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Yield, Fiber, and Spinning Performance of Interspecific Cotton Hybrids Having a Common Parent[1]

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ABSTRACT

'Pima S-5' (*Gossypium barbadense* L.) was crossed as a common male parent onto 13 upland cotton (*G. hirsutum* L.) genotypes. The F_1's, along with 'Coker 310' and Pima S-5 as checks, were grown in 1976 and 1977 to evaluate their yield, fiber, and spinning performance. The lint yield mean over 1976 and 1977 for the hybrids as a group was significantly higher than that of Pima S-5. In 1977, 10 hybrids produced essentially the same yield as Coker 310; three produced less. Boll size for all hybrids was intermediate between that of Coker 310 and Pima S-5 while lint percentage was lower than both. Fiber lengths (2.5 and 50% span lengths) of the hybrids were the same as or longer than Pima S-5. All hybrids had stronger fiber than Coker 310, and some produced fiber as strong as Pima S-5. Fiber elongation and uniformity index differences were not detected. Spinning tests of yarn and thread from lint of the hybrid ms_5ms_6 × Pima S-5 showed a slight advantage for percent elongation, percent uniformity, and number of thin places/1000 m as compared to Pima. However, this hybrid was slightly lower in yarn and thread tenacity. Number of thick places and nep count/1000 m were higher in the yarn from the hybrid, but they were lower in the thread from the hybrid as compared to Pima. Thread color and appearance, following a dyeing test, were similar in both types of cotton. The higher number of neps in the yarn from the hybrid might be partially attributed to saw ginning of its seed cotton and to the low fiber maturity characteristic of this hybrid. Nine hybrids possessed fibers with narrow diameters coupled with fiber maturity comparable to Pima and would be expected to give similar spinning performance for neppiness.

Additional index words: **Gossypium barbadense L., G. hirsutum L., Lint yield, Lint percentage, Boll size, Yarn and thread, Fiber length, Fiber strength, Tenacity, Neps, Dyeing, Micronaire, Fiber fineness, Fiber maturity.**

HETEROTIC effects in interspecific cotton hybrids between *Gossypium hirsutum* L. × *G. barbadense* L. offer a possibility for achieving progress in cotton production. Previous experiments investigating interspecific hybrids indicated an overall tendency for F_1's to possess the high yielding ability of the *G. hirsutum* parents and a close resemblance in fiber properties to those of *G. barbadense* (Ali and Lewis, 1962; Barnes and Staten, 1961; Davis, 1974, 1979; Fryxell et al., 1958; Marani, 1968; Omran et al., 1974; Patel and Patel, 1952; Stroman, 1961). However, the data on fiber fineness and maturity were conflicting. For example, Fryxell et al. (1958) found that some hybrids produced fibers with lower maturity than either parent; whereas, others (notably Pima 32 × 'Acala 1517C') produced normally mature fibers. Barnes and Staten (1961) later studied the same hybrid and found that its yarn strength and nep count approached those expected from commercial Pima cultivars. Recently, Davis (1979) obtained an interspecific hybrid with a micronaire value of 3.2 which was lower than either parent. He attributed the low value to a smaller fiber diameter because the hybrid and its parents were similar in wall thickness.

The cost of producing hybrid cottonseed could be the deciding factor in determining if hybrid cotton is planted on a large scale. In India, the conventional hand emasculation and pollination method was used for the development of a number of intraspecific and interspecific hybrids released for commercial cultivation on a large acreage. In India, manual labor is abundant and inexpensive (Singh et al., 1980). The first hybrid which ushered in the "Hybrid Cotton Era" was an intraspecific cross between two *G. hirsutum* strains. This hybrid was released in 1968 under the name of 'Hybrid-4'. It was followed by a successful extra-long staple interspecific (*G. hirsutum* × *G. barbadense*) hybrid popularly known as 'Varalaxmi'. The technique used in India is impractical in many other cotton producing regions especially where labor costs are high. However, with the recent development of a complete cytoplasmic male-sterile and a genetic fertility restorer system in cotton (Meyer, 1975), commercial production of F_1 hybrid seed is feasible.

From previous studies, fiber of interspecific cotton hybrids appear to have an array of properties different from other fibers marketed in the United States in recent times. For this reason, research should be conducted to evaluate their lint and spinning performance which in turn determines the market value of lint from interspecific hybrids. Such was the objective of the present investigation.

