Published September, 1974

Synthesis of Commercial F_1 Hybrids in Cotton. I. Genetic Control of Vegetative and Reproductive Vigor in *Gossypium hirsutum* L. × *G. barbadense* L. Crosses[1]

Dick D. Davis[2]

ABSTRACT

The hybrid vigor in *Gossypium hirsutum* L. × *G. barbadense* L. F_1 hybrids is usually associated with late maturity and excessive vegetative growth relative to reproductive development. These undesirable traits tend to limit the range of hybrid adaptability to areas with long growing seasons. Experiments reported herein demonstrate that an early semidwarf *G. hirsutum* line of Yugoslavian, Kekchi, and Acala (YKA) origin produced highly desirable agronomic types of hybrids in crosses with three *G. barbadense* lines. These F_1 hybrids were shorter-statured and as early and productive as the best-yielding locally adapted commercial variety, 'Acala 1517-70.' The YKA parent transmitted dominant factors for early, prolific fruiting to its progeny. The tendency for heavy fruiting early in the season apparently reduced the rate of vegetative growth so that hybrids were relatively short-statured at maturity. The interspecific hybrids required a longer period for boll maturation than did Acala 1517-70. Because the hybrids had fiber 4 to 6 mm longer than the check, it was reasoned that the longer boll period was associated with fiber length and that further advances in earliness might be gained from crossing very short-fibered lines of *G. barbadense* × YKA to produce short-fibered hybrids. Other properties of the hybrids were discussed, and subsequent steps to be taken in the improvement of interspecific hybrids were outlined.

Additional index words: Heterosis, Cotton breeding, Interspecific hybrids, Plant height, Internode number, Internode length, Lint yield, Earliness, Prolificacy, Boll size, Lint percentage, Fiber quality.

THE development of commercial F_1 cotton (*Gossypium hirsutum* L., *G. barbadense* L.) hybrids appears to be feasible since a cytoplasmic male-sterile and fertility-restorer system is now available (Meyer, 1973). Excellent yields of F_1 seed have been obtained in Arizona (Moffett and Stith, 1972; Stith, 1974) and New Mexico (Rosales-Izaguirre and Davis, 1974).

To my knowledge, the highest yields ever attained with cotton hybrids (about 1,900 kg/ha) were from intervarietal F_1 crosses of *G. hirsutum*. The percentage increase over the best adapted Upland variety in those tests was about 16 to 17% (Thomson, 1971). Miller and Lee (1964) have noted that the percentage increase in heterosis tends to be higher at low yield levels; therefore, absolute yield is probably the most important criterion to use in evaluating hybrids.

Striking hybrid vigor in interspecific crosses of *G. hirsutum* × *G. barbadense* was noted over 60 years ago by Cook (1909). The largest absolute (>500 kg/ha) and percentage (>50%) increases in lint yield over adapted cultivars of *G. hirsutum* have been reported for hybrids of this type (Marani, 1967). Both types of hybrid may have certain advantages, as may yet a third type which can be classed as a partial-interspecific or "introgression" hybrid. By species abbreviation these three types may be denoted as *hirsutum* intervarietal (H × H), interspecific *hirsutum* × *barbadense* (H × B) and partial-interspecific or introgressive (H × B-H). The H × B hybrids tend to have outstanding heterosis for prolificacy as measured in number of bolls per unit area (Marani, 1963, 1964; Fryxell, Staten, and Porter, 1958). This trait is offset by several disadvantages, including excessive vegetative vigor (Ware, 1930; Kearney, 1923). Marani, 1964), late maturity (Fryxell et al., 1958; Marani, 1964), and low micronaire (Marani, 1968; Fryxell et al., 1958). I have observed also that these hybrids often have poor plant conformation for machine harvesting.

A sequential problem-solving approach has been taken to find ways to overcome these difficulties so that the heterosis found in H × B crosses can be put to practical use. The research outlined in this paper illustrates how the first two problems (excessive vegetative vigor and late maturity) have been overcome by using an extremely early semidwarf *G. hirsutum* parent.

