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EXECUTIVE SUMMARY

Agricultural withdrawal has decreased water levels in the Mississippi Alluvial River Valley aquifer (MARVA), and state regulators have responded with requiring withdrawal permits, establishing permitted withdrawal limits, and instituting required minimum levels of irrigation water use efficiency practices.

The objective of this study was to determine the effect of conjunctive Irrigation Water Management (IWM) including computerized hole-selection (CHS), surge irrigation (SURGE), and sensor-based irrigation scheduling on irrigation water use, soybean grain yield, irrigation water use efficiency (IWUE), and net returns above irrigation costs at the production scale.

The experiment was conducted in the Prairie region of Arkansas and the Delta region of Arkansas and Mississippi from 2013 through 2015. The study consisted of 20 paired fields, with the same cultivar, soil type, planting date, and management practices. One field was randomly assigned as the control (CONV) and the other was instrumented with CHS, SURGE, and soil moisture sensors, i.e., IWM. Flowmeters were installed in the inlets to both fields and the farmers provided yield data.

Soybean grain yield averaged 69.0 bu/acre and did not differ between CONV and IWM (P = 0.6703).

Relative to CONV, IWM reduced water use 26% (P=0.0198) and increased IWUE 36% (P=0.0.0194).

Net returns for soybean production above irrigation costs were not different between CONV and IWM, even when pumping depth and diesel costs ranged from 18 ft to 400 ft and $1.60 per gallon to $3.70 per gallon, respectively ($P \geq 0.5376$).

These results demonstrate that implementation of conjunctive IWM at the production scale will reduce the demand on depleted groundwater resources without adversely affecting soybean grain yield or on-farm profitability.

Economically Viable Conjunctive Irrigation Water Management Practices that Reduce Water Requirements for Mid-South Furrow Irrigated Soybean

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ABSTRACT

Agricultural withdrawal has decreased water levels in the Mississippi Alluvial River Valley aquifer (MARVA), and state regulators have responded with requiring withdrawal permits, establishing permitted withdrawal limits, and instituting required minimum levels of irrigation water use efficiency practices. The objective of this study was to determine the effect of conjunctive Irrigation Water Management (IWM) including computerized hole-selection (CHS), surge irrigation (SURGE), and sensor-based irrigation scheduling on irrigation water use, soybean grain yield, irrigation water use efficiency (IWUE), and net returns above irrigation costs at the production scale. The experiment was conducted in the Prairie region of Arkansas and the Delta region of Arkansas and Mississippi from 2013 through 2015. The study consisted of 20 paired fields, with the same cultivar, soil type, planting date, and management practices. One field was randomly assigned as the control (CONV) and the other was instrumented with CHS, SURGE, and soil moisture sensors, i.e., IWM. Flowmeters were installed in the inlets to both fields and the farmers provided yield data. Soybean grain yield averaged 69.0 bu/acre and did not differ between CONV and IWM ($P = 0.6703$). Relative to CONV, IWM reduced water use 26% (P=0.0198) and increased IWUE 36% (P=0.0.0194). Net returns for soybean production above irrigation costs were not different between CONV and IWM, even when pumping depth and diesel costs ranged from 18 ft to 400 ft and $1.60 per gallon to $3.70 per gallon, respectively ($P \geq 0.5376$). These results demonstrate that implementation of conjunctive IWM at the production scale will reduce the demand on depleted groundwater resources without adversely affecting soybean grain yield or on-farm profitability.

INTRODUCTION

Groundwater from the Mississippi Alluvial River Valley aquifer (MARVA) is the primary irrigation source in the Mid-South where, over the past three decades, the number of agricultural wells has increased exponentially (Mississippi Department Environmental Quality, Personal Communication). Agricultural withdrawal from MARVA exceeds the aquifer recharge rate, thus causing a decline in groundwater levels (Guzman et al. 2014). Regulators have responded to the overdraft on MARVA with requiring withdrawal permits, instituting permitted withdrawal limits, and establishing required minimum levels of acceptable agriculture water use efficiency practices.

