Understanding Cotton Irrigation Requirements in Oklahoma

Randy Boman
Research Director and Cotton Extension Program Leader
OSU Southwest Research and Extension Center, Altus

Jason Warren
Soil and Water Conservation Extension Specialist

Making the most of available water is critical in modern production agriculture. Crop physiologists and irrigation engineers use the term water use efficiency (WUE) to describe crop response to that resource. This is simply the amount of lint produced by some quantity of water and is typically expressed as pounds of lint per inch of water. It should be noted that the WUE definition can vary. Texas A&M AgriLife data from west Texas indicate that with high irrigation efficiency systems and with modern varieties, one can expect about 50 pounds to 75 pounds of lint production per acre-inch of stored soil moisture plus effective rainfall (rainfall – runoff) and low energy precision application (LEPA) irrigation. Some irrigation engineers refer to this as in-season water resource use efficiency. When salinity is not an issue, cotton responds well to moderate levels of deficit irrigation. This can be defined as less than the potential full need of the crop, based on evapotranspiration models. If a high efficiency delivery system is used, deficit irrigation can result in higher WUE with good to excellent yields if properly managed.

Cotton Water Use Patterns

Based on long-term mesonet data from Altus, OK, seasonal water use for adequately watered and otherwise healthy cotton is approximately 30 inches in southwestern Oklahoma. Figure 1 illustrates the typical seasonal water use pattern for cotton produced in the Texas High Plains region, and this should be reasonably similar in our area.

Cotton crop evapotranspiration (ET) can be defined as the sum of evaporation and transpiration, and is both crop species and growth stage dependent. Evaporation is water loss from wet plant and soil surfaces. Transpiration is water taken up by roots and transpired through the stomata in leaves. From planting to square initiation (a period of about 40 days) ET is generally less than 0.1 inches per day. Plant water requirements are low due to the limited leaf area. Most of the water used is extracted from the top foot of soil. Most water loss during this period is due to evaporation.

ET increases to 0.1 to 0.3 inches per day during the square to early bloom stage (40 days to 75 days after planting). During this period, leaf canopy and roots develop rapidly, and transpiration exceeds evaporation. Moisture extraction occurs mainly from the top 2 feet of soil, although the taproot and some feeder roots extend to deeper depths if unrestricted by soil depth, hard pans, plow pans, etc.

From early bloom to the opening of the first bolls (usually the period from 60 days to 120 days after planting), ET values of 0.25 to 0.35 inches per day are common. At this stage, plants have reached their maximum leaf canopies and root densities. Moisture may be extracted from deeper in the entire soil profile, if available. ET values may exceed 0.4 inch per day during the peak bloom period. During extreme stress (such as 30 mph wind, 110 degree temperature), crop

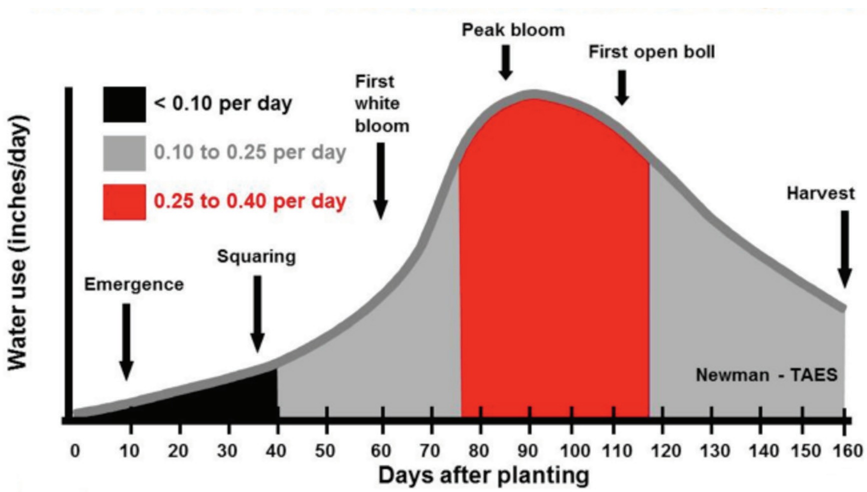

Figure 1. Rate of water use in relation to cotton development.

