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Effects of Yield Components on Lint Yield of Upland Cotton with High Fiber Strength[1]

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ABSTRACT

Seeds/boll, lint/seed, and bolls/m² were determined for several PD breeding lines and check cultivars of Upland cotton, *Gossypium hirsutum* L., representative of distinct breeding stages in the simultaneous improvement of lint yield and fiber strength. These yield components were calculated from seed cotton yield, boll size, seed size, and lint percentage measured on the stocks in one or more tests conducted for at least 3 years on the Pee Dee Experiment Station, Florence, S.C. from 1956 to 1972. The objective of the present study was to determine the influence of each component on lint yield and its breeding implication in improvement programs.

Most southeastern commercial cultivars averaged 36 seeds/boll as compared with 33 for PD lines. Seeds/boll can be increased by crossing PD lines with southeastern commercial cultivars and selecting for this characteristic. It might be possible to increase lint yields of PD lines by increasing seeds/boll, which should increase seed surface area for greater lint production. Lint/seed advanced slightly as lint percentages were improved in early developed PD lines. Lint/seed was increased significantly after the introduction of the C 6-5 breeding line because lint percentage and seed size advanced greatly. This component has not influenced yield of recent PD lines appreciably because boll size has declined and lint percentage has remained relatively constant. Bolls/m² has been the major component contributing to lint yields of PD lines. Except for the rapid increase in lint yield from the higher level of lint percentage and larger bolls and seeds derived from C 6-5, increases in lint yields have paralleled increases in bolls/m². We suspect that we will be concerned more with maintaining, rather than increasing, bolls/m² as we develop future PD breeding lines.

Additional index words: **Cotton breeding, Selection, Cotton quality.**

DURING the past 40 years, our major research effort has been to reduce the adverse genetic associations between lint yield-fiber length and lint yield-fiber strength. Culp and Harrell (2, 3) recently reviewed the progress in increasing lint yields of Upland cotton (*Gossypium hirsutum* L.), while retaining a portion of the triple hybrid fiber strength derived primarily from *G. arboreum* L. × *G. thurberi* Tod. They showed that as lint yields increased 45 to 55%, yarn strength decreased 30 to 40%. However, Culp and Harrell (5) and Harrell et al. (6) reported that recent PD breeding lines equaled or surpassed leading southeastern cultivars in lint yield and the high quality check, Pee Dee 2165, in fiber properties and yarn strength. PD breeding lines now exist that will satisfy many of the fiber quality requirements of the textile industry, while meeting the lint yield demands of the cotton producer.

Culp and Harrell (4) studied the influence of lint percentage, boll size, and seed size on lint yield of some outstanding PD breeding lines. They found that the adverse genetic association between lint percentage and extra-long staple was reduced by introducing California breeding line C 6-5 into the PD breeding program and selecting for desirable combinations of fiber length and high lint percentage. Except for the dramatic yield increases following crosses with C 6-5, which greatly raised lint percentage, their data agreed with the findings of Ramey (10) and Ramey and Worley (11) that lint percentage, boll size, and seed size had a minor influence on lint yield. Therefore, some other factor must be responsible for the major increases in lint yields of recently developed PD lines.

Our purpose was to investigate the influence of three yield components – number of seeds/boll, lint weight/seed, and number of bolls/m² – on the lint yield of PD breeding lines. A knowledge of the effects of these components on yield should be helpful in plans for improving lint yield and fiber strength of PD lines. This information should be helpful also to many breeders across the Cotton Belt as they use PD breeding stocks in their cotton improvement programs.

MATERIALS AND METHODS

The pedigree breeding system has been used to develop most PD lines (2). Their origin can be traced to several basic crosses (3) between TH 108 (K)[3], TH 171 (K), 'Earlistaple' (E), 'Sealand' (S), and AHA 6-1-4 (P) made in the middle to late 1940's. By 1952, five extra-long staple, high-fiber-strength lines, A = KSE 313, F = KPSE 330, J = KPE 363, N = KPE 482, and T = KPE 304, had been developed. These lines were intercrossed and outcrossed to southeastern cultivars and breeding lines, and a series of outstanding lines (Table 1), representing advances in fiber quality and lint yield, were selected (4).

The testing program used to evaluate PD stocks has been outlined (3). Each line was tested in one or more trials for at least 3 years on the Pee Dee Experiment Station, Florence,

Table 1. Breeding lines developed by selection for yield and fiber quality in a series of intercrosses and outcrosses in the PD breeding program from 1945 to 1972.

