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Studies on inheritance of okra leaf shape and genetic parameters for morpho-yield related traits in two F_2 populations of cotton (*Gossypium hirsutum* L.)

S. Surya Krishna[1], M. Kumar[2*], N. Premalatha[1], K. Senguttuvan[1] and L. Mahalingam[1]

[1]Department of Cotton, Centre for Plant Breeding and Genetics, TNAU, Coimbatore - 641003, Tamil Nadu, India
[2]Office of the Vice-Chancellor, TNAU, Coimbatore- 641003, Tamil Nadu, India
***E-Mail:** kumarmahadevan@rediffmail.com

Abstract
The inheritance of leaf shape vis-a-vis specific leaf area and genetic parameter determining various morpho-yield related traits were studied in F_2 populations of F2382 X CO17 and PBH115 x CO17 Wherein the female parent has okra type leaf and the male parent has a normal leaf. Leaf type was supposed to exhibit simple inheritance for 1:2:1 for normal leaf type, sub-okra leaf type and okra phenotypes showing incomplete dominance in both crosses. However, an attempt to associate leaf types with specific leaf areas across the segregants did not show any specific pattern indicating complexity in deducing the inheritance of specific leaf areas. Plant height, the number of bolls/plant and seed cotton yield per plant were highly variable traits. High heritability was observed for the traits *viz.*, plant height, boll weight, ginning out turn, upper half mean length and uniformity ratio in both the crosses.

Key words: Cotton, okra leaf type, F_2 population, Incomplete Dominance, Variance.

INTRODUCTION

Cotton (*Gossypium spp*. x=13) is known as the king of fibre due to its fibre quality and its industrial importance. It is suitable for cultivation in both tropical and subtropical areas of the world. There are 53 species of *Gossypium* available with varying genome composition and only four species are cultivated *viz*., *Gossypium arboreum* (2n) and *Gossypium herbaceum* (2n) (Asiatic cotton), *G. barbadense* (4n) (Egyptian cotton) and *G. hirsutum* (4n) (American upland cotton). *Gossypium hirsutum* is widely cultivated all over the world due to its fibre quality and yield. In India, though all the four types are cultivated, major acreage is under the varieties of *G. hirsutum*. In India, the current area under cotton cultivation is 125.84 lakh hectares with a production of 360 lakh bales resulting in productivity of 486 kg/ha (cotcorp.org.in, 2019-20 statistics). In India, the total area under cotton is around 13 million hectares which are about 41 per cent of the world's total cultivable area but the productivity of India (486 kg/ha) is very low compared to the world's productivity (775 kg/ha). Approximately 65 per cent of India's cotton is produced in rainfed areas and the varieties/hybrids of *G. hirsutum* represent 90 per cent of the hybrid cotton production in India (Business World, 2017). The present day cotton breeding focuses on evolving cotton varieties with compact plant types to suit the rainfed areas under cotton cultivation. Evolving compact cotton plant types is the major focus wherein if the okra leaf shape is combined, it will add up easy mechanization and harvest. Hence, this study was attempted to understand the genetics involved in controlling the leaf shape in cotton. This can facilitate the easy incorporation of the okra leaf type in evolved compact cotton genotypes. In the present study, an attempt was made to understand the inheritance of okra leaf type by crossing two okra leaf type genotypes individually with a cotton variety having the normal leaf with a plant type suitable for High Density Planting System (HDPS). An attempt was made to determine the association between the segregating leaf types with Specific Leaf Area (SLA) observed in all the segregants of both the F_2 population. Besides, subsets of two F_2 populations were also observed for their magnitude of variability and heritability across various morpho-yield related traits.

