XVII[th] World Congress of the International Commission of Agricultural and Biosystems Engineering (CIGR)

Hosted by the Canadian Society for Bioengineering (CSBE/SCGAB)
Québec City, Canada June 13-17, 2010

INVESTIGATING THE POTENTIAL FOR RICE PRODUCTION WITH SPRINKLER IRRIGATION

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CSBE100561 – Presented at Section I: Land and Water Engineering Conference

ABSTRACT Almost all rice (Oryza sativa L.) produced in the US Mid-South is grown in a flooded culture that requires considerably more irrigation water than other crops grown in the region. One approach investigated for reducing the water requirements for rice involved producing rice with sprinkler irrigation rather than with continuous flood. Problems, including disease, were observed that precluded widespread adoption of the system; however, recently there has been renewed interest in both the US and internationally. The objectives of this research were to develop and test a procedure for scheduling irrigations on sprinkler irrigated rice and investigate the suitability of chemigation for disease control. Studies were conducted at the University of Missouri Delta Research Center Marsh Farm at Portageville on a field with highly variable soils. An experimental crop coefficient function was developed and included in a beta version of the Arkansas Irrigation Scheduler. A total of 410 mm of irrigation water was applied, this is less than published values for flooded rice in the region, but additional observations with varying climatic conditions will be required to determine whether the crop coefficient function is adequate. Strips of blast resistant and susceptible cultivars were produced with no fungicide and with fungicide chemigation. Observed yields with chemigation (6.0 - 8.3 Mg/ha) were comparable to five-year state-average-rice yields in Missouri (7.5 Mg/ha). However, susceptible cultivars were severely impacted by blast when no fungicide was applied. These studies are continuing in 2010 and an additional study is planned to address irrigation requirements.

Keywords: Sprinkler irrigation, water management, rice, irrigation scheduling.

INTRODUCTION The US Department of Agriculture's National Agricultural Statistics Service (USDA-NASS) reported almost 80 million ha of US land in farms in 2003 (USDA-NASS, 2004). They divided the US into 20 Water Resource Areas, with the Lower Mississippi (WRA 08) containing 4.4 million ha of cropland in portions of Missouri, Kentucky, Arkansas, Tennessee, Mississippi, and Louisiana. Producers in

WRA 08, also called the Mid-South, irrigated 2.5 million ha, 12% of the US total. Of that 2.5 million ha, 2 million ha, or 80%, employed gravity flow systems, almost equally divided between furrow (52%) and controlled flooding (48%). Furrow irrigation is employed on much of the cotton, soybean, and corn grown in the Mid-South, while controlled flooding is used for nearly all of the rice.

Burt et al. (2000) reported that under practical conditions the potential application efficiency for continuous flood irrigation, the method used for most Mid-South rice, is 80%, which is within the range reported for center pivot systems (75 - 90%). However, they added that surface irrigation systems "require the most 'art' of all the irrigation methods, both to obtain a high distribution uniformity and a high application efficiency. In general, people have not learned the art." In practice, much water is lost from fields using surface irrigation, including continuous flood.

Mid-South farmers experience less-than-optimal surface irrigation application efficiencies for many reasons. Farming operations are typically spread over large areas, requiring farmers to manage numerous irrigation systems at different locations simultaneously. Often one worker is responsible for managing several fields, requiring him/her to move from field to field to determine when to begin water application and returning to the field to determine if the irrigation is complete and shut off the water supply. Each field waters differently and often differences are observed within fields due to factors like highly variable soils.

Rice (Oryza sativa L.) production is an important component Mid-South agriculture. Mid-South farmers grew over 760,000 ha of rice in 2003, 60% of the total US crop (USDA-NASS, 2004). Rice accounted for over $1.2 billion in total cash receipts, almost 10% of the state totals for all commodities for both Arkansas (9.7%) and Louisiana (8.3%) (USDA-ERS, 2004). When combined with the rice processing, agricultural equipment, and other businesses supporting rice production, it is apparent that rice is also important to the overall economy and not just in the rice-producing states.

