Establishing Irrigation Thresholds for Furrow-Irrigated Peanuts

S.D. Leininger, L.J. Krutz, J.M. Sarver, J. Gore, A. Henn, C.J. Bryant, R.L. Atwill, and G.D. Spencer*

Abstract
Scheduling irrigations for furrow-irrigated peanut (Arachis hypogea L.) based on soil moisture potential could improve yield and net returns by ensuring adequate season-long soil water availability. This research was conducted to determine if sensor-based irrigation scheduling improves peanut yield, net returns above irrigation costs, and irrigation water use efficiency relative to FAO-56, a water balance irrigation-scheduling method that determines evapotranspiration using meteorological data and crop growth stage. The effects of irrigation scheduling (FAO-56, -50 cbar, -75 cbar, -100 cbar, and non-irrigated) on peanut yield, net returns above irrigation costs, and irrigation water use efficiency were investigated at Stoneville, MS on a Bosket very fine sandy loam (fine-loamy, mixed, active, thermic Mollic Hapludalfs). Relative to non-irrigated and FAO-56, maintaining the soil moisture at -50 cbar improved peanut yield at least 12.7% and either had no effect during wet years or improved net returns above irrigation costs up to 20.7% during dry years ($P \leq 0.0376$). Maintaining soil moisture at -50 or -100 cbar either had no effect during wet years or increased irrigation water use efficiency by at least 5.3-fold relative to FAO-56 during dry years ($P = 0.0071$). Our data indicate that peanut yield, net returns above irrigation costs, and irrigation water use efficiency are more consistently optimized in furrow-irrigated environments by maintaining a season-long irrigation threshold of -50 cbar.

Within the primary peanut-growing regions of the USA, including Alabama, Florida, Georgia, southeast Mississippi, New Mexico, North and South Carolina, Oklahoma, Texas, and Virginia, the prominent technique for scheduling irrigations is the water balance method. A water balance method utilizes known environmental parameters and crop growth stage to estimate soil water content. The primary water balance methods used across the USA and other international peanut-growing regions include evaporation pans (Khan and Datta, 1982; Pahalwan and Tripathi, 1984; Rowland et al., 2010; Wright et al., 1986), Irrigator Pro (Lamb et al., 2007; Rowland et al., 2010), the University of Georgia Extension checkbook method (UGA-EXT) (Rowland et al., 2010), MOISNUT (Davidson et al., 1998a), EXNUT (Davidson et al., 1998a,b), and AQUAMAN (Chauhan et al., 2013). Relative to producer-derived methods or rainfed environments, water balance scheduling methods are purported to improve yield, net returns, and/or irrigation water use efficiency (IWUE) up to 50% in overhead-irrigated environments (Chauhan et al., 2013; Davidson et al., 1998a,b). An exception is under normal rainfall where irrigation stimulates disease (Wright et al., 1986).
To date, no research has compared the effect of water balance and irrigation scheduling methods or sensor-based scheduling on peanut yield, profitability, and water use efficiency in furrow-irrigated environments. The objective of this study was to determine the effects of irrigation scheduling method, including a water balance approach, FAO-56, and sensor-based scheduling at various thresholds, on peanut yield, net returns above irrigation costs, and irrigation water use efficiency on a common mid-southern USA peanut production soil.

**Site Description**

Field studies were conducted on a Bosket very fine sandy loam (fine-loamy, mixed, active, thermic Hapludalfs) (USDA-NRCS, 2013) at the Mississippi State University (MSU) Delta Research and Extension Center in Stoneville, MS in 2015 and 2016. Land preparation in both years included deep tillage with a parabolic subsoiler to a depth of 22 inches, disc-harrowing, and formation of 40-inch-wide beds using a high-clearance bedder hipper and a raised bed conditioner to prepare the seedbed for planting. Peanut cultivar Georgia-06G (Branch, 2007) was planted into experimental units that were 26.7 ft wide by 30.0 ft long at 6 seeds/ft to a depth of 2 inches using a four-row John Deere MaxEmerge 1700 XP vacuum planter (John Deere Seeding Group, Moline, IL). Furrows were swept with a row crop cultivator set to run shallow in the middle of the furrow prior to the first irrigation. All agronomic and pest management decisions were based on MSU Extension recommendations (Catchot et al., 2014; Mississippi State University, 2015b; Oldham, 2012), and fungicide applications were made following guidelines provided by the high-risk model of the Peanut Disease Risk Index (Kemerait et al., 2016).

