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Gene action for morphological, anatomical and biochemical traits in inter-specific crosses of cotton

V. L. Amolic, S. S. Mehetre and G. C. Shinde

Department of Botany, Mahatma Phule Krishi Vidyapeeth, Rahuri 413 722

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Abstract

The generation mean analysis of data of inter-specific crosses *viz*., *G. arboreum* var. Y-1 x *G. anomalum* (Cross I) and *G. arboreum* var. G-27 x *G. capitis viridis* (Cross II) revealed that both additive and dominance gene actions were found significant for all the characters under study except dominance gene action for chlorophyll-a in cross I and stomata breadth in cross II was found non-significant. Duplicate epistasis was observed for all the characters in cross I except for upper palisade layer length, number of cells in upper palisade, chlorophyll-a_1, b_1 content and total sugar content where complementary epistasis was observed. Whereas in cross II the duplicate epistasis was observed for all the characters except for lower palisade layer length, distance between phloem, stomata breadth and total sugar content. Presence of both fixable and non-fixable genetic components as well as duplicate type of epistasis observed for different characters, which indicated accumulation of favorable genes for the characters, it is worth to intermate and select desired characters from segregating generations, which would yield better results.

Key words : *Gossypium arboreum, Gossypium anomalum*, interspecific crosses, generation means, gene action, anatomical and biochemical characters

Introduction

Understanding the nature of genetic system that account for variability is essential in any plant breeding programme. Improvement in the crop depends upon how the existing variability for different characters of economic importance is managed and utilized. The estimates of gene effects help in understanding genetic potentiality of the population. The relative magnitude of additive and non-additive genetic variance deciding the breeding procedure to be followed for improving the population. Several workers have studied bio-chemical basis of resistance to insect pest and several plant resistant compounds have been reported. However, there is limited work on the study of inheritance and gene action for biochemical and anatomical characters in cotton and hence attempts have been made to study the nature of gene action for anatomical and biochemical parameters and bollworms incidence in two crosses *viz*., *G. arboreum* x *G. anomalum* (Cross I) and *G. arboreum* x *G. capitis viridis* (Cross II).

Materials and methods

The material for the present investigation consisted of non-segregating parental (P_1 and P_2) and F_1 generations and F_2 and F_3 segregating generations of two crosses *viz., G. arboreum* var. Y-1 x *G. anomalum* and *G. arboreum* var. G-27 x *G. capitis viridis.* Parents and F_1s were raised during off-season-2002 and were selfed. Bolls developed from selfed F_1s flowers were harvested after maturity and F_2s were grown during *Kharif*, 2002 and selfing of flowers of 20 selected F_2s was also carried out. A field experiment comprising of P_1, P_2, F_1, F_2 and F_3 generations of each of the two crosses were evaluated in compact family randomized block design with two replications during *kharif,* 2003 at All India Coordinated Cotton Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri . The parents and F_1's were grown in two rows and the F_2's and F_3's in four rows each. For germination of wild species *viz., G. anomalum* and *G. capitis viridis* seeds were soaked in GA for 24 hrs and grown in small plastic cups and then seedlings were transplanted in the field. All recommended cultural practices and plant protection measures were adopted to raise normal crop.

Five random plants were taken in case of parents and ten plants in F_1s and twenty plants each in F_2s and F_3s in each replication were used for recording the observations. The damage caused by bollworm complex *viz.,* pink (*Pectinophora gossypiella*) bollworm was recorded on locule basis of twenty plants. The data on

