Published May, 1973

Yield, Yield Component and Fiber Property Variation of Cotton (*Gossypium hirsutum* L.) Within and Among Environments[1]

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ABSTRACT

We evaluated the performance of four cotton (*Gossypium hirsutum* L.) cultivars when grown under four environments at Stoneville, Mississippi. Each variety was harvested by hand at approximately weekly intervals, averaging nine harvests per environment. We obtained estimates of yield, seven yield components, and seven fiber properties for each harvest.

Generally for the first two harvest weeks cotton bolls opened at a relatively slow rate, approximately 10 kg/ha per day. This was usually followed by 4 weeks of a greater rate of opening, approximately 24 kg/ha per day. After this period the rate of opening decreased substantially to approximately 7 kg/ha per day.

The most important cultivar × harvest interactions were for yield, number of bolls, and rate of boll opening. These interactions were related most to the distribution of yield within environments. Lint percentage was lowest for the early harvest, whereas boll size and seed index values became smaller as the season advanced. Lint index was highest for the middle harvests. There was no consistent seasonal trend in number of seed per boll.

Cultivars were the most important source of variability for fiber properties. Yarn strength, 50% and 2.5% span length, length uniformity, fiber strength, and Micronaire were usually lower for the last two harvest dates. Lower quality fiber and low yield potential in the last two harvests suggest that early season production would be advantageous to the cotton industry.

The implications of this study pertaining to sampling for yield, yield components, and fiber properties are discussed.

Additional key words: Breeding objectives, Crop management, Crop ecology, Variety × environment interactions, Sampling, Fiber quality.

COTTON (*Gossypium hirsutum* L.) breeders should put a high priority on knowing their crop. A basic understanding of the crop variation between and within environments or seasons is essential in evaluating the available genetic material. Cotton breeders in the early 1900's were especially attentive to and recorded the genetic differences that occurred within environments. Ewing (5) made intensive studies of the varying responses of 10 cultivars within environments. He observed considerable differences among varieties within seasons for date of first flower, rate of flowering, amount of boll shedding, and amount of lint per boll. McNamara, Hooten, and Porter (9) observed differences in number of nodes to first fruiting branch, rate of fruiting, and percent boll retention of six cultivars. Hintz and Green (7) also reported within environment differences in fruiting behavior among three cultivars.

Bridge, Meredith, and Chism (3) have pointed out that modern cultivars are greatly different from the earlier cultivars. They found that modern varieties had higher lint percentage, greater yield and were earlier in maturity. The modern cultivars had smaller bolls and seed.

Significant cultivar × environment interactions for modern cultivars have been detected for lint yield by Miller, Williams, and Robinson (11) and Bridge, Meredith, and Chism (2). In both these studies, the interactions could not be assigned to any particular location or year effect. In these two studies cultivar × environment interactions for yield components and fiber properties were small. When plots were hand harvested, information on maturity differences within and among environments was available to breeders. Since the change from hand to machine harvesting, less information on maturity differences has been available. This information is needed by breeders if they are to modify their objectives in keeping with changes in technology and crop management practices. The changes in yield, yield component, and fiber properties within a season due to varying environmental conditions and physiological aging are also essential in understanding crop management.

Our objectives in this study were to measure the response of four cultivars to four environments. We were particularly interested in the changes in yield, yield components, and fiber properties within and between the four environments and in relating these changes to defining breeding objectives and improving crop management practices. We also were interested in relating variability within a season to sampling procedures.

MATERIALS AND METHODS

The four cultivars we evaluated were 'Stoneville 213,' 'Deltapine 15A,' 'Coker 413,' and Acala 1517D.' The four environments studied were a Bosket very fine sandy loam planted May 11, 1966; a Beulah very fine sandy loam planted April 13, 1967; a Beulah very fine sandy loam planted April 25, 1968; and a Dundee silty clay loam planted April 25, 1968. The sandy site in 1967 and the 1968 experiment were identical. All studies were conducted at Stoneville, Mississippi. Variation within environments was studied by harvesting at approximately weekly intervals. An average of nine harvests per season was made. (The exact harvest dates are given in Table 4 and Table 8.) Individual plots consisted of three rows 1 m wide and 12.2 m long. We used nine replications in each test. Harvests were made by hand on only the middle row. Plant populations were approximately 129,000 plants per ha. planted in hills 38 cm apart. Nitrogen was applied at the rate of 112 kg/ha for each test. All tests were irrigated before August 1. Defoliants were not applied to the four tests.