**Experimental Design**

The experimental design was a randomized complete block with four replications of each treatment. Treatments included -100, -75, -50, and -50 cbar, and non-irrigated. Soil moisture was monitored using Irrrometer Watermark 200SS soil water potential sensors (Irrrometer Co., Inc., Riverside, CA) installed 2 inches from the edge of the plot. Raised beds were planted with soybean, and peanut was planted in the opposite side of the furrow with a 12-inch separation. Irrigation was applied through 12-inch by 9-mil polyethylene tubing (Ethylene tubing (Delta Plastics, Little Rock, AR) whereby flow rate (5 gal/min) and cumulative water applied were measured with a McCrometer Inc., Hemet, CA).
Measurements included peanut pod yield, market grade (percent of total sound mature kernels, TSMK), oleic acid, net returns above irrigation costs, and IWUE. Peanut maturity was determined each year using the hull scrape method (Williams and Drexler, 1981). Peanut plant digging and inversion occurred on 25 Sept. 2015 and 26 Sept. 2016. Harvest followed on 1 Oct. 2015 and 12 Oct. 2016. Peanut plants were inverted using a two-row KMC digger-shaker-inverter and harvested using a two-row KMC peanut combine (Kelley Manufacturing Co., Tifton, GA). Yield was adjusted to 10.5% moisture, and market grade was determined as described by Davidson et al. (1982). Eurofins Central Analytical Laboratory (New Orleans, LA) analyzed oleic acid content. Partial budgets (Kay et al., 2015), using estimated costs taken from MSU Delta planning budgets (Mississippi State University, 2014, 2015a) and market prices received for in-shell Mississippi peanuts during 2015 and 2016 (USDA-NASS, 2017a), were developed to analyze differences in net returns for each treatment. Irrigation water use efficiency was calculated as described by Vories et al. (2005):

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

Where \( IWUE \) is irrigation water use efficiency (lb/ac-inch), \( Y \) is peanut pod yield (lb), and \( IWA \) is irrigation water applied (acre-inch).

**Statistical Analysis**

All data were subjected to ANOVA using the GLIMMIX Procedure (Statistical Analytical System Release 9.4; SAS Institute Inc., Cary, NC). A preliminary analysis was conducted for peanut pod yield, market grade (percent TSMK), oleic acid, net returns above irrigation costs, and IWUE with year and scheduling treatment as fixed effects and replication as a random effect. The fixed effect year was significant for peanut pod yield, market grade (percent TSMK), oleic acid, and net returns above irrigation costs; therefore, a secondary analysis was performed for each year (2015 and 2016) with scheduling treatment as a fixed effect and replication as a random effect. For IWUE, scheduling treatment was the fixed effect, with replication and replication nested within year as random effects using the GLIMMIX Procedure. Means were separated using the LSMEANS statement. Differences were considered significant for \( \alpha = 0.05 \).

**Rainfall and Supplemental Irrigation**

Rainfall patterns varied by year, but every potential irrigation treatment was applied over the course of the study. For both years, precipitation from planting through late pod fill ranged from 16% below to 79% above the 10-year mean. Above-average rainfall totals in 2016 reduced overall irrigation totals and prevented the -100 cbar treatment from scheduling. At each irrigation event, 5 acre-inches were applied, and events are aligned with in-season timing at days after planting (DAP).
From late pod-fill through physiological maturity, rainfall in 2015 and 2016 was 73% less and 200% greater, respectively, than the 10-year average. Relative to FAO-56 in 2015, an additional 25 acre-inches were applied to the -50 cbar treatment, an additional 15 acre-inches were applied to the -75 cbar treatment, and the -100 cbar treatment received 15 acre-inches less than the positive control (Fig. 1). In 2016, rainfall was such that the -100 cbar threshold was not met and no irrigations were applied (Fig. 1). Cumulative irrigation was not different between FAO-56 and the -50 cbar treatments while 67% less irrigation was applied to the -75 cbar treatment relative to FAO-56.

