GENETIC CONTROL OF THE MAIN AGRONOMICALLY USEFUL GENETIC TRAITS IN COTTON

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ABSTRACT

High useful genetic variability is available in cotton. The paper presents data from the research performed during 2000-2001 at A.R.D.S. Teleorman, Romania on the genetic control of several agronomically important quantitative traits in cotton. Ten parental genotypes in C_7 inbreeding generation and 45 direct hybrids obtained by n(n-1) diallel crossing in F_1 generation were tested. The results led to the hypothesis that the genetic control of the main traits in the tested cotton parents is mainly:

- total dominance for the insertion height of the first sympodium, expressed in number of nodes;

- partial dominance for the distance between cotyledonal node and insertion node of the first sympodium (cm) and for the fibre length;

- overdominance for the weight of early yield from the total one, early yield, siliquae weight, fibre content and total yield.

The tested traits had large heritabilities except for the siliquae weight.

Key words: cotton, earliness, genetic control, fibre length, fibre content, raw cotton yield, siliquae weight.

INTRODUCTION

High genetic variability is available in cotton (Miller, 1959; Marrani, 1968; Bridge, 1969; Murray and Verhalen, 1970; Baker and Verhalen, 1973). Meredith (1984) presents the relative weight of additive and dominance components as well as dominance degree found by different researchers in some quantitative genetic traits in cotton. So, White and Kohel (1964) reported complete dominance for cotton yield while Al-Rawi and Kohel (1964) found partial dominance and Verhalen (1971), overdominance for the same genetic trait. Similar results are quoted for other traits, too: fibre content, siliquae weight and fibre length. In the case of *Gossypium hirsutum* x *Gossypium barbadense* L. interspecific crossing, the study of Ana Stoilova (1978) shows that the transmission of the insertion node of the first sympodium is closely correlated with heterosis effect, more rarely with partial dominance of one of the parents.

Genetic studies performed by Simongulian (1975) showed a partial dominance of insertion, while Baker and Laval (1973) showed that the earliness has a genetic control of overdominance type.

Rîstakov and Avtonomov (1980) supposed that the genetic variability of fibre content is conditioned by gene additive and dominance effects and Baker and Verhalen (1973) reported overdominance. For the siliquae weight, Meredith (1984) reported complete dominance while Ramey and Miller (1966), Al-Rawi and Kohel (1969) partial dominance.

For the fibre length, Ramey and Miller (1966), Verhalen and Murray (1969) reported partial dominance while Baker and Laval (1974) complete one. Therefore results regarding the heredity of a given genetic trait are highly specific to the tested germplasm.

MATERIAL AND METHODS

During 2000-2001, at A.R.D.S. Teleorman, Brânceni Center, 10 cotton lines (C_7) and their direct hybrids in F_1 generation, obtained by n(n-1)/2 diallel crossing, were tested. The earliness components (insertion height of the first sympodium, early yield weight and raw cotton early yield), components regarding the productivity (fibre content, siliquae weight, total yield) and fibre length were determined.

The determinations were made on 50 plants x 3 reps and total yields were expressed in t/ha. Analysis of variation coefficients (Ceapoiu, 1968), variance analysis for experiment groups (Ceapoiu, 1968), half diallel table analysis (Walters and Morton, 1978), estimation of genetic variance components and heritability (Jinks, 1954, Hayman, 1954a; 1954b, Mather and Jinks, 1974) were performed.

RESULTS AND DISCUSSION

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The variation coefficients of parental genotypes were low for all tested genetic traits, meaning that the lines used as parents after seven years of inbreeding had an advanced degree of homozygosity (Table 1).

Table 1. Variation coefficients of parental genotypes for the tested quantitative traits, in cotton
A.R.D.S. Teleorman, 2000-2001 average

