IRRIGATION SCHEDULING FOR COTTON AND SOYBEAN IN NORTHEAST LOUISIANA

S.S. Hague[1] and A.B. Coco[2]

ABSTRACT

Yield response from irrigation varies widely from year to year in Northeast Louisiana for cotton and soybean grown on alluvial soils. Studies were initiated to identify irrigation schedules that optimize yield and water use efficiency. Cotton and soybean experiments were conducted with furrow irrigation systems that compared various regimes derived from the Arkansas Irrigation Scheduler (AIS). Soil moisture depletion as predicted by AIS was also monitored with Watermark soil moisture sensors. The most intensive AIS irrigation schedules promoted the highest yields in cotton and soybean, but often more conservative irrigation approaches were just as effective. At low soil moisture deficits, Watermark sensors and AIS soil moisture values were similar, but as moisture deficits escalated, results from the systems diverged. Irrigation scheduling systems need to account for in-season dynamics of cotton and soybean crops, optimize yield, and eliminate unnecessary irrigation.

Keywords: Irrigation scheduling, Cotton irrigation, Soybean irrigation, Arkansas Irrigation Scheduler, Watermark soil moisture sensor.

INTRODUCTION

Rainfall in Northeast Louisiana can vary greatly from year to year. Devising irrigation schedules for relatively drought tolerant crops such as cotton and soybean grown on soils with a high water holding capacity and for deep root penetration can be very challenging. Escalating fixed costs such as land, equipment, and planting seed, coupled with low cotton and soybean commodity prices have made investment in irrigation a risky proposition. In addition, yield responses from irrigation depends on rainfall patterns during the season. This results in an extended payback period for investment in irrigation infrastructures. Nevertheless, irrigation is a tool that reduces risk of cotton and soybean production in years when rainfall is sporadic and worthy of investigation. Poorly timed irrigation can result in sub-optimal yield performance (Orgaz et al., 1992; Radin et al., 1992) and inferior fiber properties (Boquet et al., 2000). Efficient use of irrigation saves energy and water while reducing damage to the environment and enhancing long-term sustainability (Bosch and Ross, 1990; Raghuwanshi and Wallender, 1998; Howell, 2001).

Irrigation timing should be based on plant or soil water status (Steger et al., 1998). Irrigation regimes that quickly replenish soil-moisture after depletion from evapotranspiration generally are superior to less frequent, high volume irrigation (Phillips, 1980; Pringle et al., 1989; Radin et al., 1992; Orgaz et al., 1992; Bordovsky and Lyle, 1999). Delaying initial irrigation for cotton can retard lint yield potential (Johnson et al., 1989; Steger et al., 1998). Likewise, premature irrigation termination can limit lint yield (Palomo and Godoy, 1998; McConnell et al., 1999). Nevertheless, cotton has considerable compensatory abilities to recover from both early season and late season drought stress and produce acceptable lint yield (Ball et al., 1994; Pace et al., 1999; Wanjura and Upchurch, 1999). In most years on alluvial soil in Northeast Louisiana, soil moisture is plentiful enough to ensure adequate vegetative soybean development. Avoiding stress during reproductive development, especially at or near anthesis, is critical for optimal soybean yields (Board and Harville, 1998; Heatherly, 1983).

[1] Research Agronomist, LSU AgCenter-Northeast Research Station, St. Joseph, LA; [2] Research Associate LSU AgCenter-Northeast Research Station, St. Joseph, LA.

Due to the cost-return ratio of irrigation in this region, most systems generally are low-cost, low-maintenance, and make inefficient use of water. Irrigation scheduling is an imperfect process at best on most farms in Northeast Louisiana. A limited number of producers use AIS software program developed by the University of Arkansas (Cahoon, et al., 1990). The program was not specifically developed for the unique growing conditions in Louisiana and many of the input parameters require a great deal of guesswork. Conditions that confound determination of irrigation scheduling in Northeast Louisiana include availability of moisture deep within soil profiles, transpiration rates affected by high relative humidity, and frequent returns to maximum soil-water holding capacity from rainfall events within a growing season. In most regions throughout the world, water availability is generally the most limiting factor for production; however, in Northeast Louisiana crop damage from insects and weed competition often are the most restrictive forces on yield potential. Information is needed that identifies scenarios in which irrigation and irrigation schedules have the greatest impact with the limited resources that producers are willing to invest in irrigation.

