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Evaluation of organic fertilizers and biostimulants on sand-based golf greens and football fields

Report from the second experimental year 2006 and conclusions from the two year project period

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Summary:

Twelve fertilizer/biostimulant products or product families were compared with mineral fertilizer in three two-year trials on USGA greens and sand-based football fields in southern Norway. Within each trial, all treatments were received the same amount of total nitrogen per year. Substitution of some of the mineral fertilizer with **Gro-Power®** improved turfgrass quality in one trial. Otherwise, the organic fertilizers and biostimulants producted results that were equal to or inferior to the control treatment. In conclusion, fertilization of sand-based golf greens and football fields ought to be based on light and frequent applications of mineral fertilizer throughout the growing season. Organic fertilizers and biostimulants can, at best, be supplements to such a fertilizer program.

Sammendrag:

Tolv organiske gjødseltyper og biostimulanter ble sammenliknet med rein mineralgjødsel i to-årige forsøk på to USGA-greener og ett sandbasert fotballfelt. Alle forsøksledd fikk hvert år like mye totalnitrogen. Utbytting av noe av mineralgjødsla med **Gro-Power®** førte til bedre greenkvalitet i ett av forsøka; ellers var gresskvaliteten på prøverutene dårligere enn, eller på nivå med, kontrollrutene. Det konkluderes med at gjødsling av sandbaserte golfgreener og fotballbaner i Skandinavia bør baseres på små og hyppige tilførsler av mineralgjødsel. Organisk gjødsel og biostimulanter kan i beste fall være et supplement til et slikt gjødselprogram.

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Contents

Abstract

During 2005 and 2006, twelve different fertilizer/biostimulant products or product families were evaluated on a new USGA green, a new sand-based football field, and/or a two to three year old USGA green at Bioforsk Landvik, Særheim and Apelsvoll, respectively; all research centres located in Southern Norway. Within each trial, all treatments were adjusted to the same total nitrogen rate per year (3.0/2.8, 2.5/1.7, and 1.75/1.75 kg N/100 m^2 on the football field, new, and established golf green in 2005/2006, respectively). Inputs of other nutrients varied among treatments. Application intervals varied among treatments in 2005, but most products were applied at biweekly intervals in 2006. Mineral fertilizers **Arena®** (small granules) and **Fullgjødsel®** were included as control treatments on golf greens and the football field, respectively.

The mostly animal-based organic product family **Suståne** resulted in faster grow-in of the creeping bentgrass green at Landvik, while the products familiy **ProGreen** and ProGreen plus **Activo** had a similar effect on the football field established on straight sand at Særheim. When used as the only fertilizer source, neither these product families nor the animal-based product family **Bio Kombi** showed any advantage for maintenance of established turf.

The only product family resulting in a general improvement in turfgrass quality throughout experimental period was **Gro-Power®.** This product family is based on humus, with all of its nitrogen in an easily available form. Unlike most other organic product families, it was tested in combination with mineral fertilizer Arena® as used in the control treatment.

When used as the only fertilizer source, the seaweed product **Golf Algin** resulted in slower grow-in and more diseases in autumn than the control treatment. Used as maintenance fertilizer during summer, the visual ratings of Golf Algin plots were equal to or higher than the visual ratings of control plots.

The liquid organic fertilizer **Flex™** resulted in slow establishment at Landvik and Særheim. In summer, the visual ratings of Flex™ plots were mostly on level with or higher than control plots, but in autumn, the Flex™ plots at Landvik became very light green, perhaps due to leaching losses. Like Golf Algin, Flex™ seems to be a good maintenance fertilizer for the summer period.

The seaweed product **Maxicrop™** had no significant effect when used in combination with **Arena®** fertilizer at Landvik. In the tougher winter climate at Apelsvoll, the biostimulant **GoGreen** improved turfgrass colour in autumn, but had no effect on winter diseases. By contrast, replacement of some of the Arena® fertilizer with **ammoniumsulfate** resulted in significantly better winter survival, root development and overall turfgrass quality in the same experiment.

In conclusion, we recommend that fertilization of sand-based golf greens and football fields in Scandinavia are primarily based on light and frequent applications of mineral fertilizer throughout the growing season. Organic fertilizers and biostimulants can not replace mineral fertilizer, but they are important supplements that warrant further research for optimal use

The product family Turf Food and the mycorrhiza-product Endo Roots were included in the experiment on the new USGA green at Landvik. However, by claim of Roots / Novozymes, the results obtained with these products will not be disclosed.

Introduction

To improve drainage and facilitate all-weather use, modern football fields and golf greens are usually established on sand-based rootzones with very low nutrient contents and poor buffering capacity. Under such conditions, one of the biggest challenges for greenkeepers and groundsmen is to develop a cost-efficient fertilizer program that maintains a healthy, wear-resistant and high-quality turf cover, yet, at the same time minimizing leaching losses.

Over the past decade, a number of fertilizer products, many of them specifically designed for golf greens and athletic fields, have been introduced on the Scandinavian market. Most of the products contain some of the nutrients in organic form which is dependent on microbial decomposition in order to become available for plant uptake. Such organic fertilizers may well enhance the microbial activity of the rootzone, but the release of nitrogen and other nutrients depends on soil temperature, water availability, pH, carbon/nitrogen ratio and a number of other factors which makes it difficult to maintain a balance between nutrient availability and plant requirement during the growing season. Some the products also contain biostimulants, i.e. non-nutritive substances that enhance plant growth by either chelation and thus facilitated uptake of nutrients, direct supply of plant hormones, or indirect stimulation of plant hormonal activity (Elliott & Prevatte 1996). Among the claimed advantages of such biostimulants are better root development, improved disease resistance, improved stress tolerance, enhanced thatch decomposition and a general improvement in turf quality (Hunter & Butler 2005). Most of the combined organic fertilizer / biostimulant products are rather expensive, and turf managers often wonder if they are worth the extra costs compared to ordinary mineral fertilizer.

Before the growing season 2005, the Norwegian Institute for Agricultural and Environmental Research (Bioforsk, formerly Planteforsk) initiated a two-year research project with the objective of providing unbiased information on fertilizer and biostimulant products currently available on the Norwegian market. The project received basic funding from the Norwegian Ministry of Culture and Sports (Kirke- og kulturdepartementet), The Norwegian Golf Federation and the Norwegian Football Federation. For a certain fee, companies selling fertilizers and biostimulants to the turf sector were invited to have their products evaluated during the grow-in of a USGA putting green, during the grow-in of a sand-based football field and/or for maintenance fertilization of an existing USGA putting green. As our intention was to establish information on individual products or 'product families' (examples of such 'product families' are Gro-Power® products, Flex™ products, Arena® products etc.), multiple combinations of different types of fertilizers / biostimulants were not included unless the main product was also tested independently. Bioforsk defined a control treatment consisting of pure mineral fertilizer (Arena® on putting greens and Fullgjødsel® on football fields), and the companies were allowed to have their product tested either alone or in combination with these control products. In all experiments, it was ensured that all treatments gave the same amount of total nitrogen, but the supply of other nutrients varied with the various treatments. In 2005, application intervals also varied according to the companies' recommendations for their products, but in 2006 most products / product families were applied at two week intervals regardless of their nutrient release characteristics. Fertilizer plans were discussed and approved by the commercial partners before each of the two growing seasons 2005 and 2006.

As a result of varying interest among the commercial companies, eight, four and four treatments were entered for comparison with the control treatment on the new USGA putting green, the new sand-based football field and the established (two year old) USGA green, respectively. The three experiments were established in the spring / early summer of 2005 at Bioforsk's units Landvik Særheim, and Apelsvoll, respectively (Fig. 1).

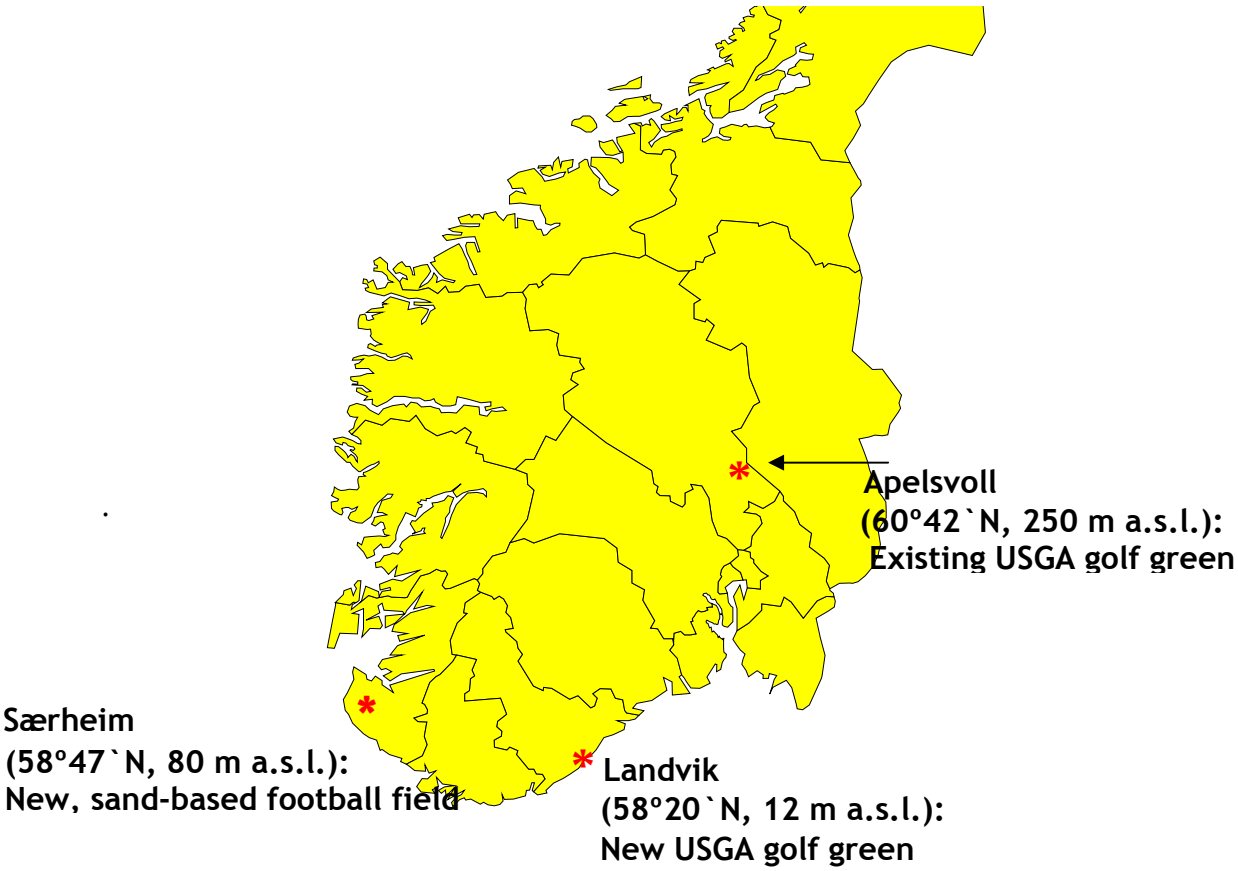


Fig. 1. Map of South Norway showing location of experiments.

Detailed results from the first project year 2005 were reported to the commercial partners in December 2005 (Aamlid 2005). The results from Landvik in 2005 have also been presented in an extension publication from Bioforsk (Aamlid 2006) and on meetings and field days held by the Norwegian Golf Federation (Photo 4). The present report gives results from 2006, as well as a general discussion and conclusions based on the whole project period.

Materials, methods and results

Experimental sites and meteorological data

The climates at Særheim in Southwest Norway and Apelsvoll in Eastern Norway can be described as oceanic and continental, respectively. Landvik on the Norwegian south coast has an intermediate climate – with high temperatures, but also high rainfall intensities. During the winter 2005/06, the trial at Landvik had almost three, and the trial at Apelsvoll almost five months of snow cover. The snow finally disappeared on 13 April at Landvik and 29 April at Apelsvoll, and the soil temperature reached 6ºC, indicating the start of the growing season, on 24 April and 3 May, respectively. Even Særheim had occasional snow during the winter 2005/06; in this field, the 6ºC soil temperature limit was surpassed on 16 April. Later in the growing season, 2006 was characterized by record-high temperatures in July, August, September and October. The precipitation in June and July was well below the 30 year normal values, but August and October were unusually wet at all experimental sites (Table 1).

Table 1. Air temperature, soil temperature and rainfall during the growing season 2006 as compared to 1961-1990 normal values for Landvik, Særheim and Apelsvoll. (Soil temperatures were not measured in the experimental fields, but at 10 cm soil depth at the near-by weather stations; normal values are not available for this character).

	Landvik					Særheim					Apelsvoll				
	Air temp, ºC		Soil temp, ºC	Rainfall, mm		Air temp, ºC		Soil temp ºC	Rainfall, mm		Air temp, ºC		Soil temp ºC	Rainfall, mm	
	2006	Norm	2006	2006	Norm	2006	Norm	2006	2006	Norm	2006	Norm	2006	2006	Norm
Apr	4.4	5.1	3.2	86	58	4.7	5.1	5.5	134	55	2.8	2.3	0.6	47	32
May	11.1	10.4	10.4	98	82	10.1	9.5	10.4	45	58	9.4	9.0	9.7	67	44
Jun	15.0	14.7	15.4	32	71	12.1	12.5	14.0	53	70	15.3	13.7	14.7	31	60
Jul	19.2	16.2	18.4	51	92	16.9	13.9	17.5	58	94	18.3	14.8	18.1	30	77
Aug	17.2	15.4	18.0	134	113	16.2	14.1	17.3	157	110	16.2	13.5	17.2	131	72
Sep	15.0	11.8	15.5	135	136	15.8	11.5	14.9	107	156	13.1	9.1	14.1	51	66
Oct	10.2	7.9	11.8	221	162	11.1	8.6	12.0	207	152	6.5	4.6	9.3	129	64
Sum/ Mean	13.2	11.6	13.2	757	714	12.4	10.7	13.1	761	695	11.7	9.6	12.0	486	415

Description of fertilizers / biostimulants entered into the project

The trials included a range of fertilizer products from organic liquids to slow-release solids and biostimulants. Based on brochures and fact sheets submitted by the participating companies, Table 2 gives an overview of products included in the project.