The majority of the irrigated acres in the Delta region of Arkansas and Mississippi is planted to maturity group (MG) IV soybean (*Glycine max* L.), which are furrow-irrigated without irrigation Best Management Practices (BMPS) using a conventional continuous flow delivery system

(CONV). Producers initiate irrigation on group IV soybean at the R1-R2 growth stage, andthereafter, default to a 7 or 10 d irrigation cycle until termination at approximately the R7 growth stage. Moreover, in this region, CONV irrigation utilizes lay-flat polyethylene tubing which is attached to the well or riser head and then laid perpendicular to the furrows at the upper end of the field. Holes that are the same size are punctured in the tubing to allow water to continuously flow down each furrow. Conventional continuous flow irrigation is the quickest method to move water over large amounts of land, but irrigation application efficiency for this delivery system is low, approximately 55% (Israeli 1988). Depending on soil texture, the low irrigation application efficiency of CONV is attributed to deep percolation losses and/or tail-water runoff (Eid et al. 1999; Goldhamer et al. 1987; Matter 2001; Varlev et al. 1995). Applying water uniformly, efficiently, and timely to maximize soybean grain yield and net returns will minimize the amount of water applied, which is imperative for the continuation of furrow irrigation in the Midsouthern US.

Computerized hole selection (CHS) is a tool that improves CONV irrigation application efficiency by computing flow and pressures along the length of lay-flat polyethylene tubing and selecting hole sizes so that down-row uniformity is improved across the irrigation set regardless of furrow length. Improved down-row uniformity means all rows are watered more evenly, thereby reducing tail water runoff, irrigation time, and water applied to the irrigation set. For example, Atwill et al. (2017) reported that CHS reduced irrigation water use in soybean 17% relative to CONV.

Similarly, surge irrigation (SURGE) is a delivery technique that improves irrigation application efficiency through the intermittent application of water to surface-irrigated furrows in a series of relatively short, on and off time periods. During the first "on" cycle, e.g. advance phase, the wetting front advances progressively down the furrow. During the "off" cycle, water is applied to a second portion of the field, while water supplied to the first portion infiltrates into the soil profile. Water applied during a subsequent "on" cycle advances rapidly across the wetted soil due to reduced infiltration rate. Once the water has advanced to the end of the furrow, runoff is reduced using short cycles in a cutback mode, e.g., soak phase, allowing the field to be irrigated to the desired depth. The intermittent application of water with surge irrigation increases furrow advance time, reduces deep percolation losses, decreases total irrigation water applied, and improves irrigation application efficiency (Bishop et al. 1981; Eid et al. 1999; Goldhamer et al. 1986; Israeli 1988; Izuno et al. 1985; Musick et al. 1987; Testezlaf et al. 1987).

Improved irrigation application timing through the utilization of scientific irrigation scheduling tools can reduce the number of irrigation events and/or the amount of irrigation water applied applied to a production scale irrigation set without adversely affecting soybean grain yield. Relative to a producer standard, irrigation events were reduced by 50% and soybean grain yield was not adversely affected when irrigation scheduling was based on soil moisture sensor data (Bryant et al. 2017). However, the adoption of scientific irrigation scheduling tools, even in regions with severe water shortages, is less than 2% (Frisvold and Deva 2012).

To date, CHS, SURGE and sensor-based irrigation scheduling have not been evaluated at the production scale. The objective of this study was to determine the effect of conjunctive Irrigation Water Management (IWM) that included CHS, SURGE, and sensor based irrigation scheduling on water use, soybean grain yield, irrigation water use efficiency, and net returns above irrigation cost at the production scale.

MATERIALS AND METHODS

Study location and design

The water requirement for soybean when furrow irrigated with disposable, thin-walled, polyethylene tubing was evaluated during the 2013 through 2015 growing seasons on the production scale in the Prairie region of Arkansas and the Delta region of Arkansas and Mississippi. The study consisted of 20 paired fields with the same cultivar, soil texture, planting date and management practices at each site (Table 1). One field was randomly assigned as IWM and the adjacent field was assigned as CONV. Total irrigation water applied to IWM and CONV fields was determined with a M^cCrometer flow tube with attached M^cPropeller bolt-on saddle flowmeter (McCrometer Inc., Hemet, California) placed at the inlet of each field. No BMPs were implemented in the CONV fields, while irrigation application efficiency and timing were optimized in IWM fields.

