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Genetics of Inheritance and Interrelationship of Various Agronomic Traits of F_2 Population in Cotton (*Gossypium hirsutum* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. Authors BN, SS and MJ comprehended and designed the experiment while authors SS, BN and BB performed experiments. Authors BN, SS and KH examined data and estimated the conclusion. Authors BN, SS and TAM wrote the paper. All authors read and approved the final manuscript.

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ABSTRACT

Background: Cotton (*Gossypium hirsutum* L.) is grown in more than sixty countries worldwide. It is an important fiber crop in the world. It plays a vital role in our national economy being the source of earning of foreign exchange, therefore, it is considered to be the backbone of the economy of Pakistan. In Pakistan, millions of families are associated with cotton and textile industry for their livelihood.

Results: In this experiment F_2 population of the cross L. A. Frego Bract x CIM-600 and their parents was sown in randomized complete block design with three replications during normal growing season of the year 2014 to sort out best performing genotypes for yield related traits. Analysis of variance (ANOVA) revealed that parental and their F_2 population showed significant differences for all the observed agronomic traits (plant height, number of monopodia branches,

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number of sympodial branches, number of bolls per plant, boll weight, ginning out turn, bract type, boll shape, beak size, seed cotton yield, staple length, fiber strength and fiber fineness). Estimation of correlation revealed that seed cotton yield was found positively correlated sympodial branches, fiber fineness and boll weight while ginning out turn, bract type, beak size, staple length and fiber strength were negatively associated with seed cotton yield. Epistasis was not found to be involved in any of the traits.

Conclusion: The correlation and genetics study of various yield related traits provides us useful information for effective selection and sustainable breeding programs. Estimation of broad sense heritability (h^2_{bs}) in F_2 populations for different traits vary as following order; ginning out turn>plant height>seed cotton yield>sympodia branches>fiber length>fiber strength>bolls per plant>monopodia branches>boll weight>fiber fineness with heritability 0.90, 0.79, 0.78, 0.75, 0.73, 0.71 0.67, 0.64, 0.63 and 0.50 respectively. Results suggested form heritability and correlation that these traits can be improved either through appropriate selection method or hybrid breeding programme.

Keywords: Correlation; heritability; agronomic traits; upland cotton (Gossypium hirsutum. L).

ABBREVIATIONS

Plant Height (PH, cm); Number of monopodial branches (MB); Number of sympodial branches (SB); Number of bolls per plant (B/P); boll weight (BW, g); Ginning out turn (GOT, %); Bract type (BT); Boll shape (B. Sh); Beak size (BS); seed cotton yield (SCY, g); Fiber length (FL, mm); Fiber strength (FS, g/tex); Fiber fineness (FF, µg/inch**).**

1. INTRODUCTION

Pakistan is an agricultural country. Its economy depends upon agriculture directly and indirectly. Agriculture sector is playing vital role in socio-economic development of the country and in alleviating poverty. Cotton is locally known as Kapas. It is an important cash crop of Pakistan as well as of the world. It has contributed greatly to the industrial sector and play important role in economic development of many countries in the world. In Pakistan, millions of families are associated with cotton and textile industry for their livelihood [1].

Cotton is perennial plant having intermediate growth habit. It is short day plant which fix carbon in C3 form. It belongs to *Gossypium* Genus and Malvaceae family [2]. This genus consists of 50 species having 13 basic chromosome number [3,4]. There are 45 diploid and five allotetraploid species (Fryxell, 1979). Four species are cultivated. Two of these are diploid (2n=2X=26) and 2 are tetraploid (2n=2X=52). *Gossypium hirsutum* (American cotton) and *Gossypium barbadense* (Egyptian cotton) are tetraploid and are called new world cotton while *Gossypium arboreum* and *Gossypium herbaceum* are called desi or old world cotton. Southern America is center of diversity of *G. barbadense* and spread from Caribbean to Mesoamerica. The species of *G. hirsutum* is native to Mesoamerica, Caribbean, Pacific Island and north South America. The origin of *G. arboreum* species is Asiatic and *G. herbaceum* is African.

It plays significant role in boosting our national economy. In addition to fiber production, it is also a source of edible oil and feed for livestock. Pakistan is the fourth largest producer of cotton. Cotton accounts for 7.1% to agriculture sector and 1.5% to GDP. The cropped area of cotton in Pakistan is 2.820 million hectares with the production of 13.983 million bales [5].

