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Genotypes and Plant Densities for Narrow-Row Cotton Systems. I. Height, Nodes, Earliness, and Location of Yield

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ABSTRACT

Recent yield advances in cotton (*Gossypium hirsutum* L.) have been associated with early fruiting and high harvest index (HI). This study was conducted to examine the effects of plant density in a narrow-row (0.76-m interrow spacing) system on plant morphology, fruiting pattern, and yield of five genotypes that differ in degree of determinacy. 'Acala SJ-2', 'Acala SJC-1', and 2218, 2280, and 2086 (USDA-ARS Shafter short-season germplasm) were grown in a factorial design at 5, 10, and 15 plants m^{-2} in 1984 and 1985. Growth data were collected four times during the season and fruiting data obtained from plant mapping at the end of the season. Genotypes did not differ in plant height until after anthesis, when the most indeterminate genotype (Acala SJ-2) continued vegetative growth longer than the more determinate genotypes 2280 and 2086. Increasing plant density from 10 to 15 plants m^{-2} delayed maturity of the more indeterminate genotypes but had no effect on the shorter, more determinate 2280 and 2086. Genotypes 2280 and 2086 were earlier maturing than the other three genotypes regardless of plant density. Earliness was associated with a lower node number of the first fruiting branch, more rapid production of early main-stem nodes, and increased retention of early fruiting forms. Lint yield decreased 59 kg ha^{-1} for each 0.1-m increase in final plant height between 0.77 and 1.36 m when genotypes were grown at 15 plants per m^{-2}; at densities of 5 and 10 plants m^{-2}, there was no significant relationship between lint yield and plant height across genotypes and years.

HIGH YIELD POTENTIAL of modern cultivars of many agronomic crops is associated with increased HI, although total biomass production is similar to older cultivars (6). Yield improvement of cotton is also associated with increased HI and early fruiting (14,15).

The use of narrow-row, high plant-density systems for cotton production was originally conceived as a means to enhance earliness and to decrease production costs (4). Increasing density reduces the rate of early node production and the final number of main-stem nodes (3,5,7). High plant density decreased plant height in one study (3) but increased final plant height in other studies (1,5). Density effects on earliness have also been inconsistent. Mohamad et al. (11) found that increasing density delayed maturity, while Smith et al. (12) reported that low plant density delayed maturity. Literature regarding the impact of early-season growth rate on earliness also is not in agreement. Ashley et al. (1) reported that early boll set was improved when early-season conditions stimulated growth. Leigh et al. (10) reported that high plant density or early irrigation increased canopy attractiveness to insect pests that feed on squares (flower buds). Loss of early fruiting forms has also been noted in high-density stands with close row spacing when accompanied by cloudy conditions (2).

Yield of cultivars selected for performance in standard row spacings of 1 m was not improved when these genotypes were grown at high plant density in narrow-row systems (4,11,12). Although it is reasonable to expect a genotype × plant-density interaction in narrow-row cotton production, this interaction has not been clearly defined. For example, genotypes with short fruiting branches, early fruiting, and high HI may be better adapted and higher yielding in narrow-row, high-density systems than cultivars selected for production in 1-m row spacing. These studies report the combined effects of plant genotype and plant density on growth, fruiting pattern, and yield of cotton when grown in a narrow-row system.

MATERIALS AND METHODS

Identical experiments were conducted in 1984 and 1985 at the Cotton Research Station, Shafter, CA (35° 32′ N, 119° 16′ W; elevation 131 m), on a Hesperia sandy loam soil (coarse-loamy, mixed, nonacid, thermic Xeric Torriorthent). The experimental design was a factorial combination of five genotypes grown at 5, 10, or 15 plants m^{-2} in four replications. The experimental unit was six rows; rows were 18 m long and were spaced 0.76 m apart.

Acala SJ-2 was the tallest cultivar and considered the most indeterminate genotype, followed by Acala SJC-1. Shafter germplasm 2218 had similar determinacy to Acala SJC-1, while 2280 and 2086 were the shortest, most determinate cultivars in the study. Initial crosses of the three Shafter lines were made by Dr. Angus Hyer between 1972 to 1974. Line 2280 is a cross between T4852 and ACC0266. Line 2086 is a cross between T4852 and CA1786. CA1786 has a very broad-based background, which includes lines from DelCerro, Stoneville, Paymaster, Dekalb, and other Shafter materials as part of its pedigree.

