TITLE: Developing Profitable Deficit Irrigation Soybean Production Systems.

PI: L. J. Krutz

COOPERATORS: Trent Irby, Bobby Golden, Lyle Pringle, Larry Falconer, and Normie Buehring

BACKGROUND AND OBJECTIVES

Mississippi soybean producers are facing two major problems—stagnant soybean yields in light of increasing production costs and restricted water use arising from declining Mississippi Alluvial aquifer levels. There is a need, therefore, to develop production systems that maintain or improve profitability if irrigation capacity is restricted because of ground water depletion issues. Restricting the amount of water producers can use from the Mississippi River Valley alluvial aquifer could result in the need for deficit irrigation programs.

Deficit irrigation is an agricultural water management strategy in which less than 100% of the potential evapotranspiration is provided by a combination of stored soil water, rainfall and irrigation throughout or at specific periods during the growing season. Deficit irrigation research in soybean has been restricted principally to the Midwest where water consumption is regulated because of declining aquifer levels. Conversely, in regions such as the Mississippi Delta where water is perceived to be abundant, deficit irrigation research is lacking. Due to the potential for restricted water use associated with declining Mississippi Alluvial aquifer levels, the development of deficit irrigation systems that maintain or improve soybean yield or profitability in Mississippi is necessary.

Generally, Midwest deficit irrigation studies indicate that R5 is the most critical time to avoid deficit irrigation, and that optimal yields occur when irrigation is initiated at R1 and continues through at least R6.5. Companion data for indeterminate MG IV soybeans from the humid MidSouth is lacking. The objective of this deficit irrigation study is to determine if, relative to the common soybean irrigation practices of the Mississippi Delta, an irrigation event can be omitted while maintaining yield and profitability. Three separate studies were designed to achieve this objective.

First, an initiation study with six treatments including four furrow initiation timings (Vn-R1, R2, R3-4, R5), well watered (FAO-56, 2-in. deficit) and a non-irrigated control were evaluated in a randomized complete block with four replications of each treatment. Field experiments were established at the USDA-ARS Crop Production Systems Research Unit Farm in Stoneville, MS on a Dundee silt loam. Experimental units were 26.7-ft wide by 250-ft long. Upon initiating irrigation, subsequent irrigations were based on FAO-56 and a 2-in. deficit assuming 50% irrigation efficiency. In-season measurements included irrigation water applied, fuel/energy...
consumption, and soil moisture level as estimated by Watermark sensors installed at 6, 12, and 24 inches.

At harvest, seed yield, yield increase from irrigation, yield increase per mm of irrigation water, seed weight and number, and seed quality were determined. Economic data including irrigation expense and income net return as affected by initiation timing were included. Data were subjected to analysis of variance using SAS PROC MIXED and means were separated with PDMIX8000. Additionally, these data were used to model the effect of deficit irrigation on yield relative to the well-watered treatment using the stepwise procedure in SAS PROC REG.

Secondly, an irrigation termination study with eight treatments including six termination timings (R2, R3, R4, R5, R6, and R7), a well-watered positive control (FAO-56, 2-in. deficit), and a non-irrigated negative control were evaluated in a randomized complete block design with four replications of each treatment. Field experiments were established at the Delta Branch Experiment Station in Stoneville, MS on a Sharkey Clay. Each experimental unit was 40 ft. wide and 200 ft. long. Irrigation was applied at a 2-inch deficit based on FAO-56. In-season measurements included soil moisture levels as estimated by Watermark sensors installed at 6, 12, and 24 inches.

At harvest, seed yield, yield increase from irrigation, yield increase per mm of irrigation water, seed weight and number, and seed quality were determined as a function of initiation timing. Economic data included irrigation expense and income net return as affected by initiation timing. Data were subjected to analysis of variance using SAS PROC MIXED and means were separated via PDMIX8000. These data were also used to model the effect of deficit irrigation on yield relative to the well-watered treatment using the stepwise procedure in SAS PROC REG.

Finally, a skip study containing seven treatments including five physiological deficit timings (R2, R3, R4, R5, and R6), a well-watered positive control (FAO-56, 2-in. deficit), and a non-irrigated negative control were evaluated in a randomized complete block design with four replications of each treatment. Field experiments were established at the Delta Branch Experiment Station in Stoneville, MS on a Sharkey Clay. Each experimental unit was 40 ft. wide and 200 ft. long. Irrigation was applied at a 2-in. deficit based on the Arkansas Irrigation Scheduler. In-season measurements included irrigation water applied, fuel consumption, and soil moisture level as estimated by Watermark sensors installed at 6, 12, and 24 inches.

At harvest, seed yield, yield increase from irrigation, yield increase per mm of irrigation water, seed weight and number, and seed quality were determined as a function of initiation timing. Economic data included irrigation expense and income net return as affected by initiation timing. Data were subjected to analysis of variance using SAS PROC MIXED and means were separated via PDMIX8000.