Line	Insertion height of the first sympodium (nodes)	Distance from cotyledonal node to the first sympodium (cm)	% early yields (arcsin $\sqrt{\%}$)	Early yield (t/ha)	Siliquae weight (g)	Fibre content (%)	Total yield (t/ha)	Fibre length (mm)
T-045	1.83	2.39	1.93	1.88	2.16	1.55	1.96	0.71
T-0225	1.54	1.77	2.01	1.83	1.73	1.82	1.82	0.72
T-0320	1.31	1.70	2.01	2.13	2.33	2.03	2.03	0.72
T-0419	2.83	2.61	1.72	1.40	1.91	1.70	1.70	0.73
T-0435	2.85	3.05	1.67	1.80	1.81	2.29	2.29	0.61
C-0438	1.90	2.24	1.99	1.73	2.01	1.73	1.73	0.69
T-0535	1.91	2.18	1.82	2.20	1.93	2.48	2.48	0.73
C-0572	1.36	1.95	1.97	2.17	1.95	2.20	2.20	0.74
T-0575	1.87	2.02	1.84	1.88	1.73	2.44	2.44	0.67
C-0577	2.28	2.13	1.81	1.85	1.81	2.08	2.08	0.67

Table 2. Mean values of the agronomically useful quantitative traits, in parental cotton genotypes
A.R.D.S. Teleorman, 2000-2001 average

Parental genotype	Insertion height of the first sympodium (nodes)	Distance from cotyledonal node to the first sympodium (cm)	% early yield from total one (arcsin $\sqrt{\%}$)	Early yield (t/ha)	Siliquae weight (g)	Fibre content (%)	Total yield (t/ha)	Fibre length (mm)
T-045	5.15	16.00	52.39	1.82	5.50	45.30	2.90	30.38
T-0225	6.13	21.60	50.48	1.87	6.87	41.18	3.13	29.90
T-0320	7.20	22.50	49.17	1.61	5.10	44.87	2.81	29.85
T-0419	3.33	14.60	58.86	2.45	6.23	39.93	3.35	29.37
T-0435	3.30	12.50	60.68	1.90	6.57	35.80	2.49	35.23
C-0438	4.95	17.03	50.92	1.98	5.93	43.50	3.29	30.93
T-0535	4.93	17.53	55.56	1.56	6.18	40.80	2.29	29.55
C-0572	6.90	19.55	51.36	1.58	6.10	41.85	2.59	28.95
T-0575	5.03	18.88	55.10	1.82	6.87	41.30	2.33	32.28
C-0577	4.13	14.88	55.86	1.88	6.57	37.75	2.74	31.97
Average	5.11	17.51	54.04	1.85	6.19	41.23	2.79	30.84
LSD 5%	0.42	0.86	1.39	0.47	0.47	2.30	0.66	0.64
LSD 1%	0.56	1.13	1.83	0.62	0.63	3.03	0.97	0.84
LSD 0,1%	0.71	1.44	2.34	0.77	0.80	3.87	1.24	1.08

The average values of tested parental genotypes for the tested traits showed a large enough variability (Table 2).

ANOVA for all tested traits emphasized that the differences between parental genotypes were distinctly significant when tested vs. error variance, the variability coefficient being of 5.57-17.34 % depending on the tested trait (Tables 3 and 4).

The statistically significant differences between average values of the tested genetic traits for the 55 genotypes (10 parental forms and 45 F_1 direct hybrids) allowed the detailed study of variance in those genetic traits.

By the half diallel table analysis, the genetic variance for each tested genetic trait was decomposed into components for additivity (g_i) and dominance (l, l_i, l_{ij}) effects of genes involved in their heredity control.

For the earliness factors (Table 5), both additivity (g_i) and dominance (l, l_i, l_{ij}) gene effects are present, being statistically significant.

Although the additivity is involved, the obtained data underline the fact that the dominance effects have a prevalent role, because the components (l, l, l_{ij}) have a larger weight into genetic variance except for the distance (in cm) from the cotyledonal node to insertion of the first sympodium (in which the additive component has the largest weight).

Table 3. ANOVA for earliness indicators in cotton
A.R.D.S. Teleorman, 2000-2001 average

Variability cause	FD	Insertion height of the first sympodium (nodes)			Distance from cotyledonal node to the first sympodium (cm)			Early yield from total one (arcsin $\sqrt{\%}$)			Raw cotton early yield (t/ha)		
		SS	s^2	F	SS	s^2	F	SS	s^2	F	SS	s^2	F
Blocks	3	0.28			1.55			6.25			0.12		
Genotypes	54	267.90	4.96	55.11**	1426.27	26.41	69.5**	2151.94	39.85	39.46	28.85	0.53	4.68**
Error	162	15.24	0.09		61.83	0.38		163.99	1.01		18.50	0.11	
Variability coeff. (%)		6.50			6.49			11.83			17.34		