morphological, anatomical and biochemical characters were recorded on the characters *viz.,* No. of days to flowering, leaf area (cm^2), hair length (µ), hair density/ cm^2, size of stomata in µ (length and breadth), stomata frequency/cm^2, length upper palisade layer (µ), lower palisade layer (µ), mesophyll (µ), distance from 1st phloem to xylem (µ), distance upto 1st phloem from lower epidermis (µ), no. of cells in upper palisade layer, no. of upper palisade layers per leaf, no. of lower palisade layers per leaf, chlorophyll a, b. and total (mg/g), total sugar (%) and bollworm incidence (%). Leaves for anatomical studies were sampled from the twelfth node of the plant at flowering stage and analyzed as per Bhatt and Andal [1]. Averages of 10 measurements were taken were considered for data analysis of hair density/cm^2 and hair length (µ) as per method suggested by Maite *et al.* [2] and Sharma and Nwanze [3]. Chlorophyll 'a' and total chlorophyll content were estimated at 90 days after germination as per Arnon [4] whereas the total sugars was estimated by phenol sulphuric acid method outlined by Sadasivam and Manickam [5] and free gossypol by Bell [6]. The generation means analysis in the two crosses was carried out as per Hayman [7] and Gamble [8].

Results and discussion

The mean performance of basic generations P_1, P_2, F_1, F_2 and F_3 of crosses *G. arboreum* var. Y-1 x *G. anomalum* (Table 1) and *G. arboreum* var. G-27 x *G. capitis viridis* (Table 2) showed existence of substantial variability in the material for the different characters under study. Parents of both the crosses showed wide divergence for almost all the characters studied, except number of cells in upper palisade layer, number of upper palisade layer per leaf, number of lower palisade layer per leaf, stomatal length, chlorophyll-a, chlorophyll-b, total chlorophyll and total sugar.

In general F_1 mean performances was better than either of parents for the characters *viz.,* upper palisade layer length in both cross I and cross II; lower palisade layer length in cross II; distance from 1st phloem to xylem in cross I; distance upto 1st phloem from lower epidermis in both crosses and leaf thickness in cross II. It appears that P_1 with high upper and lower palisade layer length in cross I, distance from 1st phloem to xylem in cross I and II, high distance upto 1st phloem from lower epidermis in cross I contributed largely towards increased these characters in F_1 of the crosses, suggesting that it carried the dominant genes for these characters. Similarly, P_2 in cross II with more upper and lower palisade layer length, more distance from 1st phloem to xylem in cross I and more leaf thickness in cross II contributed largely towards increased these characters in F_1s.

The parents P_1 *G. arboreum* var. Y-1 in cross I and *G. arboreum* var. G-27 in cross II with low mean values which are desirable for mesophyll length, days to first flower stomatal frequency, stomata breadth, chlorophyll-a, chlorophyll-b, total chlorophyll and total sugar content contributed towards intermediate to closer value of F_1s. The P_2 parents of both the crosses which are wild species had high hair density and length, which contributed towards the F_1. Significant decline in the performance of F_2 mean from F_1 mean was observed for upper palisade layer length in cross I, lower palisade layer length in both cross I and cross II, mesophyll length in cross I, distance up to 1st phloem from lower epidermis in cross I and II, suggesting presence of involvement of dominance and epistatic interactions in the expression of these traits.

In present study, out of two scaling tests 'C' and 'D' at least one or both were found significant for all the traits in both the crosses indicating the presence of non-allelic interaction for inheritance of these characters [Table 3]. To understand the major genetic effects and to discuss interactions for various characters, digenic interaction model was applied to generations raised from the two crosses *G. arboreum* var. Y-1 x *G. anomalum* (Cross I) and *G. arboreum* var. G-27 x *G. capitis viridis* (Cross II).

It can be seen from the Table 4 that in general Additive (d) effect and dominance x dominance (l) interaction effects were predominant and in desirable direction for days to flowering in both the crosses. While in cross II, additive (d) effect and additive x additive (i) interaction were more pronounced and in desirable direction for inheritance of days to first flower.

Predominance of additive (d) gene action for days to 50 % flowering in *G. hirsutum* have been reported by White and Richmond [9], Kolte and Thombre [10] while Rao [11] reported additive gene action in *G. arboreum* spp. Gupta and Singh [12], Barnes and Staten [13], Baker and Verhalen [14] and Holla [15] reported non-additive (dominance) action for this character.