MATERIALS AND METHODS

An extremely early semidwarf *G. hirsutum* parent derived from materials of Yugoslav-Kekchi and Acala (YKA) origin was used. This parent is an F_6 selection resulting from a cross made in 1967 of CA #491 × Acala 8861. CA #491 was obtained from Levon L. Ray, Research and Extension Center, Lubbock, Texas. 'Pima S-4' used as a parent and check is a commercial cultivar of *G. barbadense*. 'Acala 1517-70,' also used as a check, has been the highest-yielding cultivar in New Mexico in recent years.

P-8 and Pima S-4 L° (okra leaf), two other *G. barbadense* lines used as parents in crosses to YKA, were derived from materials obtained from E. L. Turcotte and C. V. Feaster, Cotton Research Center, Phoenix, Ariz. 'Acala 1517C,' used as a full-sized *G. hirsutum* parent, was the leading cultivar in New Mexico from 1950 to 1965. Its stature and maturity are average for the Acala 1517-type of Upland cotton. It has been used in crosses with *G. barbadense* to produce several high-yielding experimental hybrids (Fryxell et al., 1958; Marani, 1967). The *G. hirsutum* parent designed YKA × A is an experimental strain derived from the breeding program at the New Mexico Agricultural Experiment Station. It was selected as a parental type, intermediate in size and earliness between YKA and Acala 1517C.

From the above lines, five experimental hybrids were made by hand-crossing in 1972. Along with YKA, Pima S-4, and Acala 1517-70, they were evaluated in a field test at the Plant Science Research Center near Las Cruces, N. Mex. in 1973.

The experimental design was an 8 × 8 Latin square. Each entry was a 5.5-m (18-ft) single-row plot, planted on alternate beds. All odd-numbered rows were planted to Acala 1517-70, with the treatments placed on the even-numbered rows. The test entries varied widely in stature and maturity, and the alternate row design was used to provide a uniform background of interrow competition.

The test was planted on May 8 on preformed and preirrigated 96-cm (38-in) beds. The field was a Brazito loamy sand of 25 to 46 cm (10 to 18 in) depth overlying river sand. Immediately after emergence, a sampling subplot 96 × 104+ cm (1 m^2) was

[1] Journal Article No. 514, New Mexico Agricultural Experiment Station, Las Cruces, New Mexico. Received March 19, 1974.

[2] Associate Professor of Agronomy, New Mexico State Universiyt, Las Cruces, NM 88003.

Table 1. Comparisons of hybrids, parents, and a check cultivar for plant height and its components (internode number and internode length).

Entry	Plant height	Internode number	Internode length
	cm		cm
YKA	43.6 c	18.0 b*	2.39 c
YKA × Pima S-4	63.9 b	20.5 ab	3.14 b
(Midparent)	(49.3)	(18.0)	(2.73)
Pima S-4	55.0 b	18.0 b	3.06 b
Acala 1517-70	74.1 a	20.6 ab	3.59 a
YKA × Pima S-4 L^{O}	60.9 b	19.8 ab	3.10 b
YKA × P-8	62.8 b	20.3 ab	3.09 b
Acala 1517C × Pima S-4	82.5 a	21.4 a	3.88 a
(YKA × A) × Pima S-4	74.3 a	19.8 ab	3.78 a

* Means followed by the same letter are not significantly different at the 0.05 probability level according to the Neumann-Keuls test.

delineated in each plot. Plants were spaced as closely as possible to a standard of 1 plant/10 cm for checks and parents and 1 plant/15 cm for hybrids. Only one entry, (YKA × A) × Pima S-4, exhibited poor stands. Measurements and counts were taken at approximately 2-week intervals on every plant within a subplot throughout the growing season. Only five plants per subplot were used to record final plant height and number of internodes on November 15. Data recorded included plant height in cm, number of squares per m^2, number of blooms and bolls per m^2. Seedcotton and lint weights were recorded for the two harvests made on October 15 and November 15. Lint samples from the first picking were tested in the New Mexico Cotton Fiber Laboratory for 2.5% span length, 50% span length, 1/8-in gauge stelometer strength, and E_1 elongation. Micronaire was determined for both harvests since this property is often greatly affected by maturity. Lint percent was calculated for both harvests also, for more accurate determination of yield.