The objective of cotton breeding research is to produce high yielding cotton cultivars through various approaches. Further improvement in genetic architecture of cotton is possible; therefore cotton breeders are trying to develop new varieties with better quality and high yield. Seed cotton yield being a complex character, is the product of its various components. A knowledge of heritability and correlation of yield with various agronomic and fiber related characters is required to develop high yielding cotton varieties. Correlation provides the information of association among different traits which is helpful in selection of plants with a good combination of yield and quality related traits [6]. Correlation coefficient is important breeding parameter which describes that to what extent two traits are associated with each other. On the basis of heritability estimates and genetic

advance, we can select those characters that have high heritability [7].

The present research was conducted to calculate heritability components and correlation coefficient for various yield related traits like plant height, number of monopodial branches, number of sympodial branches, number of bolls per plant, boll weight, ginning out turn, bract type, boll shape, beak size, seed cotton yield, fiber length, fiber strength and fiber fineness. This information will be useful for cotton breeders to improve seed cotton yield and fiber quality traits of cotton.

2. MATERIALS AND METHODS

The experimental material consisted of two parental lines (L. A. Frego bract × CIM-600) and their F_2 population received from the Department of Plant Breeding and Genetics, University of Agriculture Faisalabad. These populations along their parents were grown using randomized complete block design with three replications under field conditions during 2014. Distance between plants and rows were maintained 30 cm and 75 cm respectively. All cultural and agronomic practices such as fertilizers, irrigation, plant protection and hoeing were applied uniformly throughout the field. The data was recorded at maturity from randomly selected five parent plants and 60 F_2 plants from each replication for the following parameters.

1. Plant height (cm)
2. Number of monopodial branches
3. Number of sympodial branches
4. Number of bolls per plant
5. Boll weight (g)
6. GOT (%)
7. Bract type
8. Boll shape
9. Beak size
10. seed cotton yield (g)
11. Fiber length (mm)
12. Fiber strength (g/tex.)
13. Fiber fineness (µg/inch)

2.1 Ginning Out Turn (%)

Dry and clean samples of seed cotton were weighed and ginned separately with single roller electrical gin in ginnery section. The lint obtained from each sample was weighed and the lint percentage was calculated by following formula:

$$\text{GOT } \% = \frac{\text{Weight of lint in a sample}}{\text{Weight of seed cotton in sample}}$$

2.2 Bract Type

Two types of bracts normal and frego were observed. They were assigned 1 and 2 respectively for correlation analysis.

2.3 Boll Shape

Two types of boll shapes, round and oval were observed. They were assigned 1 and 2 respectively for correlation analysis.

2.4 Beak Size

Two types of boll beak sizes short and medium were observed. They were assigned 1 and 2 respectively for correlation analysis.

2.5 Fiber Characteristics

Fiber characteristics (staple length, fiber strength and fiber fineness) from the lint of selected plants were measured in A. A. Spinning and textile mill Pvt. Ltd. Khurlianwala, Faisalabad. The said instrument recorded fiber fineness (µg/inch), staple length (mm) and fiber strength (g/tex) according to international standards of measurement.

Then the mean value of every genotype was calculated.

2.6 Statistical Analysis

The data subjected to analysis of variance [8]. Coefficients of correlation estimated by the formula as outlined by Dewey and Lu [7].

3. RESULT AND DISCUSSION

Analysis of variance (ANOVA) revealed that the populations (parents and the F_2 population) showed significant differences for all the observed traits (plant height, number of sympodial branches, number of monopodial branches, number of bolls per plant, boll weight, ginning out turn, bract type, boll shape, beak size, seed cotton yield, fiber length, fiber strength and fiber fineness). Mean values for the traits of the populations are given in Table 1 Heritability and Correlation matrix is given in Table 2 and 3 respectively. Frequency distribution of F_2 population for each trait is shown in Fig. 1 to 10. The analysis of variance of all the traits is given.

