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AGRONOMY AND SOILS

Narrow-Row Cotton Production under Irrigated and Non-irrigated Environment: Plant Population and Lint Yield

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ABSTRACT

The commercialization of a spindle-type harvester to pick cotton (*Gossypium hirsutum* L.) planted in 38-cm rows and the development of a second-generation of glyphosate-resistant cotton cultivars that allows glyphosate applications beyond the 4-leaf stage have sparked interest in 38-cm row cotton production. However, information on 38-cm row cotton production in the lower Mississippi River Valley alluvial flood plain is limited. Field studies were conducted during 2006 and 2007 to assess cotton canopy closure and lint yield in 38-cm rows and 25-cm paired rows each with five plant populations compared to conventional 102-cm rows at one plant population with and without irrigation. In non-irrigated cotton, canopy closed 1 to 4 wk earlier in 38-cm rows and 25-cm paired rows compared to 102-cm rows. Plant population at harvest ranged from 106,000 to 215,000 plants ha^{-1} in 38-cm rows and 99,000 to 217,000 plants ha^{-1} in 25-cm paired rows compared to 126,000 plants ha^{-1} in 102-cm rows. Under non-irrigated production, there were no differences in lint percentage, regardless of row pattern and plant population. Lint yields ranged from 1049 to 1304 kg ha^{-1} in 38-cm rows and 962 to 1110 kg ha^{-1} in 25-cm paired rows compared to 990 kg ha^{-1} in 102-cm rows. Overall, cotton planted in narrow rows had more open bolls than 102-cm rows. In irrigated cotton, canopy closure was similar to non-irrigated cotton. Lint percentage was similar between 25-cm paired row and 102-cm row, but higher than 38-cm row cotton. Under irrigated production, lint yields ranged from 1580 to 1864 kg ha^{-1} in 38-cm row and 1448 to 1519 kg ha^{-1} in 25-cm paired rows compared to 1413 kg ha^{-1} in 102-cm rows. These results demonstrated that cotton grown in 38-cm rows can close canopy early and produce lint yields higher than cotton grown in 102-cm rows at comparable plant populations, regardless of irrigation.

Traditionally cotton has been grown in rows spaced 91 to 102 cm apart. In the 1990s, there was an increased level of interest in ultra-narrow-row cotton production as an alternative to wide-row cotton systems. Ultra-narrow-row cotton production was considered a potential strategy to increase yields and reduce production costs. Ultra-narrow-row cotton was grown in rows spaced 19 or 25 cm apart and harvested using a finger-stripper (Atwell, 1996; Culpepper and York, 2000; Kerby, 1998; McAlister and Rogers, 2005; Reddy, 2001; 2004). However, the ultra-narrow-row cotton system was never widely adopted for economic reasons (e.g., high seed cost due to increased plant density and ginning penalties for ginning and fiber quality concerns associated with finger-stripper cotton) (Brown et al., 1998; Valco et al., 2001) and the dominance of conventional wide-row cotton production systems. The recent introduction of the John Deere PRO-12 VRS spindle-type picker™ (Karnei, 2005) that is capable of picking cotton on virtually any row spacing from 38 to 102 cm has rejuvenated interest in narrow-row cotton production (Buehring et al., 2006; Harrison et al., 2006; Nichols et al., 2004; Willcutt et al., 2006; Wilson et al., 2007). Cotton grown in narrow rows (38 cm) produced equal (Harrison et al., 2006; Nichols et al., 2004; Willcutt et al., 2006) or higher (Buehring et al., 2006; Karnei, 2005; Wilson et al., 2007) yield than cotton grown in conventional 97 to 102-cm wide rows.

Seed premiums and technology fees associated with transgenic cotton coupled with low commodity prices have resulted in reduced profit margins. A narrow-row cotton production system shares the same agronomic benefits as that of ultra-narrow-row cotton. Close row spacing (19 to 25 cm) and high plant populations in ultra-narrow rows lead to more

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rapid canopy closure than in wide rows (Robinson, 1993), which leads to increased light interception (Kreig, 1996) and reduced weed competition. A narrow-row cotton production system can provide early canopy closure similar to an ultra-narrow-row cotton system without increased seed cost. Recent studies in North Carolina by Wilson (2006) demonstrated that plant populations for cotton in 38-cm rows were similar to wide-row cotton.

