YIELD, FIBER QUALITY AND ECONOMIC NET RETURN COMPARING TRADITIONAL vs. PLANT-BASED IRRIGATION TRIGGERS

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Introduction

Drought events and increased awareness of water supply and usage has increased emphasis on the need to utilize water resources more efficiently. In agriculture, increases in the efficiency with which water is used for irrigation could strongly impact water use and conservation. One way to improve water productivity—sometimes referred to as "water use efficiency"—is through efficient irrigation scheduling methods.

Irrigation scheduling is the process of determining how much water to apply and when to apply it. Traditional methods of scheduling irrigation are generally based on a water balance approach. That is, irrigation is applied as a supplement to rainfall such that the sum of rainfall plus irrigation meets the growth stage and environment-specific water requirements of the crop.

Crop water use can be estimated as crop evapotranspiration using weather station data and crop specific coefficients. An even simpler approach is to assume that crop water use during a particular stage of crop development will always be the same, regardless of atmospheric conditions such as humidity, solar radiation and air temperature. The "checkbook approach" recommended by University of Georgia Cooperative Extension (Collins et al., 2014) is one such method.

These methods for approximating crop water use do not, however, account for plant-based factors that impact actual crop water use. Leaf area, for example, strongly determines crop evapotranspiration (Gardner et al., 1985). As a result, water use can be inaccurately estimated for the cotton crop if canopy development differs between varying production systems at the same phenological stage of development. Furthermore, in determining the amount of water available in the soil profile, the effective rooting depth of the crop must be estimated. The effective rooting depth may also differ widely from one production system to the next.

Because the plant itself represents the best indicator of the need for irrigation (Grimes and Yamada, 1982; Jones et al., 2004), using a measure of plant water status should greatly improve water productivity. Predawn leaf water potential is one of the best indicators of the need for irrigation and has been successfully utilized as an irrigation-scheduling tool in tree species (Ameglio et al., 1999). In a study conducted concurrently to the study reported here, using predawn water potential to schedule irrigation produced optimal lint yields while maximizing water productivity. The impact of leaf water potential-based scheduling methods on net returns in cotton has not been addressed previously, but will be of substantial importance in determining economic viability of these methods in the future.

Objective

The objective of the current study was to assess the impact of predawn water potential plant-based scheduling methods on agronomic productivity and economic productivity in cotton in relation to traditional methods and dryland production.

Methodology

For the 2013 and 2014 growing seasons, research was conducted at the C.M. Stripling Irrigation Research Park near Camilla, Georgia. Two cotton cultivars—PHY 499 WRF and FM 1944 GLB2—were strip-till planted at a rate of 3 seed per foot at a depth of three-quarters of an inch and with 36-inch inter-row spacing. Plots were 40 feet in length and six rows wide. All fertility and pest management practices adhered to UGA Extension guidelines to prevent either factor from being a yield constraint.

Prior to squaring, rainfall was supplemented with sprinkler irrigation to promote uniform stand establishment in all treatments. At squaring, five different irrigation treatments were initiated:

T1 Irrigated according to the "checkbook method" recommended by UGA Extension. The total weekly water requirement for a given phenological stage was split into three applications made on Monday, Wednesday and Friday of each week. (For example, a weekly requirement of 1 inch per week would be split into three, one-third-inch applications in the absence of rainfall.) Rainfall was always subtracted from the checkbook requirement prior to irrigating, such that a crop with a weekly water requirement of 1 inch that received more than or equal to one-third inch of rainfall prior to an application day would not have been irrigated on that date.

T2-T4 Irrigation application was triggered when the average predawn (4 a.m. to 6 a.m.) leaf water potential—measured three times per week—for each treatment fell below the following predefined irrigation thresholds for each treatment: T2 = -0.5 megapascal (MPa), T3 = -0.7 MPa and T4 = -0.9 MPa. Measurements were conducted and irrigation decisions made on the same days that irrigation decisions were made for T1. Water was applied at one-third the weekly total checkbook rate when the given plant-based irrigation threshold was reached, regardless of rainfall.

