EVALUATION OF POLYACRYLAMIDE ON IRRIGATION EFFICIENCY, SOIL CONSERVATION, AND WATER QUALITY IN FURROW IRRIGATED MID-SOUTH COTTON PRODUCTION

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Abstract

Arkansas is a leading state in irrigated acres in the U.S. As such, resulting groundwater decline and irrigation-induced soil erosion can have negative impacts. This establishes a need for irrigation management practices to improve irrigation efficiency as well as reduce soil erosion and improve water quality. Polyacrylamide (PAM) is a high molecular weight, anionic, water-soluble chemical flocculant that acts as a soil conditioner. When combined with irrigation practices, the applied water has been found to stabilize the near surface particles to decrease potential soil erosion and improve runoff water quality. The use of the polymer in the low rainfall areas of the western United States agricultural areas has shown positive water retention results in furrow-irrigated systems. Currently, limited data are available showing practical benefits of PAM in the humid Mid-South. In a 2016 field trial in Northeast Arkansas, we evaluated broadcast applications of PAM in a replicated field study and examined effects on soil erosion, water infiltration, movement of nutrients and sediments, and crop performance. Treatments included irrigation with PAM amendments, irrigation without PAM and a non-irrigated rainfed check. The experiment was arranged as a complete randomized block with three replications. A granular formulation of PAM was broadcast distributed with a hand spreader at a rate of 10 lb/acre (11.2 kg/ha) immediately after furrows were cleared using standard sweeps (Buffalo cultivator), just prior to the first irrigation event, 49 days after planting (DAP). A second application was made the 2nd week of flowering on 13 July, (76 DAP). Extensive plant, soil, water, and pest monitoring activities were conducted throughout the season. Using soil moisture sensors, we observed significant differences in irrigation water infiltration in PAM treatments. Infiltration was significantly greater in the Irrigated treatment; however, was not consistant with advancement times among treatments. There were no water quality improvements associated with application of PAM. In fact, addition of PAM significantly increased Nitrate, Nitrite, Total N, and Total P loss measured in runoff water quality. There were no differences measured in irrigation advancement rates or sediment loss associated with PAM applications. We observed no significant effects of PAM applications on insect pest infestations, plant maturity, or fiber quality. Overall, irrigated cotton yields were higher than rainfed treatment; however, PAM had no effect on yields compared to irrigation without PAM. Effectiveness of the product in the humid Mid-South and Southeast states may be limited because of precipitation patterns. In addition, lower slopes are common in precision leveled cotton production fields in the Mid-South.

Introduction

The primary source of irrigation water for Arkansas agriculture is from the Mississippi River Valley Alluvial Aquifer (MRVAA). The MRVAA underlies Arkansas, Kentucky, Louisiana, Missouri, Mississippi, and Tennessee. The alluvial aquifer has been declining at a foot yearly over the past 40 years. In 2012, Arkansas irrigated 1.7 M ha of farmland ranking third behind Nebraska and California in acres irrigated and ranked third in cotton production (NASS 2013, NASS 2015). Improvements in irrigation management are needed to reduce groundwater decline, irrigation induced soil erosion in furrow-irrigated systems, and runoff water quality. In the low rainfall agricultural crop production areas in the western U.S., applications of the polymer, polyacrylamide (PAM), in furrow irrigation systems has been shown to increase infiltration and reduce erosion (Sojka and Lentz 1996). It also has been shown to reduce irrigation stream advance times. PAM is a high molecular weight, water soluble, chemical anionic polymer acting as a soil conditioner adsorbing to the soil by cation bridging resulting in aggregated soil particles. As a result the aggregated soil particles become large and heavy, and this acts to reduce irrigation-induced erosion. The combined erosion-halting and infiltration-increasing effects of PAM appears to be an ideal practice for Mid-South cotton producers interested in improving irrigation efficiency and nutrient management. In addition, PAM application is an approved practice in the USDA-NRCS Environmental Quality Incentives Program.

Limited data are available showing practical benefits of PAM in the Mid-South. The objective of this research was to evaluate the performance of PAM in reduce soil erosion, improve water quality and quantity in cotton production by quantifying soil moisture responses to infiltration, characterizing infiltration, assessing water quality and sediment runoff, and by determining the response of plant growth mapping to soil moisture and plant development among treatments. This report summarizes the 2016 results and final field season of this 3-year research project.

