Bioforsk Rapport
Bioforsk Report
Vol. 6 Nr. 3 2011

# Impact of mowing height and late autumn fertilization on winter survival and spring performance of golf greens in the Nordic countries

## Field experiments at golf courses in Finland, Sweden and Norway

Agnar Kvalbein & Trygve S. Aamlid

**Hovedkontor/Head office**
Frederik A. Dahls vei 20
N-1432 Ås
Tel.: (+47) 40 60 41 00
post@bioforsk.no

**Bioforsk Landvik**
**Bioforsk Øst**
Reddalsveien 215
4886 Grimstad
Telefon: (+47) 40 60 41 00
agnar.kvalbein@bioforsk.no

| *Tittel/Title:* |
|---|
| Impact of mowing height and late autumn fertilization on winter survival and spring performance of golf greens in the Nordic countries. |
| *Forfatter(e)/Author(s):* |
| Agnar Kvalbein, Trygve S Aamlid |

| *Dato/Date:* | *Tilgjengelighet/Availability:* | *Prosjekt nr./Project No.:* | *Saksnr./Archive No.:* |
|---|---|---|---|
| 2011.02.15 | Åpen / Open | 1910 102 | |
| *Rapport nr./Report No.:* | *ISBN-13-nr./ISBN-13-no:* | *Antall sider/Number of pages:* | *Antall vedlegg/Number of appendices:* |
| 3 (6) 2011 | 978-82-17-00746-3 | 41 | 0 |

| *Oppdragsgiver/Employer:* | *Kontaktperson/Contact person:* |
|---|---|
| Scandinavian Turfgrass and Environment Research Foundation (STERF) | Maria Strandberg |

| *Stikkord/Keywords:* | *Fagområde/Field of work:* |
|---|---|
| gras, green, gress, høstgjødsling, klippehøyde, nitrogen, snømugg, vekststart, vinterskader,<br>Green, late fall fertilization, turf, mowing height, winter stress, nitrogen, snow mould, spring performance | Frøavl og gras til grøntanlegg<br>Sports turf |

*Sammendrag:*

Forsøk gjennom to vintre på golfgreener i Norden viste lite effekt av økt klippehøyde om høsten, men positiv effekt av sen høstgjødsling; 0,2 kg N pr 100 m$^2$ etter at veksten var avsluttet. Vinterskadene ble litt redusert og gresset ga et bedre inntrykk om våren. Det var forskjell på gressartene. Tunrapp *(Poa annua)* viste ikke klar respons på behandlingen, mens rødsvingel *(Festuca rubra)*, krypkvein *(Agrosis stolonifera)* og hundekvein *(A.canina)* delvis ga signifikante resultater.

*Summary:*

Experiments were set up over two winter seasons on golf greens i the Nordic countries. Two mowing heights in the autumn and one late application of 0.2 kg N /100 m2 were examined for effects on winter survival and turf performance in the spring. There were small effects from mowing height, but partly significant positive effects of fertilization. The results form annual meadow grass *(Poa annua)* were not consistent, but red fescue *(Festuca rubra)*, creeping bentgrass *(Agrostis stolonifera)* and velvet bent grass *(A.canina)* accorded.

| *Land/Country:* | Finland, Sweden, Norway |
|---|---|

Godkjent / Approved

Trygve S. Aamlid

Prosjektleder / Project leader

Agnar Kvalbein

# Preface

This project was funded by the Scandinavian Turfgrass and Environment Research Foundation (STERF). Thanks to all the participating greenkeepers who spent a lot of time to set up these experiments. Due to many different reasons some of the local experiments did not contribute to the conclusions from this research project, but they brought us knowledge about the unstable working conditions for greenkeepers, the unpredictable winter weather and how challenging it is to compare data collected from many different sources.

Landvik,

15 February 2011

Agnar Kvalbein

# Table of contents

Summary ....................................................................................................4

Sammendrag ..............................................................................................5

1. Introduction ..........................................................................................6
   1.1 Mowing height ....................................................................................6
   1.2 Late autumn fertilization ....................................................................7

2. Methods ..................................................................................................9
   2.1 Experimental sites ..............................................................................9
   2.2 Training of personal ..........................................................................10
   2.3 Experimental set-up ..........................................................................11
      *2.3.1 Mowing height* ............................................................................11
      *2.3.2 Fertilization* ................................................................................11
      *2.3.3 Registrations* ..............................................................................12
      *2.3.4 Statistical analyses* ....................................................................12

3. Results ..................................................................................................13
   3.1 Individual results from each of the golf courses ..............................13
      3.1.1 Keri Golf ........................................................................................14
      3.1.2 Messilä golf ....................................................................................15
      3.1.3 Peuramaa golf ................................................................................17
      3.1.4 Fullerö golf .....................................................................................18
      3.1.5 Kungliga Drottningholm Golf Club ...............................................19
      3.1.6 Saltsjöbaden golfklubb ..................................................................20
      3.1.7 Bjaavann golfklubb ........................................................................22
      3.1.8 Mørk golf ........................................................................................23
      3.1.9 Trones golf course (Stiklestad golf club) .......................................24
      3.1.10 Vestfold Golf Club .........................................................................25
      3.1.11 Landvik experimental green A ......................................................26
      3.1.12 Landvik experimental green B ......................................................27
      3.1.13 Apelsvoll experimental green .......................................................28
   3.2 Overall results for each species ........................................................29
      3.2.1 Red fescue greens ..........................................................................29
      3.2.2 Creeping bent grass greens ............................................................30
      3.2.3 Velvet bent grass greens ................................................................31
      3.2.4 Annual meadow grass greens .........................................................32

4. Discussion and conclusions ..................................................................33
   4.1 Mowing height ....................................................................................33
      4.1.1 Winter damages .............................................................................33
      4.1.2 Snow mould ....................................................................................33
      4.1.3 Conclusion on mowing height and winter injuries .........................33
   4.2 Spring performance ...........................................................................34
      4.2.1 Conclusion on mowing height and spring performance ..................34
   4.3 Mowing height in the autumn under Nordic conditions .....................34
   4.4 Late autumn fertilization (LAF) ..........................................................35
      4.4.1 LAF and winter damage .................................................................35
      4.4.2 LAF and spring performance ..........................................................37
      4.4.3 Conclusions regarding late autumn fertilization ............................38
   4.5 Suggestions for improved fertilization practice .................................38

5. References .............................................................................................39

# Summary


Positive effects from late autumn fertilization of turf grass, such as better winter colour and improved spring performance, have been reported from several studies in the US. However, applying fertilizer after growth cessation has not been common practice on golf greens in the Nordic countries.

The effects of mowing height in the autumn have not been well documented in previous studies. Increased mowing height on golf greens has been recommended by agronomists, but has not always been adopted in practice.

In autumn 2008, 18 experiments were established at golf courses in Finland (3), Sweden (3), Norway (11), and Iceland (1) with two mowing heights, 100% and 150% of normal height at the golf course. The greens were fertilized with a balanced, soluble fertilizer giving 0.2 kg N pr 100 $m^2$ when the turf had stopped growing.

The experiment was repeated during the winter 2009/2010. The winter injuries were different during these two winter seasons. The first winter was unstable, and ice cover caused severe injuries especially on annual meadow grass (*Poa annua* L.) greens. The last winter was extraordinarily stable, with permanent snow cover for 2-3 months even in Denmark.

Different grass species were represented in the trials; creeping bent grass (*Agrostis stolonifera* L.), red fescue (*Festuca rubra* L.), velvet bent grass (*Agrostis canina* L.) and annual meadow grass.

Turf cover (%) in the spring and general impression of turf quality were recorded in about 50% of the trials. Some observations of diseases and turf colour were also reported.

There were no or just small effects of different mowing heights. In red fescue we found a positive tendency on spring performance ($p$=0.10) from high mowing in one out of four trials.

There was no negative effects of late autumn fertilization but significantly better spring performance in three out of four trials with red fescue dominance. Two out of seven creeping bent grass greens and one out of four velvet bent grass greens also had significantly improved spring performance after late autumn fertilization. The same tendency was observed also in most of the other trials. Only two out of 20 greens with perennial grass species showed no effect of late autumn fertilization.

Winter injuries were not significantly affected by the late autumn fertilization, but there were tendencies to better winter survival and less snow mould on some greens.

Annual meadow grass greens were severely injured by anoxia in 2009 and by snow moulds in 2010. The trials gave not solid data for drawing conclusions concerning annual meadow grass greens.

Due to the risk of nutrient leakage after late autumn fertilization, further investigations should be done before compiling general recommendations. There are also reasons to assume that enhanced applications of fertilizer throughout the autumn will be preferable to one relatively large application of fertilizer in late autumn

# Sammendrag

Fra USA er det blitt rapportert positiv effekt av sein høstgjødsling av gress til grøntanlegg. Effekten har vært bedre vinterfarge og kondisjon om våren. Men det å tilføre gjødsel etter at veksten er avsluttet om høsten har ikke vært anerkjent praksis for golf greener i Norden.

Effekten av økt klipphøyde om høsten er ikke godt dokumentert i tidligere studier. Økt klippehøyde har blitt anbefalt av rådgivere, men dette er ikke alltid blitt fulgt i praksis.

Høsten 2008 ble det anlagt 18 forsøk på golfbaner i Finland (3), Sverige (3), Norge (11) og Island (1) med to forskjellige klippehøyder, 100% og 150% av den normale klippehøyden. Forsøksgreenene ble også tilført balansert, lettløselig gjødsel som ga 0,2 kg N pr 100 $m^2$ etter at gresset hadde sluttet å vokse.

Forsøket ble gjentatt vintersesongen 2009/2010. Vinterskadene var forskjellige de to sesongene. Første vinteren var været ustabilt og isdekke forårsaket store skader, særlig på tunrapp *(Poa annua L.)* Den siste vinteren var annerledes, med varig snødekke i 2-3 måneder selv i Danmark.

Ulike gressarter var representert i forsøket; krypkvein (Agrostis stolonifera L.), rødsvingel (Festuca rubra L.), hundekvein (Agrostis canina L.) og tunrapp.

Det ble registrert dekningsgraden om våren og generelt inntrykk av gresskvalitet på omtrent halvparten av forsøks-stedene. På noen steder ble det også registrert farge og sykdomsangrep.

Det var ingen eller små effekter av ulike klippehøyder. I rødsvingel var det tendens til positiv effekt ($p$=0,10) av høy klipping på et av fire forsøk.