METHODS AND MATERIALS

Cotton

Experiments were established near St. Joseph, LA, on Commerce silt loam and Sharkey clay at Panola Corporation in 2000 and 2001, and on Sharkey clay at the LSU AgCenter-Northeast Research Station (NERS) in 2001 and 2002. Cultivar 'Deltapine NuCOTN 33B' was planted in all tests at the Panola Corporation. Experimental design was a randomized complete block with three replications in 2000 and four replications in 2001. In 2000, plots were 32 rows (97-cm center) x 243 m. In 2001, plots were 24 rows (97-cm center) x 243 m. Treatments were furrow irrigated. The four center rows of each plot were harvested with a four-row spindle type picker. Seed cotton was weighed in a boll buggy modified with a weigh cell. In 2001, cultivar 'Deltapine 458 B/R' was planted at NERS. Experimental design was a randomized complete block with four replications. Plots were 16-rows (102 cm center) x 61 m. Treatments were furrow irrigated. Two center rows of each plot were harvested with a one-row spindle-type picker. Sub-samples were ginned at the LSU AgCenter-Northeast Research Station's ginning laboratory to determine lint fraction. In 2002, the test at NERS was arranged in a split-split plot experimental design with nitrogen rates and cotton varieties as sub-factors; however, only the main effect of irrigation versus no irrigation will be discussed in this manuscript.

AIS requires users to select an allowable soil moisture deficit as defined by the amount of acre-inches of water lost from the soil due to evapotranspiration. As the calculated water budget is exhausted, AIS recommends irrigation. AIS was set at soil moisture deficits of 2-inches (AIS-2.0) and 3-inches (AIS-3.0). Temperature and rainfall data was collected from a weather station located at NERS. Other climate data required for the AIS was obtained from Calhoun, LA. The treatment, in which irrigation was initiated at AIS soil-moisture deficit of 4-inches (AIS-4.0), was switched to a 2-inch soil-moisture deficit after initial irrigation. The 1.5-inch water budget (WB-1.5) method assumed a 56 mm daily water use beginning at first bloom and continuing until two weeks past the first open boll (Hutchinson and Sharpe, 1989). This system assumed all precipitation was held in the soil and later available to plants. Tensiometers were placed at a depth of 10-inches in each plot and irrigation was triggered when analog gauges were at –0.75 bars. Non-irrigated treatments were included in all tests. In 2002 at NERS, Watermark soil moisture sensors were placed at 76-cm depths in all main treatments in three of the four replications. This particular depth was found to be optimal for irrigation predictions based on soil moisture (Boquet, 1989). Irrigated treatments in 2002 were scheduled with AIS-2.0.

Soybean

Experiments were conducted at Louisiana Delta Plantation, near Jonesville, LA, in 2000 on Tensas-Alligator clay, and at NERS in 2001 and 2002 on Sharkey clay. At Louisiana Delta, ‘Hartz 5588 RR’, a Maturity Group V cultivar was planted. Experimental design was a randomized complete block with four replications. Treatments were AIS set at 2-inch soil moisture deficit (AIS-2.0), AIS at 2.5-inch deficit (AIS-2.5), and a non-irrigated control. Plots were 16 rows (97-cm center) x 182-m. Irrigation treatments were furrow irrigated. Severe insect damage prevented collection of harvest data. At NERS ‘Suregrow 489 RR’, a late Maturity Group IV cultivar was planted. Experimental design was a randomized complete block with four replications. Treatments included AIS at 1.5-inch deficit (AIS-1.5) and 2.5-inch deficit (AIS-2.5), plus a non-irrigated control. Plots were 16 rows (102-cm center) x 106-m. Irrigation treatments were furrow irrigated. Temperature and precipitation data was collected at NERS. Other climate information for AIS was derived from Calhoun, LA. In 2002, Watermark soil moisture sensors were placed at 76-cm depths in all treatments in three of the four replications, but irrigation was always based upon the AIS system. Two center rows were harvested for yield.

Data were analyzed using the GLM procedures of SAS (SAS Institute, 2001) and LSD was calculated for mean comparisons.

RESULTS

Data from irrigation studies in Northeast Louisiana was affected considerably by rainfall events. The 2000 growing season from June to August was uncharacteristically dry with drought conditions intensifying in July and August (Table 1). Precipitation was more abundant in the 2001 and 2002 growing seasons. Not only did more rain fall during this time but the number of days in which rainfall events occurred increased from the 2000 weather pattern.