While rice is produced in some parts of the world in an upland, rainfed culture, almost all US-produced rice is grown in a flooded culture. In the dry-seeding system commonly used in the Mid-South, the crop is usually flooded at approximately the V-4 growth stage (Counce et al., 2000) and, unless a disease or fertility problem requires the field to be dried, a continuous flood is maintained until after heading. Insufficient pumping results in dry portions of the fields, leading to increased weed and fertilizer problems and low yields, while excessive pumping wastes water and energy and increases pressure on levees. In addition, soil, fertilizers, and pesticides may be carried in the runoff from agricultural fields.

Rice requires considerably more irrigation water than other crops grown in the Mid-South (Hogan et al., 2007). Tacker et al. (2001) reported typical values for the amount of irrigation water applied to rice on Arkansas soils ranged from 610 to 1220 mm. Even at the low end of the range (610 mm), rice production in Arkansas over the five years from 1998 through 2002, based on cropland hectares from Arkansas Agricultural Statistics Service (2003), required an average of at least 3.8 million m^3 of irrigation water applied per year. The large amount of water applied to rice has resulted in two problems. The energy costs associated with pumping make up a significant portion of the rice production budget, and the cost is greatly influenced by fluctuations in energy prices. In addition, groundwater shortages are being observed in some Mid-South rice-producing areas, with the US Army Corps of Engineers (2000) reporting that by 1915 the alluvial aquifer, the principal water source for agriculture in eastern Arkansas and surrounding areas, was already being tapped at a rate that exceeded its ability to recharge. Similar problems have been encountered with some surface water sources in the region.

Reducing the water requirements for rice has been a goal of farmers and researchers for many years. One approach investigated producing rice in a row-crop culture with sprinkler irrigation rather than with continuous flood. Several studies during the 1980s addressed sprinkler irrigation of rice; however, when compared with flooded production in Louisiana (Westcott and Vines, 1986) and Texas (McCauley, 1990), large yield reductions were reported and producers will not readily abandon their practice of flooded production for an alternative system that produces lower yields.

Several problems were observed when rice was produced with center pivot irrigation that precluded widespread adoption of the system including inadequate weed control, disease outbreaks (primarily blast, caused by an airborne fungus *Pyricularia grisea*), and center pivot drive towers getting stuck in muddy soil. However, recently there has been renewed interest both in US and internationally as a result of improved cultivars and hybrids; additional herbicides, fungicides, and management strategies; and improved tower and sprinkler arrangements that reduce the likelihood of the system getting stuck. While saving water over flooded production may be possible in some cases, others are looking for additional options in crop choice on fields not well suited to flooded production.

In 2008, Valley[1] (Valmont Irrigation, Valley, Nebr.) began working with the University of Missouri and USDA-ARS to investigate center pivot irrigation of rice in Portageville (Stevens et al., 2009). The project was in conjunction with work that Valley was conducting in Brazil and the University of Missouri and USDA-ARS were conducting with the Missouri Department of Natural Resources.

Even though annual rainfall in the US Mid-South is generally sufficient for limited crop production, periods of drought during the growing season make irrigation essential for optimum yields. However, irrigation scheduling, the correct timing of irrigation during the growing season, is more difficult in humid regions like the Mid-South than in arid locations. Factors such as cloudy weather, rainfall, and temperature swings caused by the movement of weather fronts all complicate irrigation scheduling. Weather conditions in humid regions vary greatly from year to year and even within a year and the variability must be accounted for in the scheduling system. Most commonly used methods either measure or estimate the soil water content. Although many types of instruments have been developed to measure soil water content, using many different kinds of technology, all have drawbacks. In addition, the highly variable soils in the US Mid-South region have limited the use of soil water measurements for irrigation scheduling.

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[1] Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture.