Approximate year	Series	Pedigree of lines*
1952	1	A,F J,N,T
1955	2	AE,AF,AN,AT,FT
1958	3	FJA,FTA
1960	4	AC235,AC239,AC241
1963	5	AC.FJA,AC.FTA,AC.NA
1972	6	H:AC.FJA,H:AC.FTA

* Letters represent the breeding stocks as follows:

A = KSE (Hybrid 313)
C = C 6-5
D = Dixie King
E = Earlistaple
F = KPSE (Hybrid 330)
G = Auburn 56
Ho = Coker 413
H = Coker 421
J = KPE (Hybrid 363)
K = Triple Hybrid
M = Coker 100 A
N = KPE (Hybrid 482)
O = Atlas
P = AHA 6-1-4
Ro = Carolina Queen
R = Coker 201
S = Sealand
T = KPE (Hybrid 304)
V = Coker 310
W = Empire WR

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[3] Letters represent breeding stocks in footnote to Table 1.

S.C., from 1956 to 1972. A randomized block design with four to eight replications was used for each test. The mean value for yield components, which was obtained by averaging strains, tests, and years, was considered the most reliable estimate available.

Since environmental effects can influence cotton yields as much as heritable traits, we attempted to minimize variation due to locations and years by growing established cultivars as checks in each test. The cultivars used were: (a) 'Coker 100 A', from 1956 to 1964, (b) 'Carolina Queen', from 1962 to 1966, and (c) 'Coker 201', from 1967 to 1972. Lint yields of PD lines were reported (3) as a percentage of the yield of Coker 201.

Lint percentage, boll size, and seed index have been reported for each series of PD lines (4). In this paper, we are reporting the results from bolls/m^2, seeds/boll, and lint/seed as calculated from formulas, suggested by Maner et al. (7) and modified by Ramey (10).

Bolls/m^2 = seed cotton yield (kg/ha) $\div$ (boll size [g] $\times$ 10), where seed cotton yield (kg/ha) = lint yield (kg/ha) $\div$ lint percentage, and lint yield (kg/ha) = yield of PD line or check (% of Coker 201) $\times$ 1,277 kg/ha and 1,277 kg/ha = average lint yield of Coker 201.

Seeds/boll = boll size (g) $\div$ seed cotton (g)/seed, where seed cotton (g)/seed = seed index $\div$ seed percentage and seed percentage = 100— lint percentage.

Lint (g)/seed = seed cotton (g)/seed $\times$ lint percentage $\times$ 0.01.

RESULTS AND DISCUSSION

Seeds/Boll

Except for 'Coker 413,' 'Coker 421,' and 'Atlas,' all medium staple southeastern cultivars tested, regardless of boll size, averaged about 36 seeds/boll (Fig. 1). The extra-long staple cultivars of the late 1940's and early 1950's, Sealand (S) and Earlistaple (E), averaged significantly lower, about 34 seeds/boll. Most PD lines ranged from 29 to 35, averaging 33 seeds/boll. That the high-fiber-strength cultivars, Atlas (O), Coker 413 (Ho), and Coker 421 (H), were also in this range suggest the possibility of triple hybrid ancestry.

Since most PD lines have fewer seeds/boll than southeastern cultivars, the probability of a genetic association between high fiber strength and seeds/boll has to be considered. It is unlikely that a strong correlation exists, because there have been several instances of obtaining both high fiber strength and high seeds/boll. The triple hybrid cultivar, 'TH149,' averaged more than 36 seeds/boll. It is different from most other high-fiber-strength cultivars and breeding lines because it lacks *G. barbadense* L. introgression and has extra-large bolls and seeds. TH 149 was selected after crossing TH 108 to 'Rowden' once and Empire 10 twice (9). The chance of recovering 36 seeds/boll with TH 149 was much greater than with PD lines, because the latter have not been crossed as many times to large-bolled commercial cultivars with the higher number of seeds/boll. Lines with 36 seeds/boll also have been selected from Atlas $\times$ 'Dixie King' crosses (12) that involve fiber strength genes from *G. barbadense* introgression as well as the triple hybrid. Pee Dee 4381 (AC.G) and Pee Dee 9363 or Pee Dee 9364 (R.FJA $\times$ CE.FJA:AC.FJA), where 'Auburn 56' (G) and Carolina Queen (Ro) were used

