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MISSISSIPPI SOYBEAN PROMOTION BOARD
PROJECT NO. 40-2017 (YEAR 1)
2017 Annual Report

Title: Irrigation Scheduling of Soybean – A Dual Threshold Method to Eliminate Yield Reducing Stresses and Maximize Water-Use Efficiency

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BACKGROUND AND OBJECTIVES

Over the past 30 years water level surveys have proven that more water is being pumped out of the Mississippi River Alluvial Aquifer than is replenished by recharge in the Mississippi Delta. As new wells are permitted and more water is pumped from the aquifer each year, water levels will decline and the area of greatest concern will continue to expand in the mid-Delta, such that declining water levels in this area will severely affect pump operation to the point that they will eventually fail.

Efficient use of water in crop production is a necessary part of the solution. Increased emphasis is being placed on proper irrigation scheduling for all crops in the Delta using soil moisture sensors so that producers can reach maximum economical yields with the least amount of irrigation water. Research and extension has shown that irrigations can be scheduled more efficiently without reducing yield by using soil moisture sensors. In 2014, in three soybean irrigation initiation field studies, there was no response to irrigation while moisture levels were such that irrigations were recommended. The exception was one later maturing variety that had a small yield increase while experiencing a 10-day extended heat period that occurred after the other varieties had matured. This observation in 2014 along with change in yield data from the four years of this study correlating more with heat than moisture has resulted in a conclusion that soybean in our environment experiences a heat stress or combination heat and moisture stress more than strictly a moisture stress. So a hypothesis was developed suggesting that a dual irrigation threshold for soil water potential sensors may be needed to deal with extended heat periods (Tamax>=95°F) + moisture-induced stress vs. simply a moisture induced stress. For example, on a Sharkey Clay soil, a lower threshold (50 kPa) might be used when an extended heat period + moisture-induced stress is occurring while a higher threshold (80 – 120 kPa) would be used when only a moisture-induced stress is occurring. Literature agrees that soybean yield losses are greater when plants are subjected to higher temperatures and limited moisture vs. either higher temperatures or limited moisture alone. Likewise, thresholds need to be identified for volumetric water content sensors under these same conditions. Good irrigation scheduling protocol should tell you “when not to irrigate” as well as “when to irrigate”.

Objective(s): The overall purpose of this project is to maximize economic yield with the least amount of water by identifying thresholds which will alleviate temperature and moisture-related yield-reducing stresses.

1) Determine a dual irrigation threshold (heat & moisture-induced or only moisture-induced) for soybean using soil water potential sensors (Watermarks) in silt loam, silty clay loam, and silty clay textured soils;
2) Monitor and identify irrigation thresholds (heat & moisture-induced or only moisture-induced) in soybean using volumetric soil moisture sensors in silt loam, silty clay loam and clay textured soils; and
3) Economically evaluate the yields and production costs of each irrigation treatment.

REPORT OF PROGRESS/ACTIVITY

Procedures

Irrigation x variety field studies were established in 2017 on three different soils. A Sharkey SiCL site at Stoneville, MS (Site 1) and a Dundee – Forestdale SiCL at Tribbett, MS (Site 2) were both furrow irrigated. A Bosket – Dubbs SiL site at Stoneville, MS was sprinkler irrigated (Site 3).

Sites 1 and 2 were conducted in a randomized complete block design with a factorial arrangement of treatments in four replicates. Plots were six 40-inch-wide rows that were 600-650 ft long. At Site 1, two rows were left unplanted between all plots to provide a non-shrinking buffer zone between the irrigation treatments. Site 3 was conducted in a randomized complete block design with a split-plot arrangement with four replicates. Irrigation initiation treatments were randomized within replicates and varieties were randomized within initiation treatments. Plots were eighteen 40-inch-wide rows that were 67 ft long.

Site 1 was planted April 10 with Liberty Link soybean CZ4748 and HBK4950. Site 2 was planted on April 26 with AG4632 and AG4835 varieties. Site 3 was planted on May 10 with P47T89R and P49T97R varieties. Weeds were managed so that weed competition was not a factor limiting crop production for each study.

Watermark soil water potential (SWP) sensors, resistance type, were installed in each irrigation x variety treatment in 2 replicates of each study. They were installed at three depths—8, 16, and 24 in. in furrow plots and 6, 15, and 24 in. in sprinkler plots). Each site was instrumented with dataloggers and set to read and store the data at 1-hour intervals. Additionally, 18 Sentek volumetric water content (VWC), capacitance type, probes were installed in three treatments in 2 replicates of each study. These 48-in.-long probes had sensors every 4 inches from the 2 in. depth down to 46 inches.

Irrigation protocols are given below.

Protocol

1 Irrigate at SWP <= -50 kPa
2 Irrigate at SWP <= -80 kPa
3 If Ta<95°F, Irrigate at SWP <= -80 kPa; If Ta>=95°F, Irrigate at SWP <= -50 kPa
4 If Ta<95°F, Irrigate at SWP <= -120 kPa; If Ta>=95°F, Irrigate at SWP <= -50 kPa
5 If Ta<95°F, Irrigate at SWP <= -120 kPa; If Ta>=95°F, Irrigate at SWP <= -80 kPa
6 Rainfed (non-irrigated)

Whole plant samples from one square meter were taken approximately midway of each plot the week before harvest of each study, were thrashed, and seed were counted to determine number of seed per meter of row.

Air temperature was obtained from automated weather stations located in the vicinity (within a mile) of each site, while rainfall was collected and measured at each site.