RESULTS AND DISCUSSION

All H × B hybrids in the test were taller at maturity than the *G. barbadense* check, Pima S-4 (Table 1). Hybrids involving YKA as the *G. hirsutum* parent, however, were significantly shorter than Acala 1517-70 and the other two hybrids. For the YKA × Pima S-4 hybrid, comparisons can be made with both parents, the calculated midparent value, and the Acala 1517-70 check. Internode number of YKA × Pima S-4 was equivalent to the Acala check; internode length was greater than that of the YKA parent and midparent value, and essentially equivalent to the Pima S-4 parent, but significantly below the Acala check. The net result was a plant type showing some hybrid vigor for size, but still significantly smaller than commercial Acala. The same was true for the other two YKA hybrids, while the hybrid derived from the medium-statured *G. hirsutum* parent, (YKA × A) × Pima S-4, was identical in size to Acala 1517-70. The hybrid derived from full-sized Acala 1517C was slightly, but not significantly larger than the check. The differences in height in all cases were due to differences in internode length (Ware, 1930; Kearney, 1923).

The two estimates of lint yield and the one of earliness (measured as the percentage of the crop gathered at the first harvest) are shown in Table 2. The hybrid YKA × Pima S-4 exceeded the midparent in all three respects, and was significantly later than YKA. It was almost identical to the Acala check in yield and earliness.

All YKA hybrids were similar, with YKA × P-8 showing a slight, but nonsignificant increase in yield over the check. Pima S-4 normally yields about two-thirds as much as Acala 1517-70. Its relatively poor performance in this test can largely be attributed to the May 8 planting date, which is about 2 weeks late for *G. barbadense* in the Las Cruces area. This comparison emphasizes the fact that YKA-derived H × B hybrids are completely different from *G. barbadense* in rapidity of development and maturity. Although H × B hybrid yields have been reported to be higher than yields of good *hirsutum* cultivars (Marani, 1967), they have not previously demonstrated efficient or rapid production. The Acala 1517C × Pima S-4 hybrid typified the response generally shown by crosses of commercial cultivars between *G. hirsutum* and *G. barbadense*. Marani (1964) found that several interspecific hybrids initiated flowering slightly, but not significantly earlier than their *G. hirsutum* parents, which were of medium maturity. Compared to *G. hirsutum* or full-sized hybrids, the YKA H × B hybrids show the capability to set equal or greater yields on a significantly smaller plant structure. To my knowledge, this type of response has not been previously reported for H × B hybrids.

Table 2. Comparisons of hybrids, parents, and a check cultivar for lint yield and earliness.

Entry	Lint yield	Yield at first harvest	Earliness
	kg/ha		%
YKA	752 a*	667 a	90.1 a
YKA × Pima S-4	896 a	656 a	75.5 b
(Midparent)	(544)	(368)	(54.5)
Pima S-4	337 b	68 c	19.0 d
Acala 1517-70	890 a	654 a	74.9 b
YKA × Pima S-4 L^{O}	949 a	659 a	71.3 b
YKA × P-8	967 a	661 a	71.3 b
Acala 1517C × Pima S-4	778 a	408 b	53.5 c
(YKA × A) × Pima S-4	658 a	419 b	62.9 bc

* Means followed by the same letter are not significantly different at the 0.05 probability level according to the Neumann-Keuls test.

Table 3. Comparisons of hybrids, parents, and a check cultivar for bolls per m^2, boll size, and lint percentage.