Yield differences between paired-row pattern (also referred to as twin-row in the literature) and single-row pattern have been reported in several crops. Peanut (*Arachis hypogaea* L.) yields were higher in twin-row pattern (rows spaced 18 cm apart on 91-cm centers) than in single-row pattern (Jordan et al., 2001; Lanier et al., 2004). In corn (*Zea mays* L.), yields in twin rows spaced 19 to 25 cm apart were equal (Sorensen et al., 2006), lower (Nelson, 2007), or higher (Karlen and Camp, 1985) compared to single-row pattern. In the lower Mississippi River Valley alluvial flood plain, soybean [*Glycine max* (L.) Merr.] produced higher yields in twin rows spaced 25 cm apart compared to single-row pattern (Koger, 2007). In cotton, information on feasibility of growing cotton in twin rows compared to single rows is limited.

Information on plant population requirements and yield response of cotton grown in 38-cm rows and side-by-side comparisons of cotton grown in 38-cm rows, 25-cm paired rows, and 102-cm rows in the lower Mississippi River Valley alluvial flood plain is lacking. Although a spindle-type picker is not currently available for 25-cm paired-row cotton, a 25-cm row pattern was included in the study to asses any yield advantage over wide-row cotton. The purpose of this study was to compare narrow-row (38 cm) and twin-row (25 cm) cotton production systems with conventional wide-row (102 cm) cotton production systems. The specific objective was to determine time of canopy closure and cotton yield response to selected plant populations in 38-cm row and 25-cm paired-row pattern compared to conventional 102-cm wide-row pattern under an irrigated and non-irrigated environment in the lower Mississippi River Valley alluvial flood plain.

MATERIALS AND METHODS

Non-irrigated study. A 2-yr field study was conducted in 2006 and 2007 at the USDA-ARS Southern Weed Science Research farm, Stoneville, MS (33º26´ N, 90º55´ W), under a non-irrigated environment. Average daily maximum and minimum air temperatures and total rainfall for indicated months in 2006 and 2007 and the 30-year average at Stoneville, MS are presented in Table 1. The soil was a Dundee silty clay loam (fine-silty, mixed, thermic Aeric Ochraqualf) with pH 6.9; 1.6% organic matter; a cation exchange capacity of 23 cmol kg^{-1}; and soil textural fractions of 15% sand, 56% silt, and 29% clay. Field preparation consisted of an initial disking, subsoiling, a second disking, and then bedding in the fall of the previous year. Raised beds spaced 102 cm apart were formed with disk hippers. The experimental area was treated with Paraquat (Gramaxone Inteon®, Syngenta Corporation, Wilmington, DE) at 1.1 kg ai ha^{-1} or glyphosate at 0.84 kg ae ha^{-1} 1 to 2 wk prior to cotton planting to kill existing vegetation. Prior to planting, raised beds were smoothed with a reel and harrow row conditioner - as needed to plant cotton in 38- and 102-cm rows and in 25-cm paired rows.

A second-generation glyphosate-resistant cotton cultivar, DP164 B2RF (Deltapine, Memphis, TN) was planted on 19 April 2006 and 30 April 2007. A John Deere planter 1730 (Deere and Co., Moline, IL)

Table 1. Average daily maximum and minimum air temperatures and total rainfall for indicated months in 2006 and 2007 and the 30-year average at Stoneville, MS

Month	2006			2007			1964–1993 average[z]		
	Daily air temperature (ºC)		Rainfall (cm)	Daily air temperature (ºC)		Rainfall (cm)	Daily air temperature (ºC)		Rainfall (cm)
	Maximum	Minimum		Maximum	Minimum		Maximum	Minimum	
April	26.7	15.0	18.8	22.8	10.6	8.6	23.4	11.8	13.6
May	28.9	17.2	7.3	30.0	17.8	3.2	27.8	16.6	12.6
June	32.8	20.6	4.6	32.8	21.1	9.9	31.9	20.6	9.5
July	33.9	22.2	4.5	31.7	21.7	19.7	33.0	22.2	9.3
August	35.6	22.8	4.0	36.7	23.3	8.7	32.3	21.1	5.8
September	30.6	16.1	6.9	31.1	19.4	11.8	29.4	17.2	8.6