Plots were seeded on 12 Apr. 1984 and 8 Apr. 1985 at high rates, then hand thinned to the appropriate density soon after the first true leaves developed. Nitrogen was applied at 100 kg ha^{-1} during early squaring. Approximately 50 kg ha^{-1} additional N came from irrigation water. Standard commercial practices for cultivation, weed control, and pest management were used on all plots. In 1985, considerable loss of early fruiting forms occurred due to lygus bug (*Lygus hesperus* Knight) feeding.

Seven and six postplanting irrigations were applied in 1984 and 1985, respectively. In 1985, postplanting irrigations were applied at 179, 338, 529, 747, 875, and 996 heat units after planting (HUAP), compared to 221, 457, 712, 829, 983, 1117, and 1198 HUAP in 1984. The earlier irrigations in 1985 in conjunction with lygus bug damage resulted in cotton plants that were more vegetative early in the season than in 1984. Calendar dates for sampling were compared to HUAP to help interpret year differences. Heat units were determined using the single triangulation method with 15.6 °C as the low threshold (16).

Plant height (from cotyledonary node to the terminal apex) and number of main-stem nodes were determined four

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times during the growing seasons from 10 random plants taken from Row 5 of each treatment plot. Cotyledons were counted as Node 0 and the terminal node was that node which had an associated main-stem leaf >25 mm wide. Rows 2 and 3 of each plot were harvested 18 Oct. 1984 and 1 Oct. 1985 with a spindle picker, and seed cotton was ginned to determine lint yield. Earliness was determined by sequentially handpicking a harvest-date subplot 4 m long from the yield rows on three dates each year. The last hand-harvest date was the day prior to machine harvest.

Ten consecutive plants were mapped at the end of the season to determine retention of fruiting positions by node and branch location. Fruiting positions were characterized as having either aborted or retained the fruiting form. Bolls were categorized as immature, mature but not open, or open (lint fluffed sufficiently to be harvestable with a spindle picker). Node numbers were grouped as <9, 9 to 12, or 13 to 20; branch locations were grouped as first position on a sympodial branch (S1), second or greater position on sympodial branch (S > 1), or fruiting position on a monopodial branch (M).

Genotypes and plant densities were a factorial main plot with years as a subplot and sample dates during the season as sub-subplots. Sums of squares associated with replications by years were separated from the error term and included with replications as replications between years. Treatment differences were evaluated using analysis of variance. When the *F* value was significant at $P < 0.05$, the appropriate LSD ($P = 0.05$) was calculated for use in tables. The LSD values are given in the text only for those comparisons that do not have an LSD given in a table.

RESULTS AND DISCUSSION

Plant Height

Averaged over densities and years, genotypes differed in final plant height as follows: Acala SJ-2, 1.30 m; 2218, 1.12 m; Acala SJC-1, 1.06 m; 2086, 0.87 m; and 2280, 0.80 m [LSD (0.05) = 0.04 m]. Averaged over genotypes and years, final plant height averaged 1.05 m, 1.03 m, and 1.01 m for 5, 10, and 15 plants m^{-2}, respectively [LSD (0.05) = 0.04 m]. Averaged over genotypes and densities, final plant height was greater in 1984, averaging 1.08 m compared to 0.98 m in 1985 [LSD (0.05) = 0.03 m]. Averaged across genotypes, densities, and years, mean height at the four sampling dates was 0.26 m at early square, 0.81 m at early bloom, 1.02 m near peak bloom, and 1.03 m at early open boll [LSD (0.05) = 0.02 m]. Attainment of final plant height by early August is consistent with previous results (9).

For plant height, five of the six possible two-way interactions were significant, as were the three-way interaction of genotypes × years × sample dates and the four-way interaction. The two- and three-way interactions are evaluated as part of the four-way interaction (Table 1).

