NATIONAL CENTER FOR ALLUVIAL AQUIFER RESEARCH

NCAAR

2021 ANNUAL REPORT

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USDA United States Department of Agriculture

MISSISSIPPI STATE UNIVERSITY

2021 ANNUAL REPORT

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COORDINATOR'S MESSAGE

Moving Forward

Dear Readers:

We are very excited to present the 1st annual report for the National Center for Alluvial Aquifer Research (NCAAR). NCAAR, established by Congress in 2017, is a cooperative program between USDA's Agricultural Research Service, the Mississippi Agricultural and Forestry Experiment Station, and the Mississippi State University Extension Service. NCAAR was created to address water resources challenges in the Mississippi River Alluvial Aquifer. With more than 90 percent of irrigation water coming from the Mississippi River Alluvial Aquifer, the future of farming in the Lower Mississippi River Basin depends on reducing drawdowns by improving production efficiency and promoting alternate water sources through science-based, proven production methods. We are driven to solve regional water problems by building a robust research program focused on water quality and quantity in combination with farm profitability. Agriculture is the backbone of America, and we want to sustain the industry we love for future generations. The center exists to find ways to preserve the aquifer and the agriculture that depends on it.

The past year has been an important and productive time NCAAR. NCAAR has continued to renovate the West Farm laboratory facilities to enable in-house soil and water testing. ARS has completed a lease on almost 320 acres of high-quality farmland adjacent to West Farm which will enable large-scale research to be carried out efficiently. Hiring the research team to carry out the project has continued throughout the impacts of COVID-19.

This year's annual report showcases the scientist, faculty, and student projects to address the water issues in the Lower Mississippi River Basin through such efforts as sensor-based irrigation scheduling, improvements to variable hole sizing in polypipe, irrigation timing studies, soil moisture sensor showcases and developing youth interest in agriculture. More information can be found at ncaar.msstate.edu.

Sincerely,

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FIVE-YEAR PLAN

Introduction

The Agricultural Research Service (ARS) Office of Scientific Quality Review completed the review and approval of the first all-new five-year research plan to guide the work at NCAAR. The project plan is made of six broad objectives to address water quality and quantity issues for agriculture. The project plan involves basic and applied research to develop solutions for producers and includes extension and outreach to transfer the solutions from researchers to end-users. NCAAR researchers will need to collaborate with each other, with researchers at various government agencies and universities as well as with commercial agricultural producers.

Development of Best Management Practices, Tools, and Technologies to Optimize Water Use Efficiency and Improve Water Distribution in the Lower Mississippi River Basin

Uncertainty in the amount and timing of precipitation is one of the most serious risks to producers in the Lower Mississippi River Basin (LMRB). To reduce risk and increase profit, producers are increasingly reliant on irrigation. Increased irrigation has resulted in increased groundwater withdrawals and a decline in levels of the Mississippi River Valley Alluvial Aquifer (MRVAA). Ongoing depletion and slow recharging of the MRVAA jeopardize the aquifer’s long-term availability and place irrigated agriculture, as currently practiced in the region, on an unsustainable path. We will use novel sensing technologies to monitor the MRVAA dynamics and develop robust datasets and models to determine the impact of alternate water supplies on the aquifer recharge. We will develop new automated irrigation control systems and improved decision support systems for irrigation management to increase irrigation water use efficiency and reduce over-pumping of groundwater from the MRVAA for irrigation. We will conduct investigations to quantify crop water demand and crop response to environmental conditions, develop and evaluate new irrigation and crop management strategies to improve water use efficiency and water quality and address climate variability in LMRB. We will engage LMRB stakeholders with our partners at Mississippi State University (MSU) to characterize producer behavior and attitudes on irrigation and water conservation management and introduce them to cutting-edge tools, technologies, and best management practices for optimal water use. Stakeholders will participate directly in on-farm trials for sensor-based and evapotranspiration-based irrigation scheduling studies. The results of the research activities will be communicated to stakeholders through a variety of methods, including reports, stakeholder meetings, journal publications, conferences, and workshops. Success of this project will significantly increase groundwater recharge rate to the MRVAA, decrease groundwater withdrawal from the MRVAA for irrigation, increase producers’ profitability, and enhance the sustainability of the MRVAA in providing quality water resources for agricultural production in the LMRB.

Objectives

1. Develop robust datasets, models, and data visualization tools to determine the impact of alternate water supplies on aquifer recharge and groundwater levels in the LMRB.

2. Develop optimized irrigation scheduling tools for cropping systems in the LMRB that account for crop water requirements, impacts of water stress, and economic and environmental sustainability while minimizing water usage.

3. Develop new and novel sensor systems and that include optimized telemetry and efficiently integrate with decision support models and

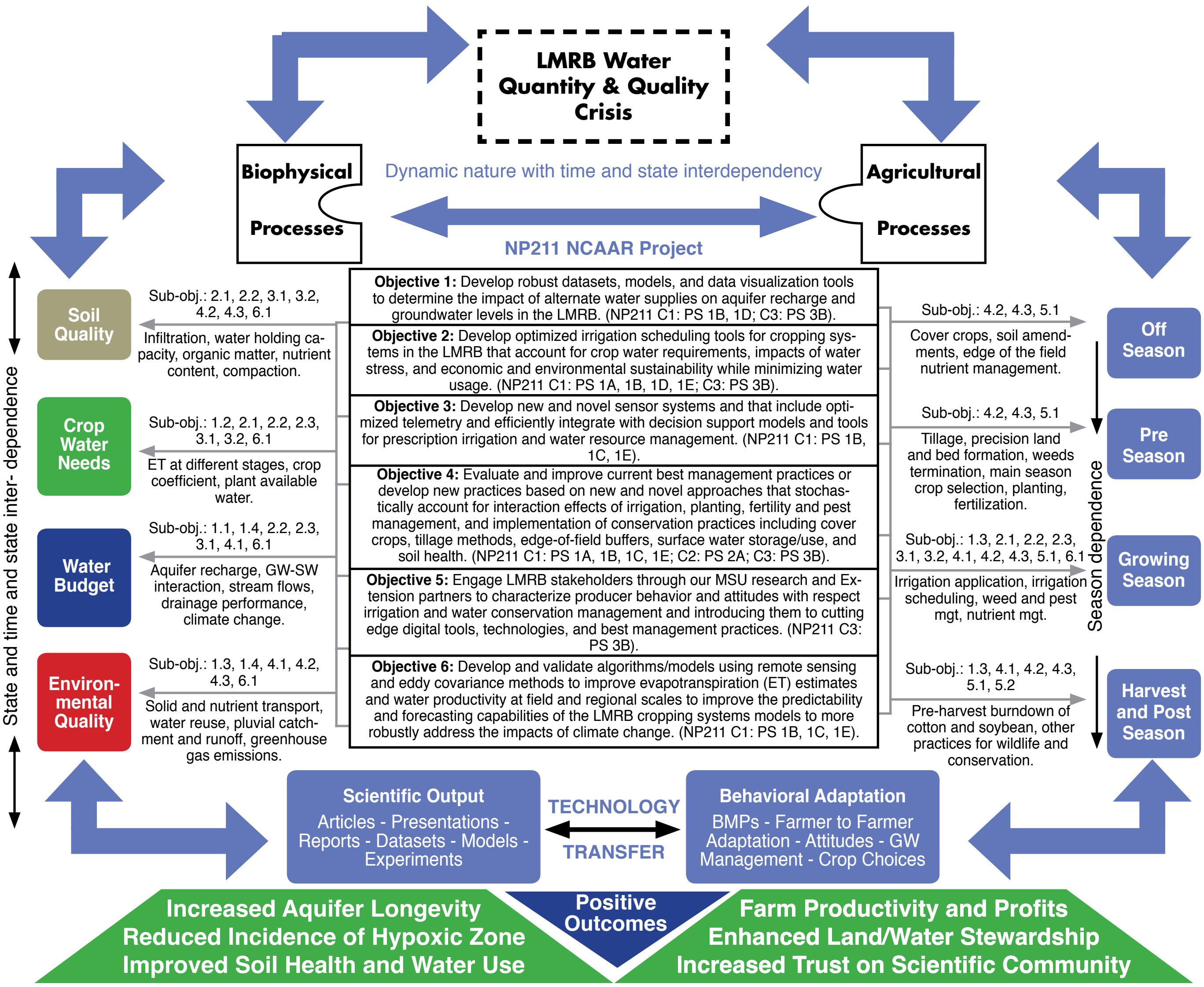

Figure 1. *This conceptual model illustrates and contextualizes NCAAR objectives for the next five years. The complexity of the problem NCAAR addresses requires complex multidisciplinary efforts. This logic diagram provides a guiding road map to ensure cohesion within the highly diverse research and technology transfer team and across their activities.*

tools for prescription irrigation and water resource management.

4. Evaluate and improve current best management practices or develop new practices based on new and novel approaches that stochastically account for interaction effects of irrigation, planting, fertility and pest management, and implementation of conservation practices including cover crops, tillage methods, edge-of-field buffers, surface water storage/use, and soil health.

5. Engage LMRB stakeholders through our MSU research and Extension partners to characterize producer behavior and attitudes with respect irrigation and water conservation management and introducing them to cutting edge digital tools, technologies, and best management practices.

6. Develop and validate algorithms/models using remote sensing and eddy covariance methods to improve evapotranspiration (ET) estimates and water productivity at field and regional scales to improve the predictability and forecasting capabilities of the LMRB cropping systems models to more robustly address the impacts of climate change.

IRRIGATION MANAGEMENT

Irrigation Systems and Row Spacing Effects on Soybean Water Use and Yield Components

Amilcar Vargas, Gurpreet Kaur, Gurbir Singh

Introduction

Soybean in Mississippi is usually grown at 36- or 38-inches row spacing. Soybean production in narrow row spacing (< 36 inches) has been proven to be feasible practice to increase soybean yield and economic returns in the Midwest states. The explanation of this increase in seed yield on narrow rows has been associated with a better light interception, nutrients, and increased water use efficiency. Water management practices are needed in Mississippi to increase the irrigation water use efficiency for soybean production and at the same time reduce pumping rates of groundwater from the Mississippi River Valley Alluvial Aquifer (MRVAA). The objective of this research was to determine the effects of irrigation methods and row spacing on soybean agronomic characteristics, yield, irrigation water use, and water use efficiency in the Mississippi Delta.

Materials and Methods

This study was conducted at the Mississippi State University's Delta Research and Extension Center on a Sharkey clay soil series. The field had a lateral move (Valley, Omaha, NE) irrigation system covering 38 acres. Extreme rainfall events limited access to the field in Fall 2020. This situation did not allow any tillage operations in fall 2020 therefore all tillage were performed in late spring 2021. Soybean variety AG 43x0 was planted on 5/27/2021 at the seeding rate of 140,000 seeds/ac. Soybean was planted in three-row patterns including 40" twin-row, 80" wide bed with six rows, and 40" single row spacing. Twin rows were planted with a Monosem NG Plus-4 8-row planter (Monosem Inc., Edwardsville, KS), single rows were planted with a John Deere 7300 4-row planter (John Deere, Moline, IL) and the 80" wide bed was planted with a Tye Grain Drill (The Tye Co., Lockney, Texas). All the planters and grain drill were calibrated for the seeding rate before planting. Irrigation treatments were rainfed, furrow, and sprinkler irrigation. Preplant application of 48 oz/ac Paraquat + 0.25% v/v Scanner was applied on 5/18/2021 for weed management. 22 oz/ac dicamba + 48 oz/ac Roundup PowerMAX 3 + 0.25% v/v Scanner + 8 oz/ac drift control compound was applied for post-emergence weed management on 6/29/2021. Soil moisture was monitored using Watermark 200SS sensors (Irrometer, Company Inc. Riverside, CA) installed at 6, 12 and 24 inches.

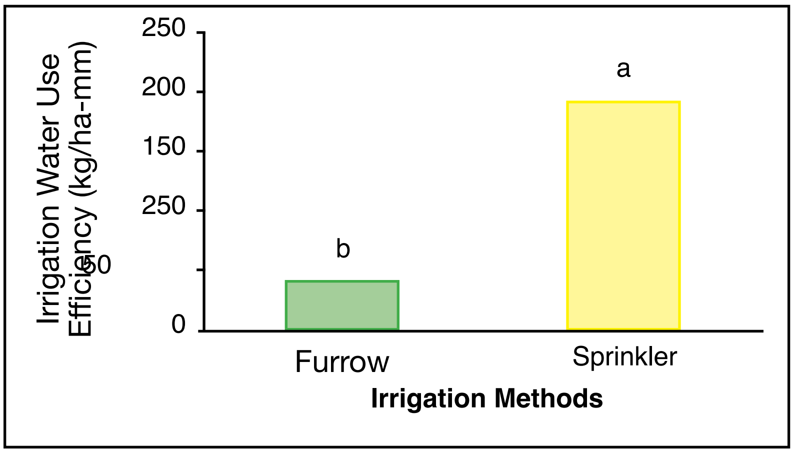

Figure 1. *Irrigation water use efficiency as affected by irrigation methods. Letters above bars are statistically different at alpha = 0.05.*

Irrigation treatments were triggered when the weighted average of the three soil-moisture sensor readings were equal or greater than -80 centibars. Data collected included soil samples, plant population, seed quality and seed yield. Soybean was harvested on 10/12/2021. Seed quality analysis was performed in November 2021 to determine protein, moisture, and oil content using a Foss Infratec grain analyzer (Eden Prairie, MN). Statistical analysis was conducted for all the data using statistical analysis software (SAS 9.4; SAS Inc. Cary, NC). Mixed model analysis was performed using the GLIMMIX procedure and mean separations were performed using Fisher's protected least significant difference test (p-value < 0.05).

Results and Discussion

There were significant differences in soybean yield, protein, oil, and moisture as affected by row spacing (Table 1). The highest yield (67 bu/ac) was achieved with a twin-row pattern at 40 inches row spacing. Irrigation water use efficiency (IWUE) was statistically different between furrow and sprinkler irrigation methods (Figure 1). The sprinkler irrigation method had the highest IWUE. These results indicated that IWUE efficiency can be improved using sprinkler irrigation method for soybean production in the Mississippi Delta and thereby can help with decreasing the water withdrawals for irrigation from MRVAA.

Table 1. *Irrigation system and row spacing effects on soybean production. The same letters in a column are not significantly different from each other at alpha = 0.05.*

Irrigation Treatments	**Row Spacing**	**Seed Yield bu/ac**	**Protein %**	**Oil %**	**Moisture %**
Rainfed		63.0	39.2	22.5	12.7
Furrow		65.2	38.9	22.6	12.6
Sprinkler		63.6	39.4	22.5	12.6
	Grain Drill, 80"	62.7 b	39.1 ab	22.5 a	12.4 b
	Single, 40"	62.0 b	39.6 a	22.4 b	12.8 a
	Twin, 40"	67.0 a	38.9 b	22.7 a	12.7 a
Rainfed	Grain Drill, 80"	59.7	39.1	22.5 b	12.5
Rainfed	Single, 40"	62.7	39.5	22.4 b	12.9
Rainfed	Twin, 40"	66.6	39.1	22.5 b	12.7
Furrow	Grain Drill, 80"	65.0	39.3	22.3 b	12.5
Furrow	Single, 40"	62.9	39.3	22.5 b	12.7
Furrow	Twin, 40"	67.5	38.3	23.1 a	12.7
Sprinkler	Grain Drill, 80"	63.4	38.9	22.6 b	12.4
Sprinkler	Single, 40"	60.3	40.0	22.4 b	12.8
Sprinkler	Twin, 40"	67.1	39.3	22.4 b	12.7
Source of Variation	df	p-values			
Irrigation Treatment (I)	2	0.2799	0.1932	0.1293	0.4056
Row Spacing (R)	2	0.0034	0.0398	0.0418	0.0005
I × R	4	0.3767	0.2568	0.0099	0.8244

IRRIGATION MANAGEMENT

Every Row and Skip Row Irrigation Impacts on Soybean Production in the Mississippi Delta

Hayden Burford, Gurbir Singh, Bhupinder Singh, Dillon Russell, Trey Freeland

Introduction

Mississippi soybean production in 2020 was more than two million acres. Around 80% of soybeans produced in Mississippi were in the Mississippi Delta Region. Within the Delta, 75% of the soybeans produced were irrigated (USDA-NASS, 2020). The Mississippi River Valley Alluvial Aquifer (MRVAA) is used to supply more than 90% of irrigation water to the Delta region (Dyer et al., 2015). Due to the excessive pumping of groundwater for irrigation, MRVAA water levels have been declining steadily. Different irrigation practices are needed to help slow and eventually stop the decline in the aquifer before the water level gets to an alarming level. Irrigating soybeans on a skip row irrigation plan instead of every row irrigation plan is one way to help lower the groundwater pumping amounts and thereby conserve the aquifer water. Therefore, the objective of this study was to evaluate soybean yield response to every row (ER) irrigation and skip row (SR) irrigation with different irrigation initiation sensor thresholds.

Materials and Methods

This experiment was conducted at the National Center for Alluvial Aquifer Research (NCAAR), Stoneville, MS (33°25′26″N, 90°54′54″W) in the 2020 and 2021 growing seasons. This study was done on a Bosket very fine sandy loam soil series. Treatments were established in a randomized complete block design. The treatments in this experiment were a combination of irrigation row spacing (every row and skip row) and irrigation scheduling sensor thresholds at three different centibars (cb) readings (-40 cb, -70 cb, and -100 cb) with a dryland control. For the 2020 growing season, Bayer Crop Science Asgrow 46X6 was planted at 130,000 seeds/ac on 40-inch beds. For the 2021 growing season, Bayer Crop

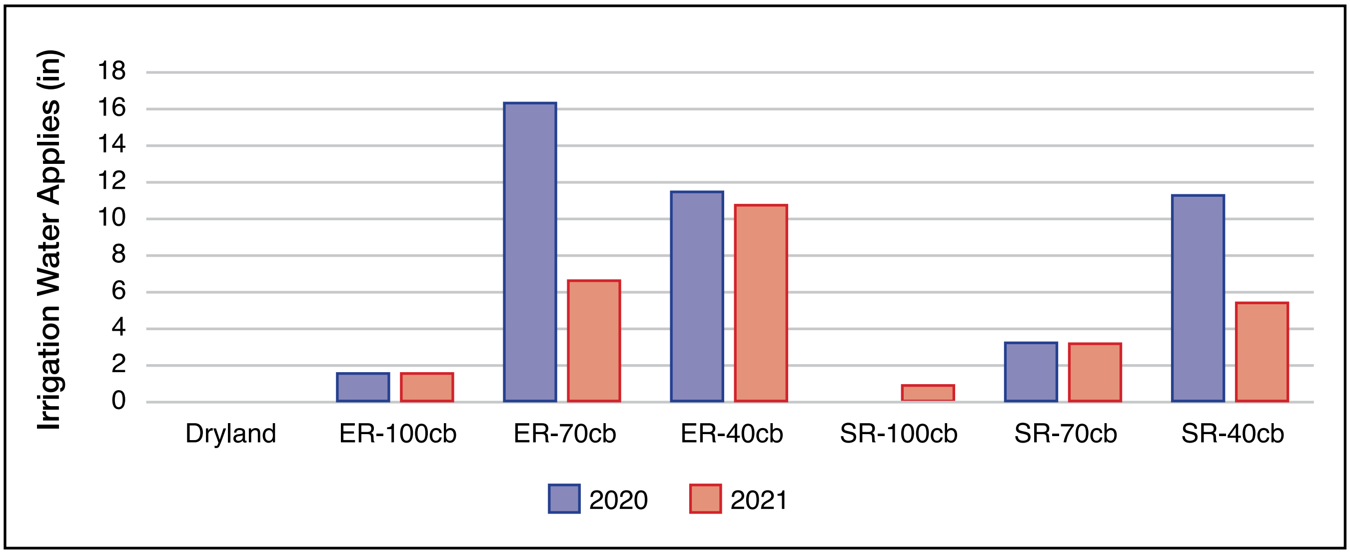

Figure 1. *Irrigation water applied to each treatment during 2020 and 2021 growing seasons.*

Science Asgrow 46X0 was planted at 130,000 seeds/ac on 40-inch beds. Soybean was planted on 5/5/2020 and 4/22/2021 with a 4-row John Deere Max-Emerge single-row planter. Fertilizer was applied on 4/7/2021 in the form of triple superphosphate (TSP) and muriate of potash (MOP) at a rate of 0-50-100 lb/ac. Watermark soil moisture sensors were installed at depths of 6, 12, and 24 inches and wired to a Trellis data logger (Peachtree Corners, Georgia) for soil water potential data collection. Soybean was harvested with a Kincaid 8xp plot combine (Haven, Kansas) equipped with a harvest master H2 grain gauge.

Results and Discussion

The SR -70 cb treatment had at least 8% higher yield than the SR -40 cb, SR -100 cb, and dryland treatments in 2020. The ER- 40 cb, ER -70 cb, and ER -100 cb were statistically the same as but numerically higher than the SR- 40 cb, SR -100 cb, and dryland treatments. In 2021, no statistical differences were observed for soybean yield. However, the most conservative treatment (SR -100 cb) had statistically the same yield as the most conventional treatment (ER -40 cb) while receiving less irrigation.

Conclusion

Results from both years of this study show that soybean yields can be maintained with skip row irrigation. This research also showed that yields can be maintained while using a more conservative irrigation plan with the SR -70 cb and the SR -100 cb having statistically comparable yields to the SR 40 cb in the 2021 growing season.

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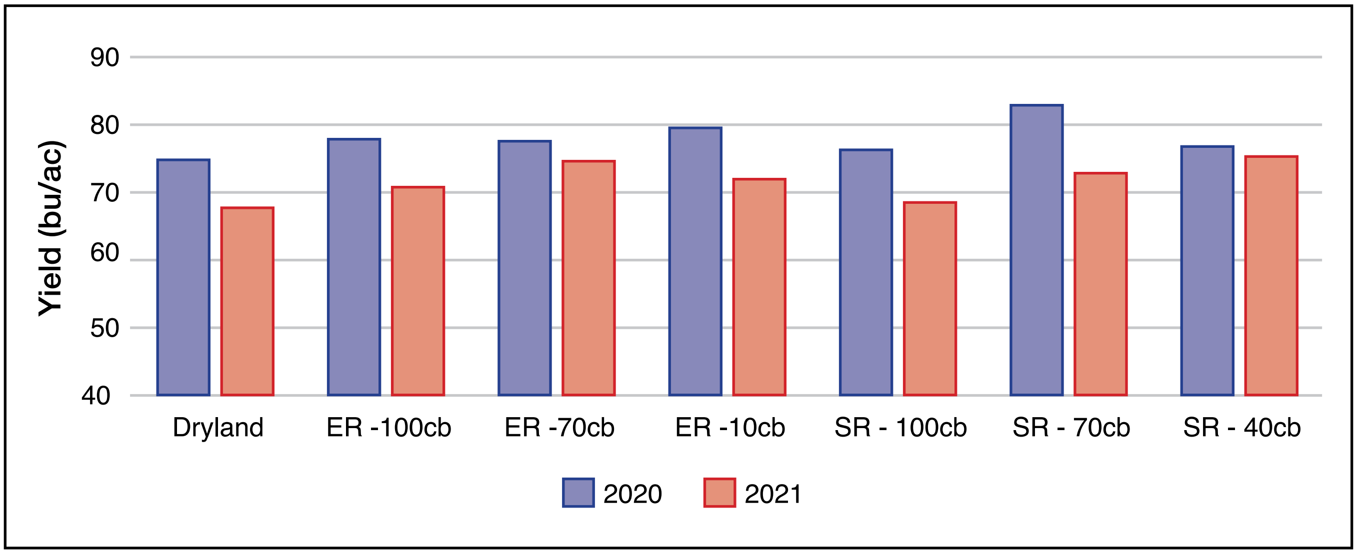

Figure 2. *Soybean yield by treatment for the 2020 and 2021 growing seasons.*

Investigating Soybean Responses to Irrigation Through Farm-Scale Trials in the Mississippi Delta

Saseendran Anapalli, Srinivasa Pinnamaneni, Krishna Reddy, Ruixiu Sui, Gurbir Singh

Introduction

The future of irrigated agriculture in the Lower Mississippi River Basin (LMRB) hinges on enhancing irrigation water use efficiency. Furrow irrigation practices dominate irrigated agriculture in the LMRB. We investigated soybean productivity in response to irrigation applied through every furrow (FI), irrigation applied through alternate furrow (AFI), and rain-fed production (RF; no irrigation). Approximately half the volume of irrigation water applied to the FI treatment was applied to the AFI treatment. The experiments were conducted in 2016, 2018, and 2020, which constituted the soybean phases of a corn-soybean rotation trial conducted on a clay soil in field-scale plots (25 ac). The plots were equipped with eddy covariance systems for quantifying crop water use (i.e., evapotranspiration (ET)). This unique study was conducted at the farm scale; as such, the results obtained directly apply to a farm environment, so they are ready to be incorporated into recommendations for adoption by soybean farmers without further field trials.

***Figure 1.** Soybean irrigation experiments equipped with eddy covariance instrumentation for crop water use measurements.*

Materials and Methods

To generate confident recommendations for adopting technologies previously developed in small-plot experiments, those experiments should be repeated at multiple locations and climates in field-scale plots. Such farm-scale trials provide the opportunity to evaluate irrigation water management technologies under realistic farming conditions. Another reason for farm-scale experiments is the three-dimensional spread of irrigation water. As the water applied to the furrows spread in all directions, irrigation in one small plot may unintentionally affect neighboring small plots. These interferences can be avoided by implementing treatments on larger field-scale plots.

The multi-year experiment was an irrigated corn-soybean rotation conducted between 2016 and 2020 at the United States Department of Agriculture (USDA)-Agricultural Research Service (ARS) Crop Production Systems Research Unit farm in Stoneville, MS. The investigation aimed to evaluate soybean production responses to FI, AFI, and RF scenarios and to quantify the water used by the crop in these systems using the cutting-edge science-based Eddy Covariance technology. A mid-maturity group IV soybean cultivar, Dyna-Gro 31RY45, was planted in the experiments without applied fertilizers.

Results and Discussion

Daily crop water use (ET) averaged across the three seasons were 0.193”, 0.197”, and 0.185”, respectively, in the FI, AFI, and RF treatments. Seasonal (emergence to R7 stage)

ET in the three treatments were 21.2”, 22.1”, and 20.7”, respectively. Averaged across the three crop seasons, seasonal rainfall was 19.4” while seasonal irrigation to the AFI and FI treatments were 1.6” and 3.2”, respectively.

Soybean yields across the three crop seasons in the FI, AFI, and RF treatments were 67.0, 65.6, and 50.9 bu/ac, respectively. Yield in the AFI treatment was only 1.4 bu/ac less than in the FI treatment, which means only a 2% yield decrease.

Conclusion

Using eddy covariance-based sensors in large field-scale plots, we quantified water used by soybean in the FI, AFI, and RF treatments. Irrigation through every furrow and alternate furrow, when combined with natural rainfall receipts and soil water storage, supplied enough water for the optimum production of the crop. Consequently, soybean grain yields were similar in the FI and AFI treatments. The RF treatment consumed less water; however, it yielded significantly lower as well. These farm-scale trials in the LMRB indicated that soybean can be irrigated through alternate furrows to save about half the irrigation water while producing comparable grain yields. This study is being continued for quantifying irrigation responses of corn, cotton, and rice across major soils and climates in the region for developing decision support information for sustainable water management.

