THE EFFECTS OF SOIL MOISTURE ON COTTON GROWTH AND YIELD: A MULTI-VARIETAL INVESTIGATION

Sydni Barwick
Wesley Porter
University of Georgia
Tifton, GA
Seth Byrd
Texas A&M University
Lubbock, TX
John Snider
Jared Whitaker
University of Georgia
Tifton, GA
Guy Collins
North Carolina State University
Raleigh, NC
Andy Shirley
Billy Griffin
Brent Allen
Brian Cresswell
Brian Hayes
University of Georgia Cooperative Extension Service
Tifton, GA
Chris Earls
University of Georgia Cooperative Extension Service
Metter, GA
Chris Tyson
Jennifer Miller
Josh Lanier
Pam Sapp
Peyton Sapp
Ray Hicks
Raynor Churchwell
Shane Curry
University of Georgia Cooperative Extension Service
Tifton, GA

Abstract

The main objective of this project was to quantify the effect of total water received and the corresponding soil moisture levels on final crop yield in a variety of production scenarios common to Georgia. The secondary objectives of this study were to determine the effect of total water received throughout the growing season on the development of the crop, the progression toward crop maturity, and to determine the effect of total water received during critical growth stages on final seed cotton yield. Rainfall, irrigation, soil moisture, and maturity data were collected throughout the cotton production season approximately every two weeks in twenty cotton variety trials in the southern region of Georgia. Soil moisture data were collected using AquaCheck capacitance probes (AquaCheck Brackenfell , Cape Town, South Africa); rainfall and irrigation data were collected using Rain-O-Matic Small tipping bucket rain gauges (Fjord Alle 8, DK-6950 Ringkobing) equipped with Decagon EM-50-R data loggers (Decagon Devices Hopkins Ct, Pullman, WA). There were a variety of soil types, and tillage and irrigation methods utilized in the trials, which have all been noted. Little correlation was found between the amount of water the crop received pre-bloom and yield however, stronger correlations were found between the total water received during the season and final seed cotton yield. Trials that received more rainfall or irrigation during flowering typically yielded higher than those that did not receive ample amounts of water during this growth stage. Overall, it was noted that well-timed irrigation or rainfall during critical growth stages produced higher yields when compared to trials that did not receive these well-timed events. Showing that on cotton it is most critical to provide ample water during squaring through bloom.

Introduction

In 2014 Georgia produced over 2.5 million bales of cotton from 1.3 million harvested acres, ranking it second in national cotton production. Georgia's cotton production is very important to the state's agricultural industry, valued at $770 million (USDA/NASS). The high value of this industry to the state has created a critical need for access to water to increase yields. Limited access to water has become an issue nationwide and has forced producers to make an effort to reduce water use. Improving water use efficiency is a necessity in many areas and is likely to become more of a concern in the future; however, incurring a reduction in yield is undesirable, especially with current commodity prices meaning the management of that water is critical. Significantly reducing the amount of irrigation applied during the wrong developmental stage could cause yield loss. Reducing available water also reduces shoot growth resulting in a lower number of fruiting sites on the plant. More available water increases growth, delays cutout, and increases fruiting sites available to support a large boll load (Gwathmey et. al 2011). Increasing irrigation efficiency has the potential to save growers valuable time and capital that can be devoted to other areas of their operation. Hiler & Howell reported that careful distribution of water over the course of the season could be the solution to using water more wisely through careful conservation (1983).

A proper, strictly followed irrigation scheduling plan implemented during the growing season could reduce the amount of water used and ensure that it is applied at critical times. Finding the most crucial times during the season to apply irrigation would save producers valuable time, resources, and money while positively impacting yield. Ideal irrigation management in Georgia has been shown to increase yields by up to 312 lb/ac (Simao et. al 2013). Yield could continue to increase with improved irrigation methods that are adapted to a variety of environmental pressures and conditions. Many disagree on the most critical growth stage at which to apply irrigation. Yield loss can be incurred due to drought stress at any growth stage, but determining the most crucial stages to apply irrigation could be very impactful. Innumerable environmental pressures and genetically predetermined factors influence yield, but careful irrigation management could negate some of these factors to improve yield potential.