Table 2. Description of products (in alphabetical order) submitted for testing. (All information provided by participating companies)

'Product family' / representative	General description	Actual products used in this project	Experimental site and application interval	Nitrogen form	Notes
Activo E.Marker AS, Denmark / Osmo Org. Fert. Belgium	Bloodmeal + humic substances + beetpulp (vinasse) in liquid form	Activo 3-3-6	Særheim: Applied three times in 2005 and every two weeks in 2006.	100% organic N	In combination with ProGreen
Algin AET AS, Norway Tilco Biochemie, Germany	Extracts from the seaweeds *Laminaria* and *Ascophyllum* Grain size: 0-2 mm.	Golf Algin S	Landvik and Særheim 2005: Combinations of the two products given every four weeks.	12% NO_3, 71% NH_4	Algin S-products are developed for soils with pH ($CaCl_2$) < 5.0. Golf Algin A is developed for soils with pH ($CaCl_2$) > 6.0.
		Algin Food S		51% NO_3	
		Golf Algin A	Landvik and Særheim 2006: Every two weeks.	10% NO_3, 75% NH_4	
Ammonium-sulfate	Mineral fertilizer	Ammoniumsulfate, 21 % N	Apelsvoll 2005 and 2006: Every four weeks in alternation with Arena® Høst Extra	100% NH_4	24% S. Strongly acidifying.
Arena® Nordic Garden, Norway / Hydro Agri International	Mineral fertilizer, granules <2 mm.	Arena® Høst Extra 3-3-15	Landvik and Apelsvoll 2005 and 2006: Combinations of Arena products every two weeks during the growing season (control treatments)	72% NH_4, 28% urea	Acidifying. Contains 5.4% Fe.
		Arena® Start 22-3-10		47% NO_3, 53% NH_4	Slightly acidifying.
		Arena® Green Plus 12-1-14		26% NO_3, 74% NH_4	With Ca and Mn. Neutral effect on soil pH
		Arena® Score 12-1-14 (2005 only)		18% NO_3, 54% NH_4, 28% urea	Acidifying.
		Arena® Golf Extra 13-0-5 (2006 only)		23% NO_3, 48% NH_4, 29% urea	Acidifying.
Bio Kombi Gyllebo Gödning, Sweden	Poultry manure, mineral fertilizer, meat / bone meal and biproducts from yeast production, Crossed to 0-2 mm.	Bio Kombi K-Special 5-1-17 + Fe	Landvik: Combinations of Bio Kombi products given every four weeks in 2005 and every two weeks in 2006	17% NO_3, 17% NH_4, 66% org. N	Iron-sulfate added to all products
		Bio Kombi Green Start 12-2-6 + Fe		10% NO_3, 10% NH_4, 66% org. N	
		Bio Kombi Green Season 10-2-10 + Fe		Mostly organic (not specified)	

Table 2 continued.

'Product family' / representative	General description	Actual products used in this project	Experimental site and application interval	Nitrogen form	Notes
Endo Roots E.Marker AS, Denmark/ Novo-zymes France	Mycorrhiza + amino acids + humic substances + sea weed.	Endo Roots 3-3-4*	Landvik 2005 and 2006: Incorporated before sowing or as part of topdressing after verticutting /aeration	17% water soluble, 83% water insoluble	Contains eight endo-mycorrhiza species. Require soil temperature of min 8ºC.
Flex™ Flex Kongsvinger AS / Fine Forest Foods, Norway	Liquid fertilizer	Flex Gjødsel™ Nr 702 NK 10-8 Golfgødning	Landvik, Særheim and Apelsvoll 2005 and 2006: Combinations of Flex products given every two weeks during the growing season.	10% NO_3, 11% NH_4, 79% org. N (amides)	pH of solution: 6.0 Diluted in minimum 4 l water / 100 m^2
		Flex Gjødsel™ Nr 700 NPK 12-2-4 Micro		17% NO_3, 17% NH_4, 66% org. N (amides)	pH of solution: 2.1 Diluted in minimum 4 l water / 100 m^2
		Flex™ Gjødsel NPK 2-2-6		100% org. N (amides)	pH of solution: 2.3
Fullgjødsel® Yara / Hydro Agri International	Mineral fertilizer developed for agricultural / horticultural crops.	Fullgjødsel® 18-3-15	Særheim 2005 and 2006: Every two weeks during the growing season (control treatment). Landvik 2005: Incorporated in control treatment before seeding	47% NO_3, 53% NH_4	Acidifying.
		Fullgjødsel® 11-5-18 micro		41% NO_3, 59% NH_4	Acidifying.
		Fullgjødsel® 6-5-20 micro (2005 only)		23% NO_3, 67% NH_4	Acidifying.
GoGreen E.Marker AS, Denmark / AmegA Sciences, UK	Granular fertilizer	2005 and 2006: GoGreen 2-0-10 + 8.7 Fe	Apelsvoll 2005 and 2006: Once or twice in autumn	Not specified	Includes surfactant. Claims to control *Microdochium nivale*

* P values are P_2O_5, and K values are K_2O

Table 2 continued.

'Product family' / representative	General description	Actual products used in this project	Experimental site and application interval	Nitrogen form	Notes
Gro-Power® Floratine Norge AS / Gro-Power® Inc., USA	Humus-based fertilizers / soil conditioners	Gro-Power® Premium Green 5-3-1* (Standard grade)	Landvik 2005 and 2006: Mostly every 2 weeks in combination with Arena as used in control treatment.	20% NH_4, 80% urea	15% humic substances, 1% soil penetrant, 1% Fe + micronutrients.
		Gro-Power® 0-0-15* + Ca (Greens Grade)		-	10% humic substances, K_2SO_4, dolomite
		Gro-Power® 45% Mg (2006 only)		-	
		Gro-Power® 35% Mn (2006 only)		-	
Maxicrop™ Nordic Garden AS, Norway	Concentrated sea weed extract	Maxicrop™ no 1 Triple Seaweed 3,0 – 0,5 –2,5	Landvik: In combinastion with Arena every four weeks in 2005 and every two weeks in 2006	Not specified	
		Maxicrop™ no 3 Pro-K Plus 2 – 0 – 15		Not specified	
ProGreen E.Marker AS , Denmark / Osmo Organic Fertilizers, Belgium	Organic and organic / mineral fertilizers formulated from both animal and plant sources. Contain 2,5% seaweed extracts. Granulated.	ProGreen Park & Fairway 12-2-4	Særheim 2005 and 2006: Combinations of these products every every two weeks during growing season.	50% urea (water soluble) 50% organic N	*Bacillus* sp. and Mg added. 45% organic material
		ProGreen Universal 7-1-7		100% organic	*Bacillus* sp. and Mg added. 50% organic material
		ProGreen Autumn 5-1-10		100% organic	*Bacillus* sp. and Mg added. 45% organic material.

* P values are P_2O_5, and K values are K_2O

Table 2 continued.

'Product family' / representative	General description	Actual products used in this project	Experimental site and application interval	Nitrogen form	Notes
Sustane Amtec Norway / Natural Fertilizers of America, USA	Aerobically composted turkey litter + hydrolysed feathermeal + sulfate of potash	Sustane 4-6-4* (Fine grade)	Landvik 2005: Grow-in fertilizer applied two times.	10% NH_4, 10% urea, 80% slowly water soluble or water insoluble org. N	All-natural fertilizer. Slow nutrient release, primarily by microbial action.
		Sustane 10-1-4*	Landvik 2006: Combinations of these products applied every two weeks.	75% NH_4, 25% water insoluble	Natural-base fertilizers. Amm.sulphate and ironsulfate added.
		Sustane 5-2-10* + Fe		26% NH_4-N, 4 % water soluble, 70% water insoluble	
		Sustane 10-2-10* + Fe		11% NH_4, 8% urea, 34 % slowly water soluble, 47% water insoluble	Natural-base fertilizer. Amm. sulphate, ironsulfate and metylenurea added.
Turf Food E.Marker AS, Denmark / Novozymes Biologicals, France	Feathermeal + humic substances + sea weed + methylen-urea + mineral N	Turf Food 14-3-5*	Landvik: Combinations of these products every four weeks in 2005 and every two weeks in 2006.	25% NH_4, 43% Urea, 32% slow release / water insoluble	All products: 12% carbohydrates 50% amono acids *Bacillus* spp. 75% of nutrients released by microbial activity, 25% by hydrolysis
		Turf Food 15-3-8*		5% NH_4, 12% Urea, 13% water insoluble org. N, 70% slow release / water insoluble	
		Turf Food 5-2-12*		12% NH_4, 13% Urea, 5% water insoluble org. N, 75% slow release / water insoluble	

*** P values are P_2O_5, and K values are K_2O**

The Landvik experiment: Evaluation of fertilizers and biostimulants on a USGA green in the grow-in year and first year after grow-in

Experimental

The USGA green at Landvik was constructed in November 2004. The rootzone layer contained 12% (v/v) of sphagnum peat. The initial pH value was only 5.0 (Table 3), but this was corrected by application of limestone before seeding, giving a average pH of 6.3 in October 2005 (Aamlid et al. 2005). The green was seeded to the triple creeping bentgrass blend 'Penn A-1', 'Penn A-4', and 'Penn G-6' (*Agrostis stolonifera*, 1/3 of each cultivar) on 7 June 2005.

Table 3. Chemical analyses of green rootzone, Landvik, November 2004.

Volume weight kg/dm^3	Loss on ignition, %	pH (H_2O)	mg per 100 g dry soil				
			P-AL	K-AL	Mg-AL	Ca-AL	Na-AL
1.63	1.50	5.0	1.1	1.6	2.3	11	0.9

The experiment had three blocks (replicates) and a plots size of 4.5 x 1.5 = 6.75 m^2. The following treatments were completely randomised within each block:

1. Arena® products (=mineral fertilizer control)
2. Suståne products
3. Gro-Power® products in combination with Arena®
4. Turf Food products
5. Turf Food products + Endo Roots 3-3-4
6. Golf Algin A
7. Bio Kombi Products.
8. Maxicrop™ products in combination with Arena®
9. Flex™ products

The fertilizers / biostimulants were applied as outlined in Appendix table 1. Originally, a last application was planned for late October, but this was not accomplished as the project was going to be finished and some of the plots had to be used for another experiment.

As the results from 2005 suggested that the highest turf quality was produced on plots receiving light and frequent fertilizer application, it was decided that all products should be applied at the same two-week interval in 2006. Solid fertilizers / biostmulants were applied with an experimental plot spreader, and liquid fertilizers / biostimulants (Maxicrop™ and Flex™) with a pressurized experimental plot sprayer, both 1,5 m wide. According to recommendations from the manufacturers, Maxicrop™ no 1 Triple Seaweed and the Flex™ products were diluted to an application volume of 5 L per 100 m^2 , and Maxicrop™ Pro K Plus to an application volume of 10 L per 100 m^2.

The recommendations for Endo Roots 3-3-4 and all types of Bio Kombi Green prescribe these products to be applied in conjunction with topdressing after vertical mowing or aeration treatments. As it was further anticipated that more irrigation would be needed after application of solid than after application of liquid fertilizer, the 'standard' procedure for fertilizer inputs in 2006 was as follows:

1. Vertical mowing to 3-5 mm or coring
2. Application of solid products.
3. Topdressing with straight sand, 1.0 L/m^2.
4. Irrigation, 10 mm if during dry periods, otherwise only 5 mm.
5. When turf is dry, application of liquid products (Maxicrop™ and Flex™).
6. Irrigation, usually 5 mm.

This procedure was followed strictly in May, June and on 7 August. The research station has its own vertical cutter, and on 25 June, solid-tine coring was carried out by Reinhardt Maskin AS. In July and August, vertical mowing and topdressing was usually omitted because of the high temperature. Summarized over the whole season, the experiment received about 5 mm of topdressing sand and 250 mm of irrigation water. Except in conjunction with fertilizer inputs, irrigation was accomplished in the early morning hours, three to five times per week.

The experiment was cut with a walk-behind green's mower three times per week. The mowing height started at 7 mm in early spring and was gradually reduced to 3 mm in mid summer. As the turf needed time to recover from winter damage, regular wear/abrasion from a drum with soft spikes was not imposed until early July. In order to avoid potential spread of diseases from one plot to another, morning dew or guttation water was not removed in 2006.

Assessments and statistical analyses

Per cent winter damage and green-up date was recorded shortly after snow melt in spring 2006. Later in the season, the overall appearance (visual merit) of the turf was assessed at biweekly intervals using a scale from 1 to 9 where 9 is the best turf quality. The first assessment in each month also included the following characters:

1. Tiller density (1-9, 9 is densest turf).
2. Turfgrass colour (1-9, 9 is darkest turf).
3. Per cent of plot affected by diseases.

Diseases were diagnosed at the Bioforsk Plant Health Clinic, Ås, Norway.

On 24 October 2006, soil samples were collected from the 0-20 cm layer in each plot. These samples were analysed for soil volume weight, pH (H_2O), loss on ignition, P-Al, K-AL, Mg-AL, Ca-AL and Na-AL by Bioforsk lab., Ås, Norway.

In November 2006, one soil core (5.6 cm diameter and 30 cm deep) was taken from each plot following the same procedure as in 2005. The thickness of the thatch layer was measured and shoot and root dry weight determined in various soil layers.

The experimental data were subjected to conventional analyses of variance (PROC ANOVA, Statistical Analyses System). Before these analyses, visual merit-, tiller density-, and colour scores were averaged over the spring (until 10 June), summer (10 June – 10 Sep.), and autumn (10 Sep. – 10 Nov.) periods. The significance levels P%<0.1, P%<1, P%<5 and ns 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.

Photo 1. Landvik, 18 April 2006

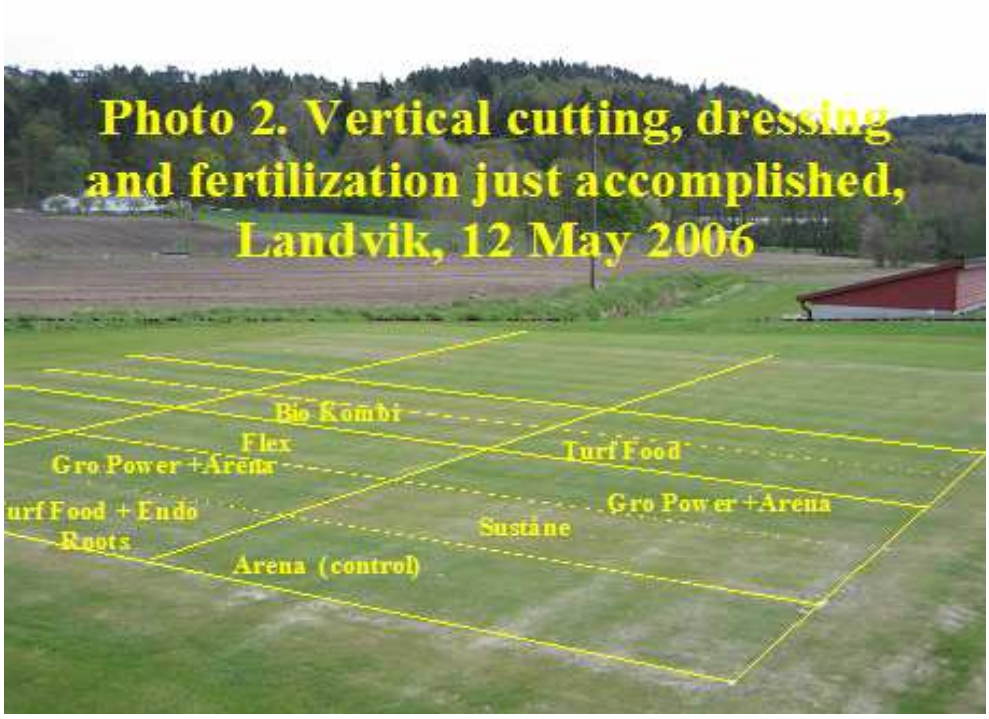



Photo 3. Spots on Arena plots,
Landvik, 24 July 2006
Golf Algin A
Bio-Kombi
Arena +
Maxicrop
Turf Food +
Endo Roots