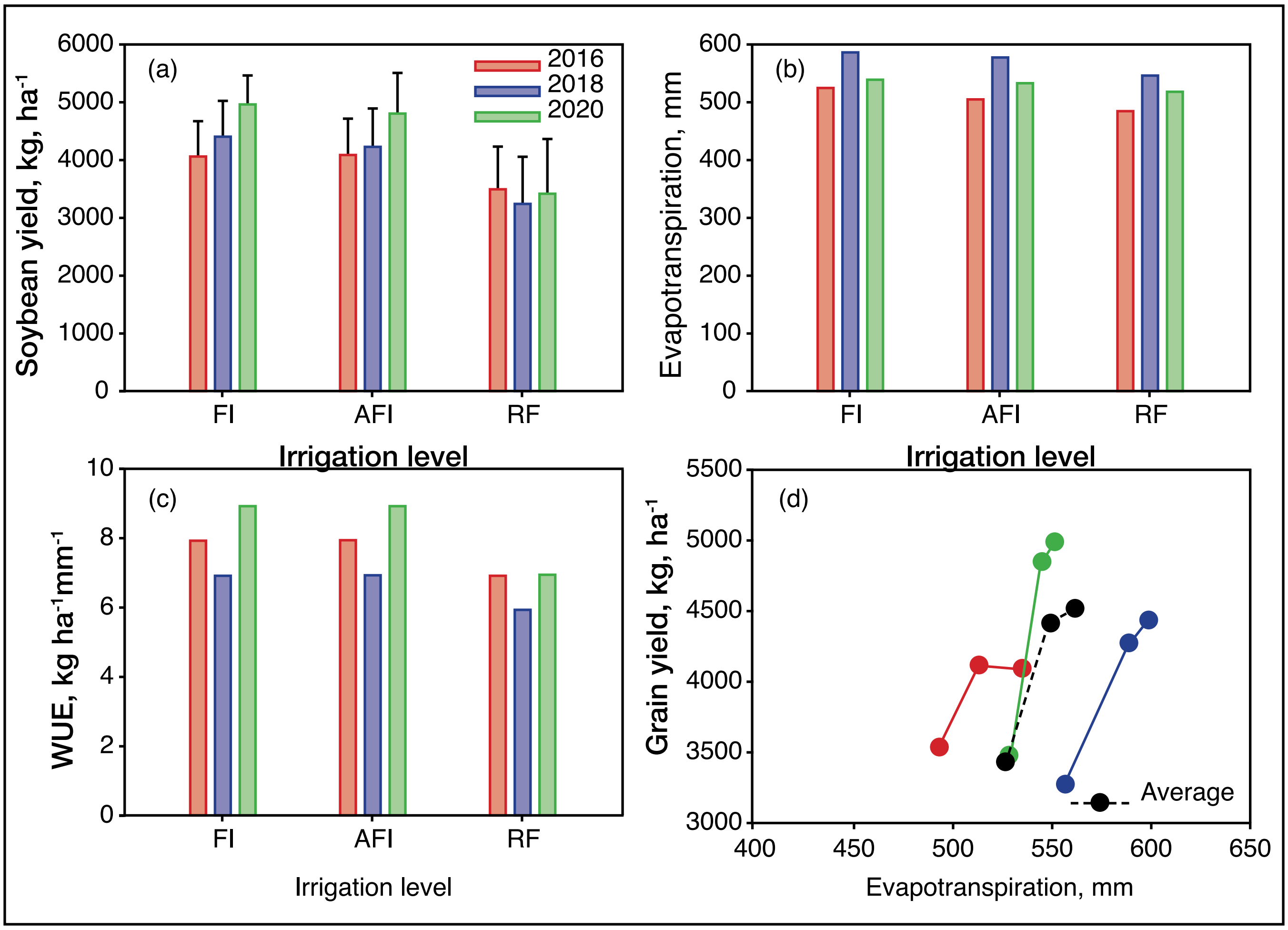

Figure 2. *a) Soybean yield, b) evapotranspiration (ET; water use), c) water use efficiency (WUE), and d) grain yield response to water use in the every-furrow irrigation (FI), alternate-furrow irrigation (AFI), and rainfed (RF) treatments in 2016, 2018, and 2020.*

IRRIGATION MANAGEMENT

Furrow Irrigation Spacing Impacts on Corn Production in Sharkey Clay Soils

Trey Freeland, Drew Gholson, Gurpreet Kaur, Gurbir Singh

Introduction

The Sharkey clay soil series, comprised mainly of 2:1 clay, is the dominant soil mapped in the Mississippi Delta, consisting of about one million acres (Pettry and Switzer, 1996). More than 40% of the land is classified under clay soils in the Mississippi Delta. Clayey soils are prone to frequent flooding and waterlogging. Kaur et al. (2020) reported that corn loses between 5-30% of yield with each day of waterlogging. Every-row and one-row-skip irrigation spacing practiced by Mississippi growers often results in saturated conditions which can lead to lower corn yield. Therefore, the objective of this research was to evaluate if altering irrigation spacings on Sharkey clay soils can reduce the waterlogging damage to corn and subsequently provide a benefit in corn yield.

Materials and Methods

An on-station field experiment was conducted at the National Center for Alluvial Aquifer Research (NCAAR), Stoneville, MS (33°25′26″N, 90°54′54″W), in 2021. All treatments were established in a randomized complete block design with four replications. Irrigation spacings included in this study were every row irrigation (ER; 40-inch spacing), 1 row skip irrigation (1R; 80-inch spacing), 4 row skip irrigation (4R; 160-inch spacing), and 8 row skip irrigation (8R; 320-inch spacing) **(Figure 1)**. For 4R and 8R, yield data was collected from rows along the irrigated furrows (4R-I and 8R-I) and from rows furthest away from the irrigated furrows (4R-NI and 8R-NI). Corn hybrid DKC66-75 was planted at a seeding rate of 42,000 seeds/ac on 4/7/2021 at 40-inch row spacing. Urea ammonium nitrate (UAN-32) was split-applied at a seasonal nitrogen rate of 244 lb/ac. Weeds were managed using a pre-emergence spray of 96 oz/ac Lexar + 48 oz/ac paraquat + 0.25% v/v Scanner. 3 pt/ac Halex GT + 48 oz/ac Roundup PowerMAX 3 + 0.25% v/v Scanner was used for post-emergence weed management. Volumetric water content (VWC) was taken using a FieldScout TDR 350 Soil Moisture Meter (Aurora, IL) at a depth of 0-8” **(Figure 2)**. Data was taken from every furrow before irrigation (event 1), after first irrigation (event 2), and after the second irrigation (event 3). Corn was harvested on 8/28/2021 using a Kincaid 8XP plot combine

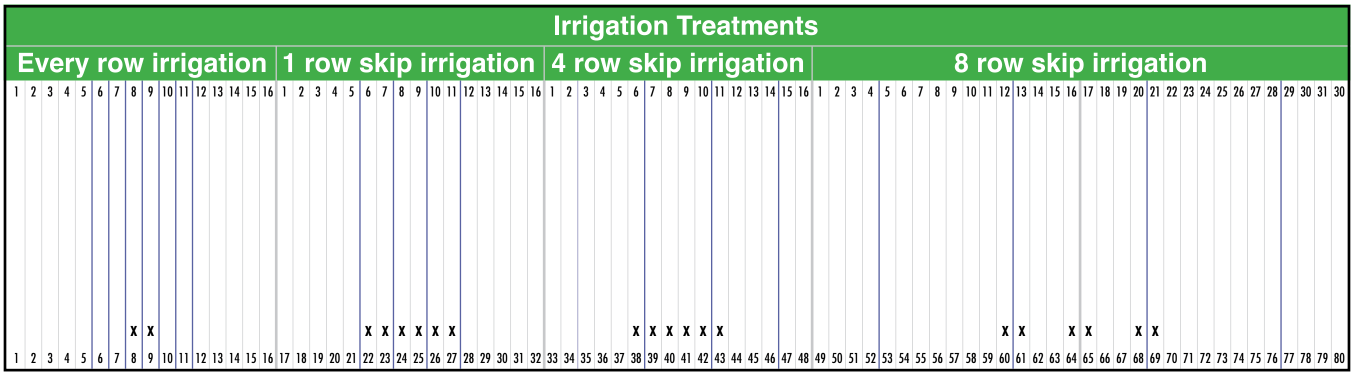

Figure 1. *Irrigation treatments used in our study. Blue lines indicate furrows that were irrigated, and an “X” indicates a corn row that was harvested for yield in 2021.*

***Figure 2a** (left) FieldScout TDR 350 being used to collect soil volumetric water content data during the crop growing season; **Figure 2b** (right) furrow irrigation being applied to an 8 row skip irrigation plot.*

equipped with a harvest master H2 grain gauge.

Results and Discussion

There were no significant differences between the 4R-NI and ER treatments for corn grain yield **(Figure 3)**. The 8R-NI had a significantly lower yield (9.21%) than all other treatments except 4R-I and 1R (Figure 3). Treatment 4R-NI yielded 10.14% higher than 8R-NI. However, the 4 row skip spacing held the highest VWC in both events 1 and 3 when compared to all other spacings **(Figure 4)**. This shows that 4 row skip irrigation had sufficient subsurface lateral movement and that water moved efficiently through the plot for crop water demands without over-saturating the soil.

Conclusion

Results from the first year of study on the Sharkey clay soil indicate that 4 row skip irrigation would be ideal for growers when accounting for the risks associated with over-saturation or soil waterlogging losses in corn grain yield with every row or skip row irrigation. This research will be continued for more years to further assess the effectiveness of 4 row skip irrigation on Sharkey clay soils without adverse impact on yields.

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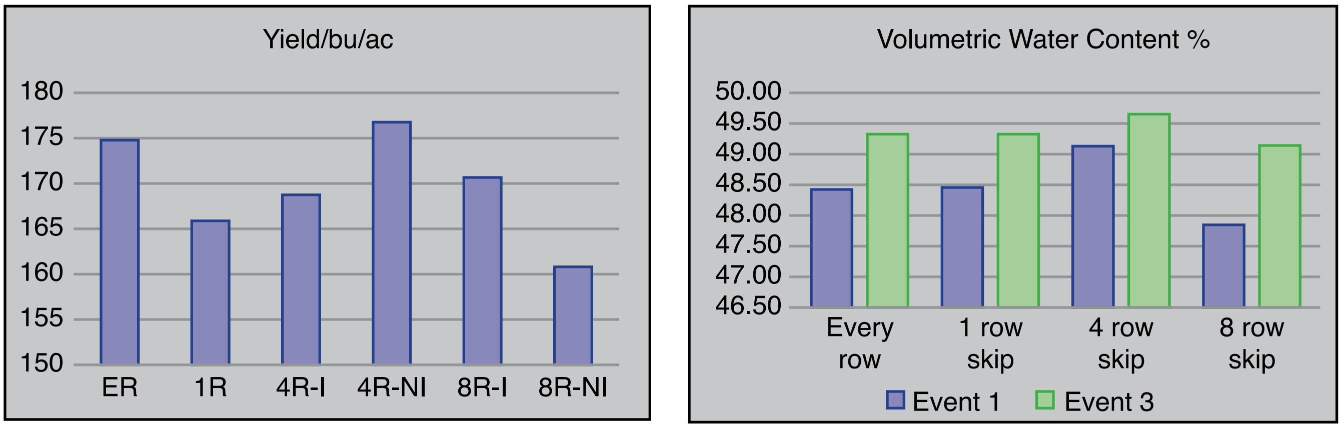


***Figure 3 (left).** Corn yields as affected by irrigation spacing, with irrigated rows designated as I and non-irrigated rows designated as NI. **Figure 4 (right).** Volumetric water content on two measurement dates as affected by irrigation spacing.*

IRRIGATION MANAGEMENT

Examining the Efficacy of Variable Hole Sizing in Polypipe for the Irrigation of Irregularly Shaped Cotton Fields

Amanda Nelson, Daryl Chastain

Introduction

Programs such as the Delta Plastics Pipe Planner program were designed to create efficient irrigation plans for various fields utilizing variable hole sizes in polypipe irrigation.

The objective of this study is to determine the effectiveness of these programs on water use and cotton yield from regularly and irregularly shaped fields.

Materials and Methods

The site consists of four fields located in Washington County, Mississippi (33.429777°, 90.948461°), at the corner of Old Leland Road and Potter Road (Figure 1) at the NCAAR West Farm facility. Fields were planted with Deltapine 1646 cottonseed at 40” row spacing.

Each length of polypipe had its own flow meter to measure independently the volume of irrigation water applied on each field. The big rectangle and big triangle **(A and B in Figure 1)** were irrigated according to the plan determined by the Delta Plastics Pipe Planner program. The trapezoid and little triangle **(C and D in Figure 1)** were irrigated under a “business as usual” plan to represent a plan that a farmer without computerized hole selection might use to irrigate similar fields in the Delta.

Hole Size	Furrow Count
5/16”	18
3/8”	8
7/16”	9
1/2”	10
9/16”	11
5/8”	11
11/16”	13
3/4”	47
11/16”	46
5/8”	37
9/16”	33
1/2”	28
7/16”	25
3/8”	21
5/16”	41

Table 1. *Hole size plan for the polypipe for the big triangle field (B in Figure 1).*

The trapezoid and little triangle **(C and D in Figure 1)** utilized two risers. The polypipe from the southern riser irrigated only the trapezoid and was tied off at the boundary between these two fields. The polypipe from the northern riser irrigated only the little triangle. Altogether from south to north, the hole sizes were 3/8” for 135 furrows, then 7/16” until the field started to taper again (~280 furrows), and finally back to 3/8” for the remainder.

The big rectangle **(A in Figure 1)** used two hole sizes, per the Pipe Planner output: 1/2” for 165 furrows and 9/16” for the remaining ~230 furrows. The triangle **(B in Figure 1)** used the hole size plan in **Table 1**.

Every 7-10 days after the previous significant rainfall or irrigation, water was applied until all furrows were wet.

Results/Current Status

2021 had a very wet spring. As a result, the cotton did not get planted until late June. In addition, it was a wet

Figure 1. *The Cotton Triangle Fields include: the big rectangle (A), the big triangle (B), the trapezoid (C), and the little triangle (D). Red dots indicate risers. The black dot is the well pump.*

growing season and, as such, irrigation was not required according to the standards we set. Handpicked samples for quality were taken in November, but harvesting did not occur until January 2022. Since no irrigation was used and the timing of management events were irregular, the 2021 season will be used as a baseline year to determine that there are no factors among the fields affecting cotton yield quantity and quality going forward. This project will be repeated in the 2022 season.

Figure 2. *Handpicked samples were taken for quality analysis in November 2021.*

IRRIGATION MANAGEMENT

Revisiting Recommendations for Sensor-Based Soybean Furrow Irrigation Scheduling on Clay Soils

Jacob Rix, Himmy Lo, Lyle Pringle

Introduction

In the Mississippi Delta, irrigated soybean on clay soils is very common. Appropriate irrigation scheduling recommendations for this crop and soil combination are thus especially important because these recommendations would be useful on many acres. Over the past decade, MSU on-station and on-farm research on irrigation scheduling has focused on the use of Watermark soil moisture sensors. The findings of those experiments led to MSU Extension recommendations that soybean on clay soils should be irrigated whenever the average sensor value across the soil profile reaches somewhere between 70 and 100 centibars. To generate additional data on the effect of triggering irrigation at different centibars, a study was performed in Stoneville, MS, from 2020 to 2021.

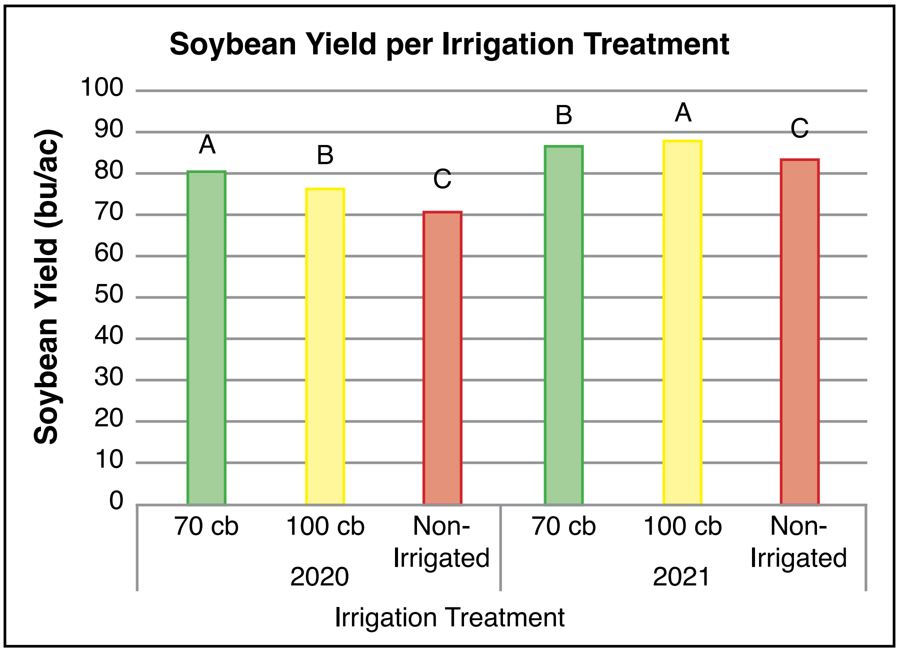


Figure 2. *Soybean yield by treatment and by year; bars from the same year are significantly different from each other if they are not marked by a shared letter.*

Materials and Methods

The experiment was conducted on a 20-acre field whose Sharkey clay soil tends to shrink and form cracks as it dries and to swell and seal up as it wets. Planting and harvest dates were 5/7 and 10/5 in 2020 and were 4/19 and 10/1 in 2021. For both years, Asgrow 48X9 soybean seed was planted in twin rows on raised beds with 40” spacing. Within a month of emergence, a Watermark soil moisture sensor set was installed two thirds the way down each plot between an interior pair of twin rows. Furrow irrigation was applied using polypipe **(Figure 1)**. The harvest area per plot was 20 feet (6 rows) wide by 530 feet long. Yield values were adjusted to a standard moisture of 13%.

The three treatments included: (1) irrigation triggered at 70 centibars, (2) irrigation triggered at 100 centibars, and (3) no irrigation. The 70 centibar treatment was irrigated five times in 2020 and six times in 2021. The 100 centibar treatment was irrigated two times in 2020 and three times in 2021. The non-irrigated treatment was never irrigated in both years. For statistical analysis, Fisher’s Least Significant

Figure 1. *Furrow irrigation application at the study site.*

Difference test was used in SAS software.

Results and Discussion

Triggering at 100 centibars rather than 70 centibars delayed irrigation by approximately four days per drying cycle. This extra time to catch rain eliminated three irrigation applications per year and reduced groundwater pumping by about 30%. Agronomically and financially, the best treatment varied between years **(Figure 2)**. In 2020, when consecutive weeks without rain were common, the 70 centibar treatment achieved the highest yield and return. Yet in 2021, when small rains that did not reach the Watermark soil moisture sensors were common, the 100 centibar treatment achieved the highest yield and return. This observation agrees with past research showing that excessive irrigation can decrease soybean productivity and profitability. On farms that require three to five days to irrigate all their soybean on clay soils, we confirm existing MSU Extension recommendations that a furrow irrigation cycle should be started when the first irrigation set dries to roughly 70 centibars. This practice minimizes both the risk of over irrigating the earlier sets and the risk of under irrigating the later sets. By following these locally proven recommendations, farmers can conserve the precious groundwater resources of the Delta while maximizing their likelihood of producing a profitable and high-yielding soybean crop.

Evaluation of Irrigation Frequency to Close the Gap in Furrow Irrigated Rice

Anna Smyly, Drew Gholson

Sponsored by Mississippi Rice Promotion Board

Introduction

Rice (*Oryza sativa L.*), in Mississippi, is typically grown using a continuous flood production system that requires large inputs of water throughout the growing season. On average, rice uses approximately 3.0 acre-feet per year of water, which, based on average acreage of rice production, equates to approximately 600,000 acre-feet per year being pumped in Mississippi. The Mississippi River Valley Alluvial Aquifer (MRVAA) serves as the major source of irrigation water for rice production in Mississippi. Irrigation water is becoming a scarce resource and the MRVAA is depleting at a rate of 300,000 acre-feet per year. Determining a more efficient approach for rice irrigation is vital to the sustainability of the aquifer for agricultural water needs. Research in Mississippi shows furrow-irrigated rice (FIR) to be a promising strategy to produce rice with less water than the regional average. However, there is limited information on how to irrigate and fertilize FIR in the most efficient way to maintain an adequate and uniform rice grain yield throughout a rice field.

The objective of this study is to evaluate the effect of four different irrigation frequencies on soil moisture, irrigation water use efficiency (IWUE), water depth levels, and rice grain yield of FIR. The data for this study is collected using Watermark® soil moisture sensors, Pani-Pipes®, and flowmeters. The hypothesis is that more frequent irrigation timings in FIR will lead to an increase in rice grain yield and close the rice grain yield gap between the top and bottom one-thirds of the rice field.

Materials and Methods

A field experiment was conducted at the Delta Research and Extension Center in Stoneville, MS on a Sharkey clay soil during 2021 and will continue in 2022 and 2023. The study is designed as a randomized complete block, including four irrigation frequencies on a calendar-based schedule of irrigating every day, every three days, every five days, and every seven days. To collect soil moisture data between each irrigation occurrence, Watermark® soil moisture sensors® were placed at 4", 8", and 12" depths below the soil surface in the top one-third of each irrigation treatment and replication. To measure the water depth levels prior to each irrigation event, a Pani-Pipe® was placed in the most representative zone in the top, middle, and bottom one-thirds of each irrigation treatment and replication. A flowmeter was used to determine water usage of each irrigation treatment throughout the growing season.

Treatment	Yield (bu/ac)
Every Day	152 a
Every 3 Days	144 b
Every 5 Days	143 b
Every 7 Days	140 c

Table 1. *Average rice grain yield (bu/ac) of each irrigation frequency treatment in 2021. Numbers followed by the same letter are not significantly different at alpha = 0.05.*

CL116 was planted onto freshly pulled beds at 65 lb/ac on May 24th. Each treatment plot was 8 rows wide with a levee constructed on either side of the rice plot to keep irrigation frequency treatments separated **(Figure 1)**.

Figure 1. *Irrigation treatment plot layout for furrow-irrigated rice (FIR).*

Figure 2. *Irrigation application to FIR treatment plots after the first nitrogen fertilizer application.*

Pre-emergent and post-emergent herbicides were broadcasted at the labeled rates across each rice plot after planting. Nitrogen fertilizer applications were aerially applied using a three-way split nitrogen fertilizer application recommended by the Arkansas Furrow-Irrigated Rice Production Handbook. Calendar-based irrigations began at the 4- to 5-leaf growth stage after the first nitrogen fertilizer application. Irrigations continued until the field was drained and prepared for harvest **(Figure 2)**. Rice grain yield data was taken from the middle four rows of each plot and analyzed using statistical analysis software SAS.

Results and Discussion

The treatment plots irrigated every day resulted in the highest rice grain yield (152 bu/ac), followed by every three days (144 bu/ac), every five days (143 bu/ac), and every seven days (140 bu/ac) **(Table 1)**. The treatment plots irrigated every day closely mimic a continuous flood production system, which could explain why watering FIR every day produced a higher rice grain yield. The rice grain yield for the every-day treatment was significantly different when compared to the other irrigation frequencies **(Table 1)**. Every three days and every five days were not significantly different from one another; however, both were significantly different from the other irrigation treatments. This suggests FIR grain yield will not differ greatly when a farmer is deciding on whether to irrigate every three or five days. However, when irrigating every seven days, the rice grain yield was significantly different from the other three irrigation frequencies.

Conclusion

The 2021 study suggests that irrigating FIR every day will produce a higher rice grain yield compared to irrigating every three, five, or seven days. The study also suggests that a farmer won't see significant differences in the rice grain yield when deciding whether to irrigate every three or five days. Furrow-irrigated rice will not reach the maximum rice grain yield when the rice is irrigated every seven days. Rice is a semi-aquatic plant and prefers to be grown in a saturated environment. Therefore, when a rice plant goes seven days without being watered, the rice becomes heavily unsaturated and that affects the growth and development of the rice plant. The Watermark® soil moisture sensors®,

Pani-Pipe®, and flowmeter data is still being analyzed. This study will be revised and continued for 2022 and 2023.

IRRIGATION MANAGEMENT

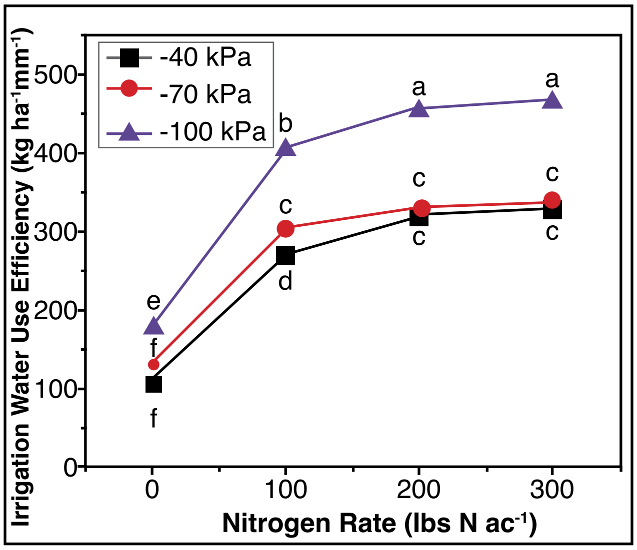
Irrigation Threshold and Nitrogen Rate Effects on Corn Water Use and Yield Response

Gurbir Singh, Amilcar Vargas, Gurpreet Kaur

Introduction

With the overuse and excessive pumping of the groundwater there is a need to use irrigation systems that are more efficient in water application and at the same time reduce drawdown of the groundwater. There is limited research available on the use of overhead irrigation systems in corn production systems in the Mississippi Delta. Therefore, understanding the relation between overhead irrigation scheduling with soil series, soil nutrients, and plant environment are essential for the effective management of corn grown under overhead irrigation systems in this region. Previous studies from the Corn Belt region of the US have reported interactions between irrigation applications, available soil water content, and nitrogen (N) rates on corn productivity. Soil texture and soil water content have been reported previously to play a very strong role in dictating irrigation and N management practices for corn production.

The overall objective of this study was to evaluate the effects of sensor-based irrigation with different N rates on corn yield and yield components. We hypothesized that drier irrigation thresholds (-70 and -100 kPa) would be ideal for irrigating corn grown on 2:1 Tunica clay soils whereas these thresholds will negatively affect corn yield on Bosket very fine sandy loam soils.



Materials and Methods

This study was conducted at Delta Research and Extension Center, Mississippi State University, Stoneville, MS, in 2021. Treatments included in this study were three irrigation scheduling thresholds (-40, -70, and -100 kPa) and a rainfed treatment, four N application rates (0, 100, 200, and 300 lb/ac N), and two distinct soil textural classes (sandy loam and clay). The treatment design was a factorial design with main factors of soil textural class and irrigation thresholds and split factor of nitrogen rates. All treatments were replicated five times. The plot size for individual N rate treatment was 27 feet × 50 feet. In total there were 160 plots.

The irrigation scheduling method consisted of the sensor-based irrigation scheduling method based on soil matric potential values recorded by soil moisture sensors installed in the field. The Watermark soil water sensors were installed at three depths: 6”, 12”, and 24”. For irrigation scheduling, whenever the weighted average sensor reading reached the designated irrigation threshold of the plot, irrigation was applied to the plot. During the corn growing season, data on irrigation water applied and precipitation received were collected using flowmeters and rain gauge, respectively. Crop growth data including plant height, plant population, and SPAD chlorophyll meter reading were also collected during the growing season. At physiological maturity, corn biomass was collected to estimate N uptake in irrigation and N rate treatments. Two rows of corn were harvested using a Kinkaid 8XP plot combine equipped with a H2 harvest master grain gauge for estimating

--------------------------p-values--------------------------				
Source of Variation	df	Corn Grain Yield	Water Productivity	Irrigation Water Use Efficiency
Soil Texture (T)	1	0.0111	0.0111	0.0207
Irrigation Thresholds (I)	3	0.0333	0.0879	<0.0001
Nitrogen Rate (N)	3	<0.0001	<0.0001	<0.0001
T*I	3	0.1772	0.1599	<.0001
T*N	3	0.0051	0.0053	0.0593
I*N	9	0.7211	0.6402	<0.0001
T*I*N	9	0.9706	0.9673	0.8785

Table 1. *Probability values (p-values) and numerator degrees of freedom (df) associated with each source of variation in the statistical analysis for soil texture, irrigation thresholds, nitrogen rates, and their interactions; effects that are statistically significant at alpha = 0.05 are underlined.*

alpha = 0.05.				
Soil Texture	Nitrogen Rates lb/ac N	Corn Grain Yield bu/ac	Water Productivity kg/ha-mm	Irrigation Water Use Efficiency kg/ha-mm
Sandy Loam	0	87d	10.59d	124.18d
Sandy Loam	100	192ab	23.33ab	277.48ab
Sandy Loam	200	206a	25.09a	291.97ab
Sandy Loam	300	207a	25.17a	297.53a
Clay	0	54e	6.54e	81.415e
Clay	100	146c	17.76c	213.46c
Clay	200	183b	22.27b	262.49b
Clay	300	188ab	22.95ab	269.93ab

Table 2. *Mean values for the interaction effects of soil texture and nitrogen rates averaged over the irrigation thresholds. Same letters within a column are not statistically different from each other at alpha = 0.05.*

corn grain yields. At the time of harvesting, grain samples were also collected for N uptake and grain quality analysis. Corn grain yield was adjusted to 15.5% moisture for reporting. The irrigation and precipitation data were used to calculate agronomic water productivity and irrigation water use efficiency. Results were analyzed using the GLIMMIX procedure in SAS statistical software at alpha = 0.05.

