Development of Irrigation Management Practices for Optimum Yield and Water Use Efficiency of Soybean in East Central Mississippi

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Introduction

In the US second largest annual rainfall state of Mississippi, during soybean growing season May to September, the average monthly rainfall between 2002 to 2013 at Macon in northeast Mississippi ranges from 84 to 131 mm, while monthly mean reference ET calculated by the FAO-56 Penman-Monteith ranges from as high as 145 to 193 mm. 35-98 mm average monthly water deficit was estimated between soybean water requirement and rainfall supply. Additionally, the difference between the lowest and the highest monthly rainfall averaged over the past 12 years in the same month ranged from 171 to 233 mm, uncertainty is fairly high. Therefore, supplemental irrigation is still required to increase and stabilize soybean productivity. Producers in east central Mississippi have steadily increased their utilization of surface pond water for irrigation in recent years and eager to learn irrigation management practices.

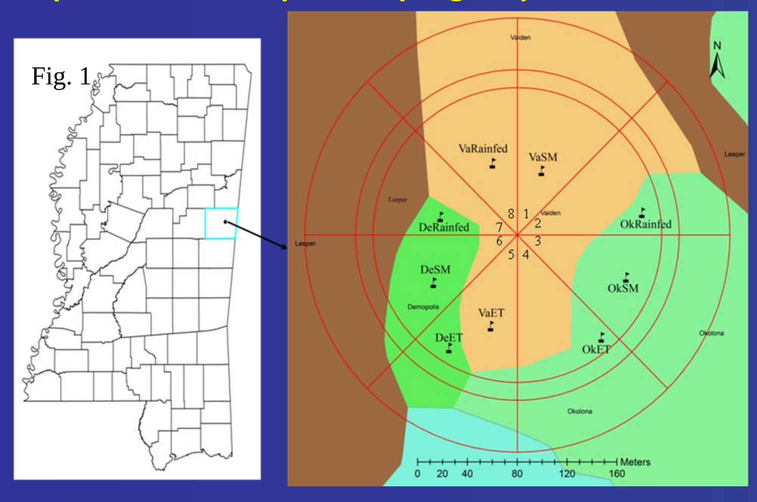
Objective

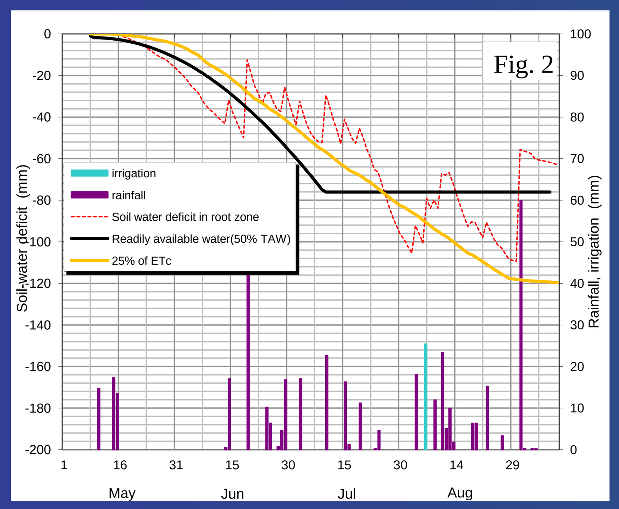
Compare ET based and soil moisture based irrigation scheduling methods to determine optimal irrigation amount, rate and timing (i.e., a triggering criteria) .

Materials and Methods

Experimental design

The project utilizes a 17-acre, pivot-irrigated field located at Good Farm in Noxubee County, MS. A group IV cultivar, Asgrow 4632, was planted on May 8, 2014. The irrigated area, which contains **Vaiden clay (Va), Okolona silty clay (Ok), and Demopolis clay loam (De)** soil types (9.4, 5.8, and 2.3 acres, respectively) was divided into eight pies to accommodate three treatments in each soil type of (i) 'RF', not irrigated (ii) 'SM', irrigation when root zone soil moisture is 50% of Total Available Water (TAW), and (iii) is 75% of calculated daily ET in the previous day, giving nine experimental plots (Fig. 1).





Sensors installation

In each plot (6 rows × 5 m), soil potential sensors (Watermark, Irrometer) and 5TM soil moisture sensor (Decagon, Inc.) at 6, 12, 24 and 36 inch depths, a pen lysimeter (Soil Moisture, Corp) and a microflume runoff collector were installed (ref. photos).

