Pak. J. Agri. Sci., Vol. 57(1), 109-114;2020
ISSN (Print) 0552-9034, ISSN (Online) 2076-0906
DOI: 10.21162/PAKJAS/20.8407
http://www.pakjas.com.pk

GENETICS OF OKRA LEAF AND AGRONOMIC TRAITS IN UPLAND COTTON

Muhammad Sajjad Nazir[1], Tanwir Ahmad Malik[1], Amir Shakeel[1] and Jam Nazeer Ahmad[2]

[1]Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, Pakistan;
[2]Department of Entomology, University of Agriculture, Faisalabad, Pakistan.
[*]Corresponding author's e-mail: Sajjadbravo@gmail.com

Okra leaf cotton has great potential to confer resistance to insect pests; however, very few okra leaf cotton cultivars have been developed in the world. Generally, cotton breeders have perception that okra leaf trait has linkage with relatively inferior agronomic traits thus avoid introducing okra leaf trait in cotton cultivars containing broad leaves. The present research was conducted to find the genetics of okra leaf trait, its correlation with agronomic traits as well as genetics of agronomic traits in okra leaf genetic background. The genetics of okra leaf and agronomic traits were studied by using six generations (P_1, P_2, BC_1, BC_2, F_1, F_2) developed by crosses involving okra leaf and normal leaf genotypes/cultivars. The okra leaf trait showed monogenic control with partial dominance of normal leaf shape. The results of generation mean analysis mainly revealed additive, dominance and additive×additive gene action for the traits. Number of sympodial branches, number of monopodial branches, number of bolls per plant, boll weight, number of seeds per boll, 100 seed weight, ginning out-turn, fiber length, fiber strength and seed cotton yield had additive, dominance and additive×additive gene action while plant height and fiber fineness had additive, dominance, additive×additive as well as additive×dominance gene action. Generally higher order interactions were not found in the genetics of agronomic trait in okra leaf genetic background. Correlation results revealed that okra leaf had not negative correlation with agronomic traits. Present study recommends tailoring of okra leaf cotton cultivars for a good control of insect pests

Keywords: cotton mutant, pest resistance, leaf traits, genetic variation, gene action

INTRODUCTION

Genus, *Gossypium* consists of approximately 50 species (old and new world) among which six are tetraploid (2n= 52) and the others are diploid with chromosome number 26 (Brubaker *et al.*, 1999). Cotton plant has succulent leaves, bearing a lot of flowers, fruits, nectaries on leaves and on flower bracts so it attracts both beneficial as well as damaging insects (Gaines, 1957). Cotton (*G. hirsutum)* has two major leaf shapes, normal and okra. Okra leaf type cotton is mutant characterized by palmately lobed leaves resulting into open canopy. Okra leaf cotton has been found resistant to insect pests compared to normal leaf cotton (Chu *et al.*, 2000; Soomro *et al*., 2000; Ahmad *et al.*, 2005; Din *et al*., 2016). A number of studies on genetics of agronomic traits in cotton have been reported. Generation means analysis is commonly used to study genetic basis of variation by analyzing segregating population. The analysis detects additive, dominance, additive×additive, additive×domminace and dominance×dominance interaction. El-Haleem *et al*. (2010) studied seven Egyptian cotton cultivars. They used six generations for six parameter model scaling test. They found dominance gene action for plant height and number of bolls per plant. Natera *et al.* (2012) reported moderate heritability estimates for plant height. Ali *et al*. (2016) reported epistasis gene action for number of seeds/boll, boll weight, seed index, lint mass/boll and surface area/seed. Kumar *et al*. (2016) reported that bolls per plant was controlled by dominance gene action while boll weight was controlled by additive gene action. Hussain *et al*. (2017) studied gene action of different fiber traits in cotton. They found that fiber traits had additive type of gene action. Kamaran *et al*. (2018) studied six generations of two crosses of cotton (TARZAN-1× CIM-602 and A-555×FH-114). They observed additive and dominance gene action for fiber uniformity, fiber fineness, fiber length and fiber maturity.