The middle six rows of each plot in Site 1 were harvested with a commercial combine and seed were augured into a weigh cart to determine yield. For Sites 2 and 3, the two middle rows of each plot were harvested with a plot combine. A sample was taken for harvest moisture, test weight, and seed weight. Yields were adjusted to 13% moisture content. Data were subjected to analysis of variance and means were separated by the least significant difference (LSD) procedure at the 5% level of significance. Water use efficiency (WUE) was calculated from change in yield within an irrigated protocol and the rainfed treatment divided by the applied water from irrigation.

The economic analysis for all three field studies is based on partial budgeting of net returns above irrigation and hauling costs since all other factors of production were held constant and no difference in the seed cost by variety was assumed. Irrigation cost estimates are based on MSU budgets for sprinkler irrigation of a ¼ mile center pivot system or for furrow irrigation of a 160-acre tract using roll-out pipe (MSU Department of Agricultural Economics Budget Report 20123-05, Appendix 13 & 14). Fixed irrigation costs were applied to non-irrigation treatment costs. The average reported soybean price for the week of the harvest date in the Delta area (USDA Market News- JK_GR110) is used to set the soybean price in the analysis for each study.

Results and Discussion

Weather

Winter rainfall (October 1, 2016 – March 31, 2017) at Stoneville, MS was a little below normal at 25.0, 20.4, and 24.4 inches for Sites 1, 2, and 3, respectively compared to the 100-year average of 28.2 inches (Table 1). Likely the entire rooting profile was recharged to start the season at Sites 1 and 3, with some concern at Site 2.

Overall, the growing season could be characterized as relatively wet and cool for Sites 1 and 3, whereas Site 2 was relatively wet but a little warmer (Table 1). There were some hot and dry periods as can be seen in Figure 1a-c, which shows daily maximum and minimum air temperatures (Ta max and Ta min) and daily rainfall.

Seed Yield and Economic Analysis

Estimated irrigation and hauling costs and soybean prices (Table 2) along with yield and water applied were used to calculate expected net returns above irrigation and hauling costs for each treatment at each site.

Soybeans were harvested for yield on October 9 (Site 3), September 11 (CZ4748) and Oct 3(HBK4950) (Site 1), and September 21-25th (Site 2). Yield results and net returns are given in Table 3a-c.

Highest yields were obtained from the earliest planted Sharkey SiC soil (Site 1). The lowest yields were obtained from the Dundee/Forestdale SiCL soil (Site 2), where significant leaf drop in late July caused by Target Spot and then a secondary infection of charcoal rot reduced yields (diagnosed by Tom Allen, pathologist). The later planted soybean on the Bosket-Dundee SiL soil (Site 3) lodged in late July, which likely caused a reduction in yield. The only positive yield response to irrigation was obtained on the Dundee-Forestdale SiL site where the longest dry period occurred in mid-July to early August and included 13 days of air temperatures greater than or equal to 95°F. In general, no yield differences were found among irrigated treatment protocols at any of the locations.

Net returns were greater for protocols 4, 5, and the rainfed treatments than for protocols 1, 2, and 3 at Site 1. At Site 2, net returns were greater for irrigation protocol 5 compared to protocol 1 for AG4632, whereas there were no differences in net returns for AG4832. No differences were found in net returns at Site 3. The later maturing HBK4950 yielded higher than CZ4748 at Site 1. AG4632 yielded higher than AG4835 at Site 2, whereas no yield differences were found among P47T89R and P49T97R at Site 3.

Irrigation protocols

There were no yield differences among the irrigation protocols and the rainfed (nonirrigated) treatments at Site 1 (Table 4a). Protocols 1, 2, and 3 called for two to four irrigations with 5.4 to 11.0 inches of water applied without a positive yield response. Protocols treatments 4, 5, and the rainfed treatment had the best net returns since an irrigation was not scheduled with these protocols and soybean did not respond to irrigation. When SWP values of the rain-fed treatment reached drier levels of -80 to -95 kPa three different times during the growing season, a rain would follow that replenished some of the soil moisture that had been lost (Fig. 2a). Rainfall occurring during a period where Ta max >= 95°F in late July appeared to negate a potential yield reducing stress (Fig. 1a). SWP was relatively wet when another heat period occurred in late August when soybeans were nearing maturity.

At Site 2, all irrigation protocols yielded better than the rainfed treatment (Table 4b). This yield response was likely due to a little less winter and May-June rainfall (Table 1) along with a much longer hot and dry period between rains in July at this location (Fig. 1b). Protocols 1-5 called for two to five irrigations; in error, protocol 4 did not receive an irrigation called for on 4 Aug. Protocols 1, 2, and 3 had 12.2, 5.2, and 5.6 inches of water applied, respectively, but resulted in lower WUE by varieties than the total of 2.6 and 4.7 inches of water applied with protocols 4 and 5, respectively (Table 3b). SWP values reached a dry level of -120 kPa in June before a rain rewet the soil, although Ta max was lower than 95°F (Fig. 1b and 2b). During a long dry period between 11 Jul and 9 Aug, with 12 of those days where Ta max >= 95F, rainfed SWP reached a very dry level of -155 kPa before rain gave any relief. It was during this period that protocols 4 and 5 were initiated which aided in alleviating this heat and moisture stress.