[z] Boykin et al., 1995.

with modifications was used to plant cotton in 38-cm rows. Cotton was planted in paired rows 25 cm apart on beds spaced 102-cm wide using a Monosem NG Plus precision planter (Monosem ATI, Inc., Lenexa, KS). Cotton was planted in 102-cm wide-rows using a MaxEmerge 2 planter (Deere and Co., Moline, IL). Cotton in 38-cm rows and 25-cm paired rows was planted at five selected seeding rates to achieve plant populations above and below a recommended plant population for conventional 102-cm row cotton (Table 2). In Mississippi, final plant populations of 100,000 to 125,000 plants ha^{-1} is recommended for 102-cm row cotton (Anonymous, 2008). Actual plant populations were estimated at harvest by counting plants for 1 m in the two center rows at three randomly selected locations in each plot. Cotton planted in 102-cm wide rows was included as a standard cotton production system to compare yield potential of cotton planted in 38-cm row and 25-cm paired-row systems.

The experiment was conducted in a randomized complete block design with four replications. Each treatment consisted of ten 38-cm rows, four 25-cm paired rows on a 102-cm center, or four rows spaced 102 cm apart. Plots were 15.2 m long and maintained weed free using both preemergence and postemergence herbicide programs. Fluometuron at 1.12 kg ai ha^{-1} plus *S*-metolachlor at 1.12 kg ai ha^{-1} were applied preemergence to the entire experimental area immediately after planting. Glyphosate at 0.84 kg ae ha^{-1} was applied postemergence twice in 2006 and once in 2007. In 2007, the second postemergence application of glyphosate was not required. Herbicides were applied with a tractor-mounted sprayer with TeeJet 8004 standard flat spray nozzles (TeeJet Spraying Systems Company, Wheaton, IL) delivering 187 L ha^{-1} water at 179 kPa. The weeds that escaped management were hand hoed to maintain weed-free plots. Plots were kept weed free to compare cotton canopy closure and yield in various row patterns without the confounding effects of weeds. Fertilizer application and insect control programs were standard for cotton production (Anonymous, 2008; Reddy, 2004).

Cotton canopy closure was visually estimated based on the extent of inter-row ground coverage by cotton foliage in relation to row width on a scale of 0 (bare ground) to 100% (complete ground cover with canopy). Canopy closure was estimated between the center two rows of 38-cm and 102-cm spaced plots. In 25-cm paired-row plots, canopy closure was estimated between the second and third pair of rows. It was noted that the canopy within the paired rows closed more rapidly than between the paired rows. Canopy closure was estimated on a weekly basis until the canopy was completely closed in all three row patterns. Seed cotton was handpicked from 1 m sections in the two center rows at three randomly selected locations in each plot. The number of cotton plants and open bolls per plant was recorded at hand picking. Seed cotton was ginned on a 10-saw laboratory gin (Continental Eagle, Prattville, AL) and the lint yield was calculated on a land area basis.

Table 2. Effect of row spacing on cotton canopy closure under non-irrigated environment in 2006 and 2007 at Stoneville, MS

Row pattern		Cotton canopy closure (%)								
Row width	Cotton population (plants/ha)	2006				2007				
		9 WAP[z]	10 WAP	13 WAP	14 WAP	8 WAP	9 WAP	10 WAP	11 WAP	12 WAP
38-cm solid	106,000	90	100	100	100	98	100	100	100	100
	111,000	95	100	100	100	100	100	100	100	100
	130,000	98	100	100	100	100	100	100	100	100
	170,000	98	100	100	100	100	100	100	100	100
	215,000	100	100	100	100	100	100	100	100	100
25-cm pair	99,000	78	93	100	100	73	80	98	100	100
	117,000	78	93	100	100	75	85	100	100	100
	142,000	80	90	100	100	70	80	100	100	100
	164,000	85	93	100	100	73	85	100	100	100
	217,000	90	93	100	100	75	85	100	100	100
102 cm	126,000	48	55	85	100	45	55	70	88	100
LSD (0.05)		12	10	4	-	8	6	2	2	-

[z] WAP, weeks after planting cotton.

