# MISSISSIPPI SOYBEAN PROMOTION BOARD
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## Title: Row-Crop Irrigation Science Extension and Research (RISER) Program

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**Objective I: Determine effect of over-irrigating (-50 cbar threshold) and under-irrigating (-125 cbar threshold) soybean at three discreet growth stages (VN through R2, R3 through R4, and R5 through R6.5) on canopy closure, yield, yield components and water use efficiency.**

Depending on varietal characteristics, soybean uses 450–700 mm of water throughout the growing season (Doorenbus and Kassam, 1979). The most critical period for drought stress in soybean is during reproductive growth (Doorenbus and Kassam, 1979; Constable and Hearn, 1980; Meckel et al., 1984). Foroud et al. (1993) reported that soybeans are more susceptible to drought stress at R1 (beginning of flowering) trough R5 (beginning of seed) stages. Similarly, Yazar et al. (1989) indicated that soybean is most susceptible to drought stress during grain filling, flowering, and vegetative stages, respectively. Meckel et al. (1984) claimed that drought stress shortens the grain-filling stage and lowers yield. Therefore, soybean needs frequent irrigation during critical growth stages in order to avoid yield loss (Constable and Hearn, 1980).

In the Mississippi Delta, approximately 70% of the farmland is irrigated, and the Mississippi River Valley Alluvial Aquifer is the primary source. Irrigation withdrawals for row crops is depleting the aquifer at unsustainable rates, with an annual overdraft of 370 million cubic meters of water per year. Furthering aquifer depletion, producers in the Delta region have not completely adopted Irrigation Water Management (IWM) practices. According to the 2017 Mississippi Soybean Promotion Board survey, only 31% of producers utilize soil moisture sensors in their irrigated fields. Soil moisture sensors can be used to determine the amount of water available to a crop, when to initiate irrigations, and how much irrigation water to apply (Hanson et al. 2000). Sensors also show depth of wetting, depth of extraction by roots, and adequacy of wetting (Hanson et al. 2000).

Determining when an irrigation needs to be applied is often a difficult task for producers in the region. The utilization of scientific irrigation scheduling tools can improve soybean yield and reduce aquifer withdrawal, but the adoption of scheduling tools by producers regionally and nationally is minimal. In Mississippi, irrigation water applied to soybean when managed with a scheduling tool was reduced by 30% compared to soybean not managed with an irrigation scheduling tool (L.J. Krutz, personal observation). As of 2008, 47% of producers irrigated based upon the condition of the crop (visual), 24% irrigated according to the feel of the soil, and only 4.6% irrigated based on a soil moisture sensing device. These data coincide with those of Frisvold and Deva (2012), who found that the adoption of scientific irrigation scheduling tools, even in regions where severe water shortages occur, is less than

2%. Moreover, there is a paucity of data regarding appropriate scientific irrigation scheduling tools for Midsouth soybean production areas. To better implement IWM practices, determining soil moisture sensor irrigation thresholds during the growing season needs to be assessed. The objective of this research was to evaluate the effect of differing soil moisture centibar thresholds at separate growth stages on soybean grain, total irrigation water applied, and irrigation water use efficiency.

## Materials and Methods

To determine the impact of differing soil moisture sensor thresholds at various soybean growth stages, an experiment was conducted at the Delta Research and Extension Center located in Stoneville, Mississippi. Soybean variety Asgrow 4632 was planted at 140,000 seeds/acre on April 26, 2016 and April 25, 2017. Plots were 31.25-m long, 4.16-m wide, and seed were planted onto a 1.04-m-wide raised bed. The soil type was a Dundee silt loam.

Treatments were in a split-plot arrangement within a randomized complete block design with four replications. The main-plot factor was soybean growth stages, which consisted of VN-R2, R3-R4, R5-R6, and season-long. The sub-plot factor was centibar thresholds of -50, -85, and -125. Three IRROMETER Watermark moisture sensors (IRROMETER Company Inc., Riverside, CA) were set at depths of 15, 30, and 61 centimeters. These sensors measure soil water tension by reading the amount of water absorbed through a granular matrix.

Treatments were irrigated based on their specific growth stage and centibar thresholds. Whenever plants within a treatment were not within the specific growth stage for that treatment, a standard threshold of -75 centibars was utilized to initiate irrigations. Growth stages and moisture sensor readings were taken twice a week to accurately track the specific treatments that would require irrigation events. Plots were furrow-irrigated by pumping water through 30.5-cm-diameter polyethylene tubing laid perpendicular to the soybean rows. Holes were punched in the polyethylene tubing to allow water to run down every row.

Plots were arranged across the field to allow furrow irrigation to easily be controlled. A M$^{c}$Crometer flow tube with attached M$^{c}$Propeller bolt-on saddle flowmeter (McCrometer, Inc. Hemet, CA) was installed on the riser to measure application volume. During each irrigation event, 24.7-cm/ha of water was applied. Plant heights, canopy width, and total plant node numbers were recorded every other week in all plots. Irrigation events were terminated at R6.5 as recommended by the Mississippi State University Extension Service.

