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The Performance of Synthetic Varieties of Cotton[1]

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SYNTHETIC varieties offer an opportunity to utilize a degree of heterosis in cross-pollinated or often cross-pollinated crop plants. Synthetic varieties of corn superior in yield and other characters to open-pollinated ones have been produced (3, 4, 11). However, there is no appreciable production of corn synthetics presumably because double-cross hybrids are generally superior to synthetics, and first generation hybrid seed of corn can be produced with relative ease and economy. Synthetic varieties should offer greater commercial possibilities in a crop such as cotton in which volume production of first generation hybrid seed is impractical at present.

Investigations of heterosis in cotton have been concerned primarily with attaining maximum increases in yield and other characters at the first generation level. Significant increases at this level have been reported by several investigators (8, 9, 10, 13, 16). Loden and Richmond (10) in a comprehensive review stated that "evidences of significant increases in most plant characters and yield resulting from heterosis have been reported in interspecific, intervarietal and intravarietal crosses."

A review of the literature reveals that there have been few studies of synthetic varieties of cotton. In reality many of the widely grown commercial varieties of cotton are, in a narrow sense, synthetics. They represent blended mixtures

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of similar biotypes selected while selfing for a limited number of generations. Varieties produced in this manner are relatively uniform for major agronomic characters, but they do retain a degree of heterozygosity and heterogeneity that provides a broad base for ecological adaptability. The degree of heterosis expected in varieties produced by this method is dependent upon the inherent heterozygosity and the amount of natural crossing that occurs during the blending process.

Empire and Deltapine 15 were two of the most widely grown cotton varieties in Tennessee and in other southeastern states at the time these studies were initiated. Empire has been crossed with many varieties, and several outstanding new varieties and strains (Empire Derivatives) have been developed as a result of these hybridization programs, indicating that Empire has contributed favorable genes. Most of these Empire Derivatives have a noncommon parent, which also may have contributed favorable genes. Those genes contributed by one noncommon parent may be unlike those contributed by another, since the noncommon parents differed in various agronomic and fiber quality characters. A group of these Empire Derivatives should contain a varied sample of favorable genes from Empire and the several noncommon parents. Field blending a mixture of Empire Derivatives in an area of high natural crossing for several generations might result in a superior-performing synthetic variety of cotton.

Deltapine 15 is grown from the Carolinas to California and produces well in all areas. Therefore, it must be heterogeneous to perform favorably under such a wide range of ecological conditions. Selection in a specific environment and blending these selections by isolated open-pollinated increase would likely result in improved local adaptation. However, the range of adaptability likely would be narrowed.

The performance of synthetics produced by *(1)* mixing and blending of Empire Derivatives in areas of high and low natural crossing and *(2)* mixing and blending of S_2 lines of Deltapine 15 in an area of high natural crossing are discussed in this paper.

MATERIALS AND METHODS

Empire Derivative synthetics—Six pounds of seed of each of the following Empire Derivative varieties or strains were assembled in 1953:

Empire Derivative variety or strain	*Patental lines* Common	Noncommon
Cobal	Empire	Coker 33–12
Ute. 6	Empire	Acala 5675
X. mal. 4	Empire	Stoneville 20
Tenn. 12	Empire	Acala 2218
Tenn. 19	Empire	Stoneville 95–9–1
Tenn. 818	Empire	Coker 100W–6
Early Fluff	Empire	Station C
Ute. 1	Empire	Delfos
Empire × Acala	Empire	Acala 5675

A mixture composed of one pound of seed from each seed lot was planted in an isolated block for increase at Knoxville, Tenn., an area of high natural crossing (14). The remaining five pounds of seed of each lot were placed in reserve storage. In 1954, five pounds of seed from the 1953 increase planting were shipped to Greenville, Texas, an area of relatively low natural crossing (14), for isolated increase. Each year, from 1954 to 1957, at Knoxville and Greenville isolated increase plantings were made from seed of the preceding increase generation produced at the respective location. Each generation increase at each location was considered a synthetic. The seed lots produced in 1954–57 at Knoxville were designated as K1 to K4 and those at Greenville as G1 to G4.

In 1958 the 8 synthetics, a mixture of the original Empire Derivatives from the reserve storage lots and breeders' Empire W. R. (current for year of test) were planted in yield trials at Knoxville and Greenville. In 1959 the test was repeated only at Knoxville because seed stocks of several of the synthetics were limited. The variety Pope was included in the Knoxville tests as an additional check. In all tests, 2-row plots 50-feet in length were randomized in 8 replications.