However, only a few studies are conducted in okra leaf genetic background. Cotton breeders have perception that okra leaf trait is linked with relatively inferior agronomic traits so okra leaf cotton has lower yield hence they do not introduce okra leaf trait in cotton cultivars. Correlation studies reveals strength and direction of relationship among different traits which help plant breeder to select plants with better combination of traits. Calculating correlation in F_2 population reveals linkage of the traits (Cramer and Wehner, 2000). Present study was designed to understand the genetics of okra leaf trait, its effect on agronomic traits and genetics of agronomic trait in okra leaf genetic background.

MATERIAL AND METHODS

Three crosses were made for present study involving okra leaf and normal leaf cotton (Table 1). Six generations of the crosses (P_1, P_2, F_1, F_2, BC_1 and BC_2) were raised in the field during normal growing season of cotton in 2016. The experiment was performed in randomized complete block design with three replications. In each replication there were two rows of each parent and F_1, three rows for each backcross and five rows for each F_2 population keeping the plant to plant distance of 30 cm and row to row distance of 75cm. Each row was of 300 cm in length having 10 plants. Nitrogen and Phosphorus fertilizer was applied at the recommended dose of the Department of the Agriculture, Government of the Punjab, Pakistan (nitrogen 34 kg/acre and phosphorus 23 kg/acre). Five irrigations were applied throughout the crop season. Weeds were removed by manual hoeing. Five pesticide applications were applied to control sucking insect pest and four pesticide applications were applied to control bollworms. At maturity, 30 plants from each of the parents and F_1, 60 plants from each backcross and 150 plants from each F_2 population were selected at random for data collection. The data of plant traits, plant height, number of sympodial branches, number of monopodial branches, number of bolls per plant, boll weight, number of seeds per boll, 100 seed weight, ginning out-turn, fiber fineness, fiber strength, fiber length, seed cotton yield and leaf type was taken at maturity.

Table 1. Crosses developed for the study

	Cross	Population
Cross 1	FH-142 x Gumbo okra	F_1, F_2
	(FH-142 x Gumbo okra) x FH-142	BC_1
	(FH-142 x Gumbo okra) x Gumbo Okra	BC_2
Cross 2	(FH-lalazar x Gumbo okra)	F_1, F_2
	(FH-lalazar x Gumbo okra) x FH-lalazar	BC_1
	(FH-lalazar x Gumbo okra) x Gumbo okra	BC_2
Cross 3	MNH-886 x Gumbo okra	F_1, F_2
	(MNH-886 x Gumbo okra) x MNH-886	BC_1
	(MNH-886 x Gumbo okra) x Gumbo okra	BC_2

Analysis of variance was conducted as in Steel *et al.* (1997). *Chi*-square test was used to study genetics of okra leaf trait. Generation means analysis (Mather and Jinks, 1982) was used for studying genetics of agronomic traits. The generation means analysis was conducted on all the generation means starting from simple model m. Further complex models ([m, d], [m, d, h], [m, d, h, i], [m, d, h, I, j] etc.) were selected if Chi-square value was found significant. The model considered to be best fit when all the parameter had significant estimates along with non-significant *Chi*-square value. For model fitting, parent of higher value was taken as P_1 for each trait. The coefficients of genetic components of generation means used are given in Table 2.

