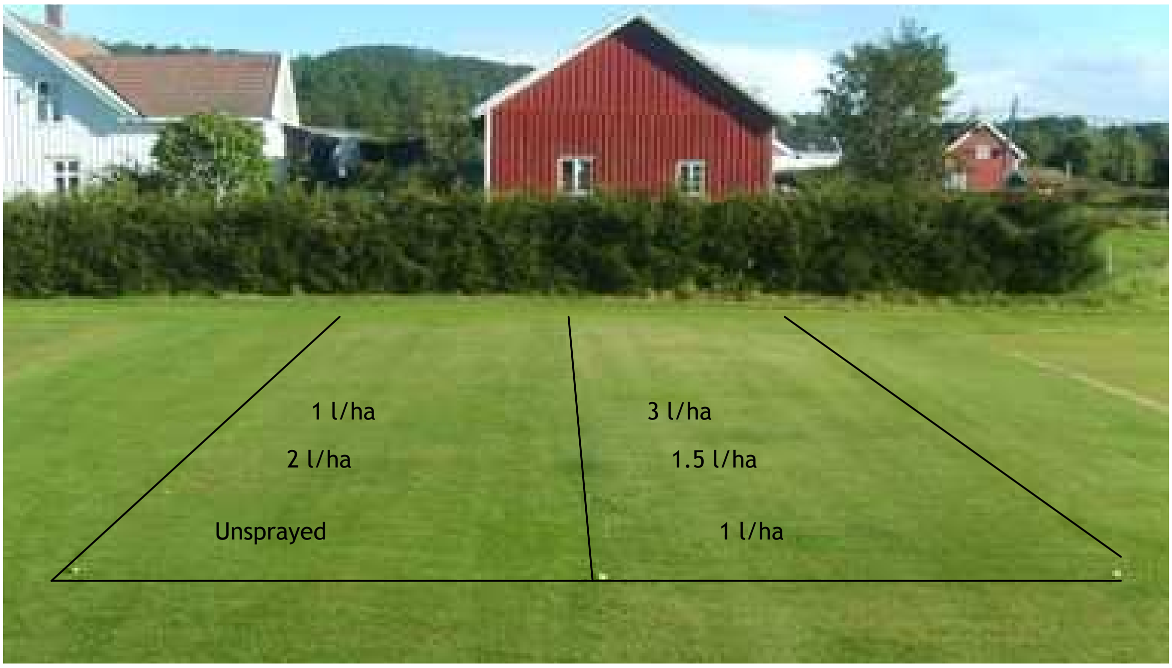


Photo 5. Visual appearance of fairway trial at Landvik, block 1 and 2, on 10 Sept. Within each block, the treatments closest to the photographer have been labeled. High rates of Primo MAXX® resulted in darker, in some cases, almost brown, turf. Photo: Trygve S. Aamlid.

Photo 6.

Turf quality / dormancy colour at growth cessation on 2 Nov. 2007 after application of Primo Maxx at 3.0 l/ha (left) and 0.5 l/ha (right), last application on 26 Sep.

Photo: Trygve S. Aamlid.

Turfgrass height and dry matter production

The average effect of Primo MAXX® on plant height and clipping yields are given in Table 11. In all blocks, the growth regulator caused a significant reduction in plant height even at the lowest rate, but contrary to expectation, this low rate also tended to increase aboveground dry matter production as compared with the unsprayed control treatment. This might reflect a higher tiller density, as also suggested in Table 10. Separate analyses for various parts of trial showed that the average reduction in clipping yield due to Primo MAXX® was stronger in blocks 1 & 2 which had more *Poa* species less red fescue and browntop bent and than blocks 3 & 4. On average for eleven harvests and all replicates, there was a slight tendency for Primo MAXX® to increase the dry matter percentage of turfgrass clippings (P% = 16, Table 11).

Table 11. Absolute and relative effects of increasing rates of Primo MAXX® on turfgrass height, turfgrass dry matter production, and per cent dry matter of clippings in fairway trial at Landvik, 2007. Mean of eleven observations. Plant height above 15 mm represents an average of four days' growth.

Primo MAXX, rate	Plant height, mm		Production of turfgrass clippings, g/m^2/day				% dry matter in clippings
	mm	Rel.	Block 1&2	Block 3&4	Mean	Rel.	
0 = Control	21.9	100	1.78	1.62	1.70	100	31.5
0.5 l/ha	20.9	95	1.91	1.93	1.92	113	32.2
1.0 l/ha	20.7	95	1.65	1.72	1.69	99	32.5
1.5 l/ha	20.0	91	1.46	1.46	1.46	86	33.6
2.0 l/ha	20.3	93	1.55	1.61	1.58	93	32.4
3.0 l/ha	19.5	89	1.31	1.70	1.51	88	33.1
P%.	<0.1	-	10	ns	<5	-	16
LSD 5%	0.7	-	-	-	0.29	-	-
CV%	2	-	10	14	12	-	3

In absolute terms, turfgrass clipping yield showed a distinct seasonal pattern with peaks during the warm and sunny periods in early June and late August (Fig. 2a). The low clipping yield on 17 July was probably due to 280 mm rainfall, and thus nutrient leaching, since the last fertilizer application on 12 June (Tables 3 and 4). Separate analyses of variance for each day indicated a significant effect of Primo MAXX® on clipping yield only on 4 June.