T5 No supplemental irrigation provided beyond stand establishment

Irrigation treatment was the whole-plot factor, and the cultivar was the split-plot factor. Irrigation was accomplished with 30-centimeter-deep subsurface drip tape between every other row. Irrigation was terminated when open bolls were first observed in the latest maturing plots. The experimental design was a randomized, complete block split-plot design with four replications of each treatment.

Predawn leaf water potential measurements were conducted between 4 a.m. and 6 a.m. using a Scholander pressure chamber. Leaves from the fourth unfurled leaf node below the apical meristem were cut from one plant per plot using a razor blade, and the petiole was sealed with a compression gasket located in the chamber head. The leaf blade was then placed in the chamber, and air pressure was increased inside the chamber at a rate of 0.1 MPa per second until water first appeared at the cut surface of the stem. These positive pressures were expressed as negative water potentials. Measurements from leaves of both varieties with four replications for each treatment (n=8) were averaged and used to make irrigation scheduling decisions.

Plots were defoliated at approximately 70 percent open boll. The two center rows of each four-row plot were mechanically harvested using a two-row spindle picker. Seedcotton was weighed in the field and ginned at the UGA microgin to determine lint turnout and lint yield. Ginned cotton was sent to the U.S. Department of Agriculture Classing Office in Macon, Georgia, to determine fiber quality measurements.

Results and Discussion

Yield

In 2013, there was no statistical difference in yield among the five treatments (Figure 1). The highest yielding treatment was T3 (irrigating when leaf water potential was below -0.7 MPa). The lowest yielding treatment was T5, the non-irrigated treatment. But there was only an 83 pound-per-acre difference between the highest yielding irrigated treatment and lowest yielding (non-irrigated) treatment. There was no statistical difference in yield among any of the irrigation triggers.

2013 was a wet growing season, with season-long rainfall. Rainfall during the season totaled 26.35 inches. The T1 treatment using the UGA checkbook method received only 6.85 inches of irrigation. T2, the first that would have been triggered under the various leaf water potential treatments, received 4.5 inches of irrigation. T3, the highest yielding treatment numerically, received only 1 inch of irrigation. Treatment T4, -0.9 MPa, was never triggered (Figure 3).

In 2014, T1 (using the UGA checkbook method) and T2 (-0.5 MPa) were the highest yielding treatments and were significantly higher than T3, T4 and T5 (Figure 2). Both T1 and T2 yielded almost 1,800 lbs per acre.

2014 was the complete opposite of 2013. July and August were dry. Rainfall during the season was 10.63 inches. The T1 treatment (using the UGA checkbook method) triggered 11.1 inches of irrigation. T2 received 8.66 inches of irrigation (Figure 3). Yields for T1 and T2 were not statistically different, and T2 received 2.44 inches less irrigation water.

Fiber Quality

2013 was not a stellar year for fiber quality in the test. The predominant Color grade was 41, but there were several instances of 42, 51 and 52 Color. There was no relationship between treatment and Color grade, but there was a variety effect. There were seven instances out of 40 plots (five treatments x four replications each x two varieties) of below-base grade Color, and five were with PHY 499.

Micronaire was a significant problem in the test in 2013, as well as statewide. Thirty of the 40 plots were high micronaire, or having a micronaire of 5.0 or higher. This is thought to be due to plant stress caused by excessive rainfall. There was no relationship between treatment and the incidence of high micronaire, however.

For 2013, there was also no relationship between treatment and staple length, length uniformity and fiber strength. There was a variety effect on Staple but no treatment effect. Staple was higher for FM 1944.

The predominate Color grade for 2014 was 31. There was no treatment effect on Color. There was a treatment effect on micronaire. 2014 was dry during July and August. Micronaire increased as the amount of irrigation water applied decreased—micronaire was higher for T4 and T5 as compared to T1, T2 and T3. Fifteen of 16 plots in the T4 (-0.9 MPa) and T5 (non-irrigated) treatments were 5.0 or higher.

There were no treatment effects on Staple and Leaf grade, but there was a variety effect. FM 1944 was higher in Staple and better in Leaf grade.

