Cotton Under Water-Limiting Conditions

Being profitable under water-limiting conditions in Texas is a challenge.

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The Fluid Journal • Official Journal of the Fluid Fertilizer Foundation • Summer 2014 • Vol. 22, No. 3, Issue #85

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Summary: *Owing to its ability to be productive and profitable under water-limiting conditions found throughout the state of Texas, cotton remains the major crop grown in Texas. As irrigation water supply becomes more limiting in West Texas, cotton production will still remain the major cash crop grown. Technology is available to greatly increase irrigation water application through reduction of surface evaporation.*

A little history first. Cotton originated in the semi-arid tropics of Central America thousands of years ago and moved across Asia, Europe, and finally to North America. Cotton is now produced in more than 90 countries with China, India, the U.S., Pakistan, Uzbekistan, and Brazil accounting for 83 percent of world cotton production, which is currently about 128 million, 480-lb bales per year, increasing about 2 percent annually.

In 1793, Eli Whitney invented the Cotton Gin, which mechanically removed fiber from the seed and led to the Industrial Revolution in the United States. Cotton acreage in the Southeastern US and across the southern states increased dramatically. Textile mills began to develop along the East Coast.

Cotton fiber is spun into yarn and used to make a variety of fabrics. Cotton seed is used to make cooking oil. The solids are very high in protein and used for cattle feed. Whole cotton seed is used by the dairy industry. Today, cotton production and processing is one of the most mechanized agricultural systems.

NASS statistics

NASS statistics are available from 1866 to the present. In 1866, the US grew 7.7 million acres of cotton, producing 2.1 million bales with 122 pounds of lint/A average. The largest cotton acreage occurred in 1925 when 45.8 million acres were planted, producing 18 million bales with 174 pounds lint/A. The production, harvesting, and processing required extensive manual labor, which led to the importation of slaves and ultimately to the Civil War. Beginning in the 1950s, cotton acreage declined to 20 million acres and has continued to decline to 10 to 15 million acres since then. Yields have increased from 200 to 300 lbs/A of lint in the 1940s to 1960s to 650 to 850 lbs/A in the last 25 to 30 years. Eradication of the boll weevil across the Cotton Belt has been the single greatest factor for the increase in productivity. The introduction of genetically modified cotton varieties tolerant to Roundup for weed control and to Heliothis species for insect control has also been a major contributor for increased yields.