One-meter sections were cut from each plot to record plant height, node counts, and pod counts prior to harvest. These counts were used to identify any differences in development that were attributable to treatments which may have affected yield. The center two rows of each plot were mechanically harvested at physiological maturity.

Season centibar thresholds were analyzed separately from the growth stage by centibar thresholds due to the difference in treatment application timings. The -125 centibar threshold did not receive irrigation either year; thus it was removed from the IWUE and total irrigation water applied analysis. For season centibar thresholds and growth stage by centibar thresholds, total irrigation water applied, soybean grain yield, and IWUE were analyzed using the MIXED procedure of SAS (Statistical Analytical System

Release 9.4; SAS Institute Inc., Cary, North Carolina), with replicate and replicate (year) as random effects.

## Results and Discussion

*Season Centibar Threshold In-Season Samples*

Centibar threshold did not significantly effect soybean height (P = 0.59), soybean canopy development (P = 0.44), or number of mainstem nodes (P = 0.93) (Data not shown).

*Season Centibar Threshold 1-m-Section Samples*

Centibar threshold did not significantly effect soybean height (P = 0.93)**.** Centibar threshold had a significant effect on total number of soybean pods (P > 0.01) (Table 1). The -85 centibar threshold had 22-24 % more pods/plant than the -50 and -125 centibar thresholds. The nonirrigated treatment was not significantly different from any treatment. Centibar threshold also had a significant effect on total number of soybean nodes (P > 0.01) with the -85 centibar threshold, with more nodes than in all other treatments (Table 1).

*Season Centibar Threshold and Soybean Grain Yield*

Centibar threshold had a significant effect on soybean grain yield (P > 0.01) (Table 2). The -50 and -85 centibar thresholds yielded significantly more than the -125 centibar threshold and nonirrigated treatments.

*Season Centibar Threshold Total Irrigation Water Applied*

Centibar threshold had a significant effect on total irrigation water applied (P > 0.01) (Table 2). The -50 centibar threshold treatment received 38.4% more irrigation water than the -85 centibar threshold treatment.

*Season Centibar Threshold Irrigation Water Use Efficiency*

Centibar threshold had a significant effect on irrigation water use efficiency (P > 0.01) (Table 2). The -85 centibar threshold had 40.5% greater IWUE than the -50 centibar threshold treatment.

*Growth Stage by Centibar Threshold In-Season Samples*

Centibar threshold did not significantly effect soybean height (P = 0.88), soybean canopy development (P = 0.86), or number of mainstem nodes (P = 0.97) (Data not shown).

*Growth Stage by Centibar Threshold 1-m Section Samples*

There was a significant growth stage by centibar threshold interaction for total number of soybean pods (P > 0.01). The R3-R4 growth stage -125 centibar threshold had 24% more pods per plant compared to the R5-R6 growth stage -125 centibar threshold (Table 3). Average number of nodes per plant was not significantly different for growth stage, centibar threshold, or growth stage by centibar threshold. There was a significant growth stage by centibar threshold interaction for final average plant height (P > 0.01). Plants in the R3-R4 growth stage -50 centibar threshold treatment were 17% taller than plants in the R5-R6 growth stage -50 centibar threshold and VN-R2 growth stage -125 centibar threshold (Table 3).

*Growth Stage by Centibar Threshold Soybean Grain Yield*

There was a significant growth stage by centibar threshold interaction for soybean grain yield (P = 0.02) (Table 4). The R5-R6 growth stage -125 centibar threshold yielded the lowest. The VN-R2 growth stage -125 and -50 centibar thresholds and the R3-R4 growth stage -85 and -50 centibar thresholds did not yield different than any other treatment, and VN-R2 growth stage -85 centibar threshold, R3-R4 growth stage -125 centibar threshold, and R5-R6 growth stage -50 and -85 centibar threshold yielded the most.

*Growth Stage by Centibar Threshold Total Irrigation Water Applied*

There was a significant growth stage by centibar threshold interaction for total irrigation water applied (P > 0.01) (Table 4). Total irrigation water applied decreased in the order of R5-R6 -50 > R5-R6 -85 > VN-R2 -50 > R3-R4 -85 > R3-R4 -125 = VN-R2 -85 = VN-R2 -125 = R5-R6 -125 > R3-R4 -50.

*Growth Stage by Centibar Threshold Irrigation Water Use Efficiency*

There was a significant growth stage by centibar threshold interaction for irrigation water use efficiency (P > 0.01) (Table 4). The R3-R4 growth stage -50 centibar threshold and VN-R2 growth stage -85 centibar threshold treatments had the highest IWUE, which was 148% greater than the lowest treatment, the R5-R6 growth stage -50 centibar threshold.