Net Returns

For each treatment, all inputs and production practices were the same, except for irrigation. For treatments T1 through T4, irrigation was applied based on the specific trigger for that treatment. Irrigation cost was calculated for each treatment. T5 was non-irrigated. Net return was calculated as:

$$\text{Net} = (\text{Yield x Adjusted Price}) - \text{VC}$$

Yield = The average lint yield (pounds per acre) for both varieties (PHY 499 WRF and FM 1944 GLB2). Yield is the average of the four replications for each treatment, each year.

Adjusted Price = The November average Southeast cash market price per pound each year for grade 41-4/34, adjusted for Color, Leaf, Staple, Strength, Micronaire, and Uniformity. This adjusted price is calculated for the grades of the sample from each replication of each treatment and is the average of all replications for both varieties by treatment.

VC = The variable costs of irrigation application (fuel and/or electricity, repairs and maintenance, and labor). This cost is the estimated cost per acre-inch times the inches applied based on the respective treatment.

Fiber quality-adjusted prices used for the 2013 and 2014 tests were determined from the November 2013 and November 2014 spot (cash) market average price paid for Color 41-Leaf 4/Staple 34 and market differentials (premiums or discounts) paid for quality (USDA-AMS). The base price (for 41-4/34) was 75.63 and 60.70 cents per pound for November 2013 and 2014, respectively, and this price was adjusted up or down for fiber quality of the treatment.

In this study, irrigation, when triggered, was applied via subsurface drip irrigation (SSDI). However, in Georgia, most irrigation is overhead via center pivot. In an attempt to more closely apply these results and to simulate cost and net returns associated with center pivot, when calculating the variable cost of irrigation, the amount of irrigation applied by SSDI in the study was increased by 23.46 percent. This implies that irrigation by overhead is 81 percent as efficient as SSDI (Amosson, et.al.). In other words, if 11.1 inches were applied by SSDI, 13.7 inches would need to be applied by overhead irrigation in order for the cotton plant to have the same water availability. Table 1 shows the actual water applied via SSDI and the equivalent water assumed applied by overhead (OVH) based on 81 percent efficiency for OVH.

The variable cost of irrigation for each treatment is the estimated equivalent amount for an overhead pivot (Table 1) multiplied by $12.12 per inch for 2013 and $11.75 per inch for 2014 (Shurley and Smith, 2013; Smith, Smith and Shurley, 2013 and 2014).

Summary results for Net Returns are given in Table 2. Net Return is the composite comparison of differences in yield, fiber quality, and cost of irrigation between irrigation trigger treatments. In 2013, treatment T3 (plant-based trigger of -0.7 MPa) resulted in the highest net return. This was due to having the highest yield and low irrigation use and cost, despite not having quite the highest fiber quality. Net return for T3 was $1,129 per acre. There was, however, no statistical difference in Net Return between T2, T3, T4 or T5. T1 (using the UGA checkbook method) had the lowest net return and was statistically different.

In 2014, the highest net return was from treatment T2 (using a plant-based trigger of -0.5 MPa). Net return was $1,052 per acre. T2 was not statistically different than T1 (using the UGA checkbook), but both T2 and T1 were statistically different that the other three treatments.

2013 was a “wet” year. There was no statistical difference in yield between any of the treatments. Treatment T1 (using the UGA checkbook) had the highest irrigation application and cost and, therefore, resulted in the lowest net return. Treatment T4 (trigger of -0.9 MPa) did not trigger an irrigation application.

In contrast, 2014 was a “dry” year. Yield was statistically different between all but T1 and T2—the treatments using the UGA checkbook method and the highest plant-based trigger (-0.5 MPa), respectively. Net Return was highest for T2 due to slightly higher yield with less irrigation compared to T1, but Net Return was not statistically different between T1 and T2. The lowest Net Return was T5 (unirrigated) and T4 among the irrigated treatments.

Summary

One way to improve water productivity—sometimes referred to as water use efficiency—is through efficient irrigation scheduling methods. Irrigation scheduling is the process of determining how much water to apply and when to apply it. The objective of this study was to assess the impact of predawn water potential plant-based scheduling methods on agronomic productivity and economic return in comparison to traditional methods and dryland production.