**significant for 1%

Table 4. ANOVA for siliquae weight, fibre content, total yield and fibre length
A.R.D.S. Teleorman, 2000-2001 average

Variability cause	FD	Siliquae weight (g)			Fibre content (%)			Total yield (t/ha)			Fibre length (mm)		
		SS	s^2	F	SS	s^2	F	SS	s^2	F	SS	s^2	F
Blocks	3	0.35			23.39			0.21			0.43		
Genotypes	54	38.22	0.71	5.95**	753.84	13.96	5.04**	49.08	0.91	4.00**	361.25	6.69	31.13**
Error	162	19.29	0.12		448.35	2.77		36.80	0.23		34.81	0.21	
Variability coefficient (%)		5.57			13.95			16.45			11.48		

**significant for 1%

Table 5. Analysis of variance of half diallel table for cotton earliness factors
A.R.D.S. Teleorman, 2000-2001 average

Variability cause	FD	Insertion height of the first sympodium						Early yield from total one (arcsin $\sqrt{\%}$)			Raw cotton early yield (t/ha)		
		nodes			cm								
		SS	s^2	F	SS	s^2	F	SS	s^2	F	SS	s^2	F
Additive contribution of i genotype (g_i)	9	64.41	7.16	79.55**	362.72	40.30	106.05**	520.63	57.85	57.28**	2.39	0.27	2.45*
Mean deviation due to dominance (l)	1	7.07	7.07	78.56**	2.01	2.01	5.29*	45.61	45.61	45.16**	0.52	0.52	4.73*
Dominance deviation due to *i* genotype (l_i)	9	16.76	1.86	20.67**	31.39	3.49	9.18**	182.65	20.29	20.01**	3.93	0.44	4.00**
Dominance deviation due to *i* x *j* cross (l_{ij})	35	111.01	3.17	35.22**	207.74	5.94	15.63**	894.13	25.55	25.30**	16.71	0.46	4.18**
Error	162	15.24	0.09		61.83	0.38		163.99	1.01		18.50	0.11	

*Significant for 5%; ** significant for 1% Mathematical model: $y_{ij}=m+g_i+g_j+l+l_i+l_j+l_{ij}$ (Walters and Morton, 1978)

The significance of dominance effect of the involved genes emphasizes the following aspects:

- dominance of height insertion of the first sympodium (cm), of % early yield from total one (arcsin $\sqrt{\%}$) and of raw cotton early yield (t/ha) is of unidirectional type (first component);
- positive and negative alleles are unequally distributed among parents for all tested traits (l_i component);
- the existence of certain specific hybrids with residual dominance reaction is obvious for this set of parental genotypes (l_{ij} component).

For the siliquae weight, fibre content, total yield and fibre length (Table 6), both additivity (g_i) and dominance (l, l_i, l_{ij}) gene effects are present, being significant. The gene dominance effects have prevalent role because the l, l_i, l_{ij} components have larger weight into genetic variance, except for the fibre content in which the gene additivity (g_i) component is higher.

The significance of the three types dominance of effects of involved genes emphasizes the fact that:

- dominance of siliquae weight (*g*), fibre content (%), total cotton yield (t/ha) is of unidirectional type, while, fibre length is of bidirectional type (*l* component);

- positive and negative alleles which control the tested traits are relatively unequally distributed among parents (l_i component);

- the existence of certain specific hybrids with residual dominance reaction is obvious for this set of parental genotypes (l_{ij} component).

Table 6. Analysis of variance of half diallel table for siliquae weight, fibre content, raw cotton total yield and fibre length in those ten cotton parental genotypes and their direct hybrids in F_1 generation
A.R.D.S. Teleorman, 2000-2001 average

Variability cause	FD	Average weight of siliquae (g)			Fibre content (%)			Raw cotton total yield (t/ha)			Fibre length on seed (mm)		
		SP	s^2	F	SP	s^2	F	SP	s^2	F	SP	s^2	F
Additive contribution of *i* genotype (g_i)	9	11.92	1.32	11.12**	315.52	35.06	12.67**	5.13	0.57	2.51**	128.18	14.24	66.28**
Mean deviation due to dominance (*l*)	1	1.00	1.00	8.41**	35.30	35.30	12.76**	0.77	0.77	3.37**	14.91	14.91	69.40**
Dominance deviation due to *i* genotype (l_i)	9	2.88	0.32	2.69**	94.72	10.52	3.80**	11.36	1.26	5.56**	11.73	1.30	6.06**
Dominance deviation due to *i* x *j* cross (l_{ij})	35	12.72	0.36	3.05**	193.75	5.54	2.00**	29.03	0.83	3.65**	70.39	2.01	9.36**
Error	162	19.29	0.12		448.34	2.77		36.80	0.23		34.81	0.21	

