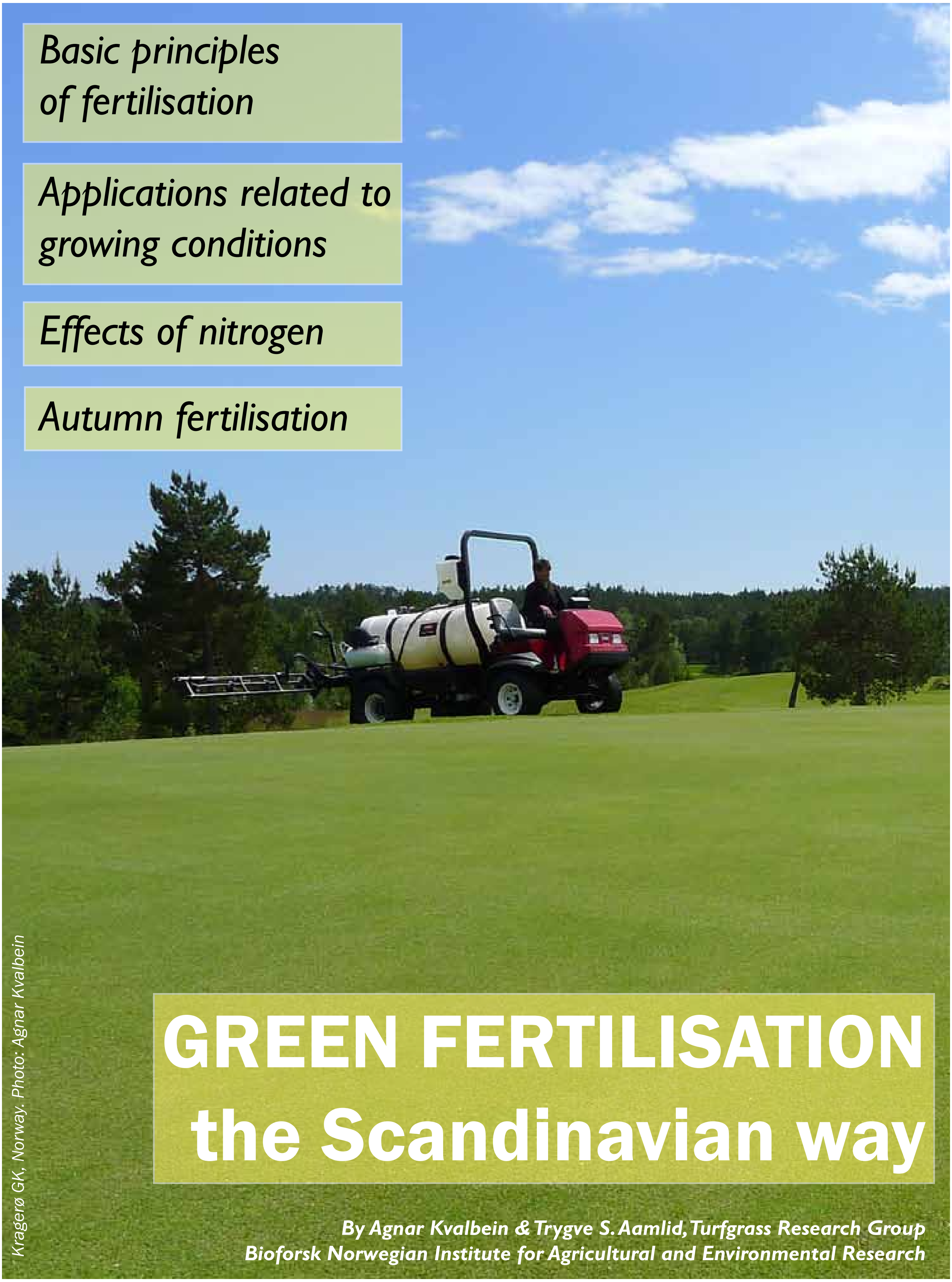

Basic principles of fertilisation

Applications related to growing conditions

Effects of nitrogen

Autumn fertilisation

Kragerø GK, Norway. Photo: Agnar Kvalbein

GREEN FERTILISATION the Scandinavian way

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Imjelt Golf, Norway. Photo: Tatsiana Espevig

Green fertilisation the Scandinavian way

Although Norway is a small country, it extends from latitude 58 to 71 degrees North. This makes light conditions comparable to those in the northern half of the Canadian mainland.