The economic analysis included in this study is based on partial budgeting of net returns above irrigation and hauling costs since all other factors of production were the same for all treatments. Irrigation cost estimates are based on MSU budgets for a 160-acre system using roll-out pipe (MSU Department of Agricultural Economics Budget Report 2012-07, Appendix 10 . Web available at http://www.agecon.msstate.edu/what/farm/budget/pdf/13/MSUDELTA13.pdf).
Estimated variable and fixed irrigation costs for irrigation setup are estimated at $67.79 per acre, with additional fixed and variable costs of $3.89 per acre-inch applied. Soybean price was set at average reported price during October 2012 and October 2013 in the Delta area (USDA Market News- JK_GR110). Soybean hauling costs were estimated at $0.28 per bushel (MSU Department of Agricultural Economics Budget Report 2012-07, Appendix 4. Web available at http://www.agecon.msstate.edu/what/farm/budget/pdf/13/MSUDELTA13.pdf).

**REPORT OF PROGRESS/ACTIVITY**

Identifying physiological periods where drought stress does not limit soybean yield potential. Multiple linear regression analysis was used to determine the cumulative and concurrent drought stress effects at Vn, R1-R2, R3-R4, R5 and R6 on yield relative to the well-watered treatment, i.e., FAO-56. Yield and drought stress data from the initiation, termination and skip studies were used to construct a multiple linear regression model that explained 78% of the variability in yield loss among drought stressed treatments given the following equation:

\[
y = -0.49482 - 2.25242(R3-R4) - 0.65915(R5)
\]

where \(y\) is the predicted yield loss (bu/acre) relative to a non-drought stressed crop, i.e., FAO-56; R3-R4 is the maximum water deficit (inches) in the rooting zone during the pod development stage; and R5 is the maximum water deficit (inches) in the rooting zone during the beginning seed fill stage (Figure 1).

Much information can be gleaned by what parameters were retained by the stepwise regression procedure. Foremost, note that the statistical procedure excluded drought stress from Vn through R2 from the model. Excluding these growth stages from the model indicates that moderate drought stress from Vn through R2 did not significantly contribute to yield loss (P>0.15).

Conversely, moderate to severe drought stress from R3 through R5 significantly reduced yield relative to the well-watered treatment (P < 0.0001). These preliminary data indicate, therefore, that at least one irrigation event could be eliminated prior to pod development without adversely affecting yield from early soybean production systems. Conversely, eliminating irrigation event(s) from R3 through R5 will likely reduce yield potential.

Yield, yield components, and economic impacts of eliminating an early-season irrigation event. We were asked by the Mississippi Soybean Promotion Board to determine if at least one soybean irrigation event could be eliminated without adversely affecting yield or profitability, and when this irrigation event could be eliminated. Preliminary modeling data indicate that eliminating an irrigation event prior to R3 in the early soybean production system should not adversely affect yield, and consequently, may improve profitability relative to the regional standard, i.e., initiating irrigation at Vn-R1.

Results from our soybean initiation study indicate there is potential to eliminate at least one irrigation event relative to the regional standard without adversely affecting yield or profitability (Table 1). There were no yield differences between initiating at Vn-R1, R3/4, or when using a scientific irrigation scheduling tool (FAO-56). However, triggering an irrigation event based on
a scientific irrigation scheduling tool (FAO-56) or waiting until R3 reduced irrigation water use by at least 17% relative to the regional standard. Moreover, these data indicate that drought stress from R3 through R5 will likely reduce yield potential.

**IMPACTS AND BENEFITS TO MISSISSIPPI SOYBEAN PRODUCERS**

This research will impact approximately 1.2 million irrigated soybean acres in Mississippi. Eliminating one irrigation would save Mississippi soybean producers approximately $12,000,000/yr.

**END PRODUCTS-COMPLETED OR FORTHCOMING**

The five most important outputs include: 1) Memphis Gin show invited talk; 2) Tristate Soybean forum invited talk; 3) Conservation Tillage Meeting invited talk; 4) Agricultural Expo invited talk; and 5) Eight county extension talks.

![Predicted yield vs Observed yield](image)

Figure 1. Predicted yield below that of well-watered treatment (FAO-56) correlated with measured yield below FAO-56 for initiation, termination and skip irrigation studies from 2012 through 2013. Predicted values were based on the multiple linear regression model $y = -0.49482 - 2.25242(R3-R4) - 0.65915(R5)$, where $y$ is the predicted yield loss (bu/acre) relative to a non-drought stressed crop, i.e., FAO-56; R3-R4 is the maximum water deficit (inches) in the rooting zone during the pod development stage; and R5 is the maximum water deficit (inches) in the rooting zone during the beginning seed fill stage.
Table 1. Yield, net return above irrigation and shipping costs, and acre-inches of irrigation water applied for non-irrigated and irrigation initiation based on FAO-56, vn-R1, R3/4, and R5 growth stages.

<table>
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<tr>
<th>Treatment</th>
<th>2012 Season</th>
<th>2013 Season</th>
<th></th>
<th></th>
<th></th>
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<tr>
<td></td>
<td>Yield bu/acre</td>
<td>Net $ acre</td>
<td>Irrigation acre-inches</td>
<td>Yield bu/acre</td>
<td>Net $ acre</td>
<td>Irrigation acre-inches</td>
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<td>Non-irrigated</td>
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<tr>
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