Irrigated study. A 2-yr field study was also conducted in 2006 and 2007 at the USDA-ARS Southern Weed Science Research farm, Stoneville, MS, under an irrigated environment. Land preparation, cotton cultivar, planting dates, plant populations, herbicides and application timings, and data collection were as described in the non-irrigated study with a few exceptions. The soil was a Dundee silt loam (fine-silty, mixed, active, thermic Typic Endoqualf) with pH 6.7, 1.1% organic matter, a cation exchange capacity 15 cmol kg^{-1}, and soil textural fractions of 26% sand, 55% silt, and 19% clay. The plots were 24.4 m long. Cotton was furrow irrigated on an as-needed basis: three times in 2006 and eight times in 2007. In 2007, more irrigation was needed due to erratic distribution of rainfall.

Data were subjected to analysis of variance using PROC MIXED (SAS, 2003) and treatment means were separated at the 5% level of significance using Fisher's protected LSD test. Canopy closure data are presented for each year because of growth differences in cotton. Data for lint yield, lint percentage, and number of open bolls were averaged across years as there was no year by treatment interaction.

RESULTS AND DISCUSSION

Non-irrigated study. Rainfall was above the 30-yr normal in April and below the 30-yr normal from May through September in 2006 (Table 1). In 2007, rainfall was average in June, above the 30-yr normal in July through September and below the 30-yr normal in other indicated months. The total rainfall for April through September was 46.1 cm in 2006 and 61.9 cm in 2007. Daily maximum and minimum air temperatures in 2006 were equal or above the 30-yr normal, except for the minimum temperature in September. In 2007, daily maximum and minimum air temperatures were above the 30-yr normal in May, June, August, and September and were below the 30-yr normal in April and July. Overall, the weather was more erratic in 2007 compared to 2006. In 2007, visible soil moisture-related stress occurred during May due to 75% less rainfall compared to the 30-yr normal.

Cotton canopy closure was 100% by 10 wk after planting (WAP) in 38-cm rows and 13 WAP in 25-cm paired rows compared to 14 WAP in 102-cm rows in 2006 (Table 2). In 2007, canopy closed at 9, 11, and 12 WAP in 38-cm, 25-cm paired, and 102-cm row cotton, respectively. Overall, canopy closure occurred 1 to 4 wk earlier in 38-cm row and 25-cm paired row cotton, compared to cotton planted in 102-cm rows in both years (Figure 1). In other research, a similar early canopy closure occurred in narrow-row cotton compared to wide-row cotton grown in Texas (Jost and Cothren, 2000).

Figure 1. Cotton grown in 38-cm rows (top) and 25-cm paired rows (middle) closed canopy 1 to 4 wk earlier compared to cotton in 102-cm rows (bottom). Rapid canopy closure creates unfavorable environment for germination and establishment of late-season weeds. Photos taken at 8 wk after planting in 2007.