*Conclusions*

The objective of this research was to evaluate the effect of differing soil moisture centibar thresholds at separate growth stages have on soybean grain yield, total irrigation water applied, and irrigation water use efficiency. Utilizing a soil moisture threshold of -85 centibars throughout a growing season yielded similar to a -50 centibar threshold, yet had significantly higher IWUE. The R5-R6 growth stage -125 centibar threshold yielded the lowest among all treatments, which suggests that drought stress during this growth stage can significantly affect soybean grain yield. Overall, a season-long soil moisture sensor threshold of -85 centibars is safe to schedule irrigations. Care should be taken to not stress plants during the R5-R6 growth stage.

**Table 1. Average soybean plant height, average number of nodes, and average number of pods per 1-m section of row in season-long centibar threshold treatments in a study conducted at Stoneville, Miss. in 2015-2016.**

| Centibar Threshold | Average Plant Height | Average Number of Nodes | Average Number of Pods |
|---|---|---|---|
| 50 | 31.6 | 58.5 b | 161.4 b |
| 85 | 30.1 | 73.1 a | 207.1 a |
| 125 | 31.1 | 52.4 b | 157.9 b |
| Non-irrigated | 31.5 | 61.5 b | 182.1 ab |

*Values in a column followed by the same letter are not significantly different at $P \leq 0.05$.

**Table 2. Soybean grain yield, irrigation water use efficiency, and total irrigation water applied to season-long centibar threshold treatments in a study conducted at Stoneville, Miss. in 2015-2016.**

| Centibar Threshold | Soybean Grain Yield ($kg\ ha^{-1}$) | IWUE ($kg\ ha\ mm^{-1}$) | Total Water Applied ($ha\ mm^{-1}$) |
|---|---|---|---|
| 50 | 3833 a | 2.5 b | 1631 a |
| 85 | 3831 a | 4.2 a | 1004 b |
| 125 | 3354 b | - | - |
| Non-irrigated | 3549 b | - | - |

*Values in a column followed by the same letter are not significantly different at $P \leq 0.05$.

**Table 3. Average soybean plant height, average number of nodes, and average number of pods per 1-m section of row in a study conducted at Stoneville, Miss. in 2015-2016.**

| Growth Stage | Centibar Threshold | Average Plant Height (cm) | Average Number of Nodes | Average Number of Pods |
|---|---|---|---|---|
| VN-R2 | 50 | 78.4 ab | 60.5 | 159.1 abc |
| VN-R2 | 85 | 77.8 ab | 55.1 | 153.2 abc |
| VN-R2 | 125 | 67.3 c | 54.9 | 150.2 abc |
| R3-R4 | 50 | 81.1 a | 51.2 | 143.0 bc |
| R3-R4 | 85 | 77.4 ab | 60.7 | 156.9 abc |
| R3-R4 | 125 | 74.9 b | 57.6 | 174.7 a |
| R5-R6 | 50 | 67.9 c | 51.7 | 155.6 abc |
| R5-R6 | 85 | 78.1 ab | 55.1 | 169.1 ab |
| R5-R6 | 125 | 76.1 ab | 49.1 | 133.2 c |

**Values in a column followed by the same letter are not significantly different at $P \leq 0.05$.

**Table 4. Soybean grain yield, irrigation water use efficiency, and total irrigation water applied in a study conducted at Stoneville, Miss. in 2015-2016.**

| Growth Stage | Centibar Threshold | Soybean Grain Yield (kg $ha^{-1}$) | IWUE (kg ha $mm^{-1}$) | Total Water Applied (ha $mm^{-1}$) |
|---|---|---|---|---|
| VN-R2 | 50 | 3934 ab | 3.8 e | 1038 c |
| VN-R2 | 85 | 4060 a | 6.6 a | 692 e |
| VN-R2 | 125 | 3958 ab | 5.6 c | 692 e |
| R3-R4 | 50 | 3895 ab | 6.8 a | 578 f |
| R3-R4 | 85 | 3916 ab | 5.7 c | 807 d |
| R3-R4 | 125 | 4022 a | 6.2 b | 692 e |
| R5-R6 | 50 | 4095 a | 2.9 f | 1499 a |
| R5-R6 | 85 | 4073 a | 3.5 e | 1268 b |
| R5-R6 | 125 | 3727 b | 5.3 d | 692 e |

**Values in a column followed by the same letter are not significantly different at $P \leq 0.05$

**Objective II: Determine effect of plant geometry and skip-row irrigation on canopy closure, yield, yield components, and water use efficiency.**

Over the past 50 years, withdrawals from the Mississippi River Valley Alluvial Aquifer (MRVAA) have increased drastically, primarily due to irrigation of row-crops. In Arkansas County, Arkansas, withdrawals increased from 133 million gallons/day in 1965 to 581 million gallons/day in 2000, a 396% rise (Halberg and Stephens, 1966; T.W. Holland, U.S. Geological Survey, written communication 2002). Clay-textured soils are the predominant type in the lower Mississippi River Valley alluvial plain, comprising over 3.7 million hectares.

