SENSOR BASED SOIL WATER & CROP MONITORING IN COTTON PRODUCTION

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Abstract

Tests were conducted to determine the effects of installation methods (Slurry versus Direct) on accuracy of capacitance moisture probes for soil moisture monitoring in Coastal Plains' soils. A further aim of the trial was to determine the water use efficiency of four cotton cultivars (DP 147 RF; DP 555 BG/RR; DP 0924 B2RF; and DP 0935 B2RF) under six irrigation regimes (0, 40, 60, 80, 100, and 120% of the full cotton water requirements) on three soil types. The feasibility of utilizing plant NDVI (Normalized Difference Vegetation Index) for irrigation scheduling in cotton production was also investigated. The results showed that, if installed and calibrated properly, multi-sensor capacitance probes can be used to accurately measure volumetric soil water contents. These sensors can be used for real-time site-specific irrigation scheduling. The "Slurry" installation method over estimated volumetric soil water contents in the sandy Coastal Plains' soils at the experiment site. There were strong correlations between seasonal irrigation depths and the seed cotton yields. There were significant differences in water use efficiency among the four cotton varieties, being highest for the DP 0924 B2RF cultivar. There were good correlations between in-season estimated yield (INSEY) (as measured by plant NDVI) and volumetric soil water contents.

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 periods (1998 to 2002 & 2007) and legal conflicts between states (GA, AL, FL, and SC) combined with significant field soil variability in the Southern U.S. have prompted a renewed interest in site-specific and automated irrigation systems. Site-specific or 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. During 2005 and 2006, 42 units of VRI system were installed on growers' center pivots in Georgia and South Carolina (Milton & Perry, 2006). Real-time, accurate, and continuous soil moisture measurements at specific depths are essential for success of VRI and automated irrigation systems.

Multi-sensor capacitance probes have been used to accurately measure volumetric soil water contents in a soil water monitoring system (Paltineanu and Starr, 1997). However, Evett and Steiner (1995) reported that the capacitance probe was unacceptable for water content measurements with fine sandy loam soils. Soils in the Coastal Plains region usually have a structure that exhibits three distinct layers: A horizon (sandy to loamy sand), E horizon or hardpan layer (yellowish brown sandy to sandy clay), and Bt horizon (sandy clay loam). Currently there is no published data on the performance of capacitance probes in multi-layer soils of the Coastal Plains region.

Increasing water use efficiency (WUE) and drought tolerance in cotton is highly valuable to U.S. and world agriculture. Screening cotton varieties for water use efficiency would help growers to maintain or increase crop production with less water. Many factors affect WUE at the field scale. It may vary both spatially and temporarily, and is influenced by soil conditions, irrigation water management, agricultural practices, and atmospheric factors. In the southeast, the screening methods for WUE should be site-specific.

Objectives

The objectives of this project were to: a) determine the effects of installation methods (Slurry versus Direct) on accuracy of capacitance moisture probes for soil moisture monitoring in Coastal Plains' soils; b) quantify the water use efficiency of four cotton cultivars under six irrigation regimes on three soil types; and c) evaluate the feasibility of utilizing plant NDVI (Normalized Difference Vegetation Index) for irrigation scheduling in cotton production.

Materials and Methods

Objective 1: Tests were conducted to determine the accuracy of the capacitance moisture probes in Coastal Plains' soils. Two installation techniques -- "Slurry" and "Direct" were compared side-by-side in a typical Coastal Plains soil (Verina sandy loam soil). Four EnviroSCAN multisensor capacitance probes (Sentek Sensor Technologies, South Australia) were used in this study and volumetric water content measurements from these probes were compared with Neutron probe measurements. The sensor depths chosen were: 4, 8, 12, 16, 20, and 24 inches. For the Direct installation method, a PVC access pipe was installed by inserting it through the guide block (Fig. 1 left) into the soil using the dry drilling technique explained in Paltineanu and Starr (1997). For the Slurry installation method, a hole was drilled using a specially designed auger. The diameter of the hole was about 0.25 inches bigger than the probe's OD. The slurry (made out of the excavated sandy clay loam soil) was poured into the hole and the probe was installed into the slurry to seal the gap between the probe and the surrounding soil (Fig. 1 right). Three months after installation, the accuracy of each sensor in measuring the volumetric moisture content of the soil was determined using standard gravimetric techniques. Three undisturbed soil cores, center at each of the six sensors depths, were collected in brass rings about 0.5 inches from the wall of the PVC access pipe. The data were also compared with Neutron probe measurements.

Figure 1: Probe installation techniques: Direct (left) and Slurry (right)

Objective 2: Tests were conducted in a 4-acre section of a field near Blackville, SC. A commercially available soil electrical conductivity (EC) measurement system (Veris Technologies 3100) was used to map variations in soil texture across the field. The test field was then divided into three management zones based on soil EC data and each zone was divided into 60 ft by 8-row plots (Fig. 2).