Correlation analysis is the measure of relationship between plant characters for which

Table 1. Mean values of the parents/progeny for Plant Height (PH, cm), Number of monopodial branches (MB), Number of sympodial branches (SB), Number of bolls per plant (B/P), boll weight (BW, g), Ginning out turn (GOT, %), Bract type (BT), Boll shape (B. Sh), Beak size (BS), seed cotton yield (SCY, g), Fiber length (FL, mm), Fiber strength (FS, g/tex) and Fiber fineness (FF, µg/inch)

Genotypes	PH	MB	SB	B/P	BW	GOT	BT	B. Sh	BS	SCY	FL	FS	FF
L. A. Frego-Bract	88.74	0.86	9.53	19.13	2.64	40.50	Frego	Round	Short	31.85	25.00	18.33	3.82
CIM-600	88.57	1.86	12.13	27.06	1.71	39.90	Normal	Oval	Medium	65.42	27.16	23.86	4.48
L. A. Frego-Bract x CIM-600	88.83	0.87	12.87	23.27	2.48	42.18	Normal and frego	Round and oval	Medium and Short	48.70	26.10	22.23	4.12

selection is applied for improvement of yield and quality of its fiber. The existence of correlation between various traits is indication of gene linkage [9]. So, the knowledge of correlation analysis revealed the expected response of other traits when selection is applied to a desired trait.

Table 2. Broad sense heritability (h^2bs) of the crosses for the traits, Plant height, Number of Monopodial branches, Number of Sympodial branches number of bolls per plant, Boll weight, Ginning out turn, Seed cotton yield, Fiber length, Fiber strength and Fiber fineness

Traits	(L. A. Frego Bract x CIM-600)
	h^2bs
Plant height	0.79
Monopodial branches	0.64
Sympodial branches	0.75
Number of bolls per plant	0.67
Boll weight	0.63
Ginning-out-turn	0.90
Seed cotton yield	0.78
Fiber length	0.73
Fiber strength	0.71
Fiber fineness	0.50

3.1 Plant Height (cm)

Mean data showed that the parent, L. A. Frego bract had 88.74cm plant height and other parent, CIM-600 plant height was 88.57cm. The results showed that F_2 population produced 88.83cm average plant height which was higher plant height than both of the parents.

Correlation analysis revealed that plant height associated positively with number of monopodial branches per plant, number of sympodial branches per plant and number of bolls per plant. It had negative association with boll weight. Broad sense heritability for plant height was 79%.

Similar finding was reported by Thiyagu et al. [10], according of which plant height had positive association with number of sympodial branches per plant. Plant height positively correlated with number of sympodial branches per plant and number of bolls per plant. Plant height showed negative association with seed cotton yield [11]. Pant height had positive association with number of monopodial branches, number of sympodial branches per plant and ginning out turn but it had negative correlation with staple length. They also found that broad sense heritability for plant height was 96.4% [12,13]. From correlation studies it was suggested that increase in plant height has positive effect on monopodial branches, sympodial branches and bolls per plant. Heritability study for this traits exhibited that appropriate breeding program can be implemented to improve this traits.

3.2 Number of Monopodial Branches

For monopodial branches parent, CIM-600 showed highest mean performance (1.86) as compared to parent, L. A. Frego bract and F_2 population that showed 0.86 and 0.87 mean performance for monopodial branches respectively.

Correlation matrix indicated that number of monopodial branches per plant linked positively with plant height, number of bolls per plant and frego bract type but it had negative association with boll weight. Broad sense heritability for this trait was 64%. 56% broad sense heritability for this character [14]. Similar result that number of monopodial branches per plant had positive association with plant height [15]. They also reported that broad sense heritability for this trait was 86%. It is suggested that selection of appropriate breeding strategies would be useful in improvement of sympodial branches per plant. As sympodial branches per plant has direct positive effect on bolls per plant so improvement of sympodial branches per plant will brought a positive change in bolls per plant that results in increase in seed cotton yield.

3.3 Number of Sympodial Branches

For sympodial branches F_2 population showed highest mean performance as 12.87 while both parents L.A. Frego bract and CIM-600 showed lower mean performance as 9.53 and 12.13 respectively. Correlation analysis showed that number of sympodial branches per plant showed positive association with number of bolls per plant, medium beak size, plant height, seed cotton yield and ginning out turn. Results also showed that number of sympodial branches per plant had negative association with boll weight. Broad sense heritability for this traits was found 75%. 88% and 43% broad sense heritability for sympodial branches per plant, respectively [16].

