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Response of an F_1 Interspecific (*Gossypium hirsutum* L. × *G. barbadense* L.) Cotton Hybrid to Plant Density in Narrow Rows[1]

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ABSTRACT

The production of cotton hybrids and the narrow-row high plant population cultural system are two approaches to counteract increasing costs of cotton production. We conducted research during the 1979 and 1980 seasons to evaluate the yield response of an adapted high yielding prototype interspecific cotton hybrid (NX-1) to three plant densities 40,000, 80,000 and 120,000 plants/ha) in 68-cm rows. A fertile isoline (B-line) of the higher yielding parent and 'Acala 1517-75' were included as checks. Field treatments were distributed in a split-plot arrangement with four replications on a soil classified primarily as a fine, montmorillinitic, thermic typic torrert. NX-1 and the B-line commenced blooming 9 days earlier than Acala 1517-75. Cumulative flower production curves for the first 3 weeks of blooming showed NX-1 and the B-line were significantly superior in blooming rate to Acala 1517-75. Flower production also increased with increasing plant density. Independently of year or plant density, lint yields of the hybrid were significantly superior to those of the check genotypes. On the average, NX-1 yielded 41 and 56% more lint than the B-line and Acala 1517-75, respectively. The highest yield was obtained with 120 000 plants/ha and the lowest with 40 000 plants/ha. The genotype × plant density and year × plant density interactions were not significant. The maximum yield potential of this hybrid was not necessarily obtained with 120 000 plants/ha. Boll traits and fiber properties were not influenced by plant densities. Compared to the checks, NX-1 is characterized by smaller bolls with fewer seeds, lower lint percentage, and by a higher seed index. NX-1 fiber is equal to that of Acala 1517-75 in fineness, but is longer and stronger.

Additional index words: **Heterosis, Early maturity, Hybrid vigor.**

THE cotton producer is beset by constantly rising production costs without corresponding increases in returns for lint and seed produced. Yield improvement without increased cultural costs is necessary to reestablish profit margins for farmers and to retain the competitiveness of cotton fiber. Among the most promising approaches to accomplish this production objective are the commercial development of cotton hybrids and the narrow-row, high plant population cultural system.

Commercial exploitation of F_1 cotton hybrids now hinges on economical F_1 seed production. NX-1, an interspecific cotton hybrid (*Gossypium hirsutum* L. × *G. barbadense* L.) developed in New Mexico, was released in 1979. Cumulative variety test results, including 32 individual tests at eight locations in four seasons, showed NX-1 was earlier blooming, and yielded significantly more than Acala 1517-75. It was also superior to Acala 1517-75 in fiber length and strength.[3]

Producing cotton at higher plant populations in narrow rows has been suggested as one way to increase yields without increasing production costs (7, 9, 13). Recent investigations (8, 13, 17) have shown that the maximum leaf area index is higher and is obtained earlier in the season with narrow row culture. Others have shown that light interception and net photosynthesis depend on leaf area development (16, 17, 25, 26).

The number of flowering sites and blooms per unit area is usually higher with more dense, but uniformly distributed plant spacing. With more plants per unit ground area, fewer bolls per plant are required to attain a particular yield level. The best results with 50 cm narrow rows have been obtained with plant densities about double those used in conventional 100 cm rows (16). Johnson, Walhood, and West (17) found the narrow-row, high-population system (117 000 plants/ha) yielded 24% more than the conventional spacing, low-population system (59 000 plants/ha). In the Imperial Valley of California, Robinson and Cudney (23) reported maximum yields at a population of 240 000 plants/ha.

In the San Joaquin Valley of California, the best performance was obtained with a row spacing of 50 cm flat-planted, or with two rows, 25 to 35 cm apart, on 100-cm beds (10, 11, 12). At equivalent plant densities Buxton, et al. (7) reported 11% more seed cotton from two rows per bed than one row per bed. In New Mexico, Saifi (24), Aden (1) and Davis et al. (9) showed that both narrow single rows (48 to 62 cm apart) and double rows (15 cm apart on 102-cm beds) increased lint yield, compared to the conventional 96 to 102 cm row spacing. At equidistant spacing configurations, Fowler and Ray (13) in Texas showed population levels of 79 000 and 155 000 plants/ha (36 and 25 cm spacings, respectively) matured earlier and produced higher yield than population levels on either side of this range.