For each harvest, lint yield and seven yield components were determined. Lint yield per plot was determined by ginning the entire seed cotton field per plot for each harvest. Bolls per plot per harvest were determined by actual count. Lint percentage was determined for each harvest, and boll size was determined as: (seed cotton weight, g)/ (number of bolls). Seed index (weight in grams of 100 seed) was determined for each plot and harvest. Lint index was calculated as: (lint percentage × seed index)/ (100—lint percentage). Seeds per boll were calculated as: (100—lint percentage) (boll size)/ (seed index).

[1] Contribution from the Cotton Physiology Research Laboratory, Agricultural Research Service, USDA and the Delta Branch of the Mississippi Agricultural and Forestry Experiment Station, Stoneville, Mississippi. Published as Journal Paper 2405 of the Mississippi Agricultural and Forestry Experiment Station. Received July 22, 1972.

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Table 1. Average lint yield and yield components of four cultivars.

Variety	Lint, kg/ha	Number bolls/ha	Lint %	Boll size	Seed index	Lint index	Seed per boll
Stoneville 213	1,115	655,777	37.9	4.49	9.58	5.84	29.1
Deltapine 15A	1,011	595,029	38.7	4.38	8.59	5.46	31.3
Acala 1517 D	870	448,733	34.3	5.63	11.61	6.07	31.9
Coker 413-67	788	500,601	34.8	4.48	9.76	5.24	30.0

The rate of boll opening for each plot was computed as the (weight of lint harvested)/(number of days from last harvest). For the first harvest date, it was difficult to determine the exact date in which the first bolls were open. For this harvest rate of boll opening was computed as the (weight of lint harvested)/10.

Total lint yield and its components were computed for every plot with information obtained from each harvest. Total lint yield was the sum of the lint weights of the individual harvests. Total number of bolls was summed over all harvests for each plot. Average lint percentage was determined as (total lint)/(total seed cotton) × 100. Average boll size was determined as (total seed cotton weight in g)/(total number of bolls). The weighted average for seed index was computed as the sum of the individual harvested seed indexes, weighted by that harvest's proportion of the total harvest. Lint index and seeds per boll were computed as before using seed index, lint percentage, and boll size estimates on a total yield basis.

Three composite fiber samples per entry, per harvest, per test were made by combining the fiber from replications 1-3, 4-6, and 7-9. Weighted averages were computed for an estimate of fiber properties on a total yield basis. Fiber length was measured as 50% and 2.5% span length (SL) on a Digital Fibrograph. Uniformity index was calculated as the ratio of (50% SL/2.5% SL) × 100. Strength (T_1) expressed as grams force per tex and elongation (E_1) were measured with the 1/8-inch gauge Stelometer. Fiber fineness is expressed in Micronaire units. The yarn strength is expressed as an index of the breaking strength of skeins of 27 tex yarn. Fiber property and yarn strength data were determined by the U.S. Cotton Fiber Laboratory and the U. S. Cotton Spinning Laboratory, respectively, of the Agricultural Research Service, U.S. Department of Agriculture, Knoxville, Tennessee.

RESULTS AND DISCUSSION

Variation in Yield and Yield Components

The average performance of the four cultivars on a total yield basis is given in Table 1. Pertinent mean squares are given in Table 2. Cultivar × environment interactions were highly significant for lint percentage, seed index, lint index, and seen per boll; however, the cultivar mean squares are of much larger magnitude for all seven traits. The average results in Table 1 provide an accurate summary of the general performance of these four cultivars. The highest yielding cultivar, Stoneville 213, produced the most harvestable bolls, but did not exceed the other three cultivars in other yield components. This suggests that the number of harvestable bolls is a strong contributor to yield, relative to other yield components. Deltapine 15A had the highest lint percentage, smallest bolls, and smallest seed. Acala 1517D had fewer harvestable bolls, lower lint percentage, larger bolls, larger seed, higher lint index, and more seed per boll than any other cultivar studied.