MATERIALS AND METHODS

The present study was carried out in the Department of Cotton, Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore during Summer, 2021. Two stabilized okra leaf types *viz*. F2382 and PBH115 were individually crossed with a recently released compact cotton variety CO17 having normal leaf. A total of 448 and 294 F_2 plants generated from F2382 x CO17 and PBH115 x CO17, respectively were observed for the segregation of leaf type. Specific leaf area (fifth leaf from the top) across all the segregants of both the F_2 populations was recorded using L1-3100C from LI-COR Biosciences equipment. Observations for various morpho-yield related traits were taken from randomly selected 186 and 100 F_2 plants of the crosses F2382 x CO17 and PBH115 x CO17, respectively. The morpho-yield related traits observed include plant height (cm), the thenumber of monopodia/plant, the number of sympodia/plant, internodal length (cm), the number of bolls/plant, boll weight (g), seed index, lint index, ginning out turn (%), upper half mean length (mm), uniformity ratio (%), fibre bundle strength (g/tex), elongation percentage, fibre fineness (µg/inch) and seed cotton yield per plant (g). The two populations and the parents (30 plants/parent) involved in making them were planted at a spacing of 75 x 30 cm and maintained without any replications by following the regular agronomic practices. The goodness of fit for the segregation of leaf type was established using Pearson's chi-square test (1900). The mean, variance, standard deviation and standard error for the fifteen morpho-yield related traits of the F_2 populations were derived by using the regular statistical formulae.

Heritability (H) in the broad sense for the morpho-yield related traits were worked out based on the formula given by Mahmud and Kramer (1951). Genetic advance (GA) and genetic advance as per cent of mean (GAM) were worked out using the formulae given by Johnson *et al.* (1955).

RESULTS AND DISCUSSION

The leaf shape in cotton is classified into five types *viz*. normal, okra leaf shape, sea-island leaf shape, sub-okra leaf shape and super-okra leaf shape (Andres *et al*., 2016). Okra leaf (OL) has been known to exist in cotton since before the 19th century (Mell, 1890). Shoemaker (1909**)** first showed that OL was controlled by a single gene. McLendon (1912) established that the sub-okra leaf shape had the simple Mendelian inheritance. The okra leaf trait is expected to have a lesser leaf area compared to the leaf area of the normal leaf. Andries *et al.* (1969) anticipated that the deeply cleft and narrowly lobed leaves with less surface area would be less favourable for pest and disease incidences by providing an open canopy. The openness of the plant canopy due to the okra leaf type may be a favourable attribute towards the development of compact plant type in cotton. Considering this and the simple genetics involved in the control of okra leaf type, two okra leaf type cotton genotypes *viz*. F2382 and PBH115 were individually crossed with the recently released CO17 compact cotton variety with normal leaf. The pattern of inheritance in the F_2 populations of both crosses was observed in the ratio of 1:2:1 for normal leaf type, sub-okra leaf type and okra leaf type showing incomplete dominance (**Table 1 and Plate 1**). A similar pattern of incomplete dominance was observed by Nawab *et al*. (2011), Chang *et al*. (2016), Sangwan *et al*. (2017) and Yahaya *et al*. (2017). The nature of simple genetics involved in the control of okra leaf type is expected to facilitate the incorporation of this character into improved compact cotton genotypes which are having more leaf lamina. Already the gene controlling okra leaf type ($L2^o$) which encodes a LATE MERISTEM IDENTITY 1 (LMI1)-like transcription factor (GhOKRA) has been cloned by Chang *et al*. (2016).

Table 1. Segregation of Normal, sub-okra and okra leaf types in the F_2 populations

Leaf type	Observed plants	Expected plants	Chi square
F2383 x CO17			
Normal	113	112	0.009
Sub-okra	215	224	0.362
Okra	120	112	0.571
	448	448	0.942
PBH115 x CO17			
Normal	84	73.5	1.500
Sub-okra	149	147	0.027
Okra	61	73.5	2.126
	294	294	3.653

Chi=square Critical = 5.99 (0.05, 2df)