Det var ingen negativ effekt av sein høstgjødsling, men signifikant bedre gress om våren på tre av fire rødsvingeldominerte greener. To av syv krypkveingsgreener og en av fire hundekveinsgreener hadde også signifikant bedre vårkvalitet etter sein høstgjødsling. Den samme tendensen ble observert på de fleste andre golfbaner. Bare to av 20 greener med flerårig gras viste overhode ingen effekt av sein høstgjødsling.

Omfanget av vinterskader ble ikke signifikant påvirket av sein høstgjødsling, men det var tendenser til bedre vinteroverlevelse og mindre snømugg på noen greener.

Tunrappgreenene ble hardt skadet av isbrann i 2009 og av snømugg i 2010. Forsøksgreenene ga ikke gode nok data til å kunne trekke konklusjoner om tunrappgreener.

Fordi det er fare for utlekking av næringsstoffer etter sein høstgjødsling, bør det utføres flere forsøk før det gis generelle anbefalinger. Det er også grunner til å hevde at økt tilførsel av gjødsel jevnt fordelt utover høsten vil være å foretrekke framfor en forholdsvis stor gjødseldose senhøstes.

# 1. Introduction

This project commenced from a discussion amongst greenkeepers and consultants about the mowing height on golf greens in autumn. Agronomists argued that a higher cut in the autumn would enlarge the photosynthesising leaf surface and increase carbohydrate storage. Some greenkeepers were sceptical that this could lead to more snow mould, especially in creeping bent grass (*Agrostis stolonifera* L)

The other subject was whether fertilizing in late autumn had any positive effect on winter survival and spring performance under Nordic conditions. American recommendations on late fall fertilization (LFF) was not embraced for environmental reasons, and the practice was not supported by consultants or agronomist.

## 1.1 Mowing height

Sunlight is the energy source for all plants through photosynthesis. When sunlight decreases in the autumn, due to shorter days and lower radiation angle, it seems obvious that a grass plant will benefit from higher mowing. More chlorophyll will absorb more energy, produce more carbohydrates for winter storage, and improve the winter survival of the turf.

We found no reports from experiments on golf greens supporting this theory. On the contrary, most textbooks and articles recommend keeping the mowing unchanged in autumn.

A four year study of creeping bent grass mowed at three different heights showed that the lowest cut gave the highest content of non-structural carbohydrates (Narra et al 2004). But the mowing heights in this study was high ((0.64, 1.27, and 1.90 cm) compared to modern greens.

Japanese workers studied creeping bent grass at two N fertilizer rates and mowed at 5 and 12 mm. They concluded that turf quality was better under high N input, but added that the quality may be further improved under high mowing height management (Razmjoo 1996). Winter injury was not the main focus of this study, but winter colour in the transition zone.

Extremely high mowing, like 5 cm on creeping bent grass, has been proven to reduce cold tolerance possibly due to aboveground elevation of crowns and stolons (White & Smithberg 1980). These authors also reported the same cold tolerance for smooth-stalked meadow grass *(Poa pratensis)* and red fescue mowed at 1.5 and 5 cm height over a three year period.

However, regarding smooth-stalked meadow grass, Beard (1972) showed data leading to a different conclusion.

In their textbook Fry and Huang (2004) recommend to keep the mowing height relatively high in spring and autumn for cool-season grasses to maximize carbohydrate storage prior to midsummer heat stress. But they do not discuss the relations between mowing height and winter stress.

Another text book says: Mowing should continue as long as the turf is growing, otherwise snow mould might be encouraged. Only if the turf has been cut shorter than optimum in the season, it is recommended to rise the mowing height to the upper limit of optimal height in the autumn (Stier and Fei 2008).

To the best of our knowledge, there is no experimental evidence supporting the practice of some Nordic greenkeepers to increase the mowing height on golf greens in the autumn to achieve better winter survival. There are some reports on winter performance of warm season grasses related to mowing height, but these are not relevant here. High temperature stress for cool-season grasses seems to have been the main focus for the researchers working with mowing height on golf greens.

## 1.2 Late autumn fertilization

Greenkeepers do fertilize in many different ways, but applying easily accessible nitrogen when the turf has stopped growing in the autumn has rarely been practised or recommended in the Nordic countries. Disturbing the hardening process could have serious consequences. Greenkeepers have therefore been reticent when applying nitrogen in the autumn to avoid vegetative growth and lush plants. On the other hand they have been rather munificent when it comes to potassium. Neither of these practices is based on studies.

In Virginia (36-37ºN) autumn and winter nitrogen application increased photosynthesis and kept the turf green throughout the winter. No measurable top growth occurred. Turf fertilized with 5 kg N pr 100 $m^2$ from October through February was very dense. The carbohydrate content in bent grass stems was highest until January for the low N treatment (0.5 kg N pr 100$m^2$ in October) but from February until May the high N treated plants had higher carbohydrate content (Powel & al. 1967).

An experiment over 7 years (Engel & Bussey 1979) showed that a single application of soluble nitrogen in December decreased annual meadow grass *(Poa annua)* content in a low cut creeping bent grass turf, compared to split application in September and December.

Most of the positive effects from late autumn fertilization; improved winter colour, earlier spring green up and improved spring performance (Kussow 1988, Hummel 1990, Grossi & al 2005), have been documented in smooth-stalked meadow grass *(Poa pratensis)* (Hanson & Juska 1961, Wilkinson & Duff, 1972, Wehner & Haley 1993). This species has, however, better winter tolerance and deeper winter dormancy than most other turf grasses, and results with winter performance of smooth-stalked meadow grass are therefore not necessarily applicable to other grass species.

Based on these and other studies, turf grass specialists in the cool-humid region of US have recommended that more than 50% of the N should be applied in two or three applications in the autumn, with September as the most essential timing. A two year study, including three species and seven different N programs was set up in Illinois by Walker &al (2006). The aim was to determine the best practice for fertilizing cool-season lawns. The researchers confirmed the positive effects of autumn fertilization but added that if the turf manager desires to apply N only once during the year, mid-November appears to be the best timing.

Late autumn fertilization of golf greens has become common practice amongst greenkeepers in the northern part of USA (Lloyd 2009)

A report from Ireland and France examining the effect of closure time and autumn fertilization concluded that there were no effects of fertilization in Ireland, but increased tiller numbers and earlier spring growth in France (Culleton & al 1991).

Winter injuries have not been the main focus for the turf grass experiments that we have seen reported.

Webster and Ebdon (2005) reported that maximum cold hardiness occurred for ryegrass (*Lolium perenne*) with low to moderate levels of nitrogen (49 – 147 kg N /ha/year) and medium-high to high levels of potassium (245 – 441 kg K/ha/year). Sixty to 70 % of the total application was given from late August through late November. Nitrogen applied in late autumn did not appear to increase the potential for winter injury.

Recommendations on late autumn fertilization normally take no reservations regarding different species, but warn against mid-autumn fertilization when temperature is high enough to stimulate foliar growth (Stier 2005)

Adaption to cold climate in winter cereals seems to be developed to avoid negative effects of photo inhibition. The production of sucrose (stored as fructans) provides a mechanism for safe dissipation of excessive light energy, through photochemical quenching. This cold hardening mechanism requires high light and low temperature conditions over some time (Huner & al 1993). Low temperatures exacerbate an imbalance between the source of energy and the metabolic sink. Photosynthesis itself functions as a sensor and interacts with the other processes causing acclimatization to cold temperatures (Ensminger & al 2006) There is a link between the function of the photosynthetic apparatus under cold stress and the frost tolerance levels for *Festuca* grass plants, and these mechanisms are controlled genetically (Sandve & al. 2010)

Late applications of soluble nutrients entail increased leakage through drainage water, even on loamy sand soil (Mangiafico & Gullard 2006). This is probably the weightiest argument against late autumn fertilization.

The concern about increased snow mould attack after moderate late autumn fertilization is to our knowledge not founded on experiments under green conditions.

# 2. Methods

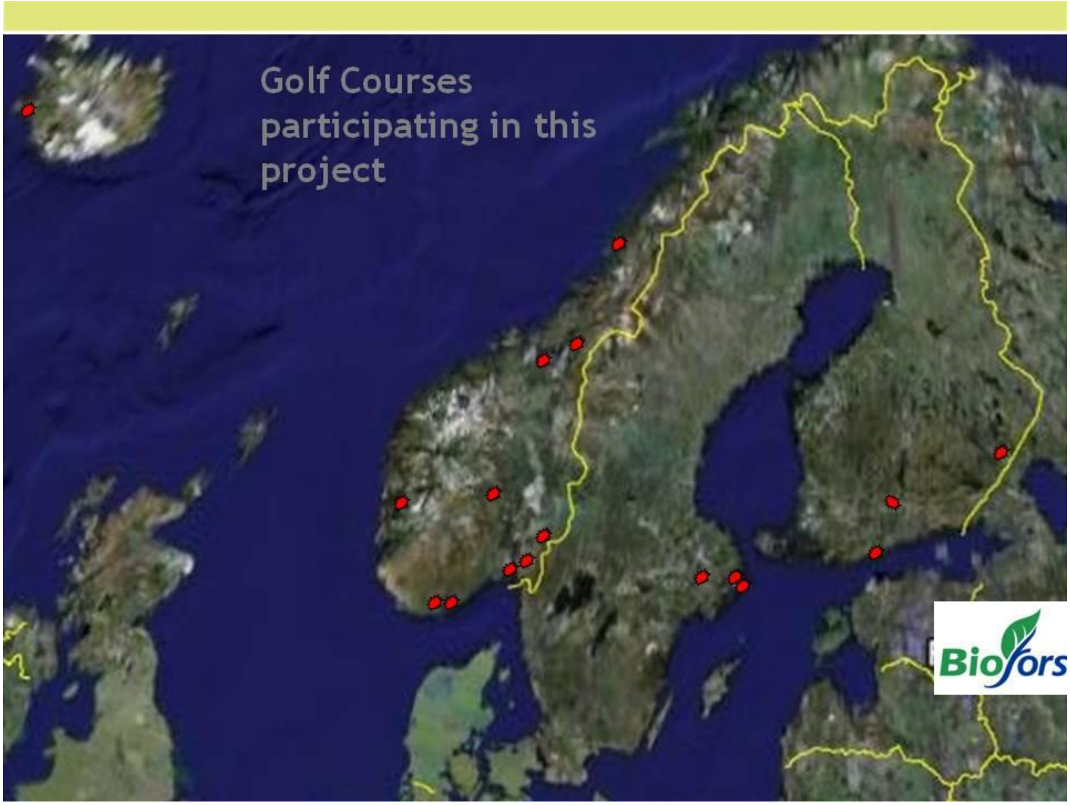
This experiment was set up on golf courses where severe winter injuries occur regularly.