Entry	Bolls/m^2	Boll size, g lint	Lint percentage
YKA	41.9 cd*	1.78 b	38.8 a
YKA × Pima S-4	65.8 ab	1.35 c	35.1 b
(Midparent)	(36.2)	(1.43)	(36.8)
Pima S-4	30.5 d	1.08 d	34.8 b
Acala 1517-70	43.9 cd	2.00 a	35.7 b
YKA × Pima S-4 L^{O}	74.3 a	1.28 c	34.2 bc
YKA × P-8	69.4 ab	1.38 c	35.5 b
Acala 1517C × Pima S-4	52.5 bc	1.48 c	33.4 c
(YKA × A) × Pima S-4	51.3 bc	1.29 c	32.4 d

* Means followed by the same letter are not significantly different at the 0.05 probability level according to the Neumann-Keuls test.

The compensations among certain components of yield are illustrated in Table 3. For YKA × Pima S-4, heterosis for yield was apparently due to prolific fruiting. Number of bolls per m^2 was greatly above that of both parents, the midparent, and the Acala check; boll size and lint percent were slightly below the midparent. The other YKA-derived hybrids showed even greater, though not significantly greater response for boll number, while the Acala 1517C and (YKA × A)-derived hybrids fall roughly into a class intermediate between the YKA hybrids and the check.

Reasons for the relative efficiency of the YKA-derived hybrids can be found in following the vegetative and reproductive development of the plants. Table 4 shows the mean plant height during the main period of development for all entries. The hybrid YKA × Pima S-4 exhibits moderate heterosis as compared to its parents at all stages of growth. It grew faster than the Acala check in the early stages, but the Acala overtook the hybrid about July 10 and by early August was significantly taller.

The reason for the midseason decline in growth rate of the hybrid is probably due to rapid fruiting. The

Table 4. Comparisons of hybrids, parents; and a check cultivar for sequential vegetative and fruiting development.

	June 22		July 3		July 17			August 1			August 15		
Entry	Plant height	Squares	Plant height	Squares	Plant height	Squares	Bolls	Plant height	Squares	Bolls	Plant height	Squares	Bolls
	cm	#/m²	cm	#/m²	cm	#/m²		cm	#/m²		cm	#/m²	
YKA	9.7b*	15.3a	18.0c	45.3a	27.4b	54.5a†	23.8a	38.2d	47.5b	39.3a	41.6d	20.8b	41.6ab
YKA × Pima S-4	11.4a	7.8b	22.2ab	39.6ab	33.9a	58.8a†	10.9b	48.8c	58.8ab†	35.6a	53.0bc	17.8b	49.9a
(Midparent)	(7.9)	(7.3)	(16.0)	(23.7)	(26.3)	(33.1)	(11.9)	(40.3)	(53.8)†	(20.6)	(45.0)	(28.4)	(29.6)
Pima S-4	6.2c	0.0c	14.0d	2.1e	25.2b	11.8c	0.0d	42.3d	48.9b†	2.0c	48.3cd	35.8ab	17.5c
Acala 1517-70	10.4ab	0.1e	20.9abc	10.1d	36.0a	28.8b	0.5d	60.5ab	42.4b†	12.8b	70.1a	32.4ab	28.3b
YKA × Pima S-4 L°	9.7b	2.6c	19.8bc	27.5c	34.0a	61.6a	6.6c	52.1bc	66.9a†	36.1a	58.7b	41.0a	50.9a
YKA × P-8	11.1ab	6.6b	21.5ab	32.8bc	34.7a	54.9a†	8.4bc	51.0c	54.1ab	31.0a	59.0b	33.6ab	49.8a
Acala 1517C × Pima S-4	12.1a	1.4c	23.4a	13.8d	38.2a	32.1b	1.8d	63.0a	43.0b†	11.8b	73.0a	30.0ab	30.4b
(YKA × A) × Pima S-4	9.1b	0.8c	19.2bc	12.5d	35.0a	35.1b	1.8d	58.7abc	51.8b†	18.9b	67.7ab	31.9ab	34.6b

