Inheritance Pattern and Association of Qualitative and Quantitative Traits in Cotton (*Gossypium hirsutum* L.) for Sustainable Breeding Goal

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Authors' contributions

This work was carried out in collaboration among all authors. Authors SS, BN and MI designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors SS, RS, BB and MS managed the analyses of the study. Authors SS, AHK, MFS and TAM managed the literature searches. All authors read and approved the final manuscript.

Original Research Article

ABSTRACT

Background: Cotton (*Gossypium hirsutum* L.) is the most important fiber crop of the world and commonly known as white gold. It plays an important role in the economy of Pakistan. It provides raw material to the local textile industry and generates considerable amount of foreign exchange. The yield of cotton is lower in Pakistan. Knowledge of association among different traits is important for the development of cultivars with better yield and quality characters.
Materials and Methods: In this research, two parents (PB-38 and Jambo Okra) and their crosses sown in randomized complete block design with three replications to sort out best performing genotypes for these profitable traits (plant height, number of sympodial branches, number of

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monopodial branches, leaf type, boll size, boll shape, number of bolls per plant, boll weight, ginning out turn, 100 seed weight and seed cotton yield).

Results: Analysis of variance (ANOVA) revealed that parental and their F_2 population showed significant differences for all the observed traits. Correlation and inheritance pattern of all characters provides information of association among all traits and percentage of inheritable attributes.

Conclusions: The association and inheritance pattern study provide us useful information for effective selection and sustainable breeding programs. Heritability estimations revealed that heritability of traits fluctuate as following order; monopodial branches> ginning outturn>boll weight>sympodial branches>plant height>yield>number of bolls plant^{-1} with heritable percentages 99%, 90%, 89%, 64%, 60%, 60% and 55% respectively.

1. INTRODUCTION

Cotton is known as white gold due to its white fibre color. The English word cotton is derived from a Greek word "quten". In the World cotton has different names in different languages e.g. in Hindi it is known as "kapas", "Katoen" in Dutch, "Catone" in French, "Carbasas" in Latin and "cotton" in Italian. Cotton, as a commercial crop, has played a vital role in agriculture, industrial development, and employment generation [1]. The economy of Pakistan depends on agriculture. From ancient times till today cotton is running industries and boosting the economy of many countries. The demand of cotton fibre is high due to its unique qualities. In addition to fiber, cotton seed Bis big source of cooking oil which is 70% of the total vegetable oil production in Pakistan [2]. In addition to fiber it also provides cotton seed cake which is used for animal feed. A huge amount of foreign exchange is earned by exporting its raw material and by-products. Cotton crop contributes 1.4% to the GDP and 6.7% in the value addition of agriculture in Pakistan. About 1.5 million population of Pakistan earn their livelihood from the cultivation of cotton. It is cultivated on 2.806 million hectares in Pakistan [3]. Cotton is a perennial plant and has indeterminate growth habit. It belongs to genus *Gossypium* and its family is Malvaceae. The genus *Gossypium* contains 50 species with basic chromosome number 13. Among these 4 species are cultivated out of which 2 are diploid (2n=2X=26) and 2 are tetraploid (2n=4X=52). The diploid species include *Gossypium arboreum* and *Gossypium herbaceum* while *Gossypium hirsutum* and *Gossypium barbadense* are tetraploid species. Commonly *Gossypium hirsutum* is known as American or upland cotton as it was first grown in uphill's as successful crop by the immigrants in the USA. In the Indian subcontinent upland cotton (*Gossypium hirsutum*) was first introduced by English in 1790.

In Pakistan 99% of cotton grown is *Gossypium hirsutum* and less than 1% is *Gossypium arboreum* L. (desi cotton). Remarkable progress in Pakistan has been made in cotton breeding after independence but Pakistan still lags the other top cotton producing countries of the world as for as yield is concerned. Improvement is possible by finding good combination of desirable traits. The numeric values obtained from correlation analysis shows relationship among different traits hence helps plant breeder in selection of desirable plants. Seed cotton yield being a complex character, knowledge of its correlation with various agronomic characters is required to develop high yielding varieties.

2. MATERIALS AND METHODS

The experiment will be conducted in the experimental area of the Department of Plant Breeding and Genetics, University of Agriculture Faisalabad. Breeding material including two parents (P.B-38 and Jambo-Okra) and 10 F_2 progeny of that parents. Genotypes will be sown in normal condition in randomized complete block design (RCBD) with 3 replications in the field. In each row there were 10 plants. Row to row and plant to plant distance was 75 cm and 30 cm respectively. All kinds of recommended crop cultural practices from seed sowing to seed cotton picking will be provided.