## 2.1 Experimental sites

Golf courses from the Nordic countries were invited through the greenkeepers associations to participate in the project. Greenkeepers from all the Nordic counties responded positively to the enquiry. However, the only Danish golf course owner would not invest in this project and cancelled the participation. Fifteen golf courses were represented when the project started in August 2008. In addition two experiments were set up at the Bioforsk turf grass research centre Landvik, Norway.

*Table 1. The locations of the golf greens participating in the experiment.*

| Golf Course | Nearest town | Dominating green grass species |
|---|---|---|
| **Finland:** | | |
| Messilä Golf | Lahti | Creeping bent grass |
| Keri- Golf | Savolinna | Annual meadow grass |
| Peuramaa Golf | Helsinki | Velvet bent grass |
| **Sweden:** | | |
| Saltsjöbaden Golf Club | Stockholm | Annual meadow grass |
| Kunglige Drottningholm GC | Stockholm | Annual meadow grass |
| Fullerö golf club | Västerås | Annual meadow grass |
| **Norway:** | | |
| Mørk golf | Spydeberg | Creeping bent grass |
| Kongsvinger GC | Kongsvinger | Creeping bent grass |
| Vestfold GC | Stokke | Red fescue /common bent grass |
| Hemsedal Golf Alpin | Geilo | Red fescue /common bent grass |
| Byneset Golf | Trondheim | Creeping bent grass |
| Voss GC | Voss | Red fescue /common bent grass |
| Trones Golf Course | Verdal | Creeping bent |
| Bodø Golf Course | Bodø | Red fescue /common bent grass |
| Bioforsk Landvik | Grimstad | Red fescue |
| Bioforsk Landvik | Grimstad | Creeping bent grass |
| Bioforsk Apelsvoll (2009/10) | Gjøvik | Velvet bent grass |
| **Iceland:** | | |
| Holmsvollur Leira GC | Sadurnesja | Red fescue |



*Picture 1 The position of the golf courses participating in the project August 2008.*

## 2.2 Training of personal

The participating greenkeepers were invited to seminars at Landvik in August 2008 and at Apelsvoll in August 2009. At Landvik they were trained to set up experiments and to do field registrations. At Apelsvoll the first winter's results were discussed, and the experiment protocol adjusted according to the greenkeepers' experiences.

*Picture 2. The greenkeepers were trained to do registrations in field experiments. Bjørn Molteberg explains how to judge the sward composition in a mixed plot. Landvik, September 2008. Photo: Agnar Kvalbein.*

## 2.3 Experimental set-up

The protocol was relatively flexible when it comes to timing and design, to fit into local conditions at the golf courses.

During the first experimental year the greenkeepers were asked to collect data on temperature and snow or ice cover throughout the winter. This was too much work and the quality of these data was variable. The second year it was not compulsory to collect these data.

The experiment factors were

A. Two different mowing heights, 100% and 150%
B. Application of 0.2 kg N pr 100 $m^2$ as late autumn fertilization versus no application

### *2.3.1 Mowing height*

The different mowing heights were established some weeks before closing the course by splitting a green into two halves (main plots). The turf on one half was left uncut until reaching a 150% of the normal autumn height at the golf course. After that, mowing intervals were the same in the two treatments

### *2.3.2 Fertilization*

The whole green received late autumn fertilization except for 6-8 control plots (3-4 replicates within each mowing height) which were covered with 1.5 x 1.5 m tarps before application of fertilizer using spreaders available on each course.

In the first experimental year all greens received a standard granular fertilizer, Arena Start 10-1-10 also containing 1% iron. In the second year the fertilizer was chosen from the store at the golf course, but the nitrogen source was always a soluble mineral type.
The fertilizer was applied when the turf had stopped growing visually but before permanent soil frost or snow cover. As a guideline, soil temperature in the afternoons should be beneath 6° C as an average for some days.

*Picture 3. The whole green was fertilized. Covers made of tarpaulin (1,5x1,5) $m^2$, defined the unfertilized plots, half of them on the high and on the low cut part of the green. Picture from Trones golf course. Photo: Pelle Dahl*

### 2.3.3 Registrations

The number of golf courses involved in the project was reduced during the experimental period. Some greenkeepers were dismissed, other left their jobs during the experiment due to the financial crisis. Extraordinarily early snow fall spoiled one experiment. One envelope with data disappeared in the mail system, and some data were incomplete or of no value due to misunderstandings or to extra treatments of some of the plots.

To compensate for the loss of participating golf courses, a trial on the experimental green at Bioforsk Apelsvoll Research Centre (velvet bent grass) was established in the second year.

Within the two mowing height registrations were accomplished on the three control plots that had not received late autumn fertilization and on 3-4 adjacent, pre-defined plots that had received fertilizer.

Autumn registrations:

- Mowing heights at the end of the growing season
- Date of late autumn fertilization

Spring observations:

- winter injury as % of plot area in early spring
- % turf cover and general impression (1-9) when opening the course for play
- % turf cover and general impression (1-9) 14 days after opening the course for play

Some greenkeepers also reported:

- % damage caused by fungi
- Spring colour (1-9)

### 2.3.4 Statistical analyses

Data from each trial were analysed according to a simple analysis of variance testing the main effects of mowing height, late autumn fertilization and their interaction against their pooled interaction with replicate (control plot) number.

After these individual analyses, average values for the four combinations of mowing height and with/without late autumn fertilization in each trial were entered into data sets for greens dominated by red fescue, creeping bent grass and annual meadow grass, respectively. When analysing these data sets, each trial was considered one block, with the main effects of mowing height, late autumn fertilization and mowing height x late autumn fertilization being tested against their individual interactions with block (trial) number.

# 3. Results

## 3.1 Individual results from each of the golf courses

The amounts of data differ from the various golf courses. On the following pages some general key results are tabled. If there is information to be drawn from the individual experiment, it is mentioned at the bottom line.

Enhanced green colour after fertilization was observed at many golf courses, but winter colour was not an important character in this project. Arena 10-1-10, fertilizer applied to all experiments in the first year, contained iron. This will normally influence green colour. In the second year fertilizer type was not standardized, and the content of iron was not reported. For these reasons green colour will usually not be reported.

General impression was evaluated using marks from 0-9 comprising turf cover, density, playing quality and colour. Since the observations were recorded by different persons, the values should not be used to compare golf courses.

### 3.1.1 Keri Golf

Site: Finland, Savolinna,
61°53´3˝N, 29°09´70˝E, 98 m a.s.l.

Turf grass species:
50% Annual meadow grass (*P.annua*), 50% Creeping bent grass (*A.stolonifera*)

*Table 2. Experimental facts from Keri Golf*

| | 2008/2009 | 2009/2010 |
|---|---|---|
| High mowing: | 7.5 mm | 7.5 mm |
| Low mowing: | 5 mm | 5 mm |
| Fertilization date: | 31 Oct | 31 Oct |
| Number of replicates: | 3 | 3* |
| Dates for registration of general impression: | 9 May | 14 April |
| | 23 May | 5 May |
| | | 24 May |
| | | 1 June |

* Three non-fertilized plots received some extra treatment. This reduced the number of replicates to two for high cut and one low cut.

*Table 3. Keri golf. One registration of winter injury as percentage of turf cover. General impression (1-9, 9 is best quality) is the average of registrations over time*

| | High mowing | | | | Low mowing | | | |
|---|---|---|---|---|---|---|---|---|
| | Fertilized | | Not fertilized | | Fertilized | | Not fertilized | |
| | Average | St.error | Average | St.error | Average | St.error | Aveage | St.error |
| **2008/2009** | | | | | | | | |
| Winter damage % | 75 | 2.9 | 65 | 9.3 | 82 | 3.3 | 78 | 12.6 |
| General impression: | 4.2 | 0.3 | 5.0 | 1.2 | 1.5 | 1.2 | 2.7 | 1.0 |
| **2009/2010** | | | | | | | | |
| Winter damage % | 80 | 5.0 | 73 | . | 73 | 4.4 | 70 | . |
| General impression: | 3.2 | 0.3 | 3.3 | . | 3.2 | 0.1 | 2.7 | . |

*Picture 4. Keri golf 9 May 2009.The green had severe winter injuries. The greenkeeper reported uneven distribution of annual meadow grass and creeping bent grass. Photo: Risto Tienberg.*

Ice cover was observed from 2 February to 14 April 2008/2009. Soil temperature was -0.4 to – 0.5 ºC in this period. Snow cover was between 30 and 41 cm.

High mowing gave tendency to less winter damage, better coverage (*p*=0.08) and significantly better overall impression in the spring 2009.

In the second experimental year material from holocoring on 25 October was left at some, but not all plots. This made statistical analyzes impossible.

These greens were a mix of annual meadow grass and creeping bent grass. The greenkeeper also reported that some fescue had survived in the spring of 2009. In 2010 he reported more creeping bentgrass in some of the plots than others.
The mixed botanical composition on the greens at Keri golf makes it difficult to draw conclusions for a certain species. In the overall analysis, these greens were categorized as annual meadow grass.

### *3.1.2 Messilä golf*

Site: Finland, Lahti,
61º00´37˝N, 25º32´46˝E, 154 m a.s.l.
Turf grass species:
75% Creeping bent grass (*A.stolonifera)*, 20% Annual meadow grass (*P.annua* )

*Table 4. Experimental facts from Messilä Golf*

| | 2008/2009 | 2009/2010 |
|---|---|---|
| High mowing: | 6 mm | 6 mm |
| Low mowing: | 4 mm | 4 mm |
| Fertilization date: | 3 Nov | Date not recorded |
| Number of replicates: | 3 | 3 |
| Dates for registration of general impression: | 30 April<br>15 May | 28 April |

In 2008/2009 Messilä golf used experimental blankets not only at the late autumn fertilization on 3 November, but also when applying fertilizer on 10 Oct., 21 Oct., 23 Oct, 29. Oct. and 3 Nov. This was a considerable deviation from the experimental protocol.

