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Earliness component analysis through diallel cross method

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Abstract

Inheritance and interrelationships of morphological and phenological components of earliness were evaluated in a diallel analysis involving five early-maturing parents and a standard cultivar. This study was initiated in 2003 by making all possible crosses, without reciprocals, among the six parents. Field evaluation of the six parental genotypes and the 15 Fl was made in 2004 in a randomized complete block design with four replications. Of 13 earliness components studied, all but days to first square, vertical flowering interval, boll maturation period, and production rate index showed significant additive genetic variance. Heritability estimates ranged from 0.08 for production rate index to 0.45 for days to first open boll. Correlation analysis showed generally that the lower the node to the first fruiting branch and the shorter the plant, the earlier was the onset of squaring, flowering, and boll opening.

Key *words :* cotton, earliness, inheritance

Introduction

Most characteristics for improving cotton are inherited as quantitative traits.. Factors such as yield, earliness, lint percentage, and resistance to pests are conditioned by quantitative genes. Many researchers have been frustrated in attempting to solve their genetic problems by using simple genetic models, wherein few genetic parameters are used to describe complex situations. Quantitative traits are difficult to study because: (I) their expression is modified by environmental and management fluctuations; (2) a trait, such as yield, is a composite of many other traits, each influenced by many genes, each of which has variable effects; (3) the expression of an individual gene is often modified by the expression of other genes; (4) linkage blocks are difficult to breakup; (5) the optimum genotype for a given environment-management system may require gene contribution from many diverse sources; and (6) the optimum genotype for any environment management system is likely to be different from that for another system, Meredith (1984).

Earliness of crop maturity is an important objective in most cotton breeding programs, although the development factors that determine it are not completely understood. Early maturity is the end result of several growth and fruiting processes, or components, which are interrelated, and which presumably can be manipulated separately in the breeding process.

The efficiency with which these manipulations can be affected depends considerably on what we understand about the inheritance and interrelationships among the determinants of earliness.

A review of available literature indicates considerable variation in how earliness is defined, and an unclear picture of how various components of earliness are inherited and related to each other. It also is apparent that no single criterion provides an adequate, functional indicator of earliness, and that effective alteration of maturity can best be achieved by selecting for more than one component of earliness.

Node number of first fruiting branch is one morphological character that can be used to indicate earliness of maturity (Low et al., 1969; and Munro, 1971).

Node number can be determined early in the season, it can be easily and precisely identified, and it is independent of complications arising from shedding of fruit forms. When considered in terms of rate of fruit development and maturity, earliness may be defined. As the extent to which squaring, flowering, and boll opening occur relative to time of planting (Richmond & Radwan, 1962). This definition does not take into account the amount of seed cotton produced, but it involves phenological events that are readily observable and measurable. Several other parameters have been used as indicators or estimators of earliness, including rates of blooming (Namken & Heilman, 1973) and maturation (Phipps, 1982), vertical and horizontal flowering intervals (Tharp, 1965), vertical and horizontal flowering intervals (Tharp, 1965), mean maturity (Christides & Harrison, 1955), production rate index (Bilbro & Quisenberry, 1963), and portion of crop harvested by specified dates (Richmond & Ray, 1966).

The study reported here was designed to address to principal objectives:

(1) To investigate the inheritance of certain phenological and morphological variables contributing to early crop maturity;

(2) To determine associations among components of earliness.

Materials and methods

Genetic material

The study utilized one standard commercial cultivar and five 'early' genotypes developed by breeders in different parts of IRAN and other countries, as follows:

Varamin. This variety constituted the check for this study; it displays vigorous vegetative growth and full season maturity.

818312. It is a compact and early maturing.

Early mutagenesis. It is a mutation derived variety.

Chirpan-539. It is a moderately compact cultivar of diminutive conformation with early to very early maturity.

Bul-539. It is a short season cultivar. It is moderately early and intermediate in height and growth habit.

B-557. It is early in maturity, moderately compact in nature.