The experiment was comprised of the 2 parental genotypes and their F_2 population.

At maturity data were recorded from five guarded plants in each row on the following traits:

Plant height (PH)
Number of monopodial branches (MB)
Number of sympodial branches (SB)
Leaf type

Boll shape
Number of bolls per plant (NB)
Boll weight (BW)
Ginning out turn (GOT %)
Seed cotton yield

2.1 Statistical Analysis of Data

The data collected was subjected to analysis of variance following the method as by Steel to determine significant differences in plant characters among the genotypes F2 generations under study [4]. The characters showing significant differences were further analyzed for correlation coefficients by the formula as outlined by Dewey and Lu using Minitab program of computer [5].

$$r\,(XY) = \frac{COV\,(XY)}{\sqrt{V(X)\,V(Y)}}$$

$r_{(XY)}$ = correlation of "X" and "Y".
COV (XY) = covariance of "X" and "Y".
V(X) = variance of "X".
V(Y) = variance of "Y".

3. RESULTS AND DISCUSSION

The analysis of variance revealed that the parental and the F_2 population showed significant difference for various traits i.e. plant height, sympodial and monopodial branches, number of bolls per plant, boll weight, ginning out turn, and seed cotton yield per plant. Analysis of variance (ANOVA) table for all the traits is given in appendix. Mean values of parents and their F_2 generation for various traits are given in Table 1. Correlation matrix of the traits is given in Table 2.

3.1 Plant Height

In case of plant height, the parents PB-38, Jambo Okra and F_2 population had mean height 61.91 cm, 79.22 cm and 84.34 cm respectively. Results revealed that plant height had positive correlation with sympodial branches, monopodial branches, okra leaf, number of bolls per plant, boll weight, ginning out turn, and seed cotton yield per plant. The trait had 60% heritability. Plant height showed positive association with number of sympodial branches per plant [6]. Moderate heritability reported for number of sympodial branches per plant and number of monopodial branches per plant [7]. Cotton yield showed positive association with number of bolls plant^{-1}, boll weight, plant height and staple length. Earliness index had maximum and positive direct effect on cotton yield.

3.2 Monopodial Branches per Plant

In case of mean values for number of monopodial branches per plant PB-38, Jamo Okra, and F_2 population had 1.58, 1.73 and 1.69 respectively. Results revealed that monopodial branches had positive correlation with okra leaf type, bolls per plant, boll weight, ginning out turn and seed cotton yield. The trait had 99% heritability. Similar findings testified that monopodial branches had positive relationship with number of bolls per plant and cotton seed yield [8]. Report indicated that number of monopodial branches per plant had positive correlation with plant height, number of bolls per plant, number of sympodial branches and seed cotton yield per plant [9].

3.3 Sympodial Branches per Plant

In case of number of sympodial branches per plant PB-38, Jamo Okra, and F2 population had 5.13, 7.53 and 10.42 respectively. Results revealed that sympodial branches had positive correlation with plant height, okra leaf type, ball shape, bolls per plant, boll weight, ginning out turn and seed cotton yield. This trait had 64% heritability.

A research found that sympodia per plant had positive correlation with number of bolls per plant and seed cotton yield [6]. Another report indicated that sympodial branches had positive relationship with plant height and yield of seed cotton [10]. Sympodial branches had positive association with plant height and boll weight [11].

3.4 Leaf Type

The F_2 population had plants with normal, okra semi-okra leaf type but Pb-38 and Jambo Okra had normal and okra leaf type respectively. Results revealed that leaf type had positive correlation with plant height, sympodial, monopodial, bolls per plant, boll weight, ginning out turn and seed cotton yield. Study of 208 families (okra leaf cotton) showed that fiber length positively associated with fiber strength. Okra leaf cotton improved genetic potential for fiber and morphological traits [12].

Table 1. Mean values of the parents/F₂ population, population effects and heritability of plant height (PH, cm), number of monopodial branches (MB), number of sympodial branches (SB), leaf type (LT), boll size (BS) boll shape (BSh), number of bolls per plant (B/P), boll weight (BW, g), ginning out turn (GOT, %) and seed cotton yield (SCY, g)

Population	PH	MB	SB	LT	BS	BSh	B/P	BW	GOT	Y/P
PB-38	61.919	1.58	5.13	Normal	Medium	Round	28.00	3.840	22.926	26.70
Jumbo Okra	79.222	1.73	7.53	Okra	Small	Oval	29.60	4.675	27.685	30.10
PB-38xJumbo Okra	84.346	1.69	10.42	Normal Okra, Semi Okra	Small, Medium, Large	Round, Oval	36.54	5.768	39.958	33.75
Population Effects	*	**	*	-	-	-	**	*	*	*
Heritability	**0.60**	0.99	0.64	-	-	-	0.55	0.89	0.90	0.60