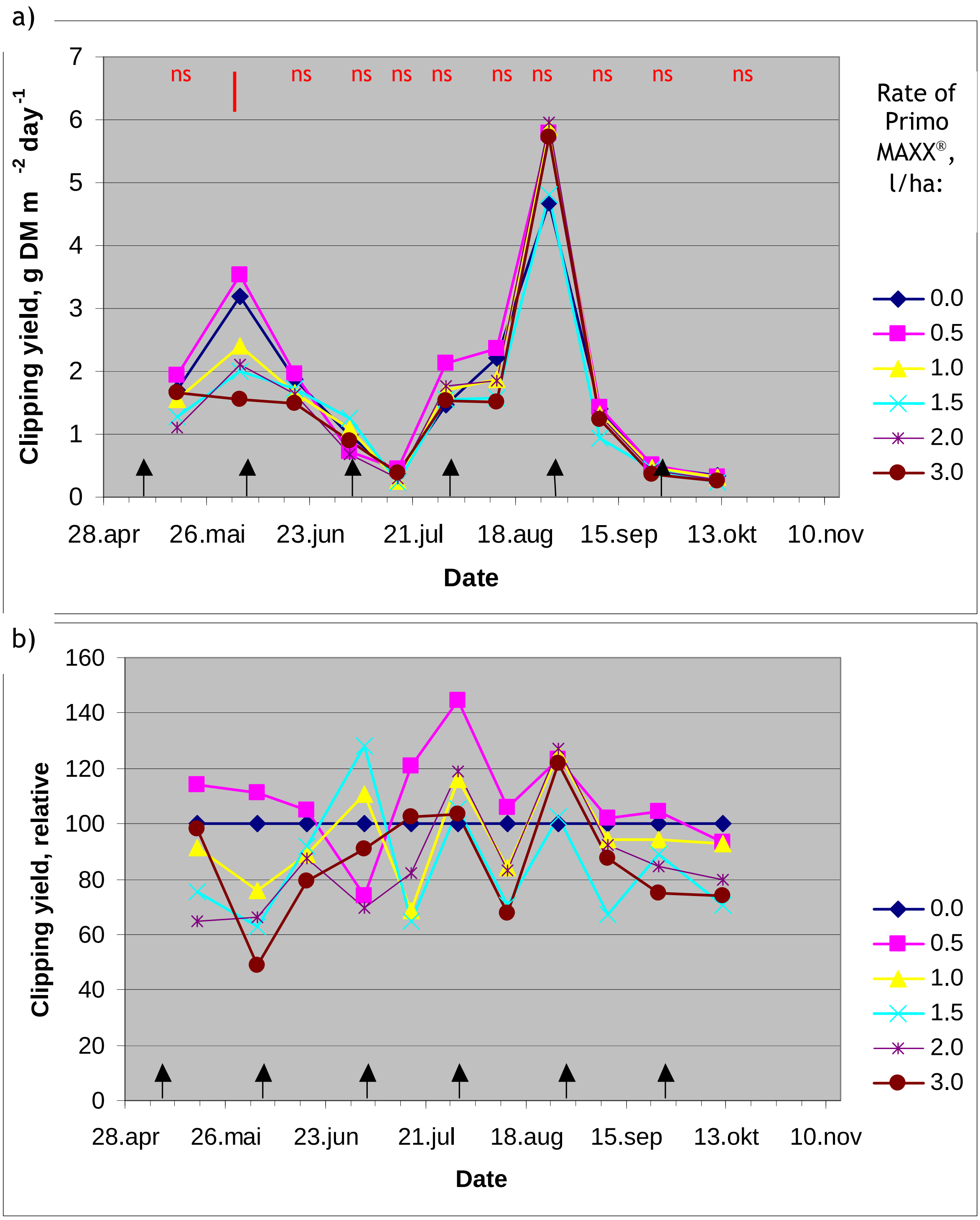


Fig. 2. Absolute (a) and relative (b) reductions in daily dry matter production of turfgrass clippings as affected by increasing rates of Primo MAXX® in fairway trial at Landvik. Red text/bars and black arrows indicate probability / LSD values and application dates 9 May, 5 June, 4 July, 31 July, 28 Aug. and 26 Sep., respectively. In (b), the clipping yield on each date was set to 100 in the unsprayed control treatment.

In relative terms, none of the Primo MAXX® treatments produced clipping yields that were lower than the unsprayed control at all harvests (Fig. 2b). Many of the treatments showed a typical suppression / rebound pattern with clipping yields lower than the control treatment at one harvest, but higher than control treatment at the next harvest.

4.2. Evaluation of Primo MAXX® on a golf course fairway, Lepaa, Finland

On average for two observations in spring, five observations in summer and two observations in autumn, Primo MAXX® had no effect on turfgrass general appearance in the fairway trial at Lepaa. Among the nine observation dates, significant differences were recorded only on 21 August when the plots sprayed with the highest dose (3.0 l/ha) had an average visual merit score of 5.5 as opposed to 6.8 for unsprayed control plots and plots sprayed with the lowest dose (0.5 l/ha).

On average for observations, increasing rates of Primo Max caused an overall increase in tiller density, while turfgrass colour was not significantly affected. No diseases were observed during the growing season.

Table 12. Turfgrass quality (1-9, 9 is best quality), tiller density (1-9, 9 is highest density) and within-season colour (1-9, 9 is darkest green) in fairway trial at Lepaa as affected by increasing rates of Primo MAXX®. Means of nine observations (two in spring, i.e. before 10 June, five in summer, i.e. from 10 June to 1 Sep., and two in autumn, i.e. after 1 Sep.). All values are means of four blocks.