Gawand *et al.* [16] found additive x additive (i) type of interaction in *G. arboreum* while Mehetre *et al.* [17] reported dominace and dominance x dominance (l) interaction in *G. hirsutum* crosses.

Additive (d) as well as dominance (h) effects were

Table 1. Mean performance of parents F_1s, F_2s and F_3s in *G. arboreum* var. Y-1 x *G. anomalum* (Cross I) for anatomical and biochemical characters

Sr. No.	Cross	P_1	P_2	F_1	F_2	F_3
1.	Days to 1st flower	62.00±0.22	87.00±0.50	64.25±0.04	78.52±0.07	68.12±0.02
2.	Upper palisade layer (µ)	1 54.68±0.01	93.86±0.06	158.37±0.05	1 16.53±0.30	125.32±0.15
3.	Lower palisade layer (µ)	85.50±0.04	56.24±0.001	77.54±0.45	64.11±0.05	83.58±0.05
4.	Mesophyll (µ)	307.04±0.51	212.42±0.63	289.73±0.38	201.82±0.17	246.10±0.93
5.	Distance from 1st phloem to xylem (µ)	49.78±0.12	63.84±0.51	94.74±0.66	95.41±0.09	74.97±0.41
6.	Distance up to 1st phloem from lower epidermis (µ)	205.82±0.27	157.70±0.32	304.68±0.11	249.52±0.27	221.84±0.15
7.	No. of cells in upper palisade layers	14.0±0.04	23.60±0.05	19.75±0.02	23.70±0.03	23.15±0.04
8	Leaf area (cm^2)	27.08±0.25	41.63±0.36	27.67±0.13	32.01± 0.04	29.82±0.24
9	Stomatal frequency/cm^2	14.50±0.06	26.0±0.17	18.05±0.05	15.77±0.03	19.50±0.10
10	Stomata length (µ)	29.64±0.51	22.38±0.14	26.95±0.02	26.44±0.05	24.89±0.10
11	Stomata Breadth (µ)	18..24± 0.09	17.40 ± 0.18	17.29± 0.03	16.91±0.03	16.63±0.02
12	Hair density/cm^2	40.0±1.06	125.30±1.63	48.58±0.50	59.09±0.20	75.68±0.41
13	Hair length (µ)	241.92±2.01	408.21±8.09	313.23±1.21	311.42±1.00	282.99±0.03
14	Chlorophyll-a (mg/g)	2.52±0.02	2.73±0.01	2.57±0.01	2.63±0.06	2.49±0.10
15.	Chlorophyll-b (mg/g)	1.49±0.08	1.78±0.05	1.51±0.04	1.37±0.05	1.61±0.03
16.	Total chlorophyll (mg/g)	4.01±0.07	4.51±0.04	4.08±0.02	4.00±0.01	4.11±0.02
17.	Total sugar (%)	14.24±0.06	17.50±0.15	14.94±0.03	13.31±0.13	12.76±0.12
18.	Bollworm incidence (%)	16.86±0.45	3.80±0.20	16.29±0.19	15.12±0.24	16.84±0.02

Table 2. Mean performance of parents F_1s, F_2s and F_3s in *G. arboreum* var. G-27 x *G. capitis viridis* (Cross-II) for anatomical and biochemical characters