Soybean

Yield data in 2000 was not obtained because of severe stinkbug damage. Irrigation frequency was greatest in AIS-2.0 (Table 2). In 2001, the test at NERS resulted in no significant yield differences among irrigation schedules. The test averaged 3,534 kg ha^{-1}. Despite the frequent rainfall, AIS-1.5 received six irrigation applications and AIS-2.5 received three. In 2002, AIS-1.5 required three irrigations and AIS-2.5 received one irrigation. The AIS-1.5 irrigation schedule produced 4,609 kg ha^{-1}, which was significantly higher than AIS-2.5 and non-irrigated treatments.

Cotton

The largest response to cotton irrigation was observed in 2000 (Table 3). Tests at Panola Corporation on both soil types showed significant responses to irrigation with the greatest yield increases on Sharkey clay. In 2001, yield results were confounded by intense losses from boll rot due to frequent rainfall in August and September. Concomitantly, the experiment on Commerce silt loam at Panola Corporation and at NERS on Sharkey clay resulted in no significant yield responses among irrigation schedules. The experiment at Panola Corporation on Sharkey clay did, however, result in AIS-2.0 and WB-1.5 irrigation schedules yielding significantly more than AIS-3.0 and the non-irrigated regime. In 2002, irrigation frequency was limited to two applications due to frequent precipitation. That test has yet to be harvested.

Comparisons between AIS and Watermark soil moisture sensors were made in 2002 at NERS (Figure 1). AIS made a more precise prediction of soil moisture as measured by the Watermark system when soil moisture was relatively high. Correlation between AIS and Watermark values ranged from R^2= 0.4200 for soybean (AIS-1.5) to R^2= 0.1293 soybean non-irrigated.

DISCUSSION

The value of irrigating cotton in Northeast Louisiana was demonstrated in most experiments in this study, but effectiveness of one scheduling system over another was not overwhelming. The compensatory nature of cotton allows plants to continue to thrive even during short periods of drought stress. Frequency of irrigation on these soils with high water holding capacity did not affect yield to a great extent. Soybean are more sensitive to drought than cotton. AIS 1.5 ensured no drought stress occurred; however, such a frequent irrigation regime may waste water and could lead to losses from waterlogging (Linkemer et al., 1998). A more conservative approach with more precision may optimize yield and guard against the squandering of water.

A system that incorporates the positive aspects of AIS, such as irrigation projections that enhance farm management, but allows for in-season adjustments based on crop development (Jackson et al., 1990), and eliminates the guesswork associated with soil variation and crop conditions within fields is needed by cotton and soybean producers in Northeast Louisiana. Watermark soil moisture sensors may fill this need if an accurate and user-friendly system can be developed.

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Table 1. Rainfall events and monthly accumulation at LSU AgCenter's Northeast Research Station, St. Joseph, LA, in June, July, and August 2000-2002.

	June		July		August	
Year	Rain Events (days)	Total (mm)	Rain Events (days)	Total (mm)	Rain Events (days)	Total (mm)
2000	7	70	5	45	2	55
2001	13	156	8	106	10	101
2002	9	99	10	262	12	93

Table 2. Soybean response to irrigation schedules at Louisiana Delta, Jonesville, LA, and LSU AgCenter's Northeast Research Station, St. Joseph, LA, 2000-2002.

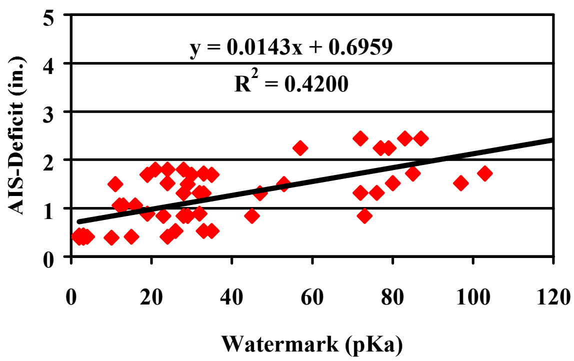
Location and Year	Schedule	kg ha^{-1}	# Irrigation
LA Delta (Tensas-Alligator clay)-2000	AIS-2.0 deficit	n/a	5
	AIS-2.5 deficit	n/a	3
	Non-irrigated	n/a	0
NERS (Sharkey clay)-2001	AIS-1.5 deficit	3,813	6
	AIS-2.5 deficit	3,462	3
	Non-irrigated	3,305	0
	Mean	3,534	
	LSD (0.05)	ns	
NERS (Sharkey clay)-2002	AIS-1.5 deficit	4,609	3
	AIS-2.5 deficit	4,446	1
	Non-irrigated	4,402	0
	Mean	4,484	
	LSD (0.05)	125	

Table 3. Cotton response to irrigation schedules at Panola Corporation and LSU AgCenter's Northeast Research Station, St. Joseph, LA, 2000-2002.