Field procedures

All possible crosses, excluding reciprocals, were made among the six parental stocks, and field evaluation of the parents and 15 F1 were made at the Experiment Station, at Varamin, Tehran, Iran in a randomized complete block design with four replications. Plots consisted of two rows of 20 plants each, with plants spaced 20 cm apart. Cultural practices followed were those considered normal for the area, and included excellent insect pest control.

Collection of *data*

After seedling plants became well established, five representative, undamaged plants were selected in each plot and marked for identification. These five plants were monitored and tagged to provide the following phenological data:

1. Date of first square (DFS) - number of days from planting to appearance of first square.

2. Date of first flower (DFF) - number of days from planting to appearance of first flower.

3. Date of first open boll (DFOB) - number of days from planting to opening of the first boll.

4. Boll maturation period (BMP) - the time from anthesis of the flower until the resulting boll was sufficiently open to see the lint.

5. Vertical flowering interval (VFI) - the number of days between flowerings at corresponding nodes on successive fruiting branches, up the main stem

6. Horizontal flowering interval (HFI) - the number of days between anthesis of flower at the first and second position on same fruiting branch.

Ten plants in the other row of each plot were utilized to obtain data for the following variables:

1. Percentage of crop harvested (PCH-I) - ratio of weight of seed cotton harvested at the first picking to total weight of seed cotton harvested, expressed as a percentage.

2. Percentage of crop harvested (PCH-2) - ratio of weight of seed cotton harvested in combined first and second pickings to total weight of seed cotton harvested, expressed as a percentage.

3. Bloom index (BI) - a weighted ratio calculated by dividing the total number of blooms recorded by thesummation of the number of blooms per day x days from planting x 100. This index was calculated for the first 30 days of production of blooms.

4. Maturity index (MI) - a weighted ratio calculated by dividing the total number of open bolls recorded by the summation of the number of open bolls per day x days from planting x 100. This index was calculated by using the total number of open bolls.

5. Mean maturity data (MMD) - the procedure to calculate MMD was the one given by Christidis & Harrison (1955) which is generalized as follows:

$$MMD = \frac{(W_1H_1) + (W_2H_2) + ... + (W_nH_n)}{W_1 + W_2 + ... + W_n}$$

Where W = weight of seed cotton; H = number of days from planting to harvest; and 1, 2 . . . n = consecutive periodic harvest number.

6. Production rate index (PRI) - the total seed cotton plot weight divided by the MMD.

Statistical analysis

The data for each measurement were tabulated and analyzed by analysis of variance using plot means. Simple correlation coefficients (r) were calculated to determine the associations among the traits. Diallel analysis of the selected measurements was used to determine how they inherited.

The diallel analysis, as developed by Jinks (1954) and Hayman (1954) for parental and F1 data was used. This biometrical genetic model is based on the assumptions of (1) diploid segregation, (2) parental homozygosity, (3) no reciprocal differences, (4) no genotype-environment interactions, (5) no epistasis, (6) no multiple allelism, and (7) independent gene distribution. Narrow-sense heritabilities were also estimated.

Results

Highly significant differences among parent were found for 13 of 15 earliness components measured, the exceptions being bloom index (BI) and boll maturation period (BMP). Thus, diallel data for these traits are not reported. Appropriate variance analysis indicated that the assumptions of the diallel were satisfied for all traits. In the following discussion, only selected portions of the results will be considered.

Phenological variables

Among the phenological variables, significant additive effects were measured for NFFB, plant height, DFF, DFOB, and HFI (Table I). Significant dominance effects were noted for NFFB, plant height, VFI, and HFI. Additive effects were greater than dominance effects only for DFF, DFOB, and HFI. The strength of additivity is reflected in the heritability estimates, of which only those plant height, DFF, DFOB, and HFI exceeded 0.25.

Fruiting and yield-associated variables

Of the fruiting and yield-associated variables, total blooms, MI, MMD, and PCH-2 showed highly significant additive variation; additive effects for PRI and PCH-I were not significant (Table 2). All of the fruiting and yield-associated traits showed highly significant dominance effects, which were greater than the corresponding additive effects. Heritability estimates ranged from 0.08 for PRI to 0.37 for MMD.