At Knoxville, prior to first picking, 20 bolls from each entry in each replication were picked at random and composited, providing 160-boll samples for determination of boll size (number of bolls required for 1 pound of seed cotton), lint percent, lint index (weight in grams of lint from 100 seed), and seed index (weight in grams of 100 seed). Fiber from each entry was analyzed by the USDA Fiber Laboratory at Knoxville, Tenn., to determine fiber length (Fibrograph, U.H.M., inches), fiber strength (Stelometer, T_1, grams/grex) and fiber fineness (Arealometer, A, $mm.^2/mm.^3$) (5, 6, 7). Fiber from each entry was spun by the USDA Spinning Laboratory, Knoxville, Tenn., to determine yarn strength (Scott tester, 22's, pounds) and other spinning characteristics.

Deltapine 15 synthetics—In 1953, five pounds of 1952 breeders' seed of Deltapine 15 were obtained for a small planting. Remnant seed was placed in reserve storage. The 172 plants grown in 1953 were selfed and picked individually. The 172 S_1 progeny rows grown in 1954 were selfed, and the seed were massed by rows for planting in 1955.

Prior to picking in 1955, comprehensive observations of agronomic type were made in this 172-row planting, and 101 of the more desirable progeny rows were selected for individual plant analysis. Selfed bolls for seed and a 5 to 7 open-pollinated boll sample for gin and fiber analysis were picked from the individual plants. Selfed seed from the 71 unselected progenies was massed by rows. No analyses were obtained from this mass selfed material.

An All Lines Deltapine 15 seed lot was made by massing approximately 10 grams of 1955 selfed seed from each of the 172 rows. The seed was taken from 2 plants at random from each of the 101 selected progenies and from mass-selfed seed in the remaining 71 rows. Using gin and fiber data as a basis for selection, a Best Lines Deltapine 15 seed lot was made by massing remnant 1955 selfed seed from 40 of the 101 selected progenies.

In 1956 these two seed lots were planted in isolated blocks for blending by natural crossing. The 1956 increase seed lots were planted in 1957 for further blending. These Deltapine 15 seed lots were considered to be synthetics after increase and blending through natural crossing for two years. In 1957 the remnant 1952 breeders' seed of Deltapine 15 was increased to provide fresh seed for subsequent testing.

At Knoxville in 1958–59 the All Lines and Best Lines synthetics (1957 seed lots), breeders' Deltapine 15 increase, breeders' Deltapine 15 and Deltapine Smooth Leaf (current for year of test) were grown in yield tests. Each year, 2-row plots 50-feet in length were randomized in 16 replications. Prior to first picking, 30 bolls in each plot were picked at random and composited by entries from replications 1 to 4, 5 to 8, 9 to 12, and 13 to 16 providing four 120-boll samples from each entry for gin and fiber determinations. Fiber quality evaluations were made on each sample in the same manner as in the Empire Derivative experiments.

RESULTS

Empire Derivative synthetics—The data from the 3 experiments were combined and analyzed in 2 ways: first as 2 years at 1 location and second as 1 year at 2 locations. The average lint yields and other characteristics of the Empire Derivative synthetic and check varieties at Knoxville in 1958 and 1959 are presented in Tables 1 and 2. Lint yield differences due to entries and years were highly significant while the interaction of entries × years was not significant.

Duncan's multiple range test (1) was used to indicate the significance of differences between entries in lint yield. The highest yield was obtained from Pope followed by the K2, K4, and K3 Empire Derivative synthetics. The lint yields of Empire W. R. and the original mixture of the Empire Derivatives were nearly equal, approximating the

Table 1—Two-year averages (1958–59) for lint yield and other characteristics of Empire Derivative synthetic and check varieties at Knoxville, Tenn.

Entry: synthetic or variety	Lint yield, lb./A.	Stat. sig.*	Bolls per lb.	Lint percent	Lint index	Seed index
Pope	820	a	72	40.5	8.32	12.2
Emp. Der. K2 1955	718	b	61	38.4	7.83	12.6
Emp. Der. K4 1957	705	bc	59	38.6	8.10	13.1
Emp. Der. K3 1956	676	bcd	59	38.3	8.14	13.1
Emp. Der. G2 1955	671	bcd	61	37.9	7.71	12.7
Emp. Der. G4 1957	657	bcd	62	38.2	8.42	13.5
Empire W.R.	644	cd	56	38.7	8.39	13.5
Emp. Der. Orig. Mix.	643	cd	59	37.7	7.72	13.3
Emp. Der. G3 1956	633	d	63	37.5	7.76	12.9
Emp. Der. K1 1954	626	d	61	38.0	7.92	12.9
Emp. Der. G1 1954	564	e	57	37.4	7.99	13.3

* Any two mean lint yields not followed by the same letter are significantly different at the 5% probability level.

Table 2—Two-year averages (1958–59) for fiber properties and yarn strength of Empire Derivative synthetic and check varieties at Knoxville, Tenn.