Results and Discussion

Corn grain yield was affected by irrigation thresholds (Table 1), with -70 kPa irrigation threshold yielding 165 bu/ac when averaged over soil texture and nitrogen application rates. Corn yield for the -70 kPa irrigation threshold was not statistically different from the -100 kPa irrigation threshold (158 bu/ac) however it was at least 8 bu/ac greater compared to rainfed and -40 kPa treatments. When averaged by irrigation thresholds, the highest corn grain yield was 206 and 207 bu/ac for sandy loam soil at 200 and 300 lb/ac N rates (Table 2), respectively. Similarly, for clay soil, the highest yields of 183 and 188 bu/ac were achieved with 200 and 300 lb/ac N rates. The three-way interaction between soil texture, irrigation thresholds, and N rate was not statistically significant. Irrigation water use efficiency when averaged over soil texture was highest for -100 kPa irrigation treatment with 200 and 300 lb/ac N rates **(Figure 1)**. At the -70 kPa irrigation threshold, the irrigation water use efficiency was similar for all N rates except the 0 lb/ac control **(Figure 1)**.

Sensor-Based Irrigation Scheduling and Cover Crop Impacts on Corn Production

Dillon Russell, Gurpreet Kaur, Gurbir Singh

Introduction

The Mississippi Delta accounts for the majority of the state's total corn production and is primarily furrow-irrigated. Excessive irrigation for row-crop production has caused significant declines in the Mississippi River Valley Alluvial Aquifer. Previous research has been conducted utilizing soil moisture sensors to mitigate the over-consumption of this aquifer; however, combining the benefits of soil moisture sensors with winter cover crops has not been documented. After decomposition, cover crop residues act as a mulch and can improve soil water retention (Sullivan et al., 1991). Cover crops also can improve water infiltration through the creation of sub-surface root channels (Blanco-Canqui et al., 2015). Therefore, the objective of this study was to determine if combinations of irrigation scheduling thresholds and cover crops could improve corn grain yield, water productivity, and irrigation water use efficiency (IWUE) in the Mississippi Delta.

Materials and Methods

A field experiment was conducted at the National Center for Alluvial Aquifer Research in Leland, MS from 2019 to 2021. The soil classification on the study site was a Bosket very fine sandy loam soil (Fine-loamy, mixed, active, thermic Mollic Hapludalfs). The experiment was designed as a randomized complete block with four replications. Each replication included 12 four-row plots (each 13 ft. × 100 ft) on 40” in. row spacing. Treatments in this study included combinations of irrigation scheduling thresholds (no irrigation, -40 kPa sensor threshold, and -90 kPa sensor threshold) and cover crops (no cover crop, cereal rye, hairy vetch, and wheat-radish-turnip mix). Cover crops were planted with a grain drill in the fall and chemically terminated in the spring before planting corn. The seeding rate for the cereal rye and hairy vetch were 60 lb/ac and 20 lb/ac, respectively. The seeding rate for the mix included 40 lb/ac wheat, 4 lb/ac radish, and 2 lb/ac turnip. The corn hybrid selected for this study was Dekalb 70-27 planted at 32,000 seeds/ac. Irrigation was applied via polyethylene tubing and was initiated when the weighted average of the sensors reached the respective threshold assigned to the treatment. Data collection included corn grain yield, water productivity (yield divided by the sum of rainfall and irrigation), and irrigation water use efficiency (yield divided by irrigation). Rainfall data used to calculate water productivity was collected from the National Weather Service's Cooperative Observing Station located in Stoneville, MS **(Figure 1)**.

Results and Discussion

In the first year of this study, cover crop treatments negatively impacted corn grain yield as the no cover crop control treatment produced 9, 19, and 26% higher corn grain yield

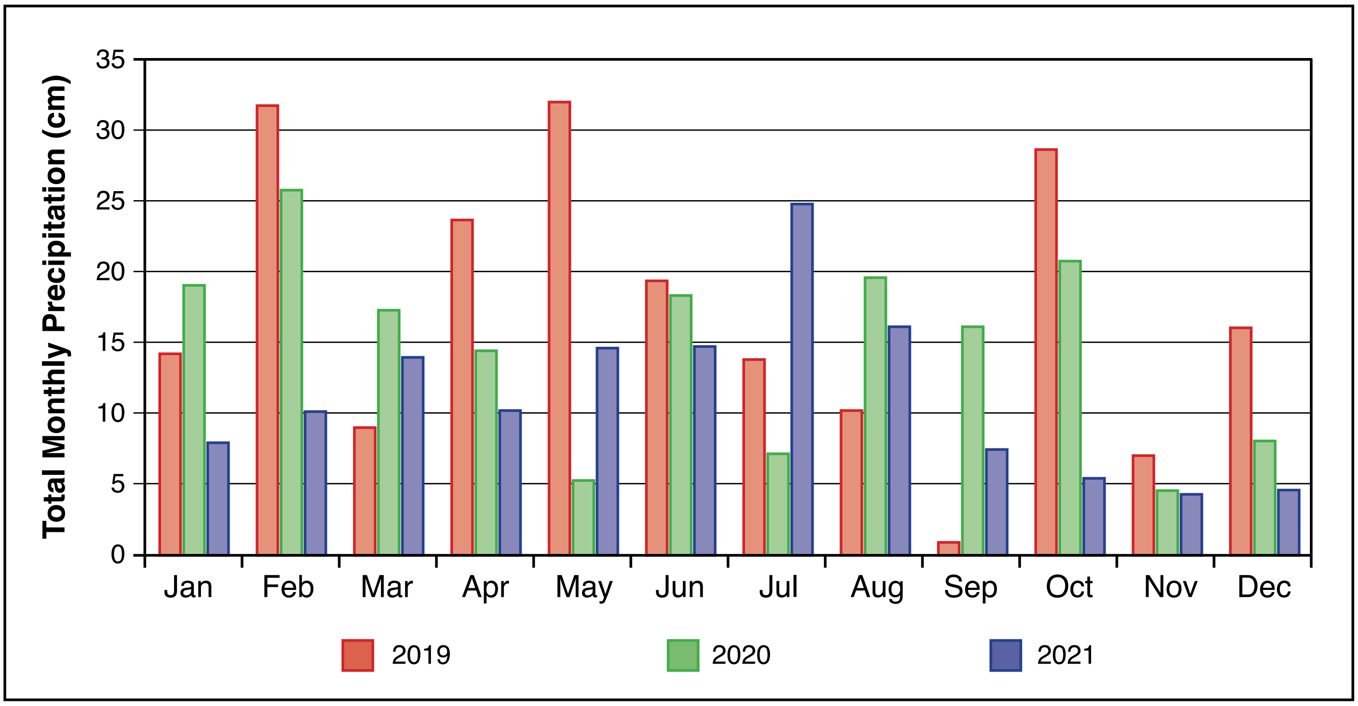


Figure 1. *Total monthly precipitation data at the study location from 2019 to 2021.*

compared to cereal rye, wheat-radish-turnip mix, and hairy vetch treatments, respectively. Water productivity was at least 16% higher in no cover crop treatments under the -90 kPa irrigation threshold compared to all other treatments. Only two treatments reached their respective sensor thresholds for irrigation initiation in year one, which were cereal rye and hairy vetch under the -40 kPa irrigation threshold. Of those two, hairy vetch contained 21% higher IWUE.

In year two, -40 kPa irrigation treatments produced 8 and 9% higher corn grain yield compared to no irrigation and -90 kPa irrigation threshold, respectively, while no differences were observed among the cover crop treatments. Water productivity was 6 and 17% higher in no irrigation treatments compared to -90 kPa and -40 kPa irrigation thresholds, respectively, while IWUE was at least 108% higher in the -90 kPa hairy vetch treatments compared to all other treatments (Table 1).

Conclusion

In year one, cover crops with irrigation thresholds negatively impacted corn yield and had practically no beneficial impacts on water productivity; however, hairy vetch treatments showed to improve IWUE regardless of the irrigation threshold. In year two, corn yields were much higher and were similar across all cover crop treatments, but the -40 kPa irrigation threshold treatments yielded higher than the other irrigation treatments. Additionally, hairy vetch treatments had the highest water productivity among cover crop treatments, while also showing drastically higher IWUE under the -90 kPa irrigation threshold in year two. Slowly, improvements were observed between cover crops and irrigation thresholds, but further evaluation is needed to determine the recommended cover crop and irrigation threshold to maximize corn production in the Delta region.

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IRRIGATION MANAGEMENT

Establishing the Water Budget of a Tailwater Recovery System

Amanda Nelson

Introuction

Tailwater recovery (TWR) systems are an important best management practice (BMP) used to address both water quality and quantity issues in the Mississippi Delta. TWRs are systems for capturing surface water runoff to be later used for irrigation. TWRs consist of a ditch to capture runoff; sometimes an on-farm storage (OFS) reservoir to store captured water; and pumps to move surface water from the ditch into the OFS reservoir and to irrigate nearby fields. To determine if TWR systems are an effective way to reduce water use and downstream nutrient loads, water quality and quantity data from a closed ditch TWR system in Sunflower County, MS, will be measured for at least five years.

The objective of this study is to establish a water budget for a closed TWR system where the TWR is used as the primary irrigation source. Seasonal and rainfall event runoff and runoff water quality trends will also be analyzed. These data will later be used to model the system to determine its impacts on aquifer dynamics.

Materials and Methods

The field experiment is being conducted at a TWR in Sunflower County, MS. There are one or two outflow pipes from each of the eight 40 acre fields contributing to the TWR. Each outflow pipe is being equipped with an automatic runoff sampler (ISCO GLS, Teledyne ISCO, Lincoln, Nebraska) and an area velocity flow sensor (ISCO 2150) to collect composite water samples and flow rates for runoff events. Management of the fields will be at the farmer's discretion and will be recorded. Within 24 hours of rainfall or irrigation events, runoff samples will be collected, placed on ice, immediately transported to the National Center for Alluvial Aquifer Research (NCAAR) laboratory, and stored at 4°C until analysis. Variables measured will include runoff, solids, and nutrients and their various species. In addition, a rain gauge will be installed at the site and laser water level loggers will be installed in the TWR ditch. Irrigation and pumping records and agronomic management information will be provided by the cooperator. Soil samples will be collected for soil bulk density, nutrient, and texture.

Current Status

This project is currently in the installation phase. Site selection occurred in spring 2021, then sampling equipment was ordered in May and began to arrive in the fall. Beginning in November, field installation began with the help of staff from C.C. Lynch, Inc. Runoff quantity is currently the only variable being recorded. The final sampling equipment is expected to be installed in January 2022 and water sampling will begin then and continue for a minimum of five years.

Figure 1 (right)*. a) Tailwater recovery ditch looking upstream prior to installation; b) recently installed solar panel and storm box for electrical components for the velocity meters; c) installation of conduit, sampling lines, and concrete pads for the water samplers and storm boxes.*


A
B
C

IRRIGATION MANAGEMENT

Evaluation of Winter Cover Crops and Irrigation Thresholds on a Subsequent Soybean Crop

Dillon Russell, Gurpreet Kaur, Gurbir Singh

Introduction

A steady decline in the Mississippi River Valley Alluvial Aquifer (MRVAA) has placed significant importance on developing better irrigation management strategies for decreasing water use while maintaining crop productivity. Previous research has been documented utilizing sensor-based irrigation scheduling on monoculture soybeans, but limited information is available on irrigation scheduling of soybean in combination with winter cover crops. Cover crops have shown to reduce irrigation water use and improve irrigation water use efficiency (IWUE) by increasing infiltration through the creation of root channels (Blanco-Canqui et al., 2015), and soil water holding capacity through residue decomposition (Irmak, 2020). The decomposed cover crop residues then act as a mulch, which aids in retaining residual soil moisture (Sullivan et al., 1991). Combining these cover crop benefits with a more conservative irrigation threshold for the subsequent soybean crop could be key to maximizing productivity. Therefore, the objective of this study was to determine if combinations of winter cover crops and irrigation scheduling thresholds could improve soybean yield, water productivity, and IWUE in the Mississippi Delta.

Materials and Methods

A field experiment was conducted at the National Center for Alluvial Aquifer Research in Leland, MS from 2019 to 2021. The soil classification for the experimental field was a Com-

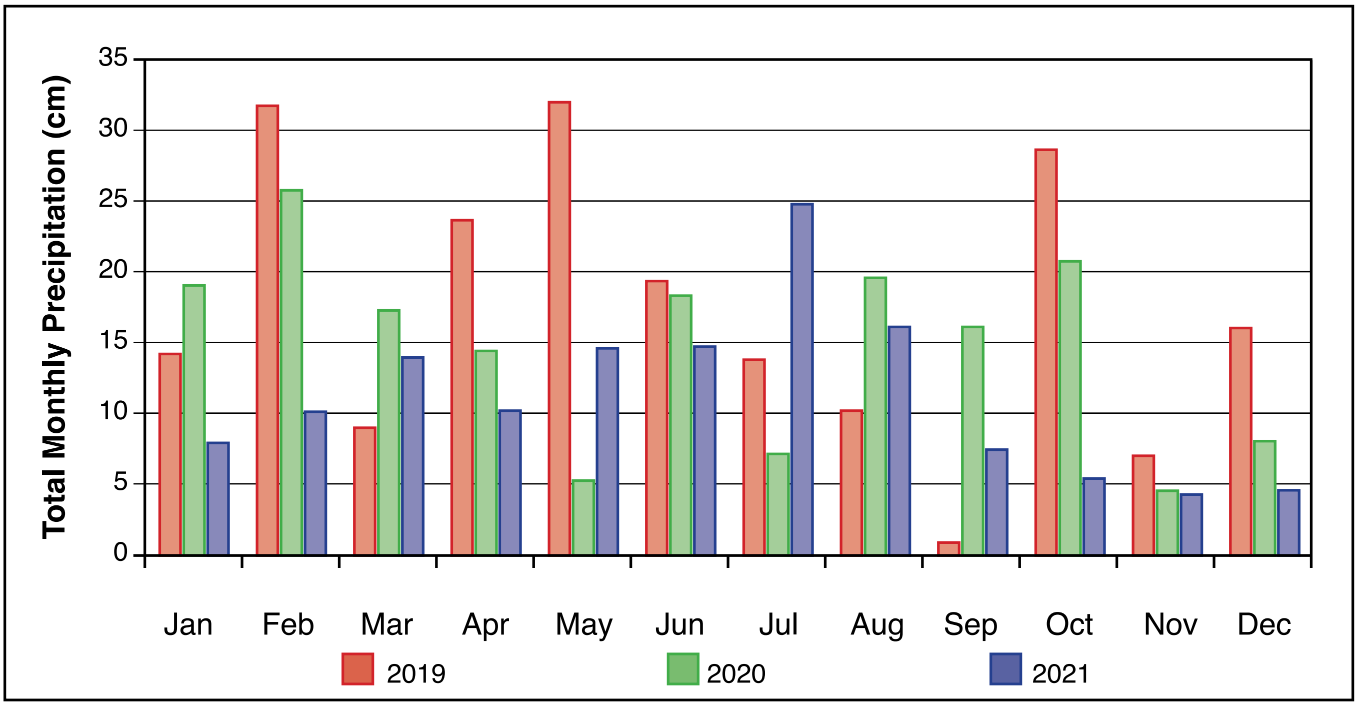
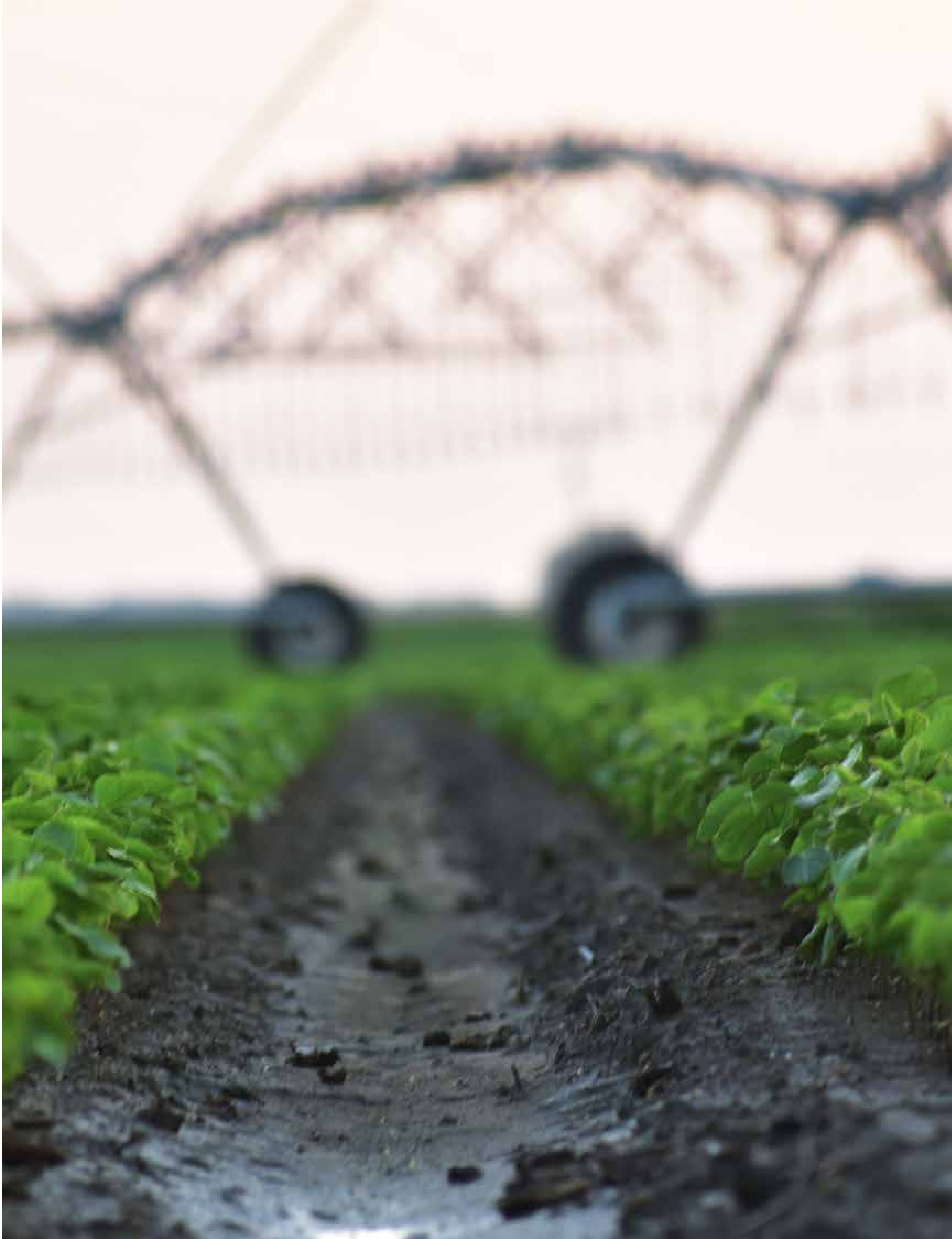


Figure 1. *Total monthly precipitation data at the study location from 2019 to 2021.*



merce silty clay loam soil (Fine-silty, mixed, superactive, nonacid, thermic Fluvaquentic Endoaquepts). The experiment was designed as a randomized complete block with four replications. Each replication included 12 four-row plots (each 13 ft × 100 ft) on 40” row spacing. Treatments in this study included combinations of winter cover crops (no cover crop, cereal rye, hairy vetch, and wheat-radish-turnip mix) and irrigation scheduling thresholds (no irrigation, -40 kPa sensor threshold, and -90 kPa sensor threshold). Cover crops were broadcasted by hand (simulating a fly-on application) into standing soybean at R6.5 growth stage and chemically terminated in the spring before soybean planting. The seeding rate for the cereal rye and hairy vetch were 60 lb/ac and 20 lb/ac, respectively. The seeding rate for the mix included 40 lb/ac wheat, 4 lb/ac radish, and 2 lb/ac turnip. The soybean variety selected for this study was Asgrow 46X6 in year one and Asgrow 43X0 in year two, and the seeding rate for both years was 120,000 seeds/ac. Data collection included soybean yield, water productivity (yield divided by the sum of rainfall and irrigation), and irrigation water use efficiency (yield divided by irrigation). Rainfall data to calculate water productivity was collected from the National Weather Service’s Cooperative Observing Station located in Stoneville, MS **(Figure 1)**.

Results and Discussion

In the first year of the experiment, soybean yield was at least 4.7 bu/ac greater in hairy vetch treatments under the -40 kPa irrigation threshold but was not different from cereal rye under the -40 kPa irrigation threshold. Water productivity in the first year was at least 2.3% higher in wheat-radish-turnip mix treatments under no irrigation but was not different from hairy vetch under no irrigation as well as cereal rye and no cover crop under the -90 kPa irrigation threshold. All irrigated treatments besides no cover crop under the -90 kPa irrigation threshold received irrigation water in year one, and among those treatments, cereal rye under the -90 kPa irrigation threshold had at least 75.2 kg/ha-mm higher IWUE compared to all other irrigated treatments.

In year two, no differences were observed pertaining to soybean yield, but differences from the main effects of irrigation thresholds were observed for water productivity. Additionally, water productivity was highest under the -90 kPa irrigation threshold, which was at least 4% higher than the other irrigation treatments. Lastly, only -40 kPa irrigation threshold treatments received irrigation in 2021. Among those treatments, cereal rye contained at least 9% higher IWUE compared to the other cover crop treatments **(Table 1)**.

Conclusion

In the first year of this study, -40 kPa irrigation treatments had the highest soybean yield but had the lowest water productivity and IWUE. As for year two, soybean yield and water productivity were lower and similar across all treatment combinations, and IWUE was highest in cereal rye under the -40 kPa irrigation. Based on these results from two years, the recommended cover crop irrigation threshold combination for soybean production in the Mississippi Delta region would be cereal rye under the -90 kPa irrigation threshold.

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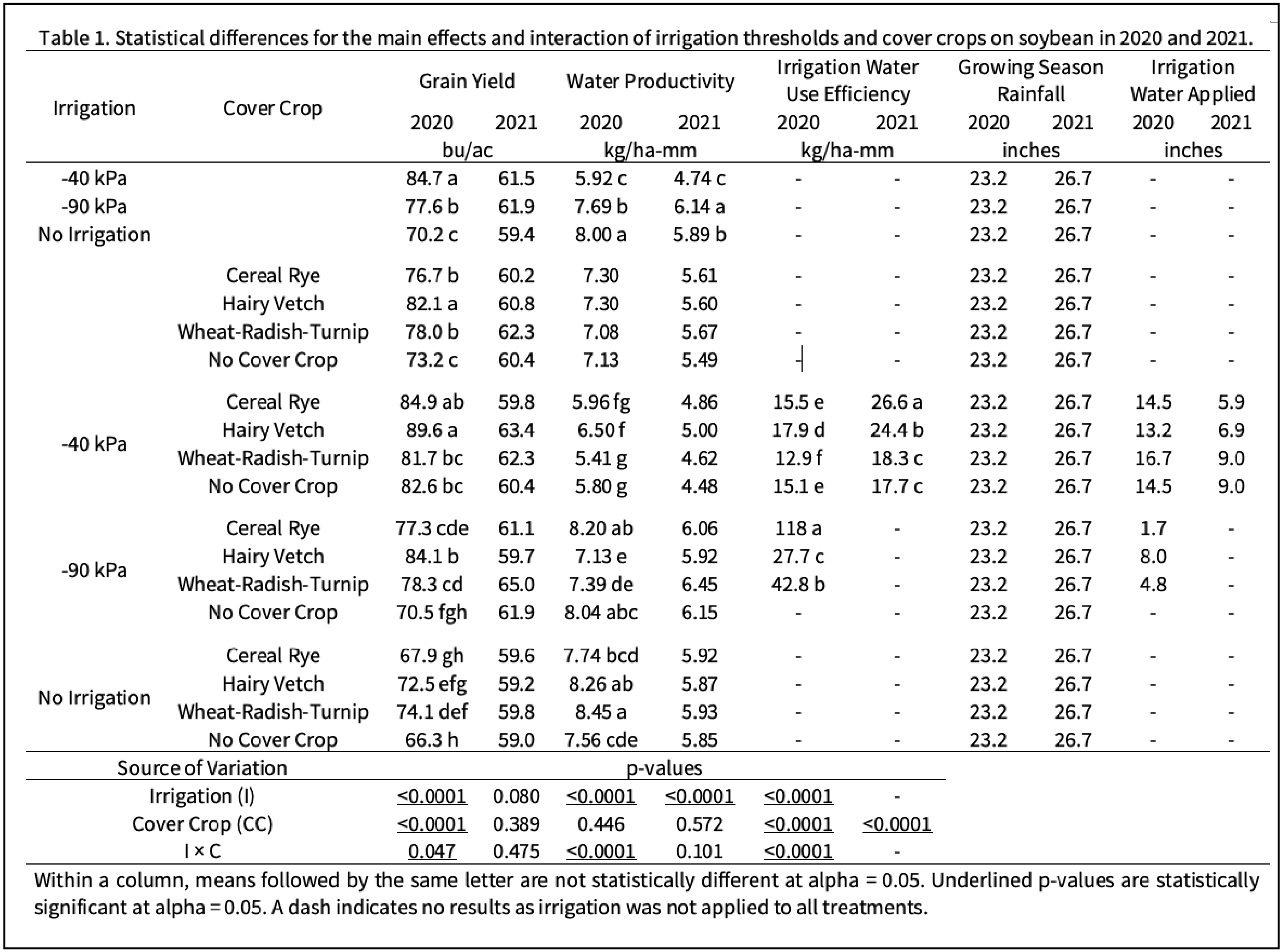


Table 1. Statistical differences for the main effects and interaction of irrigation thresholds and cover crops on soybean in 2020 and 2021.

Irrigation	Cover Crop	Grain Yield		Water Productivity		Irrigation Water Use Efficiency		Growing Season Rainfall		Irrigation Water Applied	
		2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
		bu/ac		kg/ha-mm		kg/ha-mm		inches		inches	
-40 kPa		84.7 a	61.5	5.92 c	4.74 c	-	-	23.2	26.7	-	-
-90 kPa		77.6 b	61.9	7.69 b	6.14 a	-	-	23.2	26.7	-	-
No Irrigation		70.2 c	59.4	8.00 a	5.89 b	-	-	23.2	26.7	-	-
	Cereal Rye	76.7 b	60.2	7.30	5.61	-	-	23.2	26.7	-	-
	Hairy Vetch	82.1 a	60.8	7.30	5.60	-	-	23.2	26.7	-	-
	Wheat-Radish-Turnip	78.0 b	62.3	7.08	5.67	-	-	23.2	26.7	-	-
	No Cover Crop	73.2 c	60.4	7.13	5.49	-	-	23.2	26.7	-	-
-40 kPa	Cereal Rye	84.9 ab	59.8	5.96 fg	4.86	15.5 e	26.6 a	23.2	26.7	14.5	5.9
	Hairy Vetch	89.6 a	63.4	6.50 f	5.00	17.9 d	24.4 b	23.2	26.7	13.2	6.9
	Wheat-Radish-Turnip	81.7 bc	62.3	5.41 g	4.62	12.9 f	18.3 c	23.2	26.7	16.7	9.0
	No Cover Crop	82.6 bc	60.4	5.80 g	4.48	15.1 e	17.7 c	23.2	26.7	14.5	9.0
-90 kPa	Cereal Rye	77.3 cde	61.1	8.20 ab	6.06	118 a	-	23.2	26.7	1.7	-
	Hairy Vetch	84.1 b	59.7	7.13 e	5.92	27.7 c	-	23.2	26.7	8.0	-
	Wheat-Radish-Turnip	78.3 cd	65.0	7.39 de	6.45	42.8 b	-	23.2	26.7	4.8	-
	No Cover Crop	70.5 fgh	61.9	8.04 abc	6.15	-	-	23.2	26.7	-	-
No Irrigation	Cereal Rye	67.9 gh	59.6	7.74 bcd	5.92	-	-	23.2	26.7	-	-
	Hairy Vetch	72.5 efg	59.2	8.26 ab	5.87	-	-	23.2	26.7	-	-
	Wheat-Radish-Turnip	74.1 def	59.8	8.45 a	5.93	-	-	23.2	26.7	-	-
	No Cover Crop	66.3 h	59.0	7.56 cde	5.85	-	-	23.2	26.7	-	-
Source of Variation		p-values									
Irrigation (I)		<0.0001	0.080	<0.0001	<0.0001	<0.0001	-				
Cover Crop (CC)		<0.0001	0.389	0.446	0.572	<0.0001	<0.0001				
I × C		0.047	0.475	<0.0001	0.101	<0.0001	-				

Within a column, means followed by the same letter are not statistically different at alpha = 0.05. Underlined p-values are statistically significant at alpha = 0.05. A dash indicates no results as irrigation was not applied to all treatments.