Soybean (*Glycine max* L.) and rice (*Oryza sativa* L.) are typically planted in rotation on this soil type. A significant portion of these fields have been graded to facilitate surface drainage and flood/furrow irrigation. For rice production, straight levee irrigation is most commonly used; levees run perpendicular to the slope of a field and confine water to defined areas in fields that have been graded to slope in only one direction. This method requires moderate grading to ensure uniform field slopes. During this time of flooding, an increasingly larger area is covered with water until the entire portion within the levees is finally inundated. Thus, the period of time a particular area is flooded will vary with its location within an impounded area. Producers that utilize this method for rice production will often flood irrigate soybeans as well (Heatherly 1999) because of its ease of use attributed to the dominance of crack-filling during irrigation (Mitchell and van Genuchten 1993).

With the decreasing water levels in MRVAA and state regulators response by requiring minimum levels of irrigation water use efficiency practices, the impact of furrow and flood irrigation practices in Midsouth soybean production needs to be evaluated. The objective of this study was to compare soybean grain yield, total water applied, irrigation water use efficiency, and economic return of furrow- and flood-(Straight Levee) irrigated soybean production systems.

## Materials and Methods

To determine the effect flood irrigation has on soybean grain yield, total water applied, irrigation water use efficiency and economic return as compared to furrow irrigation, seven locations were selected throughout the Mississippi Delta. Each farmer was requested to furnish two fields, one being furrow-irrigated (FURROW) and one flood-irrigated (FLOOD). All fields in this study were land-formed clay-textured soils. The fields were required to be side by side or in relatively close proximity, with the same planting date and soybean cultivar. All cultural practices were to be performed similarly on both fields.

The FURROW field utilized computerized hole selection, surge valves, and soil moisture sensors. Input parameters for computerized hole selection include accurate elevation of the crown profile where lay-flat irrigation pipe will be installed, accurate water output (gpm) from the well, furrow spacing (ft), length of irrigated furrows (ft), diameter of lay-flat irrigation pipe, furrow flow rate (gpm) required for soil to be effectively irrigated, and wall thickness (ml) and allowable pressure (ft. of head) of selected lay-flat irrigation pipe (Kebede et al. 2014). Pad elevation was determined with a Topcon® self-leveling slope matching rotary laser level (Topcon positioning systems Inc., Livermore, CA), while furrow and pad length were calculated from aerial imagery.

Furrow spacing was determined as the width between planted rows. Computerized hole selection was calculated with the Pipe Hole And Universal Crown Evaluation Tool (PHAUCET) version 8.2.20

(USDA-NRCS, Washington, DC). Surge flow irrigation was applied with a P&R STAR surge valve (P&R Surge Systems, Inc., Lubbock, TX). Four advanced phases were utilized and soak cycles were eliminated. Both FURROW and FLOOD were outfitted with a McCrometer flow tube with attached McPropeller bolt-on saddle flowmeter (McCrometer Inc., Hemet, California) to measure flow rate and water usage. Irrigation was applied to FURROW when the average soil moisture content in the 0-24-in. rooting depth was between -75 and -100 cbar as measured by Watermark Model 200SS soil water potential sensors (Irrometer Co., Riverside, CA) that were installed at 6, 12, and 24 in. FLOOD was irrigated based upon the producer's decision. Irrigation was terminated at R6.5 as recommended by the Mississippi State University Extension Service. Treatments were mechanically harvested at physiological maturity and yields were determined with a calibrated onboard yield monitor.

Irrigation water use efficiency (IWUE) was calculated by

$$\mathrm{IWUE} = \frac{\mathrm{SGY}}{\mathrm{Acre} - \mathrm{in}}$$

where SGY is soybean grain yield and acre-in is the amount of water in acre inches applied to a treatment. Total irrigation water applied, soybean grain yield, and IWUE were analyzed using the MIXED procedure of SAS (Statistical Analytical System Release 9.4; SAS Institute Inc., Cary, North Carolina), with field as a random effect.

## Results and Discussion

*Economic Analysis*

To investigate the economics, enterprise budgets were developed to represent two soybean production systems based on the use of furrow irrigation technology within a straight levee rice field (FURROW) vs. flood irrigation technology in a straight levee system (FLOOD). These budgets are modified versions of budgets in the Mississippi State University Department of Agricultural Economics Budget Report 2016–05, and revised to represent the two technologies. The results in Tables 1 and 2 represent the income, direct expenses, and fixed expenses related to the FURROW and FLOOD methods, respectively.