Table 5. Messilä golf. One registration of winter injury as percentage of turf cover. General impression (1-9) is the average of registrations over time

| | High mowing | | | | Low mowing | | | |
|---|---|---|---|---|---|---|---|---|
| | Fertilized | | Not fertilized | | Fertilized | | Not fertilized | |
| | Average | St.error | Average | St.error | Average | St.error | Aveage | St.error |
| **2008/2009** | | | | | | | | |
| Winter damage % | 34 | 25.5 | 37 | 24.5 | 41 | 25.5 | 48 | 22.0 |
| General impression: | 5.5 | 2.0 | 5.2 | 1.9 | 5.3 | 2.0 | 4.9 | 1.8 |
| **2009/2010** | | | | | | | | |
| Winter damage % | 21 | 14.7 | 51 | 23.3 | 16 | 11.5 | 35 | 23.1 |
| General impression: | 3.3 | 1.4 | 1.8 | 0.8 | 4.0 | 1.2 | 2.3 | 0.8 |

In 2008/2009 some of the plots at Messilä were nearly 100% killed due to ice encasement. This explains the high standard error in 2009 (table 5). When the dead part of the green was excluded, the results were as showed in table 6. Analyses based on table 5 showed tendencies ($p<0.20$) that late autumn fertilization gave better spring performance in both years.

*Table 6. Messilä golf. Results from the plots that were not damaged by ice encasement.,*

| | High mowing | | | | Low mowing | | | |
|---|---|---|---|---|---|---|---|---|
| | Fertilized | | Not fertilized | | Fertilized | | Not fertilized | |
| | Average | St.error | Average | St.error | Average | St.error | Aveager | St.error |
| **2008/2009** | | | | | | | | |
| Winter damage % | 9 | 1.5 | 13 | 2.5 | 11 | 1.5 | 23 | 12.5 |
| General impression: | 7.5 | 0 | 7.0 | 0.5 | 7.4 | 0 | 6.9 | 0.6 |

*Picture 5. 15 May 2009. This low cut plot, not receiving fertilizers on several occasions in autumn, was registered as having 85% coverage and a general impression = 6.5. The fertilized low cut plot beside it had 90% turf cover and general impression = 7.5.*

*Photo: Jukka Rauhameki*

*Picture 6. 28 April 2010. Some unfertilized plots were heavily injured from snow mould attack.*

*Photo: Agnar Kvalbein*

### *3.1.3 Peuramaa golf*

Site: Finland, Peuramaa,
60º05´55˝N, 24º28´17˝E, 4 m a.s.l.
Turf grass species: 100% Velvet bent grass (*Agrostis canina)*

*Table 7. Experimental facts from Peuramaa Golf*

| | 2008/2009 | 2009/2010 |
|---|---|---|
| High mowing: | 6 mm | 6 mm |
| Low mowing: | 3.5 mm | 4 mm |
| Fertilization date: | 19 Nov. | 2 Nov. |
| Number of replicates: | 3 | 3 |
| Dates for registration of general impression: | 8 April<br>15 April | 18 April<br>2 May |

*Table 8. Perumaa golf. One registration of winter injury as percentage of turf cover. General impression (1-9) is the average of registrations over time*

| | High mowing | | | | Low mowing | | | |
|---|---|---|---|---|---|---|---|---|
| | Fertilized | | Not fertilized | | Fertilized | | Not fertilized | |
| | Average | St.error | Average | St.error | Average | St.error | Aveage | St.error |
| **2008/2009** | | | | | | | | |
| Winter damage % | 2* | 0.3 | 2* | 0.0 | 2 | 0.0 | 2 | 0.0 |
| General impression: | 7.5 | 0.0 | 7.5 | 0.0 | 7.5 | 0.0 | 7.5 | 0.0 |
| **2009/2010** | | | | | | | | |
| Winter damage % | 22 | 1.7 | 25 | 3.3 | 22 | 0.0 | 20 | 0.0 |
| General impression: | 5.8 | 0.2 | 4.3 | 0.0 | 5.7 | 0.2 | 4.6 | 0.2 |

** Only two replicates*

In 2008/2009 there was a thin ice layer from the beginning of February until the end of March. The ice was covered with about 15 cm snow until melted with sand from 19 March. There were no differences between the plots.

In 2009/2010 the greens were covered with dry snow for a long period.

There were significant effects of late autumn fertilization on spring performance in 2010. There was also a tendency (p=0.09) that high mowing caused more snow mould. These data are not shown. There was no effect on winter survival.

*Picture 7. Head greenkeeper Janne Hellström is pointing at a plot which had not been fertilized in November 2009.*

*Photo: Agnar Kvalbein*

## *3.1.4 Fullerö golf*

Site: Sweden, Västerås
59°34´03˝N, 16°30´07˝E 13 m a.s.l.
Turf grass species: 50% Velvet bent grass *(A.canina)*, 50% Annual meadow grass *(P.annua)*

In both years experiments were set up according to the protocol.
Fullerö golf club practiced regular application of fertilizer every 10 days in the autumn. Ammonium sulphate and a complete fluid mix of nutrients were used.

In 2009 there was 100% winter survival on all plots and no differences between treatments except from a slightly better green colour on plots fertilized in late autumn

Data from 2010 were lost in the mailing system, but an e-mail reported that differences between plots were only in colour, not in winter damages or other characters.

These results from 2009 are included in the overall analysis for velvet bent grass.

## *3.1.5 Kungliga Drottningholm Golf Club*

Site: Sweden, Stockholm
59º19´12˝N, 17º51´19˝E, 21 m a.s.l.
Turf grass species:
95% Annual meadow grass *(P.annua)*, 5% Creeping bent grass (*A.stolonifera)*

*Table 9. Experimental facts from Kgl. Drottningholm Golf Club*

| | 2008/2009 | 2009/2010 |
|---|---|---|
| High mowing: | 6.9 mm | |
| Low mowing: | 4.6 mm | |
| Fertilization date: | 14 Nov. | |
| Number of replicates: | 3 | 3 |
| Dates for registration of general impression: | 9 May | |

*Table 10. Kgl. Drottningholm Golf Club. One registration of winter injury as percentage of turf cover. General impression (1-9) is the average of registrations over time*

| | High mowing | | | | Low mowing | | | |
|---|---|---|---|---|---|---|---|---|
| | Fertilized | | Not fertilized | | Fertilized | | Not fertilized | |
| | Average | St.error | Average | St.error | Average | St.error | Aveage | St.error |
| **2008/2009** | | | | | | | | |
| Winter damage % | 75 | 0 | 75 | 0 | 75 | 0 | 75 | 0 |
| General impression: | 5 | 0 | 5 | 0 | 5 | 0 | 5 | 0 |
| **2009/2010** | | | | | | | | |
| Winter damage % | . | . | . | . | . | . | . | . |
| General impression: | . | . | . | . | . | . | . | . |

In 2009 there was a 2 cm ice cover from 5 February to 4 March. On 20 March there was no ice left. There were no differences between the plots.

In 2010 data was not collected, but picture 9 showed no pattern that could be related to the treatments.

*Picture 8 and 9. Left: 3 April 2009 . Result of ice cover. Photo: Erik Dahl*

*Right: 26 April 2010. Result of snow cover. The photo was taken when the turf had been covered with acryl for some days. Photo: Agnar Kvalbein*

## *3.1.6 Saltsjöbaden golfklubb*

Site: Sweden, Stockholm
59°16´89˝N, 18°15´59˝E, 31 m a.s.l.
Turf grass species:
60 % Annual meadow grass *(P.annua)*, 40% Creeping bent grass *(A.stolonifera)*

*Table 11. Experimental facts from Saltsjöbaden Golf Club*

| | 2008/2009 | 2009/2010 |
|---|---|---|
| High mowing: | 6 mm | 6 mm |
| Low mowing: | 4 mm | 4 mm |
| Fertilization date: | 4 Dec | 9 Dec |
| Number of replicates: | 3 | 3 |
| Dates for registration of general impression: | 30 April | 7 April 2010 |
| | 15 May | 26 April |

*Table 12. Saltsjöbaden Golf Club. One registration of winter injury as percentage of turf cover. General impression (1-9) is the average of registrations over time*

| | High mowing | | | | Low mowing | | | |
|---|---|---|---|---|---|---|---|---|
| | Fertilized | | Not fertilized | | Fertilized | | Not fertilized | |
| | Average | St.error | Average | St.error | Average | St.error | Aveage | St.error |
| **2008/2009** | | | | | | | | |
| Winter damage % | 75 | 0 | 75 | 0 | 75 | 0 | 75 | 0 |
| General impression: | 4.5 | 0 | 4.5 | 0 | 4.5 | 0 | 4.5 | 0 |
| **2009/2010** | | | | | | | | |
| Winter damage % | 13 | 2.5 | 10 | 0.0 | 13 | 0.0 | 15 | 0.0 |
| General impression: | 2.0 | 0.3 | 2.5 | 0.0 | 2.3 | 0.1 | 2.4 | 0.1 |

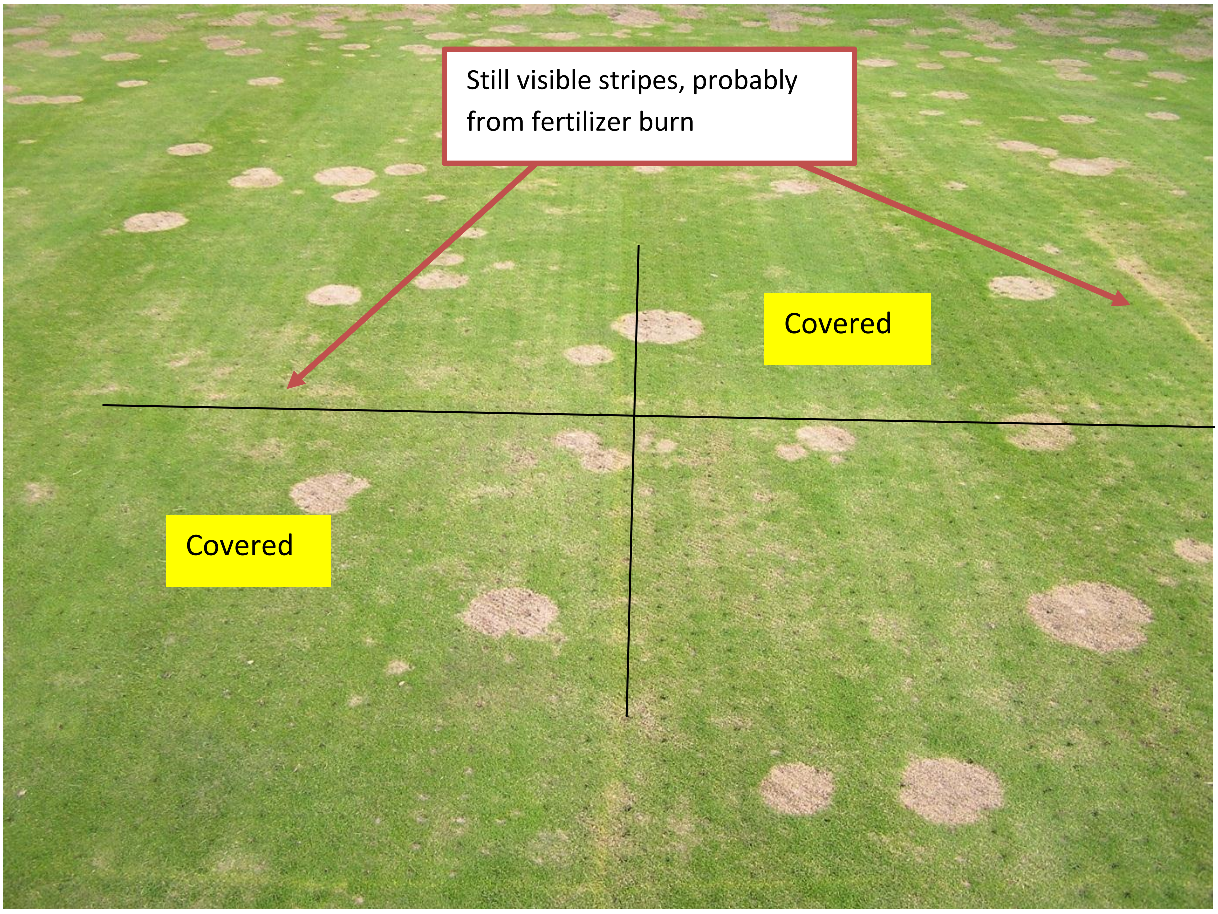
In 2009 there were no visual differences between the plots