All genotypes and plant densities had similar heights on the first sample date in both years (Table 1). At this early stage, there is little competition between early fruiting forms and vegetative organs for assimilates (8,9). Lines 2280 and 2086, which are the most determinate genotypes, were shorter than Acala SJ-2 by early July. All three Shafter lines reached maximum height by the August sample date. In 1985, when irrigation was terminated at an earlier date than in 1984, Acala SJ-2 and Acala SJC-1 also reached maximum height in August, but in 1984, with a later irrigation, these cultivars continued to grow later into the season. Differential genotype allocation of dry wt. to fruit (8), yearly differences in early boll load, and timing of irrigations contributed to the interaction.

Table 1. Plant heights for five cotton genotypes grown at three plant densities evaluated at four sample dates in 1984 and 1985.

	Sample date		Genotype				
Plants m^{-2}	Date	HUAP†	'Acala SJ-2'	'Acalala SJC-1'	2218	2280	2086
			m				
			1984				
5	12 June	315	0.30	0.22	0.26	0.20	0.28
10	12 June	315	0.30	0.28	0.28	0.22	0.23
15	12 June	315	0.27	0.30	0.25	0.27	0.29
5	9 July	614	0.95	0.85	0.89	0.68	0.77
10	9 July	614	0.91	0.77	0.82	0.65	0.75
15	9 July	614	0.91	0.80	0.77	0.68	0.72
5	6 August	931	1.43	1.09	1.29	0.83	0.87
10	6 August	931	1.38	1.01	1.03	0.81	0.88
15	6 August	931	1.31	1.05	1.08	0.81	0.85
5	4 Sep.	1246	1.47	1.14	1.32	0.84	0.89
10	4 Sep.	1246	1.46	1.13	1.08	0.80	0.84
15	4 Sep.	1246	1.36	1.08	1.08	0.83	0.86
			1985				
5	10 June	288	0.27	0.26	0.22	0.24	0.25
10	10 June	288	0.29	0.29	0.24	0.23	0.25
15	10 June	288	0.27	0.26	0.23	0.22	0.25
5	10 July	611	1.00	0.83	0.85	0.73	0.79
10	10 July	611	0.94	0.85	0.88	0.74	0.79
15	10 July	611	0.86	0.93	0.80	0.70	0.78
5	7 August	893	1.18	0.89	1.15	0.87	0.90
10	7 August	893	1.17	1.05	1.10	0.82	0.84
15	7 August	893	1.18	1.05	1.05	0.81	0.85
5	3 Sep.	1109	1.17	0.99	1.10	0.82	0.80
10	3 Sep.	1109	1.12	1.01	1.06	0.76	1.02
15	3 Sep.	1109	1.20	1.05	1.09	0.77	0.84

† Heat units after planting. Four-way interaction of genotype × density × year × sample date is significant, with LSD (0.05) = 0.10.

The genotypes can be separated into three groups according to impact of density on final plant height. Acala SJ-2 was the tallest. High plant density decreased its height in 1984 but not in 1985, when irrigation was terminated early (Table 1). Acala SJC-1 and 2218 represent intermediate-size plants. Yearly differences in plant height were significant only at 5 plants m^{-2} for 2218 and at 5 and 10 plants m^{-2} for Acala SJC-1. Plant height of the shortest genotypes, 2086 and 2280, was not affected significantly by density or year. The interaction among environment (years in this study), genotype, and plant density may explain in part the inconsistent effects of density on plant height reported in other studies (3,5).

Fruiting Branch Length

Fruiting branch length was determined at the end of the season in 1984 for main-stem Nodes 9, 12, and 15. Branch length was influenced by node number, genotype, and plant density. Branch length averaged 0.18 m at Nodes 9 and 12, compared to only 0.16 m at Node 15 [LSD (0.05) = 0.01 m]. Mean branch length separated into the same three genotypic groups as for plant height: Acala SJ-2, 0.30 m; 2218 and Acala SJC-1, 0.19m; and 2086 and 2280, 0.10 m [LSD (0.05) = 0.03 m]. Plants grown at low plant density had branches that averaged 0.22 m, compared to only 0.16

and 0.15 m for plants grown at 10 and 15 plants m^{-2} [LSD (0.05) = 0.02 m].