2013 was a wet growing season with season-long rainfall. There was no statistical difference in yield among the treatments. 2014 was the complete opposite of 2013. July and August were dry. In 2014, T1 (using the UGA checkbook method) and T2 (using a plant-based trigger at -0.5 MPa) were the highest yielding treatments and were significantly higher than the other treatments.

There was no relationship between treatment and Color grade in 2013 or 2014. High micronaire was a problem in 2013, but there was no relationship between treatment and micronaire. There was a treatment effect on micronaire in 2014. There was no relationship between treatment and staple length, length uniformity and fiber strength in either year of the study.

In 2013, there was no statistical difference in net return between T2, T3, T4 or T5. T1 (using the UGA checkbook method) had the lowest net return and was statistically different from all plant-based treatments. In 2014, the highest net return was from treatment T2 (using a plant-based trigger of -0.5 MPa). T2 was not statistically different than T1 (using the UGA checkbook) but both T2 and T1 were statistically different than the other three treatments.

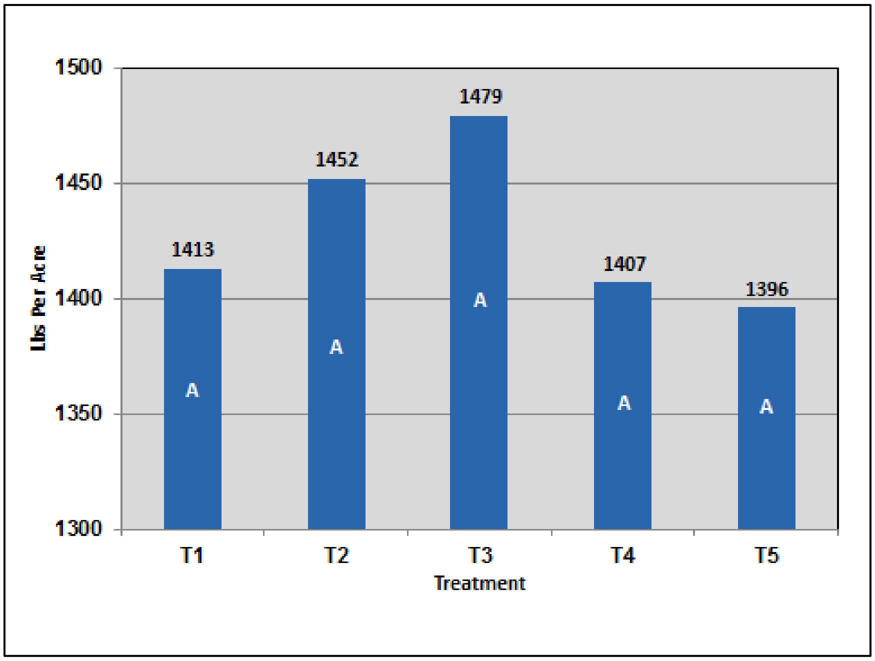

Figure 1. Average Yield Per Acre by Treatment, 2013. Average of Two Varieties. T2-T4 are Plant-Based Irrigation Triggers Based on Predawn Leaf Water Potential. Treatments With the Same Letter are Not Statistically Different at the 95 Percent Level. T1= UGA Checkbook, T2 = -0.5 MPa, T3 = -0.7 MPa, T4 = -0.9 MPa, T5 = Non-Irrigated