The complexity of scheduling irrigation can be greatly reduced by the use of publicly available computer programs, including the Arkansas Irrigation Scheduler (AIS). The AIS uses a water-balance approach to scheduling irrigation, similar to managing a checkbook. The system balance represents the soil water deficit (SWD), the difference between the soil's existing moisture content, summed over the rooting depth, and the moisture content of the soil at its well drained upper limit (~24 hours after surface water was removed). Rooting depth is not used explicitly in the program, but is implicit in the choice of a maximum allowable SWD. Cahoon et al. (1990) provided a detailed description of the program and Vories et al. (2009) provided information about changes to the program since the earlier publication. However, since US rice is almost always produced with flood irrigation, much less work has been devoted to irrigation scheduling for rice than for other crops. The objectives of this research were to develop and test a procedure for scheduling irrigations on sprinkler irrigated rice and investigate the suitability of chemigation for disease control with sprinkler irrigated rice when produced on variable soils with sprinkler irrigation.

METHODS AND MATERIALS Rice was drill seeded with a 190-mm drill spacing at the University of Missouri Delta Research Center Marsh Farm at Portageville (36° 25’N, 89° 42’W) on 19 May 2009 to investigate production with sprinkler irrigation. The field is located approximately 14 km west of the current channel of the Mississippi River and lies within the New Madrid Seismic Zone. Soil mapping units within the 10 ha study field included Tiptonville silt loam (fine-silty, mixed, superactive, thermic Oxyaquic Argiudolls), Dundee sandy loam and silt loam (fine-silty, mixed, active, thermic Typic Endoaqualfs), and Reelfoot loam and sandy loam (fine-silty, mixed, superactive, thermic Aquic Argiudolls) (USDA-SCS, 1971) (Fig. 1). Rice is not typically produced on a field with such high sand content.

Soil Mapping Units

Dd = Dundee sandy loam

De = Dundee silt loam

Re = Reelfoot loam

Rf = Reelfoot sandy loam

Tp = Tiptonville silt loam

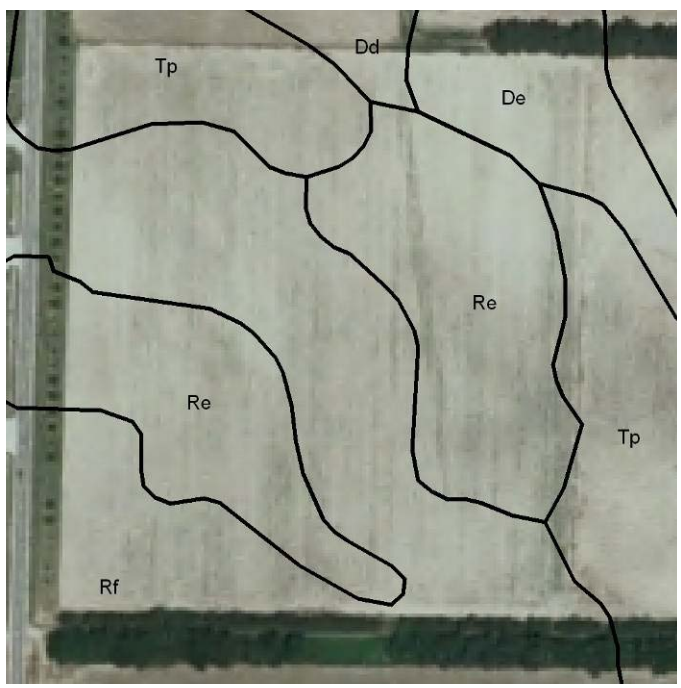


Figure 1. Study area at University of Missouri Delta Research Center Marsh Farm showing soil mapping units (USDA-SCS, 1971).

Small-plot studies were included to investigate herbicide management, fertility management, and cultivar performance (Fig. 2) and those findings were not included in this report. In addition, approximately 120 m long by 6 m wide strips of the conventional cultivars 'Catahoula', 'Cocodrie', 'Francis', 'Taggart', 'Templeton', and 'Wells' were planted in a randomized complete block arrangement with three replications. Wells and Francis are blast-susceptible cultivars, while Taggart and Templeton appear more resistant (Lee, 2009). Because sprinkler irrigation creates an environment favorable to blast, the large plots received fungicide applications applied by chemigation on 17 July and 26 August. However, to test for the presence of blast and investigate the effectiveness of the chemigation, additional 76 m long by 6 m wide strips of each of cultivar did not receive fungicide. The smaller areas were not replicated. The remaining area outside the individual studies was seeded with the RiceTec hybrid 'CL XL 729'. A total of 150 kg/ha of nitrogen (N) was applied to the plots, divided between 40 kg N/ha broadcast as urea on 18 June and five applications of 22 kg N/ha as urea ammonium nitrate (URAN) applied as fertigation between 2 July and 3 August.