Primo MAXX®, rate	Turf quality (general appearance, 1-9)				Tiller density (1-9)	Within season colour (1-9)
	Mean	Spring	Summer	Autumn		
0 = Control	6.1	5.5	6.1	6.8	5.5	6.1
0.5 l/ha	6.2	5.5	6.1	7.0	5.8	6.2
1.0 l/ha	6.1	5.4	6.1	6.9	5.8	6.1
1.5 l/ha	6.2	5.5	6.2	7.0	6.0	6.3
2.0 l/ha	6.2	5.6	6.1	6.9	6.1	6.3
3.0 l/ha	6.2	5.6	6.1	7.0	6.4	6.2
P%	ns	ns	ns	ns	<0.1	ns
LSD 5%	-	-	-	-	0.4	-
CV%	5	4	8	3	3	4

The effect of Primo MAXX® on turfgrass plant height and clipping yield depended on the time since last application. On average for five observations conducted about two weeks after application, the highest rate of Primo MAXX® caused significant reductions in plant height and clipping yield corresponding to 11 and 48 %, respectively (Table 13). On average for four observations conducted four weeks after application, the maximal reductions were only 3 and 14 %, respectively. Fig. 3 illustrates the unstable effect of Primo MAXX®, particularly toward the end of the growing season. However, unlike in the fairway trial at Landvik (Fig.2), clipping yields on sprayed plots were rarely higher than on untreated control plots in the trial at Lepaa.

Table 13. Absolute and relative effects of increasing rates of Primo MAXX® on turfgrass height and dry matter production in turfgrass clippings in fairway trial at Lepaa 2007. Observations conducted 2 weeks (5 observations) and 4 weeks (4 observations) from spraying treatment have been presented separately.

Treatment	Plant height (mm)				Weight of clippings (g DM / m^2 / day)			
Time after treatment	2 weeks	4 weeks	Mean	Rel	2 weeks	4 weeks	Mean	Rel
0 = Control	15.7	16.0	15.8	100	3.2	7.0	4.9	100
0.5 l/ha	15.7	16.0	15.8	100	2.7	6.3	4.3	87
1.0 l/ha	14.9	16.0	15.4	97	2.8	6.6	4.5	92
1.5 l/ha	14.7	15.7	15.1	96	2.3	5.8	3.9	79
2.0 l/ha	14.4	15.6	15.0	95	2.1	6.1	3.9	80
3.0 l/ha	14.0	15.5	14.6	92	1.8	6.0	3.7	75
P%	<0.1	ns	<5	-	<0.1	ns	ns	-
LSD 5%	1.1	-	1.0	-	0.7	-	-	-
CV%	3	4	3	-	13	22	18	

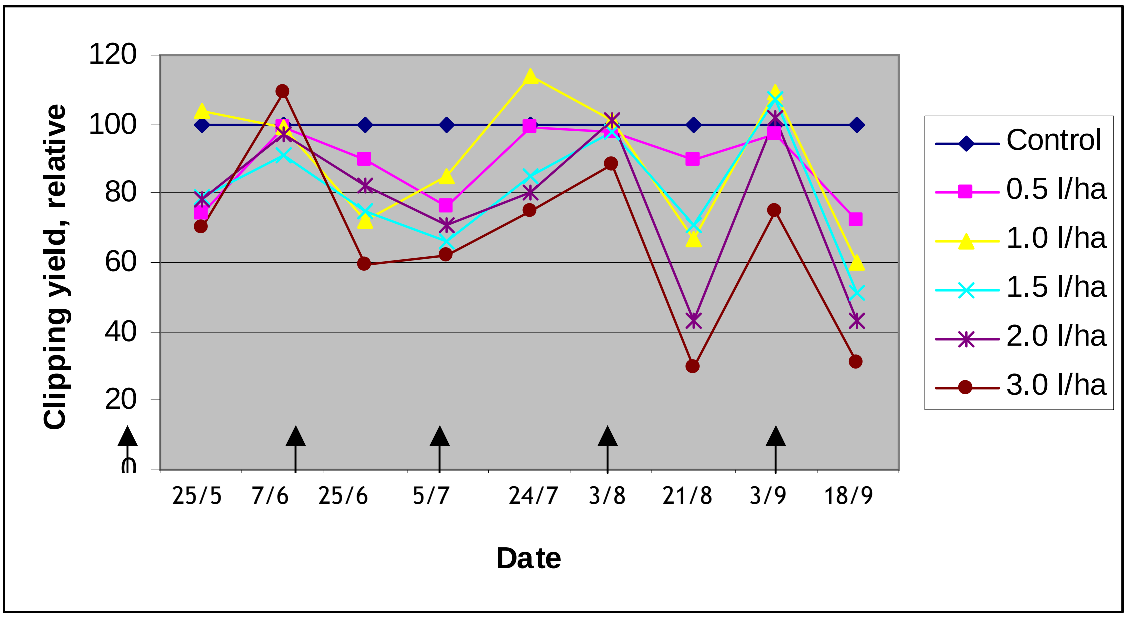


Fig. 3. Relative clipping weights (control = 100) in fairway trial at Lepaa, Finland. Spraying treatments indicated by black arrows were carried out on 11 May, 8 June, 5 July, 3 Aug. and 4 Sep. (The last spraying on 4 Oct. was done primarily to study the effect of Primo MAXX® on overwintering and was not followed by observations in late autumn.)

4.3. Evaluation of Primo MAXX® on a golf course putting green, Lepaa, Finland

On 3 Sep. 2007, a significantly higher tiller density was recorded on green plots sprayed with the highest rate of Primo MAXX® than on unsprayed control plots (data not shown). Otherwise, Primo MAXX® had no significant effect on either general appearance, tiller density or turfgrass colour in the green trial at Lepaa (Table 14). Although the effects on plant height and clipping yields were also not significant, reductions were generally stronger when recorded at two compared with four weeks after application (Table 15, Fig. 4).