Another reason for the interest in narrow-row high plant population cotton culture is its theoretical advantage for improving earliness of maturity without reducing yield (19). Many investigators (7, 8, 13, 21) have reported the combination of narrow rows and high plant densities produced more blooms than cotton grown in conventional rows. A high flower production rate early in the growing season is an important factor in promoting earliness and once-over harvesting. Several workers (2, 3, 25) reported that cotton grown in narrow rows is earlier than check planting in standard row widths; however, several others (13, 14, 18) have found no evidence that the narrow row system increased earliness.

This research was undertaken to determine how plant density in narrow rows influences performance of NX-1, a high-yielding prototype of interspecific hybrid cotton.

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MATERIALS AND METHODS

This research was conducted at the Plant Science Research Center of New Mexico State University in Las Cruces during the 1979 and 1980 crop seasons. The NX-1 interspecific hybrid, and B-line strain 5-1 and Acala 1517-75 as checks, were evaluated at three plant populations: 40 000, 80 000 and 120 000 plants/ha. These populations represent within-the-row plant spacings of 36, 18 and 12 cm, respectively, planted on 68-cm (27 in) rows. In both seasons a 3 × 3 factorial treatment design in a split-plot arrangement was employed. Genotypes were assigned to the main plots and plant populations to the sub plots. Whole plots (main plots) were arranged in a randomized block design with four replications.

NX-1 is an F_1 interspecific cotton hybrid (*Gossypium hirsutum* L. × *G. barbadense* L.). It blooms earlier than Acala 1517-75, and has a high yielding potential.[3] B-line strain 5-1 is the fertile line isogenic to the cytoplasmic male sterile A-line female parent of the hybrid. It is an early maturing, short-statured cotton. Acala 1517-75 is the leading cultivar in New Mexico(20).

The experiments were conducted on a soil classified primarily as a fine, montmorillonitic, thermic typic torrert. The 1979 experiment was planted on 12 May and the 1980 experiment on 14 May. A uniform rate of 50 kg of phosphorus/ha (preplant) and 110 kg nitrogen/ha (at approximately first square stage) was applied each season. The planting rate was about four times the amount of seed needed to obtain the desired plant density. Desired plant populations were established by hand thinning. Four post-planting flood irrigations were applied. Plot size was four 68-cm rows 8 m long.

Data recorded included earliness in blooming, flower production, lint cotton yields, boll characteristics, and fiber properties. Earliness in blooming was measured as the number of days from planting to first flower. Cumulative flower production was recorded from the two center rows of each plot for the first 25 days after blooms first appeared and was also used as a measure of earliness and fruiting capacity. The two center rows of each plot were spindle harvested once with a single-row International Harvester spindle picker. This machine has adequate clearance to pick plots of 68 cm rows if harvesting is begun on the outside row with the machine oriented so that the guide wheel is outside the unpicked area. Boll samples consisting of the seed cotton taken from 20 bolls per plot were harvested from two replications to determine boll characteristics and fiber properties. Boll characteristics measured were boll weight (in grams), lint percent, seed index, lint index and number of seeds per boll.

Lint percent was determined as the mass of lint fibers ginned from a seed cotton sample, expressed as a percentage of the total weight of the seed cotton sample before ginning. Seed index was the mass of 100 ginned seed, in grams, and lint index is the amount of lint fiber ginned from 100 seed.