* Means followed by the same letter are not significantly different at the 0.05 probability level according to the Neumann-Keuls test. † Denotes the sampling date on which that strain showed the highest rate of fruiting.

rate of square production in the hybrid followed that of the YKA parent very closely (Table 4), which indicated that a high level of dominance for this trait had been transmitted to the F_1. The onset of fruiting proceeded so rapidly in the hybrid after June 20 that by early July the fruit load on the YKA parent and the hybrid was three times that of the Acala check. It is axiomatic with cotton producers that heavy fruiting reduces excessive vegetative development. The converse is also true; cotton plants grow much taller than normally if the fruiting load on the plant is unusually low. To a certain extent, therefore, fruiting and stature are interdependent. The interdependence is very clearly expressed in this example. The YKA parent fruited most heavily, vegetative growth was greatly retarded, and its final stature was the shortest observed. The YKA-derived hybrids also fruited heavily, but vegetative heterosis was such that they kept growing for some time after the *G. hirsutum* parent had ceased. The Acala, carrying a lighter fruit load, continued a rapid growth rate well into the month of August. Pima S-4 lagged far behind the others in vegetative and reproductive development.

The same pattern of development was exhibited by all three YKA-derived hybrids (Table 4). Fruiting load (as measured in squares per m²) was significantly greater on YKA and its three H × B hybrids by July 3. These four entries held their advantage through the July 17 sampling date, but by August 1 the Acala check was beginning to equal their fruiting rate. This early fruiting was characteristic only of the YKA hybrids since the other two hybrids closely paralleled the check at all stages of development. The (YKA × A) × Pima S-4 hybrid was expected to be intermediate between the YKA-derived and the Acala 1517C-derived hybrids. Establishment of this entry was slow, however, and stands were poor. Therefore, data on rate of development may be misleading for this entry. In sequence of development, the number of blooms and bolls per m² for YKA and its three H × B hybrids significantly exceeded the Acala check on the July 17 sampling date and continued at a higher level through the August 1 and August 15 dates. This is apparently the major component of heterosis in all H × B hybrids. It is noteworthy that the YKA-derived hybrids established an advantage early and maintained it throughout the remainder of the season.

Plant height data show a reverse trend. The YKA parent was shorter than the Acala check on July 17, while the YKA-derived hybrids were equal to the check at this point. By August 1, the check was taller than the three hybrids and maintained or increased the height differential through August 15. The Acala 1517C-derived hybrid measured slightly, but not significantly taller than the check throughout the sampling period. The contrast in developmental patterns of the YKA-derived hybrids versus the commercial check was distinct, permitting the hypothesis that vegetative control in these hybrids was achieved through early onset of heavy fruiting.

Table 5. Comparisons of hybrids, parents, and a check cultivar for 2.5 and 50% span length, uniformity index, 1/8-in gauge stelometer strength, and E_1 elongation.

	2.5% span length		50% span length		Uniformity index	1/8-inch gauge stel.	E_1
	mm	in	mm	in		g/tex	
YKA	26.9	1.06e*	13.2	.52b	49.1a	27.2c	7.7b
YKA × Pima S-4	34.0	1.34bc	15.5	.61a	45.2b	29.3ab	10.7a
(Midparent)	30.2	(1.19)	14.2	(.56)	(47.2)	(28.9)	(9.2)
Pima S-4	33.5	1.32bc	15.2	.60a	45.4b	30.7a	10.7a
Acala 1517-70	29.0	1.14d	13.0	.51b	44.2b	23.9d	6.8c
YKA × Pima S-4 L°	34.5	1.36ab	15.5	.61a	44.8b	28.8b	10.4a
YKA × P-8	33.3	1.31c	15.0	.59a	45.0b	29.6ab	10.6a
Acala 1517C × Pima S-4	35.0	1.38a	15.2	.60a	43.4b	29.0ab	10.9a
(YKA × A) × Pima S-4	35.3	1.39a	15.5	.61a	44.1b	29.3ab	10.5a

* Means followed by the same letter are not significantly different at the 0.05 probability level according to the Neumann-Keuls test.