Computerized Hole Selection

Computerized hole selection was integrated into IWM fields to improve irrigation uniformity and application efficiency. Input parameters for CHS 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), and diameter of lay-flat irrigation pipe (in) (Atwill et al., 2017). Pad elevation was determined every 100 ft with a Topcon® self-leveling slope matching rotary laser level (Topcon positioning systems Inc., Livermore, CA), while furrow and pad length were obtained from aerial imagery. Furrow spacing was determined as the width between planted rows, since every furrow was irrigated. 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

Surge flow irrigation was assimilated into IWM fields to improve irrigation application efficiency by reducing deep percolation losses and tail-water runoff. Surge flow was applied with a P&R STAR surge valve (P&R Surge Systems, Inc., Lubbock, TX). For clay textured soils, four advanced phases were utilized and soak phases were eliminated. Irrigation was terminated on clay textured soils when the wetting front reached the tail-ditch—approximately 3 acre-inches were applied. For coarse textured soils, both the advance and soak phases were used. Irrigation was terminated on coarse textured soils when 2.5 to 3 acre-inches were applied. University personnel optimized SURGE advance and soak cycle to minimize tail-water runoff.

Irrigation Scheduling

Irrigation scheduling for IWM fields was based on soil moisture monitoring. Three Watermark 200SS soil moisture sensors (Irrometer Co. Inc., Riverside, CA) were installed at 6, 12, and 24-in depths in the lower-third of the irrigation set, and irrigation was applied when the weighted average of the soil water potential over the 24-in depth was between -85 and -100 cbar. Irrigation for IWM fields was terminated when soybean reached the R6.5 growth stage. Producers harvested and reported grain yield.

Irrigation water use efficiency was calculated as described by Vories et al. (2005):

$$IWUE = \frac{Y}{IWA}$$

where IWUE is irrigation water use efficiency (bu/acre-inch), Y is soybean grain yield (bu/acre), and IWA is irrigation water applied (acre-in).

Economic Analysis

The model used to project irrigation costs in this study incorporates irrigation enterprise budgets developed utilizing the Mississippi State University Budget Generator for CONV and IWM technologies at four different depths (RELIFT of 18 ft, Standard Well Depth of 140 ft, Deep Well Depth 200 Ft, and Sparta Depth of 400 ft). The model develops estimates of total receipts, total direct expenses, total fixed expenses, total specified expenses and net returns above total specified expenses on a per acre basis. The cost estimates were adjusted on an annual basis for the 2013, 2014 and 2015 crop years for changes in variable input costs other than diesel prices. Diesel costs were estimated for each observation based on the amount of water pumped at a baseline diesel cost of $2.83 per gallon, the average price used in developing MSU budgets for the 2013, 2014 and 2015 crop years. Soybean prices are held constant across all scenarios at $11.11 per bushel, the average price reported by USDA at Greenville, Mississippi for the August, September and October harvest time periods for the 2013, 2014 and 2015 crop years. To test the sensitivity of both technologies to differences in the major variable cost associated with pumping, a high diesel price and a low diesel price were evaluated. Prices for the scenarios were taken from the USDA Prices Paid Survey for the 2006-2015 timeframe for the Delta States region. The maximum annual average reported diesel price for the 2006-2015 timeframe of $3.70 per gallon is used in the high diesel price scenario and the lowest price of $1.60 per gallon is used in the low diesel price scenario.

