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MISSISSIPPI SOYBEAN PROMOTION BOARD
PROJECT NO. 55-2017
FINAL REPORT

Project Title: Row-Crop Irrigation Science Extension and Research (RISER) Program—Furrow vs. Flood Irrigation Method

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Objective: Determine the effect flood irrigation versus furrow irrigation on soybean grain yield, irrigation water use, irrigation water use efficiency, and net returns above irrigation costs.

EXECUTIVE SUMMARY

The objective of this research was to compare soybean grain yield, total water applied, irrigation water use efficiency, and economic net return of furrow (FURROW) and flood (Straight Levee) (FLOOD) irrigated soybean production systems. The research was conducted at seven locations in year one and nine locations in year two throughout the Mississippi Delta. Studies consisted of paired fields with the same cultivar, soil texture, planting date, and management practices used on both sites. Paired fields were assigned as FURROW or FLOOD irrigation method.

Total water applied and irrigation water use efficiency were not impacted by irrigation method (Table 1).

The FURROW irrigation method yielded 7.85% more than FLOOD (74.5 vs. 69.0 bu/acre, Table 1). The number of levees, well capacity, saturation, and drainage all played a role in the observed yield reductions. Farmers continuing to flood irrigate should pay close attention to well capacity, field size, and drainage to avoid soil saturation on the top and bottom of the field.

Average net return to FURROW was $33.62/acre greater than to FLOOD. Thus, the FURROW method was significantly superior to FLOOD with regard to both soybean grain yield and net return.

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. Total irrigation water applied, irrigation water use efficiency, and soybean grain yield for FURROW and FLOOD irrigation methods for a study conducted in 2016 and 2017 throughout the Mississippi Delta.

	Least Square Mean Value		
	Irrigation Method		
Parameter	FURROW	FLOOD	Significance Level
Total Irrigation Water Applied (acre in^{-1})	8.46 A[a]	8.24 A	0.7270
Irrigation Water Use Efficiency (bu $acre^{-1}$)	9.40 A	9.63 A	0.8057
Soybean Grain Yield (bu $acre^{-1}$)	74.47 A	69.05 B	0.0278
Net Return (\$ $acre^{-1}$)	183.41 A	149.79 B	< .0001

[a]Values in a row followed by the same letter are not different at the $\alpha = 0.05$ level of significance.

ABSTRACT

In the lower Mississippi River Valley alluvial plain, clay-textured soils are the predominate type, comprising over 3.7 million hectares. Rice (*Oryza sativa* L.) and soybean (*Glycine max* L.) are typically planted in rotation on these soils, with the latter being furrow- or flood-irrigated.

The objective of this research was to compare soybean grain yield, total water applied, irrigation water use efficiency, and economic net return of furrow (FURROW) and flood (Straight Levee) (FLOOD) irrigated soybean production systems. The research was conducted at seven locations in year one and nine locations in year two throughout the Mississippi Delta. Studies consisted of paired fields with the same cultivar, soil texture, planting date, and management practices used on both sites. Paired fields were assigned as FURROW or FLOOD irrigation method.

Water applied to each field was monitored with flowmeters, irrigations were initiated in FURROW based on soil moisture sensor thresholds, and irrigations for FLOOD were initiated at the producer's discretion. Treatments were mechanically harvested, and soybean grain yield was determined with a yield monitor. There were no differences in total water applied or irrigation water use efficiency ($P \geq$ 0.7270) with respect to irrigation method. Relative to FLOOD, FURROW yielded 7.85% greater ($P =$ 0.0278) and had a 22.4% higher economic net return ($P < .001$). Results from this research indicate that Midsouth producers can implement FURROW on clay-textured soils to achieve greater soybean grain yield and economic net return when compared to FLOOD without negatively affecting the region's groundwater supply.

INTRODUCTION

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 per day in 1965 to 581 million gallons per day in 2000, a 396% increase (Halberg and Stephens, 1966; T.W. Holland, U.S. Geological Survey, written communication 2002).

Clay textured soils are the predominate 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 these soils. 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 where 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 that is attributed to the dominance of crack filling during irrigation (Mitchell and van Genuchten 1993).