MATERIALS AND METHODS

In 1975, 'Pima S-5' (*G. barbadense* L.) was hand crossed, as a common male parent, onto 13 upland cotton (*G. hirsutum* L.) genotypes: 'Coker 310', 'Coker 201', 'Coker 417', Coker 1104, Coker 72-806, 'Deltapine 16', 'Deltapine 25', 'McNair 612', Pee Dee 9241, 'Dixie King III', 'Stoneville 213', 'Stoneville 603', and a double recessive genetic male-sterile line, ms_5ms_6 (backcrossed predominantly to Coker 201). The 13 F_1 hybrids, Pima S-5, and Coker 310 were grown on the Plant Sciences Farm near Athens, Ga., in 1976 and 1977. Soil type was a Cecil sandy loam (clayey, kaolinitic, thermic Typic Hapludults). The experimental design was a randomized, complete block with four replications. Plots consisted of two rows 3.7 m in length. Rows were spaced 96 cm apart with six equally spaced hills/row. The wide spacing was used because of limited seed. Plants were thinned to two/hill. Planting dates were 23 April and 15 April in the two respective seasons. Because of adequate rainfall in 1976, no supplemental irrigation was necessary; but in 1977, two irrigations (approximately 5 cm water/irrigation) were applied. Other cultural treatments were applied as usual for surrounding cotton farms. Twenty-five fully developed bolls were harvested from each plot and used to estimate boll size and lint percentage. The lint fraction from the 25 bolls from two replications was used for determination of fiber properties. Agronomic characters

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Table 1. Two-year mean performance for agronomic characters and fiber properties of 13 interspecific F_1 cotton hybrids and two check cultivars.

Genotype	Agronomic characters				Fiber properties				
	Lint yield		Lint	Boll	Length			T_1	E_1
	Mean	1977	percent	size	50% SL	2.5% SL	UI	strength	elongation
	kg/ha		%	g/boll	mm		%	mN/tex	%
Coker 310	806	1070	42.1	6.74	14.3	30.5	46.9	211	6.73
Stoneville 213†	777	1168	35.7	5.09	16.2	35.3	45.6	258	8.00
Dixie King III†	676	1011	36.1	5.23	15.5	34.3	45.2	273	7.75
Deltapine 25†	660	941	35.8	4.99	16.1	36.2	44.5	272	7.55
McNair 612†	657	948	35.9	5.03	15.9	35.3	45.0	268	7.65
ms_5ms_6†	656	909	36.2	4.86	15.5	34.3	45.2	274	7.23
Stoneville 603†	652	953	34.0	5.09	15.9	36.0	44.2	271	7.80
Coker 201†	644	954	35.8	5.15	16.1	35.6	45.2	273	7.70
Coker 1104†	639	899	35.5	4.93	16.1	35.4	45.5	267	8.10
Coker 417†	636	917	35.2	4.69	15.9	35.6	44.7	278	7.58
Pee Dee 9241†	623	914	35.1	4.67	15.9	35.5	44.8	278	7.62
Deltapine 16†	600	809	35.9	5.11	16.4	36.3	45.2	259	8.15
Coker 310†	586	872	36.4	4.75	16.2	35.7	45.4	273	7.88
Coker 72-806†	582	877	36.1	4.93	16.5	36.0	45.8	265	7.68
Pima S-5	243	324	38.5	3.41	15.9	33.8	47.0	291	7.96
Hybrids' mean	645	936	35.7	4.96	16.0	35.3	45.1	270	7.75
FLSD (0.05)‡	204	181	0.9	0.57	0.6	0.7	NS	17	NS

† Maternal *G. hirsutum* parent of F_1 interspecific cross with Pima S-5, *G. barbadense*.
‡ For comparisons between individual genotypes.

and fiber properties were statistically analyzed to study the performance of the hybrids over the 2-year period. A preliminary F-test with FLSD was used for comparison procedures (Carmer and Swanson, 1971).

