WATER USE EFFICIENCY OF DIFFERENT COTTON CULTIVARS

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Abstract

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. Replicated tests were conducted during 2009 to 2011 growing seasons to determine the water use efficiency of seven cotton cultivars (DP 0920; DP 0924; DP 0935; DP 0949; DP1028; DP1050; and DP 1137) under different irrigation regimes (0, ,33, 66, and 100% of the full cotton water requirements). Multi-sensor capacitance probes were used for irrigation scheduling and monitoring soil volumetric moisture contents. There were strong correlations between total water applied and cotton lint yields. Optimum total water (irrigation + rain) for maximizing yields for all cultivars ranged from 22 to 25 inches. There were significant differences in WUE among the cotton varieties. Water use efficiency was affected by soil texture. In addition, WUE of the same cultivar could change from one year to another as affected by environmental conditions.

Introduction

Competition for limited water resources is one of the most critical issues being faced by irrigated agriculture in the United States. From 2002 to 2007, irrigated acreage in the western states declined significantly, while in the southeastern states, irrigated acreage increased by 70% (USDA, National Agricultural Statistics Serves, 2007). According to the U.S. Department of Agriculture's Drought Monitor (http://droughtmonitor.unl.edu) dated December 27, 2011, the condition for most of the Cotton Belt ranged from Abnormally Dry to Exceptional Drought. As competition for limited water resources increases, water use efficiency for agricultural irrigation becomes more important.

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. The relationship between yield produced per unit ET or water used by crop is water use efficiency. Modern, high water use efficient cotton varieties tend to provide at least 60 pounds of lint for every inch of water used.

Generally, WUE is computed either as yield (lb/ac) per seasonal crop water use (or ET) or as yield per total applied water (seasonal irrigation plus rainfall). Since ET is soil evaporation plus crop transpiration, WUE can be increased by reducing soil evaporation and increasing crop transpiration. The WUE (yield per unit applied water) is largely influenced by the performance of the irrigation system and the degree of water losses beyond crop transpiration. Many other factors affect WUE at the field scale. It may vary both spatially and temporarily, and is influenced by soil conditions, irrigation water management, cultural practices, and atmospheric factors. Currently, traditional crop breeding and advanced gene technology methods are being used by the seed industry to develop cotton varieties with higher WUE and drought tolerance.

The objective of this project was to determine the water use efficiency of seven cotton cultivars under different irrigation regimes and soil types.

Materials and Methods

Replicated tests were conducted during 2009 to 2011 growing seasons at the Edisto Research and Educational Center near Blackville, South Carolina, on a typical Coastal Plains soil (Verina sandy loam). At the initiation of the tests, a commercially available soil electrical conductivity (EC) meter (Veris-3100) was used to identify variation in soil texture across the experimental field. The test field was then divided into management zones based on soil EC data and each zone was divided into 60 ft by 8-row plots. Figure 1 shows an example of the management zones and plot arrangements for the 2011 tests.

Figure 1: An example of the test field with zones and plot arrangements

The following treatments were replicated in plots of each zone using a Randomized Complete Block design arrangement:

- Seven cotton varieties: DP 0920; DP 0924; DP 0935; DP 0949; DP1028; DP1050; and DP 1137. Every year between two to four of these cultivars were screened for WUE.
- Four irrigation rates: 0, 33, 66, and 100% of full crop water requirements.

Cotton varieties were planted between May 15th and June 5th every year and carried to yield using recommended practices for seeding, insect, and weed control. The required irrigation rates were calculated based on the AquaSpy multi-sensors capacitance probes (Sloane, 2007) data. Before installing these probes in the test plots, their accuracy were determined by calibrating the moisture probes in Coastal Plains' soils (Bellamy et al., 2009). Calibration equations were developed for different layers of soil profile and the data were compared with Neutron probe measurements. 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), supplemental irrigation was applied to all plots to keep the cotton crop alive. The early season irrigation ranged from 1.5 to 3.0 inches, depending on the rainfall. The Clemson variable-rate LEPA system was used to apply irrigation water to the tests plots during the growing season. The LEPA system was equipped with Quad Spray® nozzles which could apply four different irrigation patterns depending upon the growth stage of cotton to increase irrigation efficiency. A Dammer Diker was used to prevent runoff from the test fields associated with LEPA system. The Diker system creates gallon size reservoirs in the furrows where the LEPA drops hung. The total rainfalls during growing season were 11.75, 20.0, and 17.5 inches for 2009, 2010, and 2011, respectively. Cotton was harvested in October, using a spindle picker equipped with an AgLeader yield monitor and a GPS unit to map changes in lint yield within and among treatments.

One cotton cultivar (DP 0924) was included in the WUE screening tests every year and used as a control. In 2011, a rain out shelter (Figure 2) was also used to determine the WUE of the DP 0924 under control environment. The automated shelter is equipped with a Hunters Rain-Clik sensor, which can command a controller to move the shelter over cotton crop immediately. The same irrigation rates (33, 66, and 100% of full crop water requirements) were calculated based on neutron-probe readings. Irrigation water was applied using drip irrigation system. Water uses efficiency for all cotton cultivars was calculated by dividing lint yields (lbs/acre) by the total applied water (seasonal irrigation + rainfall).