The field was irrigated with a 150-m-long Valley center pivot irrigation system. Because of the variable soils in the field, including some high sand contents, and the uncertainty concerning the rooting depth of the plants, it was decided to make frequent, relatively low-volume irrigation applications. A target application of 13 mm on alternate days in the absence of rain was chosen.

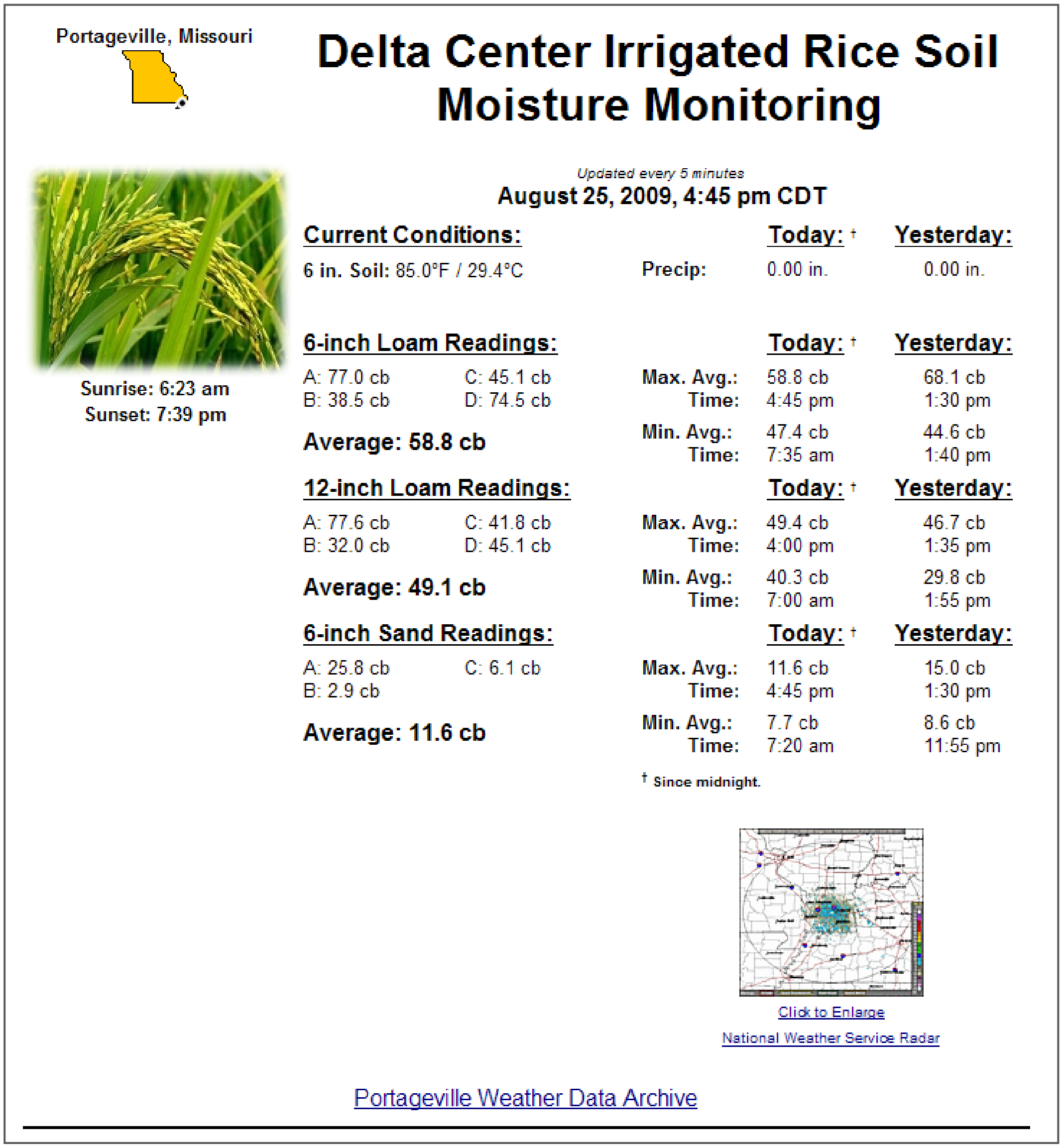
To begin to develop and test a procedure for scheduling sprinkler irrigation, an experimental grass reference crop coefficient function was developed and included in a beta version of the AIS and used to estimate the daily SWD. The crop coefficient varied from 0.2 to 1.2 based on the age of the crop. A daily grass reference evapotranspiration (ETo) was calculated using the standardized Penman-Monteith equation (ASCE-EWRI, 2004) from weather data collected at the University of Missouri Delta Research Center and placed on the Agricultural Electronic Bulletin Board (AgEBB; http://agebb.missouri.edu/). In addition to the estimated SWD, Watermark sensors (Irrometer Co., Riverside, Calif.) were placed approximately 150 and 300 mm below the soil surface in four locations, avoiding the sandiest areas. Additional sensors were placed in sandier areas. All sensors were connected to a central datalogger (Campbell Scientific, Logan, Utah). The data were automatically stored on a web page (Fig. 3) on AgEBB to be available when deciding whether to irrigate following rainfall. The web page was updated every five minutes.