The number of total nodes and the height of plants was shown to have been impacted when the crop experienced drought stress during the period of squaring to flowering, resulting in a reduced yield (Snowden et. al 2014). Fiber quality can be impacted by drought stress during certain stages of growth, specifically after peak bloom (Snowden et. al 2014). Some have concluded that one of the most critical times to avoid drought stress and avoid yield loss is during flowering and peak bloom (Sheedy et. al 1997). This yield loss is believed to be due to significant square shedding and eventually boll loss following the drought stress (Snowden et. al 2014). Yield has been shown to be negatively affected during early flowering (Simao et. al 2013). A water deficit during early flowering can cause yield loss of up to 60%, relative to a well-watered crop. Drought stress from squaring to flowering, at peak bloom, and from peak bloom to termination can cause up to a 35% yield loss at each of these growth stages (Snowden et. al 2014). Determining the ideal irrigation schedule for cotton in a variety of environments could be instrumental in increasing efficiency in production and water conservation.

Objectives

The main objective of this project was to quantify the effect of total water received and the corresponding soil moisture levels on final crop yield in a variety of production scenarios common to Georgia. The secondary objectives of this study were to determine the effect of total water received throughout the growing season on the development of the crop, the progression toward crop maturity, and to determine the effect of total water received during critical growth stages on final seed cotton yield.

Materials and Methods

A combination of thirteen of On-Farm cotton variety trials (OFT) and seven Official UGA Variety Trials (OVT) were selected for a total of twenty site locations. The sites were located across the eastern and western parts of South Georgia. Locations of the OFT trials included Burke, Screven, Washington, Appling, Tatnall, Evans, Montgomery, Bleckley, Early, Grady, and Mitchell counties. Tift, Decatur, Sumter, and Burke counties were the locations of the OVT trials. There were nine irrigated and eleven dryland trial locations. One to two weeks after emergence soil moisture sensors and rain gauges were installed.

To collect rainfall and irrigation data two small Rain-O-Matic tipping bucket rain gauges (Fjord Alle 8, DK-6950 Ringkobing) were fixed onto a board and placed in each of the plots (Figure 1). Two tipping bucket rain gauges were used to ensure that the data from at least one could be recorded in case of equipment failure. The data from the tipping bucket rain gauges were collected using a Decagon EM-50-R data logger (Decagon Devices Hopkins Ct, Pullman, WA). Rainfall and irrigation were recorded in inches at hourly intervals and downloaded as an Excel data sheet from the data logger.

Figure 1. Decagon EM-50-R data logger and the tipping bucket rain gauges.

AquaCheck capacitance probes (AquaCheck Brackenfell, Cape Town, South Africa) were utilized to collect soil moisture data at the twenty cotton variety testing locations (Figure 2). These soil moisture sensors were equipped with on-board memory and were powered with a battery. The depths at which soil moisture was measured with the AquaCheck probes were 8, 16, and 24 inches. Soil moisture data were recorded in percent volumetric water content (VWC) in hourly intervals. Soil moisture data were downloaded wirelessly every two weeks with an AquaCheck RF logger. After data were collected, the AquaCheck Logger Upload Utility was used to upload the file to agri-data.net (Figure 3). Once the file was uploaded, data from each probe were displayed in a graph specific to each probe and site location.

Figure 2. AquaCheck capacitance probe.

Figure 3. An example of a graph of the soil moisture data from agri-data.net.

All of the soil moisture, rainfall, and irrigation data were downloaded from each of the instruments every two weeks. Data collection began just after emergence when the rain gauges and soil moisture sensors were installed. From the date of first installation, the data collection schedule was followed as strictly as possible on each of the trials. This was done so that equipment damage could be identified and corrected, with a minimal amount of data lost. Crop development was monitored by selecting fifteen plants from the area around the data loggers every two weeks, corresponding to the time the rain gauge and soil moisture sensor data were downloaded from the in-field data loggers. Number of true leaves, total nodes, days after squaring and nodes above white flower were all recorded for each of the fifteen plants that best represented the area.

Results and Discussion

There was little correlation observed between the amount of rainfall and irrigation received pre-bloom and the final yield of the crop (Figure 4). The amount of rainfall and irrigation received pre-bloom included the amount of rainfall and irrigation recorded by the rain gauges from the time they were installed (1-2 weeks after emergence) until the first bloom was observed in each trial. The poor correlation between the amount of water received pre-bloom and yield could potentially be due to the crop's very low water requirement prior to squaring. Rapid root growth takes place prior to squaring and excessive moisture during this growth stage could impede the growth of the roots, subsequently limiting the further growth of the plant. During squaring water deficit is not likely to be a problem. Excessive amounts of water during squaring could cause square shedding and decrease yield (Perry et al.).