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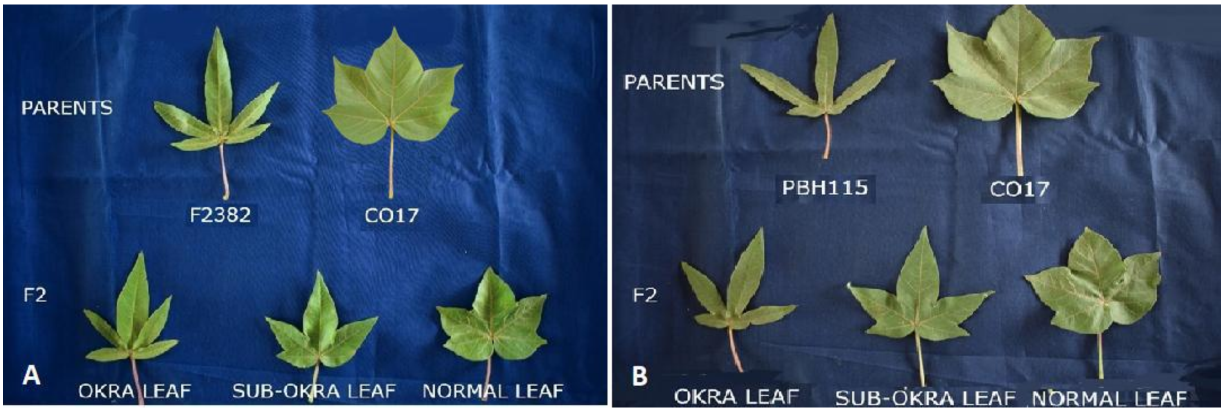

Plate 1. Parents and F_2 individuals: A) F2382 x CO17 and B) PBH115 x CO17

Andres *et al*. (2016) temporarily induced normal leaf formation in okra cotton by silencing okra locus which encoded an HD-Zip transcription factor LATE MERISTEM IDENTITY1-D1b (GhLMI1-D1b). Having the gene sequences for okra leaf type known, incorporation of okra leaf trait can be easily done at ease into compact cotton genotypes. This can be achieved by attempting a phenotype based backcross breeding or genetic transformation approach.

Leaf area is an important parameter in cotton and leaf types are classified into two *viz*., main-stem leaves (MSL) and fruiting branch leaves (FBL) (Carvalho *et al*., 2016). With the availability of okra leaf types along with sub-okra and normal leaf types, determining the variations in leaf area and their association with various leaf types becomes very important in cotton breeding. In the present study, an attempt was made to measure the SLA (in sq.cm) of the fifth leaf from the tip of all the segregating individuals of the crosses *viz*., F2382 x CO 17 and PBH115 x CO17. The overall mean of SLA (38.128 cm^2) across the segregants of PBH115 x CO17 is higher than the overall mean of SLA (27.056 cm^2) observed among the segregants of F2382 x CO 17. Though there was a wider difference in SLA of both the crosses observed, no significant differences between the mean values of groups of leaf shapes *viz.,* normal, sub-okra and okra leaf types from both the crosses indicating non-association of leaf type and leaf area (**Table 2**). This result indicated that reduced leaf area observed phenotypically in okra leaf type compared to the leaf area in normal and sub-okra leaf type may not qualify as a significant variation between these types. The result of the present study is not in conjunction with the notion of reduced leaf area in okra leaf type as proposed by Andries *et al.*(1969**)** and needs more critical genetic analysis.

High genetic advance with high heritability estimates for quantitative traits offers the most effective condition for practising selection in a highly variable population. Thus the utility of heritability in breeding programmes increases with the estimation of genetic advance which indicates the degree of gain in a character obtained under particular selection pressure. In the present study, two F_2 populations *viz*. F2382 x CO17 (186 individuals) and PBH115 x CO17 (100 individuals) were studied for a total of 15 morpho-yield related traits and the extent of variability observed for those traits are given in **Table 3**.