Site 3 was similar to Site 1 in that there were no yield differences among the irrigation protocols and the rainfed treatments (Table 4c). Yield variability was greater at this site likely due to the variable lodging that occurred among the treatments and varieties. Protocols 1-5 called for one to five irrigations, with from 0.8 to 4.1 inches of water being applied. Protocols 4 and 5 had the least amount of water applied in an environment where soybean did not respond to irrigation. Protocols 4 and 5 were irrigated when Ta max >= 95° and rainfed SWP values were -78 kPa on 20 Jul, but significant rain occurred on 22 July, thus relieving the immediate stress that was occurring (Fig. 1c and 2c). Rainfed SWP values reached -80 and -100 kPa three other times during the growing season, but Ta max was < 95°F.

Volumetric Water Content (VWC)

Sentek sensor data were collected for approximately 3 months of the growing season starting around June 8th at all three locations. Internally, a universal algorithm is applied to the capacitance readings of the Sentek probes to calculate VWC. No effort was made to calibrate these sensors to specific soils.

The manufacturer recommends looking at the data trends to determine where the root activity occurs and indicators of when the soil is not providing the water needed by the plant. Diurnal variations in VWC indicate where and when root activity is occurring at different depths and the composite VWC curves. As VWC is decreasing due to drying of the soil at specific depths or the composite VWC, a change in slope from a steeper to a less steep slope indicates that either the soil is no longer providing all the water the plant needs (a key to irrigate) or the environmental demand (ET_o) has decreased and the soil is still providing all the water the plant needs. More abrupt increases in VWC are due to rainfall or irrigation.

The diurnal variation at all depths in the top graph of figure 3a (Site 1; rainfed treatment) indicates that there was root activity down to a depth of 46 inches during the growing season. The shaded blue area on the composite VWC graph indicates when the soil would be at field capacity or above, while the green shaded area represents that soil water is not limiting to the plant. The only significant reduction in slope of the composite VWC occurred in early August and then again in late August, but each was accompanied with lower ET_o demands (bottom graph Fig. 3a) due to cooler weather (Fig. 1a). Thus, from this VWC curve there were no indicators to recommend irrigations in this growing season. This interpretation is supported since there were no yield differences among irrigated and rainfed treatments (Table 3a).

Root activity at Site 2, as denoted by the diurnal variation in the rainfed treatment, developed down to a depth of 46 inches (Fig. 3b). There appeared to be a significant reduction in slope on 23 July of the composite VWC curve that continued at that lower slope until rainfall rewet the soil in early August. This change in slope did not appear to be caused by a reduction in ET_o demand; thus, it was an indicator to recommend irrigation. The pink shaded area was shown to represent potential levels of VWC in which the soil was not providing all the water the plant needed. Irrigation protocols 3, 4, and 5 that were initiated on 20 and 25 July yielded better than the rainfed treatment, supporting this interpretation of the VWC curves (Table 3b).

Again, root activity developed down to 46 inches in the rainfed treatment as indicated by the diurnal variation at Site 3 (Fig. 3c). Similarly, as at Site 1, no significant reduction in slope occurred at Site 3 that was not accompanied by decreased ET_o demand. Thus, no irrigations were recommended by this VWC curve. This interpretation was supported by no significant yield differences among irrigated and rainfed treatments (Table 3c).

Impacts and Benefits to Mississippi Soybean Producers

The overall effort of this study is to apply water more timely to maximize yields economically while using the least amount of water. Results from this project will help determine "trigger value" recommendations on Mississippi soils of when to initiate irrigations with maximum temperature observations/forecasts and soil water potential & volumetric water content sensors. Thus, a potential savings of irrigation (water and pumping costs) on all irrigated soybean acreage can be realized. One less furrow irrigation will save approximately 3 acre-inches of water and would reduce irrigation operation costs by approximately $9.50/acre.

End Products-Completed or Forthcoming

1. A publication will be forthcoming after the conclusion of the project.
2. Delta States Irrigation Conference/ 21st Annual National Conservation Systems Cotton & Rice Conference, Memphis, TN, Soil moisture sensors sold and supported in the mid-South, January 10-12, 2018.

Graphics/Tables

Table 1. Rainfall and Air Temperature for select periods of the crop year for study areas.

SITE[A]	1	2	3	STONEVILLE HISTORICAL[B]
		Rainfall (inches)		
OCTOBER-MARCH	25.0	20.4	24.4	28.2
APRIL	5.5	4.8	5.3	5.2
MAY	5.5	3.2	5.2	4.7
JUNE	5.2	3.9	5.3	3.7
JULY	5.6	5.9	6.1	3.7
AUGUST	7.9[C]	8.0[C]	8.0[C]	2.7
SEPTEMBER	3.0	2.2	2.6	3.1
		Average Max/Min Air Temperature (°F)		
APRIL	80[C]/58[C]	80/58[C]	80[C]/60[C]	75/53
MAY	82/61	83/61	81/62	83/62
JUNE	86[C]/68	88/69	86[C]/68	90/69
JULY	91/72	94/72	92/73	92/72
AUGUST	89[C]/71	90/72	89[C]/71	92/70
SEPTEMBER	88/64	88/64	87/63	87/64

[A] Site 1 – Sharkey SiCL, Stoneville, MS; Site 2 – Dundee – Forestdale SiCL, Tribbett, MS; Site 3 –Bosket-Dubbs SiL, Stoneville, MS

[B] Historical average for Stoneville, Mississippi (Rainfall, 103 years; Air temperature, 88 years) located eight miles NNE of Tribbett, Mississippi.

[C] Values are greater than or less than one standard deviation of average.

