Crop Management

Skip Row, Furrow Irrigation Optimizes Peanut Pod Yield, Net Returns, and Irrigation Water Use Efficiency


Abstract
Soil water potential in the rooting zone of furrow-irrigated peanut (*Arachis hypogea* L.) may be influenced through seed bed formation and irrigation strategy. The objective of this study was to determine if bed formation and irrigation strategy improves peanut pod yield and profitability in rainfed and furrow-irrigated environments. The effects of land preparation method (flat vs. bed) and irrigation strategy (every furrow, every other furrow, and rainfed) on peanut pod yield, net returns above tillage and irrigation costs, and irrigation water use efficiency were investigated near Stoneville, MS on a Bosket very fine sandy loam (fine-loamy, mixed, active, thermic Mollic Hapludalfs). Relative to the rainfed environment, irrigation either had no effect or improved yield 1.8-fold regardless of land preparation method and irrigation strategy. Pooled over land preparation method, irrigating every other furrow either had no effect or improved net returns above irrigation costs up to $238/acre. Independent of year and land preparation method, irrigating every other furrow increased irrigation water use efficiency 5.3-fold relative to irrigating every furrow. Our data indicate that yield, net returns above irrigation costs, and irrigation water use efficiency are most often optimized for peanut in the Mid-Southern USA by irrigating every other furrow regardless of bed formation.

Within the primary peanut (*Arachis hypogea* L.) growing regions of the USA, including Alabama, Florida, Georgia, southeast Mississippi, New Mexico, North and South Carolina, Oklahoma, Texas, and Virginia, approximately 1.8 million acres of peanut are planted on course, well-drained soils into either flat ground or a shallow bed with two rows of peanut per bed. Sixty-eight percent of the peanut acreage is rainfed while 32% of the acreage is irrigated with overhead sprinklers (USDA-NASS, 2014). Since the 2014 farm bill, peanut acreage has expanded into non-traditional regions including the Delta region of Mississippi (J.M. Sarver, personal communication, 2016; USDA-NASS, 2018). In the Mid-Southern USA peanut region, consisting of western Tennessee, southeast Missouri, and the Delta regions of Arkansas, Mississippi, and Louisiana, peanut acreage has increased at least 50% since 2011 (USDA-NASS, 2017). Peanuts in this region are planted predominately on very fine sandy-loam or coarser-textured soils.

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Abbreviations: BMP, best management practice; IWUE, irrigation water use efficiency; TSMK, total sound mature kernels.

Conversions: For unit conversions relevant to this article, see Table A.
The majority of row-crop acres in the Mid-Southern USA are planted into 36- to 40-inch raised beds, which facilitates drainage and crop productivity in soils conducive to furrow irrigation. Relative to planting flat, planting on a bed increased corn (Zea mays L.) and/or soybean [Glycine max (L.) Merrill] biomass, plant height, root growth and uniformity, and yield, which was attributed primarily to decreased bulk density in the latter (Bakker et al., 2005; Jackson et al., 2011; Johnson et al., 1990; Siler et al., 2001; Tomar et al., 1996). Planting wheat (Triticum aestivum L.), oat (Avena sativa L.), and canola (Brassica napus L.) on raised beds rather than flat increased yield in poorly drained soils (Bakker et al., 2005; Bruns and Young, 2012; Tomar et al., 1996). Planting peanut on a bed in fine-textured soils, that is, Greenville sandy-loam (Fine, kaolinitic, thermic Rhodic Kandiudults), increased yield by 415 lb/acre over flat, but land preparation had no effect on a course-textured, Tifton loamy sand (fine-loamy, kaolinitic, thermic Plinthic Kandiudults) (Jackson et al., 2011). Increased peanut pod yield in fine-textured soils was attributed to improved digging efficiency. Land preparation strategies for furrow-irrigated peanut planted into moderately to poorly drained soils common to the Mid-Southern USA have not been evaluated.