The pooled analysis for variation within environments is given in Table 3. Highly significant cultivar × harvest interactions were detected for all traits. Lint yield, rate of boll opening, and number of bolls have interaction mean squares large enough to warrant discussing each cultivar's performance within each environment. The average yield per harvest date per cultivar for each environment is presented in Fig. 1.

Table 2. Mean squares for lint yield and yield components.

Source	df	Lint, kg/ha	Bolls/ha†	Lint, %	Boll size	Seed index	Lint index	Seed/ boll
Env.	3	466,121	83,745	8.41	4.27	18.00	5.69	15.03
Reps wn Env.	32	43,862**	10,273**	1.36**	0.09**	0.26**	0.17**	1.96
Cultivar	3	772,650**	310,940**	171.35**	12.57**	57.21**	4.98**	57.35**
Cult. × Env.	9	13,055	4,561	4.26**	0.05	0.88**	0.27**	5.03**
Error	96	8,223	2,387	0.85	0.05	0.13	0.06	2.29

** Indicates significance at the 0.01 level of probability. † Mean squares × 10^{-6}.

Similar responses were observed for each cultivar in each environment. A slow rate of boll opening, approximately 10 kg/ha per day, the first two weeks is usually followed by approximately 3 to 4 weeks of a high rate of opening, about 24 kg/ha per day. After 62 to 81% of the total yield has opened, the rate of opening suddenly drops to 7 kg/ha per day.

Several workers (4, 6, 8) have related these three stages of boll opening rate to fruiting behavior and abscission. Early in the season there are relatively few flower buds, and a high percentage of these first fruiting forms reach maturity. The peak flowering occurs approximately four weeks after first bloom. At "cut-out" the number of squares being produced is greatly reduced, and the abscission rate of young squares and young bolls is greatly increased. Cotton plants are essentially indeterminate in fruiting habit and set their bolls over a period of weeks or months until one or more factors essential for growth and development become limiting. It appears that plants transfer the use of energy and nutrients from initiating new fruit to furthering the development of roots and fruit already set, and to fostering regrowth. In the wild state, where cotton was a perennial, this would be of an evolutionary advantage to the species. However, for modern annual cotton this is wasted energy, and regrowth constitutes harvesting problems.

The specific differences due to cultivar and cultivar × harvest interactions are related to the distribution of yield within seasons. The cultivar with highest lint yield each year, Stoneville 213, averaged 868 kg/ha or 78% before the drop in the rate of boll opening which will be referred to as "cut-out." Deltapine 15A, Acala 1517D, and Coker 413 produced an average 72, 68, and 71% of their lint yield, respectively, before "cut-out." It can be observed (Fig. 1) that Stoneville 213 gained its superior lint yield before "cut-out". As shown in Fig. 1, in each environment Stoneville 213 was superior to the other cultivars in rate of lint maturing per day until the "cut-out" harvest. After "cut-out" there was little difference among cultivars. It is also evident that all cultivars in this study "cut-out" at approximately the same date (Fig. 1). However, Richmond and Ray (13) observed distinct differences in boll opening patterns including "cut-out"

Table 3. Pooled analysis for variation within (wn) environments (E) for yield and its components.

Source	df	Lint yield	Rate of opening	No. bolls†	Lint, %	Boll size	Seed index	Lint index	Seed/boll
Har‡ wn E	32	91,747**	3,106**	3,508**	96.99**	10.88	35.25**	5.99**	151.15**
Har × Reps wn E	256	1,483	28	51	1.50	0.24	0.61	0.25	13.67
Cult. wn E	12	21,678**	369**	893**	384.13**	25.54**	148.92**	12.46**	131.51**
Cult. × Har wn E	96	4,749**	77**	157**	4.33**	0.41**	1.74**	0.45**	14.09**
Error	864	1,039	20	39	1.02	0.25	0.50	0.18	9.86

† Mean square × 10^{-6}. ‡ Harvest.