Lint yield/plot was converted into kg/ha. Lint percentage was determined from the 25-boll sample as (lint weight/seed cotton weight) × 100. Boll size was expressed as seed cotton weight in g/boll. Fiber properties were determined by Starlab, Inc. at Knoxville, Tenn. Fiber length was measured as 50 and 2.5% span lengths (SL) on a digital fibrograph and expressed in millimeters. Uniformity index (UI) was calculated as the ratio of (50% SL/2.5% SL) × 100. Strength (T_1), expressed as millinewtons/tex (mN/tex), and elongation (E_1), as a percentage, were measured with the 3.2 mm gauge stelometer.

Shirley FMT tests were made by Cotton Incorporated at Raleigh, N.C., for average fiber diameter (μm), relative wall thickness (percent), linear density (millitex), micronaire equivalent (in standard micronaire units), mature fibers (percent), and causticaire maturity (percent). The lint for these determinations was obtained from the hybrid test conducted in Athens during 1977.

Spinning tests were performed by the Quality Control Laboratory of Coats & Clark Inc., Clarkdale, Ga., on the fiber produced in Athens during 1977. The seed cotton was saw ginned. Coats and Clark is a company manufacturing sewing thread from lint of long-staple Pima cotton. Thread is made by twisting two single strands of yarn together. Physical characteristics, namely, tenacity and elongation, were estimated for both yarn and thread using the Uster Strength Tester. Tenacity was measured as single-end strength of yarn or thread and expressed in mN/tex. Elongation refers to the percent elongation of the fiber bundle at the point of breaking. The Uster Evenness Tester was used to estimate uniformity (percent) of the diameter of yarn and thread. The number of thin places, thick places, and neps (/1000 m of yarn or thread) were measured by the imperfection indicator of the Uster Evenness Tester. A dyeing process was also conducted to test uniformity of color in the dyed threads from the hybrid vs. Pima.

RESULTS AND DISCUSSION

Agronomic Characters and Fiber Properties

The effects of year and genotype were significant for lint yield, lint percentage, and boll size. Effects of years were larger than genotypes for these traits. The year × genotype interaction was significant for lint yield. With high rainfall in 1976, the hybrids grew excessively tall, averaging 170 cm compared to 125 cm for the two check cultivars. The hybrids produced a large number of bolls which failed to open because of cool weather and an early frost, resulting in low lint yields. Due to this reason, the yield comparisons among experimental material in 1976 are not included in this discussion. Conversely, with low rainfall in 1977, hybrids were no taller than the check cultivars, matured as early as Coker 310, and produced higher lint yields than in 1976 (Table 1). In 1977, lint yield for most hybrids was not significantly different than that of the high yielding *G. hirsutum* cultivar, Coker 310. None were significantly higher; three hybrids gave significantly lower yield than Coker 310. Mean lint yield over both years for all hybrids was significantly higher than the lint yield of Pima S-5 and was generally more similar to that of Coker 310. Some hybrids such as Stoneville 213 × Pima S-5 and Dixie King III × Pima S-5 produced a comparatively higher yield in both years and essentially as many kg/ha of lint as Coker 310.

Lint percentage for all hybrids was significantly lower than either Coker 310 or Pima S-5 (Table 1). Boll size of the hybrids was intermediate between those of the cultivars. Hybrid boll size averaged 4.96 g; whereas, Coker 310 and Pima S-5 averaged 6.74 and 3.41 g, respectively.

Genotypic differences were found for fiber length (50 and 2.5% SL) and strength, but not for uniformity index and elongation (Table 1). Fibers of all hy-

Table 2. Spinning performance of the hybrid, ms_5ms_6 × Pima S-5 as compared to Pima cotton.

Character	F_1 hybrid†		Pima‡	
	Yarn	Thread	Yarn	Thread
Size (tex)	9.28	18.46	9.39	18.98
Tensile strength (g)	172.4	462.6	186.0	494.4
Tenacity (mN/tex)	182	246	194	269
Elongation (%)	6.7	5.0	6.3	4.6
Uniformity (%)	14.8	10.9	14.5	10.3
Thin places (/1000 m)	779	96	844	105
Thick places (/1000 m)	1070	227	1017	262
Nep count (/1000 m)	268	31	154	48

† F_1 hybrid was grown in Georgia.
‡ Pima was grown in Arizona.

brids were significantly longer (50 and 2.5% SL) and stronger than Coker 310 fibers. Elongation tended to be greater than Coker 310, but those differences were not statistically significant. Compared to Pima S-5 fibers, 12 hybrids were similar in 50% SL; and one (i.e., Coker 72-806 × Pima S-5) was longer. In 11 hybrids, 2.5% SL was significantly greater than Pima S-5, but did not differ in two others. Mean fiber strength for the hybrids as a group was lower than for Pima S-5, although several (i.e., Coker 417 × Pima S-5 and Pee Dee 9241 × Pima S-5) produced fiber with strength similar to Pima S-5.