Assumptions related to equipment utilized in each enterprise budget are reported in Table 2. The values for purchase price and fuel consumption are based on personal communication with Mississippi Delta region irrigation equipment input and service providers. The RELIFT alternative utilizes a 75 hp tractor as a power unit, with all other alternatives using a 100 hp stationary diesel engine for power. Irrigation water is assumed to be supplied at 2600 gallons per minute (gpm) for the RELIFT alternatives, 2000 gpm for the 140 ft Standard Depth well alternatives, 1800 gpm for the Deep Depth 200 ftt well alternatives, and 1250 gpm for the Sparta Depth 400 ft well alternatives.

Statistical Analysis

Irrigation water applied, soybean grain yield, IWUE, and net return above irrigation costs were analyzed using the MIXED procedure of SAS (Statistical Analytical System Release 9.4; SAS Institute Inc., Cary, North Carolina), with year and field (year) as random effects.

RESULTS AND DISCUSSION

General site statistics

During the 2013 through 2015 growing seasons, data for IWM comparisons were collected from 20 paired sites from the Prairie region of Arkansas to the Delta region of Arkansas and Mississippi, an area encompassing over 9,000 mi^2 (Table 1). Paired irrigation sets ranged in size from 6 to 80 acres. The primary soil texture contained in the boundary of paired irrigation sets included silt loam, clay, silty clay loam, and loam, which represented 45%, 40%, 10% and 5% of the sites, respectively.

Irrigation water applied

Conjunctive IWM had a significant effect on irrigation water applied in season ($P \leq 0.0003$). Eighty-five percent of the irrigators applied more water using CONV than IWM, and relative to CONV, 26% less water was applied to IWM fields (Table 3). Reduced water use in IWM at the field scale was equivalent to values observed for individual IWM practices at the meso-plot scale. For example, relative to CONV, computerized hole selection reduced irrigation water use in soybean 17% (Lee et al. 2017), and surge flow reduced irrigation water use in soybean from 24% to 80% relative to the control (Izuno et al. 1985; Testezlaf et al. 1987; Musick et al. 1987; Rodriguez et al. 2004; Wilks et al. 2017). Additionally, sensor based scheduling reduced the number of irrigations applied to soybean 50% compared to CONV (Bryant et al. 2017). These data indicate that conjunctive IWM will reduce water use in furrow irrigated soybean.

Advantages of conjunctive IWM extend beyond reduced irrigation water use in soybean. Foremost, from a regulatory perspective, the permitted value for row crops in Mississippi was not exceeded in IWM fields, while 10% of the CONV fields exceeded the permitted value, which is 18 acre-in/yr. These data indicate that adoption of IWM will reduce the probability of producers exceeding permitted withdrawal limits established by the Mississippi Department of Environmental Quality (MDEQ). Second, at the farm scale, improved irrigation application efficiency and timing provided by IWM will reduce the period required for a well to be committed to an irrigation set. In effect, IWM improves on-farm irrigation capacity, thereby allowing more acres to be irrigated by a well in a timelier manner. Improved timeliness of irrigation reduces the potential for yield loss associated with drought stress. Finally, water savings afforded by IWM are scalable and have regional implications. For instance, the agricultural overdraft on the MARVA in the Delta of Mississippi is estimated at 300,000 acre-ft/yr. Our data denote that 50% of the agricultural overdraft in the Delta of Mississippi, USA will be eliminated if conjunctive IWM is implemented on CONV soybeans.

It is plausible that these data underestimated the potential for conjunctive IWM to reduce irrigation water use in furrow irrigated soybean, primarily because of the Hawthorne effect. The Hawthorne effect states that "human subjects of an experiment change their behavior, simply because they are being studied." Under the conditions of this experiment, we noted that by 2014 approximately 50% of the producers scheduled and terminated irrigation for the CONV field based on recommendations for the adjacent IWM field. The Hawthorne effect may explain why the mean water savings with conjunctive IWM was not greater than water savings reported for discrete IWM practices alone, namely CHS, SURGE, and sensor based irrigation scheduling.