Materials and Methods

The field study was conducted at the Judd Hill Foundation Research Farm in Trumann, Arkansas. The experiment was arranged as a complete randomized block with three replications. Treatments are Irrigated with PAM (Irrigated+PAM), Irrigated, and Rainfed. Plots are 530 ft (161.54 m) long and 10 rows wide. Soils at the study site were classified as a Dundee silt loam (77.3%)—ranging from silt loam to loamy fine sand; Mhoon silt loam (20.9%)—ranging from silt loam to silty clay loam; and Hayti soils (1.8%)—ranging from loam to sandy clay loam. The field was bedded on 38 inch (96.52 cm) centers in the fall using disk bedders (hippers) and again in the spring. Tops of beds were flattened just prior to planting with a field cultivator fitted with incorporation baskets. The field was irrigated using 15 inch (38.1 cm) polyethylene irrigation tubing (polypipe), with groundwater from a well. The computerized hole selection program, Pipe Planner, was used to ensure uniformity of the irrigation advance. The field slope was 0.1%. Cultivar Stoneville ST 4946 GLB2 was planted on 28 April 2016. Granular polyacrylamide, Flobond A30 (SNF Holding Company, Riceboro, GA), was broadcast distributed with a hand spreader at a rate of 10 lb/acre (11.2 kg/ha) on 16 June (49 DAP), prior to the first irrigation event. A second application was made the 2nd week of flowering on 13 July (76 DAP).

To monitor soil moisture among treatments, Decagon EC-5 Volumetric Water Content sensors (Decagon Devices, Inc., Pullman, WA) were deployed in each treatment plot in one replication. There were three sensing stations in one center row at 3 (0.9 m), 6 (1.8 m), and 9 (2.7 m) ft from the plot edge down the furrow. Each station consisted of four sensors positioned at 6 (15.24 cm) and 12 inch (30.48) depths both at the edge of furrow and in the top of the bed directly below the plant (Figure 1). A Campbell Scientific CR1000 data logger (Logan, UT) was used to continuously record and store volumetric moisture measurements. Other monitoring activities included weekly plant monitoring with COTMAN and insect pest monitoring for tarnished plant bugs (*Lygus lineolaris*). End of season plant monitoring was conducted before harvest with COTMAP. The COTMAN plant monitoring system (Oosterhuis and Bourland 2008) was used to document differences in plant development among irrigation treatments from squaring until physiological cutout.

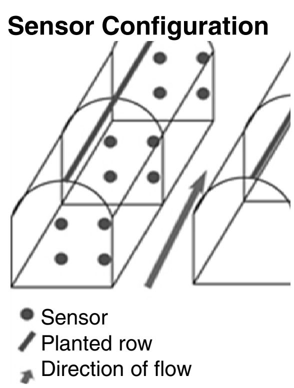

Figure 1. Schematic of soil moisture sensor configuration arranged to detect lateral infiltration of irrigation water into beds.

Irrigation was applied on 17, 24 June, 7, 14, 21, 29 July, and 5 August. Irrigation water advancement through the field was recorded for each event excluding 14 July. Furrow flumes, installed in the upper and lower portions of the field aided in monitoring inflow and outflow and soil moisture sensors were monitored for infiltration during each event. For water quality assessments, samples were collected every two hours over a six-hour period from the field edge along with a check sample directly from the polypipe that was collected at each sampling time. Water quality and suspended sediment concentration analyses were conducted for 17 June, 24 June, 14 July, and 21 July irrigations. Samples were delivered to and analyzed by the EPA-certified, Ecotoxicology Research Laboratory at Arkansas State University for suspended sediment concentration, Total P, Total N, Orthophosphate, Nitrate and Nitrite. For fiber quality evaluations, forty-boll samples from each treatment plot were hand-picked, ginned with a laboratory gin, and submitted to the Fiber and Biopolymer Research Institute (Texas Tech University, Lubbock). A two-row research cotton picker equipped with a yield monitor harvested plots. Statistical analyses were performed using analysis of variances (ANOVA) with an alpha value of 0.05 using SAS version 9.4.