Table 14. Turfgrass quality, tiller density and within-season colour (darkness) in green trial at Lepaa as affected by increasing rates of Primo MAXX®, 2007. Means of nine observations (two in spring, i.e. before 10 June, five in summer, i.e. from 10 June to 1 Sep., and two in autumn, i.e. after 1 Sep.). All values are means of four blocks.

Primo MAXX®, rate	Turf quality (general appearance, 1-9)				Tiller density (1-9)	Within season colour (1-9)
	Mean	Spring	Summer	Autumn		
0 = Control	6.4	6.1	6.6	6.3	6.3	6.4
0.2 l/ha	6.3	6.0	6.5	6.0	6.3	6.4
0.4 l/ha	6.3	5.9	6.5	6.1	6.2	6.3
0.6 l/ha	6.3	5.8	6.5	6.4	6.3	6.4
0.8 l/ha	6.2	5.8	6.4	6.3	6.2	6.4
P%	ns	ns	ns	ns	ns	ns
LSD 5%	-	-	-	-	-	-
CV%	3	5	5	7	2	3

Table 15. Absolute and relative effects of increasing rates of Primo MAXX® on turfgrass height and dry matter production in turfgrass clippings in green trial at Lepaa 2007. Observations conducted 2 weeks (5 observations) and 4 weeks (4 observations) from spraying treatment have been presented separately. Plant heights above 3 mm represent one day's growth.

Treatment	Plant height (mm)				Weight of clippings (g DM / m^2 / day)			
Time after treatment	2 weeks	4 weeks	Mean	Rel	2 weeks	4 weeks	Mean	Rel
0 = Control	4.3	3.9	4.1	100	2.60	2.21	2.43	100
0.2 l/ha	4.1	3.8	4.0	96	2.20	2.28	2.23	92
0.4 l/ha	4.0	3.9	3.9	95	1.88	2.28	2.06	85
0.6 l/ha	4.0	3.8	3.9	94	1.72	2.18	1.99	82
0.8 l/ha	3.8	3.9	3.9	93	1.75	2.28	1.92	79
P%	11	ns	ns	-	5	ns	ns	-
LSD 5%	-	-	-	-	0.9	-	-	-
CV%	6	7	8	-	20	14	16	-

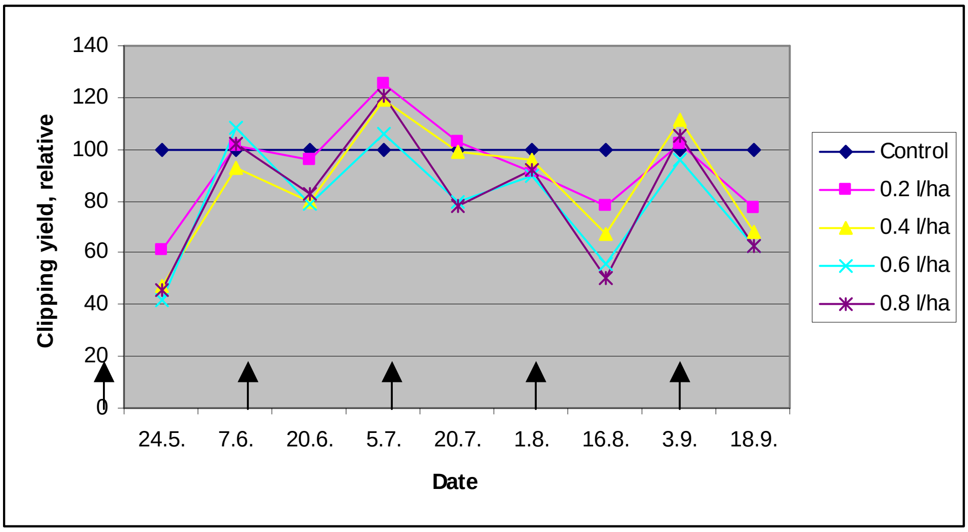


Fig. 4. Relative clipping weights (control = 100) in green trial at Lepaa, Finland. Spraying treatments indicated by black arrows were carried out on 11 May, 8 June, 5 July, 3 Aug. and 4 Sep. (The last spraying on 4 Oct. was done primarily to study the effect of Primo MAXX® on overwintering and was not followed by observations in late autumn.)

4.4. Demonstration trials with Primo MAXX® at Ballerud Golf Course, Oslo, Norway

Green trials

Applications of 0.4 l/ha Primo MAXX® on 5 and 18 June did not affect turf general appearance (Photo 7) or stimpmeter readings on green no. 9 at Ballerud. During the period 14-29 June, clippings were reduced by an average of 32%, but after spraying had been discontinued, there was a rebound effect corresponding to a 26 % increase in clipping yield in the period 12-25 July (data not shown).

Photo 7. Terje Haugen (left) and Lasse Augustsson on green no. 9 at Ballerud Golf Course, 27 June 2007. Photo: Trygve S. Aamlid.

Photo 8. Field day at Ballerud Golf Course 27 Aug. 2007. Photo: Tatsiana Espevig.

Fig. 5 summarizes results from the nursery green trial established on 9 July. In this trial, application of Primo MAXX® about every third week resulted in better colour (not shown), higher green speed (Fig. 5a), and an average reduction in turfgrass clippings of 44 % (Fig. 5b and c). Fig 5b shows that the reduction in clipping yield was most conspicuous during the periods of rapid growth in mid to late July (after only one application of Primo MAXX®) and in late August.