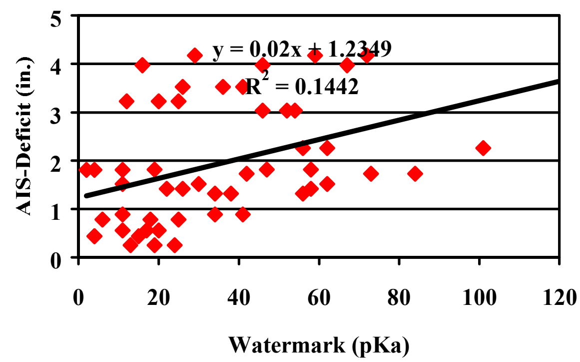
Location and Year	Schedule	Lint (kg ha^{-1})	# Irrigation
Panola (Commerce silt loam)-2000	WB-1.5 deficit	1,557	6
	AIS-2.0 deficit	1,500	5
	AIS-4.0 deficit	1,523	4
	Non-irrigated	1,193	0
	Mean	1,444	
	LSD (0.05)	249	
Panola (Sharkey clay)- 2000	AIS-2.0 deficit	1,525	5
	AIS-3.0 deficit	1,356	4
	WB-1.5 deficit	1,430	3
	Non-irrigated	886	0
	Mean	1,417	
	LSD (0.05)	175	
Panola (Commerce silt loam)-2001	AIS-2.0 deficit	974	3
	Non-irrigated	925	3
	AIS-3.0 deficit	900	2
	WB-1.5	887	0
	Mean	922	
	LSD (0.05)	ns	
Panola (Sharkey clay)- 2001	AIS-2.0 deficit	930	3
	WB-1.5 deficit	900	2
	AIS-3.0 deficit	772	2
	Non-irrigated	763	0
	Mean	841	
	LSD (0.05)	91	
NERS (Sharkey clay)-2001	AIS-2.0 deficit	1,117	3
	Tensiometer (-0.75 mb)	1,068	3
	AIS-3.0 deficit	1,068	3
	Non-irrigated	1,024	0
	Mean	1,070	
	LSD (0.05)	ns	
NERS (Sharkey Clay)-2002	AIS-2.0	n/a	2
	Non-irrigated	n/a	0

Figure 1. Relationship between soil moisture deficits as projected by AIS and indicated by Watermark soil moisture sensors in cotton and soybean at LSU AgCenter's Northeast Research Station, St. Joseph, LA, 2002.

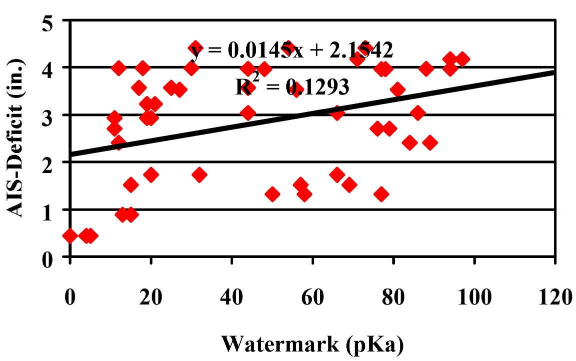
Soybean (AIS-1.5)



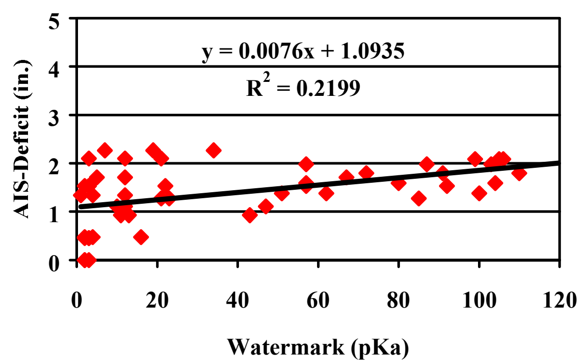
Soybean (AIS-2.5)



Soybean (non-irrigated)



Cotton (AIS-2.0)



Cotton (non-irrigated)