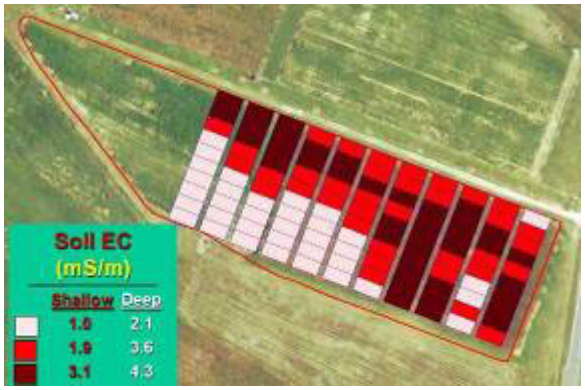

Figure 2: The test field with zone and plot arrangements

The following treatments were replicated three times using a Randomized Complete Block design arrangement:

- Four cotton varieties: DP 147 RF; DP 555 BG/RR; DP 0924 B2RF; and DP 0935 B2RF.
- Six irrigation rates: 0, 40, 60, 80, 100, and 120% of full crop water requirements.

Cotton varieties were planted on May 19th 2008, and carried to yield using recommended practices for seeding, insect, and weed control. The required irrigation rates were calculated based the capacitance probes data. For every cotton variety in each zone, there was at least one multi-sensor capacitance probe installed in the plots of 100% irrigation-rate treatment. The irrigation rates for the rest of the plots were calculated based on the percent of required irrigation for the particular variety and management zone. At the beginning of the tests (during May and June), all plots were irrigated five times (for a total of 2.5 inches) to keep the cotton crop alive. The Clemson variable-rate LEPA system was used to apply irrigation water to the tests plots during the growing season. The total rainfall during growing season was 19 inches. Cotton was harvested on October 28th 2008, using a spindle picker equipped with an AgLeader yield monitor and a GPS unit to map changes in lint yield within and among treatments.

Objective 3: Our work in 2006 and 2007 showed that cotton yield, N & PGR requirements were strongly correlated to plant NDVI (Normalized Difference Vegetation Index; Khalilian et al., 2007 and 2008). Therefore, we investigated the feasibility of utilizing plant NDVI for irrigation scheduling in cotton production. Plant NDVI readings were taken from test plots four times during the growing season using a 6-row sprayer-mounted GreenSeeker® RT-200 mapping system (NTech Industries, Inc. Ukiah, CA). In-season estimated yield (INSEY) was calculated by dividing NDVI measurements by the number of days from emergence to sensing. Linear and non-linear regression models were used to determine the relationships present between soil volumetric moisture content and NDVI using Procedures in SAS.

Results and Discussion

Figure 3 shows the effects of installation method on performance of the Sentek capacitance probe. For the Direct installation method, there was a good correlation between gravimetric soil moisture contents and the capacitance probe measurements. The depth of the E-horizon in the test area was about 12 inches, and due to higher bulk density, this compacted layer had slightly lower moisture content than the A- and Bt-horizons. For the neutron probe, data are normalized by expressing the results as the ratio of the count in soil to the standard count. The zone in the soil surrounding the probe center of sensitivity "the sphere of the influence" is larger for neutron probe than the capacitance probe (Bell et al., 1987). Therefore, the neutron probe generated a smother curve than capacitance probe or the gravimetric method. The Slurry installation method over estimated volumetric soil water contents in sandy soils of the A-horizon due to difference in texture of the slurry material and the surrounding soil.

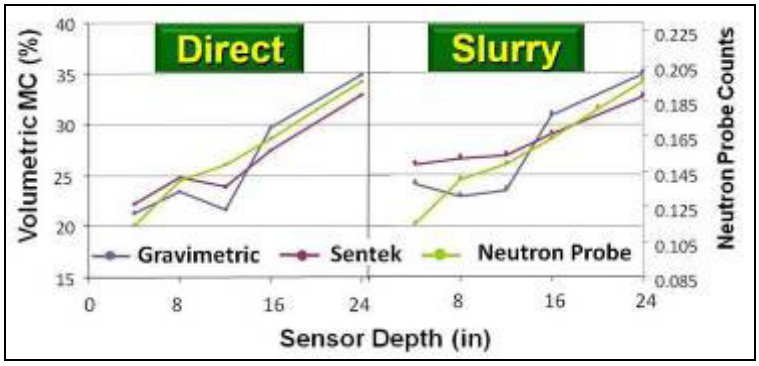

Figure 3: Effects of installation methods on performance of the capacitance probe