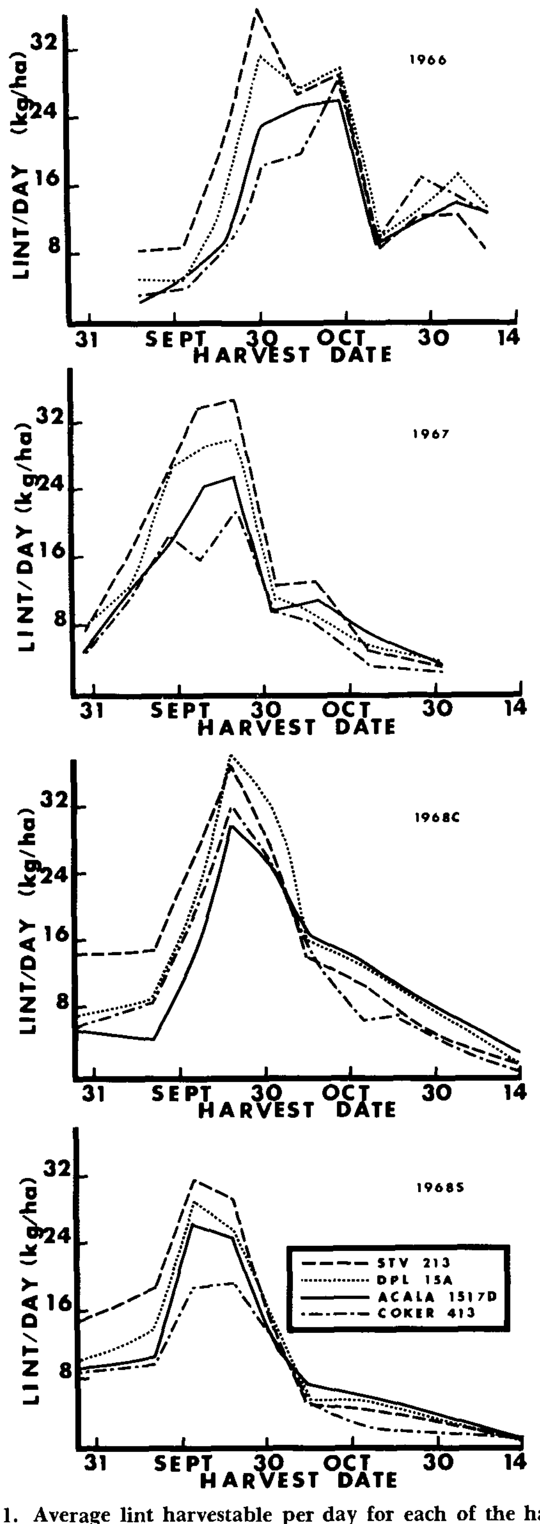

Fig. 1. Average lint harvestable per day for each of the harvest for four cultivars grown at four environments.

in three stocks. While the three stocks were selected because of their great diversity in maturity types and were grown in a population density 1/36th of ours, it does point out that genetic diversity for "cut-out" times does exist in cotton. They also stated that in maturity studies where the objectives are to produce a given amount of cotton by a given time, several harvests per variety per environment are necessary. The study herein also indicates that the true values of producing early cotton cannot be evaluated without several harvests being made over the season.

The lower yields of the 1966 and 1968 sandy environments were probably caused by the greater amount of verticillium wilt observed at these two environments. The most susceptible cultivar, Coker 413, produced its lowest yield relative to the other three cultivars at these two environments. It can be seen that Coker 413's rate of lint opened per day was reduced most during the peak production periods (Fig. 1).

Cultivars that have been successful in recent years in the Mississippi Delta have had high yield, high lint percentage, small seed, and a large number of small bolls. We were surprised to find in this study that number of seed per boll was highest for Acala 1517D (31.9) and Deltapine 15A (31.3) and lowest for Stoneville 213 (29.1). This indicates that a large number of seed per boll is not essential for high yield. Roark and Thomas (14) in studies at Stoneville found that the primary reason Stoneville 213 was more productive than Acala 1517D was that Stoneville 213 had a lower frequency of square and boll abscission. In their study, Acala 1517D actually had more fruiting forms than Stoneville 213. It seems quite logical that the superior yielding cultivars would use the best part of the environment for production. In the early season, bolls mature in an environment where temperature, sunlight, moisture, and mineral nutrition levels are high. As the season advances night temperatures are lower, and there is less sunlight, less moisture fewer available nutrients. Another important aspect of the seasonal change involves a build-up of insect and disease population. From a practical viewpoint, most of the insecticides are applied after August 15. While some of these insecticides are applied to protect bolls that mature before "cut-out," considerable amounts are applied to protect bolls maturing after "cut-out." These data suggest that from a crop management viewpoint, cotton production after "cut-out" in the Mississippi Delta is less efficient and more expensive. It would appear that research to produce more cotton before "cut-out" or to extend the number of days before "cut-out" occurs would be more profitable than research directed toward production or protection of the crop after "cut-out."