Results and Discussion

Lint yields among treatments were similar for Irrigated and Irrigated with PAM treatments but were lower for the Rainfed treatment due to limited precipitation (Table 1). There were no differences in infestation levels of tarnished plant bug among three treatments (Figure 3). COTMAN growth curves for each treatment over the cotton growing season showed no differences among treatments in pre-flower nodal development rate (Figure 4). After first flowers, impacts of water deficits were apparent for the rainfed check with earlier physiological cutout (NAWF=5). Results from fiber quality analysis (HVI) showed no significant differences among irrigated treatments for lint percent, micronaire, length, uniformity, strength, elongation, and fiber density. Length and uniformity were reduced in Rainfed samples when compared to the Irrigated and Irrigated with PAM treatments (not shown). Irrigation advance times tended to be extended for Irrigated with PAM compared to the Irrigated treatment, but advance times were not significantly different (Figure 5). Advance time means from the polypipe to the edge of field for the overall season for Irrigated was 187.3 minutes while Irrigated with PAM was 223.8 minutes. Results from soil moisture monitoring using Decagon EC-5 sensors showed that soils with the PAM treatment registered higher volumetric water content than Irrigated (Figure 6). This result could be associated with effects of PAM sealing over the soil surface allowing the soil to retain moisture for longer periods of time. There were significant infiltration differences with addition of PAM. We measured 66.4% of the applied water in the Irrigated treatment compared to 30.8% the Irrigated with PAM treatment signaling a reduction in infiltration associated with PAM (Figure 7). The values from the infiltration interpretation should be taken cautiously due to potential errors in the inflow outflow methodology.

We observed no differences between the Irrigated and Irrigated with PAM treatments in measured sediment losses (Figure 8). On 17 June, we observed a significant increase in Total N in the Irrigated with PAM when compared to Irrigated treatment (Figure 9). In runoff water quality analysis from 24 June samples, we measured significantly higher levels of Nitrate, Nitrite, and Total N for the Irrigated with PAM when compared to the Irrigated treatment. Nitrate, Nitrite, and Total P levels were significantly higher for Irrigated with PAM than Irrigated on 14 July. No differences in water quality runoff were observed in the 21 July samples (Figure 9).

Table 1. Monthly precipitation (inches) measured at the study site for the 2016 season compared with 30 year average for the county.

Month	30 year Average	2016 Rainfall	Departure
	---------------------inches---------------------		
May	5.37	5.23	-0.14
June	3.99	1.82	-2.17
July	4.04	0.96	-3.08
August	2.36	4.84	2.48
Total Season	20.51	12.85	-7.66

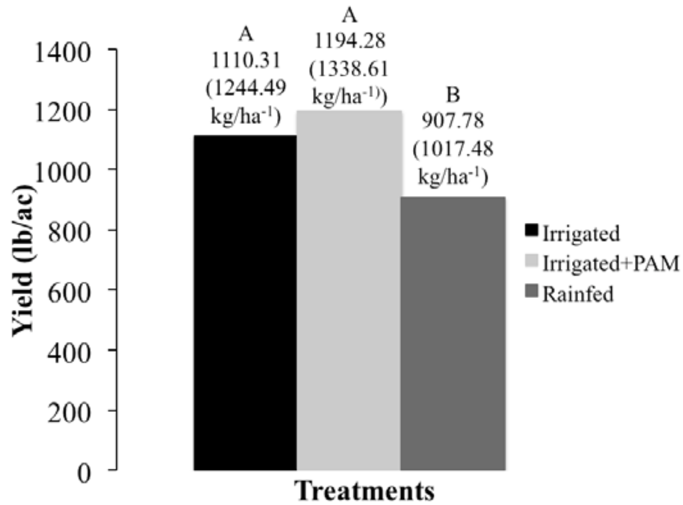

Figure 2. Lint yields for treatments in the 2016 PAM evaluation.

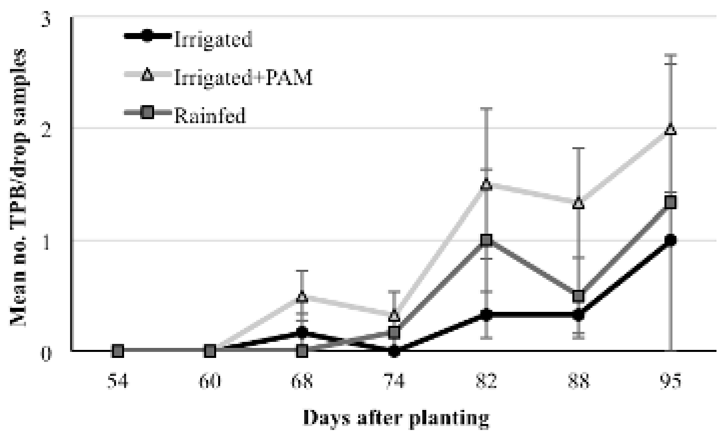

Figure 3. Tarnished plant bug infestation levels for treatments in the 2016 PAM field study. Action thresholds in Arkansas are 3 bugs/sample.

