How to save irrigation water without sacrificing turf quality

Part 2

What is deficit irrigation ?

Deficit irrigation on CREEPING BENTGRASS GREENS

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Photo 1. *Mobile rainout shelter in parked position outside irrigation trial. Once rain started, the trial was covered within 2 minutes. Dry plot in foreground received deficit irrigation once a week (treatment 6). Photo: Trygve S. Aamlid.*

Deficit irrigation on creeping bentgrass greens

In the first paper in this series, we discussed actual water use (evapotranspiration) of various turfgrass species on green and fairway. The most important conclusion was that turfgrass water use is always much higher on the first day after irrigation to field capacity, i.e. after replenishment of the entire soil water-holding capacity, than on subsequent days. This implies that there is potential for significant reductions in water use by avoiding irrigation to field capacity. This second paper examines how such a deficit irrigation practice influences turf quality compared with the perhaps more accepted practice of deep and infrequent irrigation.

How to save water without sacrificing turf quality?

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 groundwater and are only allowed to use 5-7000 m^3 per season. Regardless of country, limited capacity of water distribution systems often limits 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 concluded with the publication of scientific papers and a turfgrass irrigation handbook.

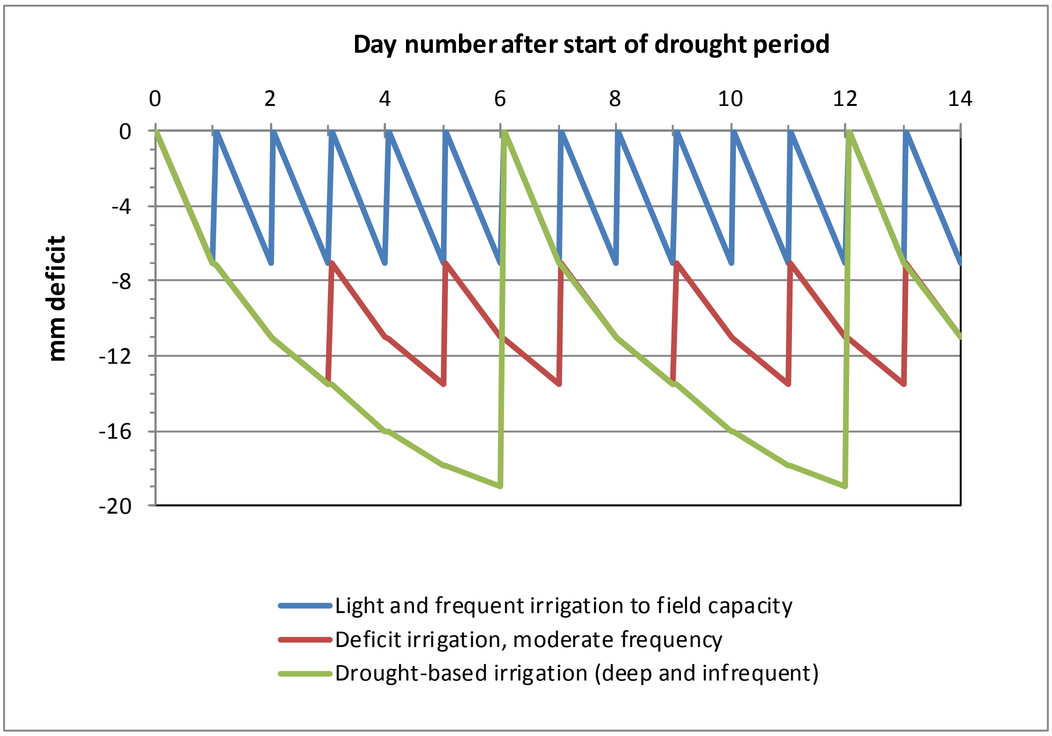

Figure 1. *The three different irrigation strategies tested, which differ in principle.*

What is deficit irrigation ?