Spinning Performance

Because the overall fiber properties of lint from interspecific hybrids are similar to Pima S-5, it is important to determine if lint produced (and ginned) in the Southeastern USA can be competitive with Pima produced (and ginned) at present time in the Southwestern USA. The F_1 hybrid, ms_5ms_6 × Pima S-5, was grown in separate plots at Athens during 1977 to produce sufficient quantities of lint for spinning. A representative lint sample from this hybrid was evaluated in comparison with Pima cotton grown in Arizona. While these results are by no means from a controlled experiment with precise comparisons, they can serve as a general reference point for similarities and differences between cottons from those two parts of the country.

The Quality Control Department at Coats & Clark Inc. reported that the lint from the hybrid ran well in each spinning operation. Results of the spinning tests for the F_1 hybrid vs. a Pima check are shown in Table 2. Yarn and thread, spun using the lint from the hybrid, were slightly weaker in tensile strength than Pima. A reduction in the lint tenacity of the hybrid compared to Pima probably explains most of the reduction in the yarn and thread tenacity of the hybrid. On the other hand, elongation which refers to the amount of stretch at the point of breaking was higher in the yarn and thread of the hybrid than in Pima. Uniformity percent of the diameter of yarn and thread of the hybrid showed an increase over Pima. The hybrid showed a decrease in the number of thin places and an increase in thick places/1000 m of yarn. As to thread, the hybrid showed a consistent decrease in thin and thick places as compared to Pima. Striking differences were found in the number of neps/1000 m; they were higher in the yarn from the hybrid, but lower in its thread, as compared to Pima.

Neps are imperfections (tangles of fibers) that appear as specks in manufactured products. In dyed products the specks are usually lighter than the background and therefore affect the appearance of the dyed fabric. Coats & Clark Inc. went a step further in testing dyeing quality and found that color and appearance following dyeing were similar in threads from the hybrid and Pima. This suggests that lint from a hybrid is suitable for the manufacture of yarn and fabric end-products; but from the standpoint of sewing thread manufactured by Coats & Clark Inc., tenacity and neps are particularly important, and it was concluded that Pima cotton is preferable for that use. This preference was based on the smaller size of neps in Pima, rather than number, because the number of neps in the thread from the hybrid was actually lower than that in the Pima thread (J. G. Lester, Coats & Clark Inc., personal communication).

The release of hybrids to successfully meet spinning and fabric demands will depend on the synthesis of hybrids essentially free from lint or spinning imperfections. In the present study, two situations related to ginning and fiber maturity were presumed to cause the higher nep count in the yarn spun from the hybrid ms_5ms_6 × Pima S-5 compared with Pima. Due to the unavailability of roller gins in the prospective growth area, seed cotton of the hybrid was saw ginned while the Pima cultivars were conventionally roller ginned in Arizona. This is probably reflected in the increased number of neps in the hybrid yarn because roller gins are normally considered more suitable for long-staple cottons. Barnes and Staten (1961) investigated this point in an interspecific hybrid and found that number of neps increased from 11 to 19 (/1000 cm^2 of card web) in roller- and saw-ginned cottons, respectively. The lack of fiber maturity in this particular hybrid will be documented in the next section.

Fineness and Maturity of the Fiber

Immature fibers, with thin or almost no secondary wall thickening, are the chief cause of neps. Three lint samples of each hybrid as well as the Pima S-5 and Coker 310 checks from material grown at Athens during 1977 were evaluated by Cotton Incorporated at Raleigh, for fineness and maturity measurements. Results are shown in Table 3. Fiber diameter is a measure of biological fineness with narrow and wide diameters standing for fineness and coarseness, respectively. Micronaire value and linear density denote fiber fineness and maturity in combination. Low estimates of relative wall thickness, causticaire maturity, and percent mature fibers are indications of immaturity. The data show that the hybrid ms_5ms_6 × Pima S-5 was significantly coarser in fiber diameter, but less mature than Pima S-5. This hybrid also showed the same trend when compared to many of the other hybrids. In that respect, a classification was made to group those hybrids with essentially equal

Table 3. Mean fiber fineness and maturity measurements for 13 interspecific F_1 cotton hybrids and two check cultivars.