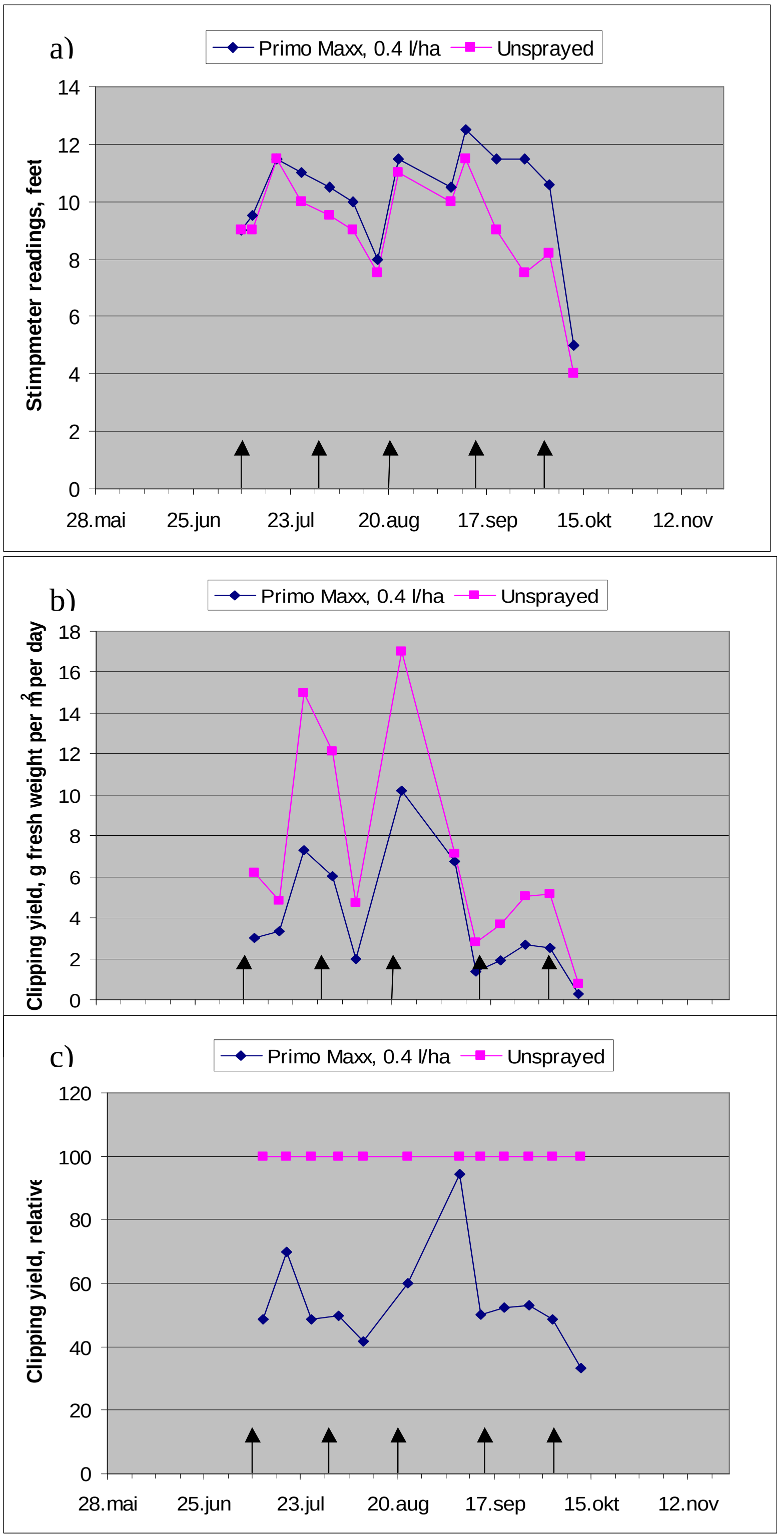


Fig. 5. Effects of spraying Primo MAXX® every three weeks of green speed and absolute and relative clipping yield on nursery green at Ballerud GC, 2007. Black arrows indicate the application dates 9 July, 31 July, 21 Aug., 13 Sep. and 4 Oct.

Fairway trial

As evaluated by the headgreenkeeper, monthly applications of 1.5 l/ha Primo MAXX® (1.5 l/ha) had no negative impact on turf quality in the fairway trial at Ballerud (Fig. 6). Photos 9-11 show, nevertheless, that treated turf was more faded, grayish, and less green than untreated turf. The pronounced colour difference in favour of Primo MAXX® in early September (Fig. 6) was due to less dry spots than the in the control area. While these spots recovered after rainfall on 10 and 17 Sep., the last application of Primo MAXX® on 4 Oct. led to an apparent loss of colour and drop in turf general appearance in late autumn (Photo 11).

On average for 17 clipping, regular application of Primo MAXX® resulted in a 37 % reduction in the fresh weight of turfgrass clippings (Fig. 7). The only time clipping yield was higher on the treated than on the untreated area was at the first clipping nine days after the first application and on 7 Sep. The latter coincided with the observation of less dry spots after use of Primo MAXX®. It may also be interpreted as a rebound effect following growth suppression after application on 31 July.