Figure 2: The automated rainout shelter.

Results and Discussion

Figure 3 shows the correlations between the total water applied (irrigation plus rain) and the lint yields for the four cultivars (DP 0920; DP 0924; DP 0935; DP 0949) tested during the 2009 growing season. 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. There were significant differences in lint yields among the cotton cultivars, especially for rain fed plots. DP 0920 and 0924 significantly yielded higher than the other two cultivars. Different varieties showed different responses to the amount of water applied during the 2009 growing season. For example for the DP 0949, the lint yields decreased when the total applied water exceeded 21 inches. Maximum yield for the other three cultivars achieved at 22 inches of total water. Increasing water application beyond this amount, did not affect the lint yields.

Similar results were obtained with WUE data in 2009. Again the WUE of DP 0920 and 0924 were significantly higher than the other two cultivars. The WUE for these four cultivars at maximum crop yield ranged from 65 to 75 lbs/in of water applied.

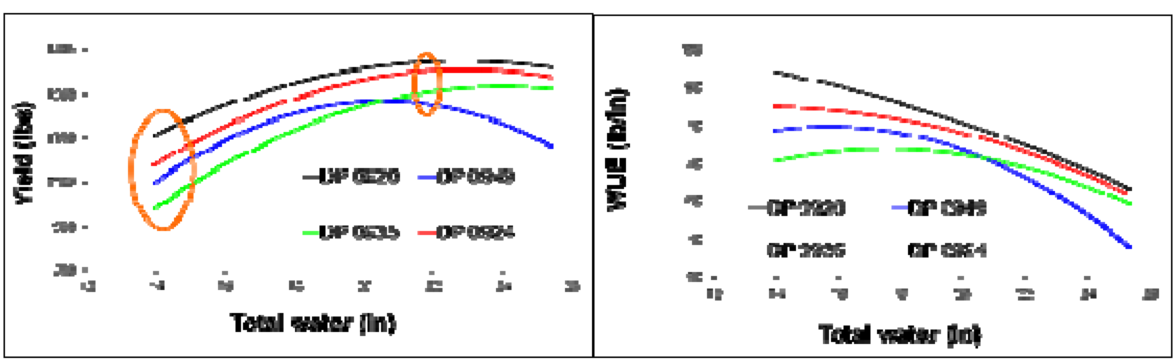

Figure 3: Effects of total water applied on lint yield and water use efficiency for the 2009 tests.

Our results during 2008 and 2009 (showing higher yields for the DP 0924 compared to DP 0935) were different from the results of some variety trial tests in the southeast. Therefore, in 2010 only two cultivars (DP 0924 and 0935) were screened for WUE with higher number of replications. Figure 4 shows the correlation between the total water applied (irrigation plus rain) and the lint yields for these two cultivars tested during the 2010 growing season. Again DP 0924 significantly yielded higher than the DP 0935. Maximum yields for both cultivars were achieved at 25 inches of total water (irrigation + rain) applied. Increasing water application beyond this amount, did not affect the lint yields. Similar results were obtained with WUE. DP 0924 had significantly higher WUE compared to DP 0935. The WUE for these cultivars at maximum crop yield ranged from 57 to 59 lbs/in of water applied.

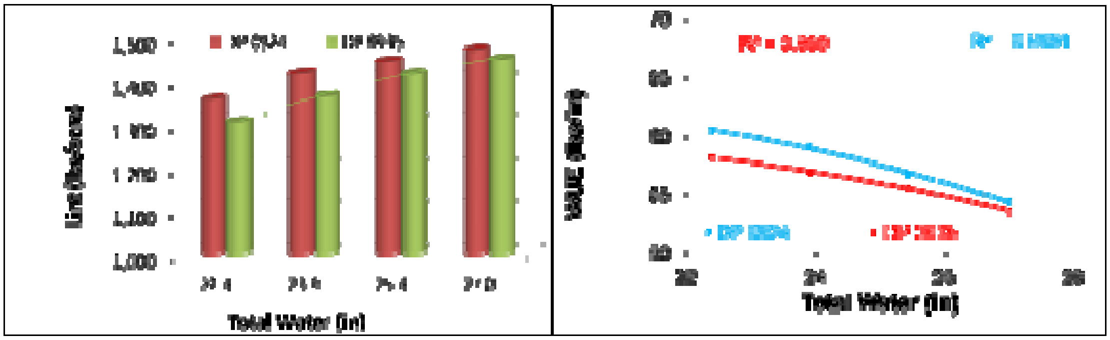

Figure 4: Effects of total water applied on lint yield and water use efficiency for the 2010 tests.