*Picture 10. Green 18 ready for fertilizing on 4 December 2008. Photo: Magnus Olofsson*

*Picture 11. Green 18. On 22 April 2009. Photo: Magnus Olofsson*

The results from 2010 showed a tendency (*p*=0.11) to negative effect from late autumn fertilization on spring growth (colour).

The fertilizer used on 9 December 2009 was Indigrow Impact fine turf 4-0-14, containing ammonium sulphate and 10% iron. Burning was observed right outside the cover blankets in the spring. There was a snowfall the day after fertilizing.




*Picture 12. Green 18, 26 April 2010. The non-fertilized (covered) plots were greener. Photo: Agnar Kvalbein*

### 3.1.7 Bjaavann golfklubb

Site: Norway, Kristiansand
58º14´30˝N, 8º03´03˝E, 22 m a.s.l.
Turf grass species: Creeping bent grass *(A. stolonifera)*

*Table13. Experimental facts from Bjaavann golfklubb*

| | 2008/2009 | 2009/2010 |
|---|---|---|
| High mowing: | 6 mm | |
| Low mowing: | 4 mm | |
| Fertilization date: | 28 Oct. | |
| Number of replicates: | 3 | |
| Dates for registration of general impression: | 23 March<br>7 April | |

In spring 2009 there were 100 % turf cover and no differences between plots except for a slightly darker colour on the fertilized plots. These have been included in the overall statistics for creeping bent grass.

No data from 2010.

*Picture 13 and 14. Greenkeeper Robert Lee is applying fertilizer on the putting green at Bjaavann golf club. In the spring of 2009 turf performance was excellent and no winter damage was observed. A small colour difference was probably due to the fertilizer containing iron. Photos: Terje Haugen*

### *3.1.8 Mørk golf*

Site: Norway, Spydeberg
59°31´54˝N, 11°00´00˝E, 125 m a.s.l.
Turf grass species: Creeping bent grass *(A. stolonifera )*

*Table 14. Experimental facts from Mørk Golf Club*

| | 2008/2009 | 2009/2010 |
|---|---|---|
| High mowing: | 5.2 mm | 5,5 mm |
| Low mowing: | 3.6 mm | 4,0 mm |
| Fertilization date: | Date not recorded | 22 Oct./27 Nov * |
| Number of replicates: | 3 | 3 |
| Dates for registration of general impression: | 8 April<br>27 April<br>11 May | 22 April<br>6 May<br>14 May |

** The total fertilizer rate of 0.2 kg N pr 100 m$^2$ was split into two equal parts and applied on 22 October and 27 November*

*Table 15. Mørk Golf Club. One registration of winter injury as percentage of turf cover. General impression (1-9) is the average of registrations over time*

| | High mowing | | | | Low mowing | | | |
|---|---|---|---|---|---|---|---|---|
| | Fertilized | | Not fertilized | | Fertilized | | Not fertilized | |
| | Average | St.error | Average | St.error | Average | St.error | Aveage | St.error |
| **2008/2009** | | | | | | | | |
| Winter damage % | . | . | 31 | 27.0 | . | . | 31 | 27.0 |
| General impression: | . | . | 7.3 | 0.9 | . | . | 7.7 | 0.9 |
| **2009/2010** | | | | | | | | |
| Winter damage % | 17 | 4.4 | 43 | 3.3 | 47 | 19.2 | 37 | 6.7 |
| General impression: | 8.3 | 0.3 | 7.3 | 0.3 | 7.3 | 0.6 | 7.3 | 0.3 |

INo data on fertilizer effects were recorded in 2008/2009.

Snow mould attack in spring 2010 was significant lower after late autumn fertilization, but the values were very low (2 vs. 3% of turf cover). There was significantly better spring colour after high mowing in autumn .Data are not shown. Unlike most observations on other courses, high mowing also resulted in a tendency (*p*=0.18) to less winter damage.

### *3.1.9 Trones golf course (Stiklestad golf club)*

Site: Norway, Verdal
63°49´91˝N, 11°24´38˝E, 25 m a.s.l.
Turf grass species: Creeping bent grass *(A. stolonifera )*

*Table 16. Experimental facts from Trones golf course*

| | 2008/2009 | 2010 |
|---|---|---|
| High mowing: | 6.7 mm | |
| Low mowing: | 4.5 mm | |
| Fertilization date: | 3 Nov | |
| Number of replicates: | 3 | |
| Dates for registration of general impression: | 1 May | |
| | 15 May | |

*Table 17. Trones golf course. One registration of winter injury as percentage of turf cover. General impression (1-9) is the average of registrations over time*

| | High mowing | | | | Low mowing | | | |
|---|---|---|---|---|---|---|---|---|
| | Fertilized | | Not fertilized | | Fertilized | | Not fertilized | |
| | Average | St.error | Average | St.error | Average | St.error | Aveage | St.error |
| **2008/2009** | | | | | | | | |
| Winter damage % | . | | . | | . | | . | |
| General impression: | 8.5 | 0 | 8.0 | 0 | 85 | 0 | 80 | 0 |
| **2009/2010** | | | | | | | | |
| Winter damage % | . | | . | | . | | . | |
| General impression: | . | | . | | . | | . | |

Colour caused a small difference in general impression in spring 2009.

### 3.1.10 Vestfold Golf Club

Site: Norway, Stokke
59°11´37˝N, 10°21´14˝E, 48 m a.s.l.
Turf grass species: 70 % Red fescue *(F.rubra)*, 30 % Common bent grass *(A.capillaris)*

*Table 18. Experimental facts from Vestfold golf club*

| | 2008/2009 | 2010 |
|---|---|---|
| High mowing: | 9 mm | 9 mm |
| Low mowing: | 6 mm | 6 mm |
| Fertilization date: | 8 Nobember | 10 November |
| Number of replicates: | 2 | 3 |
| Dates for registration of general impression | 17 April | 8 April |
| | 8 May | 22 April |

*Table 19. Vestfold golf club. One registration of winter injury as percentage of turf cover. General impression (1-9) is the average of registrations over time.*

| | High mowing | | | | Low mowing | | | |
|---|---|---|---|---|---|---|---|---|
| | Fertilized | | Not fertilized | | Fertilized | | Not fertilized | |
| | Average | St.error | Average | St.error | Average | St.error | Aveage | St.error |
| **2008/2009** | | | | | | | | |
| Winter damage % | 2 | 0.0 | 16 | 12.5 | 6 | 4.0 | 7 | 2.5 |
| General impression: | 5.1 | 0.9 | 4.5 | 0.6 | 5.3 | 0.4 | 4.0 | 0.3 |
| **2009/2010** | | | | | | | | |
| Winter damage % | 23 | 13.6 | 27 | 8.7 | 27 | 13.6 | 33 | 14.8 |
| General impression: | 5.3 | 0.7 | 4.8 | 0.4 | 5.0 | 0.4 | 4.2 | 0.5 |

The treatments had no effect on winter survival, but there was a significant positive effect of late autumn fertilization on spring performance in 2010. This year there was also a tendency ($p$=0.18) that high mowing caused better spring colour (data are not shown).

*Picture 15.*

*Head greenkeeper Oddbjørn Tidemann, 15 May 2010. The unfertilized plots were still visible and showed significantly lower regrowth and general impression.*

*Photo: Agnar Kvalbein*

### *3.1.11 Landvik experimental green A*

Site: Norway, Grimstad
58° 20'25'' N, 8° 31' 26'' E, 9 m a.s.l.
Turf grass species: Red fescue *(F. rubra)*

*Table 20. Experimental facts from Landvik experimental green A*

| | 2008/2009 | 2009/2010 |
|---|---|---|
| High mowing: | 6 mm | 9 mm |
| Low mowing: | 4.5 mm | 6 mm |
| Fertilization date: | 27 Nov | 10 Nov |
| Number of replicates: | 3 | 3 |
| Dates for registration of general impression | 15 April | 22 April |
| | 30 April | 4 May |

*Table 21. Landvik experimental green A One registration of winter injury as percentage of turf cover. General impression (1-9) is the average of registrations over time*

| | High mowing | | | | Low mowing | | | |
|---|---|---|---|---|---|---|---|---|
| | Fertilized | | Not fertilized | | Fertilized | | Not fertilized | |
| | Average | St.error | Average | St.error | Average | St.error | Aveage | St.error |
| **2008/2009** | | | | | | | | |
| Winter damage % | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| General impression: | 6.0 | 0.0 | 5.3 | 0.5 | 4.7 | 0.5 | 4.0 | 0.5 |
| **2009/2010** | | | | | | | | |
| Winter damage % | 7 | 0.9 | 11 | 0.9 | 10 | 1.0 | 7 | 2.0 |
| General impression: | 6.4 | 0.1 | 5.2 | 0.1 | 6.9 | 0.2 | 5.5 | 0.1 |

There was significantly better spring performance after late autumn fertilization in both years. In 2009 there was a tendency (*p*=0.10) that higher mowing caused better general impression.