The H × B hybrid derived from Acala 1517C eventually produced more bolls per m² than Acala 1517-70 (Table 3). On the August 15 date, these two entries were approximately equal (Table 4), indicating that a large part of the production on the Acala 1517C-derived hybrid occurred late in the season after temperatures had become suboptimal for fiber development. Marani (1964) found a similar trend toward late maturity in several hybrids of *G. barbadense* with commercial *G. hirsutum* cultivars. This developmental lag is the primary reason why such hybrids may not be commercially desirable despite their potential yield of excellent fiber except in regions with an unusually long growing season.

Selected fiber properties were measured using first-harvest lint samples (Table 5). The YKA × Pima S-4 hybrid displayed significant overdominance for 2.5% span length. This phenomenon has been reported previously (Kearney, 1923; Fryxell et al., 1958). The 50% span length, uniformity index, and fiber elongation closely resembled those of the Pima S-4 parent, indicating complete dominance for longer 50% span length, for less uniformity, and for greater elongation. Fiber strength slightly exceeded the midparent. Fiber properties of the hybrids, in general, resembled Pima rather than Acala.

Table 6 includes the micronaire values obtained from the first and second harvests and their weighted mean over harvests. This is the only economically important trait in which the YKA × Pima S-4 hybrid falls significantly below both parents, the Acala check, and the midparent. Since no advantage in micronaire

Table 6. Comparisons of hybrids, parents, and a check cultivar for micronaire.

Entry	First harvest	Second harvest	Weighted mean
YKA	4. 55a*	3. 28a	4. 42a
YKA × Pima S-4	3. 22c	2. 89a	3. 18cd
(Midparent)	(4. 34)	(3. 22)	(3. 88)
Pima S-4	4. 12b	3. 16a	3; 33c
Acala 1517-70	4. 03b	3. 00a	3. 80b
YKA × Pima S-4 L°	3. 29c	2. 76a	3. 15cd
YKA × P-8	3. 29c	2. 91a	3. 16cd
Acala 1517C × Pima S-4	3. 10c	2. 62a	2. 85d
(YKA × A) × Pima S-4	3. 04c	2. 50a	2. 84d

* Means followed by the same letter are not significantly different at the 0. 05 probability level according to the Neumann-Keuls test.

was obtained from early fruit set on the YKA hybrids over the others, this suggests that low micronaire is a trait characteristic of H $\times$ B hybrids in general and largely independent of maturity. The same conclusion has been derived previously (Fryxell et al., 1958; Marani, 1968). However, the situation is not completely negative. When second-harvest micronaires are compared with those from the first harvest, the hybrids showed only a slight decline, whereas the parental and check lines exhibited dramatic losses. Furthermore, 3.2 micronaire lint is generally considered spinnable and is only slightly discounted in price on Acala 1517 or Pima types of cotton based on the USDA grading system. There is a danger that if in years of poor conditions for micronaire development the hybrids fell far below the checks, the fiber would be heavily discounted in the market.

The implications of micronaire upon yield per se are not clear and need to be examined more intensively. A study of selection responses within varieties of Upland cotton showed that in general there is a genotypic correlation between lint yield and coarse fiber (Thomson, 1973a) and that selection for increased yield tends to increase micronaire (Thomson, 1973b). Studying materials with a wider genetic base, Miller and Rawlings (1967) found that selection for increased lint yield resulted in progenies with higher micronaire. Other studies, showed nonsignificant correlations between yield and fiber coarseness (Al-Jibouri, Miller, and Robinson, 1958; Miller et al., 1958). In most cases, however, the correlation between these two traits was positive (i.e., higher yields with coarser fibers). One suspects that there is an association of moderate magnitude between the two traits.

