How to save water without sacrificing turf quality on greens and fairways ?

Scandinavian research highlights deficit irrigation and optimal choice of turf grass species

Trygve S. Aamlid, Trond Pettersen and Agnar Kvalbein,
Bioforsk Turfgrass Research Group

Worldwide, lack of irrigation water is the foremost limitation to further expansion of golf. In the Nordic countries, surface water for irrigation is generally abundant in Finland, Norway and most of Sweden, but many Danish golf courses have to pay for abstracting ground water and are only allowed to use 5-7000 m^3 per season. Regardless of country, limited capacity of water distribution systems sometimes limit irrigation during dry periods, and pumping of water is usually a major item in the energy, CO_2 and cost budgets for golf course maintenance. Is it at all possible to use less water while maintaining turf quality on golf course greens and fairways ?

The STERF project 'Evaporative demands and deficit irrigation on golf courses' started in 2009 and is now being wrapped up by the publication of scientific papers and a turfgrass irrigation handbook. This article highlights some of the findings in the project.

Turf grass water consumption and crop coefficients

Evapotranspiration (ET) from surfaces with 100% turf coverage is mainly due to transpiration from turf grass leaves, as soil evaporation is negligible. The reference ET rates (ET_0) was formerly measured by the evaporation from an open water surfaces. Nowadays, ET_0 is calculated from irradiance, temperature, wind speed and relative humidity recorded by automatic weather stations. The average daily ET_0 from May to September in the Nordic countries is usually in the range 2.5-3.0 mm, but values between 4 and 5 mm often occur on warm and sunny days in midsummer. The crop coefficient (K_c) is defined as the ratio between actual ET (ET_a) from the turf canopy and reference ET, $K_c = ET_a/ET_0$.For cool-season grasses this has often been assumed to be a constant value in the range 0.8-1.0. However, our research showed that this is oversimplification.

In order to measure the Et_a from various grasses, we installed metal cylinders into four species/subspecies on a USGA-spec. green and a golf course fairway situated on a silt loam soil (64% sand, 29% silt, 7% clay). The green was mowed three times per week to 5 mm for fescue and 3 mm for the bent grasses, and the fairway twice per week to 15 mm for all species. The cylinders had a diameter of 10 cm and were 30 cm deep, corresponding to the depth of the USGA root zone (Photo 1). For this depth, soil physical analyses showed a plant available water holding capacity of approximately 30 mm in the green trial and approximately 40 mm in the fairway trial.

During five periods without rainfall in 2009 and 2010, each period of 5-14 days duration, the cylinders were pulled out of their sleeves and weighed on a daily basis to determine ET_a. There were six cylinders (replicates) per species, of which three were irrigated to field capacity before reinstallation into the sleeves, while the remaining three were allowed to dry out.

Figure 1 shows actual ET from chewings fescue and creeping bent grass growing on the USGA green during the first observation period in 2009. The high water consumption of turf that received daily irrigation to field capacity surprised us, but the pattern repeated itself during the following periods, on greens as well as fairways. In other words, if the turf has free access to water, it will also use it!

Based on data from all registration periods, we described crop coefficients for various species on green and fairway as hyperbolic functions of day number after irrigation to field capacity (Figure 2). This shows that K_c values in the range 0.8-1.0 were only valid at soil water contents corresponding to day no. 3-4 after irrigation to field capacity in the green trial and day no 4-6 (depending on species) in the fairway trial. On the condition that irrigation replenished the total water holding capacity of the soil, Kc values were always 2-3 times higher on the first day after irrigation.

As shown in Figure 2a, velvet bent grass was an exception to the general pattern. The water use on the first day after irrigation was not as redundant as in the other species. This may be due to a more humid microclimate that limits transpiration from extremely dense turf grass canopies (Photo 2).

Based on the K_c hyperbolic functions (Figure 2) and an assumed daily ET_0 of 3 mm, Table 1 shows that the weekly water consumption on golf greens decreased in the order chewings fescue > colonial bent grass > creeping bent grass >> velvet bent grass. Many Scandinavian greenkeepers using the traditional mixture of fescues and colonial bent grass have been surprised by this ranking as they have seen their greens to be dominated by fescue after dry periods and by bent grass after wet periods. There is, however, no conflict between these observations and our finding that pure fescue greens with open canopies cut at 5 mm and minimal amounts of thatch, will consume more water than denser and more thatchy bent grass greens cut at 3 mm. The fact that root dry weights were 410 g m^{-2} in chewings fescue and 429 g m^{-2} in velvet bent grass versus 329 g m^{-2} in colonial bent grass and 244 g m^{-2} in creeping bent grass may help to explain why the former species were able to maintain higher K_c values towards the end of the dry-down period period.

Assuming one weekly irrigation to field capacity, Table 1 also presents the relative water use of various species/subspecies in the fairway trial. Here the results are perhaps more in line with what most turf grass managers would expect, i.e. decreasing water consumption in the order perennial ryegrass >> creeping red fescue > Kentucky bluegrass > chewings fescue. The fact that perennial ryegrass was able to uphold water consumption and retain colour during dry periods better than chewings fescue, strong creeping red fescue and Kentucky bluegrass is illustrated by Photo 3 and reflects that perennial ryegrass had a significantly higher dry weight of roots in the 0-30 cm topsoil layer: 617 g m^{-2} as opposed to an average of 342 g m^{-2} in the other species.