Table 2. Coefficients of the mean (m), additive (d), dominance (h), additive × additive (i), additive × dominance (j) and dominance × dominance (l) parameters for the weighted least squares analysis of generation means

Generations	Components of genetic effects					
	M	[d]	[h]	[i]	[j]	[l]
P_1	1	1.0	0.0	1.00	0.00	0.00
P_2	1	-1.0	0.0	1.00	0.00	0.00
F_1	1	0.0	1.0	0.00	0.00	1.00
F_2	1	0.0	0.5	0.00	0.00	0.25
BC_1	1	0.5	0.5	0.25	0.25	0.25
BC_2	1	-0.5	0.5	0.25	-0.25	0.25

The data of F_2 generation was used to calculate phenotypic correlation (rp) as by Dewey and Lu (1959) and genotypic correlations (rg) as by Edhaie *et al.* (1993).

$$rp = \frac{PCOV(x,y)}{(PVx.PVy)^{\frac{1}{2}}}$$

$$r_g = \frac{GCOV(x,y)}{(GVx.GVy)^{\frac{1}{2}}}$$

RESULTS

***Genetics of leaf shape*:** In all the crosses, plants of F_1 generation showed semi okra leaf trait while F_2 and backcross population revealed ratio of 1:2:1 and 1:1 respectively (Table 3). The F_1 plants showed semi-okra type leaf which indicated incomplete dominance of narrow leaf while F_2 segregation ratio of 1:2:1 (okra: semi-okra: normal) indicated monogenic inheritance. The results of backcrosses (1: 1 ratio) confirmed the monogenic inheritance of okra leaf type.

***Genetic analysis of agronomic traits in okra leaf background*:** Analysis of variance showed significant difference among the generation means for the traits. The generation means are given in Table 4. Estimates of the best fit model for generation means of parameters by weighted least squares analysis of the traits are given in Table 5. Correlation of leaf type with agronomic traits is given in Table 6.

The results of generation means analysis mainly revealed additive, dominance and additive×additive gene action for the traits. Number of sympodial branches, number of monopodial branches, number of bolls per plant, boll weight, number of seeds per boll, 100 seed weight, ginning out-turn, fiber length, fiber strength and seed cotton yield had additive, dominance and additive×additive gene action while plant height and fiber fineness had additive, dominance, additive×additive as well as additive×dominance gene action. Generally higher order interactions were not found in the genetics of agronomic trait in okra leaf genetic background (Table 5).

Table 3. Chi-Squared values and probabilities of goodness of fit of segregation ratios of F2 and backcross generations for inheritance of okra leaf shape

Crosses	Generation	Total plants	Observed values			Expected ratios			X^2	P value
			Normal leaf	Semi okra	Okra leaf	Normal leaf : semi-okra : Okra leaf				
FH-142 x	F_1	30	0	30	0					
Gumbo okra	F_2	150	37	72	41	1	2	1	0.45	0.790
	BC_1	60	28	32	-	1	1		0.27	0.605
	BC_2	60	-	33	27		1	1	0.60	0.440
FH-lalazar x	F_1	30	0	30	0					
Gumbo okra	F_2	150	37	76	37	1	2	1	0.44	0.800
	BC_1	60	27	33	-	1	1		0.60	0.440
	BC_2	60	-	29	31		1	1	0.07	0.790
MNH-886 x	F_1	30	0	30	0					
Gumbo okra	F_2	150	35	78	37	1	2	1	0.51	0.770
	BC_1	60	27	33	-	1	1		0.60	0.440
	BC_2	60	-	29	31		1	1	0.07	0.790

Plant height (PH, cm), number of sympodial branches (SB), number of monopodial branches (MB), number of bolls per boll (NB), boll weight (BW), number of seeds per boll (NS/B), 100 seed weight (100SW), ginning out-turn (GOT%), fiber fineness (FF), fiber length (FL), fiber strength (FS) and seed cotton yield (SCY).