With the decreasing water levels in the Mississippi Alluvial River Valley aquifer and state regulators responding by requiring minimum levels of irrigation water use and adoption of efficiency practices, the impact of furrow and flood irrigation practices in Midsouth soybean production need to be evaluated. The objective of this study was to compare soybean grain yield, total water applied, irrigation water use efficiency, and economic net return of furrow and flood (Straight Levee) irrigated soybean production systems.

MATERIALS AND METHODS

Site Description

To determine the effect flood irrigation has on soybean grain yield, total water applied, irrigation water use efficiency, and economic net return compared to furrow irrigation, seven locations were selected in year one and nine locations were selected in year two throughout the Mississippi Delta. Each farmer was requested to furnish two fields, one being furrow irrigated (FURROW) and one being 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), 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 (mil) 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 M^{c}Crometer flow tube with attached M^{c}Propeller bolt-on saddle flowmeter (M^{c}Crometer 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. depths.

FLOOD was irrigated based on 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-in applied to a treatment. Total irrigation water applied, soybean grain yield, IWUE, and net return were analyzed using the MIXED procedure of SAS (Statistical Analytical System Release 9.4; SAS Institute Inc., Cary, North Carolina), with field and year as random effects. All results presented are averaged over years.

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 Reports 2016–05 and 2017-02 and were 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.

The expected income is based on a soybean price of $9.82 per bushel, taken from the Mississippi State University Department of Agricultural Economics Budget Report 2016–05 and 2017-02. All values for enterprise budgets are the average of 2016 and 2017 prices. The yields for both methods were based on the yields from this study averaged across years. 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 was $1.89 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.

RESULTS

Irrigation Water Use Efficiency and Soybean Grain Yield

Total water applied and irrigation water use efficiency were not impacted by irrigation method ($P \geq$ 0.7270; Table 5). 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.

Conversely, soybean grain yield was different by irrigation method (P = 0.0278). The FURROW irrigation method yielded 7.85% more than FLOOD (Table 5). The number of levees, well capacity, saturation, and drainage all played a role in the observed yield reductions. Farmers continuing to flood irrigate should pay 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 (P < .001) as based on budget analysis at the average soybean price used in the Mississippi State University Department of Agricultural Economics Budget Report 2016–05 and 2017-02. FURROW (Table 1) resulted in an advantage of $33.62 per acre for the average of both growing seasons when compared to FLOOD (Table 2). These results show that the FURROW method is significantly superior to FLOOD with regard to not only soybean grain yield, but also economic 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 net 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. Overall, FURROW on clay textured soils can be implemented to achieve greater soybean grain yield and economic net return without negatively affecting the region's groundwater supply.

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

ITEM	UNIT	PRICE	QUANTITY	AMOUNT
		Dollars		Dollars
INCOME				
Soybeans	bu	9.82	73.835	725.06

TOTAL INCOME				725.06
DIRECT EXPENSES				
CUSTOM SPRAY	acre	29.25	1.0000	29.25
HARVEST AIDS	acre	7.03	1.0000	7.03
FERTILIZERS	acre	41.58	1.0000	41.58
FUNGICIDES	acre	26.75	1.0000	26.75
HERBICIDES	acre	104.04	1.0000	104.04
INSECTICIDES	acre	19.22	1.0000	19.22
IRRIGATION SUPPLIES	acre	19.01	1.0000	19.01
SEED/PLANTS	acre	69.25	1.0000	69.25
ADJUVANTS	acre	4.58	1.0000	4.58
CUSTOM FERTILIZE	acre	7.25	1.0000	7.25
HAULING	acre	18.48	1.0000	18.48
CUSTOM LIME	acre	15.25	1.0000	15.25
CROP CONSULTANT	acre	6.50	1.0000	6.50
INOCULANT	acre	3.00	1.0000	3.00
SOIL TEST	acre	3.32	1.0000	3.32
HAND LABOR	hour	9.06	0.1100	1.00
IRRIGATE LABOR	hour	9.06	0.3625	3.28
OPERATOR LABOR	hour	13.33	0.5189	6.91
UNALLOCATED LABOR	hour	13.31	0.3963	5.27
DIESEL FUEL	gal	1.75	13.16375	23.04
REPAIR & MAINTENANCE	acre	18.48	1.0000	18.48
INTEREST ON OP. CAP.	acre	10.47	1.0000	10.47
TOTAL DIRECT EXPENSES				442.93
RETURNS ABOVE DIRECT EXPENSES				282.13
TOTAL FIXED EXPENSES				98.72
TOTAL SPECIFIED EXPENSES				541.65
RETURNS ABOVE TOTAL SPECIFIED EXPENSES				**183.41**

Note: Cost of production estimates are based on average of 2016 and 2017 input prices.

