COTTON IRRIGATION SCHEDULING: WHICH METHOD IS A BEST FIT? YEAR 2 OF A CONTINUED STUDY

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Abstract

Cotton is one of the most difficult crops to properly manage irrigation for because of its physiology. There are many irrigation scheduling tools available to producers, but determining which one may be the best fit for their operation can be a daunting task. The main objective of this multiyear study was to evaluate various irrigation scheduling strategies for cotton production in the Southeastern US. The subobjectives of this study were: to monitor soil moisture and determine optimal irrigation timings for each scheduling method, to log the total and distribution of rainfall and irrigation during the season, and to determine the effect of irrigation scheduling method on final crop yield and irrigation water use efficiency (IWUE). The irrigation scheduling trial consisted of nine-treatments in 2020 and seven-treatments in 2021 and was implemented at the University of Georgia's Stripling Irrigation Research Park. Cotton was planted on May 7, 2020 and harvested on October 26, 2020 and planted on May 7, 2021 and harvested on October 20, 2021. Three Watermark soil water tension sensors integrated into a probe at depths of 6, 10, and 14 inches, were installed in two of the three replications of each treatment. The nine treatments implemented in 2020 included 20, 45 and 75 kPa soil water tension treatments, USDA-ARS Irrigator Pro for Cotton, Crop Metrics CropX sensor system, Valley Irrigation's Sensor Scheduling System, UGA SmartIrrigation Cotton App, the UGA Checkbook, and a rainfed treatment. During 2021 due to plot and irrigation system size the Crop Metrics and 75 kPa treatments were eliminated. A total of 21 inches of rainfall were received during the 2020 cotton production season, while nearly 30 inches were received during the 2021 season, indicating wet production seasons. This is also reflected in the low amount of irrigation which was applied via the UGA Checkbook (only 11 and 7.5 inches respectively). After the cotton was harvested, final yield, IWUE and an estimated profit calculation was determined. While there were no significant differences between lint yield except for the rainfed treatment, there were differences in IWUE and profitability. The top three yielding treatments in order were the 45kPa, the 20 kPa and the SI Cotton App, while the CropX, 75 kPa, Checkbook were the lowest yielding treatments during 2020. There were no differences in treatments during 2021. From the perspective of IWUE, the 75 kPa (2020) and 45 kPa (2021) treatment were the highest and the Checkbook the lowest. This shows that yield alone should not be the only consideration when considering irrigation scheduling methods and end goal on the farm.

Introduction

There are many irrigation scheduling tools and methods available to producers to aid in better determining when and how much irrigation to apply during each event. These methods range from free with no additional equipment or time investment required, to inexpensive, and a slight time investment, to a perceived expensive monetary and time commitment required. Examples of some of the free methods are evapotranspiration (ET) Checkbook methods, which are usually easy to obtain for producers from crop production guides. These methods often provide a crop water use curve represented in days or weeks after planting or accumulated Growing Degree Days (GDD's) and were developed by using a crop coefficient (either published or researched) combined with local and historical ET values. Checkbook methods only require producers to keep track of local rainfall and irrigation applied to the field and make irrigation timing and rate decisions from these data. Methods that are more advanced than ET methods are computer models. The UGA SmartIrrigation Cotton App is one of these models. The SI Cotton App uses local data such as planting date, soil type, local rainfall and ET data to determine how much soil moisture is available to the plant at any given time. It recommends irrigation be applied once the available soil moisture in the root zone reaches a deficit set point, usually 40 or 50%. Computer models such as this app are usually free or relatively inexpensive and utilize information from an ET method, but make better recommendations because they use real time local data to help producers keep track of the current estimated soil moisture balance. Moving beyond computer models is using soil moisture sensor systems.

These systems have a range in cost and accuracy, but have the potential to greatly improve yield, IWUE, and on farm profitability. The cost and required data interpretation of these systems are typically why they are not more widely adopted. However, once one becomes comfortable with using sensors, they tend to become a preferred method for producers. An additional way to utilize sensors is to combine them with a crop growth model. There are many different types of these “hybrid” systems available on the market. Three of the treatments in this study utilized hybrid sensor-crop growth model systems. They were Irrigator Pro, CropX and the Valley Scheduler. Each of these systems uses information such as crop type, planting date, soil type, and combines it with the current soil moisture reading to make an estimation off plant available moisture and uses this information to recommend irrigation. These types of systems take the guess work out of soil moisture sensor data interpretation and usually make using sensors easier for producers. All of the above-mentioned methods have a fit and utility for scheduling irrigation, however, they all may not be the best fit for all operations.