Expected income is based on a soybean price of $9.74/bu taken from the Mississippi State University Department of Agricultural Economics Budget Report 2016–05. Yields for both methods were based on the average results from this study for 2016. All cultural practices other than irrigation activities are assumed to be identical for both technologies. Other than irrigation-related expenses, the only other difference in cost per acre is related to the grain hauling, which is directly related to yield, so is $2.83 per acre higher for FURROW. The irrigation supply allowance of $19.01 per acre for FURROW includes a $10.76 per acre charge for the RISER program along with an $8.25 per acre charge for rollout pipe. The RISER program allowance includes a charge for surge valves, transfer pipe, moisture sensors, batteries and data logger package

Estimated irrigation costs for FURROW are shown in Table 3. The costs shown include direct expenses for laying out and retrieving the pipe along with labor for three 3 inch irrigation events. The estimated costs for FLOOD are shown in Table 4. The costs shown include machinery and labor costs to build inside levees twice, two 4.5 inch irrigation events and machinery and labor costs to tear down the levees twice.

*Irrigation Water Use Efficiency and Soybean Grain Yield*

Irrigation method did not significantly affect total acre inches of water applied ($F = 0.19$; df = 1, 6; $P = 0.675$) or irrigation water use efficiency ($F = 0.51$; df = 1, 6; $P = 0.501$) (Table 1). These data suggest that farmers are managing water use in flood-irrigated fields very well. The majority of farmers implementing flood irrigation have been using this practice for years and have learned when and how to terminate irrigation to minimize runoff. However, irrigation method did significantly affect soybean grain yield ($F = 8.12$; df = 1, 6; $P = 0.029$). The FURROW irrigation method yielded 16.5% more than FLOOD (Table 5). The number of levees, well capacity, saturation, and drainage all played a role in the observed yield reduction. Farmers continuing to flood irrigate should play close attention to well capacity, field size, and drainage to avoid soil saturation on the top and bottom of the field.

*Economic Return*

Irrigation method significantly affected economic net return ($F = 2.98$; df = 1, 12; $P = 0.001$) as based on budget analysis at the soybean price used in the Mississippi State University Department of Agricultural Economics Budget Report 2016–05. FURROW (Table 1) resulted in an advantage of $83.07 per acre for the 2016 growing season compared to FLOOD (Table 2). These results show that the FURROW method is significantly superior to FLOOD with regard to both soybean grain yield and net return.

*Conclusion*

The objective of this research was to determine the effect of FURROW and FLOOD irrigation methods on soybean grain yield, total water applied, irrigation water use efficiency, and economic return. There were no significant differences between irrigation method with respect to total water applied or irrigation water use efficiency, yet, FLOOD did adversely affect yield and economic net return compared to FURROW. Overall, FURROW on clay-textured soils can be implemented to achieve greater soybean grain yield and net return without negatively affecting the region's groundwater supply.

**Table 1. Summary of estimated costs and returns per acre for soybeans, May-planted, RR, 12R 30 in., Rice Well FURROW irrigated, 9 ac-in., Delta Area, MS.**

| ITEM | UNIT | PRICE | QUANTITY | AMOUNT |
|---|---|---|---|---|
| | | Dollars | | Dollars |
| INCOME | | | | |
| Soybeans | bu | 9.74 | 76.9000 | 749.01 |
| | | | | --------- |
| TOTAL INCOME | | | | 749.01 |
| **DIRECT EXPENSES** | | | | |
| CUSTOM SPRAY | acre | 32.50 | 1.0000 | 32.50 |
| HARVEST AIDS | acre | 8.42 | 1.0000 | 8.42 |
| FERTILIZERS | acre | 41.61 | 1.0000 | 41.61 |
| FUNGICIDES | acre | 27.44 | 1.0000 | 27.44 |
| HERBICIDES | acre | 111.82 | 1.0000 | 111.82 |
| INSECTICIDES | acre | 32.86 | 1.0000 | 32.86 |
| IRRIGATION SUPPLIES | acre | 19.01 | 1.0000 | 19.01 |
| SEED/PLANTS | acre | 63.00 | 1.0000 | 63.00 |
| ADJUVANTS | acre | 5.55 | 1.0000 | 5.55 |
| CUSTOM FERTILIZE | acre | 7.00 | 1.0000 | 7.00 |
| HAULING | acre | 20.76 | 1.0000 | 20.76 |
| CUSTOM LIME | acre | 15.18 | 1.0000 | 15.18 |
| CROP CONSULTANT | acre | 6.50 | 1.0000 | 6.50 |
| INOCULANT | acre | 3.00 | 1.0000 | 3.00 |
| SOIL TEST | acre | 3.30 | 1.0000 | 3.30 |
| HAND LABOR | hour | 9.06 | 0.1241 | 1.13 |
| IRRIGATE LABOR | hour | 9.06 | 0.3625 | 3.30 |
| OPERATOR LABOR | hour | 13.14 | 0.4643 | 6.10 |
| UNALLOCATED LABOR | hour | 13.10 | 0.3472 | 4.55 |
| DIESEL FUEL | gal | 1.70 | 12.3269 | 20.96 |
| REPAIR & MAINTENANCE | acre | 18.12 | 1.0000 | 18.12 |
| INTEREST ON OP. CAP. | acre | 10.78 | 1.0000 | 10.78 |
| | | | | --------- |
| TOTAL DIRECT EXPENSES | | | | 462.89 |
| RETURNS ABOVE DIRECT EXPENSES | | | | 286.12 |
| TOTAL FIXED EXPENSES | | | | 99.54 |
| | | | | --------- |
| TOTAL SPECIFIED EXPENSES | | | | 562.43 |
| **RETURNS ABOVE TOTAL SPECIFIED EXPENSES** | | | | **186.58** |