Plant population at harvest ranged from 106,000 to 215,000 plants ha^{-1} in 38-cm rows and 99,000 to 217,000 plants ha^{-1} in 25-cm paired rows compared to 126,000 plants ha^{-1} in 102-cm rows (Table 3). There were no differences in lint percentage among the three row patterns. Overall lint yields were higher in 2006 (1536 kg ha^{-1}) than in 2007 (687 kg ha^{-1}) (data not shown.), mainly due to differences in weather. In 2007, because of cool and wet conditions during July (Table 1), square retention was drastically reduced, especially in the middle part of the plant, resulting in lower lint yields. Lint yields were higher with plant populations ≤ 130,000 plants ha^{-1} in 38-cm rows compared to 126,000 plants ha^{-1} in 102-cm rows. However, lint yields were not significantly different among plant populations ≤ 170,000 plants ha^{-1} in 38-cm rows, 99,000 to 217,000 plants ha^{-1} in 25-cm paired rows, and 126,000 plants ha^{-1} in 102-cm rows. Lint yields ranged from 1049 to 1304 kg ha^{-1} in 38-cm rows and 962 to 1110 kg ha^{-1} in 25-cm paired rows compared to 990 kg ha^{-1} in 102-cm rows (Figure 2). Other researchers have reported a similar seed cotton yield for cotton grown in 38-cm and 101-cm rows under non-irrigated conditions (Nichols et al., 2004). In the present study, a 32% higher lint yield in 38-cm rows at a plant population of 106,000 plants ha^{-1} compared to conventional 102-cm rows at a plant population of 126,000 plants ha^{-1} indicated that the 38-cm row cotton production system is an agronomically feasible option for farmers. The increase in lint yield in 38-cm rows was mainly due to a greater number of open bolls compared to 102-cm rows (8.8 vs. 5.6 bolls per plant, respectively). This may have been due to better plant spacing within the row (more space per plant) compared to 102-cm wide rows.

Table 3. Effect of row spacing on cotton lint yield, lint percent, and open bolls per plant under non-irrigated environment in 2006 and 2007 at Stoneville, MS

Row pattern[z]		Lint yield (kg/ha)	Lint percent (%)	Open bolls (no./plant)
Row width	Cotton population (plants/ha)			
38-cm solid	106,000	1304	39.4	8.8
	111,000	1211	38.2	7.9
	130,000	1261	39.0	7.1
	170,000	1189	39.8	4.9
	215,000	1049	39.5	3.6
25-cm pair	99,000	1077	38.7	7.8
	117,000	962	39.3	6.1
	142,000	1110	38.9	5.5
	164,000	1036	40.2	4.6
	217,000	1038	39.5	3.5
102 cm	126,000	990	39.0	5.6
LSD (0.05)		210	ns[y]	1.2

[z] Data is averaged across 2006 and 2007.

[y] ns, not significant.

Figure 2. Cotton grown in 38-cm rows (top) and 25-cm paired rows (middle) produced higher lint yield compared to cotton in 102-cm rows (bottom). Increased lint yield in 38-cm rows and 25-cm paired rows was mainly due to greater number of open bolls per plant compared to 102-cm rows. Photos taken from a non-irrigated study in 2006.

Table 4. Effect of row spacing on cotton canopy closure under irrigated environment in 2006 and 2007 at Stoneville, MS

Row pattern		Cotton canopy closure (%)								
		2006				2007				
Row width	Cotton population (plants/ha)	9 WAP[z]	10 WAP	12 WAP	13 WAP	7 WAP	8 WAP	9 WAP	10 WAP	11 WAP
38-cm solid	93,000	98	100	100	100	80	100	100	100	100
	105,000	100	100	100	100	88	100	100	100	100
	124,000	100	100	100	100	90	100	100	100	100
	167,000	100	100	100	100	91	100	100	100	100
	220,000	100	100	100	100	100	100	100	100	100
25-cm pair	90,000	60	90	100	100	65	80	93	100	100
	115,000	63	88	98	100	65	83	95	100	100
	136,000	65	90	100	100	65	80	100	100	100
	155,000	73	95	100	100	73	85	100	100	100
	194,000	75	95	100	100	78	88	98	100	100
102 cm	127,000	45	65	90	100	40	60	80	90	100
LSD (0.05)		10	7	2	-	9	4	4	0	-

[z] WAP, weeks after planting cotton.

Irrigated study. Cotton canopy closed 100% by 10 WAP in 38-cm rows and 12 WAP in 25-cm paired rows compared to 13 WAP in 102-cm rows in 2006 (Table 4). In 2007, canopy closure occurred 8, 10, and 11 WAP in 38-cm row, 25-cm paired row, and 102-cm row cotton, respectively. Similar to the non-irrigated environment, the canopy in irrigated cotton closed 1 to 3 wk earlier in 38-cm rows and 25-cm paired rows compared to cotton in 102-cm rows in both years.