In 2011, three new cultivars (DP 1028, DP 1050, and DP 1137) were compared to DP 0924 in terms of yield and WUE. All of the new cultivars yielded significantly higher than the DP 0924. Maximum yields for all four cultivars were achieved around 25 inches of total water (irrigation + rain) applied. And again, increasing water application beyond this amount, did not affect the lint yields. The results for the WUE were different from those obtained in two previous years. The WUE increased as total seasonal water application increased. The WUE decreased when the total applied water exceeded 25 inches. The highest WUE for all four cultivars coincided with the highest yields contradictory to results of the previous years. This could be due to the rainfall patterns in 2011. Although, the total effective rainfall during the growing season was about 17.5 inches, the distribution was somewhat different from 2009 and 2010. Most of the rainfalls happened during flowering and boll developments.

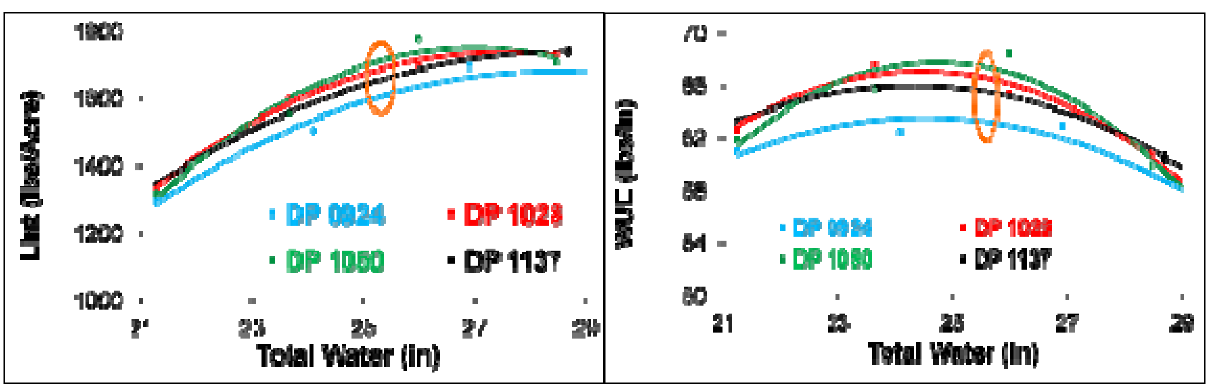

Figure 5: Effects of total water applied on lint yield and water use efficiency for the 2011 tests.

The WUE was influenced by soil EC, due to differences in soil texture. For example, in 2011 the test field was divided into four management zones based on soil EC. The sand contents of these zones were 81.5, 83.3, 86, and 87.5% for zones one to four, respectively. The water use efficiency increased as soil EC increased (Figure 6). This is due to the fact that in coastal plain soils, cotton yields are strongly correlated to soil texture and soil EC (Khalilian et al., 2008). In addition, WUE of the same cultivar could change from one year to another as affected by environmental conditions. Figure 6 shows the WUE for the DP 0924 for the 2009 to 2011 growing seasons. Also, the result of the WUE test from the rainout shelter is shown on the same graph. The WUE values from the rainout shelter in 2011 were completely different from the results obtained from a production field during the same period. This is due to the fact that no rainfall water was involved with the shelter.

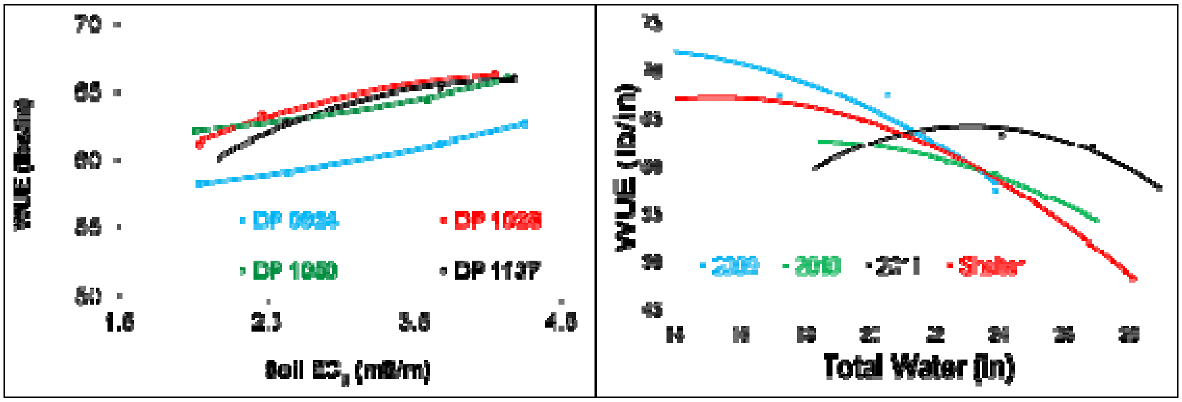

Figure 6: Effects of soil EC on WUE for 2011(left) and WUE as affected by growing seasons (right).

Summary

There were strong correlations between total water applied and cotton lint yields. Optimum total water (irrigation + rain) for maximizing yields for all cultivars ranged from 22 to 25 inches. There were significant differences in WUE among the cotton varieties. Water use efficiency was affected by soil texture. In addition, WUE of the same cultivar could change from one year to another as affected by environmental conditions.

Acknowledgements

The authors acknowledge the funding support of the South Carolina Cotton Board, Cotton Inc., and Monsanto Company.

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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