Fiber property determinations were made in the New Mexico State University Fiber Laboratory. Fiber analyses included 50 and 2.5% span length, fiber strength (T_1), elongation (E_1) and fiber fineness. The 2.5% and 50% span lengths are the lengths in mm of the longest 2.5% and 50% of the fibers in the sample as measured by scanning on the digital fibrograph. Fiber strength (T_1) was measured as the units of force in millinewtons required to break a sample of fibers in stelometer clamps, spaced 3.175 mm (⅛ in) apart. The force measurement is divided by the linear density of the fiber (Tex) which is expressed as mass in mg/m to give a strength reading in mN mg^{-1} m^{-1}. Elongation is also recorded on the stelometer in units which give a relative coefficient of stretching of the fibers at the point of breakage under the application of a steady force. Fiber fineness is measured on the micronaire instrument, and is expressed in terms of the resistance to uniform air flow of a sample of specified mass, and expressed in micronaire units. Samples of coarser fiber have less resistance to air flow for a specified mass of fibers and give higher readings.

A combined analysis of variance including years, genotypes, and plant densities was performed to determine the magnitude of the two and three-factor interactions. Duncan's multiple range test was employed to determine differences among treatment means.

Table 1. Effect of years and plant population on lint yield of three cotton genotypes.

	Genotype			
	NX-1	B-Line	A.1517-75	Average
	kg/ha			
Year				
1979	1 260	1 032	656	983 b*
1980	1 584	990	1 170	1 248 a
Plants/ha				
40 000	1 260	849	765	958 c
80 000	1 400	1 022	977	1 133 b
120 000	1 608	1 162	997	1 255 a
Avg.	1 422 A†	1 011 B	913 B	

* Means followed by the same lower case letter are not statistically different at the 1% level of probability according to Duncan's multiple range test.

† Genotype means followed by the same upper case letter are not significantly different at the 5% level of probability according to Duncan's multiple range test.

RESULTS AND DISCUSSION

Flower Production. Large differences for earliness in blooming among genotypes were found in both seasons. On the average, the NX-1 interspecific hybrid and the B-line bloomed 9 days earlier than Acala 1517-75. In both seasons early floral production of NX-1 and the B-line was far superior to the Acala 1517-75 blooming rate. During the first 3 weeks of blooming, both the hybrid and the B-line produced four times more blooms than Acala 1517-75. This early blooming advantage is an important plant characteristic for cotton production areas with short growing seasons.

In both seasons, flower production of the three genotypes increased as plant population increased from 40 000 to 80 000 plants per ha. The largest increases were shown by the earliest genotypes, NX-1 and the B-line. In the 1979 season, there was an additional flower production increase by the hybrid and B-line when plant density was raised from 80 000 to 120 000 plants/ha. In 1980, there was no response in flower production to plant populations above 80 000 plants/ha.

Lint Yield. Highly significant differences between years and genotypes for lint cotton yield were measured. Although both seasons had below average temperatures, the 1980 crop season had 3% more total heat units than the 1979 season. Averaged over years and plant densities, lint yield of the hybrid was significantly higher than the yield of either check.

Table 2. Boll characteristics of three cotton genotypes as affected by year and plant population.

Factor	Boll size	Lint percent	Seed index	Lint index	Seed/ boll
	g		g/100	g	#
Year					
1979	6.30 a	37.9 a	12.8 b	7.88 a	30.5 a*
1980	5.94 a	37.4 a	13.8 a	8.27 a	27.0 b
Genotype					
NX-1	5.45 b	37.1 b	14.0 a	8.29 a	24.4 b
B-line	6.46 a	37.0 b	13.3 b	7.80 a	30.7 a
A. 1517-75	6.46 a	38.8 a	12.7 c	8.13 a	31.2 a
Plants/ha					
40 000	6.18 a	38.0 a	13.3 a	8.28 a	28.6 a
80 000	6.28 a	37.5 a	13.3 a	8.00 a	29.7 a
120 000	5.92 a	37.4 a	13.3 a	7.93 a	28.1 a

* Means followed by the same letter are not significantly different at the level of probability using Duncan's multiple range test.

The checks were not significantly different from each other.

