Site-Specific Irrigation Management in Coastal Plain Soils

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Abstract

The main goal of this study was to determine the optimum irrigation scheduling method for cotton production in the southeastern coastal plain soils utilizing site-specific irrigation management. A variable-rate linear-move sprinkler irrigation system was developed for site-specific application of water to match crop needs. This system could monitor and apply water based on the actual soil moisture content, pan evaporation data, or the U.S. Climate Reference Network (CRN) data. Information from the moisture sensors, evaporation pan and CRN is acquired using wireless technology. Custom software collects the field information (length, width, number of irrigation zones, GPS coordinates) and generates a site-specific irrigation depth map which is used to control the irrigation system. During 2006-07 growing seasons, a field was divided into five management zones using soil electrical conductivity (EC) and soil texture data. Five irrigation scheduling treatments were applied to plots of each zone. The irrigation scheduling treatments were based on 1) soil moisture sensors (Time Domain Transmissometry, TDT); 2) pan evaporation data and a crop coefficient; 3) tensiometers; 4) reference evapotranspiration model (Jensen-Haise); and 5) no irrigation. The effects of various irrigation scheduling methods on water use, crop response, and yield were determined. The soil moisture-based treatments (tensiometer and TDT sensors) significantly increased seed cotton yields compare to the ET-based treatments (pan & reference evapotranspiration data). The irrigation depth applied was a significant factor affecting the seed cotton yield for the 2006-07 growing conditions. It was found that soil moisture sensors and tensiometers can be used successfully for site-specific irrigation scheduling in production fields. The pan and ET-based methods underestimated irrigation requirements due to inadequate crop coefficient that was not locally calibrated.

Introduction

Competition for limited water resources is one of the most critical issues being faced by irrigated agriculture in the United States. The recent drought period (1998 to 2002 & 2007) and legal conflicts between states (GA, AL, FL, and SC) have prompted a renewed interest in water conservation methods. In addition, crops in the Southern United States are generally produced in fields which are known to have a high degree of variability in soil type, topography, water holding capacity and other major factors which affect crop production. Therefore, conventional uniform-rate overhead irrigation systems tend to over- or under-apply water to the crop. Variable rate irrigation (VRI) technology is a relatively new concept in agriculture which applies irrigation water to match the needs of individual management zones within a field. VRI system is commercially available and Hobbs and Holder, LLC (Ashburn, GA) has installed over 42 units on growers' center pivot systems in Georgia, South Carolina, Florida, and Arkansas (Milton & Perry, 2006). VRI can lead to substantial water conservation while increasing crop yield.

Clemson University has also developed a variable-rate lateral irrigation (VRLI) system for site-specific application of water to match crop needs (Figure 1). This system is ready for commercial

deployment and use by growers (Khalilian et al., 2005). The Clemson system utilizes wireless technology to acquire information from moisture sensors, evaporation pan, and the U.S. Climate Reference Network (CRN) for irrigation scheduling. Custom software collects the field information (length, width, number of irrigation zones, GPS coordinates) and generates a site-specific irrigation depth map which is used to control the irrigation system.


Figure 1: The Clemson VRLI System

High production costs and low commodity prices make it more important for our growers to maximize yields. Innovative irrigation practices that use the latest technology for irrigation scheduling, will result in high water use efficiency and higher crop yields. There is no published information on optimum irrigation scheduling method in cotton production for site-specific irrigation management. Nor is there a standard procedure to schedule irrigation based on the field's spatial variability. The objective of this study was to determine the optimum irrigation scheduling method for cotton production in coastal plain soils utilizing site-specific irrigation management.

Materials and Methods

Tests were conducted for two years (2006 and 2007) in a 4-acre section of a field at the Edisto Research & Education, near Blackville, SC. Prior to planting the crop, a soil electrical conductivity meter (Veris 3100) was used to map variation in soil texture. Also, geo-referenced soil samples were collected from the test field (75 samples) and analyzed for soil texture. The test field was divided into five management zones based on soil electrical conductivity and soil texture data, and each zone was divided into five 50-ft by 60-ft plots for testing five different irrigation scheduling treatments.

The following treatments were applied at random to the plots of each zone: irrigation scheduling based on 1) soil moisture sensors; 2) tensiometers; 3) pan evaporation data and a crop coefficient; 4) reference evapotranspiration model (Jensen-Haise) utilizing NWS (NOAA) weather forecast; and 5) no irrigation.

Ten Gro-Point "Time Domain Transmissometry" (TDT) moisture sensors (two per plot) were installed at two different depths (8 and 14 inches) at five locations in the test field. For each location, a radio transmitter was used to transmit moisture data from two sensors to the control-data-acquisition (CDA) system using low power radio frequency communications. Figure 2 shows a Gro-Point soil moisture sensor and radio transmitter in the field.