Soybean grain yield

The principal concept of IWM is to ensure adequate moisture for optimum grain yield while improving irrigation application efficiency. Consequently, soybean grain yield pooled over site years averaged 69 bu/acre and was not different between IWM and CONV (P = 0.6703). The yield data for soybean produced under IWM agree with others who reported that neither computerized hole selection, surge irrigation, or sensor based irrigation scheduling alone adversely affected soybean grain yield relative to the control (Atwill et al., 2017; Bryant et al. 2017; Wilks et al. 2017). Mid-South producers associate IWM practices with reduced grain yield; however, our production scale IWM data indicate that computerized hole selection, surge irrigation, and sensor based irrigation scheduling can be adopted concurrently without adversely affecting soybean grain yield.These production scale soybean grain yield data have implications for practitioners debating the number and location of soil moisture sensors required in an irrigation set to ensure no yield loss from drought stress. From 2013 through 2015, soybean grain yield in Arkansas and Mississippi was maintained relative to the CONV by installing 3 Watermark 200SS soil moisture sensors at 6, 12, and 24-in depths at one location on the lower-third of an irrigation set. Irrigation sets varied in size from 6 to 80 acres and encompassed soil textures ranging from very fine sandy loam to clay. Results demonstrate, therefore, that one sensor location in a production scale furrow irrigation set is sufficient to maintain soybean grain yield equivalent to that of current producer practices.

Soybean irrigation water use efficiency

A hypothesis of this study was that IWM improves irrigation application efficiency, and subsequently improves soybean irrigation water use efficiency. Conjunctive IWM at the production scale had an effect on soybean IWUE (P = 0.0194). Pooled over site years, soybean IWUE was 36% higher in IWM than CONV. The IWM results for soybean IWUE are in agreement with those reported for individual IWM practices. Relative to the control, computerized hole selection and surge flow irrigation improved soybean irrigation water use 21% and 29%, respectively (Atwill et al. 2017; Wilks et al. 2017).

Economic simulation

The estimated irrigation costs per acre calculated at the average acre-in of water pumped at the baseline diesel price of $2.83 per gallon for CONV (11.1 acre-in) and IWM (8.8 acre-in) technologies are reported in Table 4 . The higher values for the “Other Direct” for the IWM technology are attributed to the extra cost associated with transfer pipe and surge valve batteries. The higher values for the “Total Fixed” costs for IWM are attributed to the capital recovery cost for the surge valves, elbows, soil moisture sensors and data logger package. As would be expected, the advantage of the CONV technology in lower total specified cost declines as the depth that water is being pumped increases.

The estimated least square means for net returns above total specified irrigation costs for the CONV and IWM at the baseline soybean price of $11.11 per bushel and baseline diesel price of $2.83 per gallon are reported in Table 5. While estimated least square means of net returns for CONV were higher at Relift and Standard Well Depths and IWM were higher at 200 Foot and 400 Foot depths, no significant difference was found between least square means for the CONV and IWM technologies at any irrigation water lifting depths.

The estimated least square means for net returns above total specified irrigation costs for the CONV and IWM technologies at the baseline soybean price of $11.11 per bushel and high diesel price of $3.70 per gallon are reported in Table 6. While higher diesel prices, relative to the baseline, resulted in estimated least square means for the IWM technology being higher at all well depths, no statistically significant difference was found between least square means for the CONV and IWM technologies at any irrigation water lifting depths.

The estimated least square means for net returns above total specified irrigation costs for the CONV and IWM technologies at the baseline soybean price of $11.11 per bushel and low diesel price of $1.60 per gallon are reported in Table 7. The pattern of results for estimated least square means changed from the baseline results, with CONV resulting in higher estimated least square means for all cases except the 400 ft well. However, as with the other two scenarios, no statistically significant difference was observed between least square means for the CONV and IWM technologies at any irrigation water lifting depths.

These economics data have implications for Mid-South producers considering implementing IWM technologies at the farm scale. The additional costs for employing conjunctive IWM associated with the purchase of surge valves, elbows, soil moisture sensors, data logger packages, transfer pipe, and batteries for surge valves and data loggers is offset by reduced water use and total irrigation costs, regardless of the pumping depth, diesel costs, or soil textures analyzed in this study. Essentially, one may infer from this study that conjunctive IWM could be implemented across the Midsouth without adversely effecting on-farm profitability.