Deficit irrigation can be defined as 'irrigation without bringing the soil moisture content back to field capacity'. This is illustrated in Figure 1, which shows three irrigation strategies that differ in principle:
(1) Light and frequent irrigation to field capacity,
(2) deficit irrigation, and
(3) deep and infrequent, drought-based irrigation.

Deficit irrigation can be carried out 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 1 suggests irrigation every other day, but daily irrigation may be just as relevant.

The STERF project *'Evaporative demands and deficit irrigation on golf courses'* included deficit irrigation trials on both greens and fairways. This paper focuses on the green trial. It was conducted under a mobile rainout-shelter constructed over creeping bent grass 'Independence' on the same green as was used to determine ET_a rates (Photo 1). Soil physical analyses showed that the plant-available water-holding capacity of the green root zone was approximately 30 mm. 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:

Factor 1: Irrigation

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)

Factor 2:

a. No surfactant

b. Revolution, 19 L ha^{-1} preventatively before the experiment started, follo wed by 9.5 L ha^{-1} every other week during the experimental period

Irrigation treatment	No. of irrigations	mm water per irrigation (mean)	Total water use, mm	SMC[4] (0-12 cm, mean of 26 obs.)	Visual turf quality (1-9, mean of 4 obs. in August)	Surface firmness (gravities- mean of 9 obs.)	Root dry weight below 5 cm at end of trial, g m^{-2}	Localised dry spots, % of plot area (mean of 2 obs. in August)
1.FC[1] 6x per week	54	6.6	358	12.3	6.0	71	138	6
2.FC 2x per week	18	12.9	232	11.5	5.6	74	161	6
3.FC 1x per week	9	19.2	173	9.5	4.6	79	196	13
4.DEF[2] 6x per week	51	2.4	122	11.2	5.5	76	183	8
5.DEF 2x per week	18	7.1	128	10.1	4.9	75	180	11
6.DEF 1x per week	9	11.8	106	8.1	4.0	85	187	27
P-value[3]	-	-	-	0.03	0.06	<0.01	>0.10	0.08

[1] FC = irrigation to field capacity
[2] DEF = deficit irrigation
[3] Effect considered statistically significant at $P<0.05$. $0.05<P<0.10$ indicate trends.
[4] Soil moisture content

Table 1. *Turfgrass water use, visual quality, surface firmness, root development and localised dry spots as affected by various irrigation treatments to creeping bent grass 'Independence' growing on a USGA-spec. green, Bioforsk Landvik, 20 June – 22 Aug. 2012.*

The amount of water added in the various treatments was calculated from the reference evapotranspiration value (ET_0) and the K_c function for creeping bent grass greens that were developed in the first part of the STERF project (Figure 2, see first paper in this series for further explanation). Irrigation in treatment 4 started on day 5 after irrigation to field capacity with replenishment of the calculated actual evapotranspiration (ET_a) on day 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 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 1 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 maxima around 20°C. Starting on 28 July we had a week with daily maxima 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 1). Contributing to these differences were less localised dry spots on plots receiving daily water inputs than on plots which 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 1).