Table 1. *Statistical differences for the main effects and interaction of irrigation thresholds and cover crops on soybean in 2020 and 2021.*

Tailwater Recovery and Reservoir Storage Benefits for Farm Profits and Aquifer Sustainability Emerge When Considering Field-Aquifer Interaction in Long Planning Horizons

Nicolas Quintana Ashwell, Drew Gholson

Benefits of Capturing, Storing and Using Pluvial and Irrigation Runoff

Tailwater recovery and storage reservoir systems are capable of capturing runoff from the fields. The system includes a large tailwater ditch which captures all runoff and stores significant amounts of water themselves depending on their design—see **Figure 1**. When the ditch fills to a prescribed level, the excess water can be pumped to a storage reservoir, back on the fields or be allowed to overflow into drainage canals. The first and more evident benefit is the capture of water that would otherwise leave the area (a type of consumptive use); which can be re-used for irrigation and reduce the amount that would otherwise be pumped from the alluvial aquifer. Because this can be a closed-loop, on-farm structure, the grower has total control, which reduces the growers risk of facing adverse consequences of groundwater use limitations.

Another benefit that is less visible and more difficult to quantify and valuate is the retention of sediments and nutrients that are not discharged into receiving streams--and ultimately affect the hypoxic zone in the Gulf of Mexico. This feature benefits the farmer (internal benefit) in terms nutrient retention and reapplication on their fields but it also benefits society including other farmers (external benefit) in terms of the environmental benefits and the preservation of alluvial aquifer. **Table 1** summarizes the main non-exploitative benefits of tailwater recovery and storage structures.

The benefits in Table 1 do not include potential yield gains or fertilizer cost reductions derived from re-application of nutrient. Researchers from NCAAR, MSU and USDA ARS are collecting data to quantify this potential effect.

Costs of Capturing, Storing and Using Pluvial and Irrigation Runoff

This significant capital investment involves the leveling of the affected fields as a catchment area from which to collect the water to be stored and reused in irrigation. **Table 2** summarizes the investment and opportunity (land) costs associated with the baseline design used by NRCS of 160 acres of cropland/catchment and10 to 12 acres of ditch and reservoir capable of supplying all irrigation needs for 80 acres. Not included are the costs of land-leveling and tributary ditches.

The largest upfront cost is earth-moving: the establishment of the levees for storage and excavation. However, these works retain 90% or more of their value at the end of the useful life, resulting in relatively low annuity cost-equivalent. The pumping plant is the second most expensive component but due to the low recovery value at the end of its useful life, it is the largest annuity cost-equivalent item. The opportunity cost of the land occupied by the ditch network and reservoir is valued at $1,308 per acre—equivalent to profits from highly productive land. However, the design can take advantage of the farm topography and occupy marginal or low-productivity tracts.

The cost of relifting water from the tailwater ditch and applying it to the fields is lower than the cost of pumping groundwater. Estimates from NCAAR put the cost of lifting one acre-ft. of


Photo by Mark Griffith.

Figure 1. *The Mason Tailwater Recovery (TWR) system is located in Sunflower County, near Drew, Mississippi. The 11-acre reservoir feeds approximately 142 acres of rice-soybean annual row-crop rotation. The ditch has approximately 13 acre feet of storage, allowing for almost all runoff to be collected and pumped back into the reservoir.*

groundwater at approximately $0.54 per foot of lift. In contrast the cost for relift and application of tailwater is estimated at approximately $3.76 per acre feet. This implies that pumping from wells more than 7 ft-deep would be more expensive than pumping water stored in the system.

Need to Think on an "Aquifer Life" Planning Horizon Rather Than on a "Farm Operations" Planning Horizon to Reveal the Economic Merits

Our research reveals that the true benefits of tailwater recovery, storage and reuse occur over an extremely long planning horizon partly because of the large recovery value of the structures. Furthermore, when the practice is evaluated in terms of optimal aquifer management rather than seasonal profits over a given horizon; the benefits in terms of aquifer conservation become more evident. Relatively short planning horizons emphasize the upfront costs.

Employing a simplified hydro-economic model to Sunflower county, MS, we show that aquifer-related benefits are virtually invisible when the time horizon is less than 30 years and the extraction behavior follows periodic individual farm profit maximization (green curve in **Figure 2**). The model anticipates that farmers would progressively adopt on-farm water storage (OFWS) as the alluvial aquifer depletes (without added incentives) but not at the optimal levels (blue curve in **Figure 2**). NRCS does offer incentive programs to develop tailwater recovery and storage facilities including incentive payments and technical assistance. Our results show that up to $520 million of additional farm-level profits across Sunflower County may be achieved over the 150-year planning horizon

Table 1. *Summary of main benefits from tailwater recovery and storage systems.*

Benefit	Value per unit	Quantity	Source
Groundwater conserved	$2 per acre-inch	Surface water applied	Kovacs and Durand-Morat (2020)
Sediment retention*	$13 per lb.	2500 lb.	Omer et al. (2019)
Phosphorous retention*	$3 per lb.	1.6 lb.	Omer et al. (2019)
Nitrogen retention*	$6 per lb.	8.4 lb.	Omer et al. (2019)
* From Omer et al. (2019) employing the cost of the best alternative reduction method. Sediment retention quantities reported as an average of 6 sites in Omer et al. (2018) which depends on site characteristics and farmer practices.			

	Initial Cost	Life Years	Salvage Value	Annual Cost
Excavation	$33,000	20	90%	$203
Levees	$45,000	20	90%	$276
Pumping plant	$42,000	20	10%	$2,321
Underground pipe	$9,240	20	80%	$113
Flowmeter stand	$1,950	20	85%	$18
Land	$1,308			$1,308
Total				$4,239
Total per acre				$353
Source: Falconer et al. (2017) and USDA NASS.				

Table 2. *Annualized investment and opportunity cost for on-farm water storage with tailwater recovery system (capital recovery method).*

when the optimal level of OFWS is employed while saving more than 4 million acre-ft. of groundwater over the same period—not including the retention benefits listed in **Table 1.**

Conclusion

Expansion of OFWS can result in large gains derived from taking advantage of off-season precipitation and keeping pumping lift distances low (i.e., high water table in the aquifer). Additional benefits of the practice that affect the quality of receiving streams and the hypoxic zone justify aggressive incentives to encourage growers to develop these structures which provide them with complete control of an important source of water for irrigation.

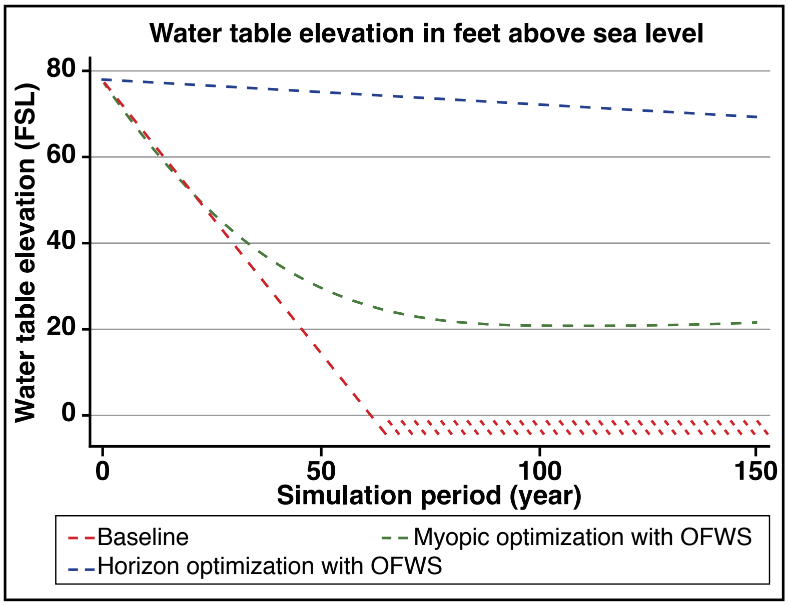


Figure 2. *Simulated evolution of alluvial aquifer water table elevation under alternative water use scenarios.*

References

This report is based on ongoing research, including the following publication:

Quintana-Ashwell, N., & Gholson, D. (2021). Optimal Groundwater Management with Pluvial and Irrigation Runoff Recycling. Poster presented at the Agricultural and Applied Economics Association annual meeting, Austin, TX.00

Cited work:

Falconer, L., Tewari, R., & Krutz, J. (2017). Cost analysis of water management scenarios for the Mississippi Delta. In Delta Sustainable Water Resources: Monitoring and Modeling (pp. 25-37). Mississippi Water Resources Research Institute.

Kovacs, K. F., & Durand-Morat, A. (2020). The influence of lateral flows in an aquifer on the agricultural value of groundwater. Natural Resource Modeling, 33(2), e12266.

Omer, A. R., Henderson, J. E., Falconer, L., Kröger, R., & Allen, P.J. (2019). Economic costs of using tailwater recovery systems for maintaining water quality and irrigation. Journal of Environmental Management, 235, 186-193.

The Mississippi Irrigation Termination Optimization On-line Application (MITOOL App)

Nicolas Quintana Ashwell, Drew Gholson, Karen Brasher

https://www.ncaar.msstate.edu/outreach/mitool.php

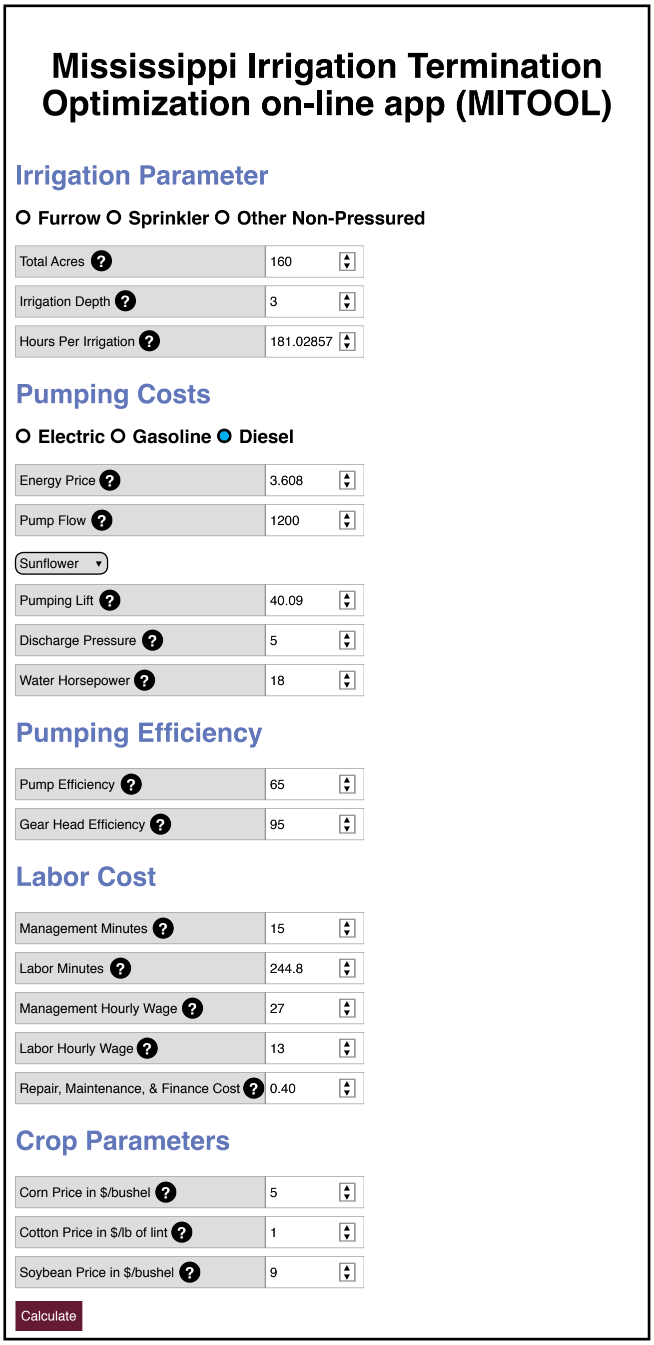
An Integrated Irrigation Event Cost Calculator and Decision Tool

The MITOOL decision tool is an enhanced irrigation cost calculator that provides cost estimates based on specific pumping station characteristics. The app allows to personalize every entry field to the user's specification allowing, for example, to compare irrigation costs differentials across different energy sources or pumping station performance levels.

The tool is highly flexible allowing the farmer to enter his known parameters and pre-filling the rest of the fields with baseline numbers. An innovative feature of the calculator is that it includes an estimate of the associated labor and capital costs associated with an irrigation event as specified.

This irrigation cost calculator can be used at any stage in the growing season to produce estimates and compare costs across different specifications. For instance, this feature can serve as a decision aid for growers deciding to renovate power plants and change energy sources from gasoline to electric or diesel powered pumping plants.

The tool exploits the most recent information from the U.S. Geological Survey regarding alluvial aquifer water table elevation to populate average county-level pumping lift distances.



Mississippi Irrigation Termination Optimization on-line app (MITOOL)

Irrigation Parameter

○ Furrow ○ Sprinkler ○ Other Non-Pressured

Total Acres	160
Irrigation Depth	3
Hours Per Irrigation	181.02857

Pumping Costs

○ Electric ○ Gasoline ● Diesel

Energy Price	3.608
Pump Flow	1200

Sunflower

Pumping Lift	40.09
Discharge Pressure	5
Water Horsepower	18

Pumping Efficiency

Pump Efficiency	65
Gear Head Efficiency	95

Labor Cost

Management Minutes	15
Labor Minutes	244.8
Management Hourly Wage	27
Labor Hourly Wage	13
Repair, Maintenance, & Finance Cost	0.40

Crop Parameters

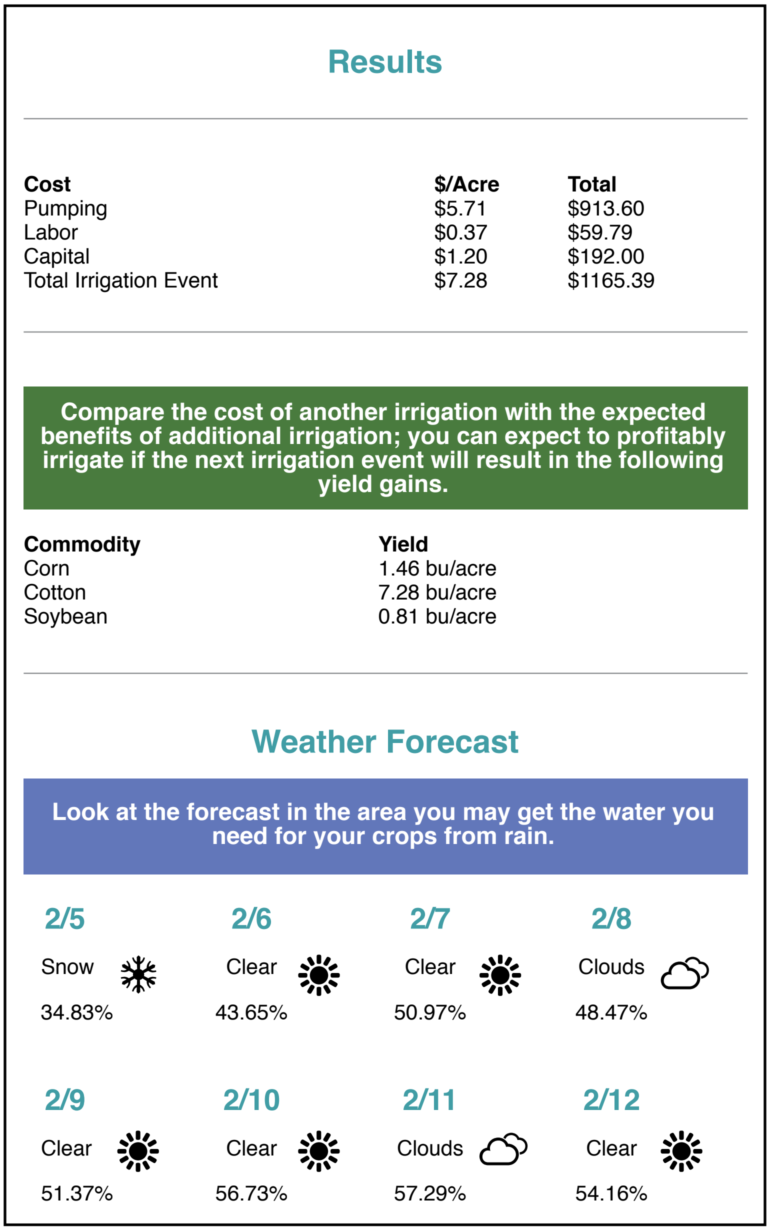
Corn Price in $/bushel	5
Cotton Price in $/lb of lint	1
Soybean Price in $/bushel	9

Figure 1. *Screen capture of MITOOL app input entry page showcasing benchmark pre-filled fields.*

An Irrigation Termination Decision Tool

The app was envisioned as a decision tool capable of encouraging farmers to avoid unnecessary final irrigation events. To aid growers to decide whether to go ahead with an additional irrigation event, MITOOL calculates the cost of the irrigation event, including the energy, capital, and labor costs associated with the event specified in the entry page.

Based on market conditions (observed crop price levels), the calculator presents the trade-off implied by the decision to start another irrigation event in terms of the yield gains that would be necessary to compensate for the cost of the added irrigation. Furthermore, a weather forecast for the county selected in the entry page is included with the caution that in addition to a cost-benefit trade-off, the producer must weigh the chances of obtaining additional water from precipitation in the near future, making the need for another irrigation event even less necessary.



Results

Cost	$/Acre	Total
Pumping	$5.71	$913.60
Labor	$0.37	$59.79
Capital	$1.20	$192.00
Total Irrigation Event	$7.28	$1165.39

Compare the cost of another irrigation with the expected benefits of additional irrigation; you can expect to profitably irrigate if the next irrigation event will result in the following yield gains.

Commodity	Yield
Corn	1.46 bu/acre
Cotton	7.28 bu/acre
Soybean	0.81 bu/acre

Weather Forecast

Look at the forecast in the area you may get the water you need for your crops from rain.

2/5	2/6	2/7	2/8
Snow ❄	Clear ☀	Clear ☀	Clouds ☁
34.83%	43.65%	50.97%	48.47%
2/9	2/10	2/11	2/12
Clear ☀	Clear ☀	Clouds ☁	Clear ☀
51.37%	56.73%	57.29%	54.16%

Figure 2. *Screen capture of results page of MITOOL app. Irrigation costs estimates presented on a total and per-acre basis as well as the required crop yield gains necessary to pay for the added cost of the event.*

Conservation Potential

A typical irrigation event for row crops is between 3 and 4 inches of irrigation depth. Consequently, the potential water savings can be significant in addition to improving farmer profitability.

This tool also helps to make all the costs of an irrigation event visible, especially towards the end of irrigation season when most of the fuel bills and payroll have been paid, giving the illusion that the decision to irrigate has zero or very low cost. Some growers may think that the fuel is already there and paid for, but that fuel could be saved and used in the next season. Similarly, the labor cost wouldn't change the payroll cost that much, but that farm-hand could be performing other duties (opportunity cost) such as starting to roll-up pipes or other harvest preparation duties.

Producers are generally aware of these costs but this tool makes them visible at decision time for those using it.

NCAAR Scientists Can Help With Irrigation Decisions

Dr. Drew M. Gholson is our irrigation specialist: drew.gholson@msstate.edu, 662-390-8505; and

Dr. Himmy Lo is our irrigation engineer: himmy.lo@msstate.edu, 662-390-8509.

IRRIGATION MANAGEMENT

Understanding Farmer Adoption of Practices That Conserve Irrigation Groundwater and the Role of Sponsored Incentive Programs

Nicolas Quintana Ashwell, Drew Gholson, Gurpreet Kaur, Gurbir Singh

Importance of Practices That Conserve Irrigation Groundwater

There are 2 types of practices that are considered groundwater-conserving. The first type consists in practices that increase the supply of irrigation water, such as managed recharge, surface water use, and pluvial and irrigation runoff capture and reuse—these are key practices to stop and reverse aquifer depletion but tend to be high upfront cost and show benefits in the long-run. The second type is related to practices that allow to sustain observed levels of agricultural output with lower levels of water use or to expand the levels of agricultural output given observed levels of water use—these practices are unlikely to stop but can slowdown aquifer decline while sustaining or expanding farmer profitability.

The Role of Practice Profitability

On-farm water conservation research and extension work pioneered in the Delta by Dr. L. Jason Krutz has consistently showed many of the type-2 practices can be implemented without reducing crop yields or farm profitability. However, many of those practices are yet to be widely adopted in the Lower Mississippi River Basin (LMRB). This indicates that other factors are important determinants in the decision to adopt water-conserving practices.

Table 1. *Farmer perceptions regarding existence of a groundwater problem at the farm or state level compared to their perception of a change in their well water level (left) and comparison of perception of problem and water level based on location within or outside the cone of depression (right).*

	Thinks There Is a GW Problem		
Frequency	**No**	**Yes**	**Total**
Well Depth to Water:			
No change	60	24	84
Increased	9	11	20
Decreased	12	13	25
Do not know	16	2	18
Refused	1	0	1
Total	**98**	**50**	**148**
Percentage	**No**	**Yes**	**Total**
Change In Depth to Water:			
No/cannot tell	51	17	68.9
Changed	14	16	30.4
Refused	1	0	0.7
Total	**66.2**	**33.8**	**100**

Pearson χ^2_4 = 13.4 with Pr = 0.009.

Note: GW is Groundwater

	Cone of Depression		
Percentages	**No**	**Yes**	**Total**
Depth to Water:			
No change	56	14	69
Changed	20	11	31
Total	76	24	100
Pearson χ^2_1 = 4.3 with Pr = 0.038.			
Groundwater Problem:			
No	54	12	66
Yes	22	12	34
Total	**76**	**24**	**100**

Pearson χ^2_1 = 5.6 with Pr = 0.018.

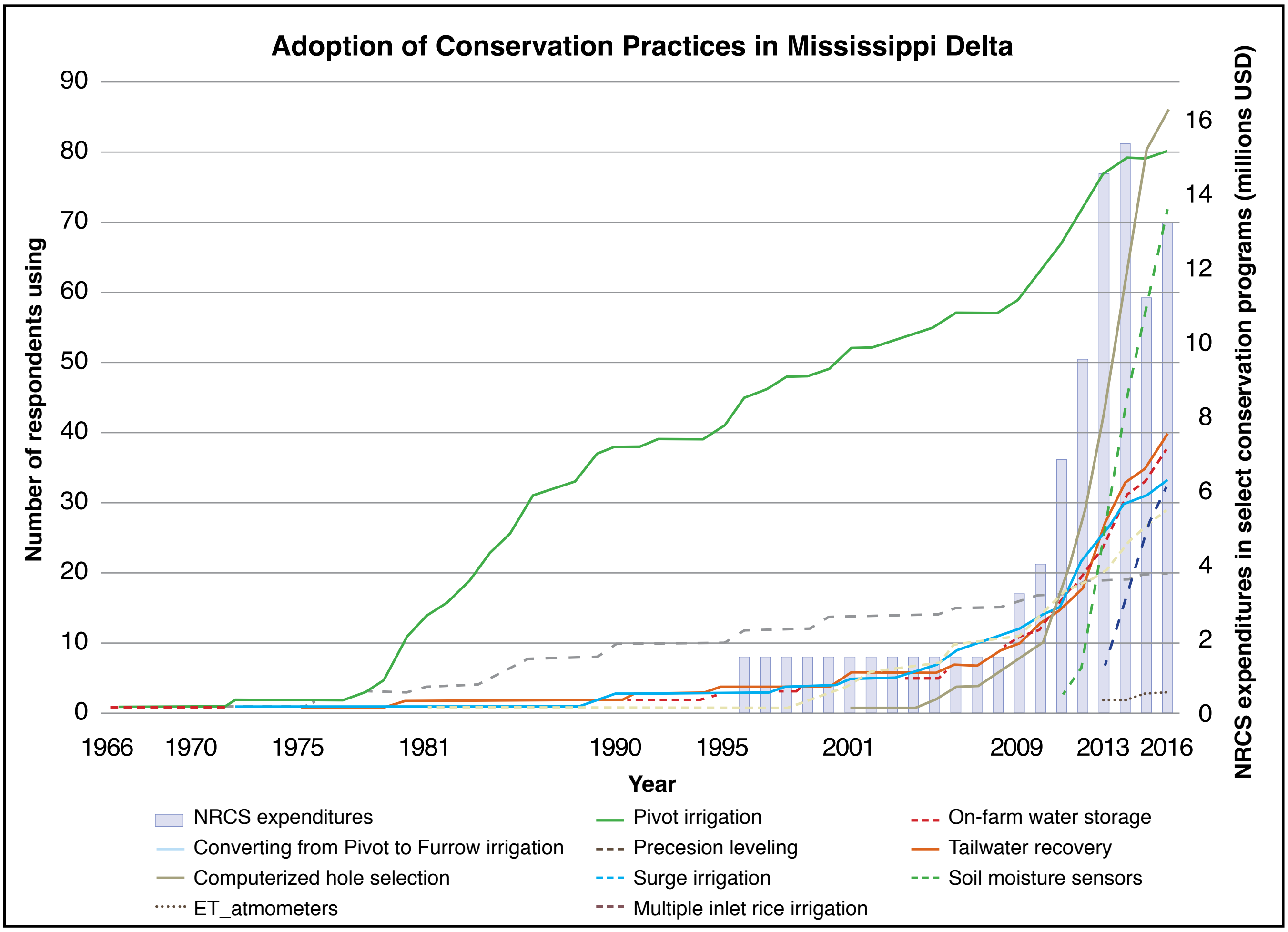


Figure 1. *Farmer adoption curves for different water-conserving practices in the Delta region of Mississippi contrasted with NRCS incentive program expenditures in the same region.*

We know farmers farm for different reasons, including financial, cultural and idiosyncratic motives. It is also clear that Delta farmers have a deep-rooted sense of stewardship towards the land and wildlife. Consequently, NCAAR researchers explored these additional factors by analyzing survey data to discover additional socio-demographic factors that influence their decision to try and continue certain conservation practices in their operation. This is a brief summary of the main lessons learned from those analyses.

The Role of Farmer Perceptions and Beliefs

Perceptions and beliefs are psychological mechanisms that help humans capture and interpret information; and subsequently inform the actions and behaviors associated with that information. In this case, the survey data collected allowed us to understand that the belief or perception that there exists a groundwater problem at the farm or state level is an important determinant of adopting several groundwater-conserving practices. For example, farmers who have this perception or belief are 25% more likely to adopt tailwater recovery systems, 30% more likely to adopt computerized hole selection, 26% more likely to employ surge irrigation, and 41% more likely to have pump timers installed. These beliefs are significantly (positively) correlated with the number of practices employed by a given producer.