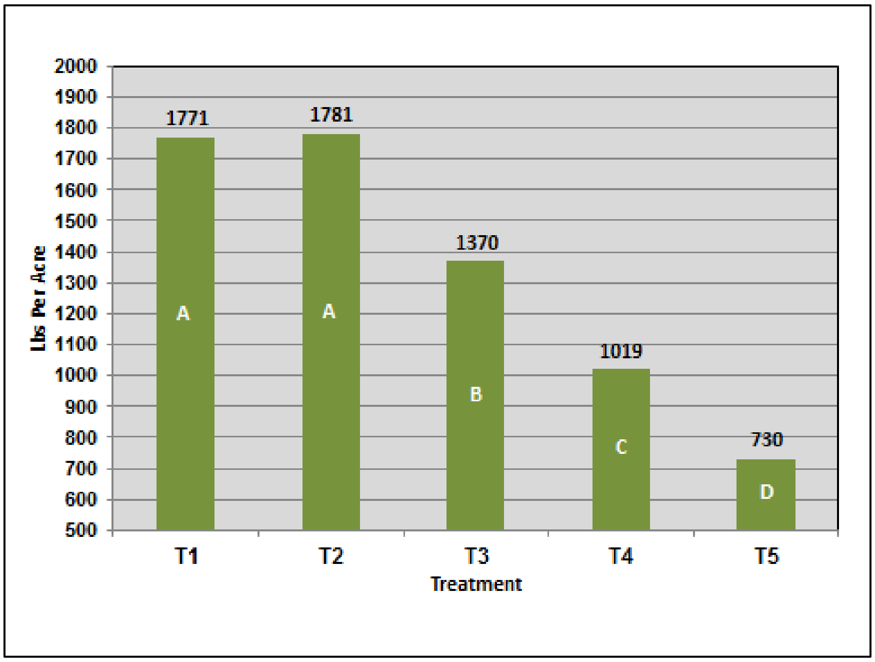

Figure 2. Average Yield Per Acre by Treatment, 2014. Average of Two Varieties. T2-T4 are Plant-Based Irrigation Triggers Based on Predawn Leaf Water Potential. Treatments With the Same Letter are Not Statistically Different at the 95 Percent Level. T1= UGA Checkbook, T2 = -0.5 MPa, T3 = -0.7 MPa, T4 = -0.9 MPa, T5 = Non-Irrigated

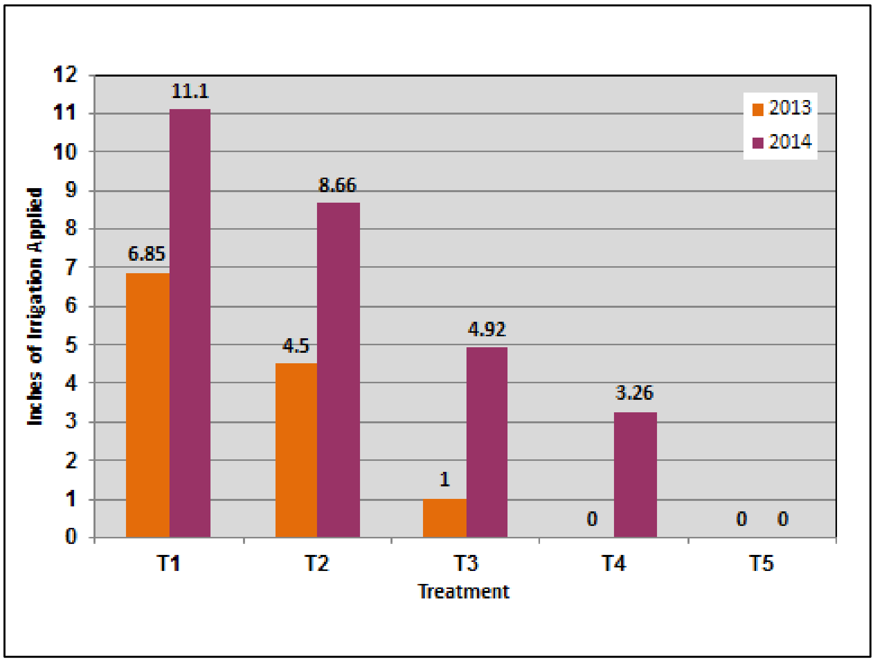

Figure 3. Irrigation Applied by Treatment in 2013 and 2014. T2-T4 are Plant-Based Irrigation Triggers Based on Predawn Leaf Water Potential. T1= UGA Checkbook, T2 = -0.5 MPa, T3 = -0.7 MPa, T4 = -0.9 MPa, T5 = Non-Irrigated. Rainfall received was 26.35 inches in 2013 and 10.63 inches in 2014.