Skip row irrigation is a best management practice (BMP) where water is applied to every other furrow and has an effect on yield, infiltration, irrigation water use efficiency (IWUE), and net returns on crops and soil textures common to the Mid-Southern USA. For moderately and poorly drained soils, infiltration and horizontal movement of water is greater for skip row irrigation, whereby corn, soybean, sorghum (Sorghum bicolor L.), and cotton (Gossypium hirsutum L.) yield is maintained relative to applying water to every furrow (Golzardi et al., 2017; Stone et al., 1979). In well-drained, course-textured soils, yield loss can occur in skip row irrigation when crop water demand is not met due to excessive vertical movement of water below and minimal lateral movement of water into the rooting zone (Ebrahimian, 2014). However, regardless of soil texture or crop, when yield is not different, IWUE is greater for skip row rather than every furrow irrigation because less water is applied in the former (Fischbach and Mulliner, 1972; Ghadage et al., 2005; Golzardi et al., 2017; Grimes et al., 1968; Kashiani et al., 2011; Musicick and Dusek, 1974; Stone et al., 1979). When yield is not different between irrigation strategies, net returns above irrigation costs are greater for skip row irrigation because of reduced fuel costs relative to every furrow. Skip row irrigation of peanut has not been evaluated in the Mid-Southern USA.

There is considerable evidence that bedding system and irrigation strategy can have an effect on the soil water potential in the rooting zone of peanut, thereby effecting yield and profitability. However, the potential interaction of bedding system and irrigation strategy on peanut yield and profitability has not been evaluated on moderately to poorly drained soils in the Mid-Southern USA. The objectives of this study were to determine if bed formation and irrigation strategy interact to have an effect on peanut pod yield, IWUE, and net returns above tillage and irrigation costs.

### Site Description and Experimental Design

Field studies were conducted from 2015 through 2016 near Stoneville, MS on a Bosket very fine sandy loam (fine-loamy, mixed, active, thermic Mollic Hapludalfs) (USDA-NRCS, 2013). The experimental design was a split plot within a randomized complete block with land preparation (bedded vs. flat) as the main plot and irrigation strategy (every furrow, every other furrow, rainfed) as the sub-plot. In both years, land preparation included deep tillage with a parabolic subsoiler to a depth of 22 inches followed by disc-harrowing in the fall. In the bedded system, 40-inch beds were formed with a high-clearance bedding hipper in the spring while in the flat-planted system, soil was compressed with a land roller. Peanut cultivar Georgia-06G (Branch, 2007) was planted into experimental units that were 27 ft wide by 30 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). Planting occurred on 1 June in 2015 and 6 May in 2016. All agronomic and pest management decisions were based on Mississippi State University Extension recommendations (Catchot et al., 2014; Mississippi State University, 2015; Oldham, 2012). Fungicide applications were based on

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**Table A. Useful conversions.**

<table>
<thead>
<tr>
<th>To convert Column 1 to Column 2, multiply by</th>
<th>Column 1 Suggested Unit</th>
<th>Column 2 SI Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.405</td>
<td>acre</td>
<td>hectare, ha</td>
</tr>
<tr>
<td>0.454</td>
<td>pound, lb</td>
<td>kilogram, kg</td>
</tr>
<tr>
<td>1.12</td>
<td>pound per acre, lb/acre</td>
<td>kilogram per hectare, kg/ha</td>
</tr>
<tr>
<td>102.8</td>
<td>acre-inch</td>
<td>meter$^3$, m$^3$</td>
</tr>
<tr>
<td>3.78</td>
<td>gallons, gal</td>
<td>liter, L (10$^{-3}$ m$^3$)</td>
</tr>
<tr>
<td>2.54</td>
<td>inch</td>
<td>centimeter, cm (10$^{-2}$ m)</td>
</tr>
</tbody>
</table>
guidelines provided by the high-risk model of the Peanut Disease Risk Index (Kemerait et al., 2015, 2016).

Prior to canopy closure, a row crop cultivator with shallow flat sweeps (Dickey Vator, Dickey Machine Works, Pine Bluff, AR) was used to facilitate irrigation movement along furrow length in all land preparation methods. Furrow preparation was conducted only in furrows receiving irrigation. Irrigation events were scheduled based on a 2-inch soil moisture deficit as estimated by the FAO-56 water balance method (Allen et al., 1998; Walter et al., 2005). Irrigation was delivered via lay-flat polyethylene tubing (poly-tubing) (Delta Plastics Inc., Little Rock, AR). Inflow rate (5 gal/min) and irrigation application volume (5 acre-inches) were monitored with a McCrometer flow tube with attached McPropeller bolt-on saddle flowmeter (McCrometer Inc., Hemet, CA) connected to the field inlet. Pipe Hole and Universal Crown Evaluation Tool (PHAUCET) version 8.2.20 (USDA-NRCS, Washington, DC) was used to calculate correct poly-tubing hole sizes to maintain proper flow rate. Peanut maturity was determined using the hull scrape method (Williams and Drexler, 1981). Digging and inverting of the center two rows occurred on 5 November and 26 September for 2015 and 2016, respectively, utilizing a KMC digger-shaker-inverter (Kelley Manufacturing Co., Tifton, GA). Peanut pod harvest was accomplished on 11 November and 11 October for 2015 and 2016, respectively, with a KMC peanut combine (Kelley Manufacturing Co., Tifton, GA).