Table 2. Association between leaf type groups and specific leaf area in F_2 populations

Groups	Count	Mean (cm^2)	Range	Variance
F2382 x CO17				
Normal	113	28.837	14.340 – 47.670	43.837
Sub-okra	215	28.100	14.870 -56.810	43.886
Okra	120	22.315	11.800 – 49.150	33.773
			F calculated: 39.367, P-value: 0.000, F critical: 3.016	
PBH115 x CO17				
Normal	84	40.531	23.740 – 66.460	53.449
Sub-okra	149	39.307	23. 560 – 74.950	58.793
Okra	61	31.944	16.820 – 47.360	44.045
			F calculated: 27.891, P-value: 0.000, F critical: 3.027	

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Table 3. Summary of the output pertaining to the morpho-yield related traits of F_2 populations

Character	Cross	Mean	Variance	SD	SE	Minimum	Maximum	Range
Plant height (cm)	Cross 1	65.430	124.722	11.167	0.819	59.000	129.000	70.000
	Cross 2	74.120	189.246	13.757	1.376	37.000	111.000	74.000
Number of monopodia/plant	Cross 1	0.349	0.507	0.712	0.052	0.000	4.000	4.000
	Cross 2	0.320	0.418	0.646	0.065	0.000	3.000	3.000
Number of sympodia/plant	Cross 1	14.527	6.099	2.469	0.181	10.000	22.000	12.000
	Cross 2	12.330	6.381	2.526	0.253	6.000	19.000	13.000
Internodal length (cm)	Cross 1	3.666	0.600	0.774	0.057	2.000	6.000	4.000
	Cross 2	3.682	0.551	0.742	0.074	2.000	6.000	4.000
Number of bolls/plant	Cross 1	16.430	4.772	2.814	0.206	12.000	24.000	12.000
	Cross 2	14.710	3.786	1.946	0.195	11.000	24.000	13.000
Boll weight (g)	Cross 1	4.135	0.246	0.495	0.036	3.001	5.785	2.784
	Cross 2	4.401	0.365	0.604	0.060	2.946	6.111	3.165
Seed index	Cross 1	7.634	1.311	1.144	0.084	4.863	10.928	6.065
	Cross 2	7.773	1.482	1.217	0.122	4.746	13.597	8.851
Lint index	Cross 1	3.928	0.337	0.581	0.043	2.640	5.810	3.170
	Cross 2	4.112	0.345	0.587	0.059	2.385	5.418	3.033
Ginning out turn (%)	Cross 1	33.971	5.161	2.272	0.167	30.016	41.319	11.303
	Cross 2	34.678	8.325	2.885	0.289	23.492	40.809	17.317
Upper half mean length (mm)	Cross 1	26.352	1.186	1.089	0.080	22.100	28.600	6.500
	Cross 2	27.523	1.229	1.108	0.111	24.700	29.900	5.200
Uniformity ratio (%)	Cross 1	81.545	5.304	2.303	0.169	74.600	86.700	12.100
	Cross 2	81.722	4.607	2.146	0.215	74.200	87.400	13.200
Fibre bundle strength (g/tex)	Cross 1	25.302	0.672	0.819	0.060	23.400	27.800	4.400
	Cross 2	26.821	0.896	0.946	0.095	25.100	29.700	4.600
Elongation percentage	Cross 1	5.672	0.003	0.054	0.004	5.500	5.800	0.500
	Cross 2	5.671	0.003	0.054	0.005	5.600	5.800	0.200
Fibre fineness (µg/inch)	Cross 1	4.436	0.182	0.426	0.031	3.300	5.200	1.900
	Cross 2	4.526	0.276	0.525	0.053	2.960	7.240	4.280
Seed cotton yield per plant (g)	Cross 1		36.130	6.01	0.441	23.076	60.622	37.546
	Cross 2	40.853	31.749	5.611	0.561	28.127	66.678	38.551

Cross 1: F2382 x CO17; Cross 2: PBH115 x CO17

Plant height, the number of bolls/plant and seed cotton yield per plant were found to be highly variable compared to other derived traits. High heritability was observed for the traits *viz*., plant height, boll weight, ginning out turn, upper half mean length and uniformity ratio in both the crosses. Moderate heritability was observed for seed cotton yield per plant. A large difference in heritability was observed for fibre fineness (µg/inch) between two crosses (**Table 4**). The results obtained from the present study almost corroborate with the results of Joshi and Patel (2018), Komala *et al.* (2018), Gnanasekaran *et al.* (2018), Lokeshkumar and Patil (2018) and Thiyagu *et al*. (2020).