** significantly for 1% Mathematical model: $y_{ij}=m+g_i+g_j+l+l_i+l_j+l_{ij}$ (Walters and Morton, 1978)

The variance analysis of the difference between covariance and variance of hybrid rows with a common parent (Wr - Vr) (Tables 7 and 8) demonstrated that, for all tested traits, the difference values are relatively homogenous and not significantly different. This means that, the non-allelic interactions involved into tested trait heredity do not have a high level of manifestation, confirming the fact that the additivity x dominance model chosen for this study is the adequate one.

Table 7. ANOVA Wr-Vr for cotton earliness indicators
A.R.D.S. Teleorman, 2000-2001 average

Variability cause	FD	Insertion height of the first sympodium (nodes)			Distance from cotyledonal node to the first sympodium (cm)			Early yield from total one (arcsin $\sqrt{\%}$)			Raw cotton early yield (t/ha)		
		SS	s^2	F	SS	s^2	F	SS	s^2	F	SS	s^2	F
Reps	3	3.32	1.1052		8.29	2.7635		51.32	17.1082		0.07	0.0241	
Rows	9	9.77	1.0852	2.23 NS	9.08	1.0097	2.22 NS	83.96	9.3292	1.96 NS	0.17	0.0184	

Error	27	13.14	0.4866		12.23	0.4528		128.51	4.7598		0.23	0.0084	2.19 NS

NS- unsignificant

Table 8. ANOVA Wr-Vr for siliquae weight, fibre content, raw cotton total yield and fibre length A.R.D.S. Teleorman, 2000-2001 average

Variability cause	FD	Siliquae weight (g)			Fibre content (%)			Raw cotton total yield (t/ha)			Fibre length (mm)		
		SS	s^2	F	SS	s^2	F	SS	s^2	F	SS	s^2	F
Reps	3	0.09	0.031		40.40	13.47		0.21	0.07		0.34	0.11	
Rows	9	0.04	0.005	0.62 NS	58.83	6.54	1.68 NS	0.37	0.04	1.39 NS	2.14	0.24	1.96 NS
Error	27	0.21	0.008		105.33	3.90		0.79	0.03		3.28	0.12	

NS- unsignificant

The estimation of genetic variance components and heritability based on covariance and variance of hybrid rows with a common parent led to the following genetic parameters: D, H_1, H_2, F and h^2 (Table 9).

For all tested genetic traits, the results emphasize the fact that the values of genetic parameters are significant, proving the fact that these traits were not too much affected by environmental conditions.

Table 9. Values of genetic variance components for cotton earliness factors, siliquae weight, fibre content, raw cotton total yield and fibre length, A.R.D.S. Teleorman, 2000-2001 average

Nr. crt.	Genetic parameters	Insertion height of the first sympodium		Early yield from total one (arcsin $\sqrt{\%}$)	Raw cotton early yield (t/ha)	Average weight of siliquae (g)	Fibre content (%)	Raw cotton total yield (t/ha)	Fibre length on seed (mm)
		nodes	cm						
1	D	1.77±0.07	10.08±0.14	14.38±0.81	1.02±0.01	0.29±0.01	7.91±0.24	0.04±0.002	3.42±0.06
2	H_1	1.80±0.14	6.19±0.29	28.23±1.72	0.64±0.03	0.46±0.01	9.76±0.50	0.07±0.004	2.34±0.13
3	H_2	1.63±0.12	5.33±0.25	23.51±1.46	0.55±0.02	0.41±0.01	8.23±0.43	0.06±0.004	2.08±0.11
4	F	0.99±0.16	-0.46±0.02	9.67±1.86	0.03±0.02	0.14±0.01	5.88±0.55	0.02±0.005	1.38±0.14
5	h^2	0.83±0.08	0.07±0.17	5.26±0.98	0.03±0.01	0.04±0.01	3.32±0.29	0.001±0.003	1.75±0.07
Proportional values									
6	$(H_1/D)^{1/2}$	1.00	0.79	1.40	1.26	1.27	1.11	1.42	0.83
7	Vr/Wr	1.01	0.85	1.80	1.55	1.81	1.62	1.78	0.87
8	$H_2/4H_1$	0.23	0.22	0.21	0.21	0.22	0.21	0.19	0.22
9	$\frac{(4DH_1)^{1/2}+F}{(4DH_1)^{1/2}-F}$	1.27	0.94	1.63	1.26	1.47	2.01	1.54	1.64
10	$\frac{1/2F}{[D(H_1-H_2)]^{1/2}}$	0.90	0.08	0.59	0.31	0.56	0.85	0.42	0.73
11	h^2/H_2	0.51	0.01	0.22	0.04	0.10	0.40	0.02	0.84
12	Heritability: - in narrow sense	0.43	0.77	0.41	0.47	0.31	0.84	0.52	0.61
	- in large sense	0.93	0.95	0.91	0.85	0.63	0.96	0.94	0.89