Table 4. Generation means and mean square (MS) in three crosses, cross 1 (FH-142 x Gumbo okra) (upper), cross 2 (FH-lalazar x Gumbo okra) (Middle) and cross 3 (MNH-886 x Gumbo okra) (Lower)

Traits	Populations						MS	LSD (0.05)
	P_1	P_2	F_1	F_2	BC_1	BC_2		
	122.97	96.83	124.79	94.61	120.79	119.87	1711.82*	4.44
PH	131.10	99.06	127.05	118.09	130.03	129.03	456.41**	2.92
	115.93	99.79	119.60	113.61	116.93	115.23	147.53**	4.31
	25.70	12.17	26.73	19.76	24.12	21.90	114.16**	0.26
SB	28.83	12.87	28.40	19.50	30.33	28.80	148.57**	2.60
	16.50	13.07	17.50	14.87	17.50	16.23	8.80**	2.71
	2.60	1.70	2.73	1.78	2.80	1.93	1.12**	0.86
MP	2.63	1.73	2.67	1.87	2.13	1.93	0.51**	0.88
	2.40	1.80	2.67	2.17	2.53	2.27	0.27**	0.34
	26.70	21.60	26.70	24.64	24.70	20.69	103.10*	1.73
NB	28.20	25.53	28.57	25.50	27.13	25.33	9.58*	3.39
	24.87	24.70	26.13	23.91	25.87	24.10	2.46**	1.32
	3.30	2.38	4.76	3.32	3.53	3.15	4.34**	1.64
BW	3.16	2.66	2.91	3.37	3.12	2.96	0.15**	0.30
	3.72	2.57	3.76	2.85	3.56	3.38	0.72**	0.24
	22.95	21.57	24.03	22.12	24.43	23.40	54.84**	2.52
NS/B	29.37	21.83	28.00	24.60	27.83	26.37	23.24**	1.53
	20.93	20.93	21.50	17.77	19.40	18.10	7.56*	2.62
	7.62	6.19	8.22	5.10	10.83	6.41	18.78**	0.90
100 SW	7.62	7.13	9.17	7.47	10.83	9.46	5.92**	0.87
	7.78	6.99	7.82	5.29	7.62	6.38	2.98**	0.61
	34.17	33.47	35.50	32.06	34.50	30.27	65.07**	2.46
GOT%	40.73	34.01	37.72	34.30	39.41	38.73	21.16**	1.18
	39.38	34.13	37.12	33.30	39.83	38.88	34.61**	2.46
	3.66	4.43	3.89	3.99	3.39	3.93	0.35**	1.15
FF	4.36	4.64	3.60	4.34	4.30	4.16	0.35**	0.24
	4.27	4.97	4.15	4.28	4.50	5.03	0.31**	0.27
	25.57	19.40	25.31	23.75	24.63	23.75	44.78**	0.39
FS	24.82	19.23	24.22	26.57	23.53	22.52	19.59**	0.73
	26.19	19.46	19.88	14.84	20.22	19.03	39.72*	1.50
	27.57	22.50	25.96	26.05	24.63	20.85	43.81**	1.82
FL	27.58	23.65	26.06	27.10	24.55	23.84	8.57**	1.26
	26.99	23.60	21.38	14.29	21.19	20.42	52.57**	3.12
	33.49	29.06	36.19	29.50	34.89	32.87	155.08**	1.17
SCY	42.10	30.06	35.21	38.91	37.75	35.32	48.49*	5.34
	34.10	29.65	33.13	29.20	33.37	31.91	12.53**	1.11

Table 5. Estimates of the best fit model for generation means parameters by weighted least squares analysis in three crosses, cross 1 (FH-142 x Gumbo okra) (upper), cross 2 (FH-lalazar x Gumbo okra) (Middle) and cross 3 (MNH-886 x Gumbo okra) (Lower)