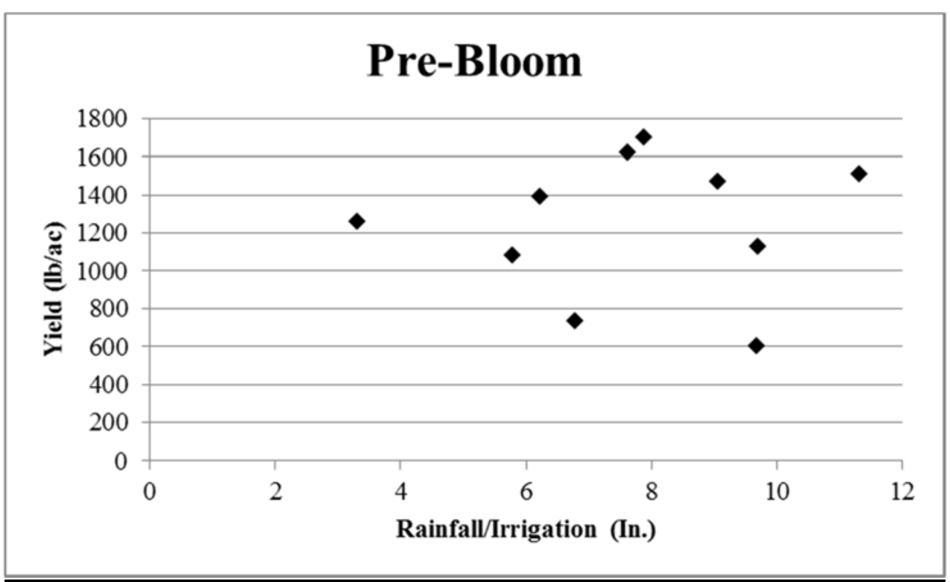

Figure 4. Correlations between rainfall and irrigation received pre-bloom and yield.

Figure 5 represents the full season total amount of water received plotted versus the final yield. Stronger correlations were found between the amount of rainfall and irrigation received throughout the season and yield. Typically with an increase in rainfall or irrigation there was an increase in yield. There were two exceptions to this case, Grady and Bleckley dryland. Grady Dryland yielded 1626 lb/ac and received about 13 inches of rainfall over the season. Figure 7 shows the monthly distribution of rainfall for the Grady trial. As represented in this figure, Grady received very well-timed irrigation especially during month three which was during squaring to flowering. Similar results can been viewed in Figure 9 for the Bleckley trial. Bleckley did not receive as much rainfall during month three as did Grady, but the rainfall was well timed allowing the crop to produce sufficient yield at the end of the season.

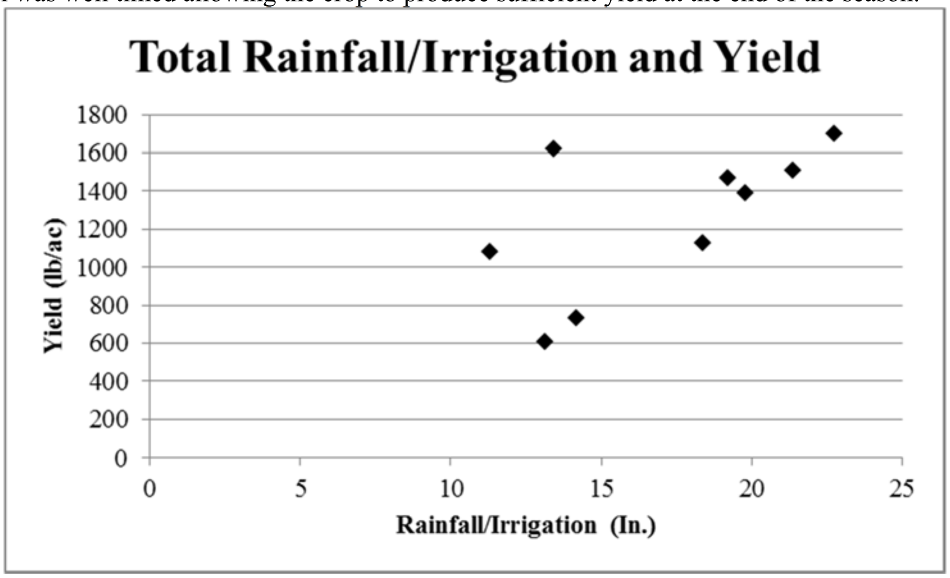

Figure 5. Correlations between rainfall and irrigation received throughout the season and yield.