If insecticides become ineffective or more restricted in their use, the demand for cultivars that produce high yields in a short time will greatly increase. Early in the breeding history of cotton, Ewing (5) emphasized the need for earlier maturing cultivars that were "fast fruiters" in order to escape the boll weevil. Bridge et al. (3) emphasized that modern varieties were earlier and more productive than old varieties. However, as a breeding objective, it appears that more emphasis should be placed on strains that produce well before or shortly after "cut-out" than on total yield per se.

The remaining five components of yield did possess highly significant cultviar × harvest interactions, but the interaction mean square was usually small relative to that of cultivars and harvest dates. For this reason we report the yield and yield component averages for each harvest date in Table 4. Cultivar comparisons are evident in Table 1.

Table 4. Yield and yield component averages for each harvest date.

Env.	Harvest date	Lint, kg/ha	No. bolls per ha*	Lint/day per ha	Lint %	Boll size	Seed index	Lint index	Seed/ boll
1966	9-9	44	25	4.4	32.1	5.41	12.4	5.8	29.1
	9-16	38	20	5.5	33.4	5.69	12.1	6.0	31.8
	9-23	83	42	11.8	34.5	5.86	12.1	6.3	31.8
	9-30	178	90	25.4	35.1	5.78	12.0	6.5	31.3
	10-7	172	84	24.6	36.9	5.65	11.3	6.6	31.6
	10-14†	197	100	28.2	37.5	5.31	10.8	6.4	30.8
	10-21	66	36	9.1	37.3	4.63	10.0	5.9	29.2
	10-28	92	56	13.1	38.2	4.44	9.6	5.9	29.0
	11-4	102	61	14.7	39.6	4.31	9.0	5.9	28.8
	11-9	57	33	11.6	38.5	4.52	8.9	5.5	31.1
1967	8-30	62	41	6.2	32.6	4.80	11.0	5.3	31.7
	9-6	86	49	12.5	35.1	5.00	10.3	5.6	31.4
	9-13	154	92	22.0	36.6	4.66	9.6	5.5	30.8
	9-19	152	85	25.6	36.4	5.06	9.9	5.7	32.4
	9-25†	167	99	27.8	36.3	4.72	9.9	5.6	30.5
	10-2	76	48	10.8	36.2	4.39	8.9	5.1	31.5
	10-9	75	44	10.8	36.3	4.85	8.8	5.0	34.9
	10-18	48	31	5.4	36.4	4.28	8.5	4.8	32.3
	10-31	41	33	3.1	36.6	3.33	7.7	4.4	27.3
1968 Clay	8-28	87	50	10.7	33.8	5.17	11.0	5.6	31.3
	9-10	123	71	9.5	35.3	4.97	10.2	5.5	31.7
	9-18	165	91	20.7	37.1	4.97	10.2	6.0	30.7
	9-24†	204	112	34.0	37.9	4.88	10.2	6.2	30.0
	10-1	193	111	27.5	37.1	4.77	10.4	6.1	29.1
	10-7	93	62	15.5	36.0	4.29	9.7	5.4	28.5
	10-17	110	64	11.0	36.2	4.74	9.4	5.3	32.5
	10-24	58	35	8.2	36.3	4.48	8.9	5.0	32.4
	11-14	26	23	1.3	35.6	3.26	8.7	4.8	24.3
1968 Sand	8-28	107	65	--	34.6	4.78	9.9	5.2	31.8
	9-10	170	103	13.1	36.8	4.57	9.4	5.5	30.9
	9-17	185	113	26.4	37.8	4.39	9.2	5.6	29.8
	9-24†	172	104	24.6	37.6	4.47	9.5	5.7	29.6
	10-1	94	61	13.5	36.8	4.32	9.3	5.3	29.7
	10-7	35	26	5.8	35.8	3.81	8.5	4.7	29.0
	10-17	47	27	4.7	37.3	4.28	8.3	5.0	33.0
	11-14	21	17	0.8	35.6	3.40	8.6	4.7	25.5

* No. bolls × 10^{-3}. † Indicates last harvest before "cut-out".