*** = P < 0.01; *= P < 0.05*

Table 2. Correlation matrix among the traits, plant height (PH), number of monopodial branches (MB), number of sympodial branches (SB), leaf type (LT), boll size (BS), boll shape (BSh), number of bolls per plant (B/P), boll weight (BW), ginning out turn (GOT)

	PH	SB	MB	LT	BS	BSh	B/P	BW	GOT
SB	0.549**								
MB	0.355**	0.512**							
Leaf type	0.434**	0.573**	0.403**						
BS	0.023	-0.084	0.040	-0.083					
BSh	0.067	0.156*	0.078	0.152*	-0.122				
B/P	0.540**	0.573**	0.387**	0.588**	-0.015	-0.109			
BW	0.611**	0.710**	0.498**	0.789**	-0.047	0.142	0.710**		
GOT	0.571**	0.711**	0.501**	0.882**	-0.072	0.156*	0.692**	0.969**	
SCY	0.592**	0.681**	0.501**	0.783**	-0.109	0.170*	0.721**	0.933**	0.925**

3.5 Boll Size

The F_2 population had plants with small, medium and large bolls but Pb-38 and Jambo Okra had medium and small boll size respectively. Results are in contrast with Kartprasertrat which reported that GOT had positive correlation with boll size [4]. Results are in contrast with Soomro which concluded that there was positive association of lint yield with yield components like boll size [13]. Results are in contrast with Imran et al. [2] which reported that boll size had positive correlation with seed cotton yield whereas correlation between number of bolls per plant and size of boll was negative.
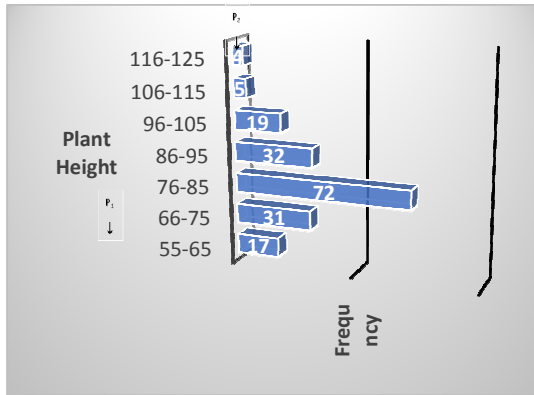
Fig. 1. Frequency distribution of F_2 for plant height (cm)
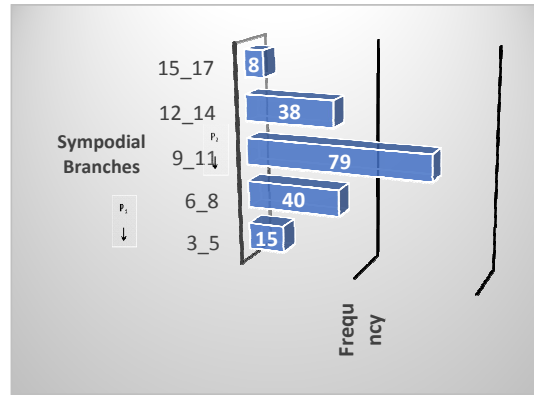
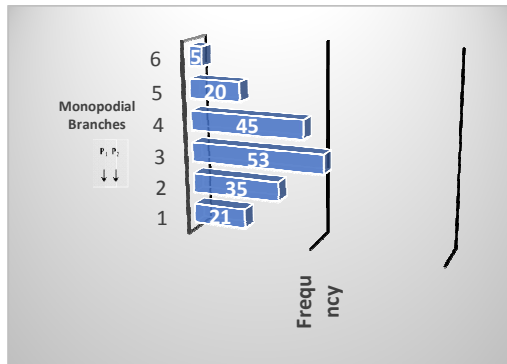**Fig. 2. Frequency distribution of F_2 for number of sympodial branches**