There was nearly 1000 lb/ac yield increase in Midville Irrigated compared to the adjacent dryland trial. Midville Irrigated had a yield of 1702 lb/ac while the Midville Dryland trial only had a yield of 737 lb/ac. This is a considerable yield increase that could be contributed to the increased amount of irrigation received during squaring and flowering. Trials shown in Figure 6 received about the same amount of rainfall in the first month. Amounts of rainfall or irrigation received during the first, fourth, and fifth months are very similar. However, during the second and third months (which would have been during squaring and flowering) the irrigated trial received much more water, or irrigation in this case which likely contributed to its significantly higher yield.

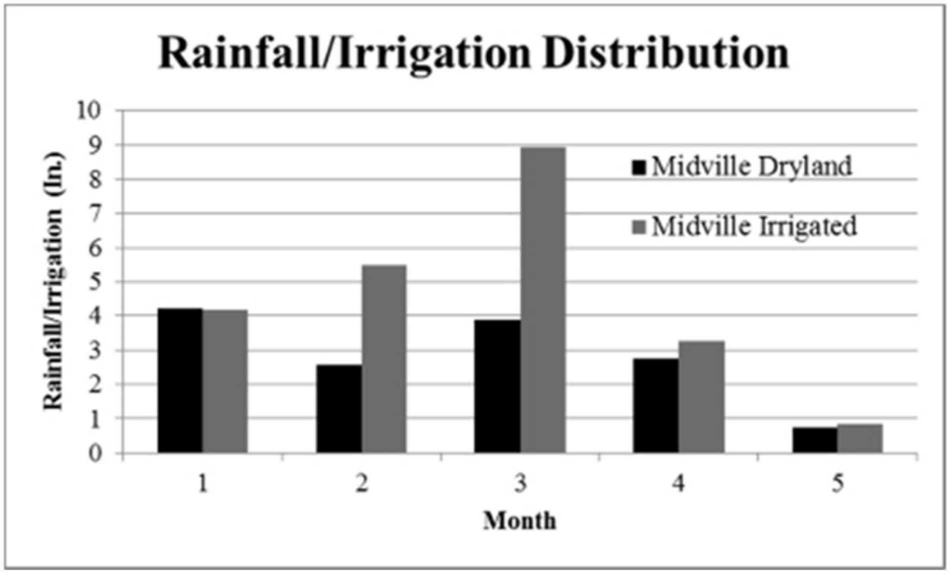

Figure 6. This graph shows the amount of rainfall/irrigation recorded by rain gauges in both Midville Dryland (black) and Midville Irrigated (grey) from the time that sensors were installed until cutout. The lower amount of rainfall recorded during month 5 is due the sensors being uninstalled during that time.

Figure 7 shows the amount of rainfall received by both Grady Dryland and Mitchell Dryland by month. Grady Dryland's final yield was 1626 lb/ac and Mitchell Dryland's yield was 607 lb/ac. Each trial received comparable amounts of rainfall during the first month. Mitchell Dryland received about an inch more in the second month than Grady Dryland. However, during the third month, which would have been during flowering, Grady Dryland received three inches of rainfall more than Mitchell Dryland. This difference in rainfall received during the critical growth period more than likely contributed to Grady Dryland's 1000 lb/ac increase in yield. The total water requirement for cotton during bloom ranges from 1.5 to 2.0 inches per week, therefore, during the third month the crop needed between 6 to 8 inches of water. As can be seen in figure 7, Mitchell fell far short of this, and Grady received between three-quarters to half of the required amount, however, the additional rainfall received by Grady added to the additional yield above that of the Mitchell trial.