CONCLUSIONS

The objective of this study was to determine the effect of the conjunctive use of CHS, SURGE, and scientific irrigation scheduling tools on water use, soybean grain yield, irrigation water use efficiency, and net return above irrigation costs. Our data indicate that adoption of IWM on soil textures ranging from very fine sandy loam to clay will have no adverse effect on furrow irrigated soybean grain yield or irrigation costs. However, IWM will reduce irrigation water use and improve soybean irrigation water use efficiency. In essence, these IWM practices can be adopted by Midsouth soybean producers without adversely affecting on-farm profitability, while concurrently reducing the demand on depleted groundwater resources.

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Table 1. Fields used in the study comparing conjunctive Irrigation Water Management (IWM) with conventional (CONV) continuous flow irrigation of soybean in the Prairie Region of Arkansas and the Delta region of Mississippi and Arkansas during the 2013 through 2015 growing seasons.

					Field Size (acres)	
					Irrigation Method	
Year	Paired fields	State	County	Soil Texture	CONV	IWM
2013	1	Mississippi	Washington	Clay	40	40
	2	Mississippi	Washington	Clay	40	40
2014	1	Mississippi	Humphreys	Clay	29	26
	2	Mississippi	Leflore	Clay	30	29
	3	Mississippi	Quitman	Silt loam	79	94
	4	Mississippi	Bolivar	Clay	40	40
2015	1	Mississippi	Bolivar	Clay	26	26
	2	Mississippi	Tallahatchie	Clay	40	29
	3	Mississippi	Washington	Silty clay	45	28
	4	Mississippi	Quitman	Silty clay loam	27	29
	5	Mississippi	Sunflower	Silty clay loam	45	53
	6	Mississippi	Sharkey	Very fine sandy loam	77	77
	7	Mississippi	Sharkey	Silt loam	40	35
	8	Mississippi	Sunflower	Silt loam	52	44
	9	Arkansas	Clay	Loam	80	80
	10	Arkansas	Arkansas	Silt loam	31	41
	11	Arkansas	Arkansas	Silt loam	84	27
	12	Arkansas	Lee	Silt loam	24	19
	13	Arkansas	White	Silt loam	32	33
	14	Arkansas	Lonoke	Silt loam	6	28

Table 2. Estimated purchase price, annual use, useful life, fuel consumption rate, fuel cost, repair and maintenance (R&M), and direct, fixed and total costs per year based on pumping nine acre-inches per year and 2015 input prices.

Item Name	Unit of Measure	Purchase Price	Useful Life	Fuel Use	Fuel Cost	R & M	Direct	Costs Fixed	Total
		dollars	*years*	*gal/hr*	*$/yr*	----------------$/yr----------------			
Land Forming ($390)	acre	450	25	0	0.00	0.00	0.00	31.92	31.92
Surge Valve-10"	each	3,483	10	0	0.00	0.00	0.00	348.30	348.30
Pipe Elbows	each	127	20	0	0.00	0.00	0.00	6.35	6.35
Soil Moisture Sensors	each	39	3	0	0.00	0.00	0.00	13.00	13.00
Irrometer Datalogger (package)	each	450	10	0	0.00	0.00	0.00	45.00	45.00
RELIFT Tractor-75hp	ac-in	21,113	10	3.86	1924.09	1055.56	2979.74	1894.94	4874.68
Engine-100 Hp 140 ft	ac-in	20,000	20	3.6	2346.13	750.00	3096.13	1604.85	4700.98
Engine-100 Hp 200 ft	ac-in	20,000	20	3.6	2592.00	750.00	3342.00	1604.85	4946.85
Engine-100 Hp 400 ft	ac-in	20,000	20	3.6	3732.48	750.00	4482.48	1604.85	6087.33
RELIFT Pump	each	6,670	25	0	0.00	160.08	160.08	473.25	633.33
Well & Pump-140 ft	each	20,250	25	0	0.00	486.00	486.00	1436.78	1922.78
Well & Pump-200 ft	each	25,150	25	0	0.00	603.60	603.60	1784.45	2388.05
Well&Pump-400 ft	each	43,150	25	0	0.00	1035.60	1035.60	3061.59	4097.19