Table 2. Estimated irrigation and hauling cost and soybean price for furrow and sprinkler irrigation studies in 2017.

		Furrow	Sprinkler
		2017	2017
Irrigation Cost ($ acre^{-1}) [a]		$74.04	$ 93.13
Water Lifting Cost ($ acre^{-1} In.$^{-1}$)		$ 2.01	$ 3.43
Haul Soybean ($ bu^{-1})		$ 0.27	$ 0.27
Soybean Price ($ bu^{-1}) [b] Site[c]	1	$ 9.48	
	2	$ 9.64	
	3		$9.54

[a] Irrigation cost excluding water lifting cost - Mississippi State University Budget Report.

[b] Greenville Farmers Grain Terminal average quote USDA-AMS JK-GR-110 for week of harvest (Site 1 - 11 September – 6 October, 2017; Site 2 – 18-22 September - 2017; Site 3 – 19-13 September 2017).

[c] Site 1 – Sharkey SiCL, Stoneville, Mississippi; Site 2 – Dundee/Forestdale SiCL, Tribbett, Mississippi; Site 3 – Bosket/Dubbs SiL, Stoneville, Mississippi

Table 3. Irrigation dates, total water applied by irrigation treatment, yield, and apparent water use efficiency in furrow irrigated, irrigation study, Delta Research and Extension Center, Stoneville, MS, 2017.

a). Furrow irrigated, Sharkey SiCL soil (Site 1).

	Irr 1	Irr 2	Irr 3	Irr 4	Irr 5	Rainfed	Average[b,d]
Irrigation protocol	----------	-----------	--kPa--	-----------	-----------		
	-50	-80	---	---	---	---	
if Ta<95°F SWP<=	---	---	-80	-120	-120	---	
if Ta>=95°F SWP<=	---	---	-50	-50	-80	---	
Irrigation dates	6/14	---	---	---	---	---	
	7/15	7/17	7/17	---	---	---	
	8/1	8/1	8/1	---	---	---	
	8/25[a]	8/25[a]		---	---	---	
Water pumped (in/acre)							
CZ4748	7.52	5.4	5.4	0.0	0.0	0	
HBK4950	11.0	8.8	5.4	0	0	0	
Yield (bu/acre)							
CZ4748	70	72	72	72	71	72	72b
HBK4950	83	84	83	83	83	82	83a
Average[c]	76	78	77	78	77	77	
Net Return ($ $acre^{-1}$)							
CZ4748	$557	$579	$575	$591	$584	$587	$579b
HBK4950	$665	$680	$680	$693	$695	$682	$682a
Average[e]	$611c	$629b	$628b	$642a	$639ab	$634ab	
WUE (bu/in)							
CZ4748	-0.20	0.07	-0.01	---	---	---	
HBK4950	0.05	0.18	0.17	---	---	---	

[a] Irrigations were applied to the later maturing variety, HBK4950, only.
[b] Variety treatment yield means followed by a common letter range are not different ($p<0.05$; LSD = 1bu $acre^{-1}$).
[c] Irrigation treatment yield means are not different ($p<0.05$; LSD = ns).
[d] Variety treatment return means followed by a common letter range are not different ($p<0.05$; LSD = $7 $acre^{-1}$).
[e] Irrigation treatment return means followed by a common letter range are not different ($p<0.05$; LSD = $12 $acre^{-1}$).

Table 3. -continued- Irrigation dates, total water applied by irrigation treatment, yield, and apparent water use efficiency in furrow irrigated, irrigation study, Delta Research and Extension Center, Stoneville, MS, 2017.

b). Furrow irrigated, Dundee - Forrestdale SiCL soil (Site 2).

	Irr 1	Irr 2	Irr 3	Irr 4	Irr 5	Rainfed	Average[a]
Irrigation protocol	----------	-----------	--kPa--	-----------	-----------		
	-50	-80	---	---	---	---	
if Ta<95°F SWP<=	---	---	-80	-120	-120	---	
if Ta>=95°F SWP<=	---	---	-50	-50	-80	---	
Irrigation dates	6/14	6/14	---	---	---	---	
	7/8	---	---	---	---	---	
	7/19	---	7/20	7/20	---	---	
	7/25	7/25	---	---	7/25	---	
	7/31	---	7/31	---	8/4	---	
Water pumped (in/acre)							
	12.2	5.2	5.6	2.6	4.7	0	
Yield[b] (bu/acre)							
AG4632	57a	57a	57a	60a	61a	43bc	56a
AG4835	41bc	40bc	44b	43bc	43b	38c	41b
Net Return[c] ($ acre^{-1})							
AG4632	$437b	$449ab	$449ab	$481ab	$487a	$326c	
AG4835	$282c	$288c	$327c	$320c	$321c	$286c	
WUE (bu/in)							
AG4632	1.19	2.75	2.56	6.63	3.89	---	
AG4835	0.18	0.24	0.98	1.60	1.00	---	

