EVALUATION OF SOIL-PLANT-WATER RELATIONS IN IRRIGATED COTTON

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Abstract

Field experiments were conducted in 2006 and 2007 at the University of Arizona Maricopa Agricultural Center investigating soil-plant-water relations in an irrigated cotton (*Gossypium hirsutum* L.) production system. Current guidelines for the management of irrigation for cotton production systems in the desert Southwest utilize parameters that have not been thoroughly validated. The objective of this project was to develop an accurate water balance in a furrow-irrigated cotton production system and evaluate the accuracy of the crop coefficients that are currently available through the University of Arizona Meteorological Network (AZMET). Measurements of water application rates were taken with each irrigation event. In-season soil-water measurements were made prior to and immediately following each irrigation event by use of neutron attenuation to a depth of four feet (approximately 120 cm). Soil-water depletion rates were compared to crop ET estimates provided by AZMET. In-season crop monitoring was conducted and final lint yield was determined. Fiber quality was determined by HVI analysis. Results provide a thorough characterization of the soil-plant system under study and indicate soil-water depletion rates compare favorably with the AZMET crop ET estimates. Accordingly, crop coefficients (Kc) calculated from the data derived from this experiment were also close to the Kc values that have been developed and used in the AZMET system.

Introduction

Three commonly recognized factors are often limiting in terrestrial ecosystems, including agroecosystems. These three factors include: sunlight, water, and plant-available N. In the desert Southwest of the U.S. water is commonly recognized as the most critical limiting factor in crop production systems. The latest Arizona Water Map (Water Resources Research Center) reports that agriculture, municipal, and industrial uses account for 68%, 25%, and 7% of our state's water use. For Maricopa, Pinal, and Pima counties, cotton accounts for the most cropland acreage (43.4% or 187,200 acres on average for 2001 and 2002, *Arizona Agricultural Statistics*). It also accounts for the most water use (39.6% or 0.68 million acre feet) of all crops, imputing consumption as reported in the latest University of Arizona Field Crop Budgets (Teegerstrom) for each county and crop. In spite of rapid urban growth, cotton will play a key role in Arizona's water management for the foreseeable future due to the following: state and city policies have supported open space, sewage sludge can be responsibly disposed of using a cotton rotation, biotechnology makes it possible for cotton to co-exist near urban housing, tribal water right settlements, a generous farm policy towards cotton, and economically attractive recharging through agriculture. However, the question of how to best use a very limited water supply in a cotton production system has yet to be addressed. The need to address this question is also evidenced by the fact that some proposed drought management plans are calling for water allocations to agriculture based on crop consumptive use data. The most recent and reliable data concerning crop consumptive use was developed and published over 30 years ago (Erie et al., 1965 and 1982).

The data provided by Erie et al. (1965 and 1982) provided a crop consumptive use estimate of approximately 42 inches of water/acre/season. Cotton production systems in Arizona typically utilize an excess of 42 inches of water/acre. This is typically due to inefficiencies in irrigation systems and in the inability to match crop-water needs. The highest levels of irrigation inefficiency typically occur early in the crop season when irrigation rates substantially exceed crop-water use and soil-water depletion. This commonly results in large leaching fractions (Silvertooth et al., 1991).

Crop water use estimates have been addressed through a number of approaches. For example, several equations for determining evapotranspiration (ET) rates using climatic data have been developed and used (the Penman-Monteith, the Priestley-Taylor, the Hargreaves, and the Stanghelli equation). Donatelli et al., (2006) used each of these four equations for calculating and comparing crop ET (ETc) values. Grismer (2002) developed a four stage model to estimate cotton ETc values from weather parameters and crop yield reports for Arizona and California production areas. In a more direct manner, Miranda et al. (2006) used precise weighing lysimeters to estimate Kc values for pepper plants (*Capsicum annuum* L.) and the Penman-Montieth equation to calculate ETo values. Erie et al. (1965 and 1982) developed very direct measurements of cotton ETc by gravimetrically measuring soil-water depletion and replenishment between each irrigation cycle for cotton grown in the low desert of central Arizona. They developed seasonal "K" values and short-term "k" values by use of a Blaney-Criddle (1962) approach. The estimates that Erie et al. (1965 and 1982) published have become the standards of reference for irrigation management in Arizona and the desert Southwest.