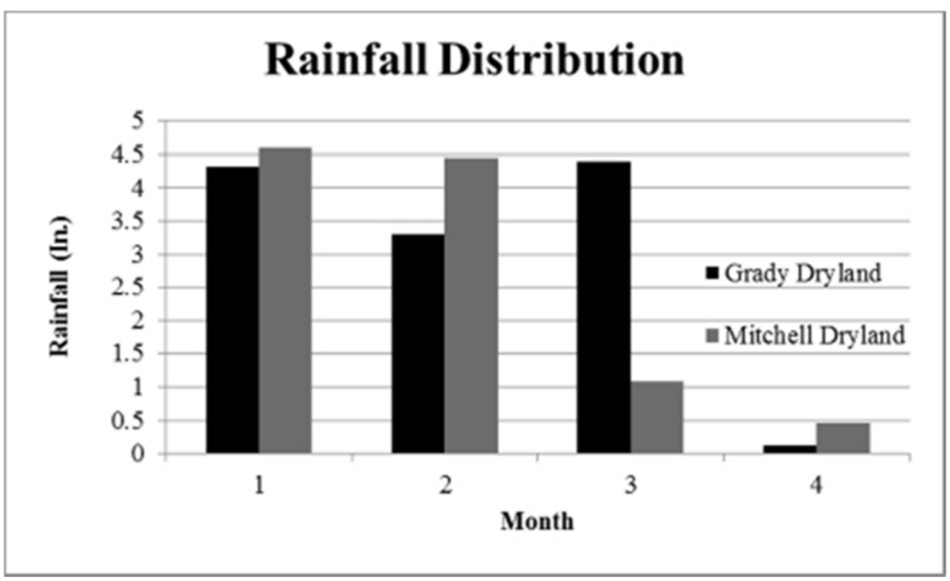

Figure 7. This graph shows the amount of rainfall/irrigation recorded by rain gauges in both Grady Dryland (black) and Mitchell Dryland (grey) from the time that sensors were installed until cutout. The lower amount of rainfall recorded during month 4 is due the sensors being uninstalled during that time.

Figure 8 shows the amounts of rainfall received by Grady Dryland and Midville Irrigated from the time sensors were installed until cutout. Grady Dryland yielded 1626 lb/ac and Midville Irrigated yielded 1702 lb/ac. Midville Irrigated received about 9 inches more rainfall and irrigation than Grady Dryland. This increase in rainfall and irrigation only increased yield by 76 lb/ac. In this case irrigation/rainfall did not appear to be the yield limiting factor. The addition of the extra irrigation to the Midville trial only increased production costs since there was no yield benefit.

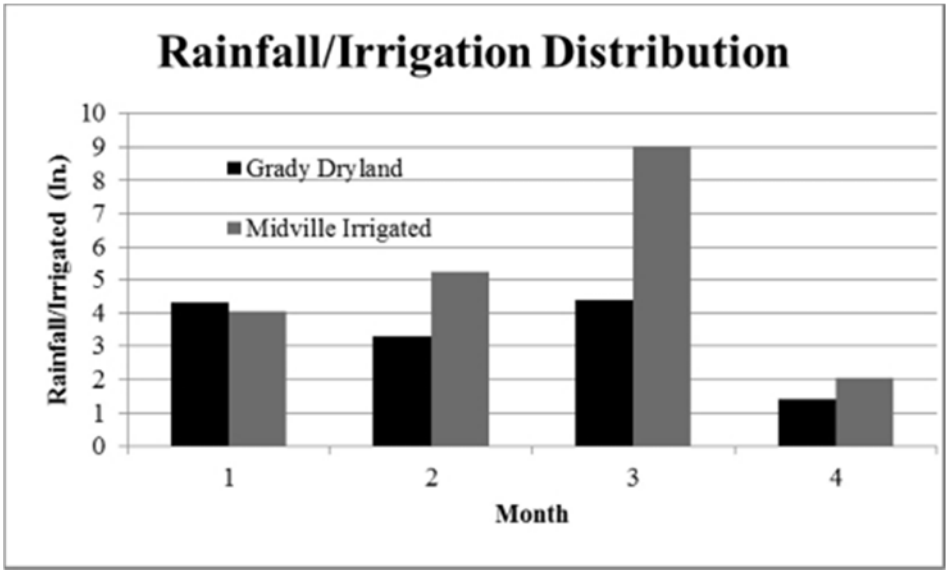

Figure 8. This graph shows the amount of rainfall/irrigation recorded by rain gauges in both Grady Dryland (black) and Midville Irrigated (grey) from the time that sensors were installed until cutout. The lower amount of rainfall recorded during month 4 is due the sensors being uninstalled in Grady Dryland during that time.