Branch length decreased in all genotypes as plant density increased. The amount of decrease, however, was related to the final plant height. There was a linear decrease in branch length of 1.24 cm for each 10-cm decrease in plant height ($r^2 = 0.87$; $n = 5$). For short, compact plant types such as 2086 and 2280, branch length and plant height were less sensitive to plant density and year effects. In more indeterminate genotypes, plant height and branch length were more responsive to year and plant density effects. For example, the fruiting branch length of 2086 averaged 0.11, 0.10, and 0.07 m for plants grown at 5, 10, and 15 plants m^{-2}, compared with 0.37, 0.28, and 0.24 m for Acala SJ-2 at the three plant densities, respectively.

Node number of First Fruiting Branch

Genotypes differed significantly in node number of the first fruiting branch. Averaged across density and years, the first fruiting-branch node was as follows: 2280, 6.2; 2086, 6.3; Acala SJ-2, 6.7; Acala SJC-1, 6.8; and 2218, 7.7 [LSD (0.05) = 0.3]. Density influenced node number of the first fruiting branch only in 1985, when for 5 plants m^{-2} the average node number was 6.4, compared with 7.3 for both 10 and 15 plants m^{-2} [LSD (0.05) = 0.4]. Across all densities, node number of the first fruiting branch averaged 6.4 in 1984 and 7.1 in 1985 [LSD (0.05) = 0.2].

Number of Main-Stem Nodes

Genotypes, densities, years, and sample dates all significantly affected the number of main-stem nodes. There were no significant four or three-way interactions, but all six two-way interactions were significant. Main effects will be discussed as part of the two-way interactions.

Averaged across sample dates, genotypes varied by a range of 1.8 nodes at the lowest plant density, compared to 0.8 nodes at highest density. Genotypes produced an average of one more main-stem node in 1984 than in 1985. Variation between years in number of main-stem nodes was greater for Acala SJ-2 than for 2280 and 2086 (data not shown).

Genotypes differed in rate of main-stem node development (Table 2). Line 2086 produced nodes more rapidly than other genotypes before peak bloom. Acala SJ-2 and Acala SJC-1 produced more nodes between the August and September sample dates, while the three experimental lines reached maximum node number by August.

Averaged across genotypes, node number was similar at the first (10.5 nodes) and last sample date (22.8 nodes) in both years. More nodes were produced by the second (July) sample date in 1985, due to more frequent early irrigation and decreased early boll load compared to 1984.

Table 2. Interaction of genotype (G) × sampling date (SD) and plant density (D) × SD for number of main stem nodes in cotton.

	Sample date			
Genotype	10–12 June	9–10 July	6–7 Aug.	3–4 Sep.
	no.			
'Acala SJ-2'	10.1	18.5	22.4	23.5
'Acala SJC-1'	10.7	19.0	22.3	23.5
2218	10.3	18.8	23.3	23.6
2280	10.4	18.3	21.3	21.7
2086	11.3	19.2	21.8	21.4
G × SD interaction LSD (0.05) = 0.5				
Plants m^{-2}				
5	10.8	19.7	23.3	23.7
10	10.6	18.6	22.1	22.4
15	10.2	18.0	21.3	22.1
D × SD interaction LSD (0.05) = 0.4				

Averaged across genotypes and years, increasing plant density reduced the number of main-stem nodes at all sample dates (Table 2). Density differences were greatest at July. Density had a greater influence on node number in 1984, when plants had more early fruit retention and a late application of the first post-sowing irrigation than in 1985. The effect of density on node development reported here is in close agreement with previous findings (3).

Fruiting Form Retention and Location of Bolls

Averaged across densities and years, the short, compact genotypes 2280 and 2086 produced more total bolls than Acala SJ-2 and 2218 (Table 3). Genotype differences in total boll number resulted from differences in boll retention at main-stem nodes <9 for S1, S > 1, and M (data not shown). Genotype differences at other node and branch locations were either not significant or small. Averaged across densities and years, 2280 and 2086 also had the highest percentage of fruiting positions that matured harvestable bolls at S1 on nodes <9 (Table 4). At higher nodes, genotypic differences were not significant or were small.