**Yield and Net Returns above Irrigation Costs**

The primary hypothesis of this study was that sensor-based scheduling would improve yield and net returns above irrigation costs relative to FAO-56 (positive control) and non-irrigated (negative control). Relative to FAO-56 and the non-irrigated treatments, maintaining the soil moisture at -50 cbar improved peanut yield at least 12.7% and either had no effect or improved peanut quality (percent TSMK and oleic acid) and net returns above irrigation costs up to 20.7% (Fig. 2 and 3). These data indicate that maintaining soil moisture at -50 cbar with sensor-based scheduling tools improves yield and profitability relative to FAO-56 and non-irrigated environments.

**Irrigation Water Use Efficiency**

Another premise for this study was that sensor-based scheduling would better estimate the soil moisture potential required to maximize yield with as few irrigations as possible. Maintaining soil moisture at -50 or -100 cbar either had no effect or increased IWUE by at least 5.3-fold relative to FAO-56 ($P = 0.0071$; Fig. 4). The -75 cbar treatment did not increase IWUE compared with FAO-56 because the additional 15 acre-inches only marginally affected yield. Conversely, the additional 25 acre-inches applied to the -50 cbar treatment relative to FAO-56 increased yield sufficiently to improve IWUE. Improved IWUE at -100 cbar was the result of applying 15 acre-inches less water than FAO-56 yet maintaining yield. These data indicate that maintaining soil moisture at -50 cbar or -100 cbar with sensor-based scheduling tools improves IWUE relative to FAO-56.

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**Fig. 2.** Peanut pod yield from an irrigation-scheduling study utilizing soil moisture sensors and a water balance method conducted at the Delta Research and Extension Center, Stoneville, MS, in 2015 and 2016. Irrigation thresholds were -50 cbar, -75 cbar, -100 cbar, and FAO-56 at a 2-inch soil moisture deficit. In 2016, the -100 cbar threshold never initiated due to above-average rainfall totals during the season.

**Fig. 3.** Net returns above irrigation costs of peanut from an irrigation-scheduling study utilizing soil moisture sensors and a water balance method conducted at the Delta Research and Extension Center, Stoneville, MS, in 2015 and 2016. Irrigation thresholds were -50 cbar, -75 cbar, -100 cbar, and FAO-56 at a 2-inch soil moisture deficit. Above-average rainfall throughout the 2016 growing season prevented the -100 cbar treatment from initiating. *(NS = not significant at $\alpha = 0.005$)*
There is a paucity of data for sensor-based irrigation scheduling across the primary peanut-growing regions in the USA. There are data indicating that checkbook irrigation-scheduling tools improve peanut yield, net returns above irrigation costs, and/or IWUE up to 50% relative to producer standards or rainfed environments (Chauhan et al., 2013; Davidson et al., 1998a, 1998b). There are no reports of soil moisture sensor-based scheduling of peanuts in the literature. However, there is evidence that sensor-based scheduling for crops other than peanuts, i.e., soybean and rice, improves yield, net returns above irrigation costs, and/or IWUE up to 2.6-fold in the mid-southern USA (Bryant et al., 2017; Atwill et al., 2018; Wood et al., 2017).

**Conclusion**

This research was conducted to determine if sensor-based irrigation scheduling improves yield, net returns above irrigation costs, and IWUE relative to FAO-56. Our data indicate that yield, net returns above irrigation costs, and IWUE are more consistently maximized when the irrigation threshold is maintained season long at -50 cbar with sensor-based scheduling tools. Adoption of this irrigation threshold across the mid-southern peanut region would maximize yield and net returns above irrigation costs while ensuring the most judicious use of water resources.

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