Soil Moisture Control of Spray and Subsurface Drip Irrigation: An Analysis of Applied Irrigation, Sensor Placement, and Turf Water Status

Mary J. Hattendorf, Ph.D.
Northern Water
220 Water Ave
Berthoud, CO 80513

Mark A. Crookston, P.E., CAIS, CLIA
Northern Water
220 Water Ave
Berthoud, CO 80513

Abstract
A spray-irrigated plot and a subsurface drip irrigated (SDI) plot of tall fescue turf grass were fitted with soil moisture sensors for automated irrigation control. Both plots have dedicated water meters to measure applied irrigation amounts. An adjacent weather station allows calculation of ETos. Sensor placement in the SDI plot (parallel to and equi-distant from adjacent laterals) may have been a factor in subsequent inability to properly control irrigations via soil moisture. Additional soil moisture sensors installed in different configurations in the SDI plot may allow improved irrigation control. Fixed mount infrared temperature sensors and Crop Water Stress Index relationships will allow normalized comparisons of turf water status in the spray and SDI irrigated plots.

Keywords: Sprinkler irrigation, sub-surface drip irrigation, turf, Crop Water Stress Index

Introduction

Subsurface drip irrigation (SDI) in turf is widely viewed as a way to reduce irrigation applications because of the higher efficiencies and uniformities of drip irrigation. Sprinkler irrigation is subject to evaporative losses and distribution effects from wind or system design.

The objective of this project was to determine whether irrigation requirements were less in the subsurface drip irrigated plot than in the sprinkler-irrigated plot. Soil moisture control of irrigation in each plot would provide a plant-based means of determining when and how much irrigation to apply. This technique, however, is dependent on setting the appropriate soil moisture levels and understanding how the soil moisture sensor depth, soil type, and turf rooting depth affect irrigation settings and subsequently, irrigation applications. Therefore, it seemed necessary to introduce an additional independent measure of turf water status. Infrared thermometry has a long history of use in identifying plant water status (Payero et al, 2005; Idso et al., 1981; Jackson et al., 1981; Jackson, 1982). Development of the empirical Crop Water Stress Index (Idso et al, 1981) reduced the data requirements to determine plant water stress. However, the empirical technique comes with its own limitations (Payero et al., 2005). Nonetheless, it is a powerful tool and has been introduced in this project to verify turf water status under the two irrigation systems. Three specific goals of this analysis were to: track irrigations in each plot with comparison to standardized grass reference evapotranspiration (ETos, ASCE-EWRI, 2005), compare soil moistures at the 5 inch soil depth, and track comparative turf water status via the Crop Water Stress Index.

Methods

Tall fescue (*Festuca arundinacea*) was established at Northern Water's headauarters in Berthoud, CO via sprinkler irrigation in each of two adjacent triangular plots in 2006. Plot areas were 1400 sq ft each. Separate valves and flow meters were installed in each plot. The soil type was a Nunn Clay Loam (Fine, smectitic, mesic Aridic Argiustolls). Soil preparation included tillage to 6 inches and amendment with 3 cu yds/1000 sq ft of high quality organic matter.

A pop-up spray irrigation system was installed in one plot. In 2012, distribution uniformity (DU) of the spray system was 0.57. In the other plot, 1/2 inch in-line drip emitter tubing was installed with lines spaced at 15" apart, well within manufacturer guidelines for a clay loam soil. Emitters were spaced at 18 inches and staggered in a triangular pattern. Drip lines were buried at 5 inches.

One 18 inch soil moisture sensor (bi-Sensor, Baseline, Inc, Boise, ID) was installed in each tall fescue plot at the 5 inch depth, slightly deeper than manufacturer's recommendations at the time (Customer Manual, BaseStation 6000, 2006). In the subsurface drip irrigated plot, the sensor was installed parallel to and halfway between the drip lines as per manufacturer's recommendations (Baseline, Inc, 2011).

A lower threshold method was used to set irrigation triggers in the spray plot. Field capacity was 0.35 in/in, while wilting point was considered to be 0.20 in/in. A 50% management allowable depletion (MAD) was set. Cycle and soak settings were employed. The SDI plot, however, was allowed to become drier at the 5 inch soil moisture sensor depth. This decision was based on observations and difficulty keeping similar soil moisture values at the 5 inch depth without over-application on the SDI plot. Applied irrigations were tracked via the flow meters and compared to ETos frequently.