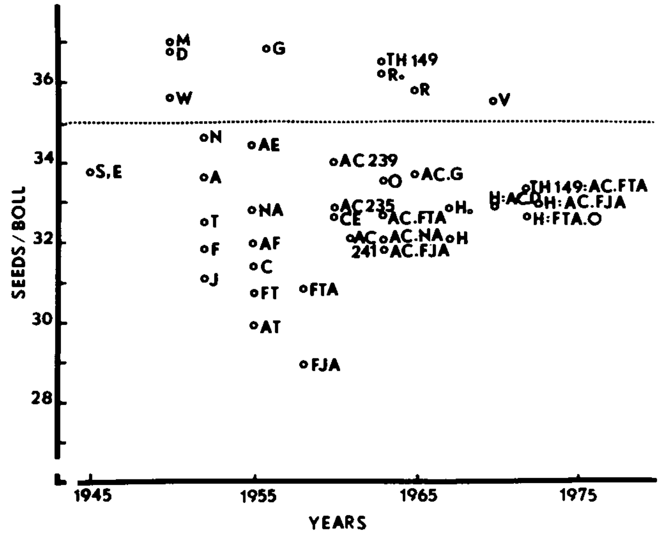

Fig. 1. Seeds/boll of breeding stocks grown at Florence, S.C. from 1945 to 1972. Letters represent the breeding stocks in footnote to Table 1.

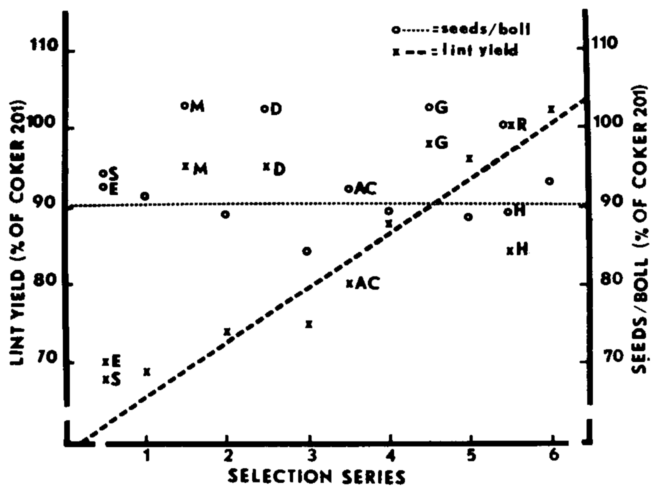

Fig. 2. Seeds/boll and lint yield of breeding stocks developed at Florence, S.C. from 1945 to 1972. Letters represent the breeding stocks in footnote to Table 1.

in crosses, have 34 and 35 seeds/boll, respectively. The recently developed line, Pee Dee 0113 (AC.G $\times$ AC.FJA), from the cross of Pee Dee 4381 (AC.G) and Pee Dee 2165 (AC.FJA) has 36 seeds/boll (5).

Since seeds/boll of PD lines have been consistently low, lint yield increases have been relatively independent of this yield component (Fig. 2). Lint yields of future PD breeding lines might be raised significantly if seeds/boll can be increased to the level of commercial cultivars.

The number of seeds/boll depends on boll and seed size. PD lines have consistently had larger seeds than commercial cultivars with similar sized bolls (4). The breeding problem of increasing seeds/boll involves reducing seed size while maintaining equivalent sized bolls. Our data indicate that the possibility of sub-

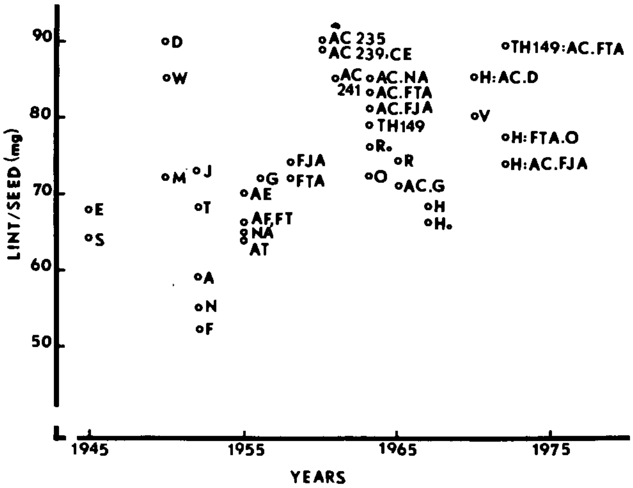

Fig. 3. Lint/seed of breeding stocks grown at Florence, S.C. from 1945 to 1972. Letters represent the breeding stocks in footnote to Table 1.