Cotton is one of the more difficult crops to optimally manage irrigation. Cotton requires the appropriate amount of moisture stress at the correct time, but not excessive stress which will cause yield reductions. Conversely, cotton is a crop that also responds negatively from the yield perspective to over-irrigation or moisture levels that are too high. Thus, to maximize yields a scientifically valid irrigation scheduling method is required. To help in determining which method or methods would be an adequate fit for a production scenario, the main objective of this study was to evaluate various irrigation scheduling strategies for cotton production in the southeastern US. The subobjectives of this study were: to monitor soil moisture and determine optimal irrigation timings for each method, to log the total and distribution of rainfall and irrigation during the season for each irrigation scheduling method, and to determine the effect of irrigation scheduling method on final crop yield and irrigation water use efficiency (IWUE).

Materials and Methods

A randomized block cotton irrigation scheduling trial was implemented under a lateral irrigation system equipped with a variable rate controller at the University of Georgia’s Stripling Irrigation Research Park, near Camilla, GA, during the 2020 and 2021 cotton production seasons. The irrigation system was designed such that 27 plots of 24 ft by 42 ft (2020) and 24 plots of the same size (2021) can be irrigated independently. This arrangement allowed for nine treatments in 2020 and seven in 2021, replicated three times and four times respectively, to be implemented under the system. Cotton variety DeltaPine 1646 was planted on May 7, 2020 and May 7, 2021 into eight row wide plots (36-inch row spacing) under each irrigation control zone. The nine irrigation scheduling treatments implemented during 2020 were rainfed, soil water tension (kPa) thresholds of 20 (wet), 45 (optimal), 75 (dry), USDA-ARS Irrigator Pro, Crop Metrics CropX system, Valmont’s Valley Irrigation Scheduling System, UGA SmartIrrigation Cotton Irrigation Scheduling App, and UGA’s Checkbook method. Due to field size and plot limitations the 75 kPa and CropX were eliminated during 2021. Three Watermark soil water tension (SWT) sensors integrated into a probe at depths of 6, 10, and 14 inches, were installed in two of the three replications of each treatment during both seasons. Data were logged and monitored hourly. Each of the three main sensor systems utilized for this trial are shown in figure 1 below. They are from left to right the Crop Metrics CropX system being installed, the Valley scheduling system, and two pictures of the SWT Watermark probe, so that one can see the probe and how it is installed into the field with its associated telemetry.

Figure 1. From left to right is the CropX Sensor systems, the Valley Scheduling system, and the SWT probe.

In all treatments except the 20, 45, 75 kPa and Irrigator Pro treatments, the SWT probes were used for irrigation monitoring only. In the 20, 45, and 75 kPa treatments, a weighted average approach was implemented by crop age and estimated rooting depth to determine when the irrigation trigger was reached. The SWT probe data were averaged by depth and entered into Irrigator Pro daily to allow it to make the irrigation scheduling recommendation. Each of the other irrigation scheduling treatments had an irrigation recommendation trigger which was followed. When a treatment called for irrigation an 0.75-inch irrigation application was applied to all three replications of this treatment on the day it reached its threshold. This procedure was followed over the course of the season. Irrigation was terminated once a field average 10% open boll was reached. This occurred on September 4, 2020 and September 10, 2021. During the time from planting until harvest, 21.36 and 29.66 inches of rainfall were received during 2020 and 2021 respectively at the research site. This is a significant amount of rainfall and means both years can be considered "wet" years, or a year in which low amounts of irrigation were required for successful yields. The center two rows of each plot were harvested on October 26, 2020 and October 20, 2021 utilizing a two row John Deere cotton picker with a bagging attachment in the basket. Each plot's bagged yield was weighed immediately after harvest, ginning subsamples were pulled and an average lint turnout value was calculated and applied to all samples to estimate lint yield from each plot. Additionally, a relative profit calculation was performed to determine which treatments had the highest profitability. This was done by simply using UGA's Enterprise Budget estimated cost of pumping irrigation, which is $7/ac-in for electrical pumps and $12/ac-in for diesel pumps, multiplying these values by the irrigation applied by each treatment and subtracting this value from an estimated $0.79/lb. (2020) and $1.00/lb. (2021) of lint value of cotton. Thus, these values do not account for any other input cost but that of pumping irrigation water. It can be assumed that all of input costs were kept consistent across all treatments and the only difference is irrigation applied. These costs do not include the cost of irrigation method, but are meant as a relative value for reference.