Table 5. Average fiber properties on a total yield basis.

Variety	YS	Length 50% SL	Length 2.5% SL	Unif.	T_1	E_1	Mic.
Stoneville 213	116	0.50	1.08	45.9	18.1	8.0	4.05
Deltapine 15A	123	0.49	1.08	45.5	18.6	9.4	3.52
Acala 1517D	152	0.56	1.17	47.8	23.0	7.2	3.71
Coker 413-67	139	0.53	1.16	45.3	20.3	6.9	3.41

Table 6. Fiber property mean squares on a total yield basis.

Source	df	YS	Length 50%†	Length 2.5%†	Unif.	T_1	E_1	Mic.
Env.	3	56.52	36.83	113.44	7.22	0.40	3.33	0.846
Reps wn E	8	18.81	1.46	6.79	0.29	0.33	0.08	0.053
Cult.	3	3,176.74**	131.78**	315.06**	15.47**	58.04**	15.37**	0.935**
E × C	9	27.17**	1.91**	3.61**	0.76*	0.41*	0.15**	0.041*
Error	24	3.06	0.46	0.76	0.29	0.13	0.03	0.014

*, ** Indicate significance at the 0.05 and 0.01 levels of probability, respectively.
† 50% and 2.5% span length × 10^4.

Table 7. Pooled analysis for variation (V) within (wn) environments (E) for seven fiber properties.

Source	df	YS	Length 50%†	Length 2.5%†	Unif.	T_1	E_1	Mic.
Har wn E	32	201**	3.11**	6.99**	11.92**	6.97**	1.61**	1.021**
Har × Reps wn E	64	24	0.50	0.54	1.97	0.62	0.14	0.057
Cult. wn E	12	7,072**	32.75**	73.85**	48.45**	128.78**	31.49**	1.725**
Cult. × Har wn E	96	42**	0.48**	0.80**	1.64	0.78**	0.18	0.070**
Error	216	16	0.33	0.38	1.51	0.41	0.17	0.033

** Indicates significance at the 0.01 level of probability. † 50% and 2.5% span length × 10^3.

The cultivar × within environment interactions for yield and its components were found to follow a similar pattern to that reported (1, 2, 11, 12) for cultivar × among environment interactions. Interactions of cultivars and environments for yield and number of bolls have been reported to be of large magnitude relative to the variation among cultivars. The remaining five yield components have usually had relatively small interaction components.

Lint percentage was lowest for the harvests just before the period of maximum boll opening, and usually changed little thereafter. Boll size and seed index were usually largest in the early season and usually became smaller with each subsequent harvest. There was a noticeable decrease in both boll size and seed index in the harvest immediately following "cut-out." Lint index was highest during the period when most bolls opened and was lowest late in the season. The number of seed per boll was variable, and we could detect no consistent trends.

Variation in Fiber Properties

The averages of seven fiber properties on a total yield basis and their pertinent mean squares are given in Tables 5 and 6. The interaction of cultivars and environments while being significant for every trait was of minor importance relative to variation among cultivars. There was a slight tendency for Acala 1517D to have a more consistent yarn strength, ranging from 150 to 155. Yarn strength ranges of 112 to 120, 118 to 126, and 135 to 142 were obtained for Stoneville 213, Deltapine 15A, and Coker 413, respectively. We were unable to relate the other interactions to any changes in environments or cultivars. The results in Table 5 show the wide differences in fiber properties between the two Mississippi Delta cultivars and the other two cultivars. Acala 1517D, which is used primarily in the western U. S., had the highest yarn strength, fiber strength, 50% and 2.5% span length, and length uniformity. Coker 413, developed in the southeastern U. S., also had excellent fiber properties.