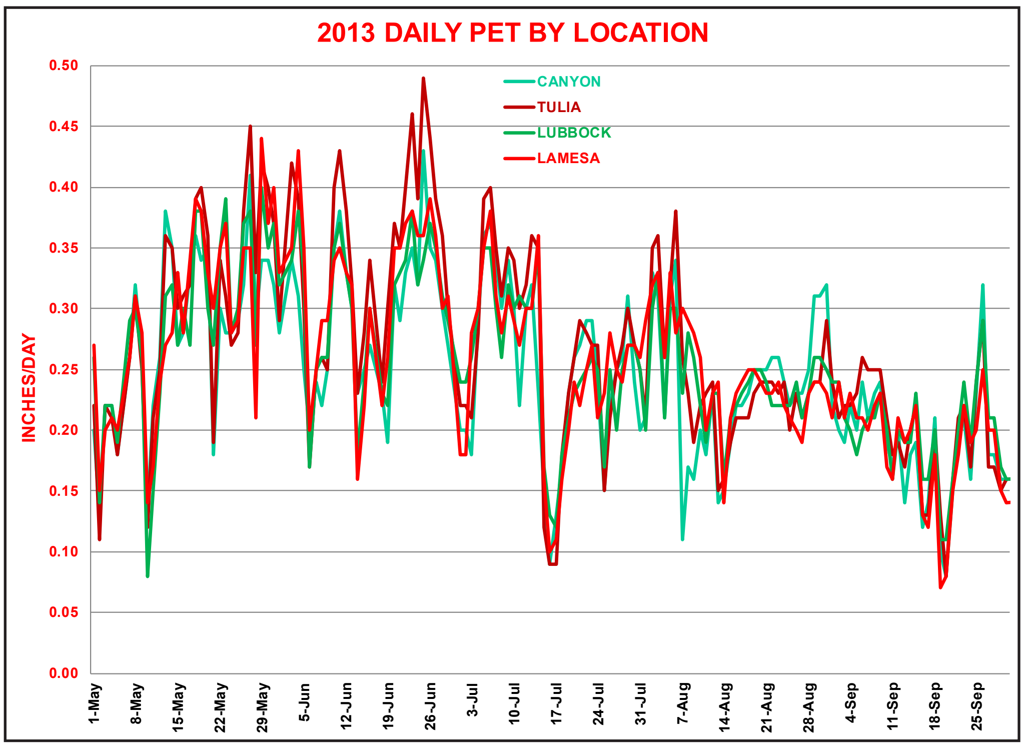

Figure 1. 2013 Daily PET by location

Texas #1

Texas is the largest cotton producing state in the US, averaging around 7 millions acres/year. Yields have increased from 200 to 300 lint lbs/A to 600 to 700 lint lbs/A in the past 20 years. Irrigated cotton makes up about 2 million acres/year, with the remainder being dependent on rainfall. Irrigated yields have increased from approximately 500 lbs lint/A