A 1.5-m-wide area was harvested from the center of each of the large strips on 20 October 2009 with a Massey Ferguson 8XP combine with an onboard system for harvest weight and moisture determination (Kincaid Equipment Manufacturing, Haven, Kans.). The harvest areas were either 90- or 120-m long, depending on the position within the pivot. Grain yields were adjusted to 0.12 g/g d.b. moisture content. Yield data were analyzed using the Statistical Analysis System (SAS 9.1 for Windows; SAS Institute Inc., Cary, NC), PROC GLM. Tests were considered significant at the 0.05 level of probability and Fisher’s protected least significant difference (LSD) was used to compare treatment means for significant ($p \leq 0.05$) effects.

RESULTS AND DISCUSSION The SWD was estimated daily from 25 May, the approximate emergence date, until 30 September (Fig. 4). Higher than normal rainfall amounts were recorded, with a total of 410 mm observed during the period. However, many of the daily rainfall amounts were small and frequent irrigations were applied to insure sufficient water in the sandy areas of the field. A total of 410 mm of irrigation water was applied over a total of 34 daily applications. This was less than the typical values reported by Tacker et al. (2001) for the amount of irrigation water applied to rice on Arkansas soils (610 to 1220 mm), but may have been excess irrigation, as suggested by the number of days with SWD = 0; however, with the experimental crop coefficient function, the variable soils, and the unknown rooting depths it was decided that excess irrigation would be preferable to insufficient. Future studies will be directed at refining the irrigation scheduling procedures to limit excess irrigation.

Figure 2. Location of individual studies within field at the University of Missouri Delta Research Center.

The Watermark sensors collected soil moisture tension data continuously from 22 July through 28 September, when they were removed in preparation for harvest (Fig 5). As expected, the tensions observed at 300 mm were more stable than those observed at 150 mm. The tension data were less indicative of excess irrigation than the estimated SWD (Fig. 4); however, the Watermark system was not operating during the relatively wet period before 22 July.