The pooled analysis for variation within environments is given in Table 7. Interaction mean squares for cultivars and harvest were frequently significant but were considerably lower than that for cultivars or harvests. Thus the cultivar × within environment interactions for fiber properties are similar to the results for interactions of cultivars × environments reported in other experiments (1, 2, 11, 12). The analyses indicate that cultivar influence is relatively consistent throughout the harvest season. We did observe a tendency for the fiber properties of Acala 1517D to be more stable than the other three cultivars. Western areas have had a reputation of producing the most uniform and best quality fiber; Acala cultivars used primarily in that area add to that reputation. The interaction of cultivars with harvest dates is related most to the trend of Deltapine 15A to produce lint with a much higher yarn strength in the early harvest than in the rest of the harvests. This trend shows that early in the harvest season Deltapine 15A had yarn strength significantly greater than Stoneville 213, but that after the September 30 harvest, there was no difference between these two cultivars (Fig. 2). The maximum difference in Micronaire among cultivars was in the early harvest and the least difference in the later harvest. We were unable to assign any biological significance to the other cultivar × environment interactions.

Previous studies (2, 12) have indicated cultivar × environment interactions without being able to identify the various locations or years that contributed most to the interactions. It is probable that the rather random harvest or within season interactions as demonstrated in this study are responsible for some of these unexplained results.

The analyses in Table 7 indicate significant changes within a season and environment. The average change

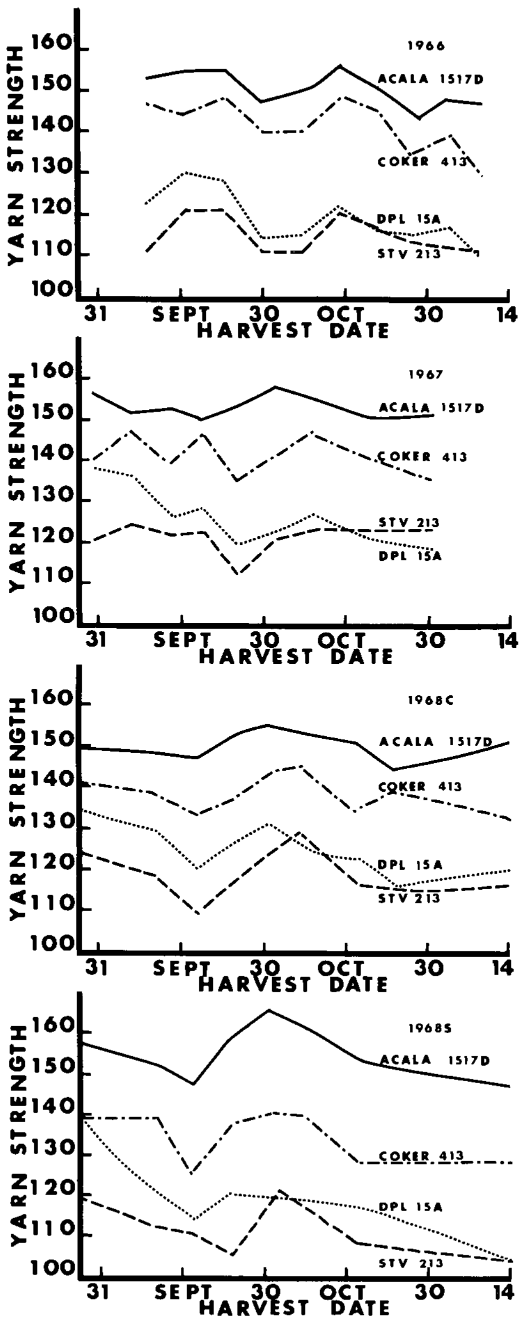

Fig. 2 Average yarn strength per harvest for four cultivars for four environments.

for each harvest in each environment is given in Table 8; the average of the four environments' weighted averages before "cut-out" and after "cut-out" is given as an aid in identifying the within environment trends.

Yarn strength and fiber strength fluctuated greatly within environments, suggesting that rather random changing climatic effects were responsible for the variations observed. Yarn strength and fiber strength were usually lower for the last two harvests than for the other harvests. Fiber length and uniformity were greater before "cut-out" than after. Fiber elongation was greater in the late harvests than in the early harvests. Micronaire values were highest for the early harvests, then declined throughout the season. The

Table 8. Average fiber properties for each harvest.