Acknowledgement

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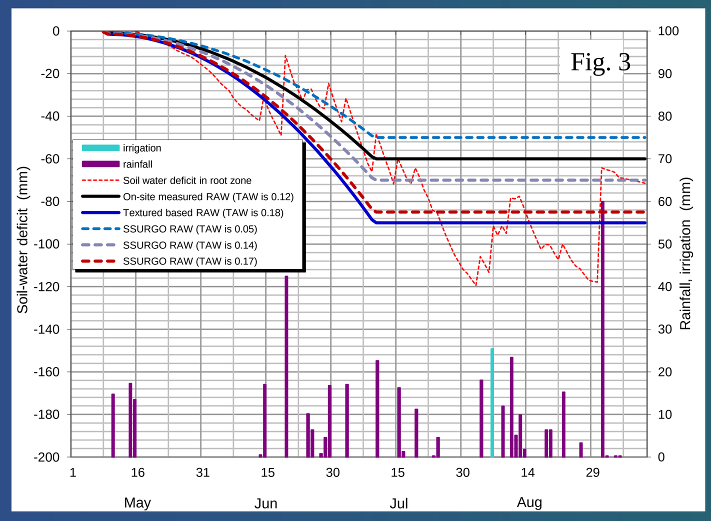
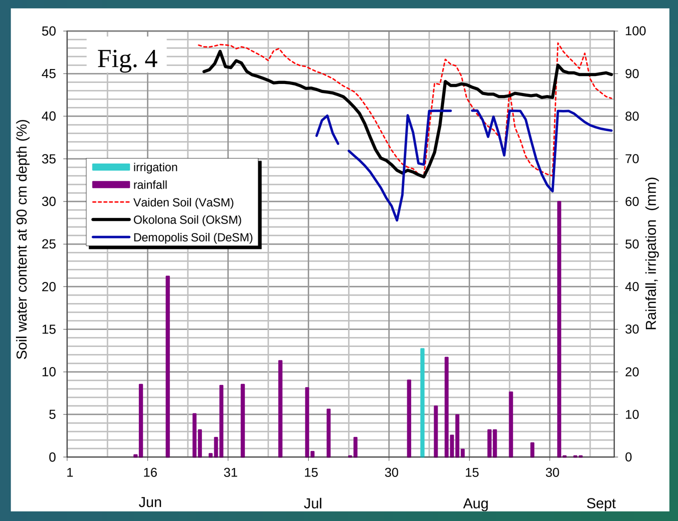
Results and Discussions

Irrigation timing

An irrigation scheduling tool was developed to determine when root zone water depletion (SWD) reaches irrigation trigger points of 50% TAW and 25% of ETc. It was found by the tool that SWD of Vaiden and Okolona soils reached both trigger points at the same time on July 26 during R5 stage (Fig. 2). Field observations and rainfall forecast indicated a need for irrigation if rainfall was not received by Aug. 3. An 18 mm rainfall on Aug. 3 replenished some depleted water, but due to remaining deficit of 20 mm to meet the trigger point, 25 mm was applied by center pivot to both irrigation treatments (i.e., five pivot pies) on Aug. 6. Thereafter, soil water deficit never reached ETc trigger point until harvest, however, soil water deficit was below the 50% of TAW level from Aug. 14 and 30, suggesting the 50% TAW trigger point was more sensitive than ET trigger point in late growing season.





Irrigation trigger point

Selection or measurement of RAW (50% TAW) can greatly affect when and how much an irrigation should be applied. As an example of Demopolis soil, Figure 3 demonstrates how RAW from different data sources affects irrigation timing and rate. On-site measured RAW could trigger an irrigation 10 more days earlier than RAW from other data sources in Mid or late July. 20 mm difference in irrigation amount for bringing back to RAW level was found among those trigger criteria. The commonly used RAW is texture based value, which is 0.18 $cm^3\ cm^{-3}$. In comparison with measured values, 13 days difference in irrigation timing and 60-70 mm difference in maximum root zone was calculated. SSURGO database provides three TAW of 0.05, 0.14 and 0.17 $cm^3\ cm^{-3}$. Differences of 18 days in irrigation timing and 60 mm in irrigation amount were calculated. Average of the three values is 0.12 $cm^3\ cm^{-3}$ which is exactly the same as measured in the field. It appears irrigation scheduling should rely on TAW averaged in SSURGO database instead of texture based value. Figure 1suggests soil sensors alone are not a reliable method to schedule irrigation, as soil-specific estimates of TAW obtained directly from field or lab measurements are equally important.

