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Gene Action in the Inheritance of Lint Index in Upland Cotton[1]

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QUANTITY of lint per seed is one of the components of lint yield in Upland cotton. This trait usually is expressed as lint percentage calculated as (weight of lint × 100)/(weight of lint + seed). Alternately, it may be expressed as lint index (1) defined as weight in grams of lint produced by 100 seeds.

Lint index has been found (see 5, 7 for reviews) to be a continuous variable in segregating populations. Ware (6) reported dominant type gene actions in interspecific hybridizations; however, little has been published on gene actions in intraspecific crosses. The purpose of this paper is to report results from an investigation of gene action in the inheritance of lint index in intraspecific crosses of Upland cotton.

MATERIALS AND METHODS

Experimental materials were derived from diallel crosses, excluding reciprocals, of eight parental lines chosen from the Regional Collection of Upland cotton for their approximately equal seed index (weight in grams of 100 seeds) in the range 11.0 to 12.0. Four lines—U4, Delfos 3506, Coker's Super Seven #5, and UA 7–9—had low lint indices ranging from 3.5 to 4.5; the others—West Texas Rough, Half and Half, Station C 42, and Delta Smooth Leaf—had lint indices ranging from 6.5 to 7.5.

The experimental plants were grown in a split plot design of three replications. The 28 combinations were allocated to the main plots and subplots were, respectively, 1 of each parent, 1 of the F_1, and 3 of the F_2. Single row subplots contained from 4 to 20 plants each. A seed cotton sample was harvested from each plant in the experiment. Lint and seed indices were determined by ginning 100 seeds from each sample and weighing the lint and seed. Plot means were calculated from individual plant values.

Actions of genes controlling traits continuously variable in segregating populations may be investigated by using generation means. When only additive type gene actions are involved, means of the parental, F_1, and F_2 generations will be equal. If dominance also is involved, the F_2 mean will deviate from the parental mean to a position halfway between the parental and F_1 means. Epistatic gene actions will cause the F_2 mean to deviate from this halfway position.

Tests for these types of gene action can be constructed using the analysis of variance. A test of generation means will determine whether genes act additively or whether there are interactions. Two other tests can be made if interactions are indicated. A test of parental vs. F_1 means would indicate heterotic responses when heterosis is defined as a deviation of the F_1 mean from the average of the parents. A heterotic response could be due to allelic (dominance) interactions and/or to nonallelic (epistatic) interactions. This can be partially evaluated using Mather's C scaling test (3, 4), whereby the F_2 mean is compared to the average of the parental and F_1 populations. If no differences are detected, only dominance is indicated; where differences are detected, the response could be due to epistasis alone or to dominance and epistasis. If differences are not detected by the parental vs. F_1 tests, but are detected by the C test, epistasis is indicated.

RESULTS AND DISCUSSION

Although the parents were chosen for their approximately equal seed indices, plot means for seed index varied from 9.2 to 14.4. Variations in seed size, as measured by seed weight, are usually accompanied by variations in seed surface area, and lint index is a function of the number of fibers produced on a given area of seed surface (2). Thus, fluctuations in seed index can influence lint index. In order to reduce the influence of seed index, covariance analysis was used to adjust lint index means. A common b value of +.358 was obtained indicating the relationship of lint index to seed index in these populations.

Tests of generation means were made using analysis of covariance. Differences between the three generation means were highly significant statistically (Table 1) indicating gene interactions occurred in the inheritance of lint index in this sample of Upland cotton. Differences detected between the F_1 and mid-parent (mean of parents) indicated heterosis. The third test, F_2 vs. $\frac{1}{2}(F_1 + MP)$, was statistically significant. Differences detected in the latter two tests indicate epistasis was operative and that dominance may or may not have been.

The combinations could be logically divided into three groups: (a) those involving high × high crosses, (b) low × low crosses, and (c) high × low crosses. Tests were made in each of these groups (Table 1). Differences in generation means were detected in each group, indicating gene interactions were operative. In both high × high and low × low groups the F_1 vs. MP test detected differences and the F_2 vs. $\frac{1}{2}(F_1 + MP)$ test did not, indicating only allelic gene interactions were involved. Differences were detected by both tests in the high × low group indicating nonallelic gene interactions were operative. Since allelic gene interactions were indicated in the other two groups involving the parental lines, it is suggested that they were operative in this group also.

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Table 1—Tests of generation means, F_1 vs. mid-parent and F_2 vs. $\frac{1}{2}(F_1 + \text{mid-parent})$, using covariance analysis, of the total population and of the 3 groups, high × high, low × low, and high × low.