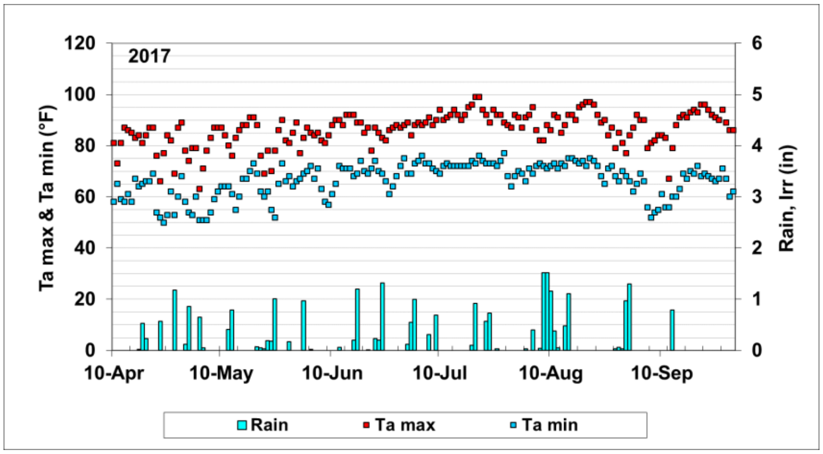
[a] Variety treatment yield means followed by a common letter range are not different ($p<0.05$; LSD = 2 bu acre^{-1}).
[b] Irrigation x variety treatment yield means followed by a common letter range are not different ($p<0.05$; LSD = 4.9 bu acre^{-1}).
[c] Irrigation x variety treatment return means followed by a common letter range are not different ($p<0.05$; LSD = $45 acre^{-1}).

Table 3. –continued- Irrigation dates, total water applied by irrigation treatment, yield, and apparent water use efficiency in furrow irrigated, irrigation study, Delta Research and Extension Center, Stoneville, MS, 2017.

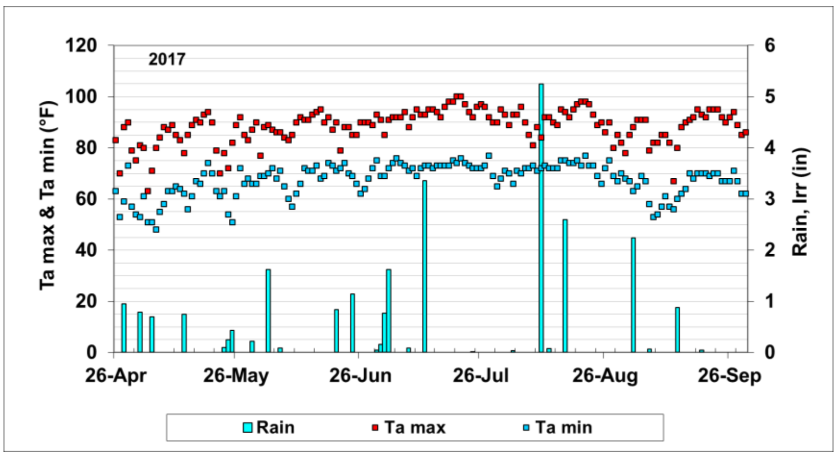
c) Sprinkler irrigated, Bosket – Dubbs SiL soil (Site 3).

	Irr 1	Irr 2	Irr 3	Irr 4	Irr 5	Rainfed	Average[a,c]
Irrigation protocol	----------	-----------	--kPa--	-----------	-----------		
	-50	-80	---	---	---	---	
if Ta<95°F SWP<=	---	---	-80	-120	-120	---	
if Ta>=95°F SWP<=	---	---	-50	-50	-80	---	
Irrigation dates	6/15	---	---	---	---	---	
	7/15	---	---	---	---	---	
	7/20	7/20	7/20	7/20	7/20	---	
	8/1	8/1	8/1	---	---	---	
	8/5	8/5	8/5	---	---	---	
Water pumped (in/acre)							
	4.1	2.5	2.5	0.8	0.8	0	
Yield (bu/acre)							
P47T89R	65	64	65	62	61	61	63
P49T97R	66	67	66	64	63	63	65
Average[b]	66	65	65	63	62	62	
Net Return ($ acre^{-1})							
P47T89R	$497	$495	$499	$478	$468	$471	$501
P49T97R	$505	$516	$508	$494	$488	$495	$485
Average[d]	$501	$506	$504	$486	$478	$483	
WUE (bu/in)							
P47T89R	1.05	1.44	1.59	1.26	-0.05	---	
P49T97R	0.62	1.27	0.92	0.29	-0.53	---	

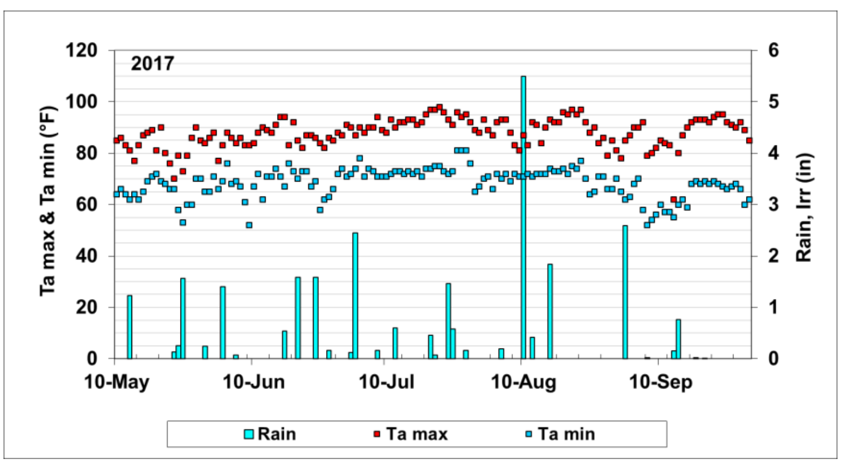
[a] Variety treatment yield means are not different ($p<0.05$; LSD = ns).
[b] Irrigation treatment yield means are not different ($p<0.05$; LSD = ns).
[c] Variety treatment return means are not different ($p<0.05$; LSD = ns).
[c] Irrigation treatment return means are not different ($p<0.05$; LSD = ns).



a) Sharkey silty clay (Site 1).