Entry: synthetic or variety	Fiber length, U.H.M., in.	Fiber strength, T_1, g./grex	Fiber fineness, A, mm.²/mm.³	Yarn strength, 22's, lb.
Pope	1.00	1.85	465	129
Emp. Der. K2 1955	1.08	1.76	473	125
Emp. Der. K4 1957	1.10	1.85	473	124
Emp. Der. K3 1956	1.08	1.79	461	127
Emp. Der. G2 1955	1.06	1.85	475	126
Emp. Der. G4 1957	1.07	1.82	465	125
Empire W.R.	1.09	1.73	490	130
Emp. Der. Orig. Mix.	1.09	1.83	465	124
Emp. Der. G3 1956	1.08	1.89	473	123
Emp. Der. K1 1954	1.08	1.89	478	125
Emp. Der. G1 1954	1.10	1.88	467	128

Table 3—Average lint yield of Empire Derivative synthetics and Empire W. R. at Knoxville, Tenn., and Greenville, Texas, 1958.

Entry: synthetic or variety	Lint yield, lb./A.	Stat. sig.*
Emp. Der. K4 1957	493	a
Emp. Der. K2 1955	465	ab
Emp. Der. K3 1956	441	bc
Emp. Der. G2 1955	425	cd
Emp. Der. K1 1954	424	cd
Emp. Der. G3 1956	424	cd
Emp. Der. Orig. Mix.	422	cd
Emp. Der. G4 1957	403	cde
Empire W.R.	395	de
Emp. Der. G1 1954	383	e

* Any two means not followed by the same letter are significantly different at the 5% probability level.

mid-point between the highest and lowest yielding synthetics.

Greatest differences in characters other than lint yield were between Pope and the other entries (Tables 1 and 2). In Pope the bolls were smaller, lint percent higher, and fiber length shorter. Differences between Empire W. R. and the Empire Derivative synthetics in characters other than lint yield were relatively minor and without any consistent trend.

The average lint yields for the Empire Derivative synthetics and Empire W. R. in 1958 at Knoxville and Greenville are presented in Table 3. Differences due to entries and locations were highly significant while the interaction of entries × locations was not significant. The K4, K2, and K3 synthetics were highest in yield. Yields of 7 of the 8 Empire Derivative synthetics were greater than Empire W. R. The K4 and K2 synthetics were significantly higher yielding than Empire W. R. and the synthetics produced at Greenville as determined by multiple range tests.

Deltapine 15 synthetics—The average performance of Deltapine 15 synthetics and check varieties at Knoxville in 1958 and 1959 is presented in Tables 4 and 5. Differences in lint yield due to entries and years were highly significant and the interaction of entries × years was significant. Deltapine Smooth Leaf was significantly higher yielding than the other entries as determined by multiple range tests. Yields of the All Lines and Best Lines synthetics and the 1952 breeders' Deltapine 15 increase were similar and all three were significantly higher yielding than current breeders' Deltapine 15.

Table 4—Two-year averages (1958–59) for lint yield and other characteristics of Deltapine 15 synthetic and check varieties at Knoxville, Tenn.

Entry: synthetic or variety	Lint yield, lb./A.	Stat. sig.*	Bolls per lb.	Lint percent	Lint index	Seed index
Deltapine smooth leaf	754	a	74	39.6	7.09	10.9
Deltapine 15 (best lines)	712	b	74	38.8	7.11	11.3
Deltapine 15 (all lines)	704	b	70	38.0	7.15	11.7
Deltapine 15 (1952 breeders)	703	b	76	38.3	7.00	11.3
Deltapine 15 (current breeders)	656	c	72	39.0	7.10	11.1

* Any two mean lint yields not followed by the same letter are significantly different at the 5% probability level.

Table 5—Two-year averages (1958–59) for fiber properties and yarn strength of Deltapine 15 synthetic and check varieties at Knoxville, Tenn.

Entry: synthetic or variety	Fiber length, U.H.M., in.	Fiber strength, T_1, g./grex	Fiber fineness, A, mm.²/mm.³	Yarn strength, 22's, lb.
Deltapine smooth leaf	1.15	1.94	439	129
Deltapine 15 (best lines)	1.14	1.88	470	129
Deltapine 15 (all lines)	1.14	1.86	469	128
Deltapine 15 (1952 breeders)	1.08	1.86	448	127
Deltapine 15 (current breeders)	1.12	1.91	455	128

Differences between entries in characters other than lint yield were relatively minor. Current breeders' Deltapine 15 had somewhat larger bolls and longer fiber than 1952 breeders' Deltapine 15 indicating the possibility of selection pressure for these two characters during the period of this study.