Sr. No.	Cross	P_1	P_2	F_1	F_2	F_3
1.	Days to 1st flower	59.95±0.41	84.50±1.36	70.1±0.39	70.27±0.15	73.99±0.14
2.	Upper palisade layer (µ)	85.88±0.25	104.30±0.06	116.77±0.17	142.10±0.54	158.45±0.70
3.	Lower palisade layer (µ)	34.96±0.08	58.06±0.20	83.58±0.12	70.86±0.12	71.88±0.03
4.	Mesophyll (µ)	1 29.20±0.03	256.80±0.10	232.36±0.06	249.12±0.13	275.43±0.03
5.	Distance from 1st phloem to xylem (µ)	103.36±0.25	96.23±0.15	70.63±0.01	86.13±0.38	87.95±0.13
6.	Distance up to 1st phloem from lower epidermis (µ)	237.42±0.03	229.52±0.12	211.75±0.18	265.10±0.25	236.92±0.09
7.	No. of cells in upper palisade layers	15.00±0.02	20.40±0.01	16.20±0.02	20.35±0.07	7.65±0.03
8.	Leaf area (cm^2)	24.68±0.42	21.99±0.19	22.55±0.47	21.81±0.20	25.79±0.07
9.	Stomatal frequency/cm^2	18.00±0.10	25.00±0.06	23.50±0.03	20.57±0.01	22.70±0.01
10.	Stomata length (µ)	22.60±0.16	26.52±0.02	25.67±0.07	25.88±0.08	25.13±0.10
11.	Stomata breadth (µ)	15.27±0.01	17.55±0.11	17.06±0.01	16.90±0.04	16.92±0.02
12.	Hair density per cm^2	33.60±0.08	165.20±0.37	70.54±0.01	61.35±0.04	82.61±0.01
13.	Hair length (µ)	221.76±4.59	303.66±10.43	319.53±0.43	348.23±0.08	276.81±0.14
14.	Chlorophyll-a (mg/g)	2.34±0.02	2.65±0.01	2.54±0.03	2.47±0.04	2.45±0.04
15.	Chlorophyll-b (mg/g)	1.31±0.004	1.58±0.02	1.44±0.07	1.50±0.05	1.51±0.01
16.	Total chlorophyll (mg/g)	3.65±0.01	4.24±0.04	3.98±0.05	3.97±0.02	4.02±0.01
17.	Total sugar (%)	15.16±0.03	17.20±0.04	16.37±0.03	15.08±0.02	14.46±0.02
18.	Bollworm incidence (%)	17.02±0.19	3.12±0.07	15.46±0.12	16.95±0.08	16.55±0.07

Table 3. Scaling test of generation means for different characters in *G. arboreum* var. Y-1 x *G. anomalum* (Cross-I) and *G. arboreum* var. G-27 x *G. capitis viridis* (Cross-II)

Sr. No.	Characters	*G. arboreum* var.Y-1 x *G. anomalum*		*G.arboreum* var. G-27 x *G. capitis viridis*	
		Scaling test			
		C	D	C	D
1.	Days to Ist flower	36.60**	-33.55**	-3.55**	10.98**
2.	Upper palisade layer (µ)	-99.16**	19.70**	144.90**	159.41**
3.	Lower palisade layer (µ)	-40.36**	64.37**	23.25**	52.79**
4.	Mesophyll (µ)	-51.65**	-58.70**	145.77**	217.47**
5.	Distance from 1st phloem to xylem (µ)	78.54**	-4.54**	3.66**	-20.03**
6.	Dist^{n}. upto 1st phloem from lower epidermis (µ)	25.22**	24.81**	169.96**	-49.46**
7.	No. of cells in upper palisade layers	17.70**	7.60**	13.60**	-5.50**
8.	Leaf area (cm^2)	3.98**	-13.43**	-4.54**	12.88**
9.	Stomatal frequency/cm^2	-13.50**	5.95**	-7.70**	6.65**
10.	Stomata length (µ)	-0.16	-5.34**	3.37**	-0.05
11.	Stomata breadth (µ)	-2.56**	-2.93**	0.67**	1.06**
12.	Hair density per cm^2	-26.08**	19.23**	-94.46**	8.93**
13.	Hair length (µ)	-30.89**	141.009**	228.46**	-144.63
14.	Chlorophyll-a (mg/g)	0.12**	-0.53**	-0.19**	-0.13
15.	Chlorophyll-b (mg/g)	-0.80**	0.44**	0.24**	0.13**
16.	Total chlorophyll (mg/g)	-0.67**	-0.095**	0.04**	0.24**
7.	Total sugar (%)	-8.38**	-7.030**	-4.79**	-4.69**
18.	Bollworm incidence (%)	18.51**	10.77**	24.73**	38.15**

important for the inheritance of upper palisade layer in cross I, additive (d) being more in magnitude. The dominance x dominance (l) was found to be most important interaction component being significant and in desirable direction. This suggested that selection for this trait would be more fruitful if it is delayed till dominance component is reduced due to selfing.