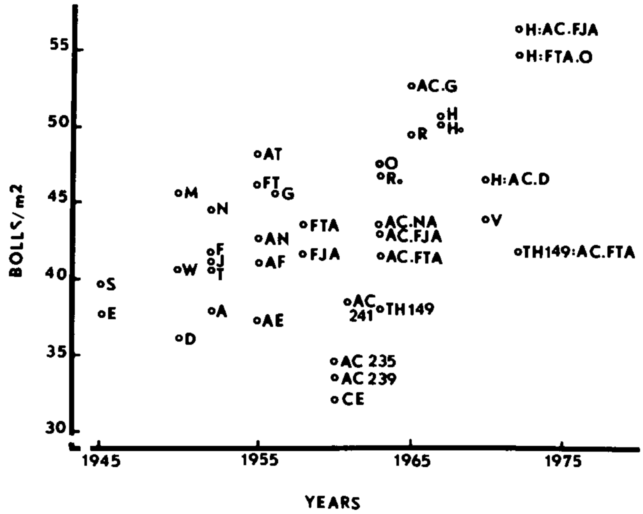

Fig. 5. Bolls/m² of breeding stocks grown at Florence, S.C. from 1945 to 1972. Letters represent the breeding stocks in footnote to Table 1.

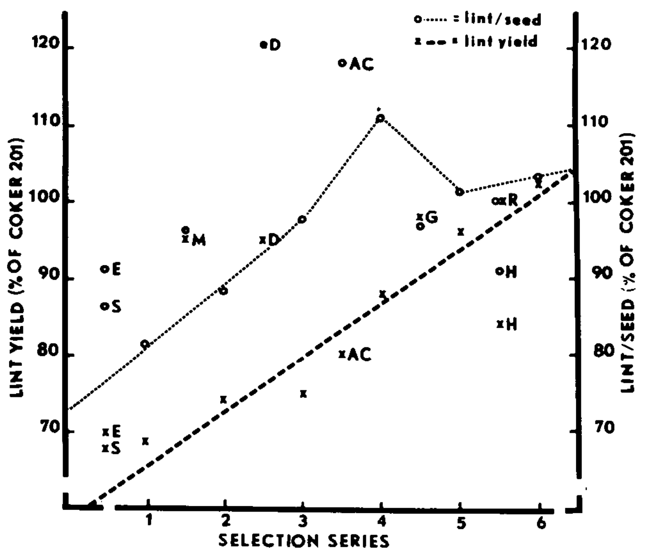

Fig. 4. Lint/seed and lint yield of breeding stocks developed at Florence, S.C. from 1945 to 1972. Letters represent the breeding stocks in footnote to Table 1.

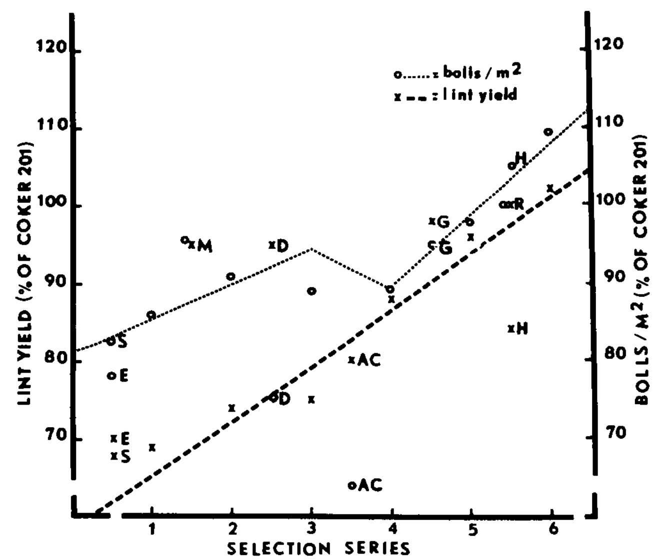

Fig. 6. Bolls/m² and lint yield of breeding stocks developed at Florence, S.C. from 1945 to 1972. Letters represent the breeding stocks in footnote to Table 1.

stantially increasing seeds/boll of PD stocks is remote, unless new germplasm is introduced. One obvious source of germplasm with more seeds/boll is the southeastern commercial cultivars that lack genes for extra fiber strength.

Although numerous crosses with southeastern cultivars have been made, we have few PD lines from these combinations because it is difficult to find plants with high lint yields and desired levels of fiber strength, length, and fineness. Recent crosses (5, 6) have produced many more promising lines, and we believe the chances of obtaining these types will increase. Selection pressure for seeds per boll should be applied in the F_2 and F_3 generations, if we hope to rapidly improve this character in PD breeding lines.