Note: Cost of production estimates are based on 2016 input prices.

**Table 2. Summary of estimated costs and returns per acre for soybeans, May-planted, RR, 12R 30 in., FLOOD irrigated, 9 ac-in., straight levee, Delta Area, MS.**

| ITEM | UNIT | PRICE | QUANTITY | AMOUNT |
|---|---|---|---|---|
| | | Dollars | | Dollars |
| INCOME | | | | |
| Soybeans | bu | 9.74 | 66.4000 | 646.74 |
| | | | | --------- |
| TOTAL INCOME | | | | 646.74 |
| **DIRECT EXPENSES** | | | | |
| CUSTOM SPRAY | acre | 32.50 | 1.0000 | 32.50 |
| HARVEST AIDS | acre | 8.42 | 1.0000 | 8.42 |
| FERTILIZERS | acre | 41.61 | 1.0000 | 41.61 |
| FUNGICIDES | acre | 27.44 | 1.0000 | 27.44 |
| HERBICIDES | acre | 111.82 | 1.0000 | 111.82 |
| INSECTICIDES | acre | 32.86 | 1.0000 | 32.86 |
| SEED/PLANTS | acre | 63.00 | 1.0000 | 63.00 |
| ADJUVANTS | acre | 5.55 | 1.0000 | 5.55 |
| CUSTOM FERTILIZE | acre | 7.00 | 1.0000 | 7.00 |
| HAULING | acre | 17.93 | 1.0000 | 17.93 |
| CUSTOM LIME | acre | 15.18 | 1.0000 | 15.18 |
| CROP CONSULTANT | acre | 6.50 | 1.0000 | 6.50 |
| INOCULANT | acre | 3.00 | 1.0000 | 3.00 |
| SOIL TEST | acre | 3.30 | 1.0000 | 3.30 |
| HAND LABOR | hour | 9.06 | 0.1241 | 1.13 |
| IRRIGATE LABOR | hour | 9.06 | 0.4500 | 4.07 |
| OPERATOR LABOR | hour | 13.14 | 0.5000 | 6.57 |
| UNALLOCATED LABOR | hour | 13.10 | 0.3472 | 4.55 |
| DIESEL FUEL | gal | 1.70 | 12.5749 | 21.39 |
| REPAIR & MAINTENANCE | acre | 18.57 | 1.0000 | 18.57 |
| INTEREST ON OP. CAP. | acre | 10.54 | 1.0000 | 10.54 |
| | | | | --------- |
| TOTAL DIRECT EXPENSES | | | | 442.93 |
| RETURNS ABOVE DIRECT EXPENSES | | | | 203.81 |
| TOTAL FIXED EXPENSES | | | | 100.30 |
| | | | | --------- |
| TOTAL SPECIFIED EXPENSES | | | | 543.23 |
| **RETURNS ABOVE TOTAL SPECIFIED EXPENSES** | | | | **103.51** |

Note: Cost of production estimates are based on 2016 input prices.

**Table 3. Estimated costs per acre for early soybeans FURROW irrigated with roll-out pipe-Rice well 80-acre system, 9 ac-in., Delta Area, Mississippi.**