Plant population at harvest ranged from 93,000 to 220,000 plants ha^{-1} in 38-cm rows and 90,000 to 194,000 plants ha^{-1} in 25-cm paired rows compared to 127,000 plants ha^{-1} in 102-cm rows (Table 5). The lint percentage was similar between 25-cm paired and 102-cm row cotton, but was slightly decreased in 38-cm row cotton compared to 102-cm row cotton. Lint yields were higher in 38-cm rows compared to 102-cm rows. There were no differences in lint yield between 25-cm paired row and 102-cm row patterns. Similar to the results observed in the non-irrigated study, lint yields under the irrigated environment were also higher in 2006 (1981 kg ha^{-1}) than in 2007 (1220 kg ha^{-1}) (data not shown.). The cool and wet conditions during July 2007 were not favorable for good square retention. Lint yields ranged from 1580 to 1864 kg ha^{-1} in 38-cm rows and 1448 to 1519 kg ha^{-1} in 25-cm paired rows compared to 1413 kg ha^{-1} in 102-cm rows. Cotton plant population of 93,000 plants ha^{-1} in 38-cm rows produced 24% higher lint yield than cotton in 102-cm rows, suggesting a yield advantage for the 38-cm row cotton production system. Increased lint yield in 38-cm row cotton compared to 102-cm row cotton was mainly due to a greater number of open bolls (12.7 vs. 7.0 bolls per plant, respectively).

Table 5. Effect of row spacing on cotton lint yield, lint percent, and open bolls per plant under irrigated environment in 2006 and 2007 at Stoneville, MS

Row pattern[z]		Lint yield (kg/ha)	Lint percent (%)	Open bolls (no./plant)
Row width	Cotton population (plants/ha)			
38-cm solid	93,000	1756	37.5	12.7
	105,000	1864	37.6	11.8
	124,000	1857	38.1	10.3
	167,000	1749	38.2	7.0
	220,000	1580	38.3	5.2
25-cm pair	90,000	1457	38.0	10.7
	115,000	1519	39.1	8.5
	136,000	1496	39.3	6.9
	155,000	1468	38.8	6.2
	194,000	1448	39.1	4.9
102 cm	127,000	1413	40.0	7.0
LSD (0.05)		333	1.3	1.6

[z] Data is averaged across 2006 and 2007.

Results of this study indicate that cotton grown in 38-cm rows and 25-cm paired rows with lower plant population (≤ 106,000 plants ha^{-1}) can close canopy 1 to 4 wk earlier and produce yields equal or 24 to 32% higher than 102-cm row cotton with about 126,000 plants ha^{-1}, regardless of irrigation. A 4 wk earlier canopy closure in 38-cm row than in 102-cm row cotton has the potential to eliminate the need for at least one postemergence herbicide application, although in the present study postemergence applications were made uniformly on all three row patterns for consistency. This study demonstrated that cotton can be grown in 38-cm rows and 25-cm paired rows without compromising lint yield compared to conventional wide-row cotton, regardless of irrigation.

In the lower Mississippi River Valley alluvial flood plain, cotton is predominantly grown on raised seedbeds spaced 91 to 102 cm apart that had been prepared the preceding fall. This Mississippi delta region receives on average 133 cm of rainfall annually of which approximately 50% is received during November through March (Boykin et al., 1995). Cotton production in solid 38-cm rows on flat land (without raised beds) is not convenient for surface drainage in winter and furrow irrigation in summer. The raised seedbeds ensure adequate surface drainage during winter and enable furrow irrigation during summer. Prior to planting, the raised beds can be conditioned by flattening the top and firming up with bed conditioners (e.g., PrepMaster® Bed Conditioner; BB Bigham Brothers, Inc. Lubbock, TX). The conditioned seedbeds (slightly raised flat tops of about 50-cm wide with small furrows) enable cotton planting in 38-cm paired rows and furrow irrigation. Two rows spaced 38 cm apart can be planted on the flat top of the bed with a 64-cm gap between rows. The agronomic and weed-control benefits of cotton production in 38-cm paired rows on 102-cm centers is being investigated in a future study.

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DISCLAIMER

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

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