Portageville, Missouri

Delta Center Irrigated Rice Soil Moisture Monitoring

Sunrise: 6:23 am
Sunset: 7:39 pm

Updated every 5 minutes
August 25, 2009, 4:45 pm CDT

Current Conditions:			**Today:** †	**Yesterday:**
6 in. Soil: 85.0°F / 29.4°C		**Precip:**	0.00 in.	0.00 in.
6-inch Loam Readings:			**Today:** †	**Yesterday:**
A: 77.0 cb	C: 45.1 cb	**Max. Avg.:**	58.8 cb	68.1 cb
B: 38.5 cb	D: 74.5 cb	**Time:**	4:45 pm	1:30 pm
Average: 58.8 cb		**Min. Avg.:**	47.4 cb	44.6 cb
		Time:	7:35 am	1:40 pm
12-inch Loam Readings:			**Today:** †	**Yesterday:**
A: 77.6 cb	C: 41.8 cb	**Max. Avg.:**	49.4 cb	46.7 cb
B: 32.0 cb	D: 45.1 cb	**Time:**	4:00 pm	1:35 pm
Average: 49.1 cb		**Min. Avg.:**	40.3 cb	29.8 cb
		Time:	7:00 am	1:55 pm
6-inch Sand Readings:			**Today:** †	**Yesterday:**
A: 25.8 cb	C: 6.1 cb	**Max. Avg.:**	11.6 cb	15.0 cb
B: 2.9 cb		**Time:**	4:45 pm	1:30 pm
Average: 11.6 cb		**Min. Avg.:**	7.7 cb	8.6 cb
		Time:	7:20 am	11:55 pm

† Since midnight.

Click to Enlarge
National Weather Service Radar

Portageville Weather Data Archive

Figure 3. Example of web page reporting soil moisture monitoring.

The cultivar Templeton had the highest observed grain yield in the fungicide-treated plots (8.31 Mg/ha; Table 1), although not significantly greater than those of Cocodrie (7.98) and Taggart (7.86). Catahoula had significantly lower yields than the other cultivars

(5.97). Although the final values are not available for the 2009 crop, these yields are comparable to the 7.47 Mg/ha state-average rice yields for Missouri for the five years 2004 - 2008 (USDA-NASS, 2010). The fungicide chemigation appeared effective at controlling blast. Although no statistical comparisons could be made, blast was observed in the area that received no fungicide and two cultivars known to be susceptible, Francis and Wells, were severely impacted. Templeton is rated resistant to common blast races (Lee, 2009) and did not appear to have been affected in this study. Taggart is rated moderately susceptible to susceptible for common blast races (Lee, 2009) and may have been impacted, but it did not appear to have been affected as severely as Francis and Wells. However, blast was also observed in some flooded fields in 2009 and additional studies will seek to provide a better understanding of the relationship between sprinkler irrigation for rice and the occurrence of blast.

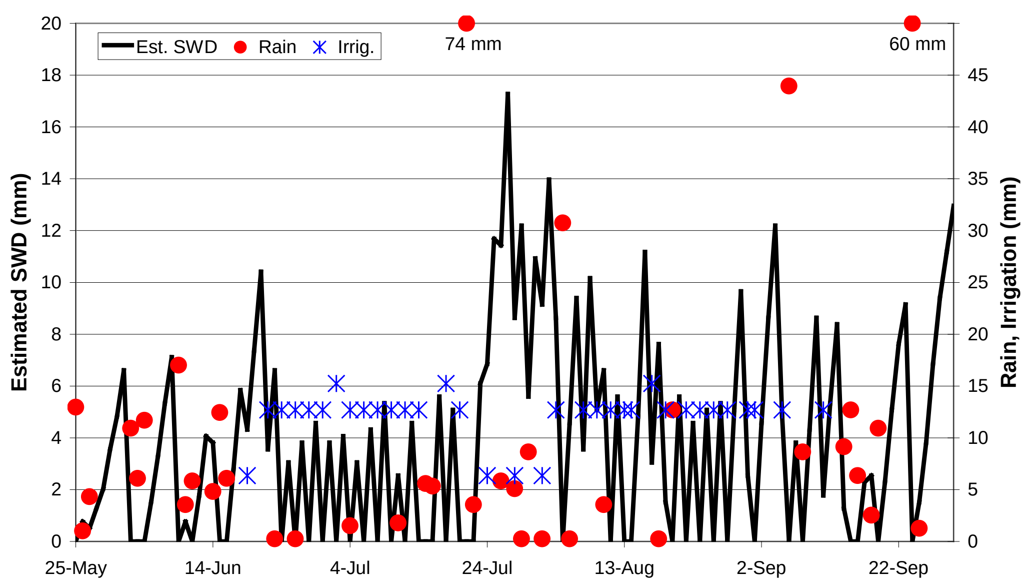


Figure 4. Rainfall and irrigation applications and the resulting estimated soil water deficit (SWD) for the center pivot irrigated rice study in 2009.