*Picture 16. Pure red fescue green 15 April 2009. High mowing to the right of the golf balls.*

*Late autumn fertilization visible on every second plot.*

*Photo: Agnar Kvalbein*

### 3.1.12 Landvik experimental green B

Site: Norway, Grimstad
58° 20'25'' N, 8° 31' 26'' E 9 m a.s.l.
Turf grass species: Creeping bent grass *(A. stolonifera)*, *'Independence'*

*Table 22. Experimental facts from Landvik experimental green B*

| | 2008/2009 | 2009/2010 |
|---|---|---|
| High mowing: | 4.5 mm | 4.5 mm |
| Low mowing: | 3.0 mm | 3.0 mm |
| Fertilization date: | 27 Nov. | 10 Nov. |
| Number of replicates: | 3 | 3 |
| Dates for registration of general impression | 15 April | 22.April |
| | 30 April | 4 May |

*Table 23. Landvik experimental greenB. One registration of winter injury as percentage of turf cover. General impression (1-9) is the average of registrations over time.*

| | High mowing | | | | Low mowing | | | |
|---|---|---|---|---|---|---|---|---|
| | Fertilized | | Not fertilized | | Fertilized | | Not fertilized | |
| | Average | St.error | Average | St.error | Average | St.error | Aveage | St.error |
| **2008/2009** | | | | | | | | |
| Winter damage % | 27 | 8.8 | 35 | 15.3 | 33 | 6.7 | 32 | 12.0 |
| General impression: | 5.0 | 0.6 | 4.5 | 0.6 | 4.8 | 0.3 | 4.7 | 0.7 |
| **2009/2010** | | | | | | | | |
| Winter damage % | 5.7 | 2.7 | 4.0 | 2.5 | 5.7 | 1.8 | 7.0 | 2.5 |
| General impression: | 6.5 | 0.4 | 6.2 | 0.5 | 6.2 | 0.2 | 5.7 | 0.6 |

In 2008/2009 the spring performance was significantly better after late autumn fertilization. In 2009/2010 this was a similar tendency ($p$<0.20). There was also a tendency to better spring performance after high mowing in 2009/2010.

*Picture 17. Creeping bentgrass green at Landvik on 15 April 2010.*

*Low mowing to the right of the golf balls.*

*The first plot to the right and the second to the left were fertilized on 10 November 2009.*

*Photo: Agnar Kvalbein*

### 3.1.13 *Apelsvoll experimental green*

Site: Norway, Toten
60° 42'04'' N, 10°52' 11'' E 265 m a.s.l.
Turf grass species: Velvet bent grass *(A. canina)*

*Table 24. Experiment facts from Apelsvoll experimental green*

| | 2008/2009 | 2009/2010 |
|---|---|---|
| High mowing: | | 4,5 mm |
| Low mowing: | | 3,0 mm |
| Fertilization date: | | 21 October |
| Number of replicates: | | 9 |
| Dates for registration of general impression | | 30 April<br>11 May<br>25 May |

*Table 25. Apelsvoll experimental green. One registration of winter injury as percentage of turf cover. General impression (1-9) is the average of registrations over time*

| | High mowing | | | | Low mowing | | | |
|---|---|---|---|---|---|---|---|---|
| | Fertilized | | Not fertilized | | Fertilized | | Not fertilized | |
| | Average | St.error | Average | St.error | Average | St.error | Aveager | St.error |
| **2009/2010** | | | | | | | | |
| Winter damage % | 20 | 4.1 | 28 | 4.7 | 194 | 2.8 | 23 | 3.8 |
| General impression: | 3.7 | 0.2 | 3.5 | 0.2 | 3.6 | 0.1 | 3.7 | 0.1 |

There was a tendency ($p$=0.10) that late autumn fertilization gave less winter damage and improved spring performance.

*Picture 18. Velvet bent grass 30 April 2010. No obvious visible effects from increased mowing height or late autumn fertilization, but 9 replicates gave some tendencies. Photo: Frank Enger*

## 3.2 Overall results for each species

### *3.2.1 Red fescue greens*

Greens included in this material:

- Vestfold golf club (red fescue /common bent grass mix) 2008/2009 and 2009/2010
- Landvik experimental green A (pure red fescue) 2008/2009 and 2009/2010

Late autumn fertilization resulted in significantly better turf coverage, general impression and turf colour in spring. There was also a tendency to better winter survival but no effect on winter diseases (table 26).

Although there was a tendency for higher mowing to give better spring performance at Landvik in 2008/2009, the overall effects of mowing height in red fescue were far from significant.

*Table 26. Main effects of mowing height in the autumn and late autumn fertilization on red fescue greens. Results from two experimental years.*

| | Winter damage % | Winter diseases % | Spring turf coverage mean of obs., % | Spring turf coverage 1st obs., % | General im-pression Mean of obs | General im-pression(1-9) 1st obs. | Colour (1-9, 9 is darkest turf) Mean of obs | Colour (1-9, 9 is darkest turf) 1st obs. |
|---|---|---|---|---|---|---|---|---|
| No of trials | 4 | 2 | 4 | 4 | 4 | 4 | 3 | 3 |
| **Mowing height** | | | | | | | | |
| Control | 11 | 10 | 81 | 71 | 5.0 | 4.4 | 4.5 | 3.4 |
| + 50% | 11 | 12 | 82 | 71 | 5.4 | 4.6 | 4.8 | 3.6 |
| *p*-value | >0.20 | >0.20 | >0.20 | >0.20 | >0.20 | >0.20 | >0.20 | >0.20 |
| **Late autumn fertilization** | | | | | | | | |
| Control | 13 | 10 | 79 | 69 | 4,7 | 4,1 | 4 | 2,8 |
| + 0.2 kg N | 9 | 11 | 83 | 73 | 56 | 4.8 | 5.3 | 42 |
| | 0.17 | >0.20 | <0.001 | 0.006 | 0.01 | 0.03 | 0.04 | 0.09 |
| Interaction *p*-value | >0.20 | >0.20 | >0.20 | >0.20 | 0.11 | >0.20 | >0.20 | 0.14 |

### 3.2.2 *Creeping bent grass greens*

Greens included in this material:

- Bjaavann golf club 2008/2009
- Landvik experimental green B 2008/2009 and 2009/2010
- Mørk golf club 2009/2010
- Trones golf course 2008/2009
- Messilä golf club 2008/2009 and 2009/2010

While the effects were not always as significant as in red fescue, the overall analyses showed a generally positive impact of late autumn fertilization on the spring performance of creeping bent grass greens (table 27).

*Table 27. Mean effects of mowing height in the autumn, and late autumn fertilization, on creeping bent grass greens. Results from two experimental years.*

| | Winter damage % | Winter diseases % | Spring turf coverage mean of obs., % | Spring turf coverage 1st obs., % | General im-pression Mean of obs | General im-pression(1-9) 1st obs. | Colour (1-9, 9 is darkest turf) Mean of obs | Colour (1-9, 9 is darkest turf) 1st obs. |
|---|---|---|---|---|---|---|---|---|
| No of trials | 6 | 4 | 7 | 7 | 7 | 7 | 4 | 4 |
| **Mowing height** | | | | | | | | |
| Control | 25 | 12 | 83 | 82 | 5.8 | 6.1 | 5.9 | 4.9 |
| +50% | 23 | 11 | 84 | 82 | 6.0 | 6.3 | 6.2 | 5.1 |
| p-value | >0.20 | >0.20 | >0.20 | >0.20 | >0.20 | >0.20 | >0.20 | >0.20 |
| **Late autumn fertilization** | | | | | | | | |
| Control | 27 | 12 | 80 | 80 | 5.6 | 5.9 | 5.6 | 4.6 |
| + 0.2 kg N | 21 | 11 | 86 | 85 | 6.1 | 6.4 | 6.5 | 5.4 |
| p-value | 0.13 | >0.20 | 0.14 | 0.12 | 0.05 | 0.05 | 0.04 | 0.12 |
| Interaction | >0.20 | >0.20 | >0.20 | >0.20 | >0.20 | >0.20 | >0.20 | >0.20 |

### 3.2.3 Velvet bent grass greens

Greens included in this material:

- Peuramaa golf club 2008/2009 and 2009/2010
- Apelsvoll experimental green 2009/2010

The overall analyses revealed no significant effect of either mowing height or late autumn fertilization on spring performance of velvet bent grass. There was an overall tendency for higher mowing to result in more winter diseases in this species (table 28).

Table 28. *Mean effects of mowing height in the autumn, and late autumn fertilization, on velvet bent grass greens. Results from two experimental years.*

| | Winter damage % | Winter diseases % | Spring turf coverage mean of obs., % | Spring turf coverage 1st obs., % | General im-pression Mean of obs | General im-pression(1-9) 1st obs. | Colour (1-9, 9 is darkest turf) Mean of obs | Colour (1-9, 9 is darkest turf) 1st obs. |
|---|---|---|---|---|---|---|---|---|
| No of trials | 3 | 1 | 3 | 3 | 3 | 3 | 2 | 2 |
| **Mowing height** | | | | | | | | |
| Control | 15 | 1 | 84 | 86 | 5.4 | 5.2 | 4.3 | 3.3 |
| +50% | 16 | 3 | 82 | 84 | 5.4 | 5.1 | 4.3 | 3.3 |
| *p*-value | 0.17 | 0.09 | >0.20 | >0.20 | >0.20 | >0.20 | >0.20 | >0.20 |
| **Late autumn fertilization** | | | | | | | | |
| Control | 17 | 2 | 83 | 85 | 5.2 | 5.0 | 4.0 | 2.9 |
| + 0.2 kg N | 14 | 3 | 83 | 85 | 5.6 | 5.3 | 4.6 | 3.7 |
| *p*-value | >0.20 | >0.20 | 0.20 | >0.20 | >0.20 | >0.20 | >0.20 | >0.20 |
| Interaction | >0.20 | >0.20 | >0.20 | >0.20 | >0.20 | >0.20 | >0.20 | >0.20 |

### 3.2.4 Annual meadow grass greens

Greens included in this material:

- Kerigolf 2008/2009 and 2009/2010
- Fullerö golf club 2009/2010
- Kungliga Drottningholm golf club 2008/2009
- Saltsjöbaden golf club 2009/2010

Unlike in red fescue, creeping bent grass and velvet bent grass, there tended to be an interaction between mowing height and late autumn fertilization on winter damage in annual meadow grass. The lowest winter damage was recorded on plots with elevated mowing height and no fertilization in late autumn. As a main effect, turf coverage in spring tended to be better with higher mowing (table 28).