Averaged across genotypes and years, the total number of bolls produced was not affected by plant density (Table 3). Increased plant density increased the percentage of total bolls produced at S1 but decreased the contribution of bolls from S > 1 and M. Increasing plant density decreased the percentage of total fruiting forms that produced harvestable bolls from 31.2 to 27.4 and 24.9% for 5, 10, and 15 plants m^{-2}, respectively (Table 4).

Averaged across genotypes and densities, total boll number was greater in 1984 than in 1985, but the opposite was true for the amount of lint per boll (Table 3). At main-stem nodes <9, S1 accounted for 15.7% of all bolls in 1984, compared to only 7.9% in 1985 (Table 3). In 1984, S1 nodes <9 retained 61.5% of the fruiting positions as harvestable bolls compared to only 35.8% in 1985 (Table 4). Years differed in retention by zones, but the whole-plant average for the two years was similar, with 28.5 and 27.2% of all fruiting positions retained as harvestable bolls in 1984 and 1985 (Table 4).

There were no significant interactions between genotypes and plant densities (Tables 3 and 4), but there were some significant interactions between plant densities and years. In 1985, when conditions for early boll set were less desirable than in 1984, plant density had a larger impact on the percentage of bolls set at nodes <9 than it did in 1984.

Several genotype × year interactions were signifi-

Table 3. Influence of genotype, plant density, and year on percent of total cotton bolls by node and branch location, total number of bolls, and boll size.

	Nodes <9			Nodes 9–12			Nodes 13–20			All Nodes			Total bolls m^{-2}	Lint $boll^{-1}$
	S1†	S>1	M	S1	S>1	M	S1	S>1	M	S1	S>1	M		
Genotype	%												no.	g
'Acala SJ-2'	10.0	7.2	1.2	23.2	15.6	2.2	30.8	9.7	0.2	64.0	32.4	3.6	79.5	1.88
'Acala SJC-1'	11.0	9.3	3.2	19.3	16.6	3.7	25.8	10.4	0.8	56.1	36.3	7.7	85.9	1.98
2218	6.3	5.1	2.4	21.7	15.6	5.0	32.7	10.0	1.1	60.7	30.8	8.5	82.2	1.85
2280	16.6	10.6	3.3	22.7	14.1	2.9	22.3	6.8	0.6	61.7	31.5	6.8	95.6	1.76
2086	15.3	10.1	3.0	19.9	13.7	1.9	28.1	7.4	0.7	63.2	31.2	5.6	108.4	1.61
LSD (0.05)	2.3	2.7	1.1	NS	NS	1.4	3.3	NS	NS	5.2	NS	2.5	11.3	0.24
Plants m^{-2} (D)														
5	9.4	11.4	5.1	15.8	17.4	5.9	23.0	10.4	1.5	48.3	39.3	12.5	89.4	1.82
10	11.5	8.2	1.5	23.8	15.4	2.1	28.9	8.1	0.5	64.2	31.7	4.1	92.3	1.80
15	14.7	5.7	1.2	24.4	12.5	1.3	32.0	8.0	0.1	71.1	26.3	2.7	89.3	1.82
LSD (0.05)	1.8	2.1	0.9	3.6	2.5	1.1	2.6	NS	0.6	4.0	4.2	1.9	NS	NS
Year (Y)														
1984	15.7	6.7	2.9	22.0	12.2	3.1	29.2	7.6	0.7	66.9	26.4	6.7	99.5	1.68
1985	7.9	10.2	2.3	20.8	18.0	3.1	26.8	10.2	0.7	55.5	38.4	6.1	81.2	1.95
LSD (0.05)	2.0	1.4	NS	NS	1.9	NS	2.4	2.9	NS	3.9	3.3	NS	5.7	0.25
Interactions														
G × D	no	no	no	no	no	no	no	no	no	no	no	no	no	no
G × Y	yes	no	no	yes	yes	yes	no	no	no	no	no	no	yes	yes
D × Y	yes	no	no	no	no	no	no	no	no	no	yes	no	no	no
G × D × Y	no	no	no	no	no	yes	no	no	no	no	no	no	no	no