Additive (d) effect was more pronounced for lower palisade layer in cross I and dominance (h) effect in cross II was relatively more important. Among the interaction dominance x dominance (l) interaction was important. For mesophyll dominance (h) effect and additive x additive (i) interaction were pronounced and in desirable directions in cross II. Duplicate interaction was found for mesophyll in both the crosses, while complementary interaction for lower palisade layer length in cross II

Considering the magnitude and direction additive (d) and additive x additive (i) were relatively important in the inheritance of distance between phloem in cross II, while in cross I, dominance (h) and additive x additive (i) effects were predominant.

Additive (d), dominance (h) and additive x additive (i) interactions were important for the inheritance of distance up to first phloem from lower epidermis in both the crosses, dominance (h) being more in magnitude. Number of cells in upper palisade showed predominance of additive x additive (i) type interaction besides the significant positive (h) in cross II. Additive (d), dominance (h) and interaction effects were negative in cross I.

Additive (d) as well dominant (h) effects were important for the inheritance of leaf area, additive in cross I and dominance in cross II being in desirable directions. Among interaction dominance x dominance (l) in cross I and additive x additive (i) in cross II were significant and in desirable direction however, opposite sign of (h) and (l) indicated duplicate epistasis.

For stomata frequency, dominance (h) and additive x additive (i) effects in both the crosses were found to be important whereas additive (d) and dominance x dominance (l) gene effects were predominant in cross II for the inheritance of stomata length and additive (d) and additive x additive (i) type of gene effect were pronounced in cross II for stomata breadth. Duplicate type of epistasis played important role for stomata

Table 4. Estimates of genetic components based on Hayman (1958) for *G. arboreum* var.Y-1 x *G. anomalum* (Cross-I) and *G. arboreum* var. G-27 x *G. capitis viridis* (Cross-II)