Source of variation	Total		High × High		Low × low		High × low	
	d. f.	m. s.	d. f.	m. s.	d. f.	m. s.	d. f.	m. s.
Generations in comb.	56	.1856**	12	.3748**	12	.1039**	32	.1429**
Error	111	.0396	23	.0567	23	.0294	63	.0377
F_1 vs. MP in comb.	28	.2500**	6	.5552**	6	.1032**	16	.1735**
Error	55	.0414	11	.0617	11	.0233	31	.0403
F_2 vs. $\frac{1}{2}(F_1 + MP)$ in comb.	28	.0666*	6	.0274	6	.0133	16	.0987**
Error	55	.0327	11	.0423	11	.0399	31	.0288

Table 2—Differences in adjusted generation means of the 28 populations expressed as $F_1 - MP$ above leading diagonal and $F_2 - \frac{1}{2}(F_1 + MP)$ below leading diagonal.*

Parent	A	B	C	D	E	F	G	H
A. U4		.30	.60	.31	-.07	.13	.32	.26
B. Delfos 3506	.07		.24	.42	.14	.30	.13	.42
C. Coker's Super Seven #5	-.03	-.03		.32	.35	.43	.24	.33
D. UA 7-9	.03	-.05	.06		-.05	.34	.22	.75
E. West Texas Rough	-.15	-.13	-.27	.00		.28	.40	.84
F. Half and Half	.00	-.31	-.12	.05	-.13		.44	.93
G. Station C 42	-.17	-.08	-.08	-.14	.15	.08		.61
H. Delta Smooth Leaf	.04	-.26	.17	.09	.01	.14	-.08	

* s.e. $F_1 - MP = \pm .1175$ $F_2 - \frac{1}{2}(F_1 + MP) = \pm .1044$

Adjusted mean differences between generations by groups:

Group	F_1 - MP	$F_2 - \frac{1}{2}(F_1 + MP)$
Total	+0.355 ± .0222	-0.041 ± .0197
High × high	+0.583 ± .0585	+0.028 ± .0485
Low × low	+0.365 ± .0360	+0.008 ± .0471
High × low	+0.265 ± .0290	-0.085 ± .0245

Three of the lines—Coker's Super Seven #5, Half and Half, and Station C 42—were grown commercially some years ago; three others—Delfos 3506, West Texas Rough and Delta Smooth Leaf—were experimental lines; U4 was developed in South Africa from American stocks and grown extensively for a number of years; and UA 7–9 was developed in India from American stocks. These lines probably exhibit as great a diversity in gene actions as would be encountered in any breeding population except in cases where interspecific hybridization is followed. A survey of variety trials conducted by the various state and federal experiment stations and the regional cotton variety test[3] indicated current commercial varieties exhibit lint indices in the high range. It follows, therefore, that epistatic types of actions of genes controlling lint index in breeding populations established through hybridization among current commercial varieties would be encountered infrequently, if at all. However, in breeding populations established by hybridization of current commercial varieties with breeding lines exhibiting lower lint index, epistatic actions among genes controlling lint index should be suspected although they may seldom occur.

Differences among generation means were detected by analysis of covariance tests, but direction of deviation was not demonstrated. Adjusted differences between the F_1 and mid-parent are presented above the leading diagonal in Table 2. F_1 means exceeded the mid-parent in all but two combinations, AxE and DxE, where the negative values were small in magnitude. This suggests that breeding procedures which take advantage of gene interactions would be useful in increasing lint index.

Differences between the F_2 and $\frac{1}{2}(F_1 + MP)$ are presented below the leading diagonal in Table 2. All values except for three combinations, BxF, BxH, and CxE, are small in magnitude and are considered as random variations. The values for the three exceptions are negative indicating the F_2 means regressed more rapidly toward the mid-parent than would be expected without epistatic gene action. Attempts to increase lint index will be more difficult when this type of epistatic gene action is involved because a greater percentage of any segregating population will be below acceptable standards. However, an awareness of this possibility occurring in populations resulting from high × low crosses will enable adjustments to be made in population sizes so that progress can be achieved without undue delay.

The adjusted mean differences between generations for the groups are presented at the bottom of Table 2. The values are all positive for the F_1 — MP comparison and values for the $F_2 - \frac{1}{2}(F_1 + MP)$ comparison are positive for the high × high and low × low groups and negative for the high × low group. These comparisons for the high × high group suggest that populations exhibiting high lint index may offer more promise for advancing lint index through selection.

[3] Results of 1960 Regional Cotton Variety Tests. USDA, ARS Publication 34–30. 1961.

SUMMARY

Gene action involved in the inheritance of lint index was investigated in the parental, F_1 and F_2 generations of 28 populations of Upland cotton which resulted from the diallel crossing of eight lines, four of which exhibited low lint index and four high. Dominant gene action was involved in populations resulting from crosses of high × high and low × low lines. Epistasis was noted in populations resulting from crosses of high × low lines, and it is suggested that dominance was also operative in this group. F_1 means generally exceeded mid-parental values. Epistasis, where found, resulted in the rapid regression of the F_2 mean toward the mid-parent. Some implications in breeding are discussed.

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