Traits	Genetic effect						X^2 (df)
	[m]	[d]	[h]	[i]	[j]	[l]	
PH	113.31±0.40	26.65±0.40	30.49±0.55				4.11(3)
	122.39±1.49	15.93±0.20	15.06±1.92	1.75±1.51			3.48(2)
	113.51±0.82	0.39±0.23	4.38±1.06		3.17±0.88		2.26(2)
	21.73±0.79	7.09±0.18	11.13±0.93	2.30±0.83			4.23(2)
SB	24.78±0.91	7.60±0.25	15.97±1.26	6.09±0.95			3.47(2)
	15.94±0.39	2.91±0.11	12.69±0.66	14.18±0.40			4.31(2)
	2.26±0.04	0.64±0.07					5.09(4)
MP	2.16±0.04	0.43±0.06					5.14(4)
	2.31±0.73	1.71±0.25	5.81±1.12	2.56±0.77			1.31(2)
	24.17±0.17	8.13±0.21					3.56(4)
NB	26.71±0.11	1.19±0.18					6.35(4)
	24.93±0.82	0.39±0.23	4.38±1.06	3.17±0.88			3.89(2)
	3.40±0.17	8.13±0.21					3.56(4)
BW	3.03±0.11	1.19±0.18					6.35(4)
	3.30±0.82	0.39±0.23	4.38±1.06	3.17±0.88			3.89(2)
NS/B	23.08±0.45	1.76±0.81		7.77±0.88			2.75(3)
	26.33±0.50	3.27±0.16	6.97±0.74	4.17±0.54			2.22(2)
	19.77±0.91	0.18±0.35	6.62±1.59	6.52±0.96			0.20(2)
	7.39±0.08	2.92±0.07	1.24±0.13				6.26(3)
100SW	8.68±0.04	1.43±0.06					4.51(4)
	6.98±0.05	0.52±0.06		1.54±0.09			4.79(3)
	33.32±0.16	5.13±0.25					2.65(2)
GOT%	37.48±0.05	3.22±0.08					5.96(4)
	37.10±1.57	2.66±0.12	35.85±2.48	22.12±1.56			1.43(2)
	3.88±0.04	0.31±0.06					0.70(3)
FF	4.23±0.03						9.12(5)
	4.53±0.14	1.82±0.31	0.25±0.21	1.68±0.34	2.61±0.67		2.71(1)
	23.74±0.25	3.97±0.24	4.48±0.34				5.40(3)
FS	23.48±0.29	1.91±0.07	4.10±0.42	5.76±0.31			2.35(2)
	19.93±0.39	2.91±0.11	12.69±0.66	14.18±0.40			1.75(2)
	24.59±0.11	3.03±0.15					4.02(4)
FL	25.46±0.03	0.82±0.04					4.56(4)
	21.31±0.57	1.44±0.15	21.32±1.00	21.08±0.59			1.50(2)
SCY	32.66±0.15	7.07±0.15	9.69±0.34				3.15(3)
	36.55±0.17	6.30±0.18					4.37(4)
	31.89±0.59	2.08±0.24	8.31±0.89	6.71±0.65			3.55(2)

Plant height (PH), number of sympodial branches (SB), number of monopodial branches (MB), number of bolls per plant (NB), boll weight (BW), number of seeds per boll (NS/B), 100 seed weight (100SW), ginning out-turn (GOT%), fiber fineness (FF), fiber length (FL), fiber strength (FS) and seed cotton yield (SCY).

***Correlation of agronomic traits with okra leaf*:** The result showed that okra leaf shape trait did not have negative correlation with agronomic traits. The negative correlation of micronaire with okra leaf trait in two crosses (Table 6) is actually positive correlation of fiber fineness with okra leaf as there is inverse relation of micronaire value with fineness of fiber. Some agronomic traits showed positive correlation with okra leaf trait and other did not corelate with okra leaf trait.

DISCUSSION

The results of present study showed monogenic inheritance of leaf shape. These results supported the findings of Jones (1982) and Nawab *et al.* (2011). Andres *et al.* (2016) reported the gene for leaf shape in cotton on chromosome 15 of D genome. The results of generation means analysis mainly revealed additive, dominance and additive×additive gene action for the traits.