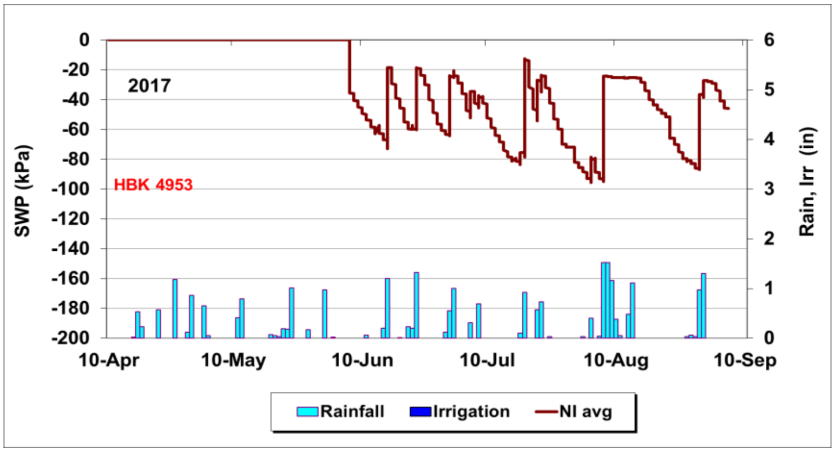


b) Dundee/Forestdale silty clay loam (Site 2).

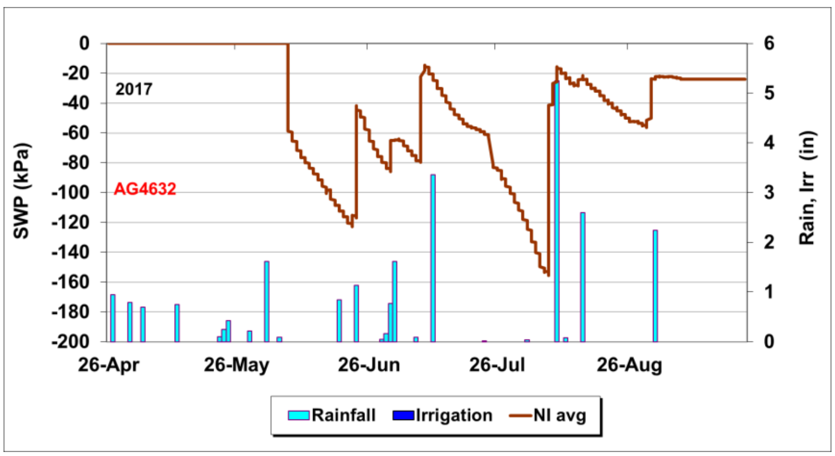


c) Bosket/Dubbs silt loam (Site 3)

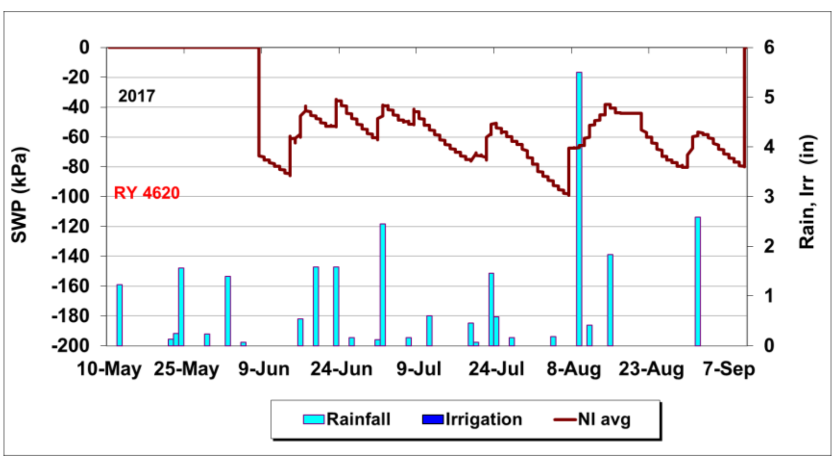
Figure 1. Weather variables (air temperature and rainfall) during growing season at Delta Research and Extension Center, 2017.



a) Sharkey silty clay (Site 1).