Previous research suggested irrigation trigger points of 50, 60 or 80 kPa tension, which correspond to 68 to 89% of field capacity at 33 kPa in the three tested soils. RAW is, in general, considered as approximately 50% of field capacity. Our on-site, field measured water release curves for the three soils common in north central Mississippi suggested the trigger point can be as high as 100 kPa.

Water balance

No runoff was measured in any collector, leachate waters ranging from 95 to 1010 ml at 90 cm depth was observed by July 10, before R5 stage of soybean. and variation in leaching due to different soil physical and chemical characteristics. More inorganic N in leachate of Vaiden and Demopolis soils than Okalona soil (Table 1).

Transpiration and evapotranspiration, were approximately 376 and 440 mm in irrigated treatments, 38 mm more than rainfed treatment. Maximum plant height was 110 cm, ground cover was 90% or greater at R3 stage in mid-June, approximately 15% of water was lost through evaporation.

Cumulative reference crop evapotranspiration (ETo) during 2014 growing season was 646 mm, 90 mm below the mean of 736 mm in the last decade. Values were similar before stage R3 and the difference after R3 resulted from lower calculated values for ETo due to higher rainfall than long-term average in this period of time. Average water use was about 2 mm day^{-1} before R1, increased at R2 (full bloom) and continued through pod-filling stage, with an average of 5 and 4 mm day^{-1} for irrigated and rainfed soybean, respectively. Peak water use occurred at pod filling stage. No large difference in ETc was observed among the three soil types.

Average adjusted crop coefficien (Kc) values before R1, from R1 to R3, and from R3 to R6 were 0.21, 0.67, and 0.94, respectively. In rainfed plots, Kc was reduced to 0.80 from R3 to R6 stage.

Soil moisture and potential sensors installed in the field indicated that the soybean plants consumed water down to the 90cm soil profile (Fig. 4).

Production

Soybean irrigated at R5 stage on Aug. 6 had mean grain yield (n=6) of 6264 kg ha^{-1} (93 bushel/acre) and a harvest index of 50%. Irrigation increased grain yield, aboveground biomass, thousand grain weight, and harvest index by 10%, 8%, 7% and 3%, respectively (Table 2). Yield and yield components did not differ significantly between irrigation treatments or soil types.

Table 1. Water volume and inorganic N at 90 cm depth.

Date	Precipitation (mm)		Volume (ml)			Total inorganic N (mg/L)		
2014	Total	Max	Va	Ok	De	Va	Ok	De
6/12	31.51	31.00	1010	603	483	8.76	7.23	7.65
6/23	59.44	42.42	850	953	523	11.66	5.73	8.10
7/1/	38.60	16.76	1038	267	202	11.06	4.69	8.30
7/10	39.63	22.61	1055	263	185	12.32	3.65	6.04
7/25	33.54	16.26	195	145		3.10	3.20	
8/8	29.94	18.03	95	145		1.13	3.62	
8/11	28.45	23.37	245	125		0.99	0.26	

Table 2. Soybean grain yield and yield components.

Soil type	Treat ment	Grain Yield kg/ha	Total above dry biomass kg/ha	HI	Thous-and grain weight g	Seeds per plant	Pods per plant	WUE grain kg/ha/mm
Vaiden (Va)	SM	6303	13575	0.46	136.30	132	56	13.67
	ET	5933	10477	0.57	158.08	107	62	14.54
	RF	6153	10995	0.56	142.44	123	45	15.08
Okolona (Ok)	SM	5834	10577	0.55	149.94	111	44	12.99
	ET	5947	12245	0.49	150.89	113	50	13.16
	RF	5614	11837	0.47	133.21	120	54	14.66
Demopolis (De)	SM	7406	15503	0.48	155.60	136	44	16.17
	ET	6158	12805	0.48	161.06	109	49	14.91
	RF	5249	11903	0.44	150.76	100	39	12.62

Summary

- Good agreement on the irrigation trigger point in early August as determined by the soil moisture readings and calculated ET. 50% of TAW trigger point was more sensitive than ET trigger point in late growing season.
- It appears that texture-based TAW serving as irrigation trigger point is not good enough.
- The use of Watermark soil sensors for irrigation management can be improved through knowledge of soil water potential in relation to water holding capacity.