Table 3. Irrigation water applied, soybean grain yield, and irrigation water use efficiency for Irrigation Water Management (IWM) fields implemented with computerized hole selection, surge irrigation, and soil moisture sensors as compared to control fields with no IWM practices in Arkansas and Mississippi from 2013 through 2015 growing seasons.

	Least Square Mean Value		
	Irrigation Method		
Parameter	CONV	IWM	P value
Irrigation water applied (acre-in)	11.5[a]	9.1	0.0198
Yield (bu/acre)	69.3	68.6	0.6703
Irrigation water use efficiency (bu/acre-in)	7.2	9.8	0.0194

[a]Least square mean of 20 replicates.

Table 4. Estimated irrigation costs per acre by system for producer standard (CONV) and conjunctive Irrigation Water Management (IWM), i.e. computerized hole selection, surge irrigation, and sensor based irrigation scheduling, at average quantities of water pumped and baseline diesel prices.

Estimated Costs per Acre for CONV Technology for 11.1 acre-in applied at $2.83 per gallon of diesel.

	Diesel	Other Direct	Total Direct	Total Fixed	Total Specified
Relift	22.82	21.55	44.37	54.98	99.35
Standard	27.42	21.76	49.18	59.22	108.40
200 ft	30.10	22.52	52.62	61.41	114.03
400 ft	42.55	25.39	67.94	69.46	137.40

Estimated Costs per Acre for IWM Technology for 8.8 acre-in applied at $2.83 per gallon of diesel.

	Diesel	Other Direct	Total Direct	Total Fixed	Total Specified
Relift	18.46	24.30	42.76	60.43	103.19
Standard	22.11	24.51	46.62	64.67	111.29
200 ft	24.23	25.27	49.50	66.86	116.36
400 ft	34.10	28.14	62.24	74.91	137.15

Table 5. Estimated least square means for net returns above irrigation costs for four water lifting depths at a baseline soybean price of $11.11 per acre and a baseline diesel price of $2.83 per gallon. Control fields (CONV) are not instrumented with conjunctive Irrigation Water Management (IWM) practices, while IWM fields are implemented with computerized hole selection, surge irrigation, and sensor based irrigation scheduling.

	PROD	RISER	P value
	---------------$/acre---------------		
Relift	671.53	670.30	0.9173
Standard Well	663.25	662.90	0.9758
200 Foot	657.96	658.27	0.9789
400 Foot	636.11	639.38	0.7761

Table 6. Estimated Least Square Means for net returns above irrigation costs for four water lifting depths at a baseline soybean price of $11.11 per acre and a high diesel price of $3.70 per gallon. Control fields (CONV) are not instrumented with conjunctive Irrigation Water Management (IWM) practices, while IWM fields are implemented with computerized hole selection, surge irrigation, and sensor based irrigation scheduling.

	PROD	RISER	P value
	---------------$/acre---------------		
Relift	660.65	661.30	0.9557
Standard Well	650.15	652.10	0.8670
200 Foot	643.51	646.37	0.8036
400 Foot	615.70	622.64	0.5376

Table 7. Estimated Least Square Means for net returns above irrigation costs for four water lifting depths at a baseline soybean price of $11.11 per acre and a low diesel price of $1.60 per gallon. Control fields (CONV) are not instrumented with conjunctive Irrigation Water Management (IWM) practices, while IWM fields are implemented with computerized hole selection, surge irrigation, and sensor based irrigation scheduling.

	PROD	RISER	P value
	---------------$/acre---------------		
Relift	677.55	674.97	0.8303
Standard Well	670.49	668.49	0.8673
200 Foot	665.85	664.35	0.9002
400 Foot	647.25	647.93	0.9540