The climate is mild due to the north Atlantic drift, which keeps the country inhabitable and the coast free from ice throughout the winter. Annual precipitation ranges from more than 2000 mm on the west coast to less than 200 mm in the valleys sheltered from the prevailing westerly winds.

Fertilisation practices on the 170 golf courses in Norway have for the last few years been influenced by Associate Professor Tom Ericsson, who is now at the Swedish University of Agricultural Sciences. He was a member of Professor Torsten Ingestad's research group, which worked on plant nutrition for some decades. Their work had a great influence on fertilisation practices in the forest industry, greenhouse production and nurseries in Norway.

Sand-based golf greens are in many ways comparable to the inactive growth media used in greenhouses, and the fertilisation techniques that gardeners use to control plant growth and quality can be transferred to golf. For some years we have based the fertilisation regime on our experimental greens at the Bioforsk Turfgrass Research Centre on these theories. This paper describes our practical experiences and presents results from completed and ongoing research.

Most of the research was funded by the Scandinavian Turfgrass and Environment Research Foundation (http://sterf.golf.se).

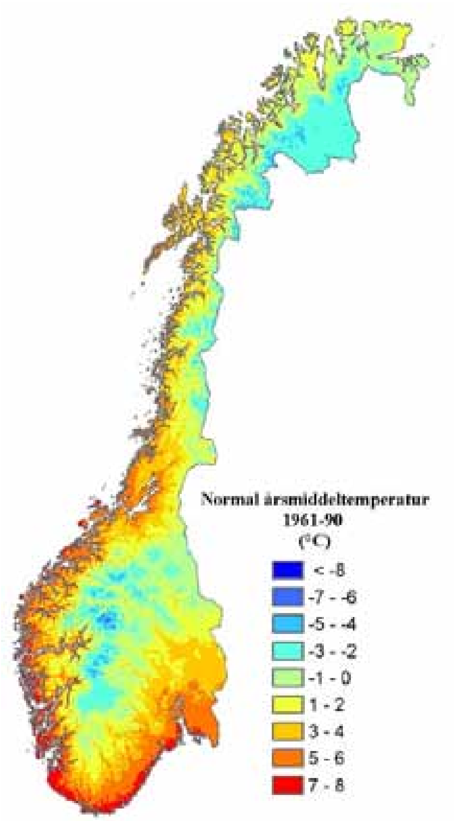

Figure 1. Normal annual temperature in Norway. Source: www.met.no

Grass growth capacity/ fertiliser requirement

Based on a greenhouse study and a two-year field experiment (Ericsson et al., 2012 a,b), the grass species for greens are ranked in the following order according to decreasing growth capacity and thus decreasing fertiliser requirement:

1. Annual meadow grass (*Poa annua* L.).

2. Creeping bent grass (*Agrostis stolonifera* L.).

3. Colonial bent grass (*Agrostis capillaris* L.) (syn. *Agrostis tenuis* Sibth.).

4. Slender creeping red fescue (Festuca rubra var litoralis) (syn. *F. rubra* var *thichophylla*).

5. Chewings fescue (*Festuca rubra* var *commutata*).

Balanced fertiliser

In our experiments we tested a mixture of nutrients, which proved to be suitable for all plants under normal, slightly acidic soil conditions (Knecht & Göransson, 2004). This basic formula provides a very good starting point for all fertilisation plans.

Table 1 shows only the nutrients that normally have to be applied under Scandinavian conditions.

Nitrogen	N	100
Potassium	K	80
Phosphorus	P	12
Magnesium	Mg	8
Sulphur	S	8
Calcium	Ca	6
Iron	Fe	0.7
Boron	B	0.2
Manganese	Mn	0.4
Zinc	Zn	0.06

Table 1. A balanced fertiliser, expressed as relative amounts of the element in relation to nitrogen (=100)

It is important that nutrients which are directly involved in photosynthesis, i.e. potassium, magnesium, iron and manganese, never become minimum factors in the mixture (Ericsson, 1995).

We recognise that an enhanced level of some elements, such as sulphur or iron, may be beneficial for reasons other than plant growth and that several non-nutrient elements such as silicon (Si) and organic molecules may provide additional strength to the plant under stressful conditions. However, this paper focuses on basic fertilisation.

We like to make fertilisation easy by stating that there is rarely any reason to deviate from this basic formula as long as the applications are made frequently (weekly) and the pH is not far from optimum. When pH is high, some micronutrients, especially manganese, should be provided as a foliar application.