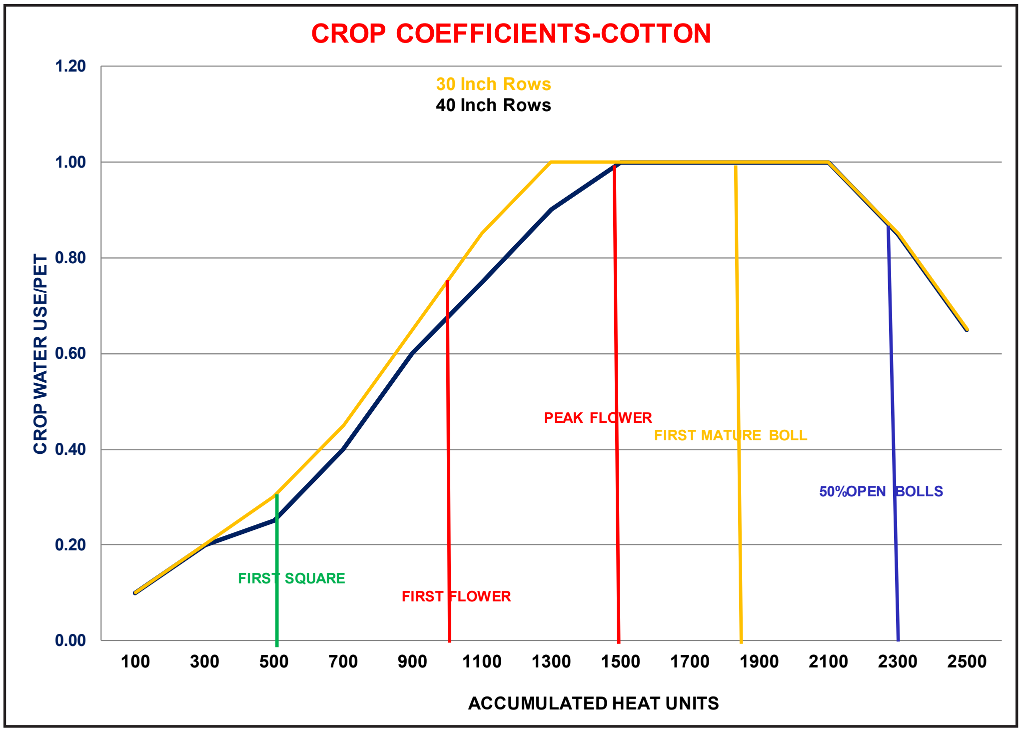

Figure 2. Crop coefficients—Cotton

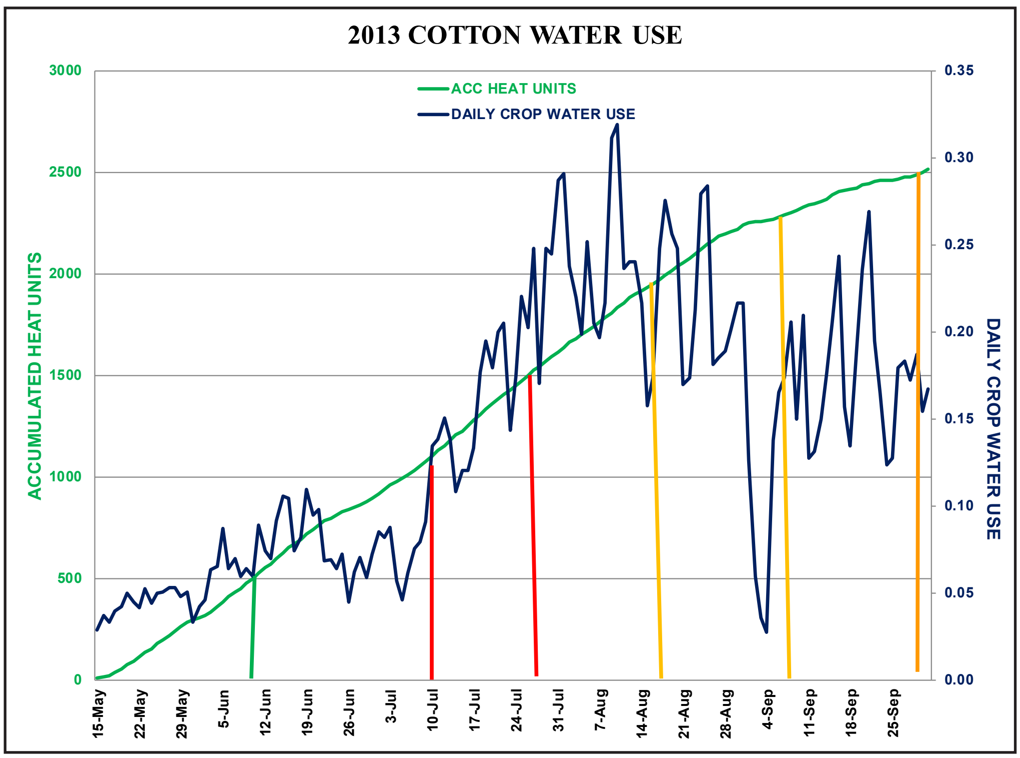

Figure 3. 2013 Cotton water use

in the 1970s and 1980s to about 1,000 lbs lint/A beginning in the mid 2000s. Dryland yields range from 250 to 300 lbs lint/A to 500 to 600 lbs lint/A, depending on the year's rainfall and timeliness of the rain.

Cotton defined

Botanically, cotton is defined as a woody perennial with an indeterminate growth habit, which means that it does not have to produce seed to survive as a plant species. When the cotton plant is subjected to environmental stress, such as limiting water supply, high temperatures, or nutritional deficiencies, it becomes a survivor rather than a producer. This requires the grower to fully understand the growth and developmental processes of the cotton plant and intensely manage the resources he can control. An adequate water supply throughout the life cycle is the single most limiting resource to attaining maximum genetic yield potential of a cotton crop. Proper management of the total water resource (rain and irrigation) is critical to maximizing yield and product quality.

PET

Water use by every growing plant is a function of the amount of leaf surface area relative to ground area (leaf area index = leaf area/ground area) and the potential evaporating of the atmosphere (PET). PET is determined using net solar radiation, air temperature, water vapor content of the air relative to water holding capacity of the air (relative humidity), and wind speed close to the crop (6-foot height). The standardized and widely accepted PET equation is the modified Penman. Weather Station Networks have been established in most states that provide hourly and daily weather information that is widely used to calculate PET on a daily basis to aid in water management, especially in irrigation water applications. Daily PET varies considerably from day to day within a location (see Figure 1, diagram of typical daily PET in West Texas). In West Texas, seasonal PET averages about 40 inches from early May through September. When plants are small and cover very little of the ground area the majority of the water loss from the field is from bare soil evaporation. However, when the plant begins to develop floral structures at the 6th to 7th main stem node until it begins to flower, leaf area index increases rapidly and daily water use increases proportionately.

Water use

The ratio of crop water use to total daily evaporative demand is defined as the crop coefficient (see Figure 2, crop coefficients for cotton grown in West Texas). The total crop water use for a season averages about 24 inches in West Texas. The volume of water can produce around 1,500 lbs of lint and 2,100 lbs of cotton seed. Cotton, similar to all other seed producing plants, is most sensitive to limited water supplies during the reproductive development phase. Due to its indeterminate growth habit, cotton never loses the ability to produce main stem nodes and leaves. Fruiting sites are produced from axillary branches beginning from the 6th main stem node through the 18th. Each fruiting branch is capable of producing 3 to 4 fruiting sites. This requires 36 to 40 days to complete the production of fruiting sites. Water stress during the production of fruiting sites stage of development results in fewer main stem nodes and thus fewer reproductive branches with each branch producing fewer floral structures, resulting in a severe reduction in potential boll number and thus yield. Each fruiting site requires about 500 heat units to reach the flowering stage. The first flower at the 6th to 7th node occurs at 1,000 total heat units or about 60 days of age in an average year. Flowering progresses up the plant in 3-day intervals and out of a fruiting branch in 5- to 7-day intervals. The first five days following