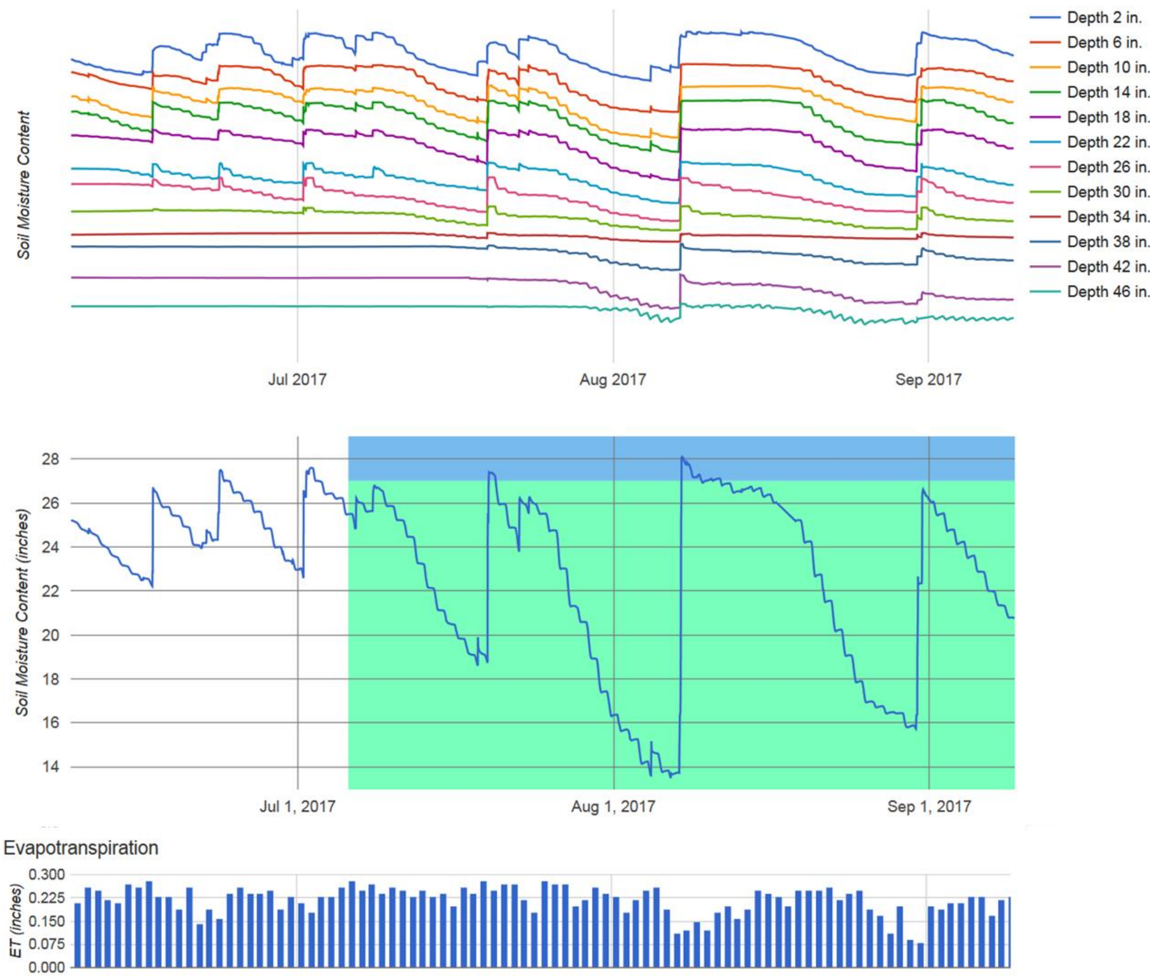


b) Dundee/Forestdale silty clay loam (Site 2).



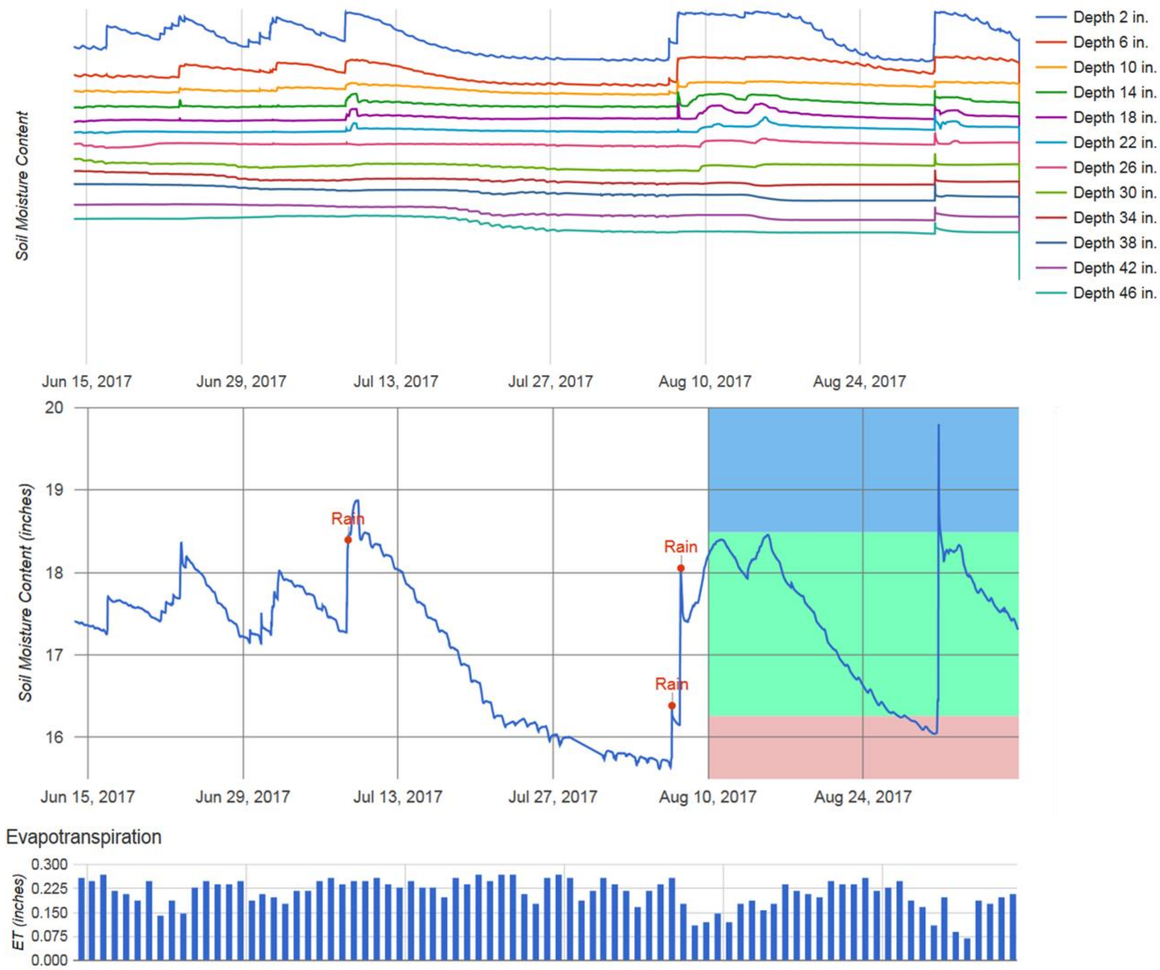
c) Bosket/Dubbs silt loam (Site 3)