Figure 9 represents the amount of rainfall received by Appling Dryland and Bleckley Dryland from the time sensors were installed until cutout. Each trial had similar yields where Appling Dryland yielded 1132 lb/ac and Bleckley Dryland yielded 1085 lb/ac. Appling Dryland received about 7 inches more rainfall and irrigation than Bleckley Dryland. This increase in rainfall only increased yield by 47 lb/ac. Thus, in this case the additional rainfall, especially very early and very late in the season had no additional yield benefit. This trial shows that it is more critical to receive the additional rainfall/irrigation during flowering to have an impact on yield, and that poorly distributed water applied to the crop is not beneficial.

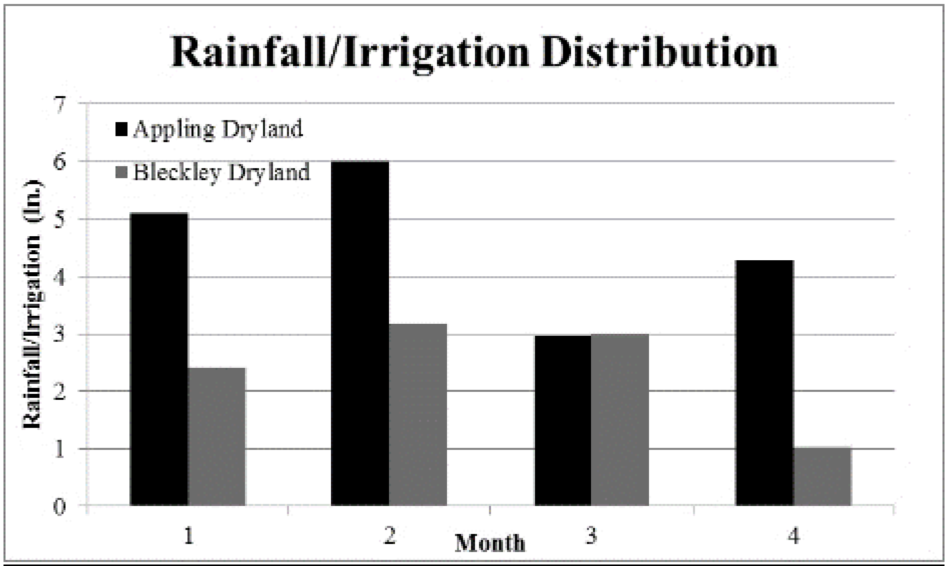

Figure 9. This graph shows the amount of rainfall/irrigation recorded by rain gauges in both Appling Dryland (black) and Bleckley Dryland (grey) from the time that sensors were installed until cutout. The lower amount of rainfall recorded during month 4 is due to the sensors being uninstalled during that time.

Figure 10 represents the amount of rainfall/irrigation received by Screven Irrigated and Burke Irrigated from the time sensors were installed until cutout. Screven Irrigated yielded 1079 lb/ac and Burke Irrigated yielded 1510 lb/ac. Screven Irrigated received more rainfall and irrigation but there was only a .5 inch difference in rainfall and irrigation amounts over the season. The difference in overall irrigation did not matter as much as when the water was applied. A more equal distribution over the season likely contributed to an increase in yield in Burke Irrigated. The excessive rainfall during the squaring to flowering stages in this case more than likely added to the reduction in yield in the Screven trial. As stated by Perry et al. excessive amounts of water during squaring could cause square shedding and decrease yield. Since the amount of irrigation/rainfall received during this stage on the Screven trial was much higher than required it is very probable that square shedding occurred. The Burke trial had an amount of rainfall/irrigation that was closer to the crop requirement applied, thus aiding it in producing a higher yield in this case.