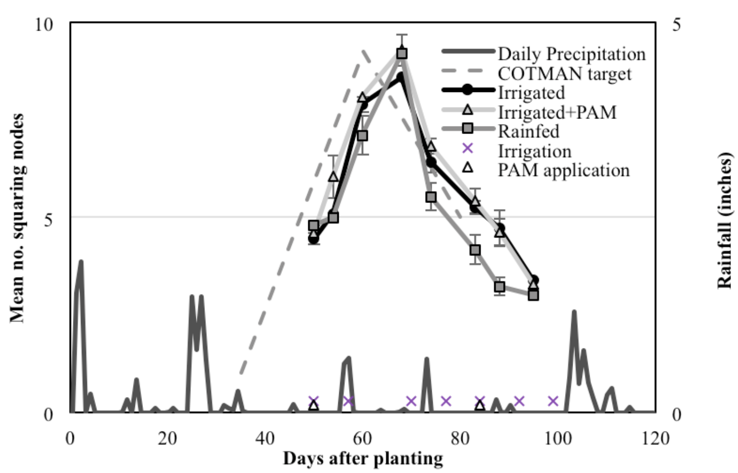

Figure 4. COTMAN growth curves for cotton in the three treatments in the 2016 PAM field study. Also included are the standard COTMAN target curve, daily precipitation, irrigation events, and PAM applications.

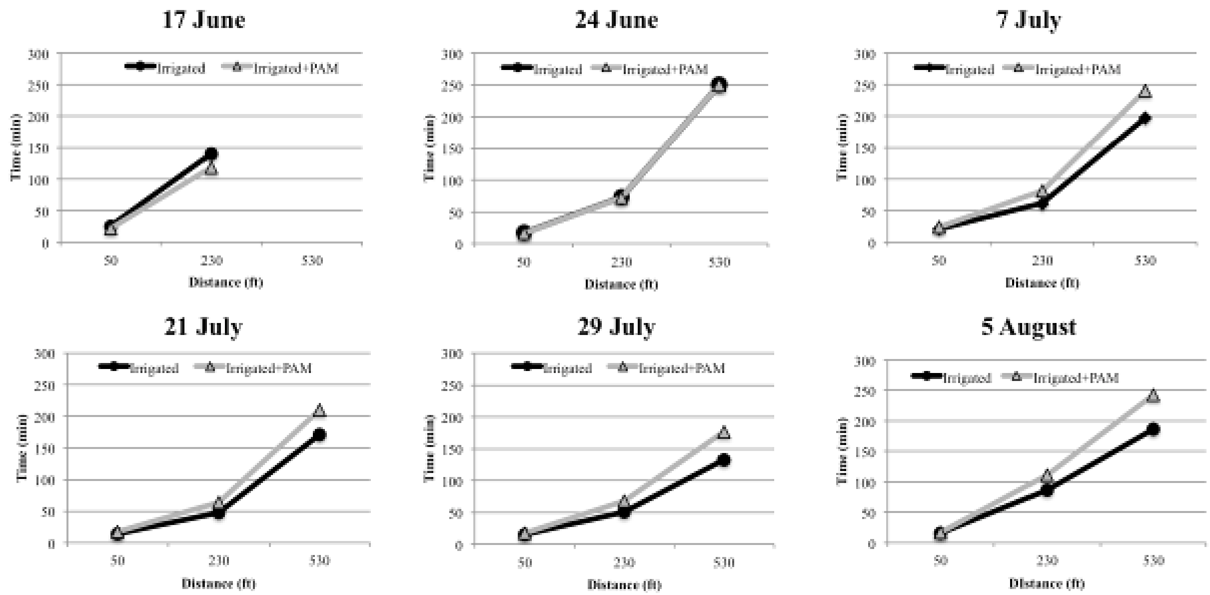

Figure 5. Furrow water front advancement for irrigation events in feet from polypipe water source to the field edge measured in minutes.