Quantified observation included peanut pod yield, peanut market grade (percent total sound mature kernels [TSMK]), net returns above irrigation costs, and IWUE. Peanut pods were bagged and then weighed with a calibrated scale and moisture adjusted to 10.5%. Peanut grading was conducted in accordance with methods described by Davidson et al. (1982). Partial budgets (Kay et al., 2015), using estimated costs from Mississippi State University Delta planning budgets (Mississippi State University, 2016, 2017) and prices received for in-shell Mississippi peanuts during 2015 and 2016 (USDA-NASS, 2017), were developed to analyze differences in net returns above tillage and irrigation costs for each treatment. Irrigation water use efficiency was calculated as described by Vories et al. (2005):

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

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

**Statistical Analysis**

All data were subjected to ANOVA using the GLIMMIX Procedure in SAS 9.4 (Statistical Analytical System Release 9.4; SAS Institute Inc., Cary, NC). Type III statistics were used to test all possible fixed effects or interactions among fixed effects. Replication of irrigation strategy, replication by fixed effects, and replication by all interactions among fixed effects (nested within year) were considered random. Treatment means were averaged for each irrigation strategy within each land preparation method for peanut pod yield, market grade (percent TSMK), net returns above tillage and irrigation costs, and IWUE. Means were separated using the LSMEANS statement, and differences were considered significant when \(\alpha \leq 0.05\).

**Rainfall**

Rainfall patterns differed between years. For both years, precipitation from planting through late pod fill ranged from 16% below to 79% above the 10-year average (Table 1). From late pod fill through physiological maturity, rainfall in 2015 and 2016 was 73% less and 200% greater, respectively, than the 10-year average. In 2015, the dry year, supplemental irrigation was applied on 15 and 24 July, 3 and 14 August, and 2 September. In 2016, the wetter year, supplemental irrigation was applied on 29 June, 20 July, and 14 September.

**Yield**

A principal hypothesis of this study was that planting on a bed and applying water to every furrow would maximize peanut pod yield in Mid-Southern USA furrow-irrigated environments. Year and irrigation strategy interacted to have an effect on peanut pod yield (\(P = 0.0071\); Fig. 1). Contrary to our hypothesis, neither planting flat or on a bed nor irrigating every vs. every other furrow had an effect on peanut pod yield. However, relative to the rainfed environment, irrigation improved yield 1.8-fold in the dry year, 2015, but had no effect in the wet year, 2016.

**Market Grade (Percent TSMK)**

Due to poor drainage in peanut-producing soils across the Mid-Southern USA, we postulated that market grade would be improved by planting into a bed rather than a flat system. Contrary to our hypothesis, planting method had no effect on market grade. However, year and irrigation strategy interacted to have an effect on market grade (\(P = 0.0453\); Fig. 2). Relative to the rainfed environment, irrigating every furrow improved market grade 1.2% in the dry year, 2015, but had no

<table>
<thead>
<tr>
<th>Month</th>
<th>2015</th>
<th>2016</th>
<th>10-year average</th>
</tr>
</thead>
<tbody>
<tr>
<td>April†</td>
<td>6.34</td>
<td>4.33</td>
<td>5.98</td>
</tr>
<tr>
<td>May</td>
<td>6.97</td>
<td>3.27</td>
<td>3.90</td>
</tr>
<tr>
<td>June</td>
<td>2.56</td>
<td>5.08</td>
<td>2.32</td>
</tr>
<tr>
<td>July</td>
<td>3.19</td>
<td>6.54</td>
<td>3.19</td>
</tr>
<tr>
<td>August</td>
<td>0.75</td>
<td>5.47</td>
<td>2.76</td>
</tr>
<tr>
<td>September</td>
<td>0.79</td>
<td>0.08</td>
<td>4.61</td>
</tr>
<tr>
<td>October</td>
<td>5.47</td>
<td>0.20</td>
<td>5.28</td>
</tr>
<tr>
<td>November</td>
<td>9.61</td>
<td>5.28</td>
<td>2.76</td>
</tr>
</tbody>
</table>

† Readings begin prior to peanut planting and conclude at peanut harvest.