An important insight gained from the analysis is that this perception or belief is greatly determined by what the farmers perceive happens with their own water well levels (see **Table 1**). Furthermore, they are more likely to perceive a change in water levels if they are located in the so-called “cone of depression” area. The challenge this imposes to conservation agencies and the farmers themselves is that the nature of the alluvial aquifer itself makes it difficult for changes in aquifer levels to be perceived or identified by farmers. Consequently, an important role exists for the agencies monitoring the evolution of the alluvial aquifer to effectively communicate with regards with the current and projected status of the aquifer in different locations.

The Role of Socio-Economic and Demographic Factors in Adoption Decisions

These factors do not necessarily have a clear mechanism by which they influence producer behavior towards conservation practices, but they are observable. There is also evidence that they correlate with the unobservable underlying factors that do affect such behavior. Consequently, it is highly important to inquire about these factors in surveys while ensuring that the producer responses remain anonymous and to reassure participating farmers that the information they provide remains unidentifiable and confidential. Once significant correlations between these factors and behaviors are identified, the social scientists describe mechanisms that could explain the correlations.

For example, the more years of formal education the farmer receives, the more likely they are to practice surge irrigation or employ sprinklers. A plausible explanation is that this factor allows the producer to better cope with systems that are more complex. In contrast, the greater the number of years of farming experience, the least likely, all else equal, the farmer is to plant cover crops—this factor is also negatively associated with the total number of practices employed. The survey inquired about broad categories of household income levels and significant relationships were identified but the use of categorical variables made it difficult to draw any inference from the result. This highlights the importance of allowing farmers to voluntarily and confidentially report approximate levels of income to facilitate the analysis.

The Role of Incentive Programs in Adoption Decisions

Sponsored conservation programs that offer incentive payment to producers are an important resource that helps cover implementation costs and reduce the risk of potential losses derived from implementing a new conservation practice. Our regression analyses revealed that these programs are not significantly associated with adoption of any particular groundwater conserving practice (except soil moisture sensors) but they are significantly and positively associated with the number of practices employed by growers. **Figure 1** illustrates this relationship graphically. The survey responses allowed us to construct adoption curves for different practices based on the estimated dates farmers started to employ different practices (left axis). Plotting administrative NRCS expenditure data for the Delta region of Mississippi (right axis) we can see the tracking and tracing of these curves.

Conclusion

The potential of agronomic practices to alleviate the depletion of the alluvial aquifer is the compounded product of the inherent water-saving potential of the practice (maximized via discoveries in agronomic research) and the degree by which they are adopted by growers (understood via social science research and propagated via outreach and extension efforts). These components are at the core of the organization design of NCAAR that aims at addressing the challenge to produce ever-increasing levels of agricultural output while sustainably accessing groundwater for irrigation from the alluvial aquifer.

References

This report is based on ongoing research, including the following publication:

Quintana-Ashwell, N., Gholson, D. M., Krutz, L. J., Henry, C. G., & Cooke, T. (2020). Adoption of water-conserving irrigation practices among row-crop growers in Mississippi, USA. Agronomy, 10(8), 1083.

IRRIGATION MANAGEMENT

Soil Moisture Monitoring Showcase

Jacob Rix, Himmy Lo, Drew Gholson

Motivation

Soil moisture sensors provide science-based information about the amount of soil water available to the crop, which can help farmers forecast and finalize decisions about irrigation scheduling. When soil moisture sensors were first promoted, minimizing capital costs tended to be the chief priority. Measurements were collected by physically connecting a handheld device to one sensor at a time across the entire farm.

Over the years, convenience has emerged as arguably the top concern. Adopters of soil moisture sensors are interested in telemetry, accessing automatically collected data anytime and anywhere through the Internet from their smart phones, tablets, and computers. Consequently, MSU Extension has been receiving an increasing number of questions related to choosing and using soil moisture telemetry services.

However, there was a scarcity of objective resources covering the diversity of the soil moisture telemetry services from which customers can select. Learning about and comparing these telemetry services were difficult for farmers and Extension professionals alike. A new Extension program was necessary to educate our clients directly and to enhance Extension's readiness to offer relevant technical assistance.

Program

The NCAAR Soil Moisture Monitoring Showcase was launched in 2020 to address this important need. In 2021, the showcase partnered with seven Mid-South vendors: EnviroSolutions, GroGuru, High Yield Ag Solutions, Irrometer, PrecisionKing, Trellis, and Vantage South. These vendors generously loaned out 12 distinct soil moisture monitoring systems, all of which were installed in the same 2-acre field at the West Farm of Delta Research and Extension Center **(Figures 1 and 2)** and presented on the NCAAR website.

An especially valuable feature of the Showcase is enabling visitors to explore on their own the user interface of each soil moisture telemetry service. With the user names and passwords posted on the Showcase web pages, visitors can log in for free—as if they were subscribers—to experience the look and feel of every interface. Additionally, each sensor type in the Showcase is briefly described, and its compatible telemetry services are listed side by side along with answers to common questions. Please go to https://www.ncaar.msstate.edu/outreach/index.php#showcase to try this feature!

***Figure 1 (left).** Soil Moisture Monitoring Showcase headline banners.* ***Figure 2 (right).** Roadside banners of the soil moisture monitoring systems.*

Figure 3. *Soil moisture sensors to be evaluated in terms of sensor-to-sensor variability within a small field entirely mapped as a Bosket very fine sandy loam according to the USDA-NRCS soil survey; from left to right and top to bottom: Irrometer Watermark 200SS, Sentek Drill & Drop, Acclima TDR-310H, and CPN 503 Elite Hydroprobe.*

As another engaging way to introduce visitors to the different soil moisture telemetry services, a two-minute walk through video was created for each telemetry service to give an overview of the associated hardware and user interface. Please go to https://www.youtube.com/playlist?list=PLf-W9M4xsif2K-mUp_60vEERrnF-gm0Tje for the complete playlist.

Despite the unique circumstances of 2020 and 2021, the Soil Moisture Monitoring Showcase reached thousands of individuals in the Delta and around the world through its web pages and videos. Noting this accomplishment, the development of online content will continue to be a key part of Extension efforts at NCAAR.

Ongoing Research

Past investigation in the Delta revealed that, even within a presumably homogeneous area, multiple replicates of the same sensor type can report substantially different soil moisture values. Therefore, an individual sensor or sensor set—however carefully sited and installed—might not always represent accurately the average condition of the field where it is located. Such sensor-to-sensor variability of four soil moisture sensor types is being assessed **(Figure 3)**. The forthcoming findings will be incorporated into MSU Extension recommendations on sensor selection and interpretation to increase farmer success with scheduling irrigation using soil moisture sensors.

IRRIGATION MANAGEMENT

Advancing Adoption of Soil Moisture Sensors Through On-Farm Training and Demonstration

Drew Gholson, Himmy Lo, Alex Deason, Mark Henry, Jacob Rix

Sponsored partially by Mississippi Soybean Promotion Board under project 13-2021, by Mississippi Corn Promotion Board under project 03-2021, and by Cotton Incorporated State Support Program under project 21-863.

Motivation

Research has shown that soil moisture sensors can help producers irrigate less while maintaining or even improving yield and profit. However, hesitation to adopt soil moisture sensors remains common in Mississippi and nationwide. Some producers assume that their irrigation scheduling is already near optimal and thus will not benefit from the information reported by sensors. Some other producers are reluctant to continue using sensors because of a negative past experience, such as suspicious sensor readings and malfunctioning telemetry systems. In either case, one-on-one guidance from MSU Extension professionals over multiple seasons can assist Mississippi producers in gaining the skills and confidence necessary to adopt soil moisture sensors on their own.

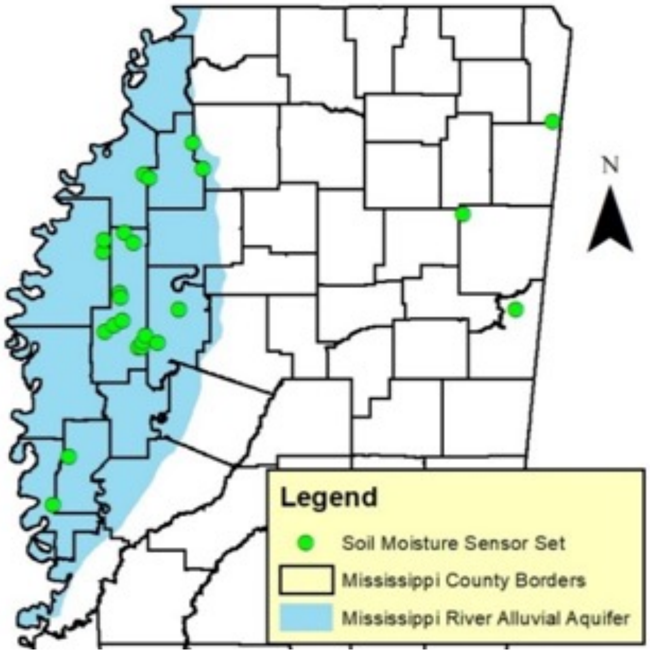


***Figure 1.** Soil moisture sensor sites in this statewide Extension program during 2021.*

Program

To empower producers to integrate soil moisture sensors fully into their farming operations, we launched an agent-led, multi-year on-farm education program. With generous funding from Mississippi commodity promotion boards and NCAAR, we give telemetry-enabled soil moisture monitoring systems and technical support to interested MSU Extension county agents. These agents recruit producers from their respective counties and provide participants with hands-on training and troubleshooting to deliver the best user experience. Agents then gradually decrease their involvement with day-to-day sensor data interpretation until the participants become active and capable independent users of soil moisture sensors. More than 20 producers across Mississippi participated in 2021, and the crops at the sensor locations included soybean, corn, cotton, and rice. Four of the sensor sites were under sprinkler irrigation while the remainder were surface irrigated **(Figure 1)**.

Outcomes

Some program participants were convinced of sensors' usefulness so quickly that they bought soil moisture monitoring systems before the first year was over. Some participants ignored the sensors during the first year and were shocked to discover at their end-of-season meeting how much they had over-irrigated. This realization motivated them to pay closer attention to the sensors during the second year. We hope to continue increasing the number of participants to expand the impact of this program.

This program also bolstered the professional competence of county agents **(Figure 2)**. Agents deepened their familiarity with installing, maintaining, and removing sensors and telemetry units as well as with setting up and understanding telemetry interfaces. Additionally, agents built stronger relationships with the participants through frequent, year-round communication to coordinate, teach, and advise for this intensive program. These relationships helped agents to advertise and offer other beneficial services and ultimately to serve their communities more effectively.

Figure 2. *Some of the county agents in this statewide Extension program; from left to right and top to bottom: Alex Deason (Sunflower County), Zach Yow (Tishomingo County), Zach Gaylor (Bolivar County), Lea Turner (Sharkey and Issaquena Counties), Michael Pruden (Coahoma County), and Drew Wilson (Quitman County).*

IRRIGATION MANAGEMENT

Identifying, Evaluating, and Demonstrating Sensor-Based Automation Irrigation Technologies in Corn and Soybean

Drew Gholson, Mark Henry, Himmy Lo, Jason Krutz, Trent Irby, Eric Larson, Brian Mills, Nicolas Quintana Ashwell, Alex Deason, Gurpreet Kaur, Gurbir Singh

Sponsored partially by Mississippi Soybean Promotion Board under project 13-2021, by Mississippi Corn Promotion Board under project 03-2021, and by the Conservation Innovation Grants program at USDA's Natural Resources Conservation Service under award number NR203A750008G007

Introduction

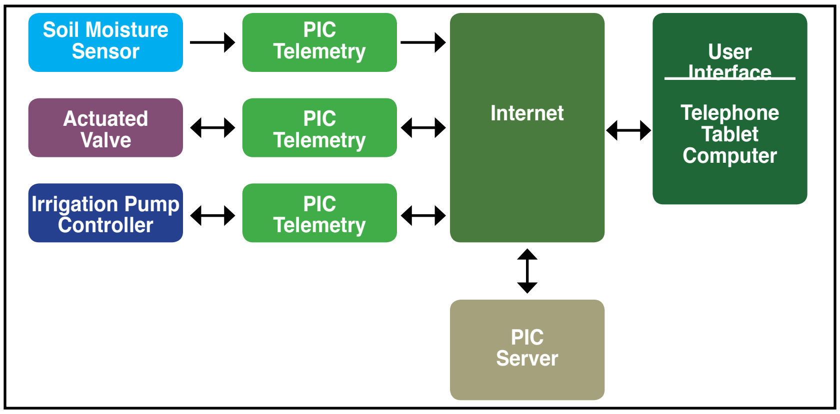
Declining aquifer levels, coupled with impending well monitoring, serve as a catalyst to improve water use efficiency. The RISER program has identified several technologies and management practices that have the potential to eliminate the 300,000 ac-ft/year overdraft on the Mississippi Alluvial Aquifer while ensuring that producers stay within permitted irrigation limits. However, the adoption of Best Management Practices (BMPs) by producers in the Mississippi Delta is minimal.

The RISER (Row-crop Irrigation Science Extension and Research) Program serves as the primary means to facilitate the widespread adoption of the latest irrigation management research findings across the Mississippi Delta. This program focuses on identifying and evaluating innovative sensor and automation technologies that can assist producers with improving their on-farm irrigation management strategies and scheduling.

Materials and Methods

An on-farm experiment was conducted in 2020 and 2021 on multiple production farm locations throughout the Mississippi Delta on corn and soybean. Each demonstration farm consisted of two nearby irrigation wells and associated fields (irrigation sets) with similar soils and planting dates. One well served as a control (no change in technologies), and the other was equipped with pump controls, actuated valves (Figure 1), and soil moisture sensors enabled with telemetry capabilities (Figure 2). Predetermined templates set an irrigation time for each set and each field. These templates were programmed to the software, and the

Figure 1 (left). *Actuated valve in soybean field.* ***Figure 2 (right).*** *Schematic of automation telemetry communication.*



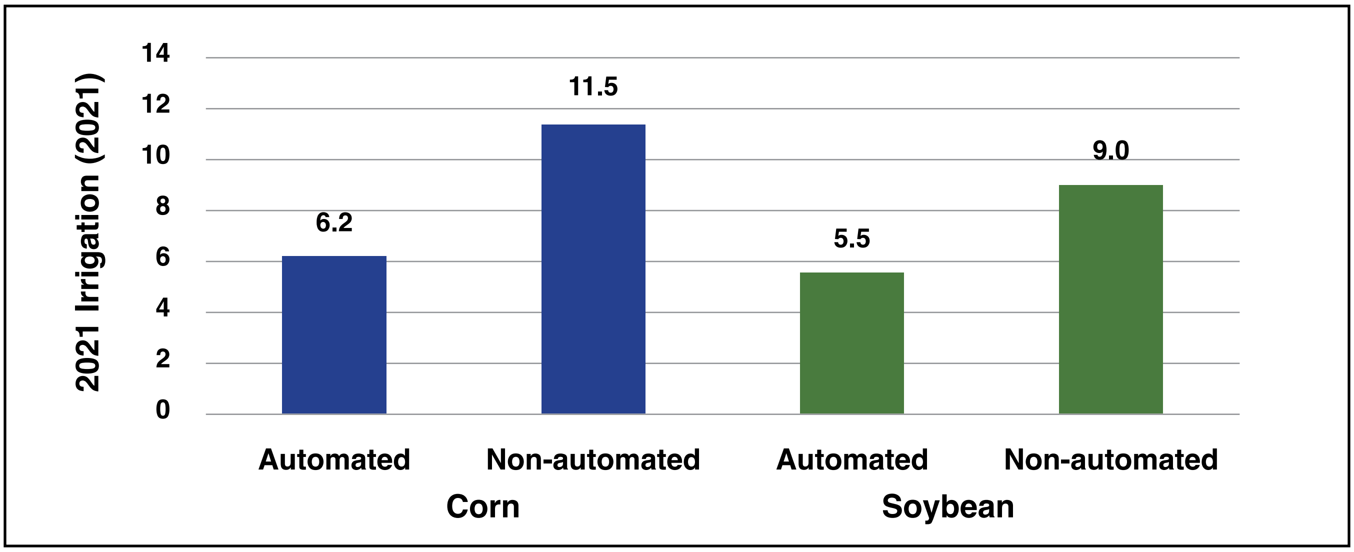


Figure 3. *Water applied in 2021 by automated irrigation and by non-automated irrigation, respectively, averaging across on farm sites for corn and for soybean separately.*

decision to irrigate was determined through field observations, soil moisture sensor readings, and weather outlook. The irrigation "spin" was initiated through the user interface. Sites were monitored throughout the growing season.

Results and Discussion

Information on irrigation application, pumping energy requirement, crop growth, and yield was collected at each field to document and display the impact of implementing irrigation automation technologies on conserving water and maintaining/improving crop yield (Figure 3; Table 1). The functionality of actuated valves was also evaluated. If a low battery caused issues with valve opening and closing, the battery was replaced. At each site for all irrigations, the automated system made a successful run.

Conclusion

As labor continues to become one of the most significant concerns across the farming community, investigating tools that can decrease labor, assist in decision making, and save water is increasingly important. This study suggests that irrigation automation may be a beneficial tool for soybean and corn irrigation, saving water and time and ultimately conserving groundwater in the Mid-South. The next step will be to continue investigating the effectiveness of automation with the addition of more sites for statistical and economic analysis.

Table 1. *On-farm comparisons between automated irrigation and non-automated irrigation in terms of crop yield, seasonal irrigation, and irrigation water use efficiency; each value represents the average across sites in 2021 for corn or for soybean.*

	Yield (bu/ac)	Irrigation (inches)	Irrigation Water Use Efficiency (bu/ac-in; yield divided by irrigation)
Corn			
Automated	220	6.2	42
Non-Automated	216	11.5	20
Soybean			
Automated	88	5.5	19
Non-Automated	88	9.0	14

IRRIGATION MANAGEMENT

Development of an Automated System to Incorporate Holes in Lay-Flat Irrigation Tubing During Initial Deployment in Mississippi Soybean Production Systems

Dru Carey, Wes Lowe, Drew Gholson, Daniel Chesser, Christopher Delhom

Sponsored partially by Mississippi Soybean Promotion Board under project 27-2021

Introduction

Currently, producers who adopt the use of prescriptive hole sizing in lay-flat irrigation tubing are faced with challenges that impede the ease of use. One of the most challenging, labor-intensive, and critical components of using computerized hole selection (CHS) in lay-flat irrigation tubing is the proper insertion of holes into the tubing.

Automating the hole punch process and incorporating it into the laying of lay-flat irrigation tubing would streamline the process into a single-pass operation, reducing both the time needed to begin irrigation activities, the labor required to perform the process, and lessen the potential for errors and omissions that could negatively affect irrigation efficacy and water usage. Carrying the process a step further, incorporating the ability to utilize CHS prescriptions would allow the software to create optimized hole prescriptions for every hole, instead of a series of holes, and allow for the precise delivery and application of irrigation water across the field. The combination of these technologies would create an efficient, single-pass implement capable of precise hole sizing and location and streamline the process of utilizing lay-flat irrigation tubing to meet water needs for improved crop efficiencies and yields.

***Figure 1.** Testing over-pressurized polypipe.*

Materials and Methods

A testing system and methodology was created to repeatably test multiple samples across varying mil thicknesses and pressures. Each sample was subjected to a series of increasing and decreasing pressures ranging from 0.2 psi (0.462 ft. of head) to 150% of yield tensile strength, or the point at which the poly-pipe material deforms and does not return to its original shape, specific to each mil thickness: 7 mil (1.035 psi), 9 mil (1.144 psi), 10-mil (1.368 psi). For each sample, flows from each hole were assessed three separate times at a range of pressures below yield tensile strength to capture mean flow before over pressurization of the pipe occurred. Samples were then over pressurized for a period of 30

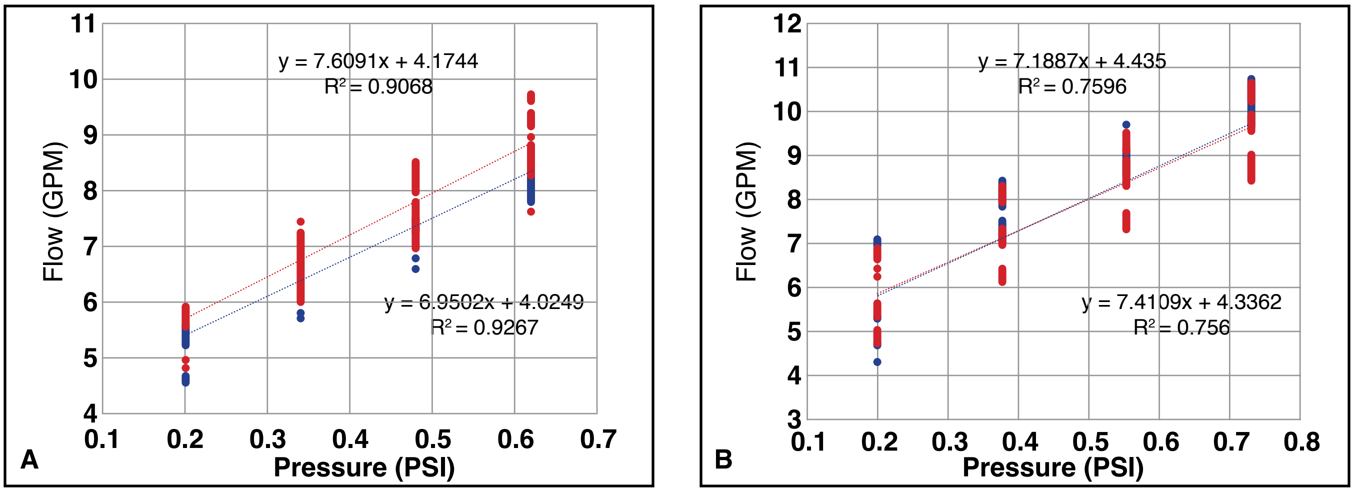


Figure 2. *Flow versus pressure relationship before (blue) and after (red) over-pressurization for a) 5/8" holes in 15" × 7-mil poly-pipe and b) 11/6" holes in 15" × 10-mil poly-pipe.*

seconds, then assessed at the same range of pressures below yield tensile strength to quantify changes in poly-pipe material with respect to hole flow.

Results and Discussion

Analysis was conducted to assess material behavior with respect to hole characteristics during irrigation events under dynamic conditions. In each of the mil thicknesses, statistically significant changes were observed with these over pressurizations. Ranges of variation for each mil thickness were as follows: 7 mil 2% - 2.5%, 9 mil 0.95% - 1.25%, 10 mil 0.10% - 0.5%. These findings further support the assumption that thinner poly-pipe (Figure 2a) will be more influenced by excess pressures than greater mil thicknesses (Figure 2b). Data analysis revealed inconsistencies in flow for similar holes punched with the Poly Piranha, the standard metal tool utilized for in-field hole insertion. These differences were more pronounced as mil thickness decreased and were easy to identify as misshapen holes with jagged edges. Stretching and material deformation at the hole site were also visible. Holes punched in the poly-pipe when the pipe was not full exhibited the greatest variability and inconsistency. To address this, a leather punch tool was used to punch holes into the material prior to charging with water. This approach created smooth, consistent holes. This method of hole insertion will be utilized as this process is automated.

These factors, along with over pressurization, may explain some of the producer complaints with computerized hole selection (CHS) as these would prevent the irrigation prescription from achieving the desired outcome. For example, a 13/16” hole in 7-mil. poly-pipe flows around 11.2 gpm before over-pressurization and 13.5 gpm afterward. This flow increase across a section of pipe would result in substantial over-watering and negatively influence water-use efficiency for the entire irrigation set.

Conclusion

This resultant information will be used to create a guide to aid producers in selecting the correct mil thickness for each of their irrigation sets, to identify potential material failures before they occur, and to potentially reduce poly-pipe costs by selecting the minimum mil thickness for each irrigation set. This lessens the probabilities for late-season poly-pipe replacement from material failure due to incorrectly selected mil thickness in poly-pipe. Additionally, this information provides a guide for correctly setting head pressures for each well, especially when CHS tools such as Pipe Planner and PHAUCET are utilized to design irrigation strategies. It also serves as a tool to develop automated well control systems that monitor and adjust well output to match output needs to material capabilities.

SOIL FERTILITY AND AMENDMENTS

Zinc and Nitrogen Rates Effects on Corn-Cotton Production in Humid Subtropics of Mississippi

Gurbir Singh, Gurpreet Kaur

Introduction

Zinc deficiency symptoms have continued to surface over the past several years and have been evident in both corn and cotton. The problem has been most evident on the sandier soils where organic matter levels are generally less than 1%. Efforts have been underway in the Mississippi Delta to increase organic matter levels by utilizing crop rotations. Soil test zinc has been observed in the deficient range and could be increased with zinc fertilizer applications. Both soil-applied and foliar products are available, but application can be quite expensive. Research at the Delta Research and Extension Center has shown significant yield increases when cotton follows corn compared to cotton following cotton. The advantage has averaged from 10-17% on a series of studies to over 20% in the Centennial Rotation. The objectives of this study were to evaluate the interaction of nitrogen rates and zinc rates for optimizing corn and cotton yields in rotation on irrigated sandy soils and to determine the economic impact of the nitrogen and zinc applications while optimizing all other inputs.

Materials and Methods

A corn-cotton rotation system is currently in place was used to evaluate the interaction of zinc rates and nitrogen rates for both the corn and cotton crops. The studies are located at the Delta Research and Extension Center with four N rates (Corn: 160, 200, 240, and 280 lb/ac N; Cotton: 30, 60, 90, and 120 lb/ac N) and four zinc rates (0, 5, 10, and 15 lb/ac Zn). The experiment is set up in a randomized complete block design with five replications. Zinc sulfate has been used by dissolving in water and applied as a sidedressed band with a coulter rig, similar to urea-ammonium nitrate solution, to each side of the planted row.

Seedbed preparation was accomplished in fall 2020. In spring 2021, seedbeds were rolled down and planted with corn hybrid DKC 70-27 at 32,000 seeds/ac on 4/5/2021. Cotton hybrid DP 1646 B2XF was planted on 5/17/2021 at 46,000 seeds/ac. Pre-emergence nitrogen was applied at 120 lb/ac N to corn and 30 or 60 lb/ac N to cotton on 4/6/2021 and 5/20/2021, respectively. The remaining N was applied as a split application to all the treatments to corn on 5/24/2021 and cotton on 6/21/2021. During preplant sidedressed application of N, zinc sulfate was also applied to the treatments. Corn biomass samples were collected from all treatments to determine silage yield. Corn biomass samples were oven-dried, weighed, grounded, and analyzed for nitrogen and zinc concentration to determine N and Zn uptake by corn. Corn was harvested on 9/3/2021 using a Kincaid 8XP plot combine and grain samples were collected to determine grain harvest moisture, bushel test weight, seed index (100-seed weight), and grain quality (protein, starch, and oil). Cotton boll samples were collected prior to picking cotton and will be processed for lint yield and fiber quality. Cotton was picked using a two-row cotton picker on 10/11/2021. After harvesting, soil samples were collected for determining available nutrients in soils.

All data were statistically analyzed using the glimmix procedure in SAS statistical software.