Summary of basic principles

- The fertilisation rate should be adapted to the genetic growth capacity of the turfgrass species.
- Fertiliser should be applied as a complete, balanced mix of nutrients where nitrogen is the minimum factor. The same nutrient solution can be used all year round.
- Fertiliser should be applied frequently at low rates (preferably weekly spoon-feeding). The application regime should be based around the main external growth factors, i.e. light and temperature (assuming that the greenkeeper controls water, soil oxygen and other limiting factors).
- Extending the period with fertiliser inputs in autumn does not impair winter survival, but improves spring performance of the turf.

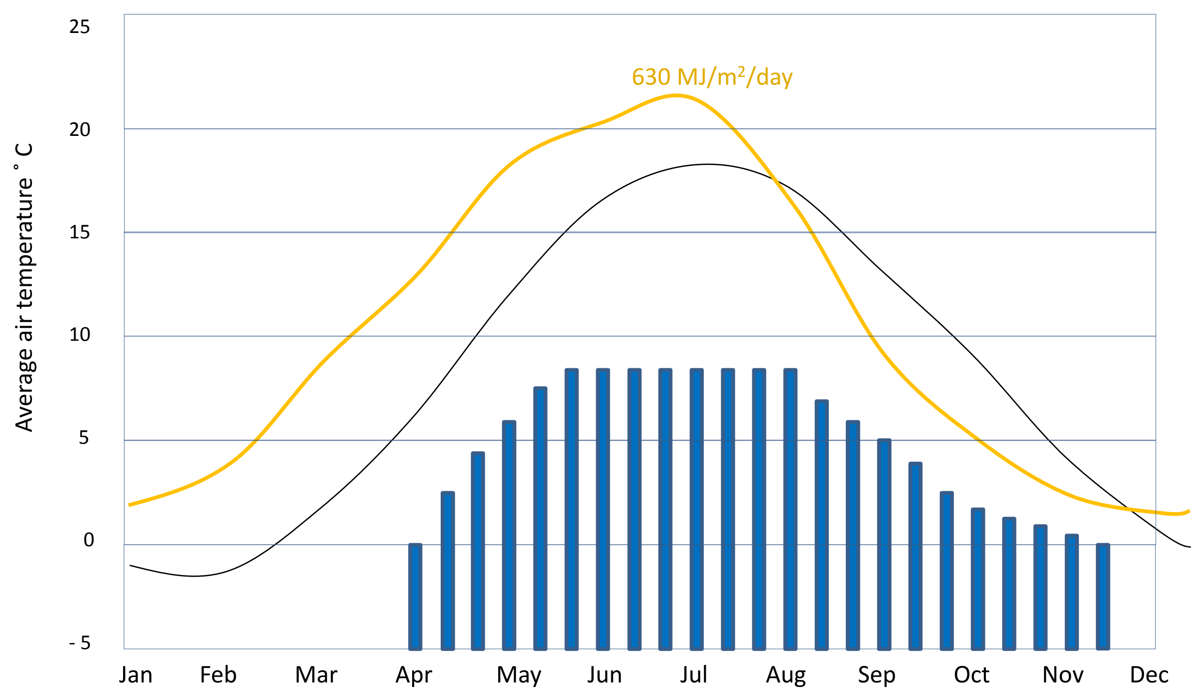

Figure 2. Distribution pattern for weekly fertilisation based on temperature and light conditions at Landvik research station on the south coast of Norway. The enhanced rates in September and October are based on the positive effect of autumn fertilisation (see text). The rates should be adapted to the genetic growth capacity of the turfgrass species.

Applications related to growing conditions

Assuming that soil moisture and gas diffusion into the soil are controlled by the greenkeeper, light and temperature are the most important environmental growth factors.

We therefore recommend that a fertilisation plan be established according to the light and temperature curves (Figure 1).

Heat stress is a major concern for most greenkeepers world-wide, but in terms of weekly growth rates, the mid-summer decline in turfgrass growth is far less distinct in Scandinavia than in North America.

In Northern Norway there is seldom any mid-summer depression at all, and even at our research centre Landvik on the Norwegian south coast, the 30-year normal temperature for July is 16.2˚C and the daily maximum rarely exceeds 25˚C. This climate difference may be important when comparing growth curves, and thus seasonal fertiliser demands, in Scandinavia and Canada.

Fertilisation based only on the light and temperature curves does not take into account the mineralisation of nutrients from the organic matter in the greens. However, on older greens or if compost is added to the soil mixture, such mineralisation should be taken into consideration in July and August.