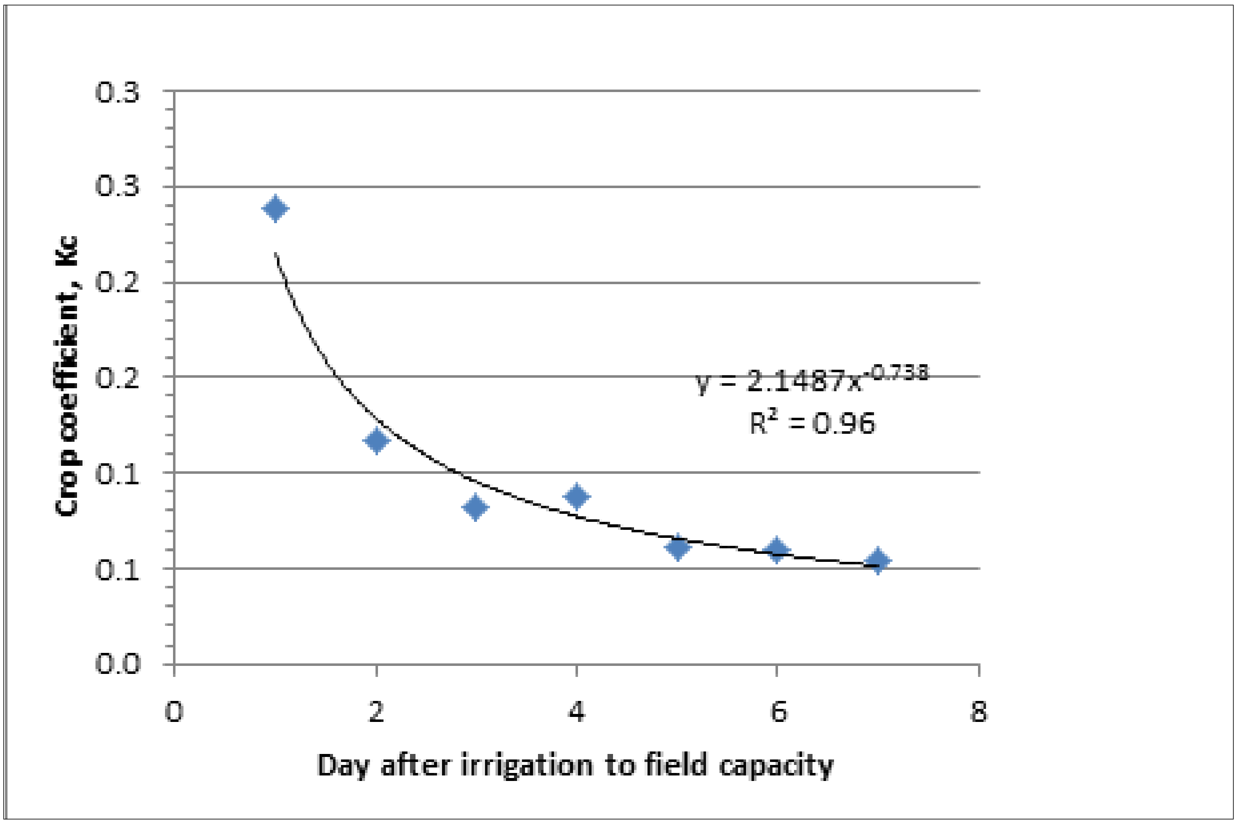

Figure 2. *Crop coefficient on creeping bent grass greens as a function of days after irrigation to field capacity.*

A commonly heard argument against light and frequent irrigation is that it will result in wet topsoil and dry subsoil, with reduced root development. The first of these arguments is obvious and substantiated by Table 1. 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 percentage units lower than in the topsoil of plots receiving light and frequent irrigation, but on the same level (treatment 3) or 2-3 percentage units higher (treatment 6) than in 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 1).

In conclusion, these results, as well as those from the corresponding fairway trial, indicate that light and frequent deficit irrigation is the best compromise to maintain turf quality while reducing water consumption for golf course turf.

On average for irrigation treatments, the soil surfactant Revolution gave a non-significant improvement in turfgrass quality from 4.8 to 5.4 during the last three weeks of the experiment. This improvement was accompanied by a reduction in localised dry spots from 24 to 4 % of plot area. Photo 2 (next page), taken at the end of the trial, suggests a greater need for a surfactant with infrequent, drought-based irrigation than with light and frequent deficit irrigation. This is in agreement with correlation analyses showing that the risk of localised 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 particle size distributions or higher contents of soil organic matter.