Results and Discussion

Tables 1 (2020) and 2 (2021) show the treatments, irrigation applied to each treatment, total amount of water (rainfall plus irrigation), lint yield, IWUE, and the calculated profit for using electric and diesel irrigation pumps. As can be seen in Table 1, the only difference in yield was between the rainfed treatment and the other treatments. There was only a 191 lb./ac difference between the highest and lowest yielding irrigated treatments. It is worth stating again that there was excessive rainfall received during the 2020 cotton production season and little irrigation was required to ensure a successful yield. However, in years with ample rainfall, this data shows that timing of the few required events is just as important as the total amount of applied irrigation.

Table 1. 2020 results for each irrigation scheduling treatment, including, yield, IWUE, and estimated profit.

TREATMENT	IRRIGATION (IN)	TOTAL WATER (IN)	LINT YIELD (LB/AC)	IWUE (LB/IN)	PROFIT FOR $7/AC-IN @ $0.79 COTTON ($/AC)	PROFIT FOR $12/AC-IN @ $0.79 COTTON ($/AC)
Rainfed	1.0	22.4	795	N/A	621	616
45 kPa	5.5	26.9	1304	237	992	964
20 kPa	7.75	29.1	1293	167	967	928
75 kPa	3.25	24.6	1129	347	869	853
Irrigator Pro	5.5	26.9	1245	226	945	918
CropX	4.0	25.4	1113	278	851	831
Valley Scheduler	8.5	29.9	1240	147	920	878
SI Cotton App	6.25	27.6	1270	203	960	928
Checkbook	11.0	32.4	1196	109	868	813

Table 2. 2021 results for each irrigation scheduling treatment, including, yield, IWUE, and estimated profit.

TREATMENT	IRRIGATION (IN)	TOTAL WATER (IN)	LINT YIELD (LB/AC)	IWUE (LB/IN)	PROFIT FOR $7/AC-IN @ $1.00 COTTON	PROFIT FOR $12/AC-IN @ $1.00 COTTON
Rainfed	1.0	30.66	1119	N/A	1112	1107
45 kPa	2.36	32.10	1191	505	1175	1162
20 kPa	3.86	33.60	1197	310	1170	1151
Irrigator Pro	2.36	32.10	1175	498	1159	1147
Valley Scheduler	2.36	32.10	1148	486	1131	1120
SI Cotton App	2.36	32.10	1164	493	1148	1136
Checkbook	7.26	37.00	1177	162	1126	1090

Similarly, during 2021, there was no difference between any of the treatments, even the rainfed treatment. The excessive rainfall masked all irrigation yield treatment differences. However, in both years, slight differences in the amount of irrigation applied to each treatment aided in delineating differences in IWUE and profit. As shown in Table 1, the 45 kPa treatment was not only the highest yielding treatment but also had the highest overall profitability. Other treatments that followed this similar trend were the 20 kPa, the SI Cotton App and Irrigator Pro. However, when looking at IWUE the 75 kPa treatment was at the top. Again during 2021 the 45 kPa treatment had the second highest numerical yield and the highest IWUE and profitability. The Checkbook treatment had the lowest IWUE during both seasons. This shows that when considering irrigation scheduling methods, one factor alone should not be considered. Even though the 20 kPa treatment in 2020 was the second highest yield and second highest profitability, it had one of the lowest IWUE values. This is because it applied the second highest amount of irrigation, indicating that even though the extra irrigation aided in increasing yields over some of the other treatments it was not necessarily the best option. The cost of the extra 2.25 inches of irrigation was $25 and $36 per acre respectively for electrical and diesel pumping costs during 2020. This is a significant cost that could be reallocated into either some other production cost or retained as profit. These figures show how important selecting the correct scheduling method can be and how some of the more advanced methods, even though perceived as expensive, can easily and quickly pay for themselves if properly utilized.