Although the YKA-derived H $\times$ B hybrids were equivalent to commercial Acala in earliness of maturity, further work is necessary. There are two separate components of maturity, the time of onset and the rate of fruit setting, and the boll-maturation period. The earliness of maturity exhibited by YKA hybrids can be almost entirely attributed to early fruit set. It would probably not be desirable to synthesize hybrids that would set fruit earlier or more rapidly than the YKA hybrids herein described. Earlier fruiting would accentuate the trend toward determinate vegetative growth, resulting in a partially dwarfed plant resembling the YKA parent; however, a certain minimum amount of plant structure probably must be attained to have a potential yield near the levels now achieved by the better cotton producers in New Mexico. There is considerable room for improvement in the earliness of YKA hybrids by decreasing the boll-maturation period. Although the YKA $\times$ Pima S-4 hybrid shows an approximate 3 week advantage in boll set over Acala 1517-70, the difference in rate of boll opening was much less (Fig. 1). The shorter boll period plus the larger boll size of the Acala nullified the advantage gained by the hybrid due to early set. Further increases in earliness must come through reduced boll period.

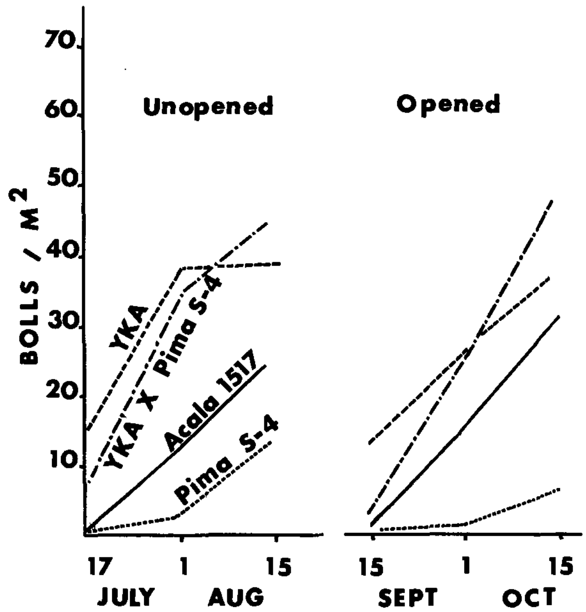

Fig. 1. Comparative development of fruits (bolls) between an interspecific hybrid (*G. hirsutum* $\times$ *G. barbadense*), its parents, and a commercial check, Acala 1517-70.

There is some evidence to suggest that boll period may be due to fiber length per se. Hawkins and Serviss (1930) stated that 6 days difference in boll period could be attributed to the time required to complete elongation of the 40-mm fibers of Pima as compared to the 30-mm fibers of Acala. Differences in boll period can also be associated with fiber length in *G. hirsutum* cultivars (Gipson and Ray, 1969, 1970). If fiber comparable to the best *G. hirsutum* types is fixed as a target for breeding, then the hybrids reported in this paper may be 4 to 6 mm longer than optimal (Table 5). The method for effectively reducing boll period may lie in shortening the fiber length of the hybrids. Long fiber appears to be complete dominant, and in some cases, even overdominant in H $\times$ B hybrids. Therefore, to produce hybrids with shorter fiber, the *G. barbadense* parent must have fiber at least as short as the fiber length desired in the hybrid. Since *G. barbadense* cultivars have been traditionally bred to supply the extra long staple market, it is difficult to obtain good breeding stocks with short fiber. However, short-fibered types can be found in introgression materials derived from mixed *G. hirsutum* and *G. barbadense origin*. Stabilization of these lines should give stocks superior to commercial *G. barbadense* as parents.

Such stocks should be collected and testcrossed to the YKA *G. hirsutum* stocks to determine if further increases in earliness can be obtained without yield loss. This challenge and the micronaire problem now appear to hold first priority in the sequential development of a practical means to realize the heterosis potential of H $\times$ B and H $\times$ B-H hybrids.