ET values can be as high as 0.55 inches per day during this period.

Following the opening of the first bolls until crop termination, ET generally declines from about 0.25 inches per day to as little as 0.1 inches per day. Actual water use will vary with the condition of the plant, soil moisture status and general growing conditions. Figure 2, provided by the Oklahoma Mesonet depicts the 10-year average cotton ET at Altus for a planting date of May 10.

Stress Sensitive Periods

Fruit production, retention and shedding are closely related to availability of soil moisture. Production is optimized with an available moisture status, allowing uninterrupted development of fruiting positions while avoiding excessive vegetative development on the one hand, or fruit shedding on the other. Many producers believe it is appropriate to allow cotton to "stress" before applying the first irrigation in order to slow vegetative growth, force root system expansion and enhance early fruit development. However, research has shown that excessive stress prior to the first irrigation may reduce mainstem node development, and result in fewer nodes above white flower at first bloom, which can ultimately reduce yield potential.

High moisture stress during the peak flowering period can have a pronounced negative effect on yield and fiber quality. However, stress either early or late in the blooming period also results in significant yield reductions. Severe moisture stress should be avoided throughout the crop development period. Early irrigations may be justified to maintain adequate, but not excessive vegetative growth. Late season water stress may be acceptable or even desirable because it hastens cutout and results in shedding of fruit that would not normally reach full maturation and potentially contribute to low micronaire if a cooler than normal fall is encountered.

Oklahoma Mesonet Irrigation Planner

Many producers with groundwater resources (center pivot, furrow or drip) can initiate irrigation on demand. Crop ET models can generally do a good job of predicting crop water use. The Oklahoma Mesonet provides a good tool that can be useful to estimate crop ET. First go to: http://www.mesonet.org/index.php/agriculture/irrigation_planner

Click on Choose Site (select the nearest Mesonet Station to the field in question), then select Cotton. The Relative Maturity Days defaults to 160, which is appropriate for most Oklahoma irrigated cotton. Select Planting Date and input the planting date for the field in question, then click on Get Data. A page with a table will be generated. This table will provide a quick estimate of daily crop ET, accumulated ET, rainfall, accumulated rainfall and the water balance. This irrigation planner is used by looking at the "water balance" value on the date of the last irrigation event or planting. Irrigation water should be applied to replenish this depth of water to ensure soil profile moisture is maintained. For fields with adequate irrigation capacity and efficient delivery systems (pivots, subsurface drip), the Irrigation Planner can be of great value to determine how much water to apply.

It should be noted that the pumping capacity and efficiency of a particular system needs to be considered. Irrigation systems vary in terms of application efficiency and can be negatively impacted by adverse environmental conditions. High temperatures and high winds can reduce application efficiencies for all systems with the exception of well managed sub-surface drip. Center pivot spray irrigation with short drops under high wind conditions will have lower efficiency than a system with longer drops which deliver water closer to the crop canopy. When determining how much irrigation water to apply, several factors must be considered. One is irrigation capacity. Higher capacity irrigation wells allow producers to apply more water in less time. Some "catch up" is possible if the system "gets behind." With lower irrigation capacity, it will be necessary to keep the system applying water to meet crop requirement. This requires knowledge of the irrigation system capacity, nozzle package and groundspeed travel of the pivot. These are vitally important in order to fine tune irrigation application rates to meet crop ET demand without over- or under-applying water. Crop ET demand (which can be reasonably estimated by the Mesonet site described above) will increase substantially once the squaring stage is reached and will continue through late boll set then will diminish once open bolls appear.