Figures 2 and 3 are graphical representations of each of the irrigation scheduling methods plotted along with the production season rainfall during 2020 and 2021 respectively. The two initial irrigation events on May 7 and 30, 2020 were for stand establishment and herbicide activation and were applied to all treatments. As can be seen in figure 2, the UGA Checkbook method irrigated almost every week during the production season unless significant rainfall was received. This is typically how a checkbook method is implemented, the rainfall for the week is totaled and the amount that is still required is applied. Most scheduling methods were relatively consistent from late June through Mid-August. As there were only sporadic rainfall events and the cotton had reached peak water requirements, irrigation was required for most of the methods. Though not expected, the three sensor methods and Irrigator Pro did not recommend irrigation after July 25th. Between crop water requirements and late season rainfall, the crop did not require additional irrigation. The main differences between the 2020 and 2021 seasons were that irrigation was required early during the 2021 growing season, but not after early June for most treatments. The excessive rainfall during the latter part of the 2021 growing season aided in increasing cotton yields, but it also masked all irrigation treatment differences since irrigation was not needed during the peak water requiring period of the cotton season. These graphs also show the importance of proper irrigation timing. In wet years it can be just as critical to decide when irrigation is not required and save that event and the associated costs. A season like 2021 would provide a difficult decision in deciding not to irrigate late in the season, or after the end of May. However, additional irrigation events later in the season did not add to total yield or profitability, thus were not required. Advanced irrigation scheduling methods aided in confidently skipping these irrigation events. In these seasons there are many instances and differences between each of the methods and when some called for irrigation and others did not. A good example of missed irrigation events is the CropX not requiring irrigation during June and early July while other methods did. If one were to just look at the total amount of irrigation applied it would be hard to explain why CropX had lower yields when a similar amount of irrigation was applied to other treatments. It can all be associated with the timing of the irrigation events and what the crop requirements were at that particular time. Thus, it should be noted that the total amount of water or applied irrigation is not as important as the timing of these events as shown between tables 1 and 2 and figures 2 and 3.

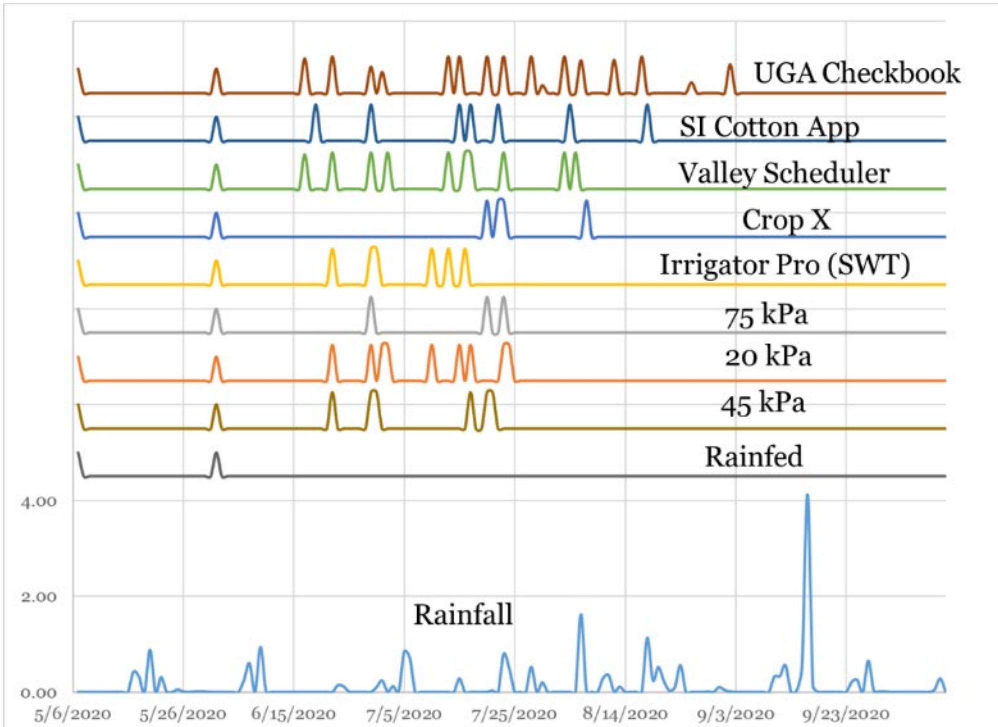

Figure 2. Timing and amount of rainfall and irrigation during the 2020 cotton irrigation scheduling trial at SIRP.