Photo 4. Field day, Landvik,
25 Aug. 2006

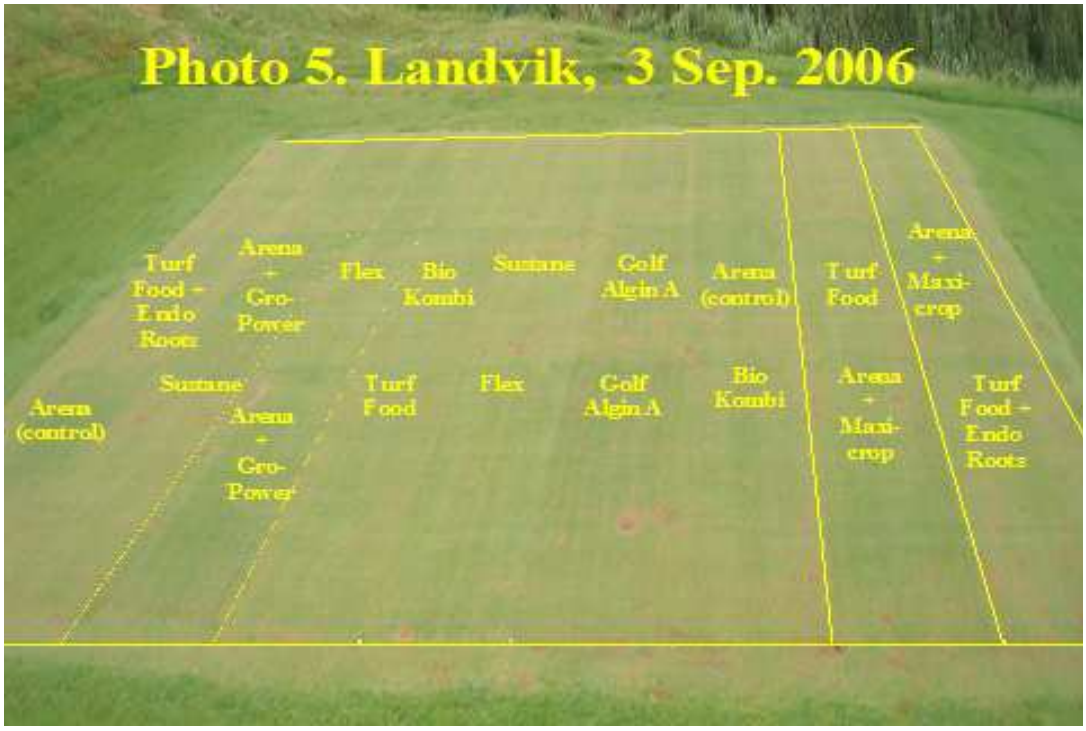


Photo 5. Landvik, 3 Sep. 2006
Turf Food – Endo Roots
Arena + Gro-Power
Flex
Bio Kombi
Sustane
Golf AlginA
Arena (control)
Turf Food
Arena + Maxi-crop
Arena (control)
Sustane
Arena + Gro-Power
Turf Food
Flex
Golf AlginA
Bio Kombi
Arena + Maxi-crop
Turf Food – Endo Roots


Photo 6. *Leptospherulina* leaf blight, Landvik, 2 Oct. 2006

Results

Winter damage / spring green up

All plots in the experiment at Landvik suffered severe winter damage (Photo 1). A composite sample taken on 22 May and analysed by the Bioforsk Plant Health clinic indicated pink snow mold (*Microdochium nivale*); other fungus diseases could not be identified. Plots that had been fertilized with Suståne in 2005 tended (P%=8) to have less snow mold than other treatments (Table 4). On the other hand, spring green-up was 1-3 days later on Suståne plots than on plots that had received other types of fertilizers. These effects may indicate a lower nitrogen status of the turf on Suståne plots than on other plots at the onset of winter. Green-up on plots fertilized with Bio Kombi was also somewhat delayed compared to the other treatments (Table 4).

Tiller density, turf color and overall visual merit

In most cases the pink snow mold damaged foliar tissues, but not the crowns of the plants. The turf therefore usually recovered within 3-4 weeks (Photo 2). The recovery, and hence, the spring ratings for overall appearance, color and tiller density, was, or tended to be, better in treatments receiving Gro-Power® plus Arena® (treatment 3) or only Arena® (treatment 1 = control) than in the other treatments (Table 4). Plots fertilized with Gro-Power® plus Arena® maintained the darkest green colour and the highest tiller density in summer, but during this period, plots fertilized with Flex™ (treatment 9), Golf Algin A (treatment 6) and Maxicrop™ plus Arena® (treatment 8) also had equal or higher scores for visual appearance than control plots. However, as compared with the control, the turf on these plots declined significantly in autumn; on Flex™ plots mostly because of a severe loss of color, and on Golf Algin A plots mostly because of diseases (see later). Regardless of season, plots fertilized Bio Kombi products or Suståne products never reached the same overall appearance, tiller density and color as the control treatment.

A disadvantage of the Arena® fertilizer used in the control treatment is that it temporarily may cause uneven color and/or black spots after application. The uneven colour is most likely due to the size of the fertilizer granules not being fine enough, while the black spots are caused by the high content of iron in many of the Arena® products. If golf players walk on the greens shortly after application of such fertilizers, the black spots may well coalesce into unattractive patches like the size of footprints. Even though our experiment was routinely irrigated after fertilization, we were not able to completely avoid these color problems in treatments 1 (Arena®) and 8 (Maxicrop™ plus Arena®) during the hot and dry period in summer (Photo 3). Plots fertilized with Gro-Power® plus Arena® (treatment 3), Flex™ (treatment 9) or Golf Algin A (treatment 6) did not suffer from the same problem, and this is one of the reasons why these treatments were rated higher for colour and overall appearance during the summer period.

When averaged over the two year experimental period, plots fertilized with Gro-Power® plus Arena® had a significantly higher score for visual turf quality and tiller density than any other treatment except the control. As for turf colour, the Gro-Power® plus Arena was significantly better also in comparison with the control treatment. At the other end of the scale, the Golf Algin A, Bio Kombi and Suståne fertilizers resulted in turf quality ratings that were significantly inferior to the control treatment.

Diseases

After recovery from pink snow mold, the experiment at Landvik was without any visible disease symptoms until early August. During August, the combination of high temperature and frequent rainfall (Table 1) lead to an outbreak of a disease that was diagnosed as Leptospherulina leaf blight (causal fungus *Leptospherulina australis*). The disease occurred on all plots (Photos 5 & 6), but it was most apparent on plots fertilized with Golf Algin A or Suståne (Table 4). Later in the fall, mosses started to invade some of the spots, especially on plots fertilized with Bio Kombi or Suståne (Table 4; Photo 7). In autumn, there were also sporadic outbreaks of *Pythium*, but these could not be related to any of the fertilizer treatments.

Over the two year testing period, the trial at Landvik has suffered attacks from *Microdochium nivale*, *Pythium* sp. and *Leptosperulina australis*. All taken together, Table 4 shows that the control treatment only receiving mineral fertilizer was less vulnerable to these diseases than treatments receiving organic fertilizers or biostimulants.

Thatch accumulation and root development

Cylinder samples taken at the end of the growing season indicated that the average thatch layer in the experiment at Landvik had increase from 4 mm in 2005 to 12 mm in 2006; this accumulation was not influenced by fertilizer treatments (data not shown). The average above-ground biomass more than doubled, and the total root mass increased by 17% from 2005 to 2006, but again, there was no significant effect of fertilizer treatments on these characters (Fig. 2).

Table 4. Effect on various fertilizers / biostimulants on visual merit (= overall turfgrass quality, 9 is highest quality), turfgrass color (9 is darkest green), tiller density (9 is highest density), date of green-up in spring 2006, % winter injury, % plant cover, and % of plot affected by diseases and mosses on a USGA green established at Landvik in June 2005.

Treatment no		Visual merit (1-9)				Color (1-9)				Density (1-9)				Green-up,day no.in April	Winter injury [1] %	Plant cover [2] %	Diseases, %[3]		Moss[4] %
		Two year mean	2006 spring	2006 summer	2006 autumn	Two year mean	2006 spring	2006 summer	2006 autumn	Two year mean	2006 spring	2006 summer	2006 autumn				Two year mean	2006	
1	Arena® (control)	6.2	5.0	6.0	6.0	5.7	5.3	5.2	6.0	6.9	5.4	6.8	6.6	17	82	96	2	2	0
2	Suståne	3.7	3.5	4.4	3.0	4.0	3.6	4.0	3.7	3.7	2.5	4.9	2.2	20	75	87	6	9	3
3	Gro-Power® + Arena®	6.5	4.8	6.6	6.5	6.1	5.9	6.0	6.3	7.2	5.8	7.6	6.5	17	92	97	5	2	0
4	Turf Food [5]																		
5	Turf Food + Endo Roots[5]																		
6	Golf Algin A	5.4	4.3	6.2	4.5	5.2	5.4	5.7	5.6	6.2	5.0	6.8	5.9	17	88	94	6	8	0
7	Bio Kombi	4.5	3.6	5.1	4.3	4.7	4.4	4.9	5.0	4.9	3.9	5.3	4.3	19	86	90	7	5	1
8	Arena® + Maxicrop™	5.8	3.9	6.0	5.7	5.1	4.6	5.2	5.6	6.3	4.4	6.9	5.9	18	88	94	3	3	0
9	Flex™	5.6	4.4	6.6	4.5	5.2	5.2	5.2	4.4	5.9	4.5	6.6	4.9	17	84	94	4	4	0
P%		<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	8	<0.1	<5	<5	<0.1
LSD5%		0.5	0.7	0.5	1.1	0.2	0.4	0.6	0.6	0.8	0.7	0.7	0.7	1	-	2	2	4	1

[1] Evaluated in April 2006. [2] Mean of all recordings in 2005 and 2006 [3] Evaluated in October 2006. [4] Evaluated in October 2005 and 2006.
[5] By claim of Novozymes / Roots, experimental results for Turf Food and Endo Roots will not be disclosed.

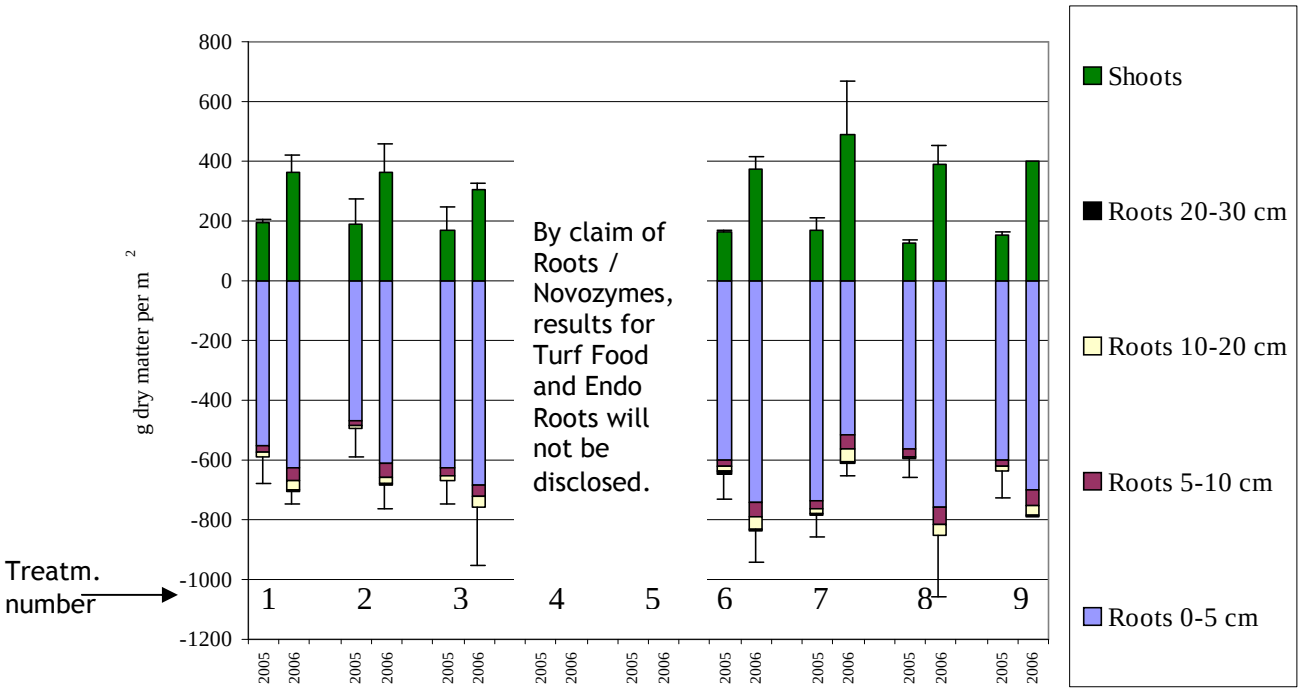


Fig. 2. Effect of various fertilizer/ biostimulant treatments on shoot- and root dry weights by the end of the grow-in year 2005 and the first green-year 2006. The size of the standard error bars indicate that differences among treatments were not significant in any year.

Table 5. Effect on various fertilizers / biostimulant treatments on pH and nutrient contents in samples taken from the 0-20 cm soil layer in late October 2006. (Statistical analyses were not possible as only one composite sample was analysed per treatment).

Treat-ment	Type of fertilizer / biostimulant	pH (H_2O)	mg per 100 g dry soil				
			P-AL	K-AL	Mg-AL	Ca-AL	Na-AL
1	Arena® (control)	6.7	1.5	4.3	4.2	41	2.1
2	Suståne	7.3	5.0	4.8	5.1	73	2.5
3	Gro-Power® + Arena®	6.8	1.4	6.0	5.1	38	2.4
4	Turf Food[1)]						
5	Turf Food + Endo Roots[1)]						
6	Golf Algin A	7.0	0.8	4.8	3.5	36	1.6
7	Bio Kombi	7.0	1.1	4.5	4.6	44	2.7
8	Maxicrop™ + Arena®	6.8	1.2	4.9	4.5	45	1.7
9	Flex™	6.8	0.9	3.2	4.0	32	1.6

[1)] . By claim of Roots / Novozymes, results for Roots / Novozymes will not be disclosed

Soil parameters

Regardless of fertilizer treatments, the pH of the 20 cm rootzone layer increased by 0.4 to 1.1 pH units, from an average of 6.3 in October 2005 (Aamlid et al. 2005) to an average of 6.9 in October 2006 (Table 5). This may reflects that the limestone (30 kg per 100 m^2) that had been worked into the 0-3 cm topsoil layer before seeding in June 2005 needed more than a year to get evenly distributed throughout the entire profile. It may also indicate that many of the organic fertilizers had a positive soil reaction, although this would not be expected for the Arena® fertilizer in the control treatment. The high phosphorous (P) levels on plots fertilized with Suståne (treatment 2) probably reflects that this treatment received about 150% more P than the control treatment during the two-year experimental period (Appendix table 1). By the same reasoning, the low P levels on plots fertilized Golf Algin A (treatment 6) and Flex™ probably reflects that these treatments received about 50% less P than the control.