REFERENCES

Al-Jibouri, H. A., P. A. Miller, and H. F. Robinson. 1958. Genotopic and environmental variances and covariances in an upland cotton cross of interspecific origin. Agron. J. 50:633-636.

Cook, O. F. 1909. Suppressed and intensified characters in cotton hybrids. USDA Plant Ind. Bull. 147.

Fryxell, P. A., G. Staten, and J. H. Porter. 1958. Performance of some wide crosses in *Gossypium*. N. Mex. Agr. Exp. Sta. Bull. 419.

Gipson, J. R., and L. L. Ray. 1969. Fiber elongation rates in five varieties of cotton (*Gossypium hirsutum* L.) as influenced by night temperature. Crop Sci. 9:339-341.

———, and ———. 1970. Temperature-variety interrelationships in cotton. I. Boll and fibre development. Cotton Grow. Rev. 47:257-271.

Hawkins, R. S., and G. H. Serviss. 1930. Development of cotton fibers in the Pima and Acala varieties. J. Agr. Res. 40:1017-1029.

Kearney, T. H. 1923. Segregation and correlation of characters in an Upland-Egyptian cotton hybrid. USDA Bull. 1164.

Marani, A. 1963. Heterosis and combining ability for yield and components of yields in a diallel cross of two species of cotton. Crop Sci. 3:552-555.

———. 1964. Heterosis and combining ability for plant height and developmental data in a diallel cross of two species of cotton. Crop Sci. 4:265-268.

———. 1967. Heterosis and combining ability in intraspecific and interspecific crosses of cotton. Crop Sci. 7:519-522.

———. 1968. Inheritance of lint quality characteristics in interspecific crosses of cotton. Crop Sci. 8:653-657.

Meyer, V. G. 1973. Fertility-restorer genes for cytoplasmic male sterility from *Gossypium harknessii*. Beltwide Cotton Prod., Proc., Nat. Cotton Counc., Memphis, Tenn. p. 65. (Abstr.)

Miller, P. A., and J. A. Lee. 1964. Heterosis and combining ability in varietal top crosses of upland cotton, *Gossypium hirsutum* L. Crop Sci. 4:646-649.

———, and J. O. Rawlings. 1967. Selection for increased lint yield and correlated responses in upland cotton, *Gossypium hirsutum* L. Crop Sci. 7:637-640.

———, J. C. Williams, Jr., H. F. Robinson, and R. E. Comstock. 1958. Estimates of genotypic and environmental variances and covariances in upland cotton and their implications in selection. Agron. J. 50:126-131.

Moffett, J. O., and L. S. Stith. 1972. Pollination by honeybees of male-sterile cotton in cages. Crop Sci. 12:476-478.

Rosales-Izaguirre, F., and D. D. Davis. 1974. Flowering, fruit set, and yield on nectaried and nectariless lines of *G. harknessii* × *G. hirsutum* male sterile cotton. Beltwide Cotton Prod. Res. Conf., Proc., Nat. Cotton Counc., Memphis, Tenn. (In press)

Stith, L. S. 1974. The potentials for hybrid cotton production. Beltwide Cotton Prod. Res. Conf., Proc., Nat. Cotton Counc., Memphis, Tenn. (In press)

Thomson, N. J. 1971. Heterosis and combining ability of American and African cotton cultivars in a low latitude under high-yield conditions. Aust. J. Agr. Res. 22:759-770.

———. 1973a. Intra-varietal variability and response to single plant selection in *Gossypium hirsutum* L. II. Genotypic variability. J. Agr. Sci. Camb. 80:147-160.

———. 1973b. Intra-varietal variability and response to single plant selection in *Gossypium hirsutum* L. III. Response to selection. J. Agr. Sci. Camb. 80:161-170.

Ware, J. O. 1930. Hybrid intensification of plant height in cotton and the relationship of node number and internode length to the phenomenon. J. Amer. Soc. Agron. 22:787-801.