† S1 = first position on a sympodial branch; S > 1 = second or greater position on a sympodial branch; M = fruiting position on a monopedial branch.

cant (Tables 3 and 4). Total number of bolls and lint per boll were similar for Acala SJ-2 in both years; the other genotypes had more bolls in 1984 than in 1985 but less lint per boll in 1985 than in 1984. Early boll set was affected differently by genotype between years. Poor conditions early in 1985 affected all genotypes, however, even under nearly ideal early growth conditions in 1984, Acala SJ-2 set only 40% of these early positions, compared to 81% for 2086. Early S1 boll retention for Acala SJ-2 is at least 60% in 1-m row spacings (9). Low retention of bolls at early fruiting positions by Acala SJ-2 under narrow-row conditions emphasizes the need to identify cultivars that have favorable fruiting patterns for production in narrow-row systems.

Sequential Harvest and Earliness

The 1985 crop had delayed maturity, with 46% of the total yield opening after 17 Sep., compared to only 15% after 22 Sep. 1984. Acala SJ-2, Acala SJC-1, and

Table 4. Influence of genotype, plant density, and year on percent of fruiting positions maturing harvestable cotton bolls by node and branch location.

	Nodes <9			Nodes 9–12			Nodes 13–20			All positions
	S1†	S>1	M	S1	S>1	M	S1	S>1	M	
	%									
Genotype (G)										
'Acala SJ-2'	38.4	18.6	8.4	52.9	19.1	11.1	37.3	9.3	8.0	24.0
'Acala SJC-1'	48.2	27.7	23.0	51.9	24.3	18.3	36.4	12.1	4.0	27.5
2218	37.6	22.6	23.6	49.1	20.4	18.4	37.2	9.1	3.2	22.7
2280	57.6	25.9	35.1	56.2	23.7	19.1	33.1	11.7	15.4	31.9
2086	61.5	28.8	36.9	60.7	21.4	22.0	45.4	13.2	12.6	33.1
LSD (0.05)	8.4	6.3	15.7	NS	NS	NS	4.6	NS	NS	3.1
Plants m^{-2} (D)										
5	56.5	31.1	38.0	63.5	27.8	25.4	46.6	14.8	16.7	31.2
10	45.1	24.8	18.7	55.0	21.3	13.9	36.1	8.9	3.4	27.4
15	44.4	18.3	19.5	43.8	16.3	14.0	30.9	9.5	5.8	24.9
LSD (0.05)	6.5	4.9	12.2	7.4	3.4	9.5	3.5	3.2	8.3	2.4
Year (Y)										
1984	61.5	22.4	22.1	57.2	21.5	12.8	41.9	9.7	5.0	28.5
1985	35.8	27.0	28.6	51.0	22.1	22.7	33.9	12.5	12.3	27.2
LSD (0.05)	6.0	3.5	NS	5.7	NS	8.6	2.9	2.5	NS	NS
Interactions										
G × D	no	no	no	no	no	no	no	no	no	no
G × Y	yes	no	no	yes	no	no	no	no	no	no
D × Y	no	yes	no	no	no	no	yes	no	no	no

† S1 = first position on a sympodial branch; S > 1 = second or greater position on a sympodial branch; M = fruiting position on a monopodial branch.

Table 5. Earliness of cotton harvest as influenced by genotype and density averaged across years.

	Sequential harvest		
Genotype	First (7 Sep.)‡	Second (20 Sep.)	Third† (9 Oct.)
	% total lint yield		
'Acala SJ-2'	28	39	34
'Acala SJC-1'	27	39	34
2218	22	43	35
2280	34	39	27
2086	41	36	23
LSD (0.05)	5	3	4
Plants m^{-2}			
5	32	39	29
10	32	39	28
15	27	40	32
LSD (0.05)	4	NS	3

† Genotype × density interaction significant at $p = 0.05$.
‡ Mean harvest date.

Table 6. Lint yield as influenced by genotype (G), plant density (D), and year (Y).