Lint/Seed

The medium to small-seeded southeastern commercial cultivars produced about 72 mg (Fig. 3) and large-seeded cultivars produced 85 to 90 mg lint/seed. Southeastern extra-long staple cultivars, PD lines A, F, J, N, and T, and lines AE, AF, AN, AT, FT, FJA, and FTA, derived from intercrosses of them, generally produced less than 70 mg lint/seed. Low lint/seed can be attributed to low lint percentages in many early PD lines (4). Lint/seed of PD lines advanced as lint percentages were improved and lint yields increased during breeding series 1, 2, and 3 (Fig. 4). The significant increase in lint per seed during series 4 is attributed to increases in both lint percentage and seed size after the introduction of C 6-5. Lint/seed of recent PD lines has declined slightly because boll and seed size have decreased, even though lint percentage has remained high.

We need a measure of lint/unit area of seed in breeding. The surface area of the seed is the site of lint production; therefore, a measure of lint on an area of seed surface would be a valuable selection tool. Work is underway at the USDA Cotton Quality Laboratories at Knoxville, Tenn. to establish such a measure. Until lint/unit area of seed can be measured economically and rapidly, we must rely on selection for high lint percentage to maintain high lint/seed.

Bolls/Unit Area

Maner et al. (7) showed that bolls/m² was the most important component contributing to lint yield in cotton. Ramey (10) and Ramey and Worley (11) came to similar conclusions, explaining the yield increases of current over obsolete cultivars in the Mississippi Delta (1). Our data (Fig. 5) suggest that the improvements in commercial cultivars of Coker 201 over Carolina Queen and Carolina Queen over Coker 100 A are due primarily to increases in bolls/m².

In the Pee Dee program, the improved lint yields of lines AE, AF, AN, AT, FT, FJA, and FTA, derived from crossing Lines A, F, J, N, and T increased in bolls/m² (Fig. 6) as well as in lint percentage (4). The introduction of the extra-large bolls and high lint percentage of C 6-5 drastically reduced bolls/m² of the AC lines. Selection AC 241, which had significantly smaller bolls, showed a major improvement in bolls/m² over other AC lines. Since the wide use of AC 241 in the Pee Dee program, most yield increases of PD lines during breeding series 4, 5, and 6 can be traced to increases in bolls/m².

Breeding Implications

Seeds/boll is a major yield component and, as such, must be taken into consideration in plans to improve lint yields of PD lines. The PD lines average about three seeds/boll less than commercial southeastern cultivars. That most PD lines have larger seeds than cultivars with similar boll size is perhaps a disadvantage, because smaller seeds have more surface area per unit of seed weight than larger ones.

Miller and Rawlings (8) found that seeds/boll increased simultaneously as lint yield was increased by selection. Ramey and Worley (11) attributed only minor lint yield increases to seeds/boll; however, several of the obsolete cultivars that they studied had more seeds/boll than current cultivars (1). Seeds/boll did not increase as higher-yielding PD breeding lines were developed, because this characteristic is lacking in the Pee Dee germplasm. Outcrossing PD lines to southeastern commercial cultivars and selecting for more seeds/boll in early generations appears promising as a method of increasing lint yield.

Ramey and Worley (11) attributed only minor yield increases to lint/seed. Our data during recent breeding series 5 and 6 agree with these findings, and as we select for smaller seeds, we expect some losses in lint/seed. Until methods for measuring the surface area of seed and the lint/unit area of seed are developed, we will select for high lint percentage and hope to maintain an acceptable level of lint/seed.

Ramey and Worley (11) attributed major yield improvements to increases in bolls/m². Except after the introduction of C 6-5 (breeding series 4) when lint percentages were raised 2 to 5 points (4), increases in the yields of PD lines have paralleled increases in bolls/m² (Fig. 6). Boll size is a major factor influencing bolls/m². We do not know the optimum boll size or number of bolls/m² to give maximum lint yields, but suggest that there must be a range for both characters that should be found during the selection process. We hope to maintain bolls/m² of PD lines at the present level, which is equal to or slightly greater than that of southeastern cultivars. Since recent PD lines have equalled southeastern cultivars in bolls/m², major yield increases through improvement of this component are not as likely as in the past.

In our efforts to increase lint yield while maintaining a desired level of fiber strength and length, we will follow reported (5, 6) breeding procedures with additional attention to increasing seeds/boll, surface area/unit of seed weight, and lint/surface area of seed.

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