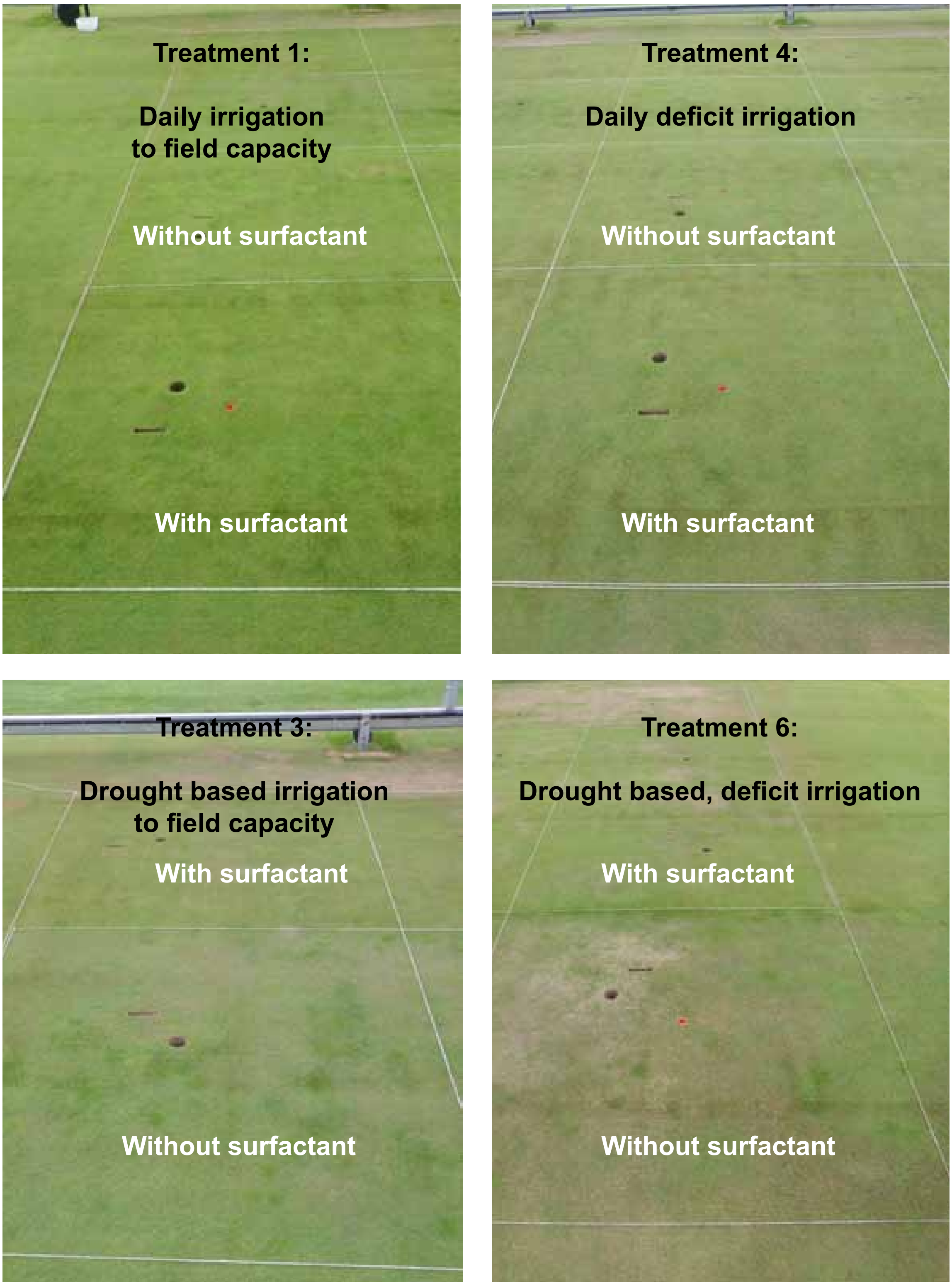

Photo 2a-d. *Plots representing eight combinations of irrigation and surfactant treatment at the end of the trial on 22 Aug. 2011. Treatments are indicated. Photos: Trygve S. Aamlid.*

Concluding remarks

This project showed great potential for reduced water consumption at golf courses by using the right turfgrass species and introducing a deficit irrigation strategy. As regards deficit irrigation, there are, however, several aspects that need further clarification before general recommendations can be made for 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 answer these and other questions in the near future.