The Særheim experiment: Evaluation of fertilizers and biostimulants to a sand-based football field in the grow-in year and the year after

Experimental

The experimental football field at Særheim was sown in May/June 2006 on a sand-based rootzone practically without organic matter. The turfgrass mixture consisted of Kentucky bluegrass (*Poa pratensis*) 'Limousine' (70%) and perennial ryegrass (*Lolium perenne*) 'Baraine' (30%).

The experiment had four replicates (blocks) and a plot size of 1.5 m x 4 m = 6.0 m^2. In 2006, the following five fertilizer / biostimulant treatments were compared:

1. Fullgjødsel® (control)
2. Golf Algin A
3. ProGreen
4. ProGreen + Activo 3-3-6
5. Flex™

The only differences in this plan compared to that in 2005 (Aamlid et al. 2005) is (1) that Golf Algin S / Algin Food S was replaced with Golf Algin A due to the high pH of the rootzone, and (2) the fertilizers in all treatments were applied at biweekly intervals. Actual application dates and rates are given in Appendix table 2. Solid fertilizers were hand spread in cross, and liquid products (Flex™ and Activo) were diluted in water and applied at a rate of 7 liters per plot using a can with a 80 cm wide irrigation boom.

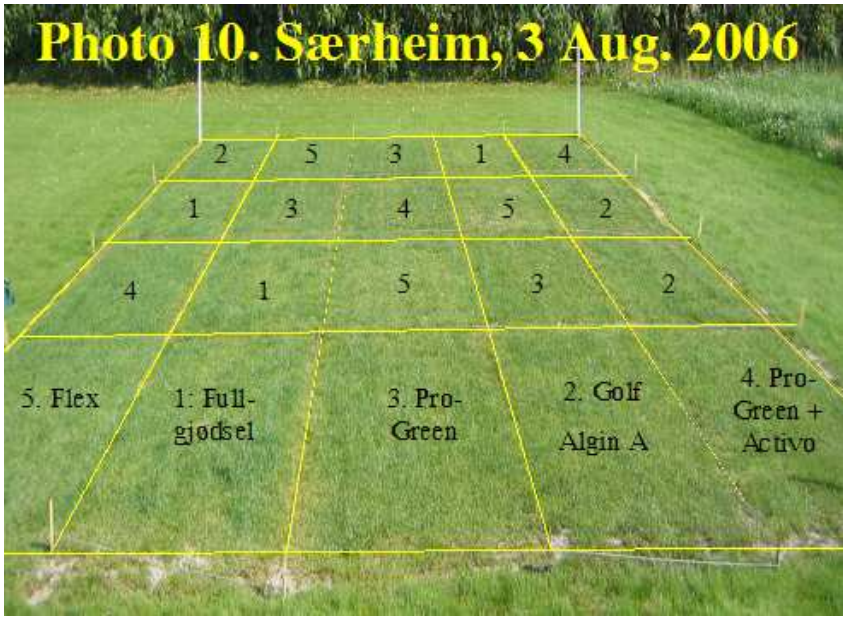
The field was irrigated with 10 mm after fertilizer application. This was usually split with approx. 7 mm after the application of dry products and the remaining 3 mm after application of liquid products. The experiment was also irrigated with 15-20 mm whenever needed between fertilizer application dates. The turf was mowed to 3.5 cm when it had reached 5.0 cm, usually one or two times per week. Clippings were always removed. Moderate wear was simulated by dragging a drum with 16 mm football spikes (Photo 8). in two directions across the field at weekly intervals, starting

with 2 passes from May until July and 4 passes from August onwards. The field was not aerated or sand-dressed during the two year experimental period.

Throughout the growing season, per cent plant cover, turf overall appearance, tiller density and color was assessed as described for the experiment at Landvik. Before the final fertilizer application in late October, one soil core (30 cm deep, 4,5 cm in diameter) was taken from each plot and used for determination of thatch thickness and shoot and root weights in different layers, and one composite sample was taken per treatment for soil analysis.

Statistical analyses were carried out as described for the experiment at Landvik.

Photo 8. Wear machine used at Særheim.



Results

Visual merit (=overall turfgrass quality), tiller density and color

Plots fertilized with Flex™ had significantly better color and tended to give better overall impression than the other treatments in spring 2006 (Table 6). During the summer period, there was a weak tendency for plots fertilized with Golf Algin A and Flex™ to get higher visual merit scores than control plots fertilized with Fullgjødsel®, which, in turn, tended to be slightly better than plots fertilized with ProGreen or ProGreen plus Activo. All test plots also tended to have a darker green color compared with the control treatment in autumn. Unlike in 2005 (Aamlid et al. 2005), the biostimulant Activo had little additional effect on plots fertilized with ProGreen; in fact, both of these treatments tended to give a lower density than the other treatments in spring.

Table 6. Effect on various fertilizers / biostimulants on visual merit (= overall turfgrass quality, 9 is highest quality), turfgrass color (9 is darkest green), tiller density (9 is highest density), % plant cover, and % of plot affected by diseases on at football field established at Særheim in May 2005.

Treatment		Visual merit (1-9)				Colour (1-9)				Density (1-9)				Plant cover[1)] %	Diseases[2)] %
		Two year mean	2006 spring	2006 summer	2006 autumn	Two year mean	2006 spring	2006 summer	2006 autumn	Two year mean	2006 spring	2006 summer	2006 autumn		
1	Fullgjødsel®	6.9	6.8	6.7	7.5	7.3	7.1	7.2	7.4	7.1	6.3	7.2	8.0	94	3
2	Golf Algin A	7.0	6.5	7.3	7.8	7.2	7.0	7.3	7.9	7.0	6.4	6.9	8.0	94	2
3	ProGreen	6.7	6.4	6.3	7.9	7.2	6.7	6.8	8.1	6.8	6.0	6.3	8.0	92	3
4	ProGreen + Activo	7.0	6.5	6.3	7.8	7.4	6.9	6.8	7.9	6.9	6.1	6.3	8.0	93	4
5	Flex™	7.0	7.3	7.1	7.8	7.4	8.1	7.3	8.3	6.9	6.4	6.8	8.0	91	4
P%		ns	9	15	ns	ns	<5	ns	10	ns	7	ns	ns	ns	ns
LSD 5%		-	-	-	-		0.6	-	-	-	-	-	-	-	-

[1)]Mean of all ratings in 2005 and 2006 [2)]Mean of all ratings in 2006

The football field at Særheim did not suffer any kind of winter damage, but in some of the plots, perennial ryegrass was selectively affected by Fusarium in May 2006 (Photo 9). There was also a certain incidence of red thread (Laetisaria fuciformis) later in the season, but neither this disease nor Fusarium showed preference for any of the fertilizer treatments.

When summarized over the two year experimental period, differences between fetilizer treatments were no significant for any of the recorded characters (Table 6).

Thatch accumulation, shoot and root development

Soil cores taken in November 2006 showed no difference in thatch accumulation. On average for all treatments, the thickness of the thatch layer had increased from 3 mm in Nov 2005 to 9 mm in Nov 2006 (data not shown). There was also no significant difference in either shoot of root dry weight between the different treatments (Fig. 3). On average for treatments, the proportion of roots deeper than 5 cm had decreased from 31% in 2005 to 24% in 2006.

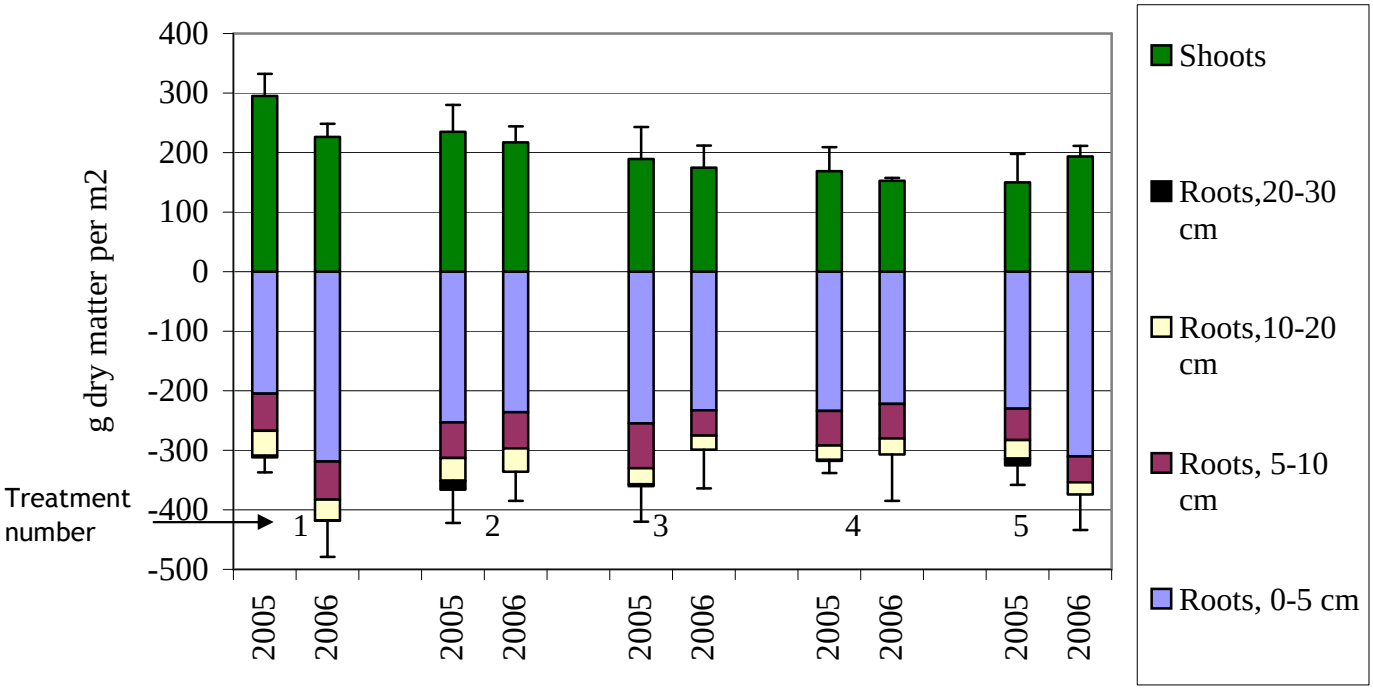


Fig. 3. Mean values of shoot and root biomass at the end of growing seasons 2005 and 2006 in the football field at Særheim. Root biomass has been partitioned into different depth intervals. Error bars (1 SE) that differences were not significant in either year.

Soil parameters

Analyses of soil samples taken in late October 2006 indicated that the pH had dropped from 2005 on plots fertilized with Golf Algin A or Flex™ , but remained stable on plots fertilized with ProGreen, ProGreen plus Activo or Fullgjødsel® (Table 7, cf. Aamlid et al. 2005). Plots fertilized with ProGreen, Progreen plus Activo or Flex tended to have lower reserves of mineral nitrogen than plots fertilized with Fullgjødsel® or Golf Algin A. The lowest content of phosphorous was recorded on plots fertilized with Golf Algin A.

Table 7. Analyses of soil samples taken just before the last fertilizer application on 31 Oct 2006 at Særheim. (Statistical analyses were not possible as only one composite sample was analysed per treatment).

		Loss on ignition, %	mg/kg dry soil		pH	mg/100 g dry soil			
			NH_4	NO_3	(H_2O)	P-AL	K-AL	Mg-AL	Ca-AL
1	Fullgjødsel®	0.3	0.96	0.82	6.8	1.6	3.3	3.4	32
2	Golf Algin A	0.3	0.99	0.75	6.2	0.9	3.2	2.0	11
3	ProGreen	0.3	0.82	0.42	7.2	1.3	2.8	2.4	12
4	ProGreen +Activo	0.2	0.82	0.47	7.1	1.4	2.4	2.1	11
5	Flex™	0.2	0.88	0.36	6.4	1.3	2.1	2.5	13

The Apelsvoll experiment: Evaluation of fertilizers and biostimulants to a three year old USGA green

Experimental

The experimental green at Apelsvoll was constructed in June 2003 with 25% (v/v) of composted yardwaste added to the rootzone mixture. The green had a turf cover of creeping bentgrass (*Agrostis stolonifera*), 50% 'Cato' and 50% 'Providence'. Results from soil analyses at the start of the project period are given in Table 8.

Table 8. Results from soil analyses at the start of the fertilizer / biostimulant project in spring 2005.

Vol. weight, kg/dm^3	pH (H_2O)	mg per 100 g dry soil				
		P-AL	K-AL	Mg-AL	Ca-AL	Na-AL
1.50	7.2	5.0	4.0	4.0	80	1.0

Throughout the growing seasons 2005 and 2006, the green was maintained according to recommended practise with mowing to 3 mm three times a week (5 mm in May and after 15 September), vertical cutting and topdressing one to two times per month and irrigation as needed.

The experiment had two blocks (replicates) and a plot size of 3.5 x 1.5 = 5.25 m^2. The following treatments were compared:

1. Arena® (control)
2. Flex™
3. Arena® + GoGreen, one application in autumn.
4. Ammoniumsulfate + Arena® Høst Extra (alternating applications)
5. Arena® + GoGreen, two applications in late summer /autumn.

Fertilizer plans and actual application dates are given in Appendix table 3. Because of a mistake in the dilution of the product, results from treatment 2, Flex™ for 2006 will not be presented. Otherwise, experimental plans were not changed from 2005, except for a small adjustment in the type of Arena® fertilizer used in the control treatment. Because of the severe winter damage (Photo 11), all plots were verticut, reseeded with 0.5 kg 100 m^{-2} of the same seed blend as used at construction, and topdressed on 10 May 2006. The solid fertilizers were always applied with a 1.5 m wide plot fertilizer spreader and the plots irrigated 10-20 mm after each application.

Visual assessments, soil and root sampling, and statistical calculations followed the same procedures as at Landvik and Særheim, except that turfgrass quality was assessed at about 10 days intervals following application of GoGreen in late summer/autumn.

Results

Winter damage

After almost five months of snow cover, the winter injury at Apelsvoll was almost total except in treatment 3 that had been fertilized with ammoniumsulfate plus Arena Høst Extra in 2005 (Table 9, Photo 11). GoGreen, which was marketed to prevent snow mold, had no effect on winter diseases in this experiment. Both pink (Microdochium nivale) and gray (*Typhula incarnata*) snow mold were identified in samples diagnosed by the Bioforsk Plant Health Clinic.

Tiller density, turfgrass color and overall appearance (=visual merit)

The superior winter survival of plots receiving ammoniumsulfate plus Arena Høst Extra was reflected in higher visual merit scores during the spring season (Table 9). Differences between plots became less apparent during summer, but in autumn, plots receiving ammoniumsulfate plus Arena Høst Extra had darker color then the other treatments. The experimental field was severely infected by *Pythium* in Sepetmber and October, but differences in susceptibility to this disease were not significant among treatments. Unlike in 2005 (Aamlid et al. 2005), application of GoGreen had no significant effect on turf color or overall appearance in the autumn 2006.

In summary for the two year experimental period, differences in overall appearance were not significant among treatments. Nonetheless, the average figures in Table 9 speak in favour of the combination of ammoniumsulfate and Arena® Høst Extra (treatment 3). Together with treatment 5 receiving two applications of GoGreen, this treatment also had the best overall color during the experimental period.