| ITEM | UNIT | PRICE | QUANTITY | AMOUNT |
|---|---|---|---|---|
| | | Dollars | | Dollars |
| **DIRECT EXPENSES** | | | | |
| IRRIGATION SUPPLIES | | | | |
| Roll-Out Pipe | ft | 0.25 | 33.0000 | 8.25 |
| OPERATOR LABOR | | | | |
| Tractors | hour | 13.14 | 0.0785 | 1.03 |
| IRRIGATE LABOR | | | | |
| Special Labor | hour | 9.06 | 0.3000 | 2.73 |
| Implements | hour | 9.06 | 0.0625 | 0.57 |
| DIESEL FUEL | | | | |
| Tractors | gal | 1.70 | 0.7262 | 1.24 |
| Engine/Rice SL | 75 gal | 1.70 | 7.3316 | 12.45 |
| REPAIR & MAINTENANCE | | | | |
| Implements | acre | 0.20 | 1.0000 | 0.20 |
| Tractors | acre | 0.44 | 1.0000 | 0.44 |
| Engine/Rice SL | 75 ac-in | 0.28 | 9.0000 | 2.61 |
| Well & Pump Flood | each | 390.00 | 0.0125 | 4.88 |
| INTEREST ON OP. CAP. | acre | 0.55 | 1.0000 | 0.55 |
| | | | | --------- |
| TOTAL DIRECT EXPENSES | | | | 34.95 |
| FIXED EXPENSES | | | | |
| Implements | acre | 1.02 | 1.0000 | 1.02 |
| Tractors | acre | 2.75 | 1.0000 | 2.75 |
| Engine/Rice SL | 75 each | 1340.05 | 0.0125 | 16.75 |
| Land Forming ($450) | each | 31.92 | 1.0000 | 31.93 |
| Well & Pump Flood | each | 1152.97 | 0.0125 | 14.41 |
| | | | | --------- |
| TOTAL FIXED EXPENSES | | | | 66.86 |
| | | | | --------- |
| TOTAL SPECIFIED EXPENSES | | | | 101.81 |

Note: Cost of production estimates are based on 2016 input prices.

**Table 4. Estimated costs per acre for straight levee soybean FLOOD irrigation 80-acre system, 9 ac-in., Delta Area, Mississippi.**

| ITEM | UNIT | PRICE | QUANTITY | AMOUNT |
|---|---|---|---|---|
| | | Dollars | | Dollars |
| **DIRECT EXPENSES** | | | | |
| OPERATOR LABOR | | | | |
| Tractors | hour | 13.14 | 0.1142 | 1.50 |
| IRRIGATE LABOR | | | | |
| Special Labor | hour | 9.06 | 0.4500 | 4.07 |
| DIESEL FUEL | | | | |
| Tractors | gal | 1.70 | 0.9741 | 1.66 |
| Engine/Mult In Rice | gal | 1.70 | 7.3316 | 12.46 |
| REPAIR & MAINTENANCE | | | | |
| Implements | acre | 0.18 | 1.0000 | 0.18 |
| Tractors | acre | 0.58 | 1.0000 | 0.58 |
| Engine/Mult In Rice | ac-in | 0.32 | 9.0000 | 2.94 |
| Well & Pump Flood | each | 390.00 | 0.0125 | 4.88 |
| INTEREST ON OP. CAP. | acre | 0.53 | 1.0000 | 0.53 |
| | | | | --------- |
| TOTAL DIRECT EXPENSES | | | | 28.80 |
| FIXED EXPENSES | | | | |
| Implements | acre | 0.86 | 1.0000 | 0.86 |
| Tractors | acre | 3.67 | 1.0000 | 3.67 |
| Engine/Mult In Rice | each | 1340.05 | 0.0125 | 16.75 |
| Land Forming ($450) | each | 31.92 | 1.0000 | 31.93 |
| Well & Pump Flood | each | 1152.97 | 0.0125 | 14.41 |
| | | | | --------- |
| TOTAL FIXED EXPENSES | | | | 67.62 |
| | | | | --------- |
| TOTAL SPECIFIED EXPENSES | | | | 96.42 |

Note: Cost of production estimates are based on 2016 input prices.

**Table 5. Total irrigation water applied, irrigation water use efficiency, and soybean grain yield for FURROW and FLOOD irrigation methods for a study conducted in 2016 throughout the Mississippi Delta.**

| | Least Square Mean Value | | |
|---|---|---|---|
| | Irrigation Method | | |
| **Parameter** | **FURROW** | **FLOOD** | **Significance Level** |
| Total Irrigation Water Applied (acre $in^{-1}$) | 9.36 (0.42)[a] | 9.91 (1.24) | 0.68 |
| Irrigation Water Use Efficiency (bu $acre^{-1}$) | 8.33 (0.69) | 7.55 (1.24) | 0.5 |
| Soybean Grain Yield (bu $acre^{-1}$) | 76.95 (4.78) | 66.22 (5.15) | 0.03 |

[a]Standard Error

**Objective 3: Determine effect of plant population on yield, yield components, crop water use efficiency, and economics for soybean planted on 19.5-inch rows.**

Clay-textured soils encompass 3.7 million ha, or 50% of the lower Mississippi River alluvial flood plain and 50% of the Mississippi Delta region (Pettiet 1974). Soybean is planted on the majority of the cropped clay soil (Heatherly et al. 2002). Soybean is economically important to Mississippi, especially the Delta region where over 70% of the total state soybean hectareage was planted in 2006 (NASS 2007).