Figure 2. Soil water potential (SWP, Watermark) observations for rain-fed (non-irrigated) soybean during growing season at Delta Research and Extension Center, 2017.



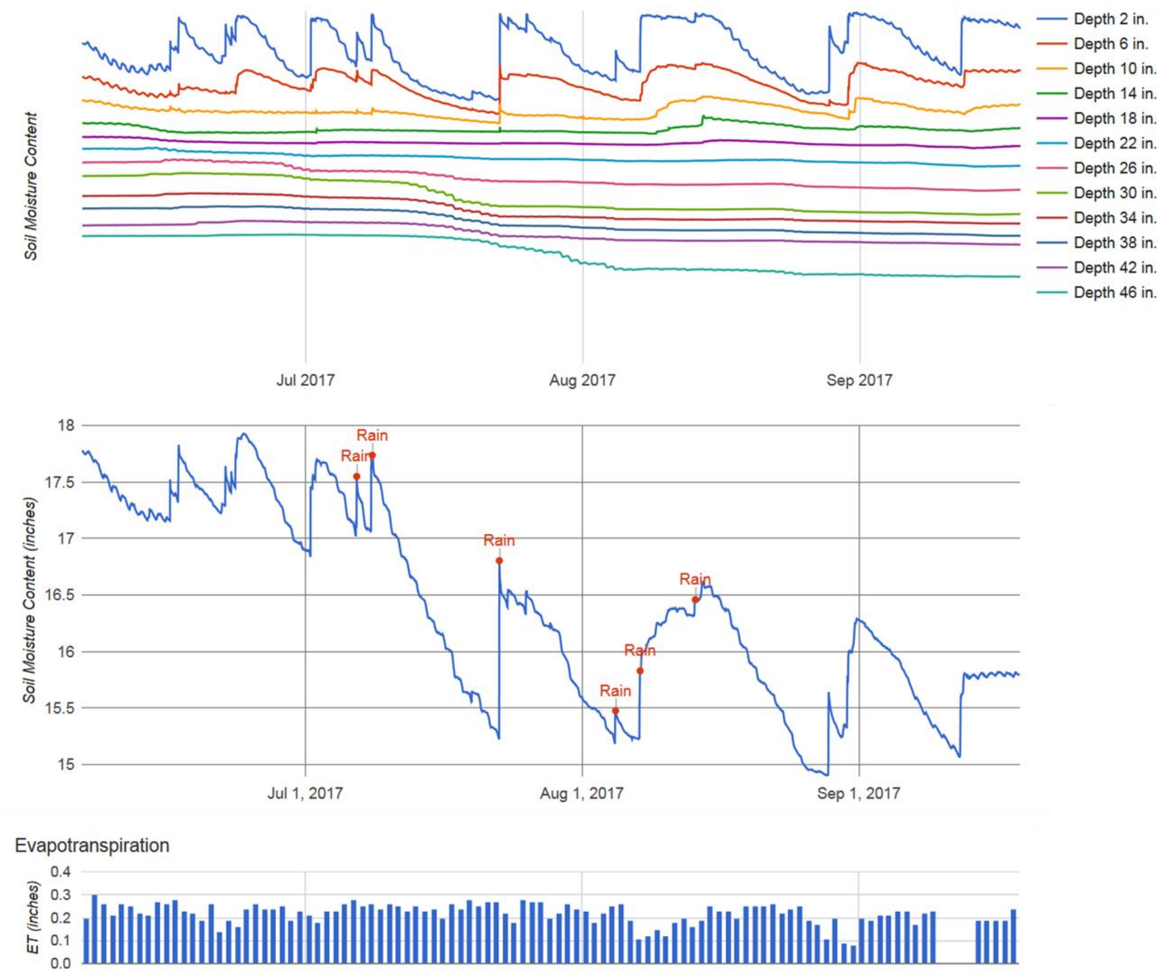
a) Sharkey silty clay (Site 1).

Figure 3. Volumetric water content (VWC, Sentek) observations for rainfed (non-irrigated) soybean during growing season at Delta Research and Extension Center, 2017.



b) Dundee/Forestdale silty clay loam (Site 2).

Figure 3. – continued- Volumetric water content (VWC, Sentek) observations for rainfed (non-irrigated) soybean during growing season at Delta Research and Extension Center, 2017.



c) Bosket/Dubbs silt loam (Site 3)

Figure 3. – continued- Volumetric water content (VWC, Sentek) observations for rainfed (non-irrigated) soybean during growing season at Delta Research and Extension Center, 2017.