In the present study, the results obtained regarding the inheritance of okra leaf showed that the trait is under the control of single gene showing incomplete dominance in the F_2 populations of F2382 x CO17 and PBH115 x CO17. The attempt to associate the nature of leaf types with leaf area did not establish any relationship between the traits indicating the genetic complexity involved in understanding the inheritance of leaf area. Considering the notion of reduced leaf area in okra leaf type, the results from the present study stresses the necessity of having a deeper understanding of the genetics of leaf shape vis-a-vis over for associating a qualitative trait (leaf type) with a quantitative trait (leaf area). Another option will be

Table 4. Heritability, Genetic Advance and Genetic Advance as percentage of Mean of morpho- yield related traits

Character	Cross	$\sigma^2 F_2$	σ^2 C017	σ^2 F2382	H (%)	GA	GAM
Plant height	Cross 1	124.7	11.592	7.440	92.555	21.291	32.541
	Cross 2	189.2	11.592	10.480	94.176	26.689	36.008
Number of monopodia/plant	Cross 1	0.507	0.120	0.140	25.640	0.337	96.661
	Cross 2	0.418	0.120	0.120	19.310	0.279	87.331
Number of sympodia/plant	Cross 1	6.099	3.600	4.560	33.579	1.708	11.757
	Cross 2	6.381	3.600	2.160	56.308	2.930	23.763
Internodal length	Cross 1	0.600	0.400	0.160	58.000	0.925	25.226
	Cross 2	0.551	0.400	0.160	54.083	0.827	22.452
Number of bolls/plant	Cross 1	4.772	4.741	3.855	10.415	0.604	3.675
	Cross 2	3.786	4.741	1.842	46.698	1.872	12.726
Boll weight	Cross 1	0.246	0.082	0.030	82.114	0.837	20.249
	Cross 2	0.365	0.082	0.050	82.740	1.029	23.392
Seed index	Cross 1	1.311	0.828	0.679	42.792	1.008	13.210
	Cross 2	1.482	0.828	1.089	35.965	0.902	11.600
Lint index	Cross 1	0.337	0.280	0.252	21.068	0.252	6.419
	Cross 2	0.345	0.280	0.247	23.768	0.287	6.989
Ginning out turn	Cross 1	5.161	0.438	0.998	87.192	4.081	12.013
	Cross 2	8.325	0.438	0.952	92.240	5.482	15.808
Upper half mean length	Cross 1	1.186	0.166	0.438	77.234	1.733	6.575
	Cross 2	1.229	0.166	0.336	80.716	1.842	6.694
Uniformity ratio	Cross 1	5.304	0.942	0.742	84.238	3.996	4.901
	Cross 2	4.607	0.942	0.792	81.268	3.593	4.396
Fibre bundle strength	Cross 1	0.672	0.654	0.486	16.071	0.271	1.072
	Cross 2	0.896	0.654	0.386	44.085	0.859	3.203
Elongation percentage	Cross 1	0.003	0.006	0.002	100.000	0.111	1.961
	Cross 2	0.003	0.006	0.002	100.000	0.111	1.962
Fibre fineness	Cross 1	0.182	0.106	0.142	32.967	0.289	6.522
	Cross 2	0.276	0.106	0.233	89.130	0.964	21.298
Seed cotton yield per plant	Cross 1	36.13	15.680	17.040	54.774	6.781	18.677
	Cross 2	31.75	15.680	12.160	56.509	6.532	15.988

Cross 1: F2382 x CO17; Cross 2: PBH115 x CO17

exploiting the available molecular tools. Though, it is sure that the minimum range of leaf area of the okra group of plants in both the crosses was lesser than its minimum range of other groups, the maximum value for leaf area in the okra group of F2382 x CO17 was observed to be more than the maximum value of normal group which might be the reason for distortion in the correlation between the traits. Sax (1923) established the relationship between the seed colour and seed size in *Phaseolus vulgaris*. In the same way, the association of other important morpho-yield related traits with okra leaf type can be explored for exploiting the relevance of the trait in breeding compact cotton genotypes with okra leaf type.

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