Genotype	Average fiber diameter	Micronaire	Linear density	Wall thickness	Causticaire maturity	Mature fibers
	μm	units	millitex		%	
Coker 310	18.1	4.80	222	67.7	86.4	74.3
Pima S-5	17.5	3.86	195	58.5	78.3	62.5
		Group A hybrids				
Coker 310†	16.9	3.92	196	59.3	79.2	63.7
Stoneville 213†	17.7	3.85	199	57.7	77.0	60.7
Deltapine 25†	17.5	3.76	193	57.3	77.3	61.0
McNair 612†	17.3	3.76	186	57.3	77.5	61.3
Coker 1104†	17.4	3.74	190	58.0	77.8	61.7
Deltapine 16†	17.9	3.95	206	57.7	76.8	60.3
Dixie King III†	17.7	3.61	192	54.7	74.8	57.7
Pee Dee 9241†	17.7	3.65	192	55.5	75.4	58.0
Coker 72-806†	17.9	3.87	203	57.0	76.2	59.3
Mean: Group A	17.6	3.78	195	57.2	76.9	60.4
		Group B hybrids				
ms_5ms_6†	18.2	3.55	199	51.7	71.6	53.0
Stoneville 603†	17.8	3.44	187	52.3	72.9	54.7
Coker 201†	17.5	3.56	187	54.7	75.3	58.3
Coker 417†	17.8	3.47	189	52.3	73.0	54.7
Mean: Group B	17.8	3.51	191	52.8	73.2	55.2
FLSD (0.05)‡	0.7	0.28	12.4	5.0	4.9	7.3

† Maternal *G. hirsutum* parent of F_1 interspecific cross with Pima S-5, *G. barbadense.*

‡ For comparisons between individual genotypes.

vs. poorer maturity compared to the Pima S-5 check. Two groups, A and B, were defined based on fiber maturity parameters and/or on micronaire values (Table 3). Group A hybrids averaged 60.4, 76.9, and 57.2% for percent mature fibers, causticaire maturity, and relative wall thickness, respectively. Those values, along with the micronaire readings, indicate that the Group A hybrids produced lint comparable to Pima S-5 and would be expected to give better results than the ms_5ms_6 × Pima S-5 hybrid discussed in the previous section, especially in the area of neppiness. Conversely, group B hybrids tended to fall in the class of the ms_5ms_6 × Pima S-5 hybrid due to lower maturity measurements and/or low micronaire values.

Fiber diameter and maturity parameters are not easily followed in cotton marketing channels. However, both fineness and maturity are involved in the micronaire reading which is easy to take, rapid, and accurate; hence, it plays an important role in determining the market value of cotton lint. Kirk et al. (1977) pointed out that an upland cotton producer may safely produce cotton throughout the entire premium range of 3.5 to 4.9 micronaire units; however, the premium range for the long-staple Pima producer is from 3.5 to 4.0 because of the special requirements for fine yarns. They added that the market could not afford to pay the higher prices for long-staple cotton if they were to be used in coarse yarns which could be manufactured more cheaply from shorter staple cotton. Consequently, this premium micronaire range for Pima cotton seemed to be the crucial requirement for interspecific hybrids involving upland × Pima types because fiber lengths of the hybrids reported herein, or by other investigators, were comparable or longer than Pima. Hybrids should be subjected to rigid screening during the various stages of their synthesis for micronaire and its two components, i.e., fineness and maturity. Some interspecific hybrids may have acceptable micronaire values due to wide fiber diameter, but still have low relative wall thickness. For example, the hybrids Coker 310 × Pima S-5 and Coker 72-806 × Pima S-5 (Table 3) had micronaire values of 3.92 and 3.87 (which were not significantly different), but the former possessed a better combination of narrow diameter (significantly different from the latter) coupled with high maturity parameters.

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