Figure 4 shows the correlation between the total water applied (irrigation plus rain) and the seed cotton yield for the DP 147 variety. There were strong correlations between the seasonal applied water (irrigation and rain) and the seed cotton yields. The yield values increased as the irrigation depth increased. Different varieties showed different

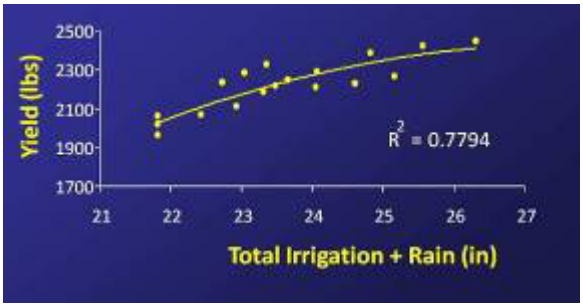

Figure 4: Correlation of irrigation water and seed cotton yield for the DP 147 RF cotton variety.

responses to the amount of water applied during the 2008 growing season (Fig. 5). For example for the DP 0924 B2RF, the seed cotton yields decreased when the total applied water exceeded 23 inches.

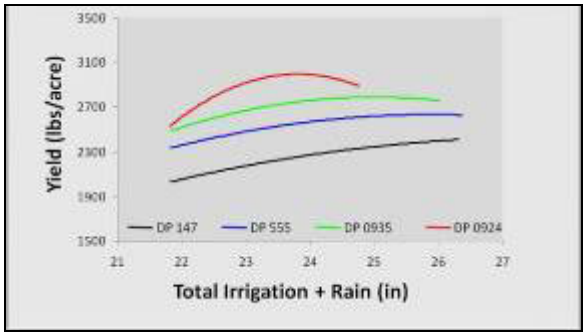

Figure 5: Correlation of irrigation water and seed cotton yield for all four varieties.

There were significant differences in seed cotton yields among the four cotton varieties (Table 1). The two new Bollgard-II varieties: DP-0924 and DP- 0935 had the highest yields. Water use efficiency was calculated by dividing the cotton yield from a unit area in lbs/acre by the unit amount of water consumed. WUE is the most important index for estimating the efficiency of water use of a cropping system. There were significant differences in water use efficiency among the four cotton varieties with the DP 0924 B2RF having the highest WUE value of 124 lbs/in.

Table 1: Seed cotton yields, water use efficiency, and total water applied (rain+ irrigation) for all varieties.

Cotton Variety	Seed Cotton Yields (lbs/acre)	WUE (lbs/in)	Average Total Water Applied (in)
DP 0924 B2RF	2865 a*	124 a	23.6 a
DP 0935 B2RF	2685 b	114 b	23.5 a
DP 555 BG/RR	2480 c	107 c	23.2 a
DP 147 RF	2218 d	94 d	23.2 a

* Means followed by the same letter are not significantly different based on LSD.

The feasibility of utilizing plant NDVI for irrigation scheduling in cotton production was investigated. Figure 6 shows the correlations between plant in season estimated yield (INSEY) and soil volumetric moisture contents. There were good correlations between INSEY (as measured by plant NDVI) and the soil moisture contents.

However, the results were affected by cotton varieties. This test needs to be repeated under different soil types, irrigation regimes, and cotton cultivars before any conclusion could be reached.

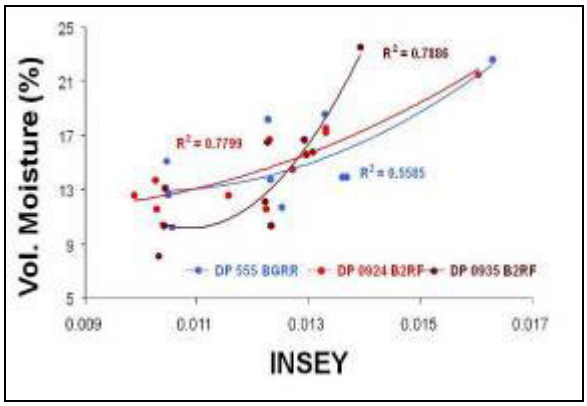

Figure 6: Correlation of plant NDVI and soil volumetric moisture contents

Summary

The results showed that, if installed and calibrated properly, multi-sensor capacitance probes can be used to accurately measure volumetric soil water contents. Our results favor the Direct installation method. These sensors can be used for real-time site-specific irrigation scheduling. The Slurry installation method over estimated volumetric soil water contents in sandy soils of the Coastal Plains. There were strong correlations between irrigation depths applied and the seed cotton yields. There were significant differences in water use efficiency among the four cotton varieties with the DP 0924 B2RF having the highest WUE. There were good correlations between INSEY (as measured by plant NDVI) and volumetric soil water contents.

Acknowledgements

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Disclaimer

Mention of a trade name does not imply endorsement of the product by Clemson University to the exclusion of others that might be available.

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