In 2012, Apogee infrared sensors (SI-121, Apogee Instruments, Inc., Logan, UT) were installed in the spray and subsurface drip irrigated plots. Two sensors per plot were installed at a height of 36" and oriented to the east and west at 45 degree angles in each plot. This angle and height kept the field of view well within the plot boundaries. The east-west orientation was intended to minimize support or sensor shadow effects during the middle part of daylight hours. A datalogger (CR850, Campbell Scientific, Inc., Logan, Utah) recorded data on 15 minute intervals. Data from the east and west directions were subsequently averaged in each time segment.

The Apogee thermal data were filtered for post-irrigation, full sunlight conditions on the spray irrigated plot. Data were split and a CWSI baseline developed on half the data. The CWSI was calculated hourly for each plot. CWSI values were used as an independent measure to track the turf water status. The only variables included in this analysis were the turf surface temperature, air temperature, and vapor pressure deficit.

Weather data were obtained from an adjacent weather station at Northern Water's headquarters in Berthoud, CO (http://www.northernwater.org/WaterConservation/WeatherandETData.aspx). Standardized grass reference evapotranspiration (ETos) was calculated from these weather data.

Results and Discussion

Tall fescue is a deep-rooted turfgrass, typically considered to have a rooting depth of 24 inches. The soil moisture sensor placement at 5 inches was not fully indicative of the soil moisture status of the remainder of the rooting zone in either plot, nor of the turf water status. Though the SDI soil moisture was much lower than the spray soil moisture (Figure 1), the SDI CWSI tracked slightly lower than the spray CWSI. This indicated that the SDI tall fescue was accessing soil moisture from deeper in the soil profile than accounted for by the 5 inch depth sensor. Allowing a dry-down in each plot from Day of Year (DOY) 212 to 220 did not increase turf water stress, further indication that the 5 inch depth of soil moisture measurement was not indicative of soil water content in the full tall fescue rooting zone.

The irrigations on the SDI plot tended to over apply (by comparison of applied irrigations to ETos) when it was required to maintain soil moisture closer to field capacity. Past experience after heavy rain has shown that the spray plot can suffer from poor aeration and subsequent stress when soil moisture at 5 inches is near field capacity for several days. It was not considered desirable to allow this condition in the SDI plot. Therefore it was a management decision to allow lower soil moisture at the 5 inch depth in the SDI plot.

The CWSI began declining into negative values in mid-August. Payero et al (2005) documented that inclusion of solar radiation in the CWSI baseline calculation allowed the CWSI to be effectively calculated for times of day other than close to solar noon and for seasonal solar radiation changes. This is likely the reason for the trend in these CWSI values.

Table 1 shows total precipitation plus irrigation (P+I) amounts, ratio of (P+I) to ETos, and total ETos from 7/13/2012-8/20/2012. The SDI P+I amounts were slightly lower than typical turf irrigation recommendations of 0.8*ETo, while the spray irrigation applications were slightly higher than the standard turf irrigation guidelines.

Newer installation guidelines (Baseline, Inc., 2012) suggest installation in the top third of the root zone. Other sources suggest installing sensors at 25% and 60% of rooting depth (Henggeler et al 2011).

Because of logistical difficulties, additional soil moisture sensors were not installed in 2012. Soil moisture sensors will likely be installed at the 60% depth (14 inches) and also at 80% of the 24 inch rooting zone to provide full accounting for soil moisture throughout the profile. These additional measurements will help give better guidance on: soil moisture sensor placement for irrigation scheduling in a deep-rooted turfgrass on a heavy soil, potential drainage through the lower portion of the root zone, and a better understanding of tall fescue soil moisture extraction throughout the soil profile.