Table 9. Effect on various fertilizers / biostimulants on visual merit (= overall turfgrass quality), turfgrass color (9=darkest green), % winter injury, % plant cover, tiller density (9 = highest density), and per cent of plot affected by diseases on an established USGA green at Apelsvoll in 2005 and 2006.

		Visual merit (1-9)				Color (1-9)				Win-	Plant	Tiller	Di-
		Two	2006			Two	2006			ter	cov-	den-	sea-
		year mean	spr- ing	sum- mer	aut- umn	year mean	spr- ing	sum- mer	aut- umn	injury %[1)]	er %[2)]	sity (1-9) [2)]	ses %[3)]
1	Arena®	5.4	2.9	5.5	4.9	5.6	4.8	5.5	5.2	99	88	6.0	40
3	Arena® + 1x GoGreen	5.5	3.0	5.7	5.2	5.7	4.5	5.7	5.0	97	88	6.0	28
4	Amm.sulfate + Arena® Høst Ex.	6.0	4.2	5.9	5.5	5.9	4.3	5.4	6.0	40	93	6.0	28
5	Arena® + 2x GoGreen	5.2	2.4	5.4	4.3	5.9	5.0	5.7	5.0	94	87	6.0	50
P%		ns	<5	ns	ns	<5	ns	ns	<1	<1	7	ns	ns
LSD 5%		-	1.1	-	-	0.2	-	-	0.4	20	-	-	-

[1)] Evaluated in May 2006. [2)] Mean of all recordings in 2005 and 2006 [2)] Mean of two recordings in autumn 2006.

Thatch accumulation and root development

Soil cores taken on 21 October 2006 indicated that plots fertilized with ammoniumsulfate plus Arena® Høst Extra tended (P%=7) to have more thatch (12 mm) than plots fertilized with Arena® products only, the GoGreen treatments ranking in between (data not shown). The same tendency was also reflected for total root biomass and for root biomass deeper than 5 cm (Fig. 4). Compared with cores taken one year earlier, the total rootmass had increased in the treatment receiving ammoniumsulfate plus Arena® Høst Extra, remained stable in the GoGreen treatment, and decreased in the control treatment. With respect to shoot biomass, there were only minor differences between various treatments.

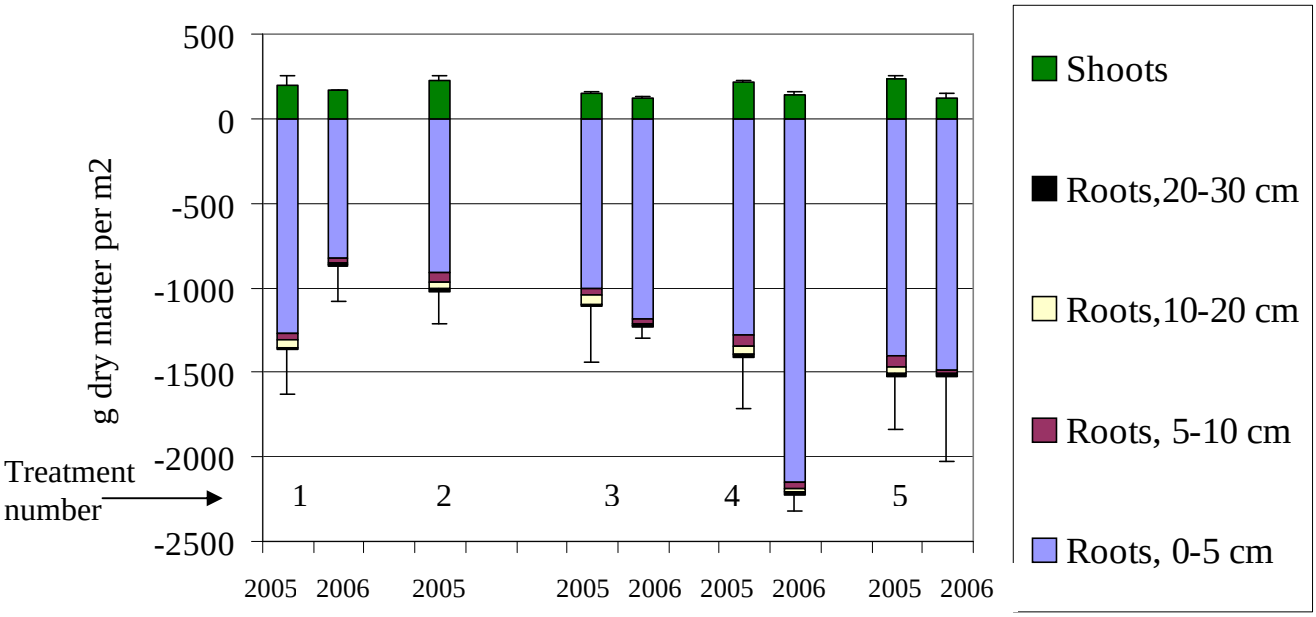


Fig. 4. Effect of various fertilizer treatments on shoot and root dry weight in cores taken by the end of the growing seasons 2005 and 2006. Bars indicate 1 SE (standard error).

Soil parameters

One composite soil sample taken from the 0-20 cm soil layer in each treatment on 20 October (Table 10) indicated no conspicuous differences, either between treatments or in comparison with values at the onset of experimentation in 2005 (Table 10). Surprisingly, application of ammoniumsulfate over two seasons had not lowered pH compared to the other treatments.

Table 10. Analyses of soil samples taken on 22 October 2006 in the experiment at Apelsvoll.

		pH (H_2O)	mg/100 g dry soil				
			P-AL	K-AL	Mg-AL	Ca-AL	Na-AL
1	Arena®	7.1	5.0	5.8	5.0	96	1.6
3	Arena® + 1x GoGreen	7.3	5.8	6.9	6.3	119	2.3
4	Ammoniumsulfate Arena® Høst Extra	7.2	5.0	4.8	4.6	86	1.9
5	Arena® + 2x GoGreen	7.2	6.0	6.1	4.9	106	1.9

Discussion

Biostimulant effects vs. classical nutritional effects

Because of the poor performance of many of the fertilizers / biostimulants in 2005, we decided to apply all products / product families at biweekly intervals in 2006. While such a frequent application regime should not be necessary based on the slow-release properties of many of the products tested, the decision was made in an attempt to investigate biostimulant effects, i.e. growth effects beyond those explained by various application patterns for nitrogen or other major nutrients.

In spite of this change in experimental plans, the ranking of various treatments for turf quality was mostly the same in 2006 as in 2005. With few exceptions, it therefore seems justified to attribute the performance of the various treatments to the availability of major nutrients, especially nitrogen, rather than to their content of seaweeds, humic substances, mycorrhizas, or other biostimulants. This does not imply that biostimulants will never play a role on sand-based golf greens or football fields, but under the present experimental conditions, the biostimulant effects were mostly too subtle to be of practical relevance. This conclusion was perhaps expected for the rootzone containing 25% (v/v) garden compost at Apelsvoll, but it is more surprising for the newly constructed rootzones with no organic matter at Særheim or with 12% (v/v) sphagnum peat of supposedly low biological activity at Landvik.

Nitrogen vs. other macronutrients

Based on findings that the proportion of various macronutrients in plant tissues is virtually the same regardless of fertilization regimes, Ericsson et al. (2006) recommended that fertilizers used for turfgrass should have a N:P:K:Ca:Mg:S ratio of 100:14:65:7:6:9. In the present experiments, the N:P ratio varied from 100:8 in treatments 4 (Turf Food) and 9 (Flex™) at Landvik in 2006 to 100:66 in treatment 2 (Suståne) at Landvik in 2005. In 2006, treatment 4 (Turf Food) was somewhat low also for potassium (N:K = 100:56), but otherwise all treatments in the three experiments received adequate or superfluous amounts of this element (up to 100:150 in treatment 5 (Arena® plus 2x GoGreen) at Apelsvoll in 2005). While some of the fertilizers contained ample amounts of sulfur (N:S ratio 100:162 in treatment 4 (ammoniumsulfate plus Arena® Høst Extra) at Apelsvoll in 2006) some of the product families (Golf Algin, Flex™ and Bio Kombi) did not supply calcium at all, and Bio Kombi was low also for magnesium (N:Mg = 100:3 at Landvik in both years). Although it cannot be ruled out that mild deficiencies occurred during certain periods in certain treatments, the fact that the soil P-AL, K-AL, Mg-Al and Ca-AL values either remained stable or increased from 2005 to 2006 suggests that turf growth or quality was rarely confined by these elements. In our opinion, nitrogen availability was therefore the most important component governing the outcome of this study.

Do the organic products / product families stand on their own feet ?

At the start of the project, commercial partners were invited to decide whether they wanted their product / product family tested alone or in combination with the mineral fertilizers Arena® or Fullgjødsel® as used in the control treatments. The latter alternative was repeated before the 2006 season, but with one exception, all companies continued to claim that their product / product family should 'stand on its own feet' without any supplement of mineral fertilizers. Although some of the product families included 'spring starters' with a higher content of nitrate and/or ammonium, we now conclude that none of the tested product families contained enough easily available mineral nitrogen to be used alone under Scandinavian conditions. It should be remembered that soil microbial activity, and thus nitrogen release, is limited by low soil temperatures during most of the growing season in Scandinavia.

GroPower®

Apart from Maxicrop™, the only fertilizer product claimed to be tested in combination with mineral fertilizer was GroPower®. This was also the only treatment that produced higher visual merit scores than the control treatment in both experimental years. Unlike most of the other products, GroPower® does not contain slow-release nitrogen, but has 80 and 20% of its nitrogen in the form of urea and ammonium, respectively. GroPower® is further based on humic substances, which is a group of biostimulants claimed to increase the soil's cation exchange capacity and water-holding capacity, enhance bacterial propagation, provide the turf with plant hormones such as auxin and cytokinins, stimulate root growth and facilitate nutrient uptake through chelation (Liu & Cooper 2000, Zhang & Schmidt 2000, Wells et al. 2003, Hunter & Butler 2005). In our study, GroPower® did not enhance root growth, but the overall, albeit insignificant, improvement in turf quality in the trial at Landvik suggest that some of the other effects occurred.

Suståne, Bio Kombi, ProGreen and Activo

The product families Suståne, Bio Kombi, ProGreen and Activo are all based primarily on animal by-products. With the exception of Bio Kombi, these products may enhance turfgrass establishment, but they appear to have little advantage on established turf. Especially in spring, they have to be used in combination with some source of mineral nitrogen. Except for Suståne, they also contain humic substances and/or seaweed extracts. The specific properties of these biostimulants would perhaps have been more expressed had the products been used in combination with mineral nitrogen, as was the case for GroPower® at Landvik.

Starting in spring 2006, all fertilizers at Landvik were applied in conjunction with topdressing immediately after vertical cutting or aeration. This procedure was based on recommendations for Bio Kombi and supposed to facilitate the release of nutrients from the organic fertilizers. However, this procedure may also have been to the disadvantage of the organic fertilizers, as the vertical cutting may have increased the demand for easily available nutrients to recover. On the advice from experienced greenkeepers, vertical cutting before fertilization was usually abandoned during the hot summer months, as it was considered too stressful to the turf.

Golf Algin

Because of soil pH values being higher than 6.0 both at Landvik and Særheim, the acidifying A-form of Golf Algin was used instead of the S-form in 2006. This resulted in a drop in pH compared with the control treatment receiving Fullgjødsel® (which is also acidifying) at Særheim, but the buffer capacity of the sphagnum-peat prevented a similar drop at Landvik. At both locations, plots fertilized with Golf Algin had among the highest scores for color, density and visual merit in summer, but the plots were slower than the control plots in spring 2006 and much slower than the plots receiving animal-based fertilizers during grow-in in 2005. According to the Norwegian representative for Tilco Biochemie, the effect of Golf Algin products are often masked or negated if used on rootsones containing organic sources such as sphagnum peat or garden compost. From now on, the products will therefore primarily be marketed for soil rootzones, where they are claimed to have a positive effect on soil structure; and on straight sand rootzones, where they are claimed to enhance biological activity and nutrient availability (E. Pettersen, personal communication, December 2006). As for most of the other products, the authors will add to this that we think the Golf Algin products ought to be used in combination with some kind of mineral fertilizer.

Maxicrop

On 19 October 2005 treatment 8 (Maxicrop™ plus Arena®) received 0.1 kg less nitrogen per 100 m^2 then the control treatment in the experiment aat Landvik (Aamlid et al. 2005). This resulted in a lighter color of the Maxicrop plots in late autumn, an effect that persisted well into the spring (Table 4). During the summer months, plots receiving Maxicrop™ at biweekly intervals were on the same level, but not better than, the control plots, and in the autumn, they were inferior. As the product specifications prescribe 'Maxicrop™ Pro-K Plus' to be followed by rain or irrigation, while heavy rainfall should be avoided after application of 'Maxicrop™ no 1 Triple Seaweed', we are somewhat confused as to whether these products are intended for foliar or root absoption. If foliar absorption is important, out procedure of irrigating 3-5 mm 30-60 minutes after spraying may perhaps have been to the disadvantage of this treatment. Despite these considerations, neither the results from 2005 nor those from 2006 justifies the use of Maxicrop™ as a supplement to mineral fertilizer on sand-based rootzones.

Flex™

At both Landvik and Særheim, turf establishment in 2005 was considerably slower after use of Flex™ than in the control treatment. Flex™ is therefore not a good choice for the grow-in situation. At Landvik, the visual rating of Flex™ plots also dropped significantly during the wet period in autumn, perhaps suggesting that the soluble amides in Flex™ leached out of the soil even before being mineralized. However, during the hot period in summer 2006, Flex™ plots obtained scores equal to or better than control plots at Landvik, and at Særheim they were on the same level or slightly better than control plots both in autumn 2005 and throughout the growing season 2006. As Flex™ implies little risk for leaf burning or other unwanted color effects, it seems to be a good maintenance fertilizer during hot and dry periods in summer.

GoGreen

Application of granular GoGreen at Apelsvoll resulted in improved turf color due to its high content of iron, but it had absolutely no effect on winter diseases and can therefore not be recommended. According to the company representative, GoGreen is now being replaced by a supposedly better product – Tourturf FDC (C. Marker, personal communication, May 2006).

Ammoniumsulfate

In contrast to GoGreen, ammoniumsulfate not only resulted in improved turf color, but it also caused a 50% reduction in winter damages at Apelsvoll. This suggests that sulfur is more important than iron for winter hardiness. Ammoniumsulfate also resulted in a conspicuous improvement in root development compared to the other treatments. All taken together, ammoniumsufate can be recommended as the main nitrogen carrier for sand-based rootzones which contain compost and which therefore have a high soil pH and a high buffer capacity.

Conclusions

In conclusion, the present project has shown that an appropriate fertilization programs is of outmost importance for the quality of sand-based golf greens and football fields. In our opinion, frequent applications of mineral fertilizer should be the cornerstone in such programs. Organic fertilizers and biostimulants are no silver bullet, but when used correctly, they may have an important supplemental role in turfgrass management programs.

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Appendix 1. Fertilizer treatments compared in 2006 on USGA-green established at Landvik in 2005.