N Rate (lb/ac N)	Seed Cotton Yield (lb/ac)					Fiber Fineness (millitex)					Fiber Color (Rd)				
	Zinc Rate (lb/ac Zn)				Main Effects	Zinc Rate (lb/ac Zn)				Main Effects	Zinc Rate (lb/ac Zn)				Main Effects
	0	5	10	15		0	5	10	15		0	5	10	15	
30	2528g	2538g	2654fg	2909d-g	2924b	4.57	4.59	4.5	4.53	4.55a	83.7	82.63	83.65	83.7	83.42b
60	2878d-g	3038c-f	3064cde	3561ab	2872b	4.33	4.54	4.63	4.67	4.54ab	83.93	83.85	83.88	84	83.91a
90	3039c-f	3228bcd	3359abc	3491ab	3278a	4.15	4.42	4.5	4.59	4.41bc	84.28	84.28	83.73	83.68	83.99a
120	2729efg	2761efg	3052cde	3665a	3050b	4.26	4.38	4.31	4.41	4.34c	84.78	84.38	84.28	84	84.36a
Main Effects	2658c	3135ab	3279a	3052b		4.33b	4.48a	4.48a	4.55a		84.17	83.78	83.88	83.84	

Table 1. *Means represent nitrogen (N) and zinc (Zn) rate treatments' main effects and their interactions for corn silage N and Zn uptake, corn grain yields, harvest moisture and grain protein content. Means followed by the same letter within a column or a row do not differ significantly at alpha = 0.05.*

N Rate (lb/ac N)	Silage N Uptake (lb/ac)					Silage Zn Uptake (lb/ac)					Corn Yield at 15.5% (bu/ac)					Harvest Moisture (%)					Grain Protein (%)				
	Zinc Rate (lb/ac Zn)				Main Effects	Zinc Rate (lb/ac Zn)				Main Effects	Zinc Rate (lb/ac Zn)				Main Effects	Zinc Rate (lb/ac Zn)				Main Effects	Zinc Rate (lb/ac Zn)				Main Effects
	0	5	10	15		0	5	10	15		0	5	10	15		0	5	10	15		0	5	10	15	
160	186	186	155	180	177c	7.1	9.9	12.8	11.8	10.4b	155	157	150	149	153c	17.8	17.9	18.2	17.5	17.8c	9.1	8.7	8.7	8.6	8.8d
200	194	180	198	194	192c	6.5	9.4	13.2	12.7	10.5b	169	164	168	168	167b	17.2	18.4	18.3	18	18.0bc	9.4	9.6	9.3	9.4	9.4c
240	231	224	209	217	220b	10.2	12	12.4	16.3	12.8a	172	171	174	170	172ab	17.5	18.6	18.8	18.5	18.3ab	10	9.7	10	10	9.9b
280	210	252	272	256	248a	8	13.4	17.8	16.2	13.8a	173	176	168	183	175a	18.4	18.6	18.3	18.5	18.5a	10.4	10.2	10.4	10.1	10.3a
Main Effects	205	211	209	212		7.9c	11.2b	14.1a	14.3a		167	167	165	168		17.7b	18.4a	18.4a	18.1a		9.7	9.6	9.6	9.5	

Table 2. *Means represent nitrogen (N) and zinc (Zn) rate treatments' main effects and their interactions for seed cotton yield, lint yield, cotton fiber quality (fineness and color). Means followed by the same letter within a column or a row do not differ significantly at alpha = 0.05.*

Nitrogen and zinc rates were treated as fixed factors and replications of the treatment were random factor. The model parameters were tested at alpha = 0.05. Mean comparisons were made using the T-grouping method with LS-MEANS statement.

Results and Discussion

There were no interaction effects of Zn and N rate application for corn silage N uptake, corn silage Zn uptake, corn grain yield, corn grain protein content and harvest moisture in 2021. However, corn silage N uptake, corn grain protein content and corn yield were affected by the main effects of N rate application **(Table 1)**. The highest yield of 175 bu/ac was received with 280 lb/ac N. Corn yield for 240 and 280 lb/ac N was similar between both treatments and was at least 19 bu/ac greater when compared to 160 lb/ac N treatment. Corn silage Zn uptake was more than 14.1 lb/ac for the 10 and 15 lb/ac Zn treatments when averaged over N application treatments. Harvest moisture for corn increased as the N application rate was in-

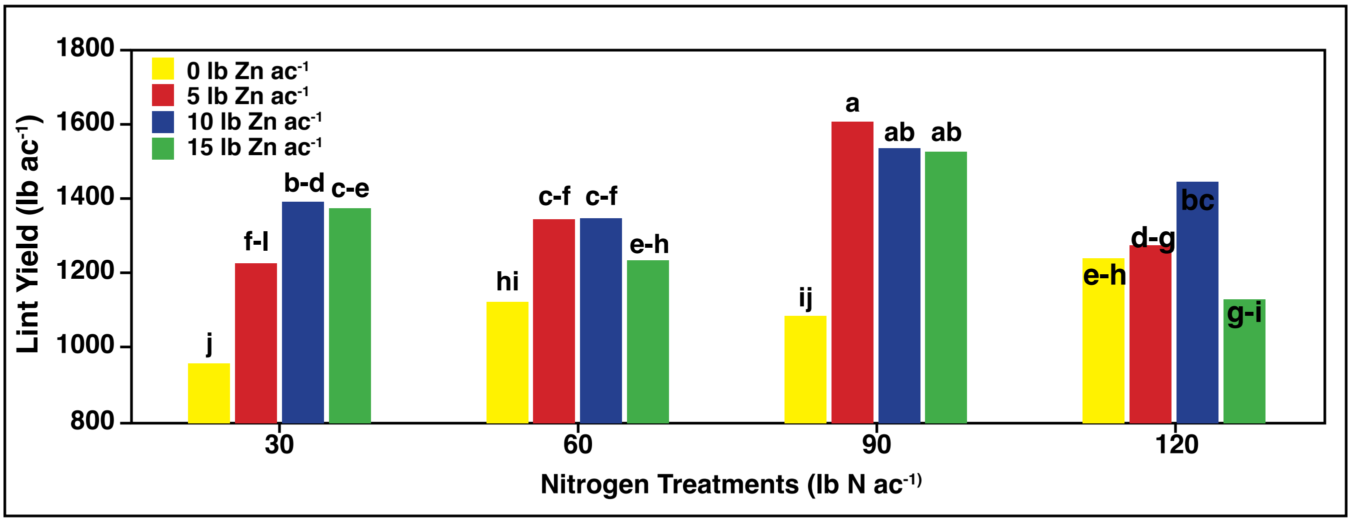


Figure 1. *Average cotton lint yields for an interaction effect between N and Zn rate treatments. Means followed by the same letters on the bars do not differ significantly at alpha = 0.05.*

creased when averaged over the Zn application treatments.

Seed cotton yield was affected by the two-way interaction of N and Zn rate treatments **(Table 2)**. The lowest seed cotton yield of 2528 lb/ac was observed in the 30 lb/ac N + 0 lb/ac Zn treatment whereas a higher seed cotton yield of 3278 lb/ac was observed in the 120 lb/ac N + 15 lb/ac Zn treatment. When N was applied at 30, 90, and 120 lb/ac with 10 or 15 lb/ac Zn, the seed cotton yield showed no significant differences (Table 2). Cotton lint yield also showed an interaction effect and highest cotton lint yield of 1611 lb/ac was achieved with the 90 lb/ac N + 5 lb/ac Zn treatment **(Figure 1)**. This yield was not different when additional Zn was added with 90 lb/ac N treatment. Therefore, agronomic optimum cotton yield can be achieved with a fertilizer rate of 90 lb/ac N plus 5 lb/ac Zn. Cotton fiber fineness showed difference only with the main effects where cotton fiber fineness decreased with increasing rate of N application. In contrast, cotton fiber fineness increased with increasing rate of Zn application. Cotton fiber color showed significant differences with only N application rates **(Table 2)**.

COVER CROPS

Nitrogen and Cover Crop Effect on Yield and Soil Water for Cotton and Corn

Ruixiu Sui, Saseendran Anapalli, Gurpreet Kaur, Gurbir Singh

Introduction

Tillage radish has been adopted as a cover crop by farmers for over a decade. The large and deep taproot of this crop can penetrate compacted soil layers by “bio-drilling” the crop root zone, which increases water infiltration into the soil, reduces surface runoff, and supports the subsequent crop by obtaining water and nutrients from deep soils. Because of its robust rooting system and rapid growth characteristics, a tillage radish cover crop can scavenge for residual nitrogen (N) in the soil, which can reduce excess N leaching into the groundwater. Optimizing N application rates and minimizing excess N leaching from crop production systems can help maximize farm profits and minimize environmental impacts. The objective of this study is to assess interacting effects of N rates and tillage radish cover crop on cotton and corn yield and soil water in the Mississippi Delta.

Materials and Methods

Field studies were conducted from 2017 to 2020 in cotton and 2021 in corn in Stoneville, MS. The field was approximately 12 acres and constituted one-half of the area under a center pivot irrigation system for sprinkler irrigation. The predominant soil map unit in the field was Commerce very fine sandy loam. Twelve plots were laid out in the field. Plots were 600 feet long and 75 feet (24 rows) wide. A 2 × 2 factorial experiment in randomized complete block design (RCBD) with three replications was used to test the effect of two N application rates (75 and 125 lb/ac N in cotton; 150 and 250 lb/ac N in corn) with tillage radish cover crop (CC) and with no cover crop (NCC) on crop yield and soil water. After cotton was harvested each year, cotton stalks were shredded using a rotary shredder. Then, the tillage radish cover crop was planted at a seeding rate of 8 lb/ac using a seed drill.

Soil water sensors were used for irrigation scheduling. An irrigation was triggered as the percentage of plant available water dropped to approximately 50%. The cotton was picked using a cotton picker. The corn was harvested using a combine equipped with a yield monitor. Crop yield data were collected and analyzed.

Results and Discussion

The tillage radish cover crop grew very well in spring 2017 **(Figure 1)**. The average TRCC height was about 24”. On average, the radish taproot was about 10” long and 2” in diameter. In 2018, 2019, and 2020, the cover crop did not grow as well as in 2017. One of the reasons for the poor growth in these seasons was that the radish suffered severe cold winter weather, which seriously damaged the plants and limited their growth in the subsequent spring seasons.

We examined the soil water changes during the cotton growing season. Some increases in soil water content due to the tillage radish cover crop were evident. The higher soil water content in the CC plots could be due to the increase of rainwater infiltration and to enhanced soil physical properties, thus capturing and retaining more water in the soil profile.

Lint yield responses to N rate and tillage radish cover crop are given in **Figure 2** and **Table 1**. In general, the results showed that, compared to N rate of 75 lb/ac, the N rate of 125 lb/ac could increase lint yield while the cover crop could decrease the lint yield. However, yield re-

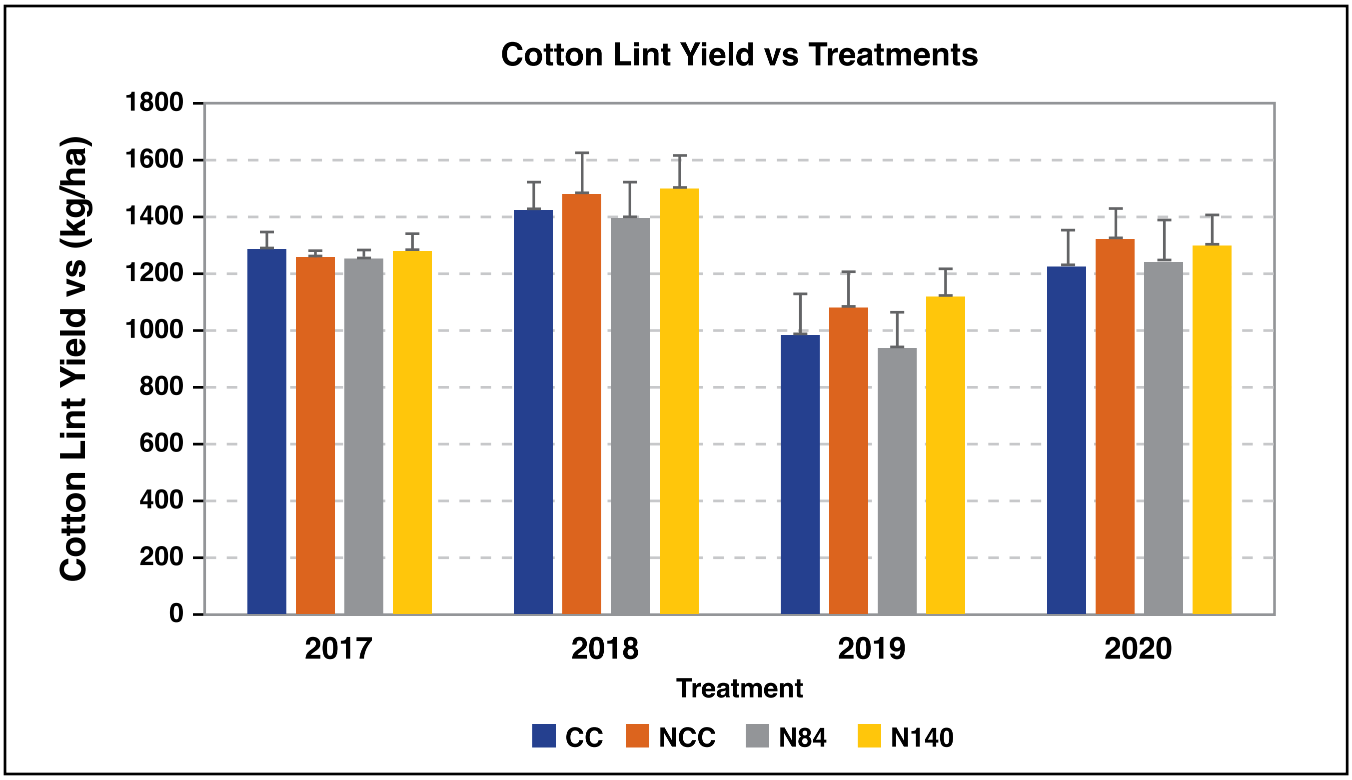
Figure 1. *(A) Aboveground and (B) below-ground growth of the tillage radish cover crop in 2016–2017 winter season.*

sponse to cover crop and N rate in 2017 did not follow that trend well. In 2017, the CC treatment had a higher lint yield than the NCC treatment, which was the reverse of the 2018, 2019, and 2020 seasons. The yield responding differently in 2017 could be caused by the residual N left in the field from the 2016 growing season. Corn yield data in 2021 is still being processed and will be reported later.

Conclusion

This study indicated that a tillage radish cover crop increased soil water infiltration capacity and enabled the soil to retain higher soil water content. Increasing N rate from 75 lb/ac to 125 lb/ac could possibly increase cotton yield but needs further investigations to confirm. The non-significant impact of tillage radish cover crop on cotton yield could be caused by poor tillage radish growth as a result of cold temperatures and excessive winter rains. What we learned was that a tillage radish cover crop should be planted no later than the middle of October in this region to allow the plant to be well-developed prior to the cold winter weather for optimum regrowth in the subsequent spring.

Figure 2. *Cotton lint yield with cover crop (CC), no cover crop (NCC), 75 lb/ac N, and 125 lb/ac N.*



COVER CROPS

Soil Management Effects on Furrow Infiltration and Rainfed Corn Yield

Jacob Rix, Himmy Lo, Drew Gholson, Gurbir Singh, Daran Rudnick

Introduction

In the Mississippi Delta, many silt loam soils tend to form a surface seal or crust as the growing season progresses, which limits infiltration of rain and irrigation into the soil. The consequence of this problem is decreased yield on rainfed fields and increased pumping on irrigated fields, which can compensate for lower infiltration but accelerates groundwater depletion. Regardless of irrigation availability, more runoff as a result of surface sealing can worsen flooding, soil erosion, and contamination of

Figure 1. *The seven soil management treatments of this study; from left to right and top to bottom: cereal rye, furrow diking, conventional tillage, no tillage, no tillage + gypsum, polyacrylamide, and subsoiling.*

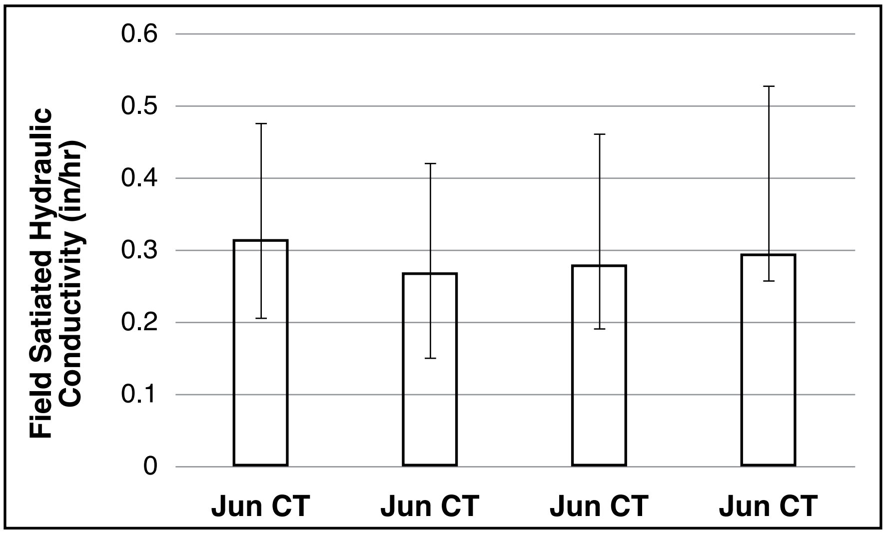


Figure 2. *Field satiated hydraulic conductivity in non-trafficked furrows for conventional tillage (CT) and no tillage (NT) on two dates in 2021; each error bar marks one standard deviation from the mean.*

downstream waters and habitats. Research is being conducted on a 7-acre silt loam field in Stoneville, MS, to find practical solutions to reduce surface sealing.

Materials and Methods

A randomized complete block design was followed to replicate each of seven treatments **(Figure 1)** in eight continuous corn plots: cereal rye, furrow diking, conventional tillage (CT), no tillage (NT), NT + gypsum, polyacrylamide (PAM), and subsoiling. 2021 represented the third consecutive year for the subsoiling treatment and the fifth consecutive year for the CT, NT, and cereal rye treatments.

Results and Discussion

In 2021, field satiated hydraulic conductivity was measured in the CT and NT treatments because they were originally expected to be most different. Field satiated hydraulic conductivity indicates the ease of water infiltrating into the soil under nearly saturated field conditions, such as during furrow irrigation. Infiltration tests were conducted in June and again in October, each time using three cylindrical steel rings in the middle non-trafficked furrow of every CT and NT plot. There was no significant difference between NT and CT at alpha = 0.05 for either measurement time **(Figure 2)**, suggesting that solely converting from CT to NT for several years might not improve in-season infiltration under circumstances similar to this experiment.

The rainfed corn yield of the seven treatments was also measured as an indirect indicator of soil infiltration because treatments with higher infiltration would store more soil moisture to withstand drought later in the season. In 2021, PAM and furrow diking were significantly higher in yield than NT at alpha = 0.05 **(Figure 3)**. Future research will further investigate PAM, furrow diking, subsoiling, and cereal rye treatments to quantify the effect of these treatments on furrow infiltration.

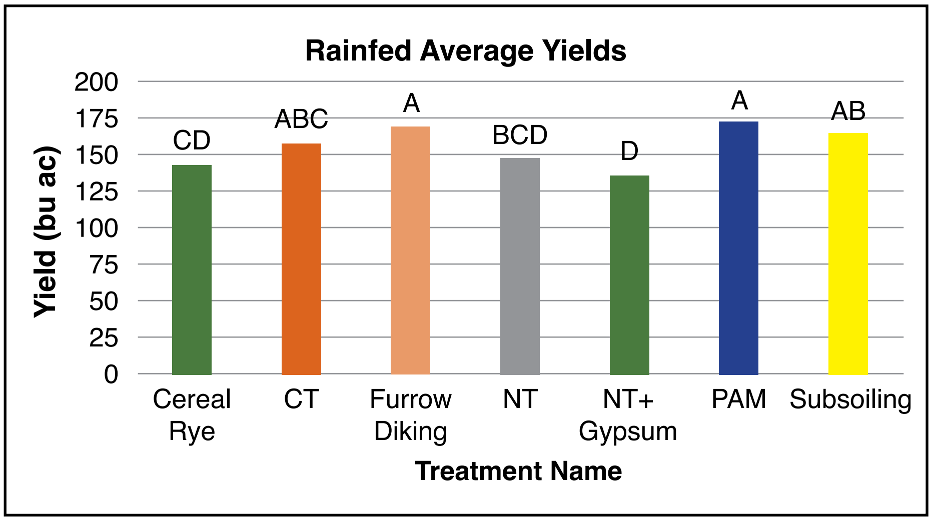


Figure 3. *2021 rainfed corn grain yield by soil management treatment; bars sharing a letter are not significantly different at alpha= 0.05.*

Can Winter Cover Crops Benefit Growth and Yield in Irrigated Continuous Corn?

Bhupinder Singh, Gurbir Singh, Gurpreet Kaur, Jagmandeep Dhillon, Nicolas Quintana Ashwell

Introduction

Farmers sometimes engage in continuous corn production when the market returns for corn rise. However, a risk of yield reduction is associated with continuous corn due to cooler and wetter soils, nitrogen (N) immobilization, increased disease risk, and allelopathy. Past studies have observed a yield reduction from 2 to 29% in continuous corn compared to corn following soybean. Nitrogen immobilization plays a dominant role in yield reduction in continuous corn among various factors. The substantial production of crop residue with high carbon-nitrogen (C/N) ratio in continuous corn has been a major cause of N immobilization. The corn residue in continuous corn decomposes slowly in winter due to low soil temperatures and low available N to soil microorganisms. Cover crops (CC) are proven to reduce leaching and deliver available N to the following cash crop. However, the impact of N cycling may vary with CC species, soil characteristics, and weather conditions. The overall objective of this study was to determine the benefit of CC to corn growth and grain yield in Mississippi.

Materials and Methods

Field experiments were conducted from 2019 to 2021 at three different sites in Mississippi including Stoneville (2019-2020), Starkville (2020-2021), and Stoneville (2020-2021). The combinations of experimental site and year were referred to as environments, i.e., Environment 1 (Stoneville 2019-2020), Environment 2 (Stoneville 2020-2021), and Environment 3 (Starkville 2020-2021). The ten treatments consisting of a single CC or mix of CC species (brassica, grasses, and legumes) and a fallow treatment (check) were planted in the fall 2019 and 2020 at Stoneville and in fall 2020 at Starkville **(Table 1)**. The corn hybrid DKC 70-27 (DEKALB®, Illinois, USA) was planted following CC termination in the

Table 1 (right). *Statistical differences among treatments for traits measured in cover crop and corn crop season in all three environments.*

Treatment and Seeding Rate lbs/ac	CC Biomass lb/ac	C -----%-----	N -----%-----	C/N	TN lb/ac	Corn Height inches	Corn Yield bu/ac
Environment 1							
Untreated Check 0	280.10b†	9.87b	0.92d	7.78f†	3.25c	90.00abc	179ab
Cereal Rye 60	3197.91a	25.67a	1.8c	14.07ab	56.44ab	89.10bc	157bc
Crimson Clover 8	683.04b	12.34b	1.05d	11.77bcd	7.07c	89.50bc	182ab
Hairy Vetch 20	436.95b	8.87b	0.8d	10.18def	4.20c	90.00abc	177ab
Radish 8	4310.70a	32.11a	3.5a	8.96def	154.18a	95.40a	184a
Wheat 60	2146.35a	24.95a	1.56cd	15.72a	31.06b	85.60cd	164ab
Hairy Vetch 10; Radish 4	4250.68a	31.09a	3.5a	8.77ef	150.19a	91.20ab	170ab
Cereal Rye 30; Crimson Clover; 4	3789.72a	28.82a	2.18b	13.34abc	82.06ab	83.60d	136c
Wheat 30; Crimson Clover 4	9734.18a	26.81a	1.88c	14.44ab	231.02ab	90.10abc	166ab
Wheat 40; Radish 4; Turnip 2	4589.20a	27.88a	2.6b	10.79cde	129.04a	87.70bcd	158abc
Environment 2							
Untreated Check 0	1270.28	26.82ab	2.19	12.89abcd	29.31	83.40	185
Cereal Rye 60	1816.47	34.97a	2.46	14.60ab	47.08	80.60	152
Crimson Clover 8	1614.80	25.61b	1.9	14.08abc	29.94	79.40	167
Hairy Vetch 20	2154.99	30.69ab	2.79	10.92d	60.43	84.00	169
Radish 8	1546.37	29.94ab	2.5	11.67cd	40.48	84.60	173
Wheat 60	1731.24	26.73ab	1.75	15.26a	30.84	83.00	158
Hairy Vetch 10; Radish 4	2305.03	30.85ab	2.8	10.94d	62.67	83.00	183
Cereal Rye 30; Crimson Clover; 4	2249.82	31.29ab	2.4	13.11abcd	51.58	79.80	157
Wheat 30; Crimson Clover 4	1206.65	29.32ab	2.26	13.29abcd	25.96	81.90	178
Wheat 40; Radish 4; Turnip 2	2311.04	31.05ab	2.46	12.64bcd	58.12	81.00	169
Environment 3							
Untreated Check 0	1555.98f	32.7e	1.7d	18.78a	28.87e	.	169
Cereal Rye 60	5011.98abc	39.5a	2.48c	16.09abc	125.70bc	.	174
Crimson Clover 8	2229.41ef	36.6cd	2.42c	15.68bc	56.07ed	.	157
Hairy Vetch 20	3080.51def	38.4abc	2.92ab	13.31cd	92.50cd	.	153
Radish 8	4855.93abc	36.99bcd	3.15a	11.80d	152.70ab	.	113
Wheat 60	5181.24abc	39.94a	2.40c	17.34ab	120.09bc	.	154
Hairy Vetch 10; Radish 4	3982.02bcd	35.86d	2.4c	11.145d	127.88bc	.	115
Cereal Rye 30; Crimson Clover; 4	6191.99a	39.19ab	3.2a	14.89bc	178.65a	.	182
Wheat 30; Crimson Clover 4	3461.04cde	39.32a	2.8abc	15.53bc	90.39cd	.	102
Wheat 40; Radish 4; Turnip 2	5118.82abc	36.51cd	2.6bc	13.783cd	137.98abc	.	145

The same letter within a column in each environment indicates no significant difference for a given factor or combination of factors at alpha = 0.05.

CC, cover crop; C, cover crop carbon concentration; N, cover crop nitrogen concentration; C/N, cover crop carbon to nitrogen ratio; TN, cover crop total nitrogen content.

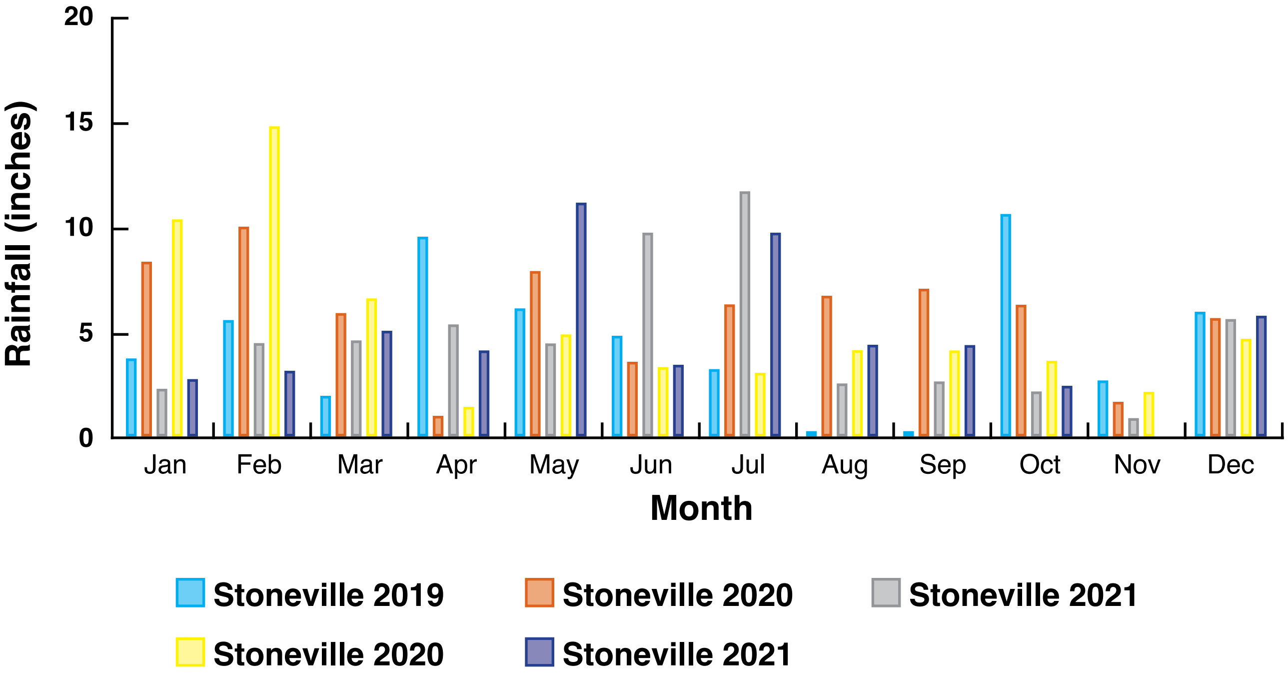


Figure 1. *Variability for monthly total rainfall among three environments used in this study.*

spring 2020 and 2021 at all sites. Field management—such as tillage, weed, pest, fertilization, and termination of cover crops—was conducted following Mississippi State University Extension Service recommendations. Data collected includes CC aboveground biomass production, CC biomass %C, %N, C/N ratio, and total nitrogen uptake (TN), corn plant height, and corn grain yield.