Effects of nitrogen

The art of fertilising a green is a delicate balance between the need for density and recuperative capacity and the negative consequences such as higher mowing costs and thatch accumulation.

Assuming that the plant is not suffering from nitrogen deficiency but has a normal green colour, enhanced N levels will reduce plant stress tolerance. This problem becomes more distinct when growth conditions are not optimal (Figure 3).

Everyone seems to be aware of the positive correlation between nitrogen rate and growth (dry matter production), but the fact that enhanced growth rate reduces the sugar content in the plant is probably less well known. Sugar reserves are very important for the plant, as they are the source of energy needed for respiration, uptake of nutrients, growth, defence against pests and diseases and feed for the beneficial microbes that surround the roots in the rhizosphere. This leads to the conclusion that fertility should be reduced when the grass plant's growth potential is limited by suboptimal temperatures, shade, lower mowing height, compaction or drought. Experiments suggest that a leaf N concentration of 3.1-3.5 % is the lower limit for producing healthy-looking turf of fescues and bent grasses (Ericsson et al., 2012a,b).

Some do not consider it logical to decrease the fertiliser rates on a shaded green, but this is important to keep stress tolerance and root development as strong as possible. Of course this practice cannot totally eliminate the effects of shaded conditions.

To summarise: Turfgrass species have different growth potential and a corresponding optimal demand for nutrients. Correct fertilisation involves keeping the nitrogen levels in the grass plants low and stable, while still encouraging enough plant growth to repair wear and tear. To keep the plant healthy, nitrogen should always be the minimum factor and should be applied as part of a balanced complete mixture of nutrients.

In practice, we recommend weekly spoon-feeding with a liquid fertiliser. This gives the greenkeeper the opportunity to adjust for changes in cutting height or weather conditions and to adapt the rates to other maintenance practices.

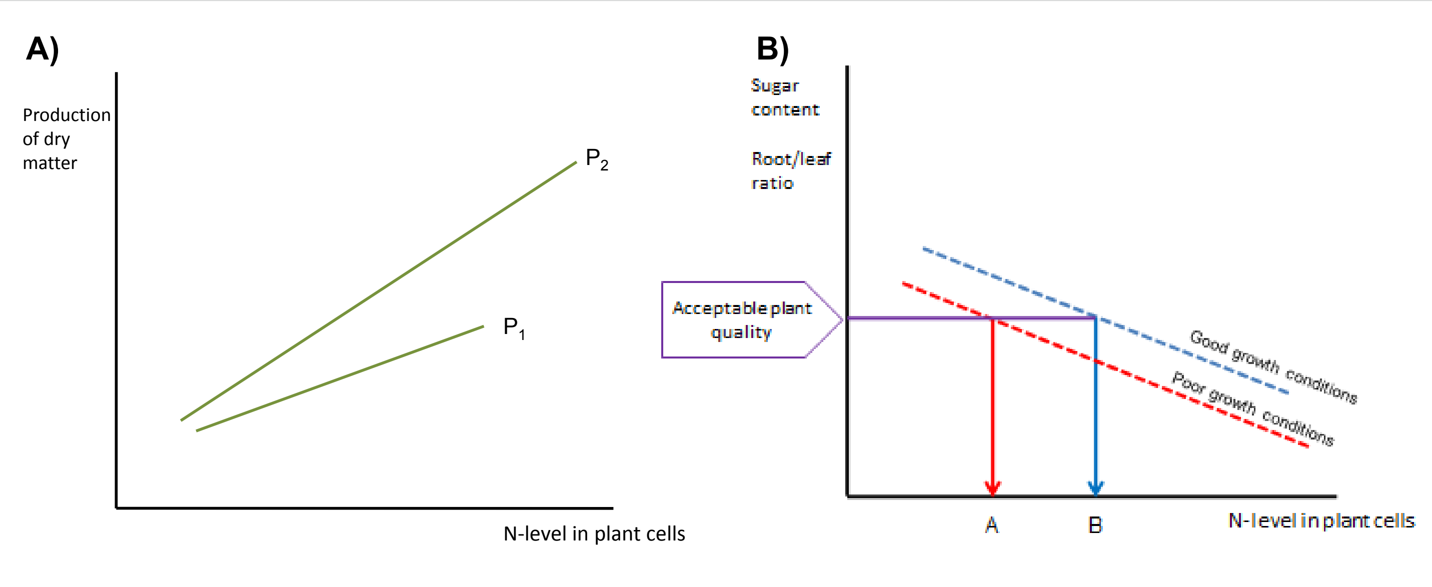

Figure 3. a) Relationship between nitrogen and plant growth. Plant production increases with N availability. P1 and P2 represent plants with low and high growth potential, respectively. b) Relationship between nitrogen and plant quality. Plant sugar content (or root/shoot ratio) decreases with increasing nitrogen levels in plant cells. Under poor growth conditions, nitrogen application should be reduced (from B to A) to preserve the energy reserves in the plant.