Table 6. Phenotypic (upper) and Genotypic (lower) correlation of okra leaf trait in three crosses, cross 1 (FH-142 x Gumbo okra), cross 2 (FH-lalazar x Gumbo okra) and cross 3 (MNH 886 x Gumbo okra)

Trait	Okra leaf		
	Cross 1	Cross 2	Cross 3
PH	0.11	0.38**	0.36*
	0.18	0.39	0.38
SB	0.42*	0.42**	0.12
	0.47	0.46	0.16
MP	0.41*	0.09	0.04
	0.44	0.19	0.19
NB	0.06	0.27*	0.32*
	0.11	0.29	0.36
BW	0.03	0.09	0.14
	0.19	0.12	0.16
NS/B	0.15	0.58**	0.15
	0.27	0.61	0.18
100SW	0.14	0.16	-0.11
	0.15	0.18	-0.19
GOT%	0.31*	0.15	0.16
	0.35	0.19	0.18
FF	-0.47*	-0.02	-0.22*
	-0.49	-0.11	-0.33
FS	0.17	0.19	0.29*
	0.12	0.21	0.31
FL	0.32*	0.34*	0.33*
	0.36	0.36	0.38
SCY	0.29*	0.55**	0.29*
	0.34	0.57	0.31

Plant height (PH), number of sympodial branches (SB), number of monopodial branches (MB), number of bolls per plant (NB), boll weight (BW), number of seeds per boll (NS/B), 100 seed weight (100 SW), ginning out-turn (GOT%), fiber fineness (MIC), fiber length (FL), fiber strength (FS), seed cotton yield (SCY).

Difference in gene action of traits in different crosses may be due to different genetic background of parents involved in the crosses. Bertini *et al.* (2001) reported additive gene action for monopodial branches and ginning out turn. El-Haleem *et al*. (2010) studied seven Egyptian cotton cultivars. They used six generations for six parameter model scaling test and found dominance gene action for plant height and number of bolls per plant. Natera *et al.* (2012) reported moderate heritability estimates for plant height. Ahmad *et al.* (2016) evaluated 6 crosses of cotton and reported additive and dominance type of gene action for agronomic traits. Ali *et al*. (2016) reported epistasis gene action for seed number/boll, boll weight, seed index, lint mass/boll and surface area/seed. Gawande *et al.* (2016) observed complex gene action in cotton for fiber fineness. Kumar *et al*. (2016) reported that bolls per plant was controlled by dominance gene action while boll weight was controlled by additive gene action. Hussain *et al*. (2017) studied gene action of different fiber traits in cotton. They found that fiber traits had additive type of gene action. Kamaran *et al*. (2018) studied six generations of two crosses (TARZAN-1× CIM-602 and A-555×FH-114). They observed additive and dominance gene action for fiber uniformity, fiber fineness, fiber length and fiber maturity. However, only a few studies are conducted in okra leaf genetic background. The result of present study did not show high order interaction for agronomic traits in okra leaf background. So, breeding for okra leaf with good combination of agronomic trait may not be difficult.

Correlation studies reveals strength and direction of relationship among different traits which help plant breeder to select plants with better combination of traits. Calculating correlation in F_2 population reveals linkage of the traits (Cramer and Wehner, 2000). It was observed in the present study that okra leaf trait had not negative linkage with agronomic traits. Whereas, okra leaf trait had positive correlation with some agronomic traits. Rahman *et al.* (2005) also reported similar results. It is reported that okra leaf cotton had higher net photosynthetic rate per unit leaf area (Pettigrew *et al*., 1993; Heithholt, 1994). So lower leaf area of okra leaf cotton may not have negative effect on yield (Malik *et al*., 2009). Soomro *et al.*, (2000) reported that okra leaf cotton had higher yield compared to normal leaf cotton. They also observed that okra leaf cotton genotypes had good fiber quality.

Conclusion**:** The present study observed that okra leaf trait did not have any negative linkage with agronomic traits in cotton. Higher order interactions were not found in the genetics of agronomic trait in okra leaf genetic background. The leaf trait is monogenic in inheritance. So, breeding of high yielding with good fiber quality okra leaf cotton cultivars resistant to insect pests may not be difficult.

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[Received 12 Dec 2018; Accepted 25 Feb- 2019; Published (online) 16 Nov 2019]