Figure 2: The TDT soil moisture sensors

For treatment 2, 10 tensiometers (two/plot) were installed at two different depths (8 and 14 inches) at

five locations in the test field. Moisture sensors and tensiometers were used to determine depleted soil moisture by converting sensor readings to volumetric soil moisture content (VSMC) and subtracting it from the field capacity for each soil layer. Irrigation depth was calculated by adding the depleted water in both soil layers.

For treatments 3, an automatic evaporation pan was used to collect and transmit real-time evaporation data to the CDA system using radio signals. The irrigation intervals for this treatment were based on pan evaporation data and crop coefficient values for days after planting using water balance method explained by Harrison and Tyson (1993).

For treatment 4, the reference evapotranspiration (ET_0) was estimated using the Jensen-Haise equation (Jensen et al., 1990) and climate data. The U.S. Climate Reference Network (CRN) is a network of climate stations now being developed as part of a National Oceanic and Atmospheric Administration (NOAA) initiative. Mean daily solar radiation, average daily temperature, and rainfall data was downloaded from the NOAA WebPages and used in calculation of the (ET_0). The crop water use (ET_c) for irrigation scheduling was calculated by multiplying the reference evapotranspiration (ET_0) by a crop coefficient (K_c) for cotton. The crop coefficient curve for cotton is given by Harrison and Tyson (1993).

A base-station radio (Environmental Sensors Inc.) installed on the top of the lateral, receives the information from the soil moisture sensors and the evaporation pan. The CDA system utilizes this data and the real time information from the National Weather Service (utilizes wireless technology) to determine irrigation depth in each plot. The tensiometer data are typed into the CDA system manually. A customized software package generates a site-specific irrigation depth map which is used to control the irrigation system.

Results and Discussion

Figure 3 shows the total irrigation water applied to different treatments. At the beginning of the tests, all plots were irrigated two times in 2006 (1.0 in total) and three times in 2007(2.0 in total) to get crop established and maintain early uniform growth. The total rainfall during growing season (May 15 to September 15) was 11.5 and 14.1 inches in 2006 and 2007, respectively. There was a significant difference in depth of irrigation water applied to different treatments. Irrigation scheduling based on soil moisture sensors (TDT moisture sensor & tensiometer); on average applied 2.6 in. more water than ET-based (pan and NOAA) treatments.

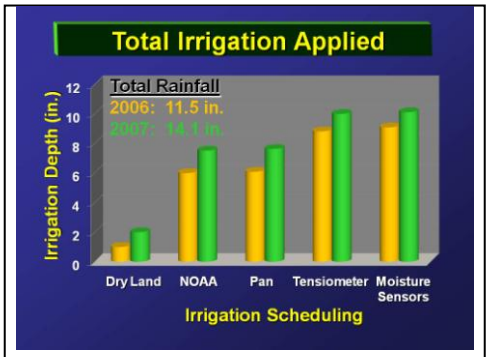

Figure 3: Total water applied to different irrigation scheduling treatments.

All irrigated plots yielded significantly higher than the non-irrigated plots (Figure 4). Also, irrigation scheduling based on soil moisture measurements (TDT moisture sensor & tensiometer) significantly increased the cotton yields compared to ET-based (pan and NOAA) treatments. The yield increases due to soil moisture-based treatments averaged 263 lbs/acre seed cotton (105 lbs

lint/acre).

The irrigation depth applied was a significant factor affecting the seed cotton yield. There was a strong positive correlation between the depth of total water applied (irrigation plus rainfall) and seed cotton yields. The yield increased as the depth of irrigation water increased. Therefore, the ET-based scheduling methods underestimated the depths of optimum irrigation water for cotton production under the 2006 and 2007 growing conditions. The crop coefficient (K_c) curve for cotton (Harrison and Tyson, 1993) which was used to calculate the crop evapotranspiration (ET_c) is not for the humid regions of southeastern USA. This could be one reason that ET-based methods underestimated the required irrigation water.

Conclusions

- The soil moisture-based treatments (tensiometer and TDT sensors) significantly increased seed cotton yields compare to the ET-based treatments (pan & NOAA). This was mostly because there were smaller amounts of irrigation as a result of ET modeling in the latter case.
- The underestimation of irrigation by the pan and ET based methods may be due to inadequate crop coefficients that were not locally calibrated.
- All irrigated plots yielded significantly higher than the non-irrigated plots.
- Tensiometers and soil moisture TDT sensors can be used successfully for site-specific irrigation scheduling. The pan and ET-based methods underestimated irrigation requirements due to inadequate crop coefficient that was not locally calibrated

Acknowledgements

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