Fig. 3. Frequency distribution of F_2 for number of bolls per Monopodial branches plant
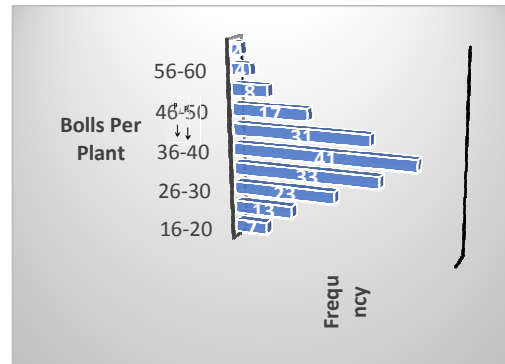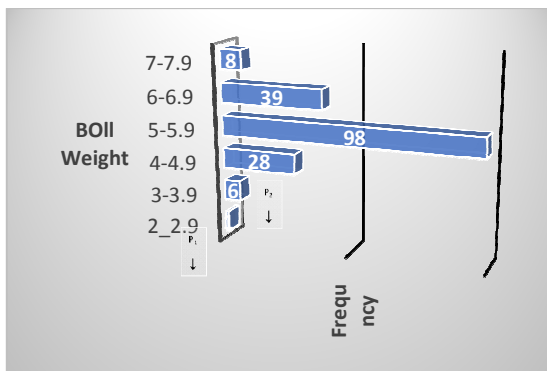

Fig. 4. Frequency distribution of F_2 for number

Fig. 5. Frequency distribution of F_2 for Boll weight ginning out turn

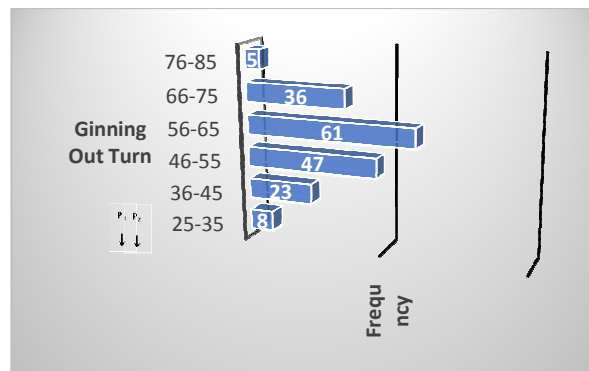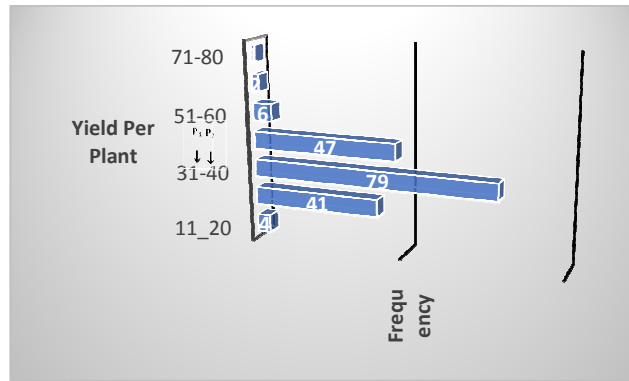**Fig. 6. Frequency distribution of F_2**

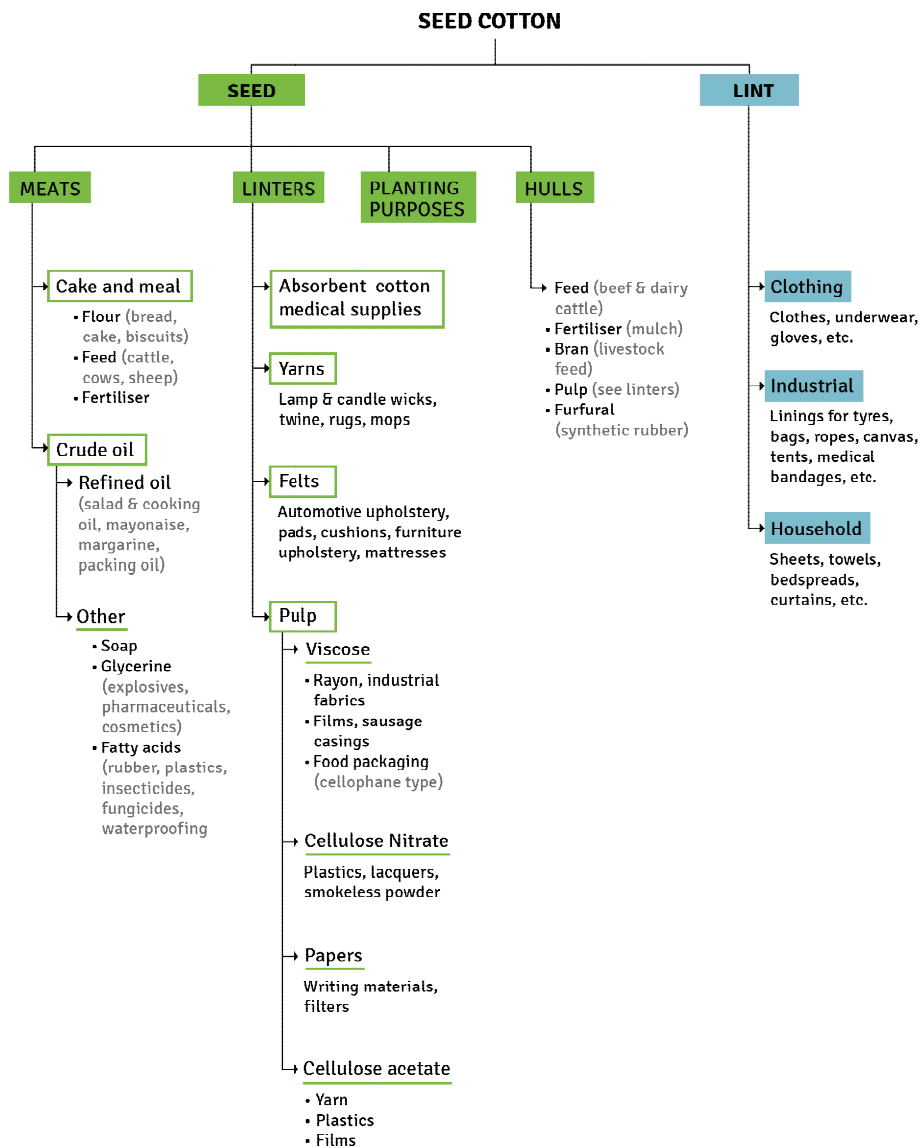**Fig. 7. Frequency distribution of F$_2$ for seed cotton yield**