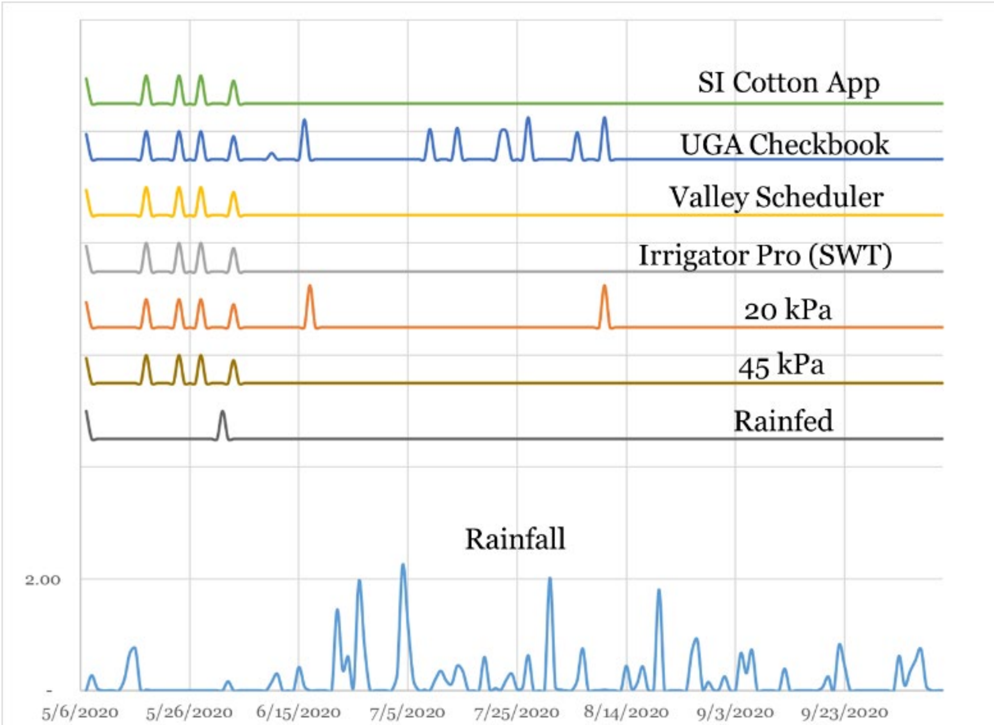

Figure 3. Timing and amount of rainfall and irrigation during the 2021 cotton irrigation scheduling trial at SIRP.

Summary

In conclusion, nine different irrigation scheduling treatments were tested over two years to evaluate various irrigation scheduling strategies for cotton production in the southeastern US. Soil water tension data were monitor in two of the three replications of each treatment along with the documentation of the total amount of rainfall received and irrigation applied to each treatment. The effect of irrigation scheduling treatment on final crop yield and IWUE was determined for each of the nine methods. There were not significant differences in lint yield between treatments except for the rainfed treatment in 2020 which had a lint yield that was approximately 500 lb./ac less than the rest of the treatments. Thus, even though both seasons could be considered wet years, there still was a benefit for irrigating the crop at the appropriate time, or in the case of 2021, not irrigating the crop during most of the season. The highest yielding treatment was the 45 kPa treatment which applied approximately 5.5 inches of irrigation during the 2020 season and had an IWUE of 237 lbs. of lint per inch and applied 2.4 inches of irrigation and had an IWUE of 505 lbs. of lint per inch during 2021. Even though this method had the highest yield during 2020 it did not have the highest IWUE as the 75 kPa treatment had the highest IWUE at 347 lbs. of lint per inch. However, a rough profit calculation showed that the 45 kPa treatment was the most profitable of all treatments. The Checkbook method called for the highest amount of irrigation, thus had the lowest IWUE. The Checkbook method tends to be more conservative, ensuring that water is not the limiting factor, but in years with excessive rainfall it tends to over-irrigate either reducing yield, IWUE, or profitability. The data from this trial provides information for producers to be able to make an educated decision on which irrigation scheduling method would be the best fit for their operation. As can be observed from these results, a method more advanced than a Checkbook method is recommended for optimizing cotton yield, IWUE, and profitability.

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