DISCUSSION

The significantly higher yield of Pope in the Empire Derivative tests might be expected, since it is a small-boll, eastern prolific variety well adapted to conditions at Knoxville. The combined data for the three tests show that the yields of the Knoxville synthetics were superior to the Greenville synthetics and Empire W. R. Differences in percent natural crossing between the two locations (14) where the synthetics were produced could account for the higher yield of the Knoxville synthetics. The average percent natural crossing for Knoxville has been reported as 46% and for Greenville as 15% (14). Greater amounts of natural crossing at Knoxville would provide for more blending and heterozygosity, which should be reflected in higher yields for synthetics produced under such conditions.

The lower yields of the K1 and G1 synthetics are of interest. Natural crossing varies some from year to year (14) and could have been lower in 1953, when the base stock mixture was grown at Knoxville, and in 1954 at both locations when the K1 and G1 synthetics were produced. The possibility that amounts of natural crossing in these years would have been low enough to account for the reduced yields is remote. A more reasonable explanation is that at least three years of field blending were necessary to obtain a significant level of heterosis. The data indicate maximum effect on yield from field blending after three years with relatively small differences in yield from additional blending.

Yields of the original Empire Derivative mixture in comparison with Empire W. R. are in agreement with the findings of Richmond and Lewis (12) who concluded that there were no consistent differences between yields of mixtures and the component pure stocks.

Natural selection over a period of several years could be important in the performance of synthetic varieties of cotton. The nonsignificant entry × location interaction in the combined analysis of the Empire Derivative tests in 1958 indicates that natural selection had little effect.

No measurements were taken to show the degree of plant-to-plant variation within the entries in these tests. The range of variation observed in the Empire Derivative synthetics was no greater than that in a commercial variety of cotton. This indicates that the percent natural crossing occurring at the two locations over the period of years involved in producing each synthetic was sufficient to provide an acceptable product.

No difficulties were encountered in spinning any of the entries in the Knoxville tests. Small differences in fiber quality within the original mixture and the synthetics had no effect on spinning performance. These results might be expected since Simpson et al. (15) reported that blending seed cotton of varieties having widely diverse fiber qualities had no appreciable effect on spinning performance.

These Empire Derivative synthetics are of potential value as breeding stocks. Improvement in cotton through the use of conventional breeding methods is an accomplished fact. However, the failure to obtain certain desired combinations of characters is likewise well known. Cotton chromosomes are short and the chiasmata frequency low. Hence, immediate selection in the F_2 may leave large blocks of the initial parental chromosomes intact and reduce the chances of obtaining the desired recombinations. Intermating in areas of high natural crossing for several years might increase the probability of obtaining desirable combinations (2). A selfing and selection program to study this possibility was initiated in 1958 using the K4 synthetic.

The similarity of the Deltapine 15 All Lines and Best Lines synthetics to 1952 breeders' Deltapine 15 increase for yield and other characteristics indicates that the two methods followed in reconstituting Deltapine 15 from a group of S_2 lines did not result in improvement of measured characters. The superiority of these three entries over current breeders' Deltapine 15 is probably due to heterosis resulting from blending through natural crossing. It seems that improved local adaptation could have had little effect on yield due to the short periods of time involved. Since the performance of the Empire Derivative synthetics indicated that at least three years of open-pollinated increase were needed to attain an effective level of heterosis, additional years of increase of the two Deltapine 15 synthetics and 1952 breeders' Deltapine 15 could possibly result in increased yield.

From a practical breeding standpoint the results from the Empire Derivative and Deltapine 15 tests indicate that blending of component stocks of cotton varieties through natural crossing is desirable. Greatest heterosis is likely where stocks are blended for at least three years in areas of high natural crossing. Blending may be difficult to achieve in areas of low natural crossing, which may be further reduced by the application of broad-spectrum insecticides. Synthetic varieties involving more diverse component stocks than those in these experiments would likely result in greater heterosis and seem worthy of consideration in practical breeding programs located where the natural crossing percent is high enough to produce a well blended product.

SUMMARY

Seed of 9 Empire Derivative strains of cotton were mixed and blended for 1 generation at Knoxville, Tenn. to provide a base stock. Eight synthetic varieties for testing were produced in 1954–57 by further blending at Knoxville and Greenville, Texas. The synthetics produced at Knoxville were higher yielding generally than those produced at Greenville due apparently to greater heterosis resulting from more complete field blending. At least three years blending appeared necessary to obtain the highest level of heterosis under the conditions of these experiments. Additional years of blending had little effect on measurable characters.

Two reconstituted Deltapine 15 synthetics produced by massing and blending all or a selected (best) group of S_2 lines were not improvements over the original variety (1952 breeders') that had been increased and blended through natural crossing. The two synthetics and the 1952 breeders' increase were significantly higher yielding than current breeders' Deltapine 15 probably due to heterosis from field blending.

The potential use of the Empire Derivative synthetics as breeding stocks and the importance of natural crossing in blending component stocks of varieties produced by practical breeding programs are discussed.

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