Deficit irrigation

Deficit irrigation can be defined as 'irrigation without bringing the soil moisture content back to field capacity'. This is illustrated in Figure 3 showing the three principally different irrigation strategies; (1) light and frequent irrigation to field capacity, (2) deficit irrigation, and (3) deep and infrequent, drought-based irrigation. Deficit irrigation can be conducted at different frequencies, but the idea of exposing the turf to a moderate but constant drought stress implies that intervals must not be too long. Figure 3 suggests irrigation every other day, but daily irrigation may be just as relevant.

The STERF project included trials with deficit irrigation on greens as well as fairways, but only the green trial will be presented here. This trial was conducted under a mobile rainout-shelter that had been constructed over creeping bent grass 'Independence' on the same green that had been used to determine ET_a-rates (Photo 4). Different irrigation strategies were tested alone or in combination with 'Revolution', which is currently one of the most widely used surfactants in Scandinavia.

The experimental plan was as follows:

<u>Factor 1: Irrigation</u>

1. Irrigation to field capacity six times per week (only day off: Sunday)
2. Irrigation to field capacity twice per week (Mondays and Fridays)
3. Irrigation to field capacity once per week (Mondays)
4. Deficit irrigation six times per week (only day off: Sunday).
5. Deficit irrigation twice per week (Mondays and Fridays)
6. Deficit irrigation once per week (Mondays)

<u>Factor 2:</u>

a. No surfactant
b. Revolution, 19 L ha^{-1} preventatively before experiment started followed by 9.5 L ha^{-1} every other week during the experimental period

The amount of water added in the various treatments was calculated from reference values (ET_0) and the K_c function for creeping bent grass greens (Figure 2). Irrigation in treatment 4 started on day no 5 after irrigation to field capacity with replenishment of the calculated ET_a on day no. 4 only (on Mondays, we had to replenish the calculated ET_a on both Saturday and Sunday). In treatments 5 and 6, we only replenished the calculated ET_a on day no. 3 onwards. Soil water content was recorded two to three times per week using a portable TDR instrument for the 0-12 cm topsoil layer and a stationary probe for the 10-20 and 20-30 cm soil layers.

Table 2 presents some key figures from the main, nine-week experimental period 20 June - 22 August 2011. The total water consumption in treatment 4 (light and frequent deficit irrigation) was 66% lower than in treatment 1 (light and frequent irrigation to field capacity) and 29% lower than in treatment 3 (drought-based, deep and infrequent irrigation). Despite this, there was no significant difference in turf quality during the first five to six weeks of the nine week experimental period. These weeks had temperatures close to the 30 year normal values, with daily maximums around 20°C. Starting 28 July we had a week with daily maximums around 25°C that put the turf under more stress and caused differences to show up among irrigation treatments. For the rest of the experimental period, turf quality was always better in treatment 4 (light and frequent deficit irrigation) than in treatment 3 (deep and infrequent, drought-based irrigation, although not as good as in treatment 1 (light and frequent irrigation to field capacity (Table 2). Contributing to these differences were less localized dry spots on plots receiving daily water inputs than on plots that were allowed to dry out between irrigation treatments. Green speed was not significantly affected by irrigation treatments but surfaces became softer with more frequent irrigation and with increasing irrigation rates (Table 2).

A commonly heard argument against light and frequent irrigation is that it will result in wet topsoils, but dry subsoils with reduced root development. The first of these arguments is obvious and substantiated by Table 2. Soil moisture content at 10-20 cm is not shown in the table, but our data confirm that it was mostly 1.5 to 2.5 per cent units lower than in the topsoil on plots receiving light and frequent irrigation, but on the same level (treatment 3) or 2-3 units higher (treatment 6) on plots receiving drought-based irrigation. However, as long as irrigation amounts were reduced as in treatment 4 to retain a soil moisture deficit, this only had minor consequences for root growth (Table 2). In conclusion, these results, as well as those from the corresponding fairway trial, therefore speaks in favour of light and frequent deficit irrigation as the best compromise to maintain turf quality while reducing water consumption for golf course turf.

On average for irrigation treatments, the soil surfactant Revolution caused an insignificant improvement in turf grass quality from 4.8 to 5.4 during the last three weeks of the experiment. This improvement was accompanied by a reduction in localized dry spots from 24 to 4 % of plot area. Photo 5, taken by the end of the trial, suggests greater need for surfactant in combination with infrequent, drought based irrigation than with light and frequent deficit irrigation. This is in agreement with correlation analyses showing that the risk for localized dry spots on this particular green increased dramatically if the soil moisture content was allowed to drop below 9%. Other thresholds may exist on greens with different grain size distributions or higher contents of soil organic matter.

Concluding remarks

This project showed a great potential for reduced water consumption at golf courses by using the right turfgrass species and introducing a deficit irrigation strategy. As for deficit irrigation, there are, however, several aspects that need further clarification before making general recommendations to golf courses:

- Are today's irrigation systems sufficiently uniform, or will deficit irrigation require additional labour for hand-watering beyond the budget of the golf course ?
- Will light and frequent deficit irrigation result in more invasion of *Poa annua* or more problems with moss compared with drought-based irrigation?
- What are the implications of deficit irrigation for turfgrass carbohydrate levels, and thus tolerance to various types of biotic and abiotic stresses ?
- To what extent is deficit irrigation feasible on greens with a predominant cover of *Poa annua* ?

It is our hope that intensified collaboration between greenkeepers and researchers in Scandinavia and Canada will help to elucidate these and other questions in the near future.

Box

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 is 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 prioritize 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 role models with respect to multifunctional golf courses and collaborations between different interests in society.

Sustainable water management
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.

More information about STERF and ongoing research projects can be found on **http://sterf.golf.se**