		Genotype				
Density	Year	'Acala SJ-2'	'Acala SJC-1'	2218	2280	2086
		kg ha^{-1}				
Plants m^{-2}						
5	1984	1497	1604	1440	1313	1367
10		1483	1571	1602	1487	1583
15		1255	1537	1481	1541	1621
5	1985	1279	1357	1355	1609	1543
10		1477	1362	1282	1547	1565
15		1357	1405	1335	1555	1629

The following factors were significant at LSD (0.05): G = 72, Y = 41, G × Y = 82, and G × D × Y = 142.

2218 were later than the short, compact 2280 and 2086 (Table 5). Plants grown at 15 plants m^{-2} were delayed in maturity, compared to 5 or 10 plants m^{-2}.

The genotype × density interaction was significant for the percentage of total yield in the third harvest. The two shortest genotypes, 2280 and 2086, both averaged 25% of their lint yield from the latest harvest, regardless of plant density. The tall Acala SJ-2 and 2218 averaged 31% of their yield from the last harvest when grown at either 5 or 10 plants m^{-2} but 41% at the highest density. These results are not in agreement with the findings of Smith et al. (12), who reported that low plant density delayed maturity of commercial cultivars grown under 1-m row spacing. Our results are consistent with the findings of Mohamad et al. (11), who reported delayed maturity with increasing plant density for full-season, indeterminate cultivars but not for early, more determinate cultivars grown under 0.51-m row spacing.

Lint Yield

Lint yields averaged 1468 kg ha^{-1} in this two-year test. Yields were slightly higher in 1984, averaging 1492 kg ha^{-1} (compared to 1444 kg ha^{-1} in 1985). Year differences were small, even though early boll retention was poorer in 1985 (Tables 3 and 4). Favorable late-season weather in 1985 provided sufficient time for the late crop to develop fully, which compensated for poor early boll retention. This compensation supports the conclusions of Ungar et al. (13) that yield recovery from early fruit loss is possible when the growing season is sufficiently long. Economic impact from delayed maturity could still result if harvest conditions deteriorated enough to reduce fiber quality.

The three-way interaction effects of genotypes, densities, and years on lint yield were significant (Table 6). Genotypes 2086 and 2280 had the highest yield in both years at 15 plants m^{-2}. Acala SJC-1 was not affected by plant density in either year, while the best density for Acala SJ-2 in 1984 gave the lowest yield in 1985.

Yield was related to final plant height only at 15 plants m^{-2}. Final plant height of genotypes grown at high density ranged from 0.77 to 1.36 m and lint yield varied from 1255 to 1629 kg ha^{-1}. Lint yield increased 59 kg ha^{-1} for each 0.1-m reduction in final plant height ($r^2 = 0.76$, $n = 10$).

Short genotypes were not superior to tall ones at low plant density. This result may reflect the lower leaf-area index and reduced biomass of short genotypes, which was most apparent at low plant density (8). At 15 plants m^{-2}, however, their smaller plant size was not a disadvantage. Increased dry-matter partitioning to fruit (8) resulted in higher lint yield for the more determinate genotypes used in this study, while at the same time providing earliness.

CONCLUSIONS

Plant size and earliness of large, indeterminate cultivars were strongly influenced by environment, while short, compact cultivars varied much less across plant densities and years.

At least three factors were associated with earliness of 2086: low node number of the first fruiting branch, more rapid early node production, and increased retention of fruiting forms. These attributes resulted in a larger early boll load, which slowed subsequent node production and controlled plant height (8). Imposing stress by withholding irrigation (as is done at present to control excess early growth of more indeterminate commercial cultivars grown in row spacings of 1 m) is neither necessary nor desirable for short, determinate cultivars grown in narrow-row spacings.

When grown at high plant density in 0.76-m row spacings, commercial Acala cultivars had delayed maturity and equal or decreased yield. Yield of more determinate cultivars, however, was highest at high plant densities, without a loss of earliness. For irrigated cotton in California, cultivar screening for yield in narrow-row cotton production systems should be done at plant densities near 15 plants m^{-2} and early-season growth-limiting stresses should be avoided.

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