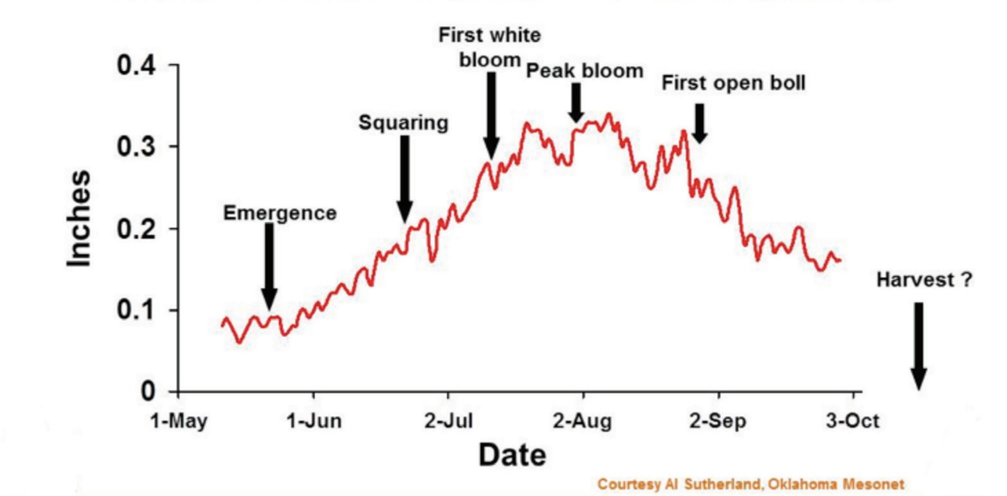

Figure 2. Altus Mesonet, May to September long-term average (10-year), daily cotton ET (May 10 planting date).

Amount of Cotton Evapotranspiration Replacement for Various 60-Acre Center Pivot Irrigation Pumping Capacities and Delivery Efficiencies.

Pumping capacity delivered to center pivot					Acre-In/acre/day	In/acre/day delivered at Irrigation application efficiency (%)			For 85% irrigation application efficiency % ET replacement if actual crop ET (in inches/day) is:			
						95	85	75	0.25	0.35	0.45	0.55
GPM	*GPM/acre*	*Gal/day*	*Acre-ft/day*	*Acre-in/day*	*at 100% efficiency*	*(LEPA, SDI)*	*(Low elevation spray)*	*(Poor spray)*	*(moderate)*	*(high)*	*(very high)*	*(extreme)*
100	1.7	144,000	0.44	5.3	0.09	0.08	0.08	0.07	30	21	17	14
200	3.3	288,000	0.88	10.6	0.18	0.17	0.15	0.13	60	43	33	27
300	5.0	432,000	1.33	15.9	0.27	0.25	0.23	0.20	90	64	50	41
400	6.7	576,000	1.77	21.2	0.35	0.34	0.30	0.27	120	86	67	55
500	8.3	720,000	2.21	26.5	0.44	0.42	0.38	0.33	150	107	83	68
600	10.0	864,000	2.65	31.8	0.53	0.50	0.45	0.40	180	129	100	82
700	11.7	1,008,000	3.09	37.1	0.62	0.59	0.53	0.46	210	150	117	96
800	13.3	1,152,000	3.53	42.4	0.71	0.67	0.60	0.53	240	172	133	109
900	15.0	1,296,000	3.98	47.7	0.80	0.76	0.68	0.60	270	193	150	123
1000	16.7	1,440,000	4.42	53.0	0.88	0.84	0.75	0.66	300	215	167	137

Note: 12 acre inches = ~326,000 gallons.
Texas High Plains research indicates that ~75% ET replacement can generally maximize water-use efficiency (lbs of lint/inch of water) but not necessarily total yield/acre. Salinity will complicate this response.

Amount of Cotton Evapotranspiration Replacement for Various 120-Acre Center Pivot Irrigation Pumping Capacities and Delivery Efficiencies.