CONCLUSION Most of the rice produced in the US is grown in the Mid-South and most of it is produced in a flooded culture that requires more irrigation water than the other crops produced in the region. Previous attempts to produce rice with sprinkler irrigation did not lead to widespread adoption, but improvements in management, agrochemicals, and equipment suggest that an appropriate production system can be developed. In some cases, saving water may be possible over flooded production, while in others it will provide additional options in crop choice to farmers on fields that are not well suited to flooded production.

An experimental crop coefficient function was developed and included in a beta version of the AIS. Additional observations with varying climatic conditions will be required to determine whether the function is adequate or should be adjusted. Yields of conventional cultivars grown in 90 - 120-m long strips with fungicide chemigation (6.0 - 8.3 Mg/ha) were comparable to five-year state-average-rice yields in Missouri (7.5 Mg/ha). However, susceptible cultivars were severely impacted by blast when no fungicide was applied. These studies are continuing in 2010 and an additional study is planned to address irrigation requirements.

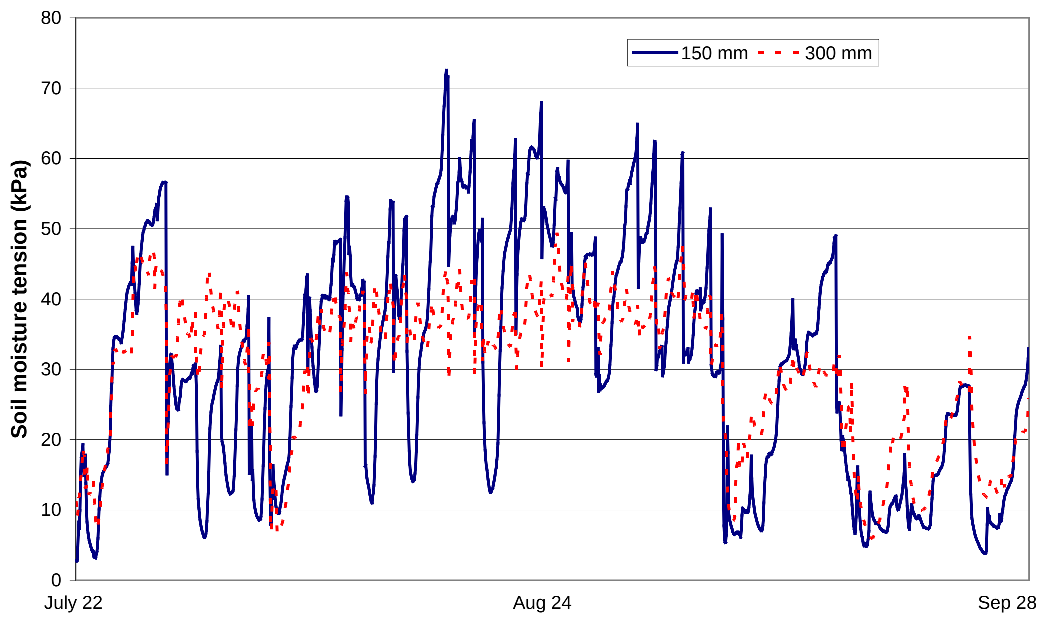


Figure 5. Soil moisture tension observed with Watermark sensors placed at two depths in the least sandy areas of the study field.

Table 1. Grain yield from large-plot cultivar study.

Cultivar	Grain yield (Mg/ha @ 12 g/g d.b.)	
	fungicide*	no fungicide
Catahoula	5.97 c	7.34
Cocodrie	7.98 ab	5.51
Francis	7.33 b	0
Taggart	7.86 ab	5.41
Templeton	8.31 a	7.92
Wells	7.20 b	0.86

* Means in a column followed by the same letter are not significantly different at the 5% level of significance. The plots without fungicide were not replicated and therefore no statistical comparisons were made.

Acknowledgements. The authors express appreciation for the assistance of Valmont Irrigation, Mid-Valley Irrigation, the Missouri Department of Natural Resources, Jim Heiser, Matt Rhine, and Steve Hall.

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