Table 1. Irrigation Applied By Treatment By Year

	2013 Irrigation Applied[1]		2014 Irrigation Applied[1]	
Treatment	**Actual SSDI**	**Est Equiv OVH[2]**	**Actual SSDI**	**Est Equiv OVH[2]**
T1	6.85	8.46	11.10	13.70
T2	4.50	5.56	8.66	10.69
T3	1.00	1.23	4.92	6.07
T4	0.00	0.00	3.26	4.02
T5	0.00	0.00	0.00	0.00

1/ Inches per acre.

2/ Inches applied using SSDI divided by 0.81 or multiplied by 1.2346

Table 2. Yield, Price, Irrigation Cost and Net Returns by Treatment, 2013 and 2014.

Treatment		2013					2014					2-Yr
		Yield[1]	Price[2]	VC[3]	Net[4]		Yield[1]	Price[2]	VC[3]	Net[4]		Avg[5]
T1		1,413	76.00	$102.54	$971[b]		1,771	65.24	$161.02	$994[a]		$983
T2		1,452	77.95	$67.36	$1,064[a]		1,781	65.43	$125.62	$1,040[a]		$1,052
T3		1,479	77.36	$14.97	$1,129[a]		1,370	65.42	$71.37	$825[b]		$977
T4		1,407	76.25	$0.00	$1,073[a]		1,019	63.29	$47.29	$598[c]		$835
T5		1,396	77.42	$0.00	$1,081[a]		730	62.83	$0.00	$459[d]		$770

1/ Average of two varieties—PHY 499 WRF and FM 1944 GLB2.

2/ Cents per pound. Base price of 75.63 cents/pound for November 2013 and 60.70 cents/pound for November 2014, adjusted for fiber quality. Average price for the two varieties.

3/ Variable costs of irrigation application—$12.12 per acre-inch in 2013 and $11.75 per acre-inch in 2014.

4/ Yield per acre times price per pound, minus irrigation variable cost. Net returns followed by the same letter are not statistically different at the 95 percent level.

5/ Average net return of 2013 and 2014.

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References

Ameglio, T., Archer, P., Cohen, M., Valancogne, C., Daudet, F. A., Dayau, S., & Cruiziat, P. (1999). Significance and limits in the use of predawn leaf water potential for tree irrigation. *Plant and Soil, 207*, 155-167.

Amosson, S., Almas, L., Girase, J., Kenny, N., Guerrero, B., Vimlesh, K., & Marek, T. (2011). *Economics of irrigation systems* (B-6113). College Station, TX: Texas AgriLIfe Extension Service.

Collins, G. (Ed.). (2014). *2014 Georgia cotton production guide* (CSS-14-01). Tifton, GA: University of Georgia College of Agricultural and Environmental Sciences.

Gardner, F. P., Pearce, R. B., & Mitchell, R. L. (1985). *Physiology of crop plants.* Ames, IA: Iowa State University Press.

Grimes, D., & Yamada, H. (1982). Relation of cotton growth and yield to minimum leaf water potential. *Crop Science, 22*(1), 134-39.

Jones, H. G. (2004). Irrigation scheduling: Advantages and pitfalls of plant-based methods. *Journal of Experimental Botany, 55*(407), 2427-2436.

Shurley, D., & Smith, A. (2013). *Cotton- strip-till, irrigated: 2013 estimated per acre costs and returns, south and east Georgia*. Retrieved from: http://www.caes.uga.edu/departments/agecon/extension/budgets/cotton/index.html

Smith, A. R., Smith, N. B., & Shurley, W. D. (2013). *Crop comparison tool: Summary of south Georgia crop enterprise estimates, 2013.* Retrieved from: http://www.caes.uga.edu/departments/agecon/extension/budgets/cct/index.html

Smith, A. R., Smith, N. B., & Shurley, W. D. (2014). *Crop comparison tool: Summary of south Georgia crop enterprise estimates, 2014*. Retrieved from: http://www.caes.uga.edu/departments/agecon/extension/budgets/cct/index.html

U.S. Department of Agriculture, Agricultural Marketing Service, Cotton and Tobacco Program. (2013). *Cotton price statistics (Mp_cn820)*, 95(4).

U.S. Department of Agriculture, Agricultural Marketing Service, Cotton and Tobacco Program. (2014). *Cotton price statistics (Mp_cn820)*, 96(4).