Table 1. The sum of monthly rainfall totals for the 2015 and 2016 peanut growing seasons and the previous 10-year average rainfall amounts, by month, for a peanut land preparation and furrow-irrigation system study conducted in Stoneville, MS.
effect in the wet year, 2016. Improvements in market grade could be due to increased calcium uptake producing fuller kernels, a very slight delay in maturity allowing increased kernel development time, or a general improvement in overall plant health due to a lack of water stress during reproductive growth.

Net Returns above Tillage and Irrigation Costs
We assumed that planting peanut on a bed and irrigating every furrow would maximize yield and grade, thereby improving net returns relative to alternative production systems. Year and irrigation strategy interacted to affect net returns above tillage and irrigation costs ($P = 0.0448$; Fig. 3). Net returns above tillage and irrigation costs were not different between bedded and flat production systems. However, applying water to every other furrow improved net returns above tillage and irrigation costs up to 2.16-fold in the dry year, 2015, but had no effect in the wet year, 2016.

Irrigation Water Use Efficiency
A primary assumption of this research was that irrigating every furrow would increase yields, thereby increasing IWUE. For IWUE, the irrigation strategy main effect was significant ($P = 0.0078$). Independent of year and land preparation method, applying water to every other furrow rather than every furrow improved irrigation water use efficiency 5.3-fold.

Fig. 1. Peanut pod yield, pooled across land preparation method, for three irrigation strategies used in a furrow-irrigated peanut study during the 2015 and 2016 growing seasons in Mississippi.

Fig. 2. Peanut market grade, pooled across land preparation method, for three irrigation strategies used in a furrow-irrigated peanut study during the 2015 and 2016 growing seasons in Mississippi. TSMK = total sound mature kernels.
Land preparation was a critical factor for this study because in the Mid-Southern USA peanut is planted flat or on a bed and furrow-irrigated in soils that are poorly drained relative to those in the traditional Peanut Belt, i.e., Georgia, Florida, and Alabama. The majority of the row crop acres in the Mid-Southern USA are planted on a raised bed because furrow irrigation is the primary irrigation delivery system for the region (USDA-NASS, 2014). Under the conditions of this study, land preparation method had no effect on peanut pod yield, market grade, net returns above tillage and irrigation costs, or IWUE. In a similar study, land preparation method, i.e., flat, tiller-shaper, disk-bedder, and ripper-bedder, had a minimal and inconsistent effect on peanut pod yield and net returns (Wright and Porter, 1980). These data indicate that land preparation method should have no effect on peanut yield, profitability, or IWUE in the Mid-Southern USA.

Skip row irrigation is a best management practice for furrow delivery systems that purportedly has little to no adverse effect on yield while improving IWUE and profitability. Our data indicate that relative to irrigating every furrow, skip row irrigation has no adverse effect on peanut pod yield but improves IWUE and net returns up to fivefold. Similarly, skip row irrigation had no adverse effect on cotton, soybean, potato (Solanum tuberosum L.), sugar beet (Beta vulgaris L.), or grain sorghum yield but improved IWUE up to 2.0-fold (Fischbach and Mulliner, 1972; Ghadage et al., 2005; Grimes et al., 1968; Kashiani et al., 2011; Musick and Dusek, 1974; Stone et al., 1979). The exception to skip row irrigation having no adverse effect on yield is when crop water demand is not met because of low rainfall and/or greater than average evapotranspiration rates (Allen et al., 1998; Stone et al., 1979; Stone et al., 1982). These data indicate that for the humid, sub-tropical Mid-Southern USA, peanut pod yield, net returns above tillage and irrigation costs, and IWUE are optimized by skip row irrigation.

**Conclusion**

The objective of this study was to determine if bed formation and irrigating every furrow is required to optimize peanut pod yield and profitability in Mid-Southern USA furrow-irrigated environments. Bed formation did not have an effect on peanut pod yield, economics, or water use efficiency. Conversely, skip row irrigation increased net returns and IWUE up to fivefold compared with applying water to every furrow. Our data indicate that yield, net returns above tillage and irrigation costs, and IWUE are most often optimized for peanut in the Mid-Southern USA by irrigating every other furrow regardless of bed formation.

**References**