Phenotypic correlations

Phenotypic correlations were calculated for all possible combinations among the various earliness variables. Of the 105 values, only 21 were non-significant, and 16 of these

Table 1. Estimates of additive and dominance gene effects and of heritability for phenological variables

Variable	Additive effects	Dominance effects	Heritability
NFFB	1.296*	8.188**	0.14
Plant height	38.601**	47.141	0.44
DFS	1.038	2.787	0.15
DFF	3.370**	1.212	0.35
DFOB	8.542**	3.865	0.45
VFI	0.065	0.113**	0.10
HFI	0.188*	0.179**	0.34

*,** Significant at 0.05 and 0.01 probability levels, respectively.

Table 2. Estimates of additive and dominance gene effects and of heritability for fruiting and yield associated variables.

Variable	Additive effects	Dominance effects	Heritability
Total blooms	43.708**	58.817**	0.30
MI	0.531**	0.647**	0.29
MMD	7.930**	8.353	0.37
PRI	0.921	32.295**	0.08
PCH-1	2.450	90.260**	0.19
PCH-2	231.791**	362.080**	0.32

*,** Significant at 0.05 and 0.01 probability levels, respectively.

Table 3. Phenotypic correlations among selected earliness components.

Component		DFF	DFOB	NFFB	Plant height
DFS		0.91**	0.77**	0.29**	0.36**
DFF		-	0.83**	0.32**	0.43**
DFOB		-		0.37**	0.44**
VFI		- 0.54**	0.35**	-0.17	- 0.36**
HFI		0.14	0.19	0.10	0.32**
Total	blooms	- 0.65**	- 0.58**	0.33**	- 0.34
BI		- 0.51**	0.59**	0.26**	0.39**
MI		- 0.52**	- 0.66**	- 0.35**	- 0.30**
BMP		0.26*	0.40**	0.23	0.19
NFFB		0.32**	0.37**	-	0.40**
Plant	height	0.43**	0.44**	0.40**	
PRI		0.18	0.38**	0.26*	0.41**
MMD		0.57**	0.70**	0.33**	0.31**
PCH-l		- 0.64**	- 0.78**	- 0.40**	- 0.33**
PCH-2		0.55**	- 0.67**	- 0.30**	0.27 **

*, ** Significant at 0.05 and 0.01 probability levels, respectively.

involved either horizontal flowering interval or production rate index. A select group of Correlations are presented in Table 3, which shows how the four variables DFF, DFOB, NFFB, and plant height are associated with other earliness components.

These four parameters were selected because they are ones that can be most easily measured, and they probably can be considered prime criteria for use in selecting for earliness in a breeding program. The correlation data generally indicate that the lower the node of the first fruiting branch and the shorter the plant, the earlier will be the onset of squaring, flowering, and boll opening. Genotypes with These characteristics tend to have a short boll maturation period and require fewer days to 50% cumulative maturity. Further, these genotypes tend to produce flowers and to open their bolls at faster rates.

Discussion

Information gained from this study provides useful guidelines on how earliness components might be viewed in selection and testing programs.

Number of node to the first fruiting branch. Considering the results summarized here and recognizing the risks of extrapolation, it appears that, the use of NFFB as a tool for selection for rapid-fruiting, early -maturing genotypes probably would be quite ineffective, as the small additive variance for this trait resulted in a narrow sense heritability of only 0.14. This confirms the finding of Tiffany & Malm (1981) who reported heritability of 0.06.

Plant height. On the other hand, plant height showed a relatively high heritability (0.44), suggesting that selection for this attribute would be moderately effective.

Since NFFB and plant height are highly correlated, selection for reduced plant height should result in low NFFB and also effect a correlated selection for early squaring, early flowering and faster rate of maturity.

Date of first square. As a selection criterion, DFS has the advantage of being closely associated with several other components and estimators of earliness. These associations support the work of Richmond & Radwan (1962) who concluded that anyone of several methods, including date of first square, can be used with confidence to estimate earliness in cotton on a single plant basis. However the use of DFS has certain disadvantages. Date of square appearance is a somewhat subjective determination because early recognition is difficult, and requires a measurement standard to establish when a square can be considered to be recognizable. Further, very young square frequently abscise in response to environmental stress or insect damage. A final drawback to the use of DFS as a selection criterion is its low heritability (0.15), which reflects the high proportion of non-genetic variance associated with the trait.