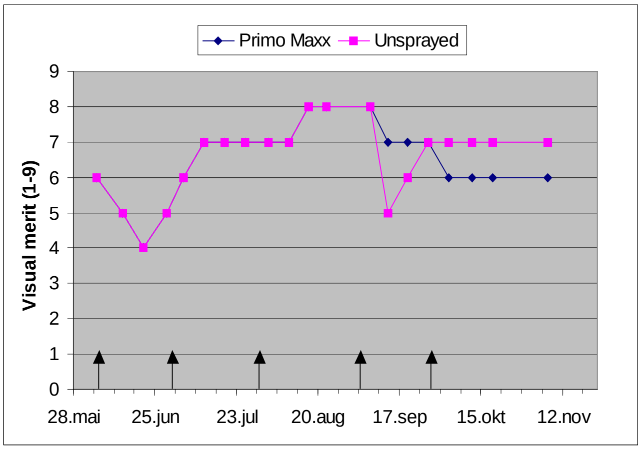


Fig. 6. Effect of Primo MAXX® on turfgrass general appearance in fairway trial at Ballerud GC. Black arrows indicate application dates. (Sprayed an unsprayed plots had identical scores until the beginning of September)

Photo 9. Difference in colour and general appearance of treated and untreated fairway Ballerud GC, 27 June. Photo: Trygve S. Aamlid.

Photo 10. Difference in colour and general appearance of treated and untreated fairway Ballerud GC, 27 Aug. Photo: Tatsiana Espevig.

Photo 11. Difference in colour and general appearance of treated and untreated fairway Ballerud GC, 3 Dec. Photo: Terje Haugen.

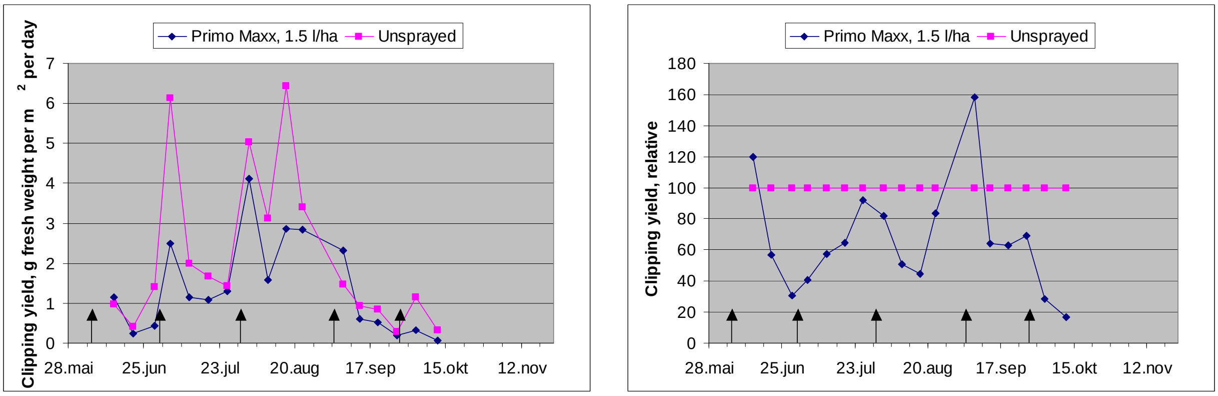


Fig. 7. Absolute (a) and relative (b) reductions in clipping yield resulting form application of Primo MAXX® in fairway trial at Ballerud GC. Arrows indicate application dates.

Spraying 2.2 l/ha of Primo MAXX® at six weeks interval resulted in discoloration and consistent drop in turf quality in the rough trial at Ballerud (Fig. 8, Photos 12 and 13). The effect was most conspicuous in late autumn. Primo MAXX® had less effect on tufts of perennial ryegrass which stood out very markedly in the turf which was otherwise dominated by smooth meadowgrass. Clipping yields were not recorded in this trial.