Recent studies in Arizona have addressed irrigation management in an effort to utilize crop-based measurements such as infrared thermometry (Husman et al., 1992 and 1993), pressure chamber measurements (Brown et al., 1993 and Steger et al., 1998). Efforts have also been directed at the development of crop models such as AZSCHED for irrigation management (Clark et al., 1992 and 1993; Fox et al., 1992; and Martin et al., 2003). Models such as AZSCHED have been tested in the field but the Kc values used have not been validated. Thus, there is a need to address crop water use in a direct and quantitative manner to provide us the best foundation to make assessments for crop water needs.

Materials and Methods

Field experiments will be conducted at the University of Arizona Maricopa Agricultural Center (MAC, 1,175ft. elevation) with the objective of evaluating the effects of two irrigation management regimes (I-1 and I-2) in terms of plant-water use patterns among all stages of growth and lint yield of an Upland cotton (Gossypium hirsutum L.) variety with Bollgard and Round-Up resistant characteristics. The experimental design will be a randomized complete block design with three replications. The soil type for the experimental area is a Casa Grande sandy loam (Fine-loamy, mixed, hypothermic Typic Natriargid).

The crop will be dry planted and watered up as seasonal weather conditions allow. The general target for planting and crop initiation will be early April. In general, crop management followed optimal standard procedures of practice (Silvertooth et al., 1991 and Silvertooth et al., 1999). Soil fertility was managed in accordance to guidelines provided by Silvertooth and Doerge (1990) and Silvertooth (2000). A complete set of plant measurements were collected inseason from all plots on 14-day intervals to monitor progress of growth and development of the crop (Silvertooth and Norton, 1998). Measurements taken included: plant height, number of mainstem nodes, first fruiting branch, total number of aborted sites (positions 1 & 2), number of nodes above the top (1^{st} position) fresh flower (NAWF), canopy closure, and number of blooms per unit area. Climatic conditions were also monitored on a daily basis throughout the growing season using an automated AZMET station sited at the location. The AZMET station is automated and is used to determine the hourly temperature values and the HU accumulations (86/55 ºF thresholds) are calculated by a method presented in Baskerville and Emin (1969) and modified by Brown (1989). The daily HU accumulations are summed up from the time of planting and reported as HUAP. The crop was mechanically harvested on 14-16 November. Lint turnout estimates were made using sub-sample analyses.

The first treatment (I-1) was structured to provide adequate plant-available water (PAW) throughout the growing season and to avoid plant water stress. The second treatment (I-2) received one-half the irrigation amounts provided in I-1 with the intention of imposing substantial water stress on the crop. In this experiment, the I-2 treatments received irrigations on alternate cycles to the I-1 treatment areas. The experimental area was dry-planted and watered-up on 11 May 2006 and 15 May 2007 and the final irrigations were applied on 16 August 2006 and 21 September 2007. The experimental area was managed to complete a single cycle fruit set in both years. The experimental areas were defoliated on 27 August 2006 and mechanically harvested on 17 October 2006. In 2007 the experimental areas were defoliated on 16 October and mechanically harvested on 17 – 19 November 2007. During the growing season volumetric water (θ_v) content readings were made consistently through each irrigation cycle by use of a neutron probe – moisture meter to a depth of 120 cm by 10 cm increments. The θ_v readings were taken immediately before an I-1 irrigation event and 24 hours after the irrigation event for all treatment areas (including I-2 areas).

From the data collected from the field, Kc values were calculated using the measured soil-water depletions for each irrigation interval and the standard reference ETo values taken from the AZMET station at MAC. All data were subjected to appropriate procedures of summary and analysis (Steel and Torrie, 1980 and the SAS Institute, SAS, 1990).

Results and Discussion

Results from this experiment revealed Kc values that ranged from approximately 0.6 to 1.18 and were similar to those used by AZMET. Overall, the measured CU levels were slightly less (20%) than the AZMET estimates and much lower than the CU values provided by Erie et al. (1965 and 1982). Based on the amount of water that was actually applied versus the CU, the measured WUE was 64%. Yields were 1,690 kg lint/ha (s.d. = 140) for I-1 and 826 kg lint/ha (s.d. = 129) for I-2. The crop water production function that was developed from this experiment was linear (two treatments) indicating an increase of 18 kg lint/ha per additional centimeter of irrigation water.

Summary

As we better understand the mechanisms associated with soil-plant-water relations and crop growth and development from both a physical and physiological level we are better suited to manage our crop (cotton) production systems more efficiently (agronomically, economically, and environmentally). Therefore, the development of solid, quantitative determinations of soil-plant-water relationships are fundamental and critical to both short and long-term sustainability of crop (cotton) production systems.

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