Sr.No.	Characters	Cross	m	d	h	i	l
1.	Days to flowering	CI	78.52*	-12.50**	18.21**	3.46**	-93.53**
		CII	70.27**	-12.27**	-10.03**	-32.46**	19.37**
2.	Upper palisade layer (µ)	CI	116.53**	30.41**	4.44**	31.16**	158.48**
		CII	142.10**	-9.21**	-60.47**	-100.57**	19.62**
3.	Lower palisade layer (µ)	CI	64.11**	14.63**	-42.97**	-20.38**	139.64**
		CII	70.86**	-11.55**	5.74**	-54.42**	39.38**
4.	Mesophyll (µ)	CI	261.82**	47.31**	60.53**	125.14**	-9.40**
		CII	249.12**	-63.80**	-81.32**	-248.28**	95.60**
5.	Dist^{n}. from 1st phloem to xylem (µ)	CI	95.41**	-7.03**	54.04**	2.05*	-110.77**
		CII	86.13**	3.56**	-15.19**	21.09**	-31.58**
6.	Dist^{n}. upto 1st phloem from lower epidermis (µ)	CI	249.52**	24.06**	110.58**	35.78**	-0.54*
		CII	265.10**	3.95**	39.58**	69.20**	-292.56**
7.	No. of cells in upper palisade layers	CI	23.70**	-4.80**	-1.16*	-11.71**	-13.46**
		CII	20.35**	-2.70**	4.43**	0.53*	-25.46**
8.	Leaf area (cm^2)	CI	32.01**	-7.27**	2.93**	-4.92**	-23.22**
		CII	21.81**	1.34**	-10.13**	-6.65**	23.24**
9.	Stomatal frequency/cm^2	CI	15.77**	-5.75**	-8.41**	-17.71**	25.93**
		CII	20.57**	-3.50**	-3.71**	-12.71**	19.13**
10.	Stomata length (µ)	CI	26.44**	3.63**	4.47**	10.79**	-6.90**
		CII	25.88**	-2.11**	1.86**	-3.62**	-4.56**
11.	Stomata breadth (µ)	CI	16.91**	0.42**	0.99**	2.36**	-0.49 NS
		CII	16.90**	-1.14**	0.05 NS	-2.87**	0.52 NS
12.	Hair density per cm^2	CI	59.09**	-42.65**	-51.23**	-102.46**	60.41**
		CII	61.35**	-65.80**	-50.55**	-153.29**	137.85**
13.	Hair length (µ)	CI	331.42**	-83.15**	77.03**	-77.44**	-146.82**
		CII	348.23**	-40.95**	171.31**	32.59**	-457.45**
14.	Chlorophyll-a (mg/g)	CI	2.47**	-0.16**	0.10NS	-0.26**	0.08 NS
		CII	2.63**	-0.11**	0.32**	0.16**	-0.88**
15.	Chlorophyll-b (mg/g)	CI	1.50**	-0.14**	-0.57**	-0.32**	-0.15**
		CII	1.37**	-0.14**	-0.55**	-0.72**	1.65**
16.	Total chlorophyll (mg/g)	CI	3.97**	-0.29**	-0.11**	-0.74**	0.27**
		CII	4.00**	-0.25**	-0.23**	-0.55**	0.77**
17.	Total sugar (%)	CI	5.32**	-1.50**	2.02**	-0.83	1.27**
		CII	6.77**	-0.95**	2.17**	0.37 NS	0.12 NS
18.	Bollworm incidence (%)	CI	25.61**	8.88**	12.52**	13.66**	-10.32**
		CII	26.95**	11.94**	-9.93**	2.58**	17.89**

*,**Significant at 5 % and 1 %, respectively

frequency, stomata length, stomata breadth in both the crosses except for stomata breadth in cross II where complementary epistasis was present.

Hair density was influenced by additive (d) and dominance x dominance (l) gene action for both the crosses. Singh and Raut [18] also reported additive (d) and dominance (h) effects for hair density in cotton. While, dominance (h) in both crosses and additive x additive (i) in cross II were important for inheritance for hair length.

Considering the biochemical characters *viz.,* chlorophyll-a, b and total chlorophyll, additive effect (d) was in both crosses for chlorophyll-a and total chlorophyll; while dominance effect (h) was pronounced

in both the crosses for chlorophyll-b. Among the interaction effects additive x additive (i) effect was playing important role for the inheritance of chlorophyll-a, b and total chlorophyll in both the crosses except for chlorophyll-a in cross II where dominance effect was predominant.

Complementary epistasis was found for chlorophyll-a, b content in cross I; whereas, duplicate epistasis was predominantly for total chlorophyll in both crosses, chlorophyll-a and b in cross II. Additive and dominance gene action for chlorophyll-a and only additive for chlorophyll b have also reported by Phul *et al.* [19] in pearl millet.

Additive (d) and dominance (h) effects were found important for total sugar content. However, additive (d) effect was negative while dominance (h) effect was positive and significant. Among the interaction effect both effects (i) and (l) were non significant in both the crosses. Similar sign of (h) and (l) indicated complementary epitasis for total sugar content.

In case of bollworm incidence, additive, dominance effects, additive x additive (i) interactions were positive and significant while dominance x dominance (l) interaction effect was negative but significant in cross I, whereas in cross II, dominance (h) effect was pronounced in desirable direction. The (i) and (l) interactions were positive and significant in cross II.

Most of the characters in either of crosses were found to be under the control of additive gene effect and additive x additive (i) indicating that those characters could be improved upon selection in segregating generations while the non-additive gene action was predominant for some other character which limits the scope for improvement through selection.

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