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

ITEM	UNIT	PRICE	QUANTITY	AMOUNT
		Dollars		Dollars
INCOME				
Soybeans	bu	9.82	68.2000	669.72

TOTAL INCOME				669.72
DIRECT EXPENSES				
CUSTOM SPRAY	acre	32.50	1.0000	32.50
HARVEST AIDS	acre	7.03	1.0000	7.03
FERTILIZERS	acre	41.58	1.0000	41.58
FUNGICIDES	acre	26.75	1.0000	26.75
HERBICIDES	acre	94.85	1.0000	94.85
INSECTICIDES	acre	32.46	1.0000	32.46
SEED/PLANTS	acre	68.25	1.0000	68.25
ADJUVANTS	acre	4.58	1.0000	4.58
CUSTOM FERTILIZE	acre	7.25	1.0000	7.25
HAULING	acre	16.12	1.0000	16.12
CUSTOM LIME	acre	15.25	1.0000	15.25
CROP CONSULTANT	acre	6.50	1.0000	6.50
INOCULANT	acre	3.00	1.0000	3.00
SOIL TEST	acre	3.32	1.0000	3.32
HAND LABOR	hour	9.06	0.1241	1.12
IRRIGATE LABOR	hour	9.06	0.4500	4.08
OPERATOR LABOR	hour	13.33	0.5000	6.66
UNALLOCATED LABOR	hour	13.29	0.3472	4.61
DIESEL FUEL	gal	1.75	12.5749	22.01
REPAIR & MAINTENANCE	acre	21.51	1.0000	21.51
INTEREST ON OP. CAP.	acre	10.28	1.0000	10.28
TOTAL DIRECT EXPENSES				429.69
RETURNS ABOVE DIRECT EXPENSES				240.03
TOTAL FIXED EXPENSES				90.24
TOTAL SPECIFIED EXPENSES				519.93
RETURNS ABOVE TOTAL SPECIFIED EXPENSES				**149.79**

Note: Cost of production estimates are based on average of 2016 and 2017 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	15.94	0.0785	1.25
IRRIGATE LABOR				
Special Labor	hour	9.06	0.3000	2.72
Implements	hour	9.06	0.0625	0.57
DIESEL FUEL				
Tractors	gal	1.75	0.7262	1.27
Engine/Rice SL	75 gal	1.75	7.3316	12.83
REPAIR & MAINTENANCE				
Implements	acre	0.41	1.0000	0.41
Tractors	acre	0.39	1.0000	0.39
Engine/Rice SL	75 ac-in	0.53	9.0000	4.73
Well & Pump Flood	each	390.00	0.0125	4.88
INTEREST ON OP. CAP.	acre	0.55	1.0000	0.55

TOTAL DIRECT EXPENSES				37.83
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	31.92
Well & Pump Flood	each	1152.97	0.0125	14.41
TOTAL FIXED EXPENSES				66.85
TOTAL SPECIFIED EXPENSES				104.68

Note: Cost of production estimates are based on average of 2016 and 2017 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	13.33	0.1142	1.52
IRRIGATE LABOR				
Special Labor	hour	9.06	0.4500	4.08
DIESEL FUEL				
Tractors	gal	1.75	0.9741	1.70
Engine/Mult In Rice	gal	1.75	7.3316	12.83
REPAIR & MAINTENANCE				
Implements	acre	0.27	1.0000	0.27
Tractors	acre	0.38	1.0000	0.38
Engine/Mult In Rice	ac-in	0.67	9.0000	6.03
Well & Pump Flood	each	390.00	0.0125	4.88
INTEREST ON OP. CAP.	acre	0.53	1.0000	0.53

TOTAL DIRECT EXPENSES				32.21
FIXED EXPENSES				
Implements	acre	0.86	1.0000	0.77
Tractors	acre	3.67	1.0000	2.39
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				66.24
TOTAL SPECIFIED EXPENSES				98.45

Note: Cost of production estimates are based on average of 2016 and 2017 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 and 2017 throughout the Mississippi Delta.

	Least Square Mean Value		
	Irrigation Method		
Parameter	FURROW	FLOOD	Significance Level
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