Table 3. Correlation matrix of two parents/cross among the traits, Plant height (PH), Number of Monopodial branches (MB), Number of Sympodial branches (SB), Number of bolls per plant (B/P), Boll weight (BW), Ginning out turn (GOT), Bract type (BT), Boll shape (B. Sh), Beak size (BS),Seed cotton yield (SCY), Fiber length (FL), Fiber strength (FS) and Fiber fineness (FF)

	PH	MB	SB	B/P	BW	GOT	BT	B. SH	BS	SCY	FL	FS
MB	0.275**											
SB	0.457**	0.070										
B/P	0.541**	0.433**	0.641**									
BW	-0.241**	-0.164*	-0.380**	-0.491**								
GOT	-0.036	-0.105	0.127*	0.031	0.067							
BT	0.039	0.159*	-0.039	0.104	-0.122	-0.093						
B. SH	0.012	0.092	0.087	0.055	0.049	-0.13*	0.216**					
BS	0.042	0.088	0.156*	0.185**	-0.137*	-0.067	0.227**	0.324**				
SCY	0.052	0.020	0.131*	0.003	0.598**	-0.049	-0.041	0.105	-0.105			
FL	0.047	0.060	0.068	0.050	-0.151*	-0.101	0.082	-0.064	-0.005	-0.118		
FS	0.054	0.033	0.053	0.018	-0.118	-0.092	0.079	-0.056	-0.023	-0.116	0.930**	
FF	0.055	0.037	0.037	0.003	-0.140*	-0.092	0.052	-0.059	-0.002	0.136*	0.931**	-0.900**

*Significant *=p<0.05*
*Highly significant **=p<0.01*

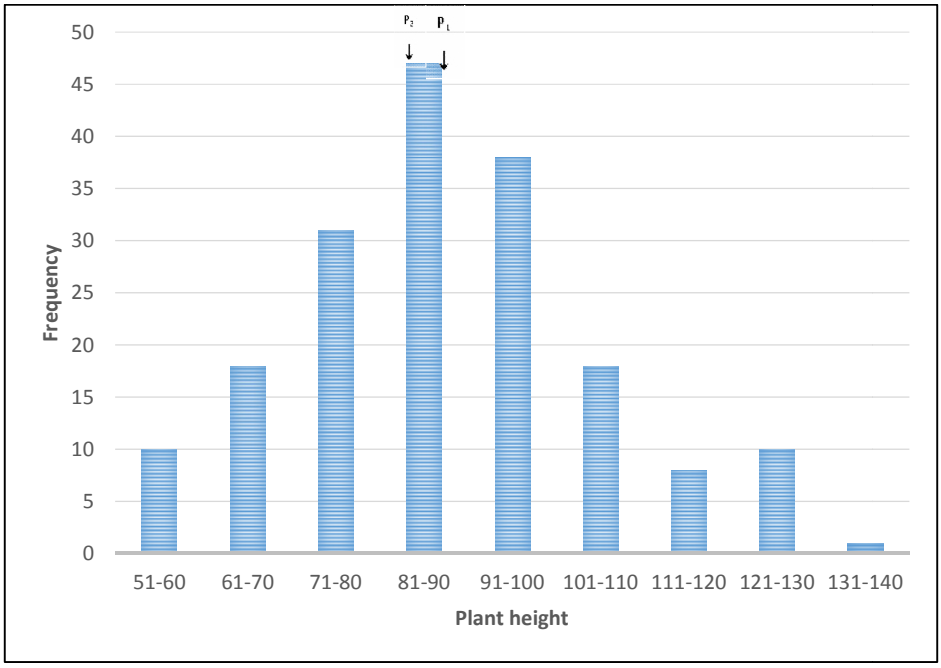

Fig. 1. Frequency distribution of F_2 for plant height (cm)