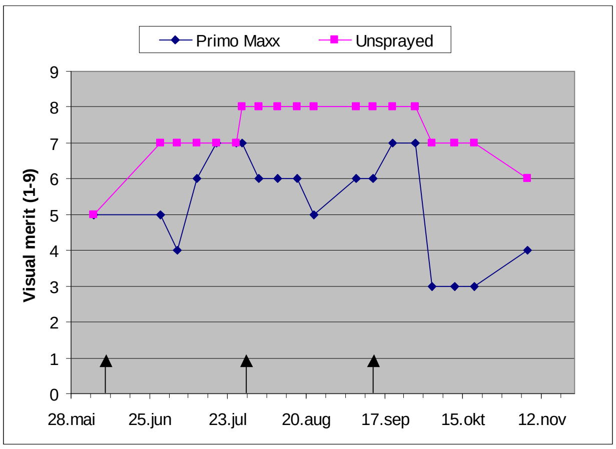


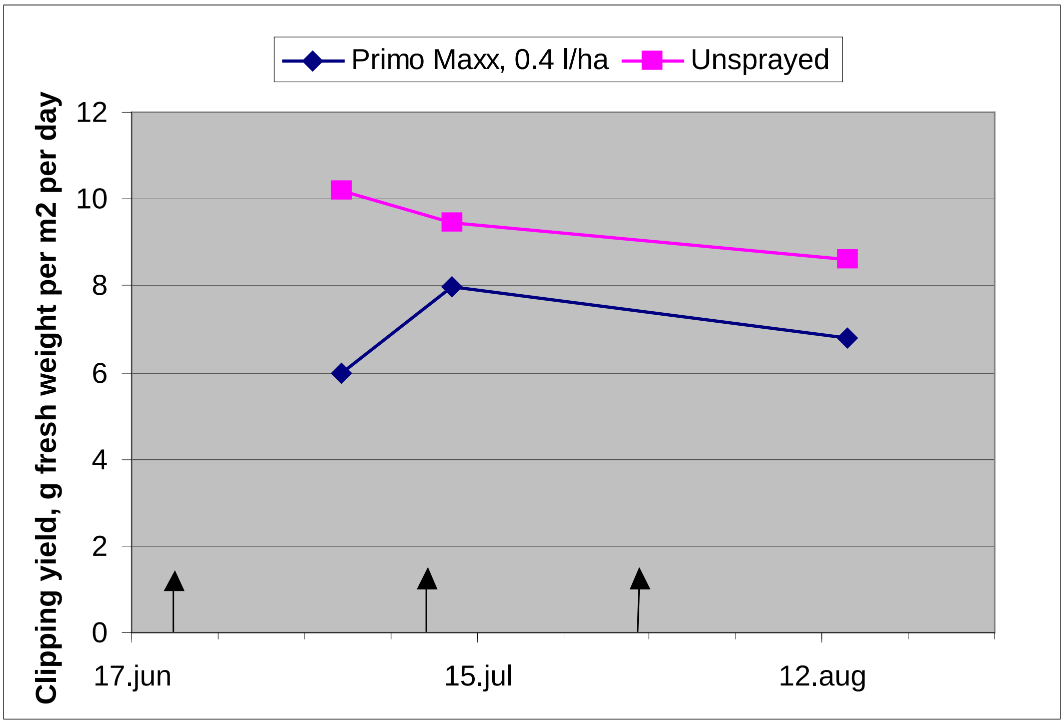
Fig. 8 (upper left). Difference in colour and general appearance of treated and untreated area in rough no 9, Ballerud, 27 June. Photo: Trygve S. Aamlid.

Photo 12 (upper right). Terje Haugen (left) and Lasse Augustsson in rough trial at Ballerud GC, 27 June. Photo: Trygve S. Aamlid.

Photo 13 (lower left). Trygve S. Aamlid inspecting rough trial at Ballerud GC, 27 August 2007. Tufts of ryegrass stand out very markedly on sprayed area.
Photo: Tatsiana Espevig.

4.5. Demonstration trial with Primo MAXX® at Oslo Golf Club, Bogstad, Norway

Application of 0.4 l Primo MAXX® at three week intervals resulted in darker turf but had otherwise no effect on the turfgrass quality of annual meadowgrass at Oslo GC. On average for three registrations, the Primo MAXX led to a 26% reduction in clipping yields (Fig. 9).



5. Discussion and suggestions for 2008

The starting point for evaluating Primo MAXX® in this two-year project was the rates and applications frequencies recommended for the product in Europe (Syngenta 2007, Table 16). Based on our experiences from agricultural crops that the optimal rates may be different in the Nordic countries than countries further south, higher and lower rates were included in the GEP trials both to determine the potential growth inhibition and the risk for discoloration or other phytotoxic effects. All taken together, the results from the first project year confirms that the guidelines in Table 16 are not directly applicable in Scandinavia and that further research is needed to find the optimal way of using the product under Nordic conditions.

Table 16. Dose rates and applications frequencies recommended for Primo MAXX® in the United Kingdom (Syngenta 2007).

	Dose rate		Application
	Primo MAXX®, l/ha	trinexapac-ethyl, g a.i./ha	frequency
Fairways	0.8 – 1.6	90 - 180	Every four to five weeks
Roughs & semi-roughs	1.6-2.4	180 - 240	Every five to eight weeks
Greens	0.4	45	Every two to four weeks

On fairway, the average reduction in clipping yield caused by monthly application of the intermediate Primo MAXX® rate of 1.5 l/ha was 15 and 21 % in the GEP trials at Landvik and Lepaa, respectively. By contrast, monthly application of 1.5 l/ha resulted in a 37 % reduction in clipping yield in the demonstration trial at Ballerud GC, which is closer to the data presented by Syngenta (2007). In agreement with Table 11 showing an increase in turfgrass dry matter percentage (i.e. decreased succulence) after application of Primo MAXX®, one of the reasons for this difference might be that clipping yields were determined on a dry weight basis in the GEP trials but on a fresh weight basis at Ballerud GC and in the data presented by Syngenta (2007). Another, and probably more important explanation, is the difference in species composition among the three trials. While the plant cover at Ballerud was almost 100% by annual meadowgrass, the species composition at Landvik varied with the two blocks showing the least response to Primo MAXX® having a plant cover of 74 % red fescue (Tables 1 and 11). By contrast, smooth meadowgrass dominated over red fescue at Lepaa due to the heavy soil type, use of irrigation, and relatively high nitrogen input. Unfortunately, we have not been able to find many references about the specific effects of Primo MAXX® on red fescue turf, but our results are in partial agreement with Pannacol et al. (2004) who found 40 %, 21 %, and no significant reduction in clipping yield after using trinexapac-ethyl in smooth meadowgrass, chewing fescue and creeping red fescue, respectively.