Date of first flower. From a practical point of view, date of first flower (DFF) is easier to work with than is DFS. Appearance of first flower is a discrete event, easily recognizable, and error of determination is less. Date of first flower also shows favorable associations with several other earliness estimators that reflect early and rapid fruiting, such as bloom index, maturity index, mean maturity date (Table 3).

In the present study, a substantial portion of the genetic variance for DFF was additive, and the heritability estimate of 0.35 suggests that date of first flower can be selected with high efficiency. Results reported here compare favorably with those of Tiffany & Malm (1981) who reported a heritability value of 0.26 and of Al-Rawi & Kohel (1969) who reported considerable variance for DFF.

Date of first open boil. As Richmond & Radwan (1962) indicated, the utility of DFOB as an earliness indicator is limited by considerable time needed for scoring plants, by shedding of squares and immature bolls, and by a relatively long boll maturation period.

Of the last three primary fruiting variables, date of first open boll showed the highest heritability estimate (0.45), prompting the conclusion that selection for DFOB would be more effective than selection for DFS and DFF.

Vertical flowering interval. Results of this study suggest that vertical fruiting interval would not be a suitable plant character for use in selection. Heritability was estimated as 0.10, and the diallel data (Table 1) show small additive variance, and partial dominance for high values of VFI. Smith (1984) likewise suggests that VFI does not provide an effective criterion for breeding of early-rapid fruiting genotypes.

Horizontal flowering interval. Heritability of HFI was estimated at 0.34, and suggests that the trait can be manipulated reasonably well in a breeding program. The use of HFI is limited by the time involved in detailed bloom tagging that is necessary to establish this interval of individual plants.

Bloom index. The diallel analysis revealed no significant information regarding genetic components or heritability for bloom index (BI). From a practical point of view, bloom index appears not to be a useful criterion for selection, but it would be a valuable indicator of differences among lines and advanced strains being evaluated for fruiting performance.

Maturity index. Even though significant levels of additive and dominance variation were measured, and the heritability estimate is reasonably good (0.29), use of maturity index for phenotypic selection of early maturity would not be feasible because of the expense and time required to make repeated, successive counts of open bolls. Maturity index would be most useful for assessing relative rates of maturity among lines and cultivars in performance testing, as demonstrated previously by Niles (1970).

Boll maturation period. Use of boll maturation period (BMP) as an indicator of maturity is questionable, as Morris (1964) suggested that evaluation of BMP may be confounded by the effects of temperature that may tend to negate genotype differences in BMP. Results of the diallel genetic analysis were not significant.

Mean maturity date. Christides & Harrison (1955) proposed mean maturity date as an indicator of maturity. Its calculation requires periodic harvesting during the crop opening season, and, as such, its best application is in comparative evaluation of cultivars, strains, and lines, and not for primary plant selection.

Use of MMD to differentiate genotype differences for maturity has been recognized by several researchers (Tiffany & Malm, 1981; Bilbro & Quisenberry, 1973; Richmond & Ray, 1966). The relatively high estimate of heritability (0.37) is supported by results of studies reported by Tiffany & Malm (1981) and Ray and Richmond (1966).

Production rate index. The genetic analysis of production rate index (PRI) has shown dominance effects, and essentially low heritability. Utility of production rate index is limited by the need to make several periodic harvests, and the two variables can be used most effectively for evaluating strains and cultivars, rather than as criteria for selection.

Percentage of crop harvested at first and second picking. Results of the diallel analysis indicate significant dominance effects for both percentage of harvest at first (PCH-l) and second pickings (PCH-2), and with a significant additive effect only for PCH-2. Considering the low estimate of heritability associated with PCH-l, Percentage of crop harvested at second picking is indicated as the better estimator of maturity in advanced stages of strain development and in performance testing.

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