In both years of testing, lint yields increased as plant density increased (Table 1). Averaged over seasons and genotypes, the highest plant density (120 000 plants/ha) yielded 11 and 31% more than yields of medium (80 000 plants/ha) and low (40 000 plants/ha) plant populations, respectively. Since there is no evidence that maximum yields were obtained with a plant density of 120 000 plants/ha (plants spaced 12 cm apart), it is possible that greater plant densities may have resulted in higher yields as suggested by the findings of Davis et al. (9).

The year × plant density and the genotype × plant density interactions were not significant. Thus, when these genotypes are tested under the range of plant populations considered in this research, the same yield differences in favor of the hybrid and the high plant density would be expected.

In spacing-population studies, Acala cultivars have proven to be quite sensitive to crowding (17). In very close spacing, the Acala types tend to excessive vegetative growth and fail to set a good crop. Previous research (unpublished data) has shown NX-1 grows slightly larger than the Acala 1517-75 cultivar. There was no a priori reason to suspect that it would adapt to narrow rows or high populations. In these experiments an early and rapid rate of blooming and boll setting seemed to hold vegetative growth of the hybrid within manageable limits and contribute to its adequate adaptation to the narow-row high plant population system

Boll Characteristics. The interspecific hybrid had smaller bolls, fewer seed per boll, and larger seed than either Acala 1517-75 or the B-line (Table 2).

Significant differences in seed index and number of seeds per boll were measured between years (Table 2). In 1979 there were more and smaller seeds per boll than in 1980. This may be the result of temperature differences during the boll set and boll maturation period between seasons. Mid-summer temperatures in 1980 were higher than in 1979 and near the highest ever recorded.

Boll characteristics were not affected by the range of plant population used. These results do not agree with the findings of many researchers (4, 5, 6, 7, 13, 15, 22) who found regular decreases in boll size, seed

Table 3. Effect of year and plant density on fiber properties of three cotton genotypes.

Factor	Span length 50%	Span length 2.5%	Micro- naire	Elonga- tion	Strength
	mm	mm	units	units	mN/Tex
Year					
1979	13.7 b	28.7 b	3.72 a	6.97 b	232 b*
1980	14.7 a	30.0 a	3.99 a	7.75 a	262 a
Genotype					
NX-1	14.7 a	31.7 a	3.64 b	8.23 a	258 a
B-line	14.2 ab	27.4 c	4.15 a	7.45 b	257 a
A.1517-75	13.7 b	28.7 b	3.78 b	6.41 c	226 b
Plants/ha					
40 000	14.2 a	29.5 a	3.83 a	7.38 a	246 a
80 000	14.5 a	29.7 a	3.93 a	7.45 a	248 a
120 000	14.0 a	29.0 a	3.81 a	7.25 a	246 a

* Means followed by the same letter are not statistically different at the 1% level of probability according to Duncan's multiple range test.

index, lint index, and number of seed per boll as the number of plants/ha increased. Fowler and Ray (13) reported boll characteristics were all reduced as plant spacing decreased. Our results may reflect the relatively narrow range of plant populations tested.

Fiber Properties. The hybrid had the longest and finest fiber with the greatest elongation value as compared to Acala 1517-75 and the B-line (Table 3). The B-line had the shortest and coarsest fiber. The hybrid and the B-line produced the strongest fiber. As a result of better climatic conditions during boll maturation, fiber quality values were higher in 1980 than in the 1979 crop season.

Plant population did not influence fiber properties (Table 3). These results agree with the findings of many investigators (1, 3, 4, 18, 22, 25).

CONCLUSION.

NX-1, an interspecific hybrid with high potential yield, was shown to maintain its superiority over two check varieties when planted in 68 cm narrow rows over three different levels of plant population ranging from 40 000 to 120 000/ha. This hybrid has earlier onset and a more rapid rate of blooming when compared to commercial Acala 1517-75. The prolificacy of the hybrid is believed to play an important role in enabling it to adapt satisfactorily to the higher level of plant population.

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