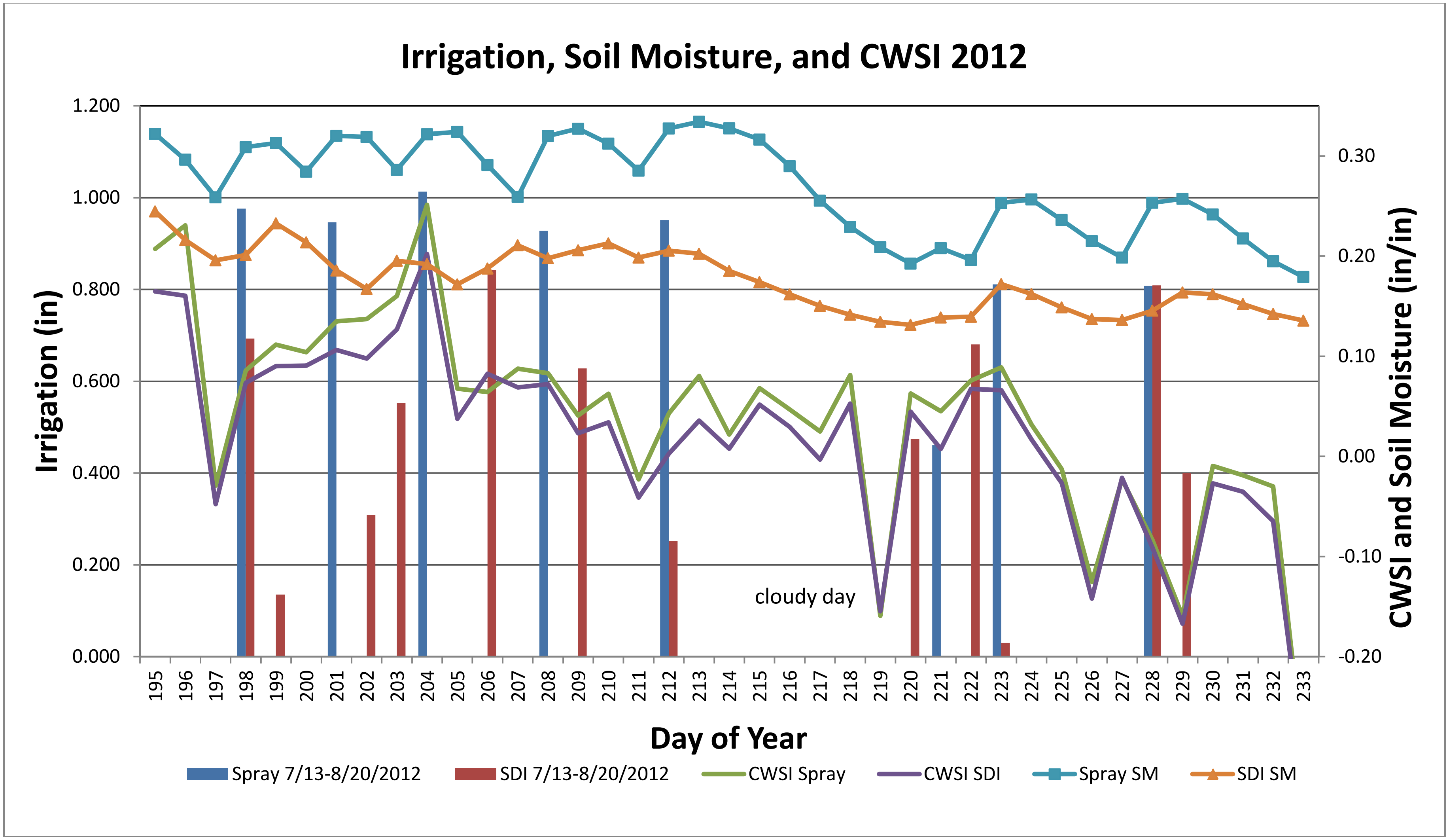

Figure 1. Irrigations, soil moisture, and Crop Water Stress Index for tall fescue from 7/13/2012 to 8/20/2012.

Table 1. Precipitation plus irrigation (P+I) , ratio of P+I to reference ET (ETos), and ETos for the period 7/13/2012-8/20/2012.

7/13-8/20/2012	**Precipitation + Irrigation (in)**	**(P+I)/ETos**	**ETos(in)**
Spray	7.37	0.86	8.61
SDI	6.29	0.73	8.61

Conclusions

The two soil moisture sensors placed as per older recommendations in the tall fescue should be either relocated to deeper depths or supplemented with soil moisture sensors placed at currently recommended depths of 60% of the rooting zone (Henggeler et al., 2011). Placement of soil moisture sensors at the 24 inch depth will provide more complete accounting of soil moisture use and transit in the soil profile.

The CWSI was an independent measure of turf water status. The CWSI in each plot tracked very closely, but irrigation amounts in the SDI plot were considerably less than in the spray plot. Solar radiation will be incorporated into the CWSI baseline calculation to refine the analysis.

These very preliminary results infer that SDI can lead to water savings. This initial year of more intensive effort will lead to some refinements in irrigation practices to optimize performance and standardize procedure.

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