	Harvest date	YS	Length 50% SL†	Length 2.5% SL†	Unif.	T_1	E_1	Mic.
1966	9-9	134	0.56	1.17	47.5	21.1	7.6	4.36
	9-16	138	0.56	1.19	47.1	21.8	7.8	4.04
	9-23	138	0.57	1.21	46.7	21.3	8.3	3.95
	9-30	128	0.55	1.18	46.5	19.2	8.3	3.99
	10-7	129	0.53	1.16	46.1	19.6	8.4	3.90
	10-14‡	136	0.54	1.17	46.0	20.3	8.5	3.68
	10-21	132	0.53	1.16	45.3	20.1	9.0	3.36
	10-28	127	0.52	1.13	46.1	19.1	8.9	3.39
	11-4	129	0.52	1.11	46.9	19.3	9.1	3.26
	11-9	124	0.51	1.11	45.9	18.5	8.7	3.42
1967	8-30	139	0.53	1.17	45.5	20.5	7.3	3.40
	9-6	140	0.52	1.13	45.5	20.6	7.8	3.33
	9-13	135	0.52	1.11	46.8	19.6	7.7	3.26
	9-19	137	0.52	1.12	45.9	19.4	7.7	3.49
	9-25‡	130	0.51	1.11	45.5	19.6	8.0	3.40
	10-2	137	0.51	1.12	45.2	20.7	8.2	3.28
	10-9	138	0.51	1.14	44.8	19.9	8.4	3.16
	10-18	134	0.49	1.13	43.7	19.6	8.1	2.99
	10-31	133	0.48	1.10	42.9	19.8	8.2	2.80
1968 Clay	8-28	137	0.53	1.13	46.7	19.9	7.2	3.77
	9-10	134	0.52	1.12	46.8	19.7	7.5	3.76
	9-18	127	0.51	1.09	47.1	19.5	7.4	4.23
	9-24‡	133	0.54	1.11	48.8	20.2	7.9	4.24
	10-1	138	0.55	1.14	48.1	20.9	8.2	4.07
	10-7	138	0.54	1.15	46.6	20.4	8.6	3.73
	10-17	130	0.52	1.13	46.3	19.1	8.2	3.64
	10-24	128	0.50	1.11	45.0	18.6	7.9	3.50
	11-14	130	0.49	1.10	44.5	19.3	7.8	3.17
1968 Sand	8-28	138	0.51	1.13	44.8	20.2	6.8	3.53
	9-10	131	0.51	1.10	46.0	20.3	7.0	3.70
	9-17	124	0.49	1.06	46.2	19.5	7.0	3.94
	9-24‡	131	0.50	1.06	47.1	20.7	7.5	3.91
	10-1	137	0.51	1.10	46.5	21.2	7.5	3.69
	10-7	134	0.49	1.09	44.5	20.6	7.9	3.24
	10-17	127	0.49	1.08	45.1	19.7	7.7	3.53
	11-14	125	0.47	1.07	44.4	18.7	7.5	3.25
	BCO§	133	0.52**	1.13*	46.5**	20.0	7.7	3.79**
	ACO	133	0.51	1.12	45.5	19.8	8.3**	3.39

*, ** indicate statistical differences at the 0.05 and 0.01 levels of probability respectively. † SL = span length. ‡ Indicates last harvest before "cut-out". § BCO = before "cut-out", ACO = after "cut-out".

fiber properties were usually of lowest value after "cut-out." This was especially noticeable for the last two harvests of each environment. The fiber property data further emphasize that late season production receives higher priority than is warranted by its performance. It was previously shown that rate of production was low after "cut-out." These results suggest that both breeding and agronomic objectives for more early season production is desirable.

Sampling Implications

In most cotton research studies a sample is taken of the crop rather than using the whole crop. These studies offer some insight on sampling problems that might arise. For most yield components and fiber properties significant variation within harvest dates and cultivar × harvest interactions were detected. These results indicate that very early sampling might over estimate some traits, such as boll size, seed index, fiber length, uniformity, and Micronaire. Other traits, such as lint percentage and fiber elongation, might be under estimated. As long as the samplers technique is consistent, relative cultivar comparisons would not appear to be greatly affected by sampling only a portion of the environment. The exceptions of yarn strength and Micronaire, which show greatest genetic variability in the early season, were pointed out. Sampling techniques that allow the sampler to use selectivity could introduce large cultivars by sampling technique errors. This would most likely occur where the genetic material is very diverse in growth and maturity. Our results suggest that the sampling technique should be consistent, and preferably, the sample should represent as much of the total season as possible.

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