Soybean production in the Midsouth generally uses raised beds on wide rows to accommodate furrow irrigation, and uses the same equipment for cotton (*Gossypium hirsutum* L.) and corn (*Zea mays* L.) planting and tending. Common row widths used for soybean in the lower Mississippi River Valley range from 88 to 102 cm. Bedding refers to ridging soil or raising the seedbed above the area of peak water accumulation or above the mean water elevation of the field. Bedding systems vary by the height and width of the bed and the number of planted rows each bed supports. Wide beds capable of supporting more than one row can be constructed and could be incorporated with narrow row configurations currently utilized in the Mississippi Delta and ESPS. Wider beds may also last longer than one growing season, fitting well into increased adoption of no-till or conventional tillage systems.

Soybean yields in the midwestern United States usually are greater from plants in narrow rows than in the historical 102-cm rows (Pendleton and Hartwig, 1973; Cooper, 1977). This yield increase, at equivalent plant populations, is attributed to the development of a canopy that provides complete ground cover in narrow rows by the time rapid pod-fill occurs (Shibles and Weber, 1966). Full ground cover canopies intercept more solar radiation and have greater photosynthesis than do partial ground cover canopies (Shibles and Weber, 1965). Rapid canopy development may be a disadvantage during dry years, however, because the increased early-season exposure of leaves to full sunlight usually increases the use of stored soil water, if other factors are equal. If more stored soil water is used early in the growing season, less water is available during the critical pod-filling stages and supplemental water would need to be applied.

Approximately 70% of the farmland in the Mississippi Delta is irrigated, and the MRVAA is the primary source. Irrigation withdrawal for row crops is depleting the aquifer at unsustainable rates, with an annual overdraft of 370 million cubic meters of water per year. To improve irrigation management in the region, exploring cultural practices and their impacts on irrigation water use efficiency needs to be evaluated. The objective of this research is to determine the impact row spacing and plant populations have on soybean grain yield, total irrigation water applied, and irrigation water use efficiency.

## Materials and Methods

To determine the effect that row spacing and plant population have on soybean grain yield and irrigation water use efficiency, an experiment was conducted at the Delta Research and Extension Center located in Stoneville, Mississippi. Soybean (HBK LL 4653) was planted on 26 May 2016. Plots were 12.1-m wide and 30.3-m long. Soil type of the field was Sharkey Clay. Treatments were in a split-plot arrangement within a randomized complete block design with four replications. The main plot factor was row spacing that consisted of 1-m- and 2-m-wide raised seed beds.

The 2-m-wide beds contained four rows of planted soybean spaced 50 cm apart. The sub-plot factor was plant populations that consisted of 276, 640, 345, 800, and 414, 960 plants $ha^{-1}$. Plots were furrow-irrigated where water was pumped through 30.5-cm-diameter polyethylene tubing laid perpendicular to the soybean rows. Holes were punched in the polyethylene tubing to allow water to run down the middle three furrows to mitigate water moving into other plots. Plots were arranged across the field to allow furrow irrigation to easily be controlled. Care was taken to insure water did not deviate from one treatment to another. A $M^{c}$Crometer flow tube with attached $M^{c}$Propeller bolt-on saddle flowmeter (McCrometer, Inc. Hemet, CA) was installed on the riser to measure application volume.

Three IRROMETER Watermark moisture sensors (IRROMETER Company Inc., Riverside, CA) were set at depths of 15-, 30-, and 61-cm soil depths immediately following planting. These sensors measure soil water tension by reading the amount of water absorbed through a granular matrix. Every plot in one replication was outfitted with a set of moisture sensors. Soil moisture sensors were connected to a data logger that recorded soil moisture every 4 hours. Irrigations were initiated for any treatment that exceeded -100 centibars of available soil moisture. Irrigation events were terminated when irrigation water moving down the furrow and passed the end of the plot. The amount of water needed to reach this point was recorded for each irrigation event.

Irrigation events were terminated at R6.5 as recommended by the Mississippi State University Extension Service. Plots were mechanically harvested at physiological when seed moisture was between 15-18%. In-season measurements included growth stage, stand counts, and cumulative irrigation water applied. At harvest, seed yield, yield increase per mm of irrigation water, and yield increase due to irrigation will be determined. Data were subjected to analysis of variance using SAS PROC MIXED and means separated by PDMIX8000.

## Results and Discussion

During the growing season, only one irrigation event was required. The treatments that received this irrigation event were all plant populations planted on 2-m-wide beds and 276,640 plants $ha^{-1}$ planted on 1-m-wide beds. In-season soil moisture readings are being analyzed to determine if any differences in water use existed among treatments.

There was no significant plant population by row spacing interaction for soybean grain yield ($P = 0.54$). Plant population did not have a significant effect on soybean grain yield ($P = 0.52$). Row spacing did significantly affect soybean grain yield ($P = 0.04$). Soybean planted on 2-m-wide beds (4363 kg $ha^{-1}$) yielded 4% more than soybean planted on conventional 1-m-wide beds (4210 kg $ha^{-1}$).