Stockholm Golf Club. Photo: Björn Andersson.

Autumn fertilisation

Late autumn fertilisation of fine turf has not been common practice in the Nordic countries to date. Fears of winter damage have left greenkeepers sceptical about the practice, probably unnecessarily.

Eighteen experiments conducted from 2008 to 2010 on greens all over the Nordic countries confirmed that the positive results from the US and Canada are applicable even under Scandinavian conditions (Kvalbein & Aamlid, 2012).

The experiments showed no negative effects when applying 2 g/m^2 as a balanced NPK soluble fertiliser in late autumn (LAF). The results were reported as four datasets where the greens were classified based on the dominant grass species. Annual meadow grass showed no effect of LAF, but creeping bent grass and red fescue had better spring performance, and red fescue even had less winter damage. Our data also showed that greenkeepers who had stopped fertilising early in the autumn gained more benefit from LAF than those who had continued fertilising at low rates until frost and/or snowfall. Therefore, we now recommend keeping on fertilising with diminishing rates until the frost and snow is permanent.

The theoretical background to this recommendation is that the acclimation of plants before winter is based on their genetic make-up and is not influenced by reasonable amounts of nitrogen. In other words, a plant species which is well adapted to a cold climate will cease growing despite having access to nitrogen.

Another aspect is that perennial grasses, unlike conifers and deciduous trees, are able to transform solar radiation into sugar even at low temperatures (Huner et al., 1993). Photosynthesis continues throughout the autumn because the grass plant is able to produce more of the enzymes necessary for CO_2 reduction, and is also able to establish alternative pathways for sugar production. This adaptation to cold benefits from good access to nitrogen. By keeping turfgrasses green and well-fertilised in the autumn, plants can produce more sugar and are better able to resist all kinds of winter damage.

We still need more fine-tuned experiments to determine the optimal autumn fertiliser rates for each grass species. There may be distinct differences between the fine fescues and bent grasses, which are genetically well adapted to cold climates, and perennial ryegrass and annual meadow grass, which tend to keep growing in the autumn.

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SCANDINAVIAN TURFGRASS AND ENVIRONMENT RESEARCH FOUNDATION

STERF is a research foundation that supports existing and future R&D efforts and delivers 'ready-to-use research results' that benefit the Nordic golf sector. STERF was set up by the golf federations in Sweden, Denmark, Norway, Finland, Iceland and the Nordic Greenkeepers' Associations.

Vision
The Nordic golf sector's vision with respect to golf course quality and the environment is:

To promote high-quality golf courses, whilst guaranteeing that ecosystem protection and enhancement are fully integrated into golf facility planning, design, construction and management.

The aim of STERF is to support R&D that can help the golf sector to fulfil this vision. The activities of STERF are intended to lead to improvements in golf course quality, as well as economic and environmental gains.

STERF prioritises research and development within the following international thematic platforms:

Integrated pest management
STERF together with the golf sector, universities and research institutions and authorities takes responsibility for ensuring that R&D activities that are important for integrated pest management are coordinated and executed and that new knowledge is delivered.

Multifunctional golf facilities and healthy ecosystems
Multifunctional golf courses can contribute to the achievement of environmental goals and help improve people's health and quality of life, especially in areas surrounding dense conurbations, where there are a large number of golf courses. Through utilising joint expertise, our region can become a role model with respect to multifunctional golf courses and collaborations between different interests in society.

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STERF´s goal is to provide science-based information on integrated management practices, based on existing knowledge and new research results, to reduce water consumption, protect water quality and document the effects – both positive and problematic – of well-managed turfgrass areas on water resources.

Overwintering
Winter damage is the foremost reason for dead grass, reducing the aesthetic and functional value of turf. UN climate scenarios predict that due to high precipitation and unstable temperature, ice and water damage will become the most important cause of winter damage in the future. STERF takes responsibility for developing strategic expertise and new knowledge to avoid and manage such damage.

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