Treatment 1: Arena® (Control)

Week	Fertilizer type	Planned applications									Date when fertilizer was applied
		kg product per 100 m^2	kg nutrient per 100 m^2								
			N	P	K	Mg	Ca	S	Fe	Mn	
16	Arena® Høst Extra 3-3-15	1.70	0.054	0.056	0.248	0.017	0.000	0.179	0.092	0.005	28 Apr
18	Arena® Start 22-3-10	0.70	0.154	0.021	0.070	0.000	0.000	0.028	0.000	0.000	11 May
20	Arena® Green Plus 12-1-14	1.50	0.180	0.015	0.218	0.027	0.032	0.090	0.000	0.006	26 May
22	Arena® Start 22-3-10	0.80	0.176	0.024	0.080	0.000	0.000	0.032	0.000	0.000	9 Jun
24	Arena® Golf Extra 13-0-15	1.30	0.173	0.000	0.199	0.020	0.000	0.178	0.026	0.005	28 Jun
26	Arena® Start 22-3-10	0.70	0.154	0.021	0.070	0.000	0.000	0.028	0.000	0.000	13 Jul
28	Arena® Green Plus 12-1-14	1.15	0.138	0.012	0.167	0.021	0.024	0.069	0.000	0.005	24 Jul
30	Arena® Start 22-3-10	0.60	0.132	0.018	0.060	0.000	0.000	0.024	0.000	0.000	7 Aug
32	Arena® Golf Extra 13-0-15	1.10	0.146	0.000	0.168	0.017	0.000	0.151	0.022	0.004	21 Aug
34	Arena® Start 22-3-10	0.70	0.154	0.021	0.070	0.000	0.000	0.028	0.000	0.000	4 Sep
36	Arena® Green Plus 12-1-14	1.20	0.144	0.012	0.174	0.022	0.025	0.072	0.000	0.005	18 Sep
38	Arena® Golf Extra 13-0-15	0.80	0.106	0.000	0.122	0.012	0.000	0.110	0.016	0.003	5 Oct
	SUM		1.712	0.200	1.646	0.134	0.081	0.988	0.156	0.034	

Appendix 1 continued.

Treatment 2: Suståne (Amtec Norge AS)

Planned applications											Date when fertilizer was applied
Week	Fertilizer type	kg product per 100 m2	kg nutrient per 100 m2								
			N	P	K	Mg	Ca	S	Fe	Mn	
16	Suståne 5-2-10	1.10	0.055	0.022	0.110	0.007	0.051	0.025	0.006	0.001	28 Apr
18	Suståne 10-1-4	1.54	0.154	0.015	0.062	0.010	0.072	0.035	0.008	0.001	11 May
20	Suståne 10-1-4	1.80	0.180	0.018	0.072	0.012	0.084	0.041	0.009	0.001	26 May
22	Suståne 10-1-4	1.76	0.176	0.018	0.070	0.011	0.082	0.040	0.009	0.001	9 Jun
24	Suståne 10-1-4	1.73	0.173	0.017	0.069	0.011	0.080	0.039	0.009	0.001	28 Jun
26	Suståne 5-2-10	3.10	0.155	0.062	0.310	0.020	0.144	0.071	0.016	0.002	13 Jul
28	Suståne 10-2-10	1.38	0.138	0.028	0.138	0.009	0.064	0.031	0.007	0.001	24 Jul
30	Suståne 10-2-10	1.32	0.132	0.026	0.132	0.009	0.061	0.030	0.007	0.001	7 Aug
32	Suståne 10-2-10	1.46	0.146	0.029	0.146	0.009	0.068	0.033	0.007	0.001	21 Aug
34	Suståne 10-2-10	1.54	0.154	0.031	0.154	0.010	0.072	0.035	0.008	0.001	4 Sep
36	Suståne 10-2-10	1.44	0.144	0.029	0.144	0.009	0.067	0.033	0.007	0.001	18 Sep
38	Suståne 10-2-10	1.06	0.106	0.021	0.106	0.007	0.049	0.024	0.005	0.001	5 Oct
	SUM		1.713	0.316	1.513	0.125	0.894	0.438	0.096	0.010	

Appendix 1 continued.

Treatment 3: Arena® + Gro-Power® (Floratine Norge AS)

Week	Fertilizer type	Planned applications: kg product per 100 m²	kg nutrient per 100 m²: N	P	K	Mg	Ca	S	Fe	Mn	Date when fertilizer was applied
16	Arena® Høst Extra 3-3-15	1.70	0.054	0.056	0.248	0.017	0.000	0.179	0.092	0.005	28 Apr
16	Gro-Power® 45% Mg	1.00	0.000	0.000	0.000	0.450	0.016	0.000	0.000	0.000	28 Apr
16	Gro-Power® 35% Mn	1.00	0.000	0.000	0.000	0.000	0.070	0.000	0.000	0.350	28 Apr
18	Arena® Start 22-3-10	0.45	0.099	0.014	0.045	0.000	0.000	0.018	0.000	0.000	11 May
18	Gro-Power® 0-0-15	1.00	0.000	0.000	0.125	0.030	0.070	0.020	0.020	0.001	11 May
18	Gro-Power® 5-3-1	1.10	0.055	0.014	0.009	0.006	0.000	0.000	0.011	0.001	11 May
20	Arena® Green Plus 12-1-14	1.50	0.180	0.015	0.218	0.027	0.032	0.090	0.000	0.006	26 May
20	Gro-Power® 35% Mn	1.00	0.000	0.000	0.000	0.000	0.070	0.000	0.000	0.350	26 May
22	Arena® Start 22-3-10	0.80	0.176	0.024	0.080	0.000	0.000	0.032	0.000	0.000	9 Jun
22	Gro-Power® 0-0-15	1.00	0.000	0.000	0.125	0.030	0.070	0.020	0.020	0.001	9 Jun
24	Arena® Golf Extra 13-0-15	1.30	0.173	0.000	0.199	0.020	0.000	0.178	0.026	0.005	28 Jun
26	Arena® Start 22-3-10	0.70	0.154	0.021	0.070	0.000	0.000	0.028	0.000	0.000	13 Jul
26	Gro-Power® 0-0-15	1.00	0.000	0.000	0.125	0.030	0.070	0.020	0.020	0.001	13 Jul
28	Arena® Green Plus 12-1-14	0.55	0.066	0.006	0.080	0.010	0.012	0.033	0.000	0.002	24 Jul
28	Gro-Power® 5-3-1	1.45	0.073	0.019	0.012	0.007	0.000	0.000	0.015	0.001	24 Jul
30	Arena® Start 22-3-10	0.60	0.132	0.018	0.060	0.000	0.000	0.024	0.000	0.000	7 Aug
30	Gro-Power® 0-0-15	1.00	0.000	0.000	0.125	0.030	0.070	0.020	0.020	0.001	7 Aug
32	Arena® Golf Extra 13-0-15	1.10	0.146	0.000	0.168	0.017	0.000	0.151	0.022	0.004	21 Aug
34	Arena® Start 22-3-10	0.70	0.154	0.021	0.070	0.000	0.000	0.028	0.000	0.000	4 Sep
34	Gro-Power® 0-0-15	1.00	0.000	0.000	0.125	0.030	0.070	0.020	0.020	0.001	4 Sep
36	Arena® Green Plus 12-1-14	1.20	0.144	0.012	0.174	0.022	0.025	0.072	0.000	0.005	18 Sep
38	Arena® Golf Extra 13-0-15	0.80	0.106	0.000	0.122	0.012	0.000	0.110	0.016	0.003	5 Oct
38	Gro-Power® 0-0-15	1.00	0.000	0.000	0.125	0.030	0.070	0.020	0.020	0.001	5 Oct
	SUM		1.713	0.220	2.302	0.766	0.644	1.062	0.301	0.736	

Appendix 1 continued.

Treatment 4: Turf Food (E.Marker A/S, Denmark)

Planned applications											Date when fertilizer was applied
Week	Fertilizer type	kg product per 100 m^2	kg nutrient per 100 m^2								
			N	P	K	Mg	Ca	S	Fe	Mn	
16	Turf Food 5-2-12	1.07	0.054	0.010	0.107	0.021	0.032	0.021	0.011	0.001	28 Apr
18	Turf Food 14-3-5	1.10	0.154	0.013	0.046	0.006	0.011	0.044	0.044	0.001	11 May
20	Turf Food 14-3-5	1.29	0.181	0.015	0.054	0.006	0.013	0.052	0.052	0.001	26 May
22	Turf Food 14-3-5	1.26	0.176	0.015	0.053	0.006	0.013	0.050	0.050	0.001	9 Jun
24	Turf Food 14-3-5	1.24	0.174	0.015	0.052	0.006	0.012	0.050	0.050	0.001	28 Jun
26	Turf Food 15-3-8	1.03	0.155	0.012	0.068	0.005	0.010	0.010	0.010	0.001	13 Jul
28	Turf Food 15-3-8	0.92	0.138	0.011	0.061	0.005	0.009	0.009	0.009	0.001	24 Jul
30	Turf Food 15-3-8	0.88	0.132	0.011	0.058	0.004	0.009	0.009	0.009	0.001	7 Aug
32	Turf Food 12-2-12	1.22	0.146	0.011	0.122	0.006	0.012	0.024	0.012	0.001	21 Aug
34	Turf Food 12-2-12	1.28	0.154	0.012	0.128	0.006	0.013	0.026	0.013	0.001	4 Sep
36	Turf Food 12-2-12	1.20	0.144	0.011	0.120	0.006	0.012	0.024	0.012	0.001	18 Sep
38	Turf Food 12-2-12	0.88	0.106	0.008	0.088	0.004	0.009	0.018	0.009	0.001	5 Oct
	SUM		1.712	0.143	0.957	0.083	0.155	0.337	0.280	0.013	

Appendix 1 continued.

Treatment 5: Turf Food + Endo Roots (E.Marker A/S, Denmark)

Week	Fertilizer type	Planned applications									Date when fertilizer was applied
		kg product per 100 m^2	kg nutrient per 100 m^2								
			N	P	K	Mg	Ca	S	Fe	Mn	
16	Turf Food 5-2-12	1.07	0.054	0.010	0.107	0.021	0.032	0.021	0.011	0.001	28 Apr
18	Turf Food 14-3-5	0.33	0.046	0.004	0.014	0.002	0.003	0.013	0.013	0.000	11 May
18	Endo Roots 3-3-4	3.60	0.108	0.047	0.119	0.029	0.324	0.054	0.036	0.000	11 May
20	Turf Food 14-3-5	1.29	0.181	0.015	0.054	0.006	0.013	0.052	0.052	0.001	26 May
22	Turf Food 14-3-5	1.26	0.176	0.015	0.053	0.006	0.013	0.050	0.050	0.001	9 Jun
24	Turf Food 14-3-5	1.24	0.174	0.015	0.052	0.006	0.012	0.050	0.050	0.001	28 Jun
26	Turf Food 15-3-8	1.03	0.155	0.012	0.068	0.005	0.010	0.010	0.010	0.001	13 Jul
28	Turf Food 15-3-8	0.92	0.138	0.011	0.061	0.005	0.009	0.009	0.009	0.001	24 Jul
30	Turf Food 15-3-8	0.88	0.132	0.011	0.058	0.004	0.009	0.009	0.009	0.001	7 Aug
32	Turf Food 12-2-12	0.32	0.038	0.003	0.032	0.002	0.003	0.006	0.003	0.000	21 Aug
32	Endo Roots 3-3-4	3.60	0.108	0.047	0.119	0.029	0.324	0.054	0.036	0.000	21 Aug
34	Turf Food 12-2-12	1.28	0.154	0.012	0.128	0.006	0.013	0.026	0.013	0.001	4 Sep
36	Turf Food 12-2-12	1.20	0.144	0.011	0.120	0.006	0.012	0.024	0.012	0.001	18 Sep
38	Turf Food 12-2-12	0.88	0.106	0.008	0.088	0.004	0.009	0.018	0.009	0.001	5 Oct
	SUM		1.712	0.220	1.072	0.132	0.786	0.396	0.313	0.012	

Appendix 1 continued.

Treatment 6: Golf Algin A (AET AS)

Week	Fertilizer type	Planned applications								Date when fertilizer was applied
		kg product per 100 m^2	kg nutrient per 100 m^2							
			N	P	K	Mg	Ca	S	Fe	Mn	
16	Golf Algin A	0.69	0.054	0.005	0.034	0.009		0.056	0.015	0.000	28 Apr
18	Golf Algin A	1.97	0.154	0.016	0.097	0.025		0.159	0.042	0.000	11 May
20	Golf Algin A	2.31	0.180	0.018	0.114	0.029		0.186	0.050	0.000	26 May
22	Golf Algin A	2.25	0.176	0.018	0.111	0.028		0.181	0.048	0.000	9 Jun
24	Golf Algin A	2.22	0.173	0.018	0.109	0.028		0.179	0.048	0.000	28 Jun
26	Golf Algin A	1.98	0.154	0.016	0.097	0.025		0.159	0.043	0.000	13 Jul
28	Golf Algin A	1.77	0.138	0.014	0.087	0.022		0.142	0.038	0.000	24 Jul
30	Golf Algin A	1.69	0.132	0.013	0.083	0.021		0.136	0.036	0.000	7 Aug
32	Golf Algin A	1.87	0.146	0.015	0.092	0.024		0.151	0.040	0.000	21 Aug
34	Golf Algin A	1.98	0.154	0.016	0.097	0.025		0.159	0.043	0.000	4 Sep
36	Golf Algin A	1.85	0.144	0.015	0.091	0.023		0.149	0.040	0.000	18 Sep
38	Golf Algin A	1.36	0.106	0.011	0.067	0.017		0.109	0.029	0.000	5 Oct
	SUM		1.711	0.175	1.079	0.276		1.766	0.472	0.000	

Appendix 1 continued.

Treatment 7: Bio Kombi Green (Gyllebo Gödning AB, Sverige)

Week	Fertilizer type	Planned applications									Date when fertilizer was applied
		kg product per 100 m^2	kg nutrient per 100 m^2								
			N	P	K	Mg	Ca	S	Fe	Mn	
16	Bio Kombi K spec.5-1-17 + Fe	1.08	0.054	0.011	0.184	0.001	0.000	0.103	0.000	0.000	28 Apr
18	Bio Kombi Start 12-2-6 + Fe	1.28	0.154	0.026	0.077	0.004	0.000	0.017	0.000	0.000	11 May
20	Bio Kombi Start 12-2-6 + Fe	1.50	0.180	0.030	0.090	0.005	0.000	0.020	0.000	0.000	26 May
22	Bio Kombi 10-2-10 + Fe	1.76	0.176	0.035	0.176	0.005	0.000	0.042	0.000	0.000	9 Jun
24	Bio Kombi 10-2-10 + Fe	1.73	0.173	0.035	0.173	0.005	0.000	0.042	0.000	0.000	28 Jun
26	Bio Kombi 10-2-10 + Fe	1.54	0.154	0.031	0.154	0.005	0.000	0.037	0.000	0.000	13 Jul
28	Bio Kombi 10-2-10 + Fe	1.38	0.138	0.028	0.138	0.004	0.000	0.033	0.000	0.000	24 Jul
30	Bio Kombi 10-2-10 + Fe	1.32	0.132	0.026	0.132	0.004	0.000	0.032	0.000	0.000	7 Aug
32	Bio Kombi 10-2-10 + Fe	1.46	0.146	0.029	0.146	0.004	0.000	0.035	0.000	0.000	21 Aug
34	Bio Kombi 10-2-10 + Fe	1.54	0.154	0.031	0.154	0.005	0.000	0.037	0.000	0.000	4 Sep
36	Bio Kombi 10-2-10 + Fe	1.44	0.144	0.029	0.144	0.004	0.000	0.035	0.000	0.000	18 Sep
38	Bio Kombi 10-2-10 + Fe	1.06	0.106	0.021	0.106	0.003	0.000	0.025	0.000	0.000	5 Oct
	SUM		1.711	0.331	1.673	0.049	0.000	0.456	0.000	0.000	

Appendix 1 continued.