The very significant values of D parameter (which estimates the additivity effects) as well as H_1, H_2, F and h^2 ones (which estimate the dominance effects) confirm the fact that both effect types are present in the heredity of the tested traits, the dominance effects having prevalent role.

The positive and significant value of the F parameter suggests the fact that the presence of dominant genes is in excess vs. recessive ones for all tested traits except the distance from cotyledonal node to insertion of the first sympodium for which, the recessive gene frequency is in excess vs. dominant genes.

The ratios $(H_1/D)^{1/2}$ and Vr/Wr emphasize a genetic control of type:

- complete dominance for height insertion of the first sympodium (in nodes);
- partial dominance for insertion height of the first sympodium (cm) and fibre length (mm);
- over dominance for percentage early yield from total one (arcsin$\sqrt{\%}$), early yield (t/ha), siliquae weight (g), fibre content (%) and total yield (t/ha).

The value, supra-unitary and different from 1, of ratio $[(4DH_1)^{1/2} + F/(4DH_1)^{1/2} - F]$ emphasizes the asymmetry of dominant and recessive gene distribution among parents for insertion of the first sympodium (cm), percentage early yield from total one (arcsin$\sqrt{\%}$), early yield (t/ha), siliquae weight (g), fibre content (%), total yield (t/ha) and fibre length, hypothesis confirmed by $H_2/4H_1$ ratio value which estimates the relative distribution of dominant and recessive genes (value < 0.25, corresponding with the genes having equal frequency).Average degree of dominance variation at the level of different loci is given by the value of $\frac{1}{2}$ $F/[D(H_1-H_2)]^{1/2}$, which shows that the dominance is not variable for the first sympodium insertion (cm), early yield weight, early yield, siliquae weight and total yield but is variable from one locus to another for the insertion node of the first sympodium, fibre content and length.

For this set of parental genotypes, the h^2/H_2 ratio emphasizes a gene or a group of genes closely associated which demonstrate dominance only for fibre length (0.84) and maybe for insertion node (0.51).

Generally, the heritability coefficients have high values for all tested traits: 0.41-0.84 in narrow sense and 0.85-0.96 in large sense, except for the siliquae weight for which values are 0.31 in narrow sense and 0.63 in large sense.

CONCLUSIONS

The used parental genotypes had an advanced degree of homozygosis (C_7), the variation coefficients having low values (1.55-2.48).

The differences among the 55 cotton genotypes were distinctly significant.

The variability of the tested traits was large enough for the purpose of the study.

Both gene additivity effects (g_i) and dominance ones (l, l_i, l_{ij}) were involved into heredity of the traits under study.

The genetic control of the heredity of the studied agronomically useful traits in the tested germplasm, was mainly:

- complete dominance for insertion height of the first sympodium (number of nodes);
- partial dominance for insertion of the first sympodium (cm) and fibre length;
- overdominance for percentage early yield from total one, early yield, siliquae weight, fibre content and total yield.

The dominant and recessive genes were relatively unequally distributed among parents for all tested traits.

The dominance was not variable from one locus to another for insertion of the first sympodium (cm), percentage early yield from total one, early yield, siliquae weight and total yield but was variable from one locus to another for insertion node of the first sympodium, fibre content and fibre length.

For this set of parental genotypes, a gene or a group of genes which demonstrate dominance only for fibre length was emphasized.

Generally, the tested traits have high heritabilities in narrow sense as well as in large sense.

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