Results and Discussion

The three single species CC were significantly different; grasses and brassica exhibited the highest biomass, grasses had the highest C/N, and legumes and brassica had high %N and TN. The mixture of two CC species balanced those traits for N scavenging and availability compared to single species. When planted as a single species or mixed with other CC species, radish enhanced corn plant height and corn grain yield of the following crop. Although a combination of cereal rye and crimson clover had higher %N than single species CC, there were no benefits to the following corn crop. The rainfall patterns were variable among environments and might have highly regulated CC N credits to the following corn crop based on traits measured in the study **(Figure 1)**. For instance, high rainfall during CC season in Environment 1 might have resulted in lower N and TN in legumes (hairy vetch and crimson clover) with no difference from the untreated check. Legumes under low rainfall scenarios in Environment 3 had significantly higher N and TN than the untreated check. Although CC differed in C/N in all environments, only one of the three environments had treatments effects significant for corn plant height and corn grain yield. Cover crops belonging to different and even same species showed differential responses for traits measured among three environments. The information on species-specific functionality of CC in continuous corn under variable rainfall patterns suggests farmers consider a high diversity mixture of CC that outperformed among all three environments.

ADVANCED TECHNOLOGIES AND ALTERNATIVE PRACTICES

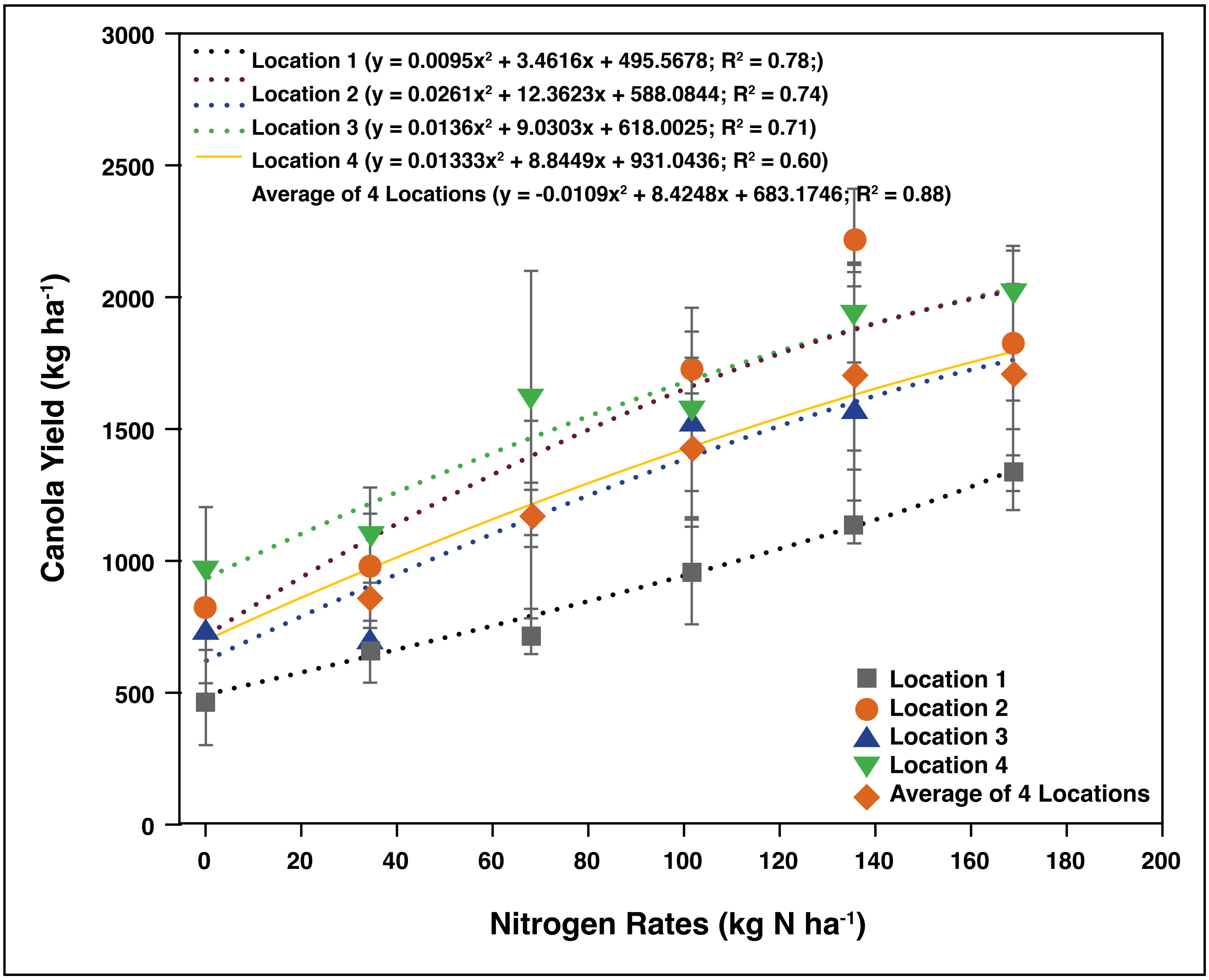
Potential of Rainfed Canola as a Double Crop in a Corn-Soybean Rotation in Mississippi

Gurbir Singh, Gurpreet Kaur, Jagmandeep Dhillon

Introduction

Currently, the most predominant winter crop grown in Mississippi for profit is wheat. Most of the research or demonstrations currently being cited have reported no economic return of growing wheat in Mississippi. Canola offers a potential alternative that could be grown during the same time frame as wheat and could work into a double-crop/cover-crop scenario and provide a harvestable and potentially profitable

Figure 1. *Canola yield response to nitrogen (N) rate. Individual points represent the mean values and error bars represent the 95% confidence intervals.*



Nitrogen Application Rate lb/ac N	Seed Yield bu/ac	Test Weight lb/bu	Seed Moisture ----g/kg----	Oil ----g/kg----	Seed Index g/400	Plant Population plants/ft^2	Plant Height inch
0	13d	48.5c	165a	467	1.75a	7	36d
30	15d	48.3c	164a	464	1.73a	7	38dc
60	21c	49.9a	134c	471	1.66b	8	40bc
90	26b	50.0a	130c	470	1.62b	7	42b
120	31a	50.2a	136bc	466	1.62b	7	44a
150	31a	49.3b	149b	462	1.65b	7	44a
p-values	<0.0001	<0.0001	<0.0001	0.1127	<0.0001	0.8238	<0.0001

Table 2. *Mean and probability values (p-values) associated with the N rate treatments for the statistical analysis of seed yield, test weight, seed moisture, seed oil, seed index, plant population and plant height. Underlined numbers are statistically different at alpha = 0.05.*

N Application Rate	Dry Weight	N	P	K	Na	Ca	Mg	S	Zn	B	Fe	Al	Mn	Cu
lb/ac N	-----lb/ac-----													
0	791c	12.9d	3.3c	21.5c	9.8b	15.7c	2.2c	4.0c	1.8c	2.4d	7.4b	4.9b	1.6e	0.18d
30	990c	17.4bcd	4.2bc	27.2bc	13b	19.2bc	2.7bc	5.4bc	2.2bc	3d	9.8b	5.3b	2de	0.23cd
60	1092bc	17.2cd	4.4bc	29bc	13.7b	20.8bc	2.9bc	4.9bc	2.4bc	3.4cd	8.1b	5b	2.3cd	0.27bc
90	1370ab	22.4abc	5.3ab	36.3ab	29ab	26.4b	3.4ab	5.8bc	2.9ab	4.3bc	10.9ab	8ab	2.8bc	0.27abc
120	1587a	26.2a	6.4a	45.8a	50.4ab	34.8a	4a	6.9ab	3.4a	5.4a	13.9a	10.2a	3.4a	0.34a
150	1608a	22.7ab	6.1a	45.8a	78.2a	35.3a	4.2a	8.8a	3.2a	5.2ab	14.2a	10.5a	3ab	0.31ab
p-values	<0.0001	<0.0001	<0.0001	<0.0001	0.0495	<0.0001	0.0007	0.0269	0.0003	<0.0001	0.0032	0.0017	<0.0001	0.0023

Table 3. *Mean and probability values (p-values) associated with the N rate treatments for the statistical analysis of aboveground biomass dry weight and nutrient uptake. Underlined numbers are statistically different at alpha = 0.05.*

crop. The objectives of this research were to evaluate yield potential, oil seed quality, and nutrient uptake of canola grown as a double crop after corn in a corn-soybean rotation; to determine nitrogen (N) requirement and nitrogen use of canola grown in Mississippi; and to determine the economic implications of the cultural practices of canola.

Materials and Methods

The study was conducted at three locations (Locations 1, 2, 3) at the National Center for Alluvial Aquifer Research, Stoneville, MS, and one location at R. R. Foil Plant Science Research Center, Starkville, MS (Location 4). The soil series selected for these research locations were Bosket very fine sandy loam (Location 1), Commerce very fine sandy loam (Location 2), Commerce silty clay loam (Location 3), and Catalpa silty clay loam (Location 4). The experiment was designed as a randomized complete block with four replications. Nitrogen rate treatments were 30, 60, 90, 120, and 150 lb/ac N applied as urea. Nitrogen was split applied, with 30 lb/ac N at planting and the remainder at stem elongation stage during the first week of February 2021. A non-treated control with no N applications was also included in the study. Additionally, to compare the effects of double-crop canola on corn-soybean rotation, we added a winter fallow treatment where no cover crop or canola was added to a corn-soybean rotation. To determine the economic implications of the cultural practices for cover crop management with both harvestable and non-harvestable covers, we added a cover crop treatment that was planted with hairy vetch. A seed drill was used to plant canola and hairy vetch in 13 ft

× 30 ft plots. Roundup Ready canola variety Star 930W was grown at all four locations at a seeding rate of 8 lb/ac. The seeding rate for hairy vetch was 20 lb/ac. Locations 1, 2, 3, and 4 were planted on 10/2/2020. 10/23/2020, 10/23/2020, and 11/6/2020, respectively. A postemergence application of Roundup at 22 oz/ac for winter weed management was applied on 12/16/2020.

Data collection included plant heights and plant populations measurements at the beginning ripening growth stage. Canola aboveground biomass samples were collected before harvesting to estimated nutrient uptake in stalk and seed. Canola was harvested in Stoneville on 5/21/2021 and in Starkville on 5/27/2021 from an 80 inch swath width with a Kinkaid 8XP plot combine (Haven, KS) equipped with a harvest master grain gage (Juniper Systems, Logan, UT). Seed samples were collected during harvesting for seed quality analysis including oil, moisture, test weight and seed index. On 6/1/2021 at a seeding rate of 140,000 seeds/ac, soybean variety Asgrow 48X9 was planted in Stoneville while soybean variety Asgrow 48X0 was planted in Starkville. Soybean planted after canola in Stoneville was maintained as irrigated whereas at Starkville it was non-irrigated. Soybean was harvested on 10/8/2021 in Stoneville and on 10/11/2021 in Starkville. Soybean yield, test weight, harvest moisture, and soybean grain quality were collected at harvest in 2021. Data were analyzed using the GLIMMIX procedure in SAS 9.4 (SAS Institute, Cary, NC).

Results and Discussion

Averaged over four locations, canola seed yield was 16 to 57% greater for 120 and 150 lb/ac N treatments compared to all other N rate treatments **(Figure 1)**. Seed yields were similar for 120 and 150 lb/ac N treatments when average over four locations; therefore, no additional benefit was observed from 150 lb/ac N application. Maximum yield potential for the canola variety Star 930W was achieved by an N rate of 120 lb/ac N **(Figure 1)**. There were no significant differences in oil content and plant population among N rate treatments **(Table 2)**. Test weight ranged from 48.5 to 49.9 lb/bu and was highest for 120 lb/ac N treatment. The seed index was calculated based on the weight of 400 seeds. Non-treated control and 30 lb/ac N had the highest seed indices of 1.75 and 1.73 grams per 400 seeds, respectively, among all treatments. Seed moisture ranged between 13.0 to 16.5 % and decreased with increasing N rate.

Aboveground biomass dry weight was 1587 and 1608 lb/ac for 120 and 150 lb/ac N treatments, respectively, which was 31-50% greater compared to 0, 30, and 60 lb/ac N treatments **(Table 3)**. Nitrogen uptake in the aboveground biomass was similar among 90, 120, and 150 lb/ac N treatments and ranged from 22.4 to 26.2 lb/ac. Sulfur uptake in the aboveground biomass was similar among 120 and 150 lb/ac N treatments **(Table 3)**. Sulfur uptake in the aboveground biomass was 8.8 lb/ac for the 150 lb/ac N treatment which was at least 2 lb/ac higher than the 0, 30, 60, and 90 lb/ac N treatments. Canola yield from four sites in Mississippi was at least 4.5 bu/ac lower compared to the national average yield of 37.8 and 35.5 bu/ac for 2018 and 2019, respectively (USDA-NASS, 2020).

Conclusion

Maximum yield potential for the canola variety Star 930W was achieved by an N rate of 120 lb/ac N. At an average selling price of $22/bu, the estimated gross return of canola was $682/ac. Soybean was planted after harvesting canola in May 2021 and average yield of soybean from all four locations was 53 bu/ac. The soybean gross return was $716/ac when average selling price was estimated to be $13.50/bu.

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ADVANCED TECHNOLOGIES AND ALTERNATIVE PRACTICES

Strip Tillage and Fertilizer Placement Effects on Irrigated and Dryland Corn Production

Gurbir Singh, Chad Hankins, Gurpreet Kaur, Drew Gholson

Introduction

Many farmers in the Delta perform most of their tillage operations in the fall both to save time in the spring and to create furrows for improved drainage during rainy winter months. Another reason for fall tillage in this region is that soil tends to be dryer during this time, which results in less resistance and draft on equipment (Raper et al., 2000) and less compaction than tillage on the normally moist soils in early spring (Tupper, 1974). No-tillage and reduced-tillage systems have not been widely adopted in this region due to poor natural drainage, high weed and disease pressure, and the need to remove equipment ruts after harvest (Blessitt, 2008). The overall objective of this study was to evaluate the effects of conservation tillage system (strip tillage) and conventional tillage systems (conventional tillage and sub-soiling) with fertilizer placement on corn stand establishment, grain yield and quality, and P and K uptake in continuous corn production. We hypothesized that among the strip-till treatments, the deep banded fertilizer placement treatment will have greater P and K agronomic efficiency due to greater P and K uptake in the crop biomass. The combination of strip tillage and deep banded fertilizer placement will prove cost-effective on larger farm operations (>1,000 ac), maintaining similar yields compared to sub-soiling or conventional tillage while saving in fuel and labor costs.

Materials and Methods

In this project, we compared existing tillage systems—conventional tillage and conventional tillage with sub-soiling—to strip tillage for both irrigated and dryland corn. This study was established at the National Center for Alluvial Aquifer Research (NCAAR), Delta Research and Extension Center (DREC) at Stoneville, MS. A field with a history of continuous corn with low to medium soil phosphorus and potassium values was selected for this research. The soil series of the research field was Bosket very fine sandy loam. Conventional tillage operation involved two passes of disk followed by a pass of hipper and

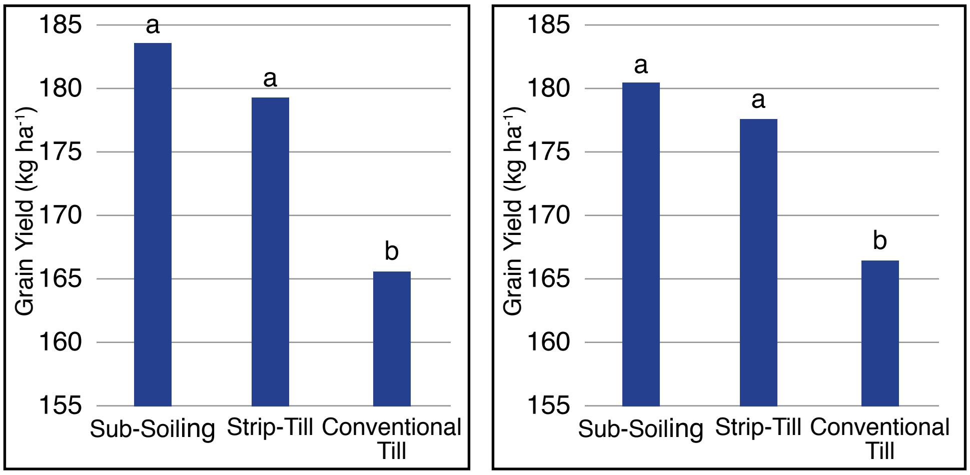

Figure 1. *Two-year (2020 and 2021) mean corn grain yield averaged over fertilizer placement treatments under irrigated (A) and dryland (B) conditions. Mean values followed by the same letters within a column indicate no significant differences between treatments at alpha = 0.05.*

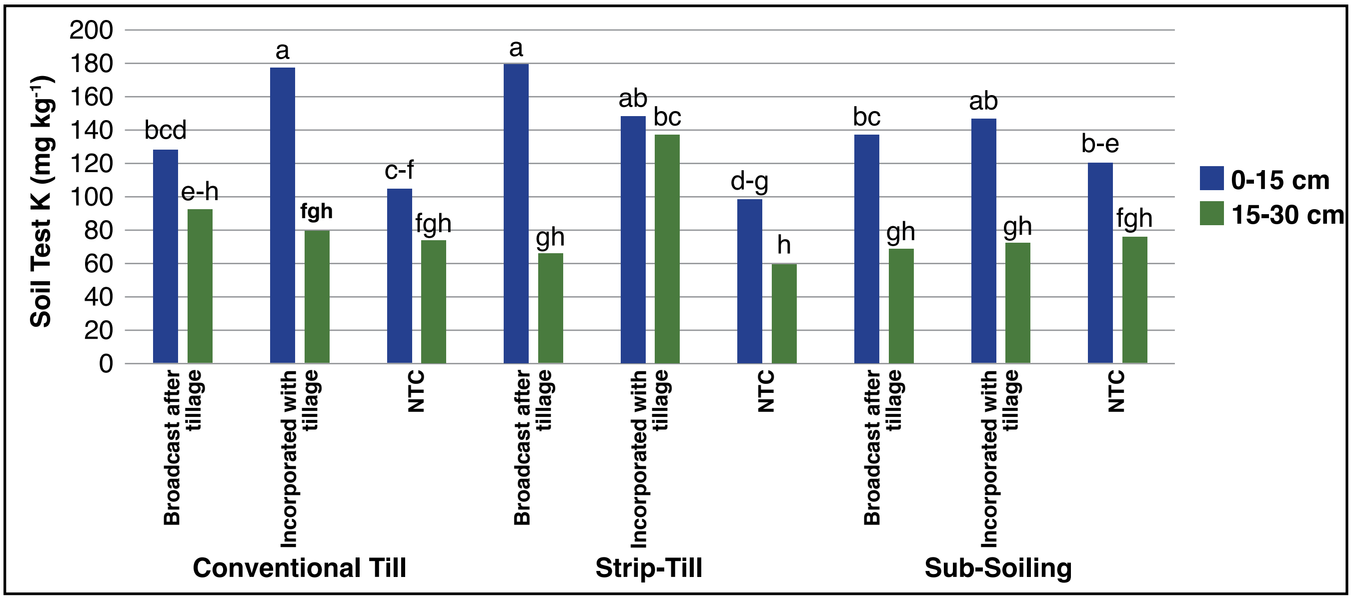

Figure 2. *Mean values of soil test K measured from spring 2021 soil sampling at two depths at 0-6 and 6-12 inches under three tillage and three placement treatments for irrigated conditions. Mean values followed by the same letters within a column indicate no significant differences between treatments at alpha = 0.05.*

a pass of do-all bed preparation before planting. The sub-soiling involved a single pass of parabolic subsoiler in addition to all operations of conventional tillage. The strip tillage included a single pass operation with Orthman 1tripr strip-tiller which had a vertical tillage shank of 11 inches that tilled soil underneath the seedbed. We also evaluated phosphorus and potassium fertilizer placement in the split plots under three tillage systems. Fertilizer placements included broadcasting fertilizer and incorporating it with tillage, broadcasting fertilizer after tillage operation, and banding fertilizer with strip-till below the seedbed. The experimental design was a split-plot design with four replications planted under both irrigated and dryland conditions. All tillage and fertilizer placement treatments were carried out in fall after harvesting corn.

Corn hybrid DKC 70-27 was planted in a twin-row pattern on 4/6/2020 and 3/10/2021 at a seeding rate of 38,000 and 40,500 seeds/ac, respectively. The fertilizer rates applied to corn were 232-50-100 lb/ac N-P2O5-K2O. Corn aboveground biomass was collected on 8/8/2020 and 8/11/2021 for determining corn silage yield and its phosphorus and potassium uptake. Due to the timely precipitation, irrigation was only applied three times over the whole growing season in both growing seasons of 2020 and 2021. Two center rows of each 4-row plot were harvested on 9/11/2020 and 8/27/2021 using a Kincaid 8xp plot combine. At the time of harvesting, grab samples were collected to determine grain moisture, bushel test weight, seed index (100-seed weight), and grain quality (protein, starch, and oil). Grain samples were also sent to a lab for a complete nutrient analysis for determining nutrient uptake.

Soil samples were collected at two depths after harvesting in fall 2020, before planting in spring 2021, and after harvesting in fall 2021. These soil samples were sent to a lab for Mehlich-3 extractable available nutrient analysis. Soil physical properties including compaction (bulk density and penetration resistance), electrical conductivity, volumetric water content were also determined before planting in spring 2021.

All the data were analyzed using the univariate procedure in SAS (SAS Institute, Cary, NC) for determining the normality of the data, and wherever needed data was transformed to lognormal and transformed back to normal for reporting. The Glimmix procedure was used for analyzing the significance of the model. The dryland and irrigated studies were analyzed separately with tillage and placement as fixed effects and replications as the random effect. The placement of fertilizer was the split factor in the model. The model analysis was conducted at alpha = 0.05. The least-square differences among treatment means were analyzed using T-grouping in SAS at alpha = 0.05.

Results and Discussion

Corn Grain Yield

Sub-soiling and strip tillage both increased corn grain yield by 18.5 and 13.7 bu/ac when compared to conventional tillage under irrigated conditions **(Figure 1)**. Under dryland conditions, conventional tillage yielded 14.0 and 11.5 bu/ac less compared to sub-soiling and strip tillage treatments, respectively. No significant differences were obtained between sub-soiling and strip-till treatments for corn grain yield when pooled over fertilizer placement treatments. Similar corn grain yields among strip-till and sub-soiling treatments indicate that 1-pass operation of strip tillage can be economically beneficial to Mississippi growers and have the potential to replace sub-soiling with conventional tillage which is at least a 3 to 4 tillage passes operation.

Soil Fertility

In spring 2021 soil sampling, a three-way interaction between tillage, fertilizer placement, and depth was significant for Mehlich-3 extractable potassium (p-value < 0.05).Potassium fertilizer when deep banded (incorporated) with strip tillage at 8-inch depth retained the highest potassium in the soil at the depth of 6-12 inches suggesting that potassium nutrient losses were reduced when compared to other tillage by placement treatments **(Figure 2)**. Under irrigated conditions for fall 2021, soil test P for strip-till incorporated treatment was 27.3 mg/kg and was at least double in P nutrient concentrations when compared to all other tillage by placement treatments **(Figure 3)**. Similarly, strip-till incorporated soil test K was highest during fall 2021 soil sampling and was significantly different from all other tillage by placement treatments except strip-till broadcast (Figure 3). Overall, soil sampling results indicate that if the goal of the grower is to maintain and retain P and K fertilizer in the soil, a best management practice would be to incorporate the P and K fertilizer below the rooting depth. Over time bands of high fertility can be created in the field and precision planting on these high fertility bands can be accomplished using RTK planting systems.

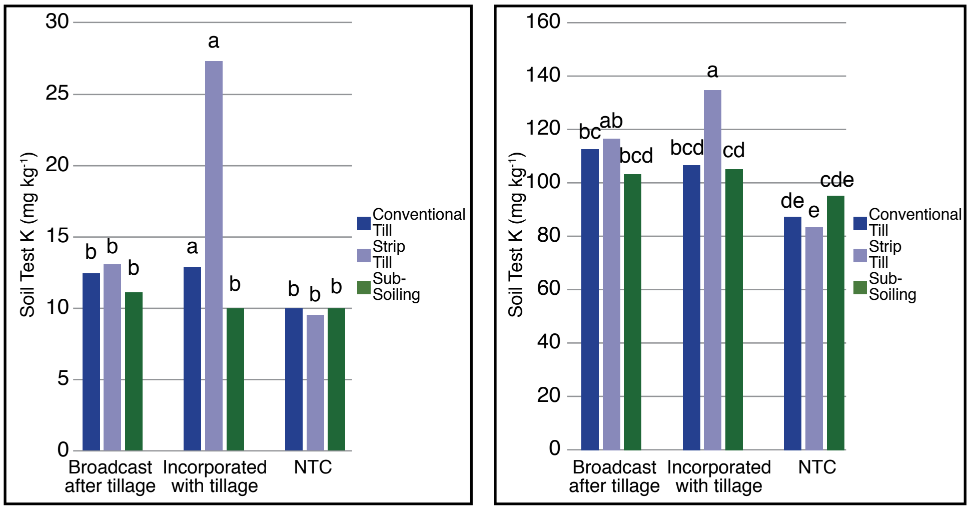

Figure 3. *Mean values of soil test P and K measured from fall 2021 soil sampling under three tillage and three placement treatments for irrigated conditions. Mean values followed by the same letters within a column indicates no significant differences between treatments at alpha = 0.05.*

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ADVANCED TECHNOLOGIES AND ALTERNATIVE PRACTICES

Strip Tillage and Cover Cropping Work Well When Transitioning to Conservation Systems in Mid-South Cotton

Carson Roberts, Drew Gholson, Martin Locke, Dave Spencer, Whitney Crow, Brian Pieralisi

(Sponsored partially by Cotton Incorporated under project 21-863)

Introduction

Clean, warm, moist, and uncompacted seedbeds are often the best conditions for uniform, vigorous cotton seedling growth. Transitioning to conservation systems like no-till and cover cropping may change seedbed conditions causing reductions in yield. However, producers in other areas have adopted conservation cropping practices and experienced reduced runoff, reduced erosion, saved fuel and labor, and reduced irrigation water use. In recent years, these benefits have attracted some producers in the Mid-South to conservation practices despite the risk of reduced yield. However, few studies in the Mid-South have addressed the potential trade offs of conservation cotton production while exploring methods that improve soil and seedbed conditions. This study was developed to investigate how conservation tillage and cover crop systems influence lint yield and irrigation water use efficiency. It is hypothesized that water use can be reduced, and yield can be maintained or improved under conservation systems in the Mid-South.

Materials and Methods

A study is being conducted in Stoneville, MS, from 2021 to 2023 on a Dubbs silt loam (fine-silty, mixed, active, thermic Typic Hapludalfs). Study treatments include reduced tillage with subsoiling (RT), strip tillage (ST), strip tillage with cover crops (ST,CC), strip tillage with cover crops and subsoiling (ST,CC,SS), no tillage (NT), no tillage with cover crops (NT,CC), and no tillage with cover crops and minimal surface disturbance subsoiling (NT,CC,SS). This study is organized as a randomized com-

Figure 1 (left). *Strip tillage implement in a terminated cover crop.* ***Figure 2 (right)****. Runoff measurement and sampling equipment.*

plete block design with three replications. Plots consist of eight 40” rows that are 500’ in length.