Treatment 8: Arena® + Maxicrop™ (Nordic Garden AS)

Week	Fertilizer type	Planned applications									Date when fertilizer was applied
		kg product per 100 m^2	kg nutrient per 100 m^2								
			N	P	K	Mg	Ca	S	Fe	Mn	
16	Maxicrop™ no 3 Pro-K Plus	1.22	0.024	0.000	0.195	0.000	0.000	0.000	0.000	0.000	29 Apr
16	Arena® Høst Extra 3-3-15	0.95	0.030	0.031	0.139	0.010	0.000	0.100	0.051	0.003	28 Apr
18	Maxicrop™ no 1 Triple Seaweed	0.12	0.004	0.001	0.001	0.000	0.000	0.000	0.000	0.000	11 May
18	Arena® Start 22-3-10	0.68	0.150	0.020	0.068	0.000	0.000	0.027	0.000	0.000	11 May
20	Maxicrop™ no 1 Triple Seaweed	0.12	0.004	0.001	0.001	0.000	0.000	0.000	0.000	0.000	26 May
20	Arena® Green Plus 12-1-14	1.47	0.176	0.015	0.213	0.026	0.031	0.088	0.000	0.006	26 May
22	Maxicrop™ no 1 Triple Seaweed	0.12	0.004	0.001	0.001	0.000	0.000	0.000	0.000	0.000	9 Jun
22	Arena® Start 22-3-10	0.78	0.172	0.023	0.078	0.000	0.000	0.031	0.000	0.000	9 Jun
24	Maxicrop™ no 1 Triple Seaweed	0.12	0.004	0.001	0.001	0.000	0.000	0.000	0.000	0.000	26 Jun
24	Arena® Golf Extra 13-0-15	1.27	0.169	0.000	0.194	0.019	0.000	0.174	0.025	0.005	28 Jun
26	Maxicrop™ no 1 Triple Seaweed	0.12	0.004	0.001	0.001	0.000	0.000	0.000	0.000	0.000	11 Jul
26	Arena® Start 22-3-10	0.68	0.150	0.020	0.068	0.000	0.000	0.027	0.000	0.000	13 Jul
28	Maxicrop™ no 1 Triple Seaweed	0.12	0.004	0.001	0.001	0.000	0.000	0.000	0.000	0.000	24 Jul
28	Arena® Green Plus 12-1-14	1.12	0.134	0.011	0.162	0.020	0.024	0.067	0.000	0.004	24 Jul
30	Maxicrop™ no 1 Triple Seaweed	0.12	0.004	0.001	0.001	0.000	0.000	0.000	0.000	0.000	7 Aug
30	Arena® Start 22-3-10	0.58	0.128	0.017	0.058	0.000	0.000	0.023	0.000	0.000	7 Aug
32	Maxicrop™ no 1 Triple Seaweed	0.12	0.004	0.001	0.001	0.000	0.000	0.000	0.000	0.000	22 Aug
32	Arena® Golf Extra 13-0-15	1.07	0.142	0.000	0.164	0.016	0.000	0.147	0.021	0.004	21 Aug
34	Maxicrop™ no 1 Triple Seaweed	0.12	0.004	0.001	0.001	0.000	0.000	0.000	0.000	0.000	7 Sep
34	Arena® Start 22-3-10	0.68	0.150	0.020	0.068	0.000	0.000	0.027	0.000	0.000	4 Sep
36	Maxicrop™ no 1 Triple Seaweed	0.12	0.004	0.001	0.001	0.000	0.000	0.000	0.000	0.000	18 Sep
36	Arena® Green Plus 12-1-14	1.17	0.140	0.012	0.170	0.021	0.025	0.070	0.000	0.005	18 Sep
38	Maxicrop™ no 1 Triple Seaweed	0.12	0.004	0.001	0.001	0.000	0.000	0.000	0.000	0.000	5 Oct
38	Arena® Golf Extra 13-0-15	0.77	0.102	0.000	0.118	0.012	0.000	0.105	0.015	0.003	5 Oct
	SUM		1.707	0.180	1.512	0.124	0.079	0.887	0.114	0.031	

Appendix 1 continued.

Treatment 9: Flex™ (Flex Norge AS)

Week	Fertilizer type	Planned applications									Date when fertilizer was applied
		kg product per 100 m^2	kg nutrient per 100 m^2								
			N	P	K	Mg	Ca	S	Fe	Mn	
16	Flex™ 2-2-6	2.70	0.054	0.049	0.162	0.054	0.000	0.041	0.000	0.014	28 Apr
18	Flex™ 12-2-4	1.31	0.155	0.024	0.052	0.026	0.000	0.013	0.000	0.000	11 May
20	Flex™ 12-2-4	1.52	0.179	0.027	0.061	0.030	0.000	0.015	0.000	0.000	26 May
22	Flex™ 10-0-8	1.81	0.176	0.000	0.141	0.000	0.000	0.045	0.000	0.000	9 Jun
24	Flex™ 10-0-8	1.78	0.173	0.000	0.139	0.000	0.000	0.045	0.000	0.000	28 Jun
26	Flex™ 10-0-8	1.59	0.154	0.000	0.124	0.000	0.000	0.040	0.000	0.000	13 Jul
28	Flex™ 12-2-4	1.17	0.138	0.021	0.047	0.023	0.000	0.012	0.000	0.000	24 Jul
30	Flex™ 10-0-8	1.36	0.132	0.000	0.106	0.000	0.000	0.034	0.000	0.000	7 Aug
32	Flex™ 10-0-8	1.50	0.146	0.000	0.117	0.000	0.000	0.038	0.000	0.000	21 Aug
34	Flex™ 12-2-4	1.31	0.155	0.024	0.052	0.026	0.000	0.013	0.000	0.000	4 Sep
36	Flex™ 10-0-8	1.48	0.144	0.000	0.115	0.000	0.000	0.037	0.000	0.000	18 Sep
38	Flex™ 10-0-8	1.09	0.106	0.000	0.085	0.000	0.000	0.027	0.000	0.000	5 Oct
	SUM		1.710	0.144	1.202	0.160	0.000	0.359	0.000	0.014	

Appendix 2. Fertilizer treatments compared in 2006 on sand-based football ground established at Særheim in 2005.

Treatment 1: Fullgjødsel® (control)

		Planned applications									Date when fertilizer
		kg product	kg nutrient per 100 m^2								
Week	Fertilizer type	per 100 m^2	N	P	K	Mg	Ca	S	Fe	Mn	was applied
16	Fullgjødsel® 11-5-18 mikro	1.70	0.187	0.078	0.248	0.027	0.039	0.162	0.000	0.005	27 Apr
18	Fullgjødsel® 18-3-15	1.45	0.255	0.038	0.212	0.022	0.019	0.055	0.000	0.000	10 May
20	Fullgjødsel® 18-3-15	1.45	0.255	0.038	0.212	0.022	0.019	0.055	0.000	0.000	22 May
22	Fullgjødsel® 18-3-15	1.45	0.255	0.038	0.212	0.022	0.019	0.055	0.000	0.000	7 Jun
24	Fullgjødsel® 18-3-15	1.40	0.246	0.036	0.204	0.021	0.018	0.053	0.000	0.000	20 Jun
26	Fullgjødsel® 18-3-15	1.25	0.220	0.033	0.183	0.019	0.016	0.048	0.000	0.000	30 Jun
28	Fullgjødsel® 18-3-15	1.10	0.194	0.029	0.161	0.017	0.014	0.042	0.000	0.000	17 Jul
30	Fullgjødsel® 18-3-15	1.10	0.194	0.029	0.161	0.017	0.014	0.042	0.000	0.000	1 Aug
32	Fullgjødsel® 18-3-15	1.25	0.220	0.033	0.183	0.019	0.016	0.048	0.000	0.000	14 Aug
34	Fullgjødsel® 18-3-15	1.25	0.220	0.033	0.183	0.019	0.016	0.048	0.000	0.000	29 Aug
36	Fullgjødsel® 18-3-15	1.00	0.176	0.026	0.146	0.015	0.013	0.038	0.000	0.000	12 Sep
38	Fullgjødsel® 18-3-15	0.90	0.158	0.023	0.131	0.014	0.012	0.034	0.000	0.000	27 Sep
40	Fullgjødsel® 18-3-15	0.75	0.132	0.020	0.110	0.011	0.010	0.029	0.000	0.000	9 Oct
44	Fullgjødsel® 11-5-18 mikro	0.90	0.099	0.041	0.131	0.014	0.021	0.086	0.000	0.003	24 Oct
	SUM		2.812	0.493	2.475	0.257	0.246	0.792	0.000	0.008	

Appendix 2 continued.

Treatment 2: Golf Algin A (AET AS)

Planned applications											Date when fertilizer
		kg product	kg nutrient per 100 m^2								
Week	Fertilizer type	per 100 m^2	N	P	K	Mg	Ca	S	Fe	Mn	was applied
16	Golf Algin A	2.40	0.187	0.019	0.118	0.030		0.193	0.052	0.000	27 Apr
18	Golf Algin A	3.27	0.255	0.026	0.161	0.041		0.263	0.070	0.000	10 May
20	Golf Algin A	3.27	0.255	0.026	0.161	0.041		0.263	0.070	0.000	22 May
22	Golf Algin A	3.27	0.255	0.026	0.161	0.041		0.263	0.070	0.000	7 Jun
24	Golf Algin A	3.16	0.246	0.025	0.155	0.040		0.254	0.068	0.000	20 Jun
26	Golf Algin A	2.82	0.220	0.022	0.139	0.036		0.227	0.061	0.000	30 Jun
28	Golf Algin A	2.49	0.194	0.020	0.123	0.031		0.200	0.054	0.000	17 Jul
30	Golf Algin A	2.49	0.194	0.020	0.123	0.031		0.200	0.054	0.000	1 Aug
32	Golf Algin A	2.82	0.220	0.022	0.139	0.036		0.227	0.061	0.000	14 Aug
34	Golf Algin A	2.82	0.220	0.022	0.139	0.036		0.227	0.061	0.000	29 Aug
36	Golf Algin A	2.25	0.176	0.018	0.111	0.028		0.181	0.048	0.000	12 Sep
38	Golf Algin A	2.02	0.158	0.016	0.099	0.025		0.163	0.043	0.000	27 Sep
40	Golf Algin A	1.69	0.132	0.013	0.083	0.021		0.136	0.036	0.000	9 Oct
42	Golf Algin A	1.27	0.099	0.010	0.062	0.016		0.102	0.027	0.000	24 Oct
	SUM		2.811	0.268	1.655	0.424	0.000	2.708	0.723	0.000	

Appendix 2 continued.

Treatment 3: Progreen (Osmo, Belgium)

Planned applications											Date when fertilizer
		kg product	kg nutrient per 100 m^2								
Week	Fertilizer type	per 100 m^2	N	P	K	Mg	Ca	S	Fe	Mn	was applied
16	Progreen Autumn 5-1-10	1.98	0.099	0.020	0.198	0.036	0.048	0.119	0.002	0.000	27 Apr
16	Progreen Park&Fairway 12-2-4	0.73	0.088	0.016	0.031	0.013	0.023	0.001	0.000	0.000	27 Apr
18	Progreen Park&Fairway 12-2-4	2.13	0.256	0.047	0.089	0.038	0.066	0.004	0.001	0.000	10 May
20	Progreen Park&Fairway 12-2-4	2.12	0.254	0.047	0.089	0.038	0.066	0.004	0.001	0.000	22 May
22	Progreen Universal 7-1-7	3.64	0.255	0.036	0.255	0.066	0.076	0.153	0.003	0.000	7 Jun
24	Progreen Park&Fairway 12-2-4	2.05	0.246	0.045	0.086	0.037	0.064	0.004	0.001	0.000	20 Jun
26	Progreen Universal 7-1-7	3.14	0.220	0.031	0.220	0.057	0.066	0.132	0.003	0.000	30 Jun
28	Progreen Universal 7-1-7	2.77	0.194	0.028	0.194	0.050	0.058	0.116	0.002	0.000	17 Jul
30	Progreen Park&Fairway 12-2-4	1.62	0.194	0.036	0.068	0.029	0.050	0.003	0.001	0.000	1 Aug
32	Progreen Universal 7-1-7	3.14	0.220	0.031	0.220	0.057	0.066	0.132	0.003	0.000	14 Aug
34	Progreen Universal 7-1-7	3.14	0.220	0.031	0.220	0.057	0.066	0.132	0.003	0.000	29 Aug
36	Progreen Park&Fairway 12-2-4	1.47	0.176	0.032	0.062	0.026	0.046	0.003	0.001	0.000	12 Sep
38	Progreen Universal 7-1-7	2.26	0.158	0.023	0.158	0.041	0.047	0.095	0.002	0.000	27 Sep
40	Progreen Universal 7-1-7	1.89	0.132	0.019	0.132	0.034	0.040	0.079	0.002	0.000	9 Oct
42	Progreen Autumn 5-1-10	2.00	0.100	0.020	0.200	0.036	0.048	0.120	0.002	0.000	24 Oct
	SUM		2.812	0.462	2.222	0.613	0.829	1.098	0.027	0.001	

Appendix 2 continued .

Treatment 4: Progreen + Activo (Osmo, Belgium)

Planned applications											Date when fertilizer was applied
		kg product	kg nutrient per 100 m^2								
Week	Fertilizer type	per 100 m^2	N	P	K	Mg	Ca	S	Fe	Mn	
16	Progreen Autumn 5-1-10	1.98	0.099	0.020	0.198	0.036	0.048	0.119	0.002	0.000	27 Apr
16	Progreen Park&Fairway 12-2-4	0.71	0.085	0.016	0.030	0.013	0.022	0.001	0.000	0.000	27 Apr
16	Activo 3-3-6 liquid	0.10	0.003	0.003	0.006	0	0	0	0	0	27 Apr
18	Progreen Park&Fairway 12-2-4	2.11	0.253	0.046	0.089	0.038	0.065	0.004	0.001	0.000	10 May
18	Activo 3-3-6 liquid	0.10	0.003	0.003	0.006	0	0	0	0	0	10 May
20	Progreen Park&Fairway 12-2-4	2.09	0.251	0.046	0.088	0.038	0.065	0.004	0.001	0.000	22 May
20	Activo 3-3-6 liquid	0.10	0.003	0.003	0.006	0	0	0	0	0	22 May
22	Progreen Universal 7-1-7	3.60	0.252	0.036	0.252	0.065	0.076	0.151	0.003	0.000	7 Jun
22	Activo 3-3-6 liquid	0.10	0.003	0.003	0.006	0	0	0	0	0	7 Jun
24	Progreen Park&Fairway 12-2-4	2.02	0.242	0.044	0.085	0.036	0.063	0.004	0.001	0.000	20 Jun
24	Activo 3-3-6 liquid	0.10	0.003	0.003	0.006	0	0	0	0	0	20 Jun
26	Progreen Universal 7-1-7	3.10	0.217	0.031	0.217	0.056	0.065	0.130	0.003	0.000	30 Jun
26	Activo 3-3-6 liquid	0.10	0.003	0.003	0.006	0	0	0	0	0	30 Jun
28	Progreen Universal 7-1-7	2.73	0.191	0.027	0.191	0.049	0.057	0.115	0.002	0.000	17 Jul
28	Activo 3-3-6 liquid	0.10	0.003	0.003	0.006	0	0	0	0	0	17 Jul
30	Progreen Park&Fairway 12-2-4	1.59	0.191	0.035	0.067	0.029	0.049	0.003	0.001	0.000	1 Aug
30	Activo 3-3-6 liquid	0.10	0.003	0.003	0.006	0	0	0	0	0	1 Aug

Appendix 2 continued.