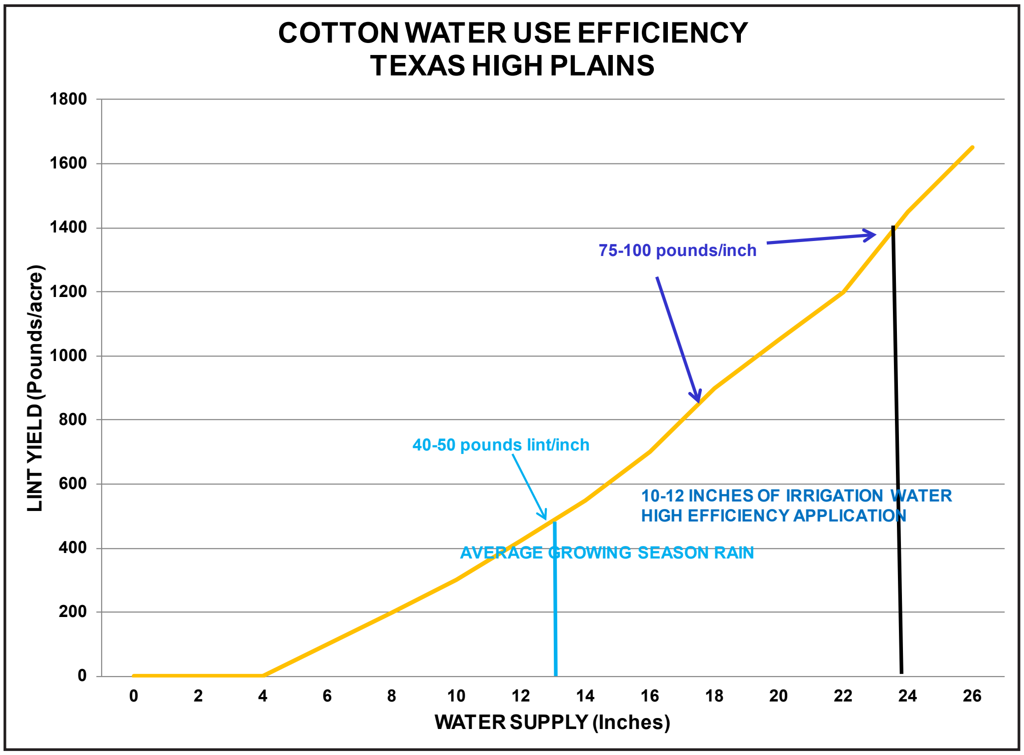

Figure 4. Cotton water use efficiency

pollination of an individual fruit are also very sensitive to both water and nutritional stress, resulting in a reduction in seed number per fruit (less seed results in less lint/boll) or fruit abortion.

Daily water use for a cotton crop grown in West Texas during the 2013 season is depicted in Figure 3. Analyses of cotton yield components and water supply during development were conducted over a 10-year period, which included irrigated and dryland production. Regression analyses were used to determine the impact of water supply during each component's development. The regression coefficients obtained revealed that the water supply from floral bud initiation through peak flower (about a 50 to 60 day period) had the largest impact on total yield, boll number, and boll size. Managing the total water resource during this critical period maximizes water use efficiency and yield.

Efficiency. Water use efficiency of cotton can be defined biologically and economically. The biological water use efficiency for cotton grown in West Texas is depicted in Figure 4. Cotton requires about four inches of water use by the crop to get large enough to produce the first increment of harvestable yield. As the water supply increases, cotton produces about 100 to 125 pounds of seed cotton (45 to 50 pounds of lint) per inch of additional crop water use. As the water supply continues to increase, water use efficiency increases, attaining a maximum of 220 to 240 pounds of seed cotton (90 to 100 lbs of lint) per inch of crop water use with 22 to 25 inches of total crop water use.

Cotton water use efficiency expressed on an economic basis ranges from $40 to $45/inch of water consumed at relatively low water supplies (<15 inches) to $75 to $85/inch at optimum water supplies (24 to 26 inches) and proper water management during the growing season (lint value = $0.75/lb and seed value = $160/ton). Irrigation pumping costs vary significantly across the West Texas Region, ranging from $5 to $10/acre inch, depending on pumping depth and pump plant efficiency. It is obvious that irrigated cotton production in West Texas can be a very profitable enterprise when adequate water supply is available. Other irrigated crops grown in this area either require greater amounts of irrigation water or have lesser value for the product.

Summing up

Cotton is the major crop grown in Texas due to its ability to be productive and profitable under water limiting conditions found throughout the state at certain critical times of the growing season. As the irrigation water supply, especially in West Texas, becomes more limiting, cotton production will remain as the major cash crop grown. Technology is available to greatly increase irrigation water application through reduction of surface evaporation. This technology is rapidly being adopted and will extend the life of the aquifer for West Texas cotton production.

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