Table 29. *Mean effects of mowing height in the autumn, and late autumn fertilization, on annual meadow grass greens. Results from two experimental years.*

| | Winter damage % | Winter diseases % | Spring turf coverage mean of obs., % | Spring turf coverage 1st obs., % | General im-pression Mean of obs | General im-pression(1-9) 1st obs. | Colour (1-9, 9 is darkest turf) Mean of obs | Colour (1-9, 9 is darkest turf) 1st obs. |
|---|---|---|---|---|---|---|---|---|
| Courses | 5 | 2 | 5 | 5 | 5 | 5 | 1 | 1 |
| **Mowing height** | | | | | | | | |
| Control | 48 | 6 | 67 | 59 | 3.8 | 3.2 | 7.6 | 7.6 |
| +50% | 47 | 6 | 73 | 63 | 4.3 | 3.5 | 7.5 | 7.5 |
| *p*-value | >0.20 | >0.20 | 0.15 | 0.12 | >0.20 | >0.20 | >0.20 | >0.20 |
| **Late autumn fertilization** | | | | | | | | |
| Control | 46 | 6 | 70 | 61 | 4.2 | 3.4 | 7.9 | 7.9 |
| + 0.2 kg N | 49 | 5 | 71 | 61 | 3.9 | 3.2 | 7.2 | 7.2 |
| *p*-value | 0.16 | 0.11 | >0.20 | >0.20 | >0.20 | 0.20 | 0.11 | 0.11 |
| Interaction | 0.08 | >0.20 | >0.20 | >0.20 | >0.20 | >0.20 | >0.20 | >0.20 |

# 4. Discussion and conclusions

## 4.1 Mowing height

The sun radiation angle in the Nordic counties is rather low in autumn. Light is important for the plant hardening process and it seems logical to assume that larger leaf area will absorb more energy and strengthen the plants for better winter survival. However, we have not found reports from experiments with various mowing heights in cool season grass that are relevant to either winter survival or spring performance on golf greens.

### *4.1.1 Winter damages*

Our data encompass only two experiments that support the theory of less winterdamage after high mowing. One of them was the trial at

Keri golf in 2008/2009. This green was a mix of annual meadow grass and creeping bent grass. Creeping bent grass is more tolerant to winter stress than annual meadow grass (Tompkins 2000). The greenkeeper reported that the distribution of species was not even on the green. This may have influenced the result. See picture 4.

At Mørk golf club in 2009/2010, high mowing of creeping bent grassreduced the winter damage from 42% to 30% (table 15), However, the effect was not significant, and the result were also in conflict with other creeping bent grass greens in 2010.

Messilä golf club also had positive effect of high mowing on winter survival in 2008/2009, but ice damage on parts of the green reduced the statistical value of this observation (table 5 and 6). The next year a snow mould attack gave the opposite result.

### *4.1.2 Snow mould*

The numbers of registrations of diseases were three in 2009 and six in 2010. Snow mould injuries occurred on all greens in 2010, but this was reported as winter damage. The increased winter damage at Messilä GC after high mowing, 36% versus 26% was most likely caused by snow mould. See picture 6.

Perumaa GC (velvet bent grass), showed a tendency ($p=0.09$) to more snow mould after high mowing, but the fungi attack (2.5%) was just a small part of the total winter damage (22% ) reported.

### *4.1.3 Conclusion on mowing height and winter injuries*

In a winter with little snow mould attack (2009), we found only small and conflicting differences between the treatments, leading to the conclusions that mowing height had no influence on winter survival of the plants.
In a winter with heavy snow mould attack (2010) we found tendency towards more winter injury after high mowing on bent grass greens

## 4.2 Spring performance

We did not find negative effects on colour or general turf performance after 50% increased mowing height in the autumn on any green but one. The exception was a velvet bent grass green where snow mould attack reduced spring quality.

The positive effects was significant only at Keri golf in 2009 (Annual meadow grass / creeping bent grass mix). Uneven distribution of the species may have influenced this result.

There were two green with tendencies to better colour (Mørk 2010 and Vestfold GK 2010). Colour was not recognized as an important character in this experiment and not reported from all trials.

Two greens showed tendencies to better general impression in the spring 2010, one red fescue green and one creeping bent grass green, both located at Landvik.

### *4.2.1 Conclusion on mowing height and spring performance*

There were none or just small positive effects from increased mowing height on spring performance of the greens.

## 4.3 Mowing height in the autumn under Nordic conditions

Bent grass and annual meadow grass greens should be cut at a normal height until stopped growing in the autumn to avoid increased risk of snow mould attack.

50% increased mowing height in the autumn may improve the spring performance of red fescue greens.

## 4.4 Late autumn fertilization (LAF)

The effect of late autumn fertilization may be explained by the uptake of nutrients through roots which are still active at low temperatures. Some would call the late autumn fertilization 'an early spring fertilization'. However, there are many reports on improved turf colour after late autumn fertilization, and this will lead to the assumption that better spring performance is a result from enhanced photosynthetic activity and higher carbohydrate content.

Our project was not designed to discuss mechanisms, but to examine the visual effects of late autumn fertilization.

### *4.4.1 LAF and winter damage*

On average LAF reduced the winter damage by 3.1 percentage units from 35.6% to 32.6%.

Only on one green showed a tendency to increased winter injury after LAF, Keri-Golf 2009. As mentioned, this green was reported to be a mix of annual meadow grass and creeping bent grass with uneven distribution of the two species. Neither of the two other annual meadow grass greens (Saltsjøbaden GC and Drottningholm GC) was influenced by LAF. The winter injuries on all these three locations were comprehensive.

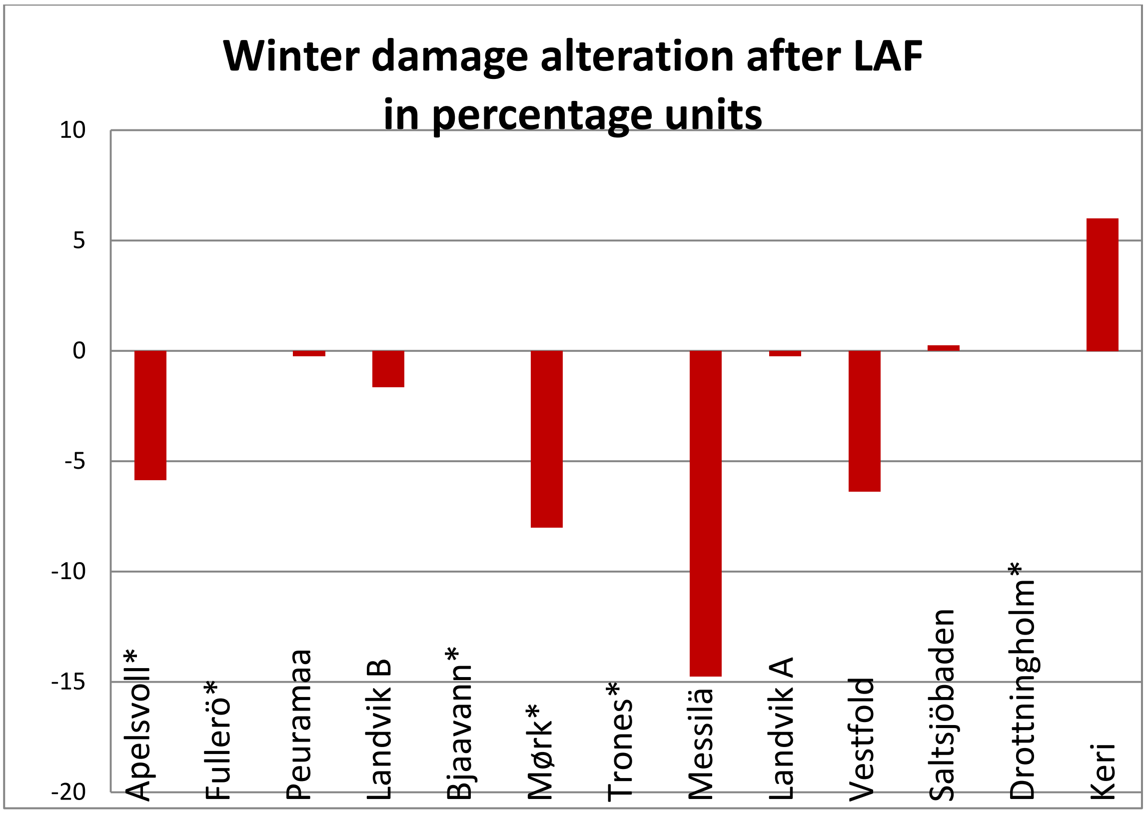



*Figure 1. The effects of late autumn fertilization on winter damage each experimental site. * Result from one experiment year only. The others show the average of two years.*

Among the creeping bent grass greens, Messilä GC and Mørk GC had less winter damage after LAF. This can partly be explained by the application dates at these two sites.

Data from Mørk GK is only from 2010. The fertilizer application was split into two, and half the rate was spread while the grass was still growing. The other half was applied as LAF. Mørk had significantly less snow mould after LAF.

Data from Messilä are from two years. In the first year the tarpaulins were used every time fertilizer was spread, 5 times from 10 October to 5 November. The rate of fertilizer applied in this period was not reported, but there were three applications of liquid 4-7-28 and one of granular 6-5-25. The last application was the fertilizer which was handed over for the experiment, Arena Start 10-1-10. The deviating treatments at these two golf courses may have blown up the differences between fertilized and non-fertilized plots.

The experiment at Apelsvoll (velvet bent grass) followed the protocol in all aspects, and showed tendency (p=0.10) to less winter damage after LAF.

The results from Landvik (creeping bent grass) and Vestfold GC (red fescue) were not statistically validated.

### *4.4.2 LAF and spring performance*

In average LAF improved the general impression of the turf with 0.34 on a scale from 0 to 9.