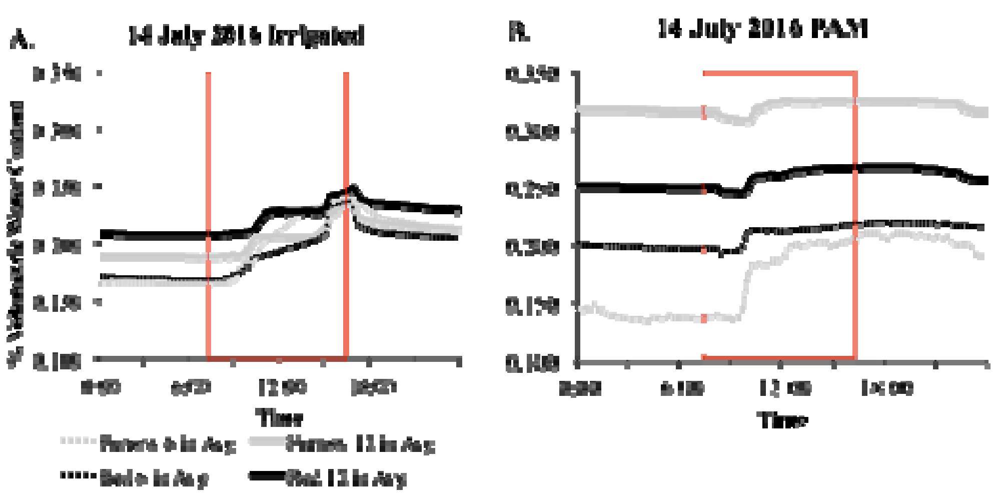

Figure 6. A. Irrigated and B. Irrigated with PAM results from Decagon EC-5 soil moisture sensors showing % volumetric water content for sensors placed at 6 and 12 inch depths in the bed below the plant and the edge of the furrow during 24-hour time period of 14 July irrigation.

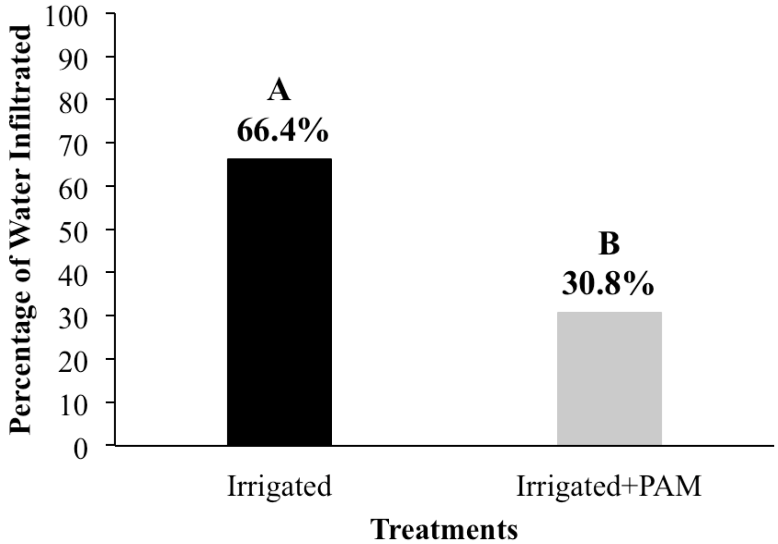

Figure 7. Infiltration in percent of water infiltrated for Irrigated and Irrigated with PAM treatments measured throughout the season during irrigations.

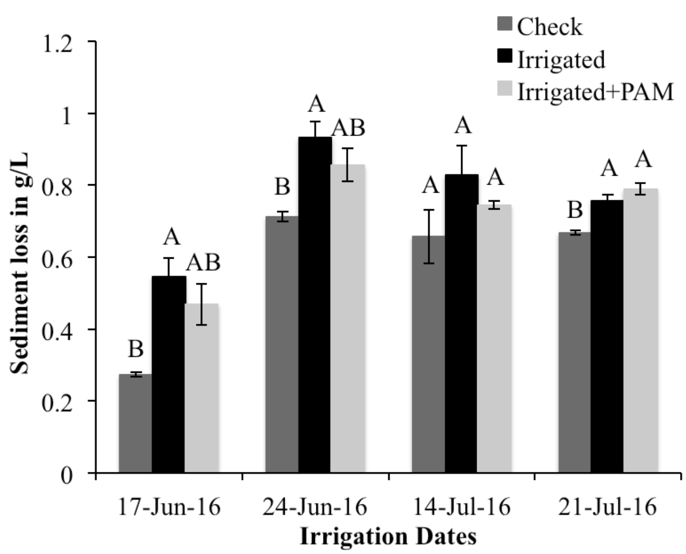

Figure 8. Sediment loss in g/L for four irrigation events. Categories represent samples from Check (polypipe sample), Irrigated, and Irrigated with PAM.