Fig. 8. Cotton and it's various uses [20]

3.6 Boll Shape

The F_2 population had plants with round and oval boll shape but Pb-38 and Jambo Okra had round and oval boll shape respectively. Results revealed that boll shape had positive correlation with plant height, monopodial branches, boll weight. Results showed that boll shape had positive association with sympodial branches, leaf type, ginning out turn and seed cotton yield.

3.7 Number of Bolls per Plant

In case of mean values for number of bolls per plant PB-38, Jamo Okra, and F_2 population had 28, 29.60 and 36.54 respectively. Results revealed that bolls per plant had positive correlation with plant height, sympodial, monopodial, leaf type, boll weight, ginning out turn and seed cotton yield. This trait had 55% heritability. The number of bolls per plant positively correlated with lint percentage while it negatively correlated with boll [14]. Research illustrated that number of bolls per plant positively correlated with ginning out turn and fiber fineness [3].

3.8 Boll Weight

In case of mean values for number of boll weight PB-38, Jamo Okra, and F_2 population had 3.84, 4.67 and 5.76 respectively. Results revealed that boll weight had positive correlation with plant height, sympodial, monopodial, leaf type, bolls per plant, ginning out turn and seed cotton yield. This trait had 89% heritability. Boll weight had negative association with number of bolls per plant and lint percentage [15]. A Report found that boll weight positively associated with fiber fineness and fiber strength [16].

3.9 Ginning Out Turn

In case of mean values for number of ginning out turn PB-38, Jamo Okra, and F_2 population had 22.92, 27.68 and 39.95 respectively. Results revealed that ginning out turn had positive correlation with plant height, sympodial, monopodial, leaf type, bolls per plant, boll weight, boll shape, seed cotton yield. This trait had 90% heritability.

Fiber fineness and fiber strength found as positively associated with seed cotton yield [17]. Fiber fineness reported as negatively associated with fiber length and fiber strength [18]. Research

found that seed cotton yield is positively correlated with micronaire value [19].

4. CONCLUSION

Correlation coefficient revealed that plant height had positive and highly significant association with boll weight and had moderate heritability (60%). Sympodial branches showed highest positive and highly significant relationship with GOT and had moderate heritability (64%). Results showed that monopodial branches had highest positive and highly significant association with sympodial branches and had high heritability (99%).

Leaf type showed highest positive and significant association with GOT. Results of correlation analysis showed boll size had positive and non-significant association with plant height and monopodial branches, while negative and non-significant with all other traits studied. Boll shape had positive and significant association with seed cotton yield, while non-significant with all other traits studied. Bolls per plant had positive and highly significant association with seed cotton yield and had moderate heritability.

Seed cotton yield had highest positive and significant association with boll weight, followed by G0T%, boll shape, bolls per plant, sympodial branches, plant height, monopodial branches, boll shape, while negative and non-significant with boll size. Heritability estimates revealed that monopodial branches (99%) had highest heritability, followed by GOT (90%), boll weight (89%), sympodial branches (64%), plant height (60%), yield per plant (60%) and bolls per plant (55%). Hence, keeping in view the above-mentioned results we can improved our cotton germplasm by developing improved varieties to ensure future food safety.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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