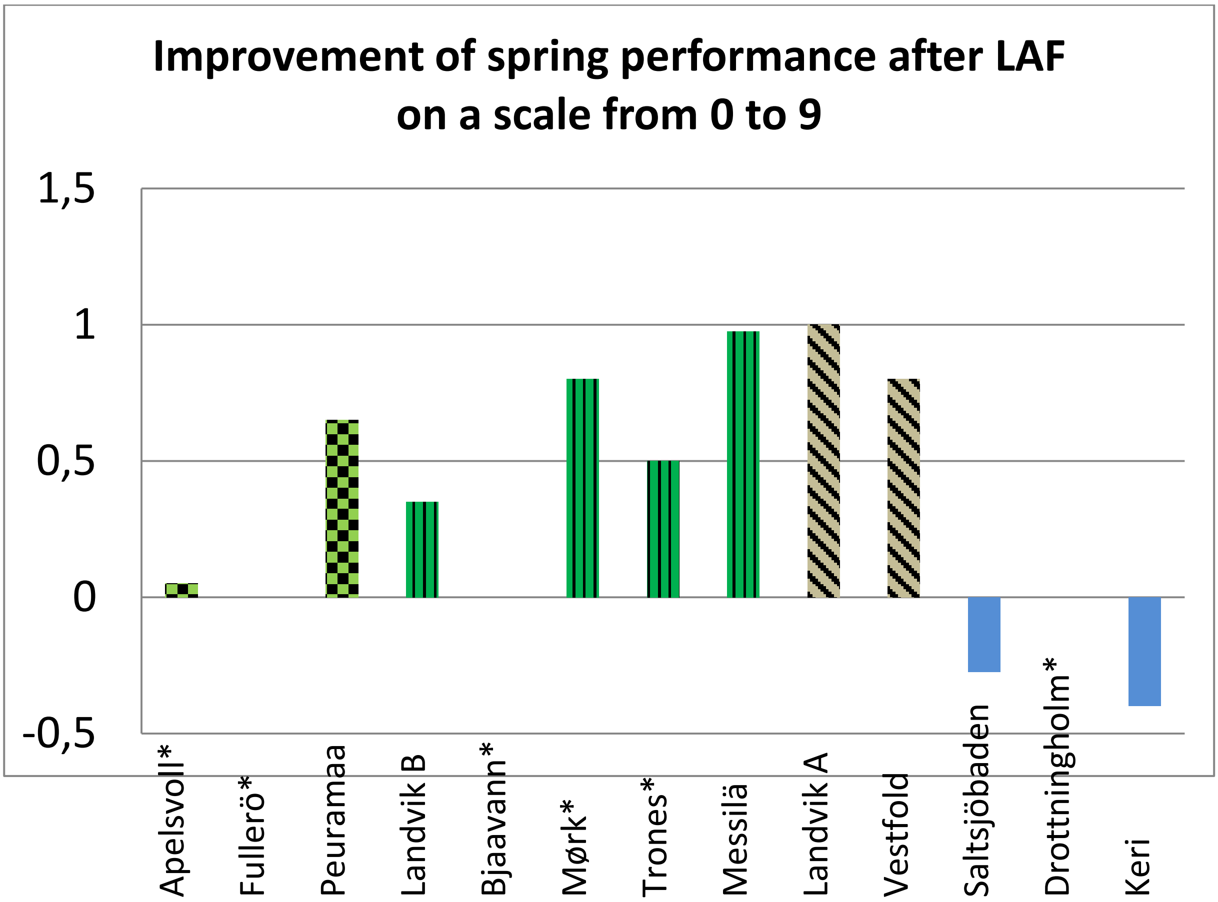



*Figure 2. The effects of late autumn fertilization on each experimental site. * one experiment year only. The others are the average from two years. Pattern/ colours refer to different grass species.*

The annual meadow grasses did not benefit from LAF. The negative effect at Keri-golf can be a result from uneven distribution of creeping bent grass. The tendency to negative effect at Saltsjöbaden GC was probably a result of burning.
The reports from the annual meadow greens were difficult to interpret. We will not draw definite conclusions from this material, but the experiments suggest that annual meadow grass benefits less from LAF than the other turf grass species.

The bent grass and fescue trials showed positive effects from LAF. Even from Bjaavann GC and Fullerö GC the greenkeepers reported small improvement in the green colour. See picture 14.

Tree of the four red fescue greens showed significantly improved spring performance after LAF.

The velvet bent grass greens all showed improved general impression after LAF. At Peuramaa the result was significant in 2010.

The results from creeping bent grass greens were significant at two of the seven trials, Landvik 2009 and Mørk GC 2010, and there were tendencies ($p$<0.20) at three other trials.

### *4.4.3 Conclusions regarding late autumn fertilization*

The application of 0.2 kg N as soluble NPK fertilizer after the turf had stopped growing in the autumn had no negative effect, but reduced the winter damage at some greens and increased the spring performance at most greens.

Red fescue dominated greens benefitted most from this treatment, but also bent grasses showed statistically verified evidence for improvements.

Annual meadow grasses showed negative effects from LAF, but the quality of these experiments can be questioned, and we will not draw a definite conclusion.

## 4.5 Suggestions for improved fertilization practice

Why did not Fullerö and Bjaavann report any positive effects from LAF? According to the greenkeepers journals these greens were fertilized with nitrogen (and other nutrients) every 10 days throughout the autumn. At Bjaavann the whole green even got an extra application of nitrogen fertilizer after the experimental application on 28 October.
It is likely that these two greens were very well prepared for the winter regarding nutrients, and did not benefit much from the additional LAF.

Picture 17 is from the creeping bent grass green at Landvik. It shows improved spring performance just outside the unfertilized spots. A tarpaulin covered the plots when the fertilizer was applied. This method gave increased application rate just outside the tarpaulin. (See also picture 12).

This observation hints that this green could benefit from even a higher application than 0.2 kg N pr 100 $m^2$.

The idea that N-fertilization in the early autumn may disturb the hardening processes of the grass plants is not well documented, and modern spoon feeding practice is very different from the extreme methods used in old turf grass experiments. (Wilkinson & Duff 1972)

Late applications of fertilizers increase the nitrogen leakage (Mangiafico 2006). From an environmental view LAF is not advantageous.

Although this experiment encourages LAT, an enhanced N application as spoon feeding through the autumn may be a better fertilization strategy. Further investigations are necessary to find the optimal rate and timing of autumn fertilization.

# 5. References

Beard J.B. 1972 Turf Management. Prentice.Hall (Englewood Cliffs, N.J) ISBN 013933002X

Culleton N., Lemaire G., Keane G., 1991: The Effects of Atumn Management on Grass Growth in Winter and Spring. Irish Journal of Agricultural Research 30: 41-51, 1991.

Engel R.E. & Bussey C.W., 1979: The Effect of Fertilization on Annual Bluegrass, Golf Course Management, Sept-Oct, p 40-42

Ensminger, I., Busch, F., Huner N.P.A .2006. Photostasis and cold acclimation: sensing low temperature through photosynthesis. Physiologia Plantarum Vol 126, Issue 1, pages 28.44

Fry J. and Huang B., 2004, Applied Turfgrass Science and Physiology, Wiley, ISBN 0-471-47270-0

Grossi N., Filippo L., Volteerrani M. and Sergio M.: Timing of fall nitrogen application on Tall Fescue turf. Int. Turf. Society Research Journal Vol10, 2005

Hanson A.A. & Juska F.V. 1961. Winter root activity in Kentucky bluegrass (*Poa pratensis* L.). Agronomy Journal 53: 372-374.

Hummel N.W. 1990. Late-season fertilization. Landscape Management 28: 30 and 30-33.

Huner N.P.A., Öquist G., Hurry V.M., Krol M., Falk S., Griffith M.: Photosynthesis, photoinhibition and low temperature acclimation in cold tolerant plants, Photosynthesis Research 37, 19.39, 1993

Kussow W.R. 1988. Fall-fertilization of cool-season turfgrasses. Golf course Management Sept. 1988: 22-30.

Lloyd D. 2009 Low Temperature Nitrogen Uptake and Utilization of Turfgrass. MsS Review and Thesis, University of Wisconsin-Madison

Mangiafico S. and Buillard K.: Fall Fertilization Timing Effects on Nitrate Leaching and Turfgrass Color and Growth, (2006) Plant Science Articles. Paper 14. http://digitalcommons.uconn.epu/plsc_articles/14

Narra S., Fermanian T .W., Swiader J. M., Voigt T. B. and Branham B. E.,2004: Total Nonstructural Carbohydrate Assessment in Creeping Bentgrass at Different Mowing Heights, Crop Science vol 44 No 3, p 908-913

Powell A.J., Blaser R.E. and Schmidt R.E., 1967: Effects of nitrogen on winter root growth of bentgrass. Agronomy Journal, vol 59: 529-530, July. August 1967

Powell A.J., Blaser R.E. and Schmidt R.E., 1967: Physilogical and Color Aspects of Turfgrasses with Fall and Winter Nitrogen. Agronomy Journal, vol 59: 303-307, July. August 1967

Razimjoo K.,Imada T., Suguira J., Kaneko S., 1996: Effect of nitrogen rates and mowing heights on color, density, uniformity, and chemical composition of creeping bentgrass cultivars in winter. Journal of plant nutrition Vol. 19, no12, pp. 1499.1509 (2 p.)

Sandve S.R., Kosmala A., Rudi H., Fjellheim S., Rapacz M., Yamada T. and Rognli O. A. 2010. Plant Science Vol 180 ,Issue 1, January 2011 Pages 69-77.

Stier J. C. and Fei S.: Cold Stress Physiology and Management for Turfgrasses. Handbook of Turfgrass Management and Physiology, Ed Mohammad Pessarakli (edit), CRC Press 2008 p.490.

Stier J.C., Peparing for Winter, The grass roots, September/October 2005 p.4.11

Tompkins D.K., Ross J.B., Moroz D.L., 2000: Dehardening of Annual Bluegrass and Creeping Bentgrass during Late Winter and Early Spring. Agron. J 92:5-9

Walker K.S., Bigelow C.A., Smith, D.R., Van Scoyoc G.E., Reicher Z.J, 2006: Aboveground Responses of Cool-Season Lawn Species to Nitrogen Rates and Application Timings. Crop Science 47, 3 p.1225 -1236

Webster D.E. and Ebdon J.S. Effects of Nitrogen and Potassium Fertilization on Perennial Ryegrass Cold Tolerance During Deacclimation in Late Winter and Early Spring. HortScience 40(3): 842.849. 2005.

Wehner, D.J. & Haley, J.E. 1993. Effects of late fall fertilization on turfgrass as influenced by application timing and N source.  International Turfgrass Society research Journal 7:580-586.

White, D.B and Smithberg, M.H., Cold Acclimation and deacclimation in cool season grasses, in Porc. 3rd Int. Turfgrass Res. Conference, Beards J.G. Ed , ASA.CSSA.SSA and Int. Turfrass Socciety, Madison, WI 1980, 149.154

Wilkinson, J.F. & Duff, D.T. 1972. Effects of fall fertilization on cold resistance, color, and growth of Kentucky bluegrass. Agronomy Journal 64:345-348.