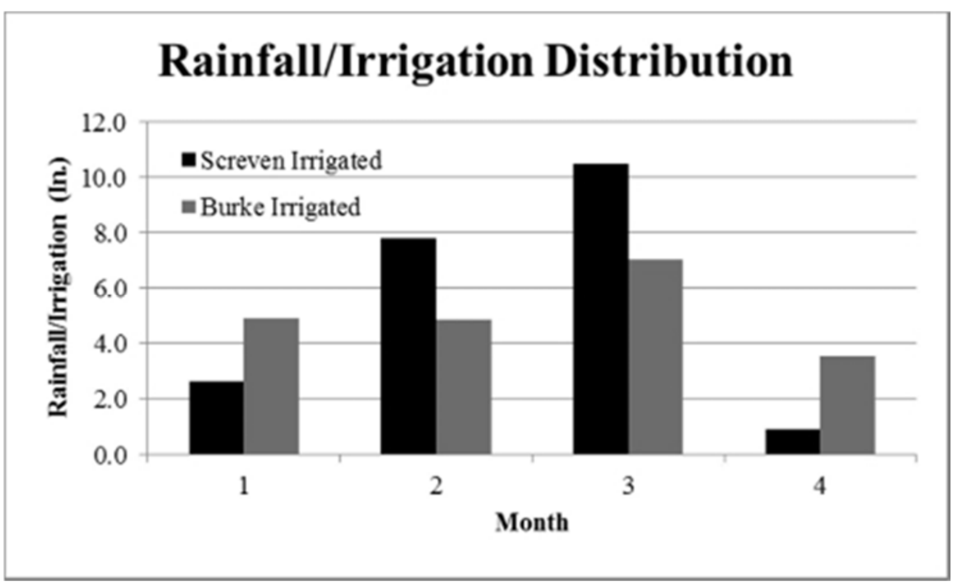

Figure 10. This graph shows the amount of rainfall/irrigation recorded by rain gauges in both Screven Irrigated (black) and Burke Irrigated (grey) from the time that sensors were installed until cutout. The lower amount of rainfall recorded during month 4 is due the sensors being uninstalled during that time.

Conclusions

Twenty trials were monitored for rainfall, irrigation, and soil moisture across the southern part of Georgia in order to help quantify the effect of water received at different growth stages on final crop yield. Overall, throughout the data strong correlations were not found due to a high number of sites and inability to monitor fields continually. Very weak correlations were found between pre-bloom total water received and final yield. Suggesting that there is little correlation to how the crop will perform based on the amount of rainfall and irrigation it receives pre-bloom. The same poor correlations were found between the volumetric water content pre-bloom and final yield. Stronger correlations were found between total water received over the entire season and final yield. Primed acclimation studies have shown that cotton has the ability to recover from water stress early in the season (pre-squaring and bloom), if ample water is received once the crop reaches bloom. This strengthens the argument that timing of irrigation throughout the season especially during bloom is very critical. Rainfall and irrigation distribution was shown to be the most important factor on final crop yield throughout the season. Different trials showed that excessive water pre-bloom did not help to compensate for a lack of rainfall during bloom, while other trials, supported the argument that a lack of sufficient water pre-bloom could be compensated for by the addition of sufficient well distributed water during the bloom period. Growing degree days seemed to have a small influence that affected some of the trials final yield, but not as significantly as water distribution. Excessive amounts of water received by the crop in some cases appeared to have limited the crop yield. There were also trials in which no additional yield benefit was found when the total amount of applied irrigation or rainfall exceeded the amount required by the crop for that particular growth stage. The critical point that can be gathered from this research is that the timing and amount of irrigation and/or rainfall during critical growth stages of the crop, specifically during bloom on cotton, has the largest impact on final crop yield.

References

Gwathmey, C.O., B.G. Leib, C.L. Main. Lint Yield and Crop Maturity Responses to Irrigation in a Short-Season Environment. 2011. The Journal of Cotton Science. 15: 1-10.

Hiler, E. A., T. A. Howell. 1983. Irrigation Options to Avoid Critical Stress: An Overview. Limitations to Efficient Water Use in Crop Production. American Society of Agronomy.

Perry, C.D and E Barnes. 2012. Cotton Irrigation Management for Humid Regions. Cotton Incorporated. http://www.cottoninc.com/fiber/agriculturaldisciplines/engineering/irrigation-management/cotton-irrigation-web.pdf

Sheedy, M.D., J.E. Watson, E.C Martin. 1997. Economic Thresholds for Irrigation Management Decisions. Proceedings of the Beltwide Cotton Conference. 1: 593-597.

Simao, F.R., G.L. Ritchie, C.W. Bednarz. 2013. Cotton Physiological Parameters Affected by Episodic Irrigation Interruption. Journal of Agricultural Science and Technology. 3: 443-454.

Snowden, M.C., G.L. Ritchie, F.R.Simao, J.P. Bordovsky. Timing of Episodic Drought Can Be Critical in Cotton. Agronomy Journal. 106: 452-458.

"USDA/NASS 2014 State Agriculture Overview for Georgia." Nass.usda.gov. USDA, 30 Nov. 2015. Web. 30 Nov. 2015.