Perhaps the most conspicuous feature of the present results was the unstable effect of Primo MAXX® on clipping yields due to the postsuppression rebound effect. In the fairway trial at Lepaa, Finland, this resulted in clipping yield reductions being significant only two weeks after application (Table 13), and a similar tendency could be seen also in the green trial (Table 15). In Norway, clipping yields four weeks after spraying were often higher than on unsprayed control plots in the fairway trial at Landvik (Fig. 2), and a strong rebound effect was observed also after spraying treatments had to discontinued at green no. 9, Ballerud GC. The unstable effect in of Primo MAXX® in these trials was probably due to a rapid degradation of trinexapac-ethyl in plant tissue and a higher regrowth potential due to accumulation of carbohydrate reserves and GA_1 precursors during the suppression phase (Lickfeldt et

al. 2001, Branham & Beasley 2007). In North-American experiments, Lickfeldt et al. (2001) reported clipping yields reductions in smooth meadowgrass to be much more consistent when trinexapac-ethyl was applied at four than at six week intervals, but under Nordic long-day conditions, spraying every second, or at least every third week, may well be necessary to stabilize low GA_1 levels, not only on greens, but also on fairways and tees. Although there was a surge effect during the driest period in mid September, the most stable clipping reductions in our trials, on average 44 % on a fresh weight basis, were, indeed, obtained on the nursery green which was sprayed about every third week at Ballerud GC (Fig. 5c). While Branham & Beasley (2007) noted that temperature was the most important factor determining degradation of trinexapac-ethyl in turfgrass tissue, our results suggest that other factors such as light and water availability may also be important for the rebound effect under Nordic conditions. Very clearly, application frequency is a major question that has to be addressed during the continuation of this project.

The potential reductions in mowing costs from using a plant growth regulator will always have to be weighed against the risks for discoloration or other harmful effects on turf quality. In the present trials, reductions in general appearance (visual merit) scores were far more conspicuous in the GEP trial at Landvik than in the GEP trials at Lepaa or the demonstration trials at Ballerud GC. Apart from possible effects of different botanical compositions, this might reflect a subjective human factor, i.e. different backgrounds and attitudes of the observers in the various trials. While the fairway trial at Landvik was evaluated by turfgrass scientists and technicians with long experience from turfgrass variety testing, the trials at Lepaa and Ballerud were evaluated by greenkeepers working on the course. While the observers at Landvik may have paid more attention to turf aesthetic values such as less intense colour, and less vigorous and uniform plots, the observers at Lepaa and Ballerud may well have been more attentive to ball roll and other functional characteristics of the playing surface. The less succulent but significantly darker green turf resulting from high Primo MAXX® rates at Landvik are in agreement with other studies showing higher mesophyll cell densities and chlorophyll concentrations resulting from less elongation of leaf cells (Heckman et al. 2001, Ervin & Zhang 2008). As for tiller density, most literature supports the Finnish rather than the Norwegian results; i.e. enhanced tillering after Primo MAXX® application (Branham & Beasley 2007, Ervin & Zhang 2008).

As compared with the unsprayed control treatment, the strongest negative effect of Primo MAXX® on turfgrass general appearance at Landvik was recorded after the first spraying in early June, in mid July and at the last observation in early November. Each of these observations might be explained by suboptimal conditions causing reduced turfgrass growth. From 6 to 15 June there was a dry and warm and period with maximum temperatures in the range 25-30 ºC that obviously reduced turfgras tillering and aesthetic appearance; until mid July exceptional rainfalls starting on 22 June were not compensated by increase nitrogen inputs, and in autumn, the last application of Primo on 26 September was followed by several nights of frost. Although most studies have failed to document significant interactions between nitrogen and trinexapac-ethyl on turfgrass quality (Steinke & Stier 2001, Goss et al. 2002, McCullogh et al. 2006), it seems reasonable to assume that potential negative effects on Primo MAXX® on turfgrass quality will be most pronounced under suboptimal growing conditions. As in the trials at Landvik (Photo 6) and Ballerud (Photo 11), Beam et al. (2002) reported significant discoloration of trinexapac-ethyl-treated smooth meadowgrass following frost in autumn.

Undoubtedly, the most convincing argument for official approval of Primo MAXX® on Nordic golf courses would be a clear documentation that it improves winter survival. Preliminary results with annual meadowgrass suggested that low rates of trinexapac-ethyl prevented winter injury, whereas high rates had opposite effects due to discoloration during the hardening phase in late autumn (Rossi & Buelow 1997). While trinexapac-ethyl has been shown to increase water soluble carbohydrate contents (Goss et al. 2002) and result in faster spring greenup, Ervin & Zhang (2008) recently called for more detailed investigations into the effect of trinexapac-etyl on freezing tolerance as the research to date has provided scarce information on this aspect. Under Nordic conditions, desiccation if growth resumes when soils are still frozen and irrigation not yet operational in spring, or damage due to unstable winters with ice and water covering the turf, sometimes resulting in suffocation, appear to be more

important that direct freezing injury. In this regard, trineexapac-ethyl may well have a positive effect as it reduces mitochondrial respiration (Ervin & Zhang 2008). In 2008, it will therefore be very interesting to study winter injury and spring green-up and recovery in the on-going trials at Landvik, Lepaa and Ballerud which all had their last application of Primo MAXX® in late September or early October.

Even with winter survival and spring observations included, the amount of data presented in this report is too limited to recommend any listing of Primo MAXX® for turf use in the Nordic countries. Therefore, as stated in the contract between Syngenta and Scandinavian Turfgrass and Environment Research Foundation, there is a need for new GEP trials to be started in spring 2008 and followed until registration of winter survival in spring 2009. For this purpose, a new experimental green was constructed and seeded to creeping bentgrass at Landvik in 2007. In the trial to be established on this green in spring 2008, we suggest to compare Primo MAXX® at three rates (0.15, 0.30 and 0.45 l/ha) and two application frequencies (every 10/11 days and every 21 days), i.e. six combinations plus an unsprayed control treatment. As different grass species seem to vary in their response to Primo MAXX®, similar trials should preferably be carried out on also red fescue/browntop greens and velvet bentgrass greens, although this would require additional funding from Syngenta/STERF.

In Finland, a new GEP trial will be established in spring 2008 on a fairway that is regularly subjected to winter injury. New demonstration trials might be added to the project depending on interest from superintendents and funding from the national golf unions.

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