Pumping capacity delivered to center pivot					Acre-In/acre/day	In/acre/day delivered at Irrigation application efficiency (%)			For 85% irrigation application efficiency % ET replacement if actual crop ET (in inches/day) is:			
						95	85	75	0.25	0.35	0.45	0.55
GPM	*GPM/acre*	*Gal/day*	*Acre-ft/day*	*Acre-in/day*	*at 100% efficiency*	*(LEPA, SDI)*	*(Low elevation spray)*	*(Poor spray)*	*(moderate)*	*(high)*	*(very high)*	*(extreme)*
100	0.8	144,000	0.44	5.3	0.04	0.04	0.04	0.03	15	11	8	7
200	1.7	288,000	0.88	10.6	0.09	0.08	0.08	0.07	30	21	17	14
300	2.5	432,000	1.33	15.9	0.13	0.13	0.11	0.10	45	32	25	20
400	3.3	576,000	1.77	21.2	0.18	0.17	0.15	0.13	60	43	33	27
500	4.2	720,000	2.21	26.5	0.22	0.21	0.19	0.17	75	54	42	34
600	5.0	864,000	2.65	31.8	0.27	0.25	0.23	0.20	90	64	50	41
700	5.8	1,008,000	3.09	37.1	0.31	0.29	0.26	0.23	105	75	58	48
800	6.7	1,152,000	3.53	42.4	0.35	0.34	0.30	0.27	120	86	67	55
900	7.5	1,296,000	3.98	47.7	0.40	0.38	0.34	0.30	135	97	75	61
1000	8.3	1,440,000	4.42	53.0	0.44	0.42	0.38	0.33	150	107	83	68

Note: 12 acre inches = ~326,000 gallons.
Texas High Plains research indicates that ~75% ET replacement can generally maximize water-use efficiency (lbs of lint/inch of water) but not necessarily total yield/acre. Salinity will complicate this response.

Irrigation System Type

Irrigation application efficiency can be described as the amount of water delivered to an irrigation system that contributes to transpiration of a crop. Application efficiency information provided by Jim Bordovsky, Research Engineer with Texas A&M AgriLife Research at Halfway has noted that flood/furrow typically ranges from 40 percent to 80 percent, center pivot sprinkler/spray ranges from 65 percent to 90 percent, center pivot low energy precision application (LEPA) ranges from 85 percent to 95 percent, and sub-surface drip ranges from 85 percent to 99 percent. The theoretical goal is to be 100 percent efficient.

If using a spray system, make sure to use nozzle applicators that generate large droplet sizes. This should help reduce evaporation losses during application. Apply at least 1 inch per application if it can be done without causing runoff. Larger applications will increase the depth water infiltrates into the soil, which will decrease evaporation from the soil surface. Be thoughtful not to over-apply and cause drainage. The likelihood of drainage can be better estimated if an irrigation planner or soil moisture probes are used to estimate soil moisture status.

The tables on page 3 provide information concerning ET replacement for 60-acre and 120-acre center pivots with various pumping capacities and delivery efficiencies. The tables also show the percent of ET replacement that can be achieved with the pumping capacities assuming an 85 percent application efficiency. This analysis shows that an ET of 0.35 inches per day (recall from the Mesonet data in the graph above that on average this represents a maximum daily ET) will require 400 GPM for a 60 acre pivot or 700 GPM for a 120 acre pivot. These irrigation pumping system capacities will ensure sufficient water is supplied to the crop to maximize water use efficiency, regardless of rainfall. However, these irrigation capacities assume that all of the water is supplied through irrigation. Rainfall in Southwest Oklahoma will generally supplement these irrigation requirements and reduce the irrigation capacity requirements to 200 and 400 GPM for the 60 and 120 acre pivots (Based on long term rainfall and ET from Mesonet). During periods of limited rainfall, high temperatures and wind; irrigation capacity requirements can dramatically increase as illustrated by the irrigation capacities required when the maximum daily ET is 0.55 inches. This was experienced in western Oklahoma in 2011. In fact, maximum daily ET values as high as 0.58 inches were experienced with no rainfall leading to reduced crop performance with irrigation capacities that were generally sufficient.

Water Quality

Irrigation water quality should not be overlooked. High salinity water and/or saline soils can adversely affect crop performance. If high salinity water is the sole source of water input (because of lack of rainfall) for the crop, there is a high risk the crop will ultimately suffer. These effects can vary with seasonal rainfall, soil type, and soil salinity, however this discussion is beyond the scope of this fact sheet. Oklahoma Cooperative Extension Fact Sheet PSS-2401 provides classification of irrigation water quality, describes how irrigation water quality is determined and the conditional use of low quality water for various crops including cotton.

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