Cover crop treatments were terminated using 44 oz/ac glyphosate two weeks prior to planting. After termination, ST plots were tilled using a strip tillage implement **(Figure 1)**. The variety Deltapine® 2012 B3XF was planted, and routine fertility, pesticide, and plant growth regulator applications were made. Watermark® soil moisture sensors were installed, irrigation was triggered at 90 kPa, and runoff was monitored **(Figure 2)**. Data were analyzed in R studio using the lmer function in the lme4 package, and means were separated using unrestricted LSD at alpha = 0.05.

Excessive rainfall occurred during the 2021 growing season. This resulted in the irrigation of only one RT plot after reaching the -90 kPa irrigation trigger, so no assumptions were made regarding irrigation water use efficiency in 2021.

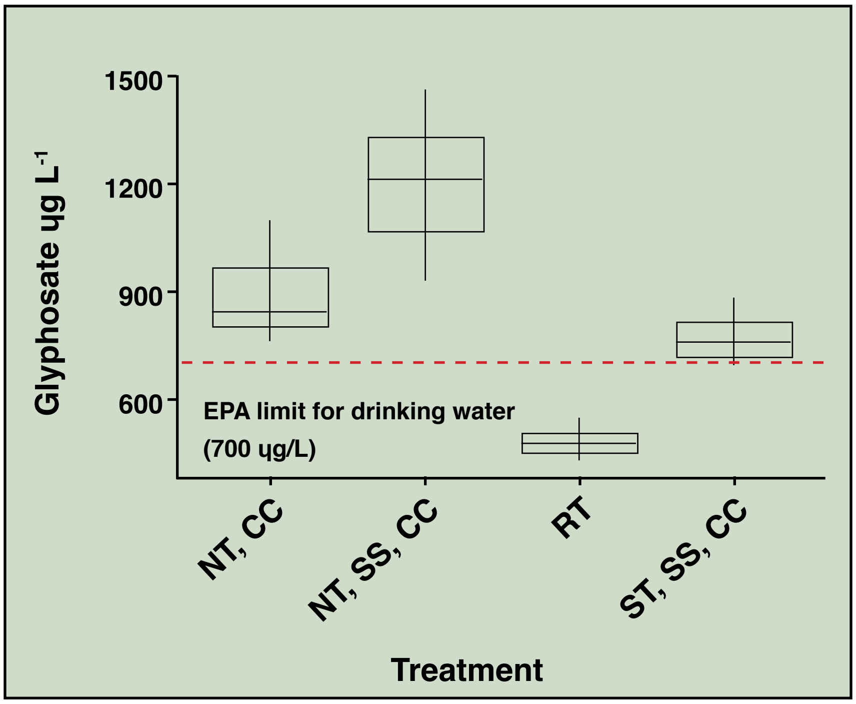


Figure 3. *Runoff glyphosate concentration (µg/L) in 2021. Values with the same letter are not statistically significant at alpha = 0.05.*

Lint yields were greatest where RT treatments were implemented and were comparable to ST,CC,SS and ST,CC treatments. The combination of strip tillage and cover crops resulted in an excellent seedbed. However, ST systems that lacked cover crops did not produce high yields. This is likely a product of poor soil tilth. The strip tillage operations without cover crops resulted in large chunks of soil and consequently a less than ideal seedbed for cotton establishment. All NT treatments reduced lint yield by at least 23%. Initial yield reductions when transitioning to NT have been reported by producers who have experimented with this practice. As is the case in this study, reduced yields during the first year of adoption are usually a result of poor stand establishment associated with the lack of experience in planting cotton in untilled soil with heavy residue.

Preliminary data that investigates runoff water quality shows some differences in pollutant concentrations between the different treatments. Concentrations of glyphosate in the water from a burndown application of glyphosate are higher in NT,CC and NT,SS,CC than in the RT treatment **(Figure 3)**. It is possible that these data can be misleading until coupled with runoff water quantity to evaluate total runoff pollutants on a volume basis. A volume measurement will offer more meaningful information about the quantity of pollutants entering the environment.

Conclusion

Cotton yield was not maintained under all conservations systems, but strip tillage with the addition of a cover crop is a system that shows promise. The irrigation aspect of this study needs to be studied further to reach any conclusions about the effectiveness of conservation systems to hold water. Sediment, nutrient, and total water runoff will be further analyzed to investigate potential volume differences in conservation systems. Since this is the first year of research, further investigation at this site is needed to determine the potential of these systems in the Mid-South.

ADVANCED TECHNOLOGIES AND ALTERNATIVE PRACTICES

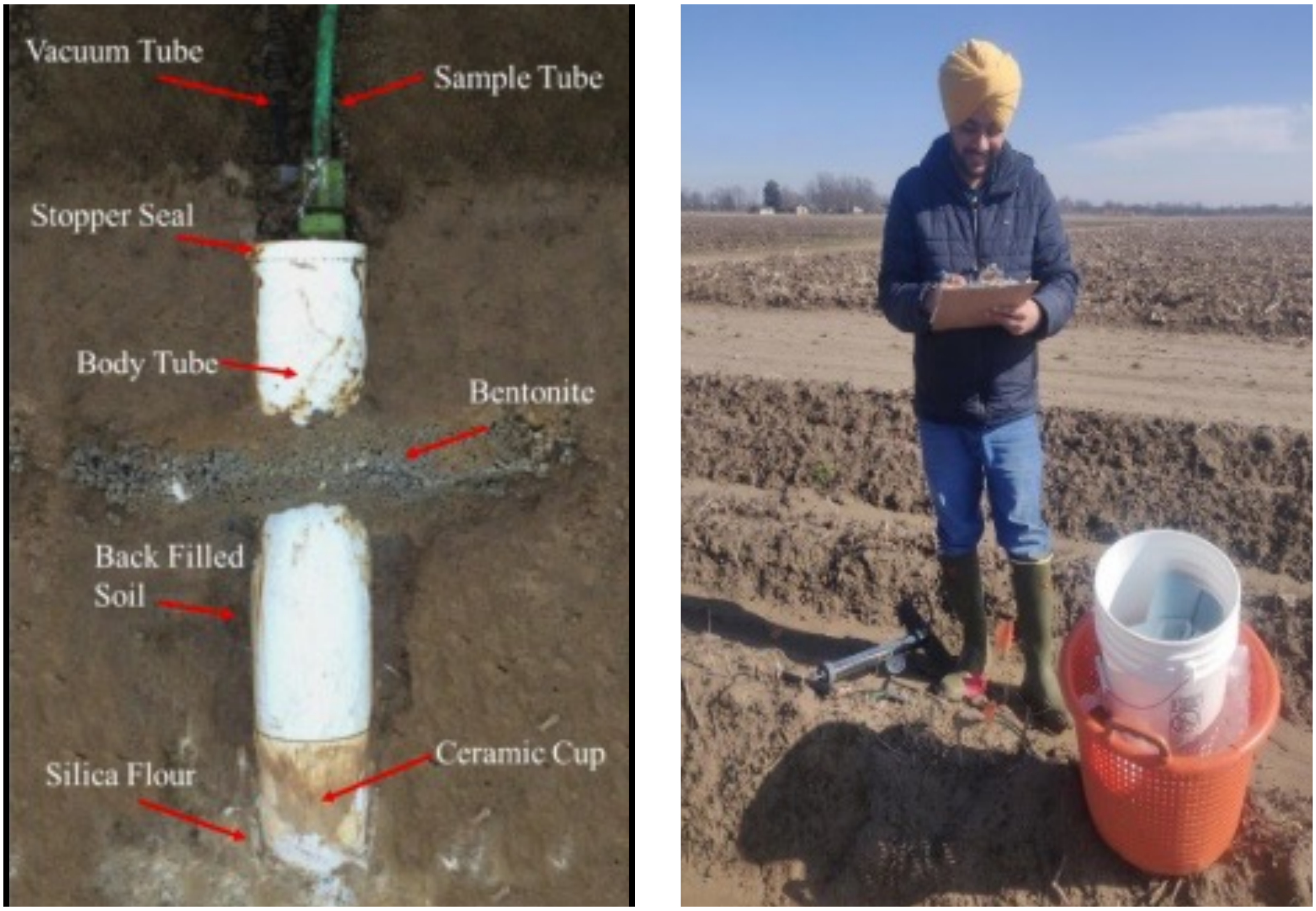
Water Quality Evaluations of Biochar in Cotton Production Systems in the Mississippi Delta

Amrinder Jakhar, Gurpreet Kaur, Gurbir Singh, Saseendran Anapalli

Introduction

Conventional tillage practices commonly followed in the Mississippi Delta cause soil compaction, deteriorate soil structure, reduce soil organic matter reserves, and consequently result in nutrient losses from the soil. Nutrient leaching from agricultural soils might increase soil acidity, add up fertilizer cost for farmers, and adversely affects the quality of surface and groundwater. Soil amendments such as biochar could be a potential solution to this issue. Biochar is a carbonaceous product obtained through the pyrolysis process by subjecting organic biomass to heat treatment (212-1292°F) either in the absence or limited availability of oxygen. The overall objective of this study was to evaluate the impact of sugarcane biochar amendment on nutrient leaching in dryland cotton production systems on Sharkey clay soil in the Mississippi Delta.

Figure 1. *a) Suction cup Lysimeter installed in the field; b) collection of soil solution samples from the research field.*



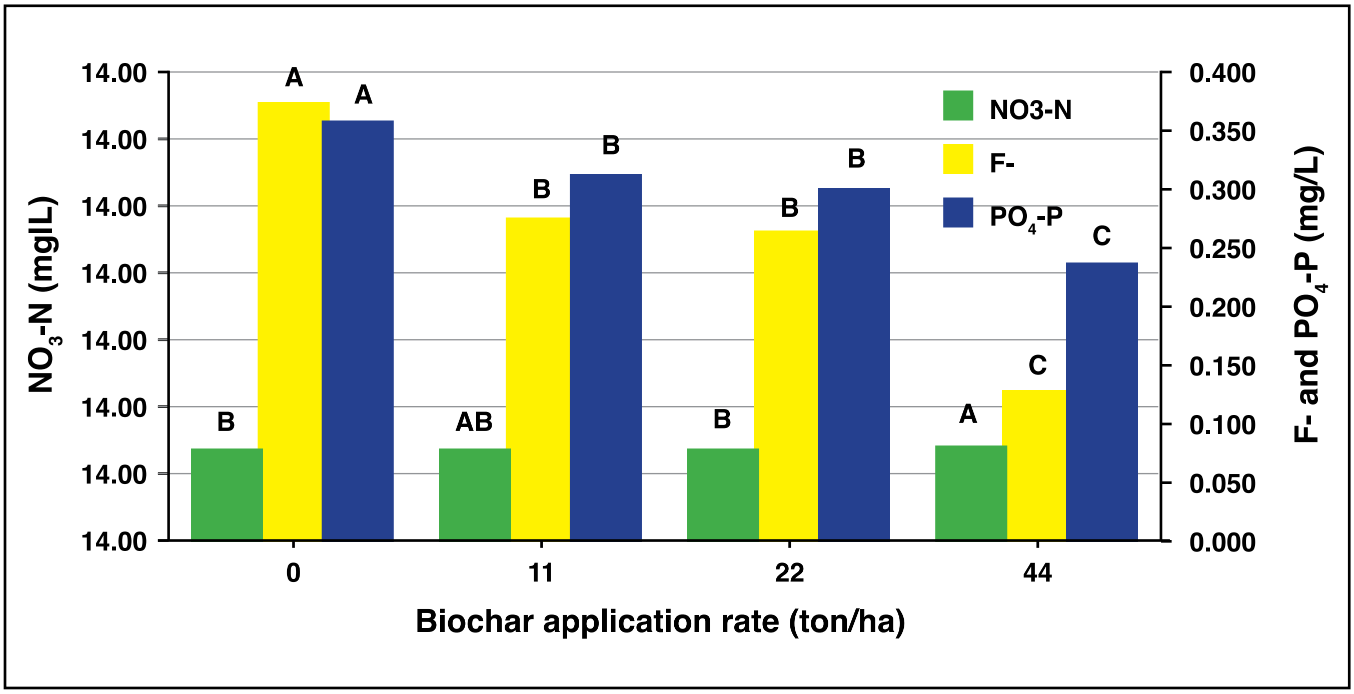


Figure 1. *Concentrations of NO3-N, F-, and PO4-P in soil solution as affected by different rates of biochar application. Similar letters on bars indicate no significant differences between means at alpha = 0.05*

Materials and Methods

A field experiment was conducted at the USDA-ARS Crop Production System Research Unit's farm in Stoneville, MS. The experiment was carried out in a completely randomized design with four replications. Each plot included 6 rows and the size of the treatment plot was 60 ft × 20 ft. Treatments included biochar application at rates of 0, 11, 22, and 44 tons/ha. Two suction-cup lysimeters were installed in each plot at a depth of 18 and 32 inches to collect the soil solution samples.

Soil solution samples were collected after every significant precipitation event (>0.25 inches). A total of 32 events of soil solution samples were collected from December 2019 to August 2021.

After collection, soil solution samples were brought to the lab and analyzed for pH and electrical conductivity (EC) using the Fisherbrand pH Combination Electrodes (Chelmsford, MA) and Fisherbrand Four Cell conductivity probe (Chelmsford, MA), respectively. The soil solution samples were then vacuumed filtered using a 0.45-micrometer filter and were analyzed for anions including nitrite-N (NO2-N), Nitrate-N (NO3-N), fluoride (F-), chloride (Cl-), phosphate-P (PO4-P), and sulfate-S (SO4-S) using the Dionex Integrion High Pressure Ion Chromatograph (Sunnyvale, CA) and for ammonia (NH4-N) using Lachat 8400 series II automated ion analyzer (Hach Corp., Loveland, CO). The GLIMMIX procedure in SAS software (version 9.4) was used for analyzing the data.

Results and Discussion

Biochar application rate had a pronounced effect on nitrate and phosphate level of the soil (Figure 1). Nitrate and phosphate concentration in soil solution declined by 26 to 66% and 11 to 31%, respectively, with the increasing rate of biochar application compared to the control plots (0 ton/ha). Fluoride concentration in soil solution increased by 9% with biochar application at the rate of 44 ton/ha than the control plots. Nitrite-N reduced by 13% and 35 % at 18 and 36 inches depth, respectively, with biochar application at 44 ton/ha **(Table 1)** compared to control plots. Reduced leaching of nutrients with the addition of biochar was due to the increase in cation exchange capacity of soils.

For biochar application rates at 22 and 44 ton/ha, the electrical conductivity for soil solution samples was lower in the deeper soil layer (32 inches) than at the 18 inches depth **(Table 1)**. There was a higher buildup of SO4-S at 18-inch depth with biochar applied at the rate of 22 and 44 ton/ha.

Conclusion

Biochar application confirmed a reduction in nutrient leaching losses, viz. nitrate, chloride, and phosphate. In the present study, the application of 44 ton/ha biochar indicated the maximum reduction in leaching of nitrate, phosphate, and chloride in soil solution. However, the biochar application rate of 11 ton/ha may be more economical, with sufficient reduction in nutrient leaching in dryland cotton production systems over time.

Table 1. *Mean values of EC, Cl-, NO_2-N, SO_4-S in soil solution at 18- and 36-inches soil depth as affected by different biochar application rates. Means followed by the same letter within a column are not significantly different at α=0.05*

Biochar Application Rate (ton/ha)	Depth (inches)	EC (µS/cm)	Cl^- (mg/L)	NO_2-N (mg/L)	SO_4-S (mg/L)
0	18	518bc	41.74a	0.22b	23.79d
11	18	474cd	35.88c	0.25ab	29.40cd
22	18	555a	41.59a	0.25ab	35.24ab
44	18	505ab	30.13d	0.19c	38.98a
0	32	485bcd	39.13ab	0.28a	29.65bc
11	32	458de	36.76bc	0.23ab	36.28a
22	32	419e	32.66d	0.24ab	24.57cd
44	32	400f	30.83d	0.18c	26.66cd

ADVANCED TECHNOLOGIES AND ALTERNATIVE PRACTICES

High Throughput Image Analytics for Crop Phenotyping

James Kim, Myungna Shin, Jihyun Lee, Weontai Jeon, Seungho Cho

Sponsored partially by USDA-ARS under project 6066-13000-005-000D

Introduction

Image-based phenotyping provides the most promising tool for consistent quantitative measurement of phenotypic metrics. High throughput phenotyping is particularly desired to provide a timely process of the breeding pipeline. Challenges remain to address a seamless integration of sensor, processing, analytics, and data management for the accuracy and consistency.

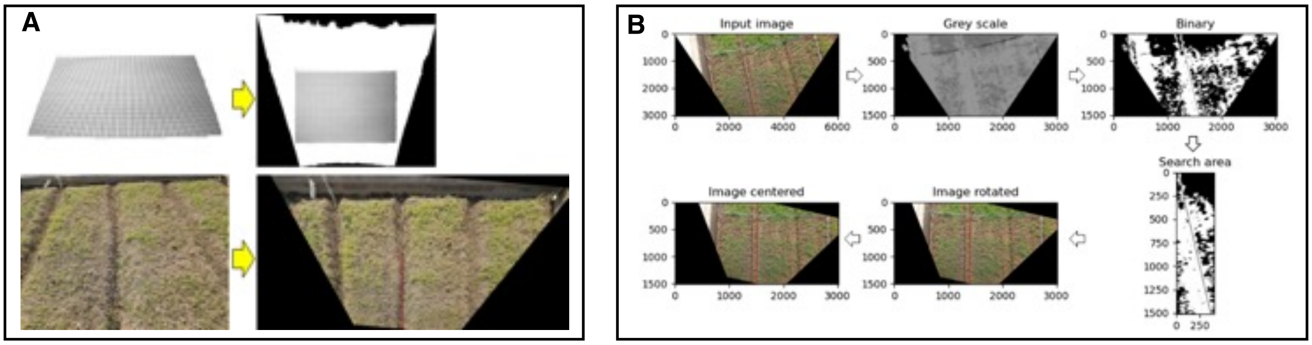
The goal of the study is to develop high throughput image analytics to implement field mapping and plant phenotyping using a handheld camera, e.g., smart phone. Specific objectives are to develop algorithm to transform raw images into geo-rectified images using row detection and design software to automate image alignment and stitching to extract plot-level metrics.

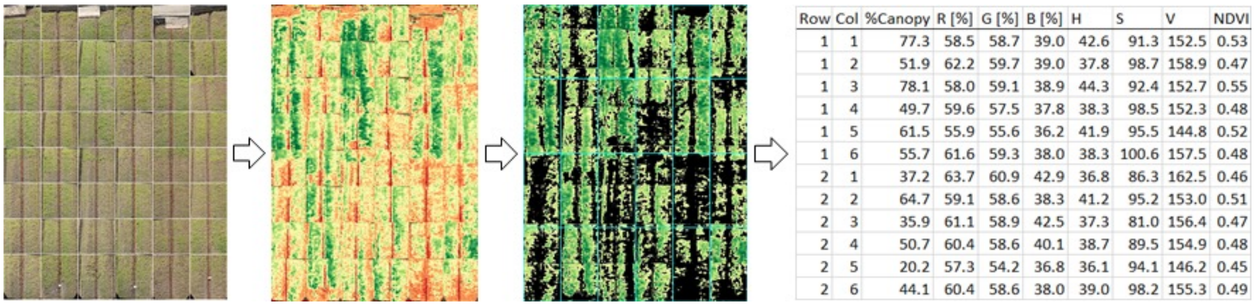
Materials and Methods

Experiment was conducted in international collaboration with National Institute of Crop Science in Korea on wheat crop field with four different varieties (Shinyoung (SY), Joseong (JS), Taewoo (TW), and Cheongwoo (CW)). The plants were seeded at 196 lb/ac on October 22, 2020 on three replicated subfields located at 37° 27' N, 126° 99' E. Each subfield was sized to 7,611 ft2 (43 ft × 177 ft) and split to four plots, creating total 12 plots. Images were collected during the spring of 2021 on 2/19, 3/8, 3/17, 3/25, 4/2, and 4/22 by a field operator using a smart phone camera that was mounted on a selfie stick to reach 8 ft high and capture oblique view (i.e., skewed) images **(Figure 1a)**. Image collection was triggered in 23-ft interval at four locations per plot with 20% overlaps.

When deskewed images are stitched together, misaligned tile images occur due to an acquisition inconsistency which causes errors in gridding analysis and thus must be rectified to align the crop rows. Geometric calibration was developed by detecting a row line using Hough Transformation and rotating the image to make the line vertical **(Figure 1b)**. A GUI-based Python application, iStitch, was developed to implement a series of image process-

Figure 1. *a) Image deskewing that rectifies the skewed images to the nadir-view images; b) Image alignment using Hough Transformation.*





Row	Col	%Canopy	R [%]	G [%]	B [%]	H	S	V	NDVI
1	1	77.3	58.5	58.7	39.0	42.6	91.3	152.5	0.53
1	2	51.9	62.2	59.7	39.0	37.8	98.7	158.9	0.47
1	3	78.1	58.0	59.1	38.9	44.3	92.4	152.7	0.55
1	4	49.7	59.6	57.5	37.8	38.3	98.5	152.3	0.48
1	5	61.5	55.9	55.6	36.2	41.9	95.5	144.8	0.52
1	6	55.7	61.6	59.3	38.0	38.3	100.6	157.5	0.48
2	1	37.2	63.7	60.9	42.9	36.8	86.3	162.5	0.46
2	2	64.7	59.1	58.6	38.3	41.2	95.2	153.0	0.51
2	3	35.9	61.1	58.9	42.5	37.3	81.0	156.4	0.47
2	4	50.7	60.4	58.6	40.1	38.7	89.5	154.9	0.48
2	5	20.2	57.3	54.2	36.8	36.1	94.1	146.2	0.45
2	6	44.1	60.4	58.6	38.0	39.0	98.2	155.3	0.49

Figure 2. *Image processing for the field images of wheat field that includes image conversion, segmentation, masking, filtering, gridding and heatmap.*

ing algorithms from image loading to metrics extraction through deskewing, row detection, image alignment, and stitching. The aligned tile images are mosaicked to create a stitched field image and further processed for plot-level metrics extraction.

Results and Discussion

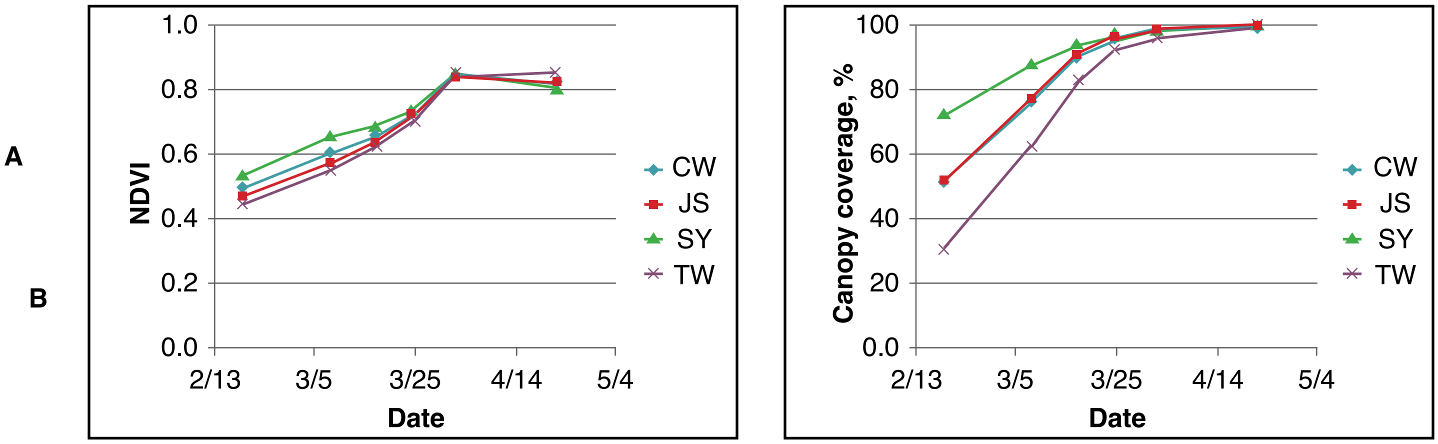
The image was converted from RGB to HSV and segmented in hue image band with pre-defined thresholding values. A 4 × 6 grid was applied to cover 24 plot boundaries. Each sub-grid, i.e., ROI, was individually processed to calculate vegetation and leaf area indexes (LAI) per plot. **Figure 2** illustrates the image processing from the field image to the gridded vegetation image.

The field images were analyzed for temporal responses of phenotypic metrics of four wheat varieties during the growing season. Overall, SY variety showed the best performance in both NDVI and canopy coverage throughout the season especially in early stages, whereas the TW variety performed the lowest with a difference of average NDVI = 0.08 and 21% canopy coverage lower than those of SY variety **(Figure 3a)**. The canopy coverage was significantly different between SY and TW varieties **(Figure 3b)**.

Conclusion

Four wheat varieties were tested to monitor the plant growth conditions using an image-based phenotyping approach. GUI-based image stitching software was developed to allow the user to automate the stitching process and successfully delivered the stitched images through deskewing, geometric rectification, trimming, and resizing. The proposed approach of the stitching and gridding was applied on the skewed images acquired by a smart phone camera in the study but can be directly used for images acquired in greenhouse or fields from a grid of stationary or mobile cameras.

Figure 3. *Phenotypic metrics of wheat crops in four varieties in a growing season: a) NDVI; b) Canopy coverage.*



DECISION TOOLS, EXTENSION RESOURCES AND EDUCATION

Increasing Mississippi Youth Interest in and Entry to Sustainable Agriculture Practices and Careers

Tinuola Osho, Himmy Lo, Drew Gholson, Leslie Burger, Beth Baker, Mary Love Tagert, Manola Erby, Carolyn Banks, Jacqueline McComb, Sonia Eley, Karla Turner-Bailey, and Steele Robbins

Sponsored by USDA's Natural Resources Conservation Service under award NR204423XXXXC116

Introduction

Mississippi agriculture is facing increases in the rate of technological advancement, the intensity of economic competition, and the complexity of environmental challenges. To propel the continued success of this important industry, Mississippi must develop a skilled and motivated workforce to fill agricultural jobs and must cultivate a conservation-minded citizenry to support improvements in sustainability. Therefore, educational efforts that stimulate Mississippi youth interest in and entry to agriculture are essential to securing a thriving future for Mississippi agriculture and the rural communities that depend on it.

To amplify such efforts, a collaboration was formed between Mississippi State University, Alcorn State University, Hinds Community College, and Mississippi Delta Community College. The project focuses on three goals. First, high school students will better understand the scientific principles and societal importance of soil and water conservation. Second, high school students will become more aware of the breadth and prospects of college and employment options in agriculture and natural resources. Third, disadvantaged high school students will gain greater opportunities for hands-on learning related to agriculture and natural resources.

2021 Progress

A two-module classroom outreach curriculum was created and implemented. Each module is about an hour in duration and uses fun activities to spark curiosity about agriculture. The first module exposes students to diverse aspects of agricultural science, including groundwater hydrology **(Figure 1)** and soil erosion **(Figure 2)**. The second module introduces students to agricultural careers other than farming. Both modules were taught to dozens of students at Leland High School .

Future Work

Classroom outreach is expected to be expanded to high schools across the Delta and eventually statewide. The gradual addition of other outreach methods is also planned, including social media, field trips, summer camps, and mentoring. Participant feedback is being collected to refine the project and assess its effectiveness. Educators, agricultural employers, and other interested entities are invited to contact Ms Osho (mto70@msstate.edu) for ways to partner with this project!

LHS Science Students Learn About Environmental Elements

Ms. Mary Tinuola Osho spoke with the Leland High School environmental, earth and space science students about soil erosion and what can be done to halt it, how essential water is to our everyday lives, what crops and animals provide us with food, clothing, and chemical reactions that occur within foods. Shown above are Antavion Gibbs, Leland High School 10th grader and Ms. Mary Tinuola Osho, Extension Associate at Delta

Figure 2. *A news clipping about this project from The Leland Progress newspaper; the photo depicts an interactive simulation of soil loss as rain falls on and runs off a bare soil.*

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NATIONAL CENTER FOR ALLUVIAL AQUIFER RESEARCH

2021 ANNUAL REPORT

Publication number: Bulletin 1239

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