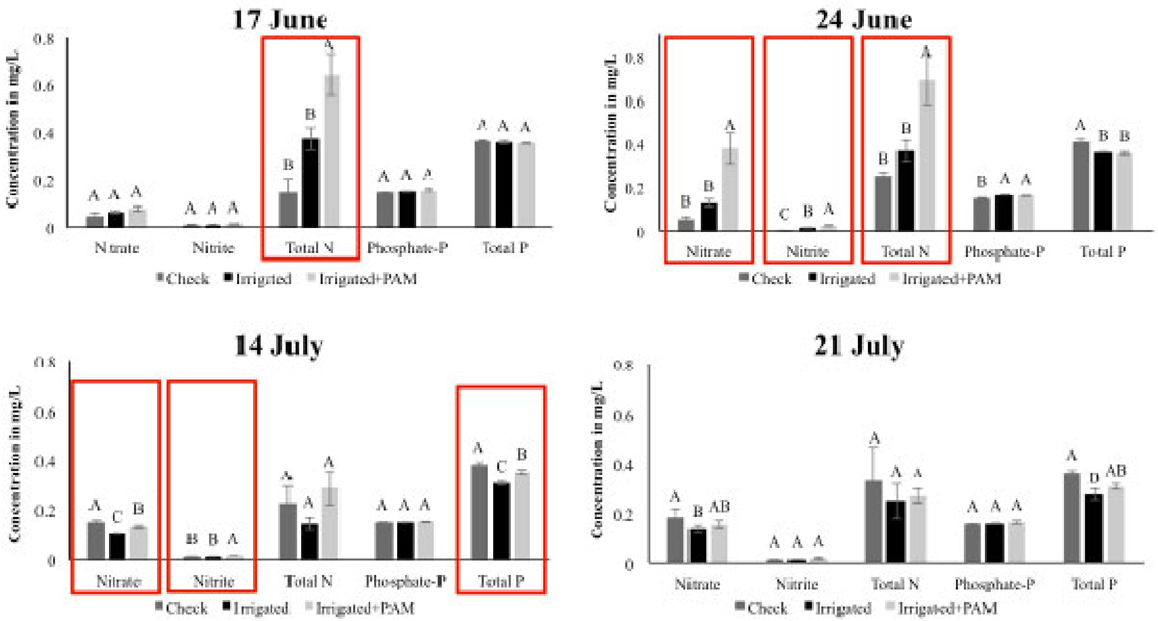

Figure 9. Run-off water quality levels of Nitrate, Nitrite, Total N, Phosphate-P, and Total P expressed in mg/L for four irrigation events. Categories include check (polypipe sample), Irrigated, and Irrigated with PAM.

Discussion

Yield was not significantly impacted by PAM in this 2016 trial. Infiltration was significantly greater in the Irrigated treatment when compared to Irrigated+PAM but was not consistant with advancement times among treatments. Discrepancies in the inflow outflow methodology to measure infiltration need to be considered and could propose further analysis. Soil moisture responses suggest PAM held moisture deeper into the soil profile. There was no reduction in sediment losses associated with PAM application. Nutrient levels in runoff significantly increased in Irrigated with PAM when compared to Irrigated treatment. Levels of Total N, Nitrate, Nitrite, and Total P expressed significant increases when PAM was applied. In studies in the western U.S., PAM applications increased soil aggregate stability resulting in reduced soil erosion, improved water quality, improved infiltration and reducing advance times (Sojka and Lentz 1996). We failed to observe these positive benefits from PAM application in this 2016 field trial. In previous work in this Cotton Incorporated suppored project, our group did not observe positive outcomes in any of our field studies PAM in Arkansas cotton systems (Barnes et al 2015; Lewis 2015; Lewis et al 2013). Differences in results from previous research in western U.S. compared to results in this study may be explained by increased amounts of precipitation, timing of precipitation, application timing of PAM and lower slopes in the Mid-South region.

Acknowledgements

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