Treatment 4: Progreen + Activo (Osmo, Belgium) continued.

Planned applications											Date when fertilizer was applied
		kg product	kg nutrient per 100 m^2								
Week	Fertilizer type	per 100 m^2	N	P	K	Mg	Ca	S	Fe	Mn	
32	Progreen Universal 7-1-7	3.10	0.217	0.031	0.217	0.056	0.065	0.130	0.003	0.000	14 Aug
32	Activo 3-3-6 liquid	0.10	0.003	0.003	0.006	0	0	0	0	0	14 Aug
34	Progreen Universal 7-1-7	3.10	0.217	0.031	0.217	0.056	0.065	0.130	0.003	0.000	29 Aug
34	Activo 3-3-6 liquid	0.10	0.003	0.003	0.006	0	0	0	0	0	29 Aug
36	Progreen Park&Fairway 12-2-4	1.44	0.173	0.032	0.060	0.026	0.045	0.003	0.001	0.000	12 Sep
36	Activo 3-3-6 liquid	0.10	0.003	0.003	0.006	0	0	0	0	0	12 Sep
38	Progreen Universal 7-1-7	2.22	0.155	0.022	0.155	0.040	0.047	0.093	0.002	0.000	27 Sep
38	Activo 3-3-6 liquid	0.10	0.003	0.003	0.006	0	0	0	0	0	27 Sep
40	Progreen Universal 7-1-7	1.84	0.129	0.018	0.129	0.033	0.039	0.077	0.002	0.000	9 Oct
40	Activo 3-3-6 liquid	0.10	0.003	0.003	0.006	0	0	0	0	0	9 Oct
42	Progreen Autumn 5-1-10	1.92	0.096	0.019	0.192	0.035	0.046	0.115	0.002	0.000	24 Oct
42	Activo 3-3-6 liquid	0.10	0.003	0.003	0.006	0	0	0	0	0	24 Oct
	SUM		2.811	0.497	2.271	0.604	0.816	1.081	0.027	0.001	

Appendix 2 continued.

Treatment 5: Flex™ (Flex Norge AS)

		Planned applications									Date when fertilizer
		kg product	kg nutrient per 100 m^2								
Week	Fertilizer type	per 100 m^2	N	P	K	Mg	Ca	S	Fe	Mn	was applied
16	Flex™ 2-2-6	4.00	0.080	0.072	0.240	0.080	0.000	0.060	0.000	0.020	27 Apr
16	Flex™ 12-2-4	0.91	0.107	0.016	0.036	0.018	0.000	0.009	0.000	0.000	27 Apr
18	Flex™ 12-2-4	2.16	0.255	0.039	0.086	0.043	0.000	0.022	0.000	0.000	10 May
20	Flex™ 12-2-4	2.16	0.255	0.039	0.086	0.043	0.000	0.022	0.000	0.000	22 May
22	Flex™ 10-0-8	2.63	0.255	0.000	0.205	0.000	0.000	0.066	0.000	0.000	7 Jun
24	Flex™ 10-0-8	2.54	0.246	0.000	0.198	0.000	0.000	0.064	0.000	0.000	20 Jun
26	Flex™ 12-2-4	1.86	0.219	0.033	0.074	0.037	0.000	0.019	0.000	0.000	30 Jun
28	Flex™ 10-0-8	2.00	0.194	0.000	0.156	0.000	0.000	0.050	0.000	0.000	17 Jul
30	Flex™ 10-0-8	2.00	0.194	0.000	0.156	0.000	0.000	0.050	0.000	0.000	1 Aug
32	Flex™ 10-0-8	2.27	0.220	0.000	0.177	0.000	0.000	0.057	0.000	0.000	14 Aug
34	Flex™ 12-2-4	1.87	0.221	0.034	0.075	0.037	0.000	0.019	0.000	0.000	29 Aug
36	Flex™ 10-0-8	1.81	0.176	0.000	0.141	0.000	0.000	0.045	0.000	0.000	12 Sep
38	Flex™ 10-0-8	1.63	0.158	0.000	0.127	0.000	0.000	0.041	0.000	0.000	27 Sep
40	Flex™ 10-0-8	1.36	0.132	0.000	0.106	0.000	0.000	0.034	0.000	0.000	9 Oct
42	Flex™ 2-2-6	4.95	0.099	0.089	0.297	0.099	0.000	0.074	0.000	0.025	31 Oct
	SUM		2.812	0.250	1.922	0.278	0.000	0.570	0.000	0.025	

Appendix 3. Fertilizer treatments compared in 2006 on a three year old USGA green at Apelsvoll

Treatment 1: Arena® (control)

Week	Fertilizer type	Planned applications: kg product per 100 m^2	kg nutrient per 100 m^2: N	P	K	Mg	Ca	S	Fe	Mn	Date when fertilizer was applied
18	Arena® Høst Extra 3-3-15	2.50	0.080	0.083	0.365	0.025	0.000	0.263	0.135	0.008	4 May
20	Arena® Golf Extra 13-0-15	1.30	0.173	0.000	0.199	0.020	0.000	0.178	0.026	0.005	19 May
22	Arena® Start 22-3-10	0.80	0.176	0.024	0.080	0.000	0.000	0.032	0.000	0.000	31 May
24	Arena® Green Plus 12-1-14	1.50	0.180	0.015	0.218	0.027	0.032	0.090	0.000	0.006	14 Jun
26	Arena® Golf Extra 13-0-15	1.30	0.173	0.000	0.199	0.020	0.000	0.178	0.026	0.005	29 Jun
28	Arena® Start 22-3-10	0.70	0.154	0.021	0.070	0.000	0.000	0.028	0.000	0.000	17 Jul
30	Arena Golf Extra 13-0-15	1.20	0.160	0.000	0.184	0.018	0.000	0.164	0.024	0.005	27 Jul
32	Arena® Green Plus 12-1-14	1.30	0.156	0.013	0.189	0.023	0.027	0.078	0.000	0.005	8 Aug
34	Arena® Golf Extra 13-0-15	1.30	0.173	0.000	0.199	0.020	0.000	0.178	0.026	0.005	25 Aug
36	Arena® Start 22-3-10	0.60	0.132	0.018	0.060	0.000	0.000	0.024	0.000	0.000	7 Sep
38	Arena® Green Plus 12-1-14	1.00	0.120	0.010	0.145	0.018	0.021	0.060	0.000	0.004	20 Sep
41	Arena® Høst Extra 3-3-15	2.50	0.080	0.083	0.365	0.025	0.000	0.263	0.135	0.008	11 Oct
	SUM		1.756	0.266	2.271	0.195	0.080	1.536	0.372	0.052	

Appendix 3 continued.

Treatment 2. Flex™ (Flex Norge AS)

Week	Fertilizer type	Planned applications: kg product per 100 m^2	kg nutrient per 100 m^2: N	P	K	Mg	Ca	S	Fe	Mn	Date when fertilizer was applied
18	Flex™ 2-2-6										
20	Flex™ 12-2-4										
22	Flex™ 10-0-9										
24	Flex™ 10-0-9										
26	Flex™ 10-0-9										
28	Flex™ 10-0-9										
30	Flex™ 10-0-9										
32	Flex™ 10-0-9										
34	Flex™ 10-0-9										
36	Flex™ 10-0-9										
38	Flex™ 10-0-9										
41	Flex™ 2-2-6										
	SUM										

Not presented because of mistakes when calculating application rates.

Appendix 3 continued.

Treatment 3. Arena® + one application of GoGreen in autumn (AmegA Sciences , UK / E. Marker, Denmark)

Planned applications											
			kg nutrient per 100 m^2								Date when fertilizer
Week	Fertilizer type	kg product per 100 m^2	N	P	K	Mg	Ca	S	Fe	Mn	was applied
18	Arena® Høst Extra 3-3-15	2.50	0.080	0.083	0.365	0.025	0.000	0.263	0.135	0.008	4 May
20	Arena® Golf Extra 13-0-15	1.30	0.173	0.000	0.199	0.020	0.000	0.178	0.026	0.005	19 May
22	Arena® Start 22-3-10	0.80	0.176	0.024	0.080	0.000	0.000	0.032	0.000	0.000	31 May
24	Arena® Green Plus 12-1-14	1.50	0.180	0.015	0.218	0.027	0.032	0.090	0.000	0.006	14 Jun
26	Arena® Golf Extra 13-0-15	1.30	0.173	0.000	0.199	0.020	0.000	0.178	0.026	0.005	29 Jun
28	Arena® Start 22-3-10	0.70	0.154	0.021	0.070	0.000	0.000	0.028	0.000	0.000	17 Jul
30	Arena® Golf Extra 13-0-15	1.20	0.160	0.000	0.184	0.018	0.000	0.164	0.024	0.005	27 Jul
32	Arena® Green Plus 12-1-14	1.30	0.156	0.013	0.189	0.023	0.027	0.078	0.000	0.005	8 Aug
34	Arena® Golf Extra 13-0-15	1.30	0.173	0.000	0.199	0.020	0.000	0.178	0.026	0.005	25 Aug
36	Arena® Start 22-3-10	0.60	0.132	0.018	0.060	0.000	0.000	0.024	0.000	0.000	7 Sep
38	Arena® Green Plus 12-1-14	0.33	0.040	0.003	0.048	0.006	0.007	0.020	0.000	0.001	20 Sep
38	GoGreen 2-0-10 + Fe	4.00	0.080	0.000	0.400	0.000	0.000	0.000	0.348	0.000	20 Sep
41	Arena® Høst Extra 3-3-15	2.50	0.080	0.083	0.365	0.025	0.000	0.263	0.135	0.008	11 Oct
	SUM		1.756	0.259	2.574	0.183	0.066	1.496	0.720	0.049	

Appendix 3 continued.

Treatment 4. Ammoniumsulfate + Arena® Høst Extra

Planned applications											
			kg nutrient per 100 m^2								Date when fertilizer was applied
Week	Fertilizer type	kg product per 100 m^2	N	P	K	Mg	Ca	S	Fe	Mn	
18	Arena® Høst Extra 3-3-15	2.50	0.080	0.083	0.365	0.025	0.000	0.263	0.135	0.008	4 May
20	Ammoniumsulfate	1.40	0.297	0.000	0.000	0.000	0.000	0.339	0.000	0.000	19 May
22	Arena® Høst Extra 3-3-15	1.50	0.048	0.050	0.219	0.015	0.000	0.158	0.081	0.005	31 May
24	Ammoniumsulfate	1.40	0.297	0.000	0.000	0.000	0.000	0.339	0.000	0.000	14 Jun
26	Arena® Høst Extra 3-3-15	1.50	0.048	0.050	0.219	0.015	0.000	0.158	0.081	0.005	29 Jun
28	Ammoniumsulfate	1.30	0.276	0.000	0.000	0.000	0.000	0.315	0.000	0.000	17 Jul
30	Arena® Høst Extra 3-3-15	1.50	0.048	0.050	0.219	0.015	0.000	0.158	0.081	0.005	27 Jul
32	Ammoniumsulfate	1.30	0.276	0.000	0.000	0.000	0.000	0.315	0.000	0.000	8 Aug
34	Arena® Høst Extra 3-3-15	1.50	0.048	0.050	0.219	0.015	0.000	0.158	0.081	0.005	25 Aug
36	Ammoniumsulfate	0.65	0.138	0.000	0.000	0.000	0.000	0.157	0.000	0.000	7 Sep
38	Ammoniumsulfate	0.40	0.085	0.000	0.000	0.000	0.000	0.097	0.000	0.000	20 Sep
38	Arena® Høst Extra 3-3-15	1.20	0.038	0.040	0.175	0.012	0.000	0.126	0.065	0.004	20 Sep
41	Arena® Høst Extra 3-3-15	2.50	0.080	0.083	0.365	0.025	0.000	0.263	0.135	0.008	11 Oct
	SUM		1.758	0.403	1.781	0.122	0.000	2.842	0.659	0.039	

Appendix 3 continued.

Treatment 5. Arena® + two applications of GoGreen in late summer / autumn (AmegA Sciences , UK / E. Marker, Denmark)

Planned applications											
			kg nutrient per 100 m^2								Date when fertilizer was applied
Week	Fertilizer type	kg product per 100 m^2	N	P	K	Mg	Ca	S	Fe	Mn	
18	Arena® Høst Extra 3-3-15	2.50	0.080	0.083	0.365	0.025	0.000	0.263	0.135	0.008	4 May
20	Arena® Golf Extra 13-0-15	1.30	0.173	0.000	0.199	0.020	0.000	0.178	0.026	0.005	19 May
22	Arena® Start 22-3-10	0.80	0.176	0.024	0.080	0.000	0.000	0.032	0.000	0.000	31 May
24	Arena® Green Plus 12-1-14	1.50	0.180	0.015	0.218	0.027	0.032	0.090	0.000	0.006	14 Jun
26	Arena® Golf Extra 13-0-15	1.30	0.173	0.000	0.199	0.020	0.000	0.178	0.026	0.005	29 Jun
28	Arena® Start 22-3-10	0.70	0.154	0.021	0.070	0.000	0.000	0.028	0.000	0.000	17 Jul
30	Arena® Golf Extra 13-0-15	1.20	0.160	0.000	0.184	0.018	0.000	0.164	0.024	0.005	27 Jul
32	Arena® Green Plus 12-1-14	1.30	0.156	0.013	0.189	0.023	0.027	0.078	0.000	0.005	8 Aug
34	Arena® Golf Extra 13-0-15	0.70	0.093	0.000	0.107	0.011	0.000	0.096	0.014	0.003	25 Aug
34	GoGreen 2-0-10 + Fe	4.00	0.080	0.000	0.400	0.000	0.000	0.000	0.348	0.000	25 Aug
36	Arena® Start 22-3-10	0.60	0.132	0.018	0.060	0.000	0.000	0.024	0.000	0.000	7 Sep
38	Arena® Green Plus 12-1-14	1.00	0.120	0.010	0.145	0.018	0.021	0.060	0.000	0.004	20 Sep
41	GoGreen 2-0-10 + Fe	4.00	0.080	0.000	0.400	0.000	0.000	0.000	0.348	0.000	11 Oct
	SUM		1.757	0.184	2.615	0.161	0.080	1.191	0.921	0.041	