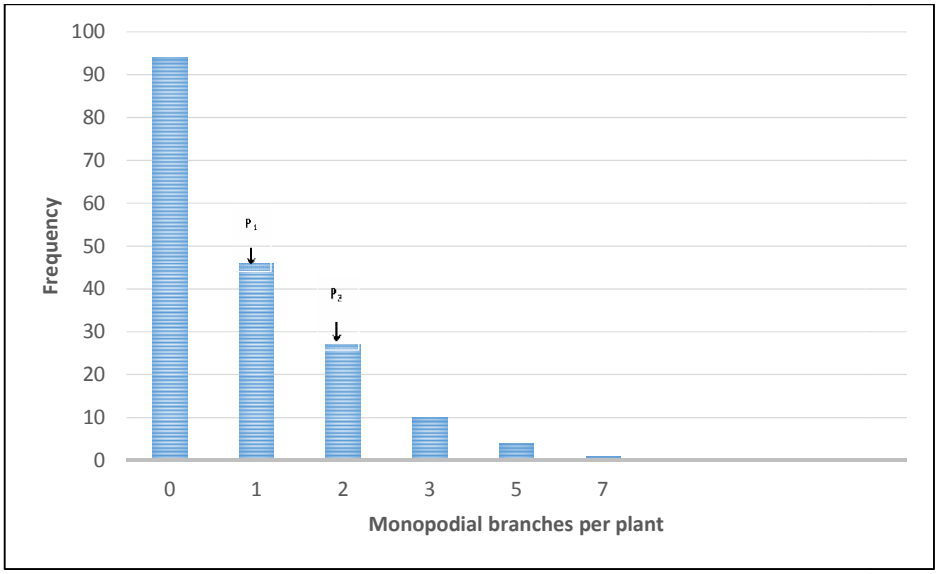

Fig. 2. Frequency distribution of F_2 for number of monopodial branches

It had high heritability which showed that selection will be useful. Range showed that large amount of variability was present among genotypes for this trait, therefore we can use this germplasm for further breeding program. Sympodial branches per plant associated positively with plant height, seed cotton yield and ginning out turn. They also concluded that broad sense heritability for sympodial branches per plant was 79.17% [17].

3.4 Number of Bolls per Plant

It was predicted from mean performance of both parents and F_2 population that highest numbers of bolls per plant observed in parent CIM-600 as

27.06 while parent L. A. Frego bract and F_2 population produced lower number of bolls per plant as 19.13 and 23.27 respectively. Correlation matrix showed that Number of bolls per plant showed positive association with plant height, number of monopodial branches and number of sympodial branches. It had negative association with boll weight. For this trait heritability value was 67%. Number of bolls had negative association with boll weight and positively correlated with seed cotton yield [18, 19,20]. Number of bolls had negative association with boll weight and positively correlated with number of sympodial branches per plant [21]. Correlation studies suggested that improvement in bolls per plant had positive direct effect on sympodial and monopodial branches per plant.

3.5 Boll Weight

It was predicted from mean performance table that parent L. A. Frego bract produced highest boll weight as 2.64 g while parent CIM-600 and F_2 population showed smaller boll weight as 1.71g and 2.48 g respectively. Correlation analysis revealed that boll weight exhibited positive association with fiber fineness and seed cotton yield. It had negative association with plant height, number of sympodial branches per plant, number of monopodial branches per plant, number of bolls per plant, medium beak size and fiber length. Broad sense heritability for this trait was found 63%. Similar findings were also reported by Ahsan [5] boll weight had positive association with seed cotton yield. Boll weight had positive association with seed cotton yield and number of bolls per plant. They concluded that broad sense heritability for this trait was 93.58% [22]. Abdullah et al. [21] also found similar result that boll weight had positive genotypic association with seed cotton yield [21].

3.6 Ginning Out Turn

It was predicted from mean performance table that F_2 population showed higher ginning-out-turn (42.18%) as compared to both parents that showed ginning out turn 40.50% and 39.90% respectively. Correlation studies showed that ginning out turn percentage positively associated with number of sympodial branches per plant and negatively associated with oval boll shape. Broad sense heritability was found for this 90%. Negative association existed between lint yield and fiber quality parameters. Short fiber associated negatively with fiber fineness [7]. Hussain concluded that ginning out turn showed negative association with fiber strength [4]. Baloch concluded that ginning out turn had positive association with plant height and number of sympodial branches per plant [23]. They concluded that broad sense heritability for this trait was 91.48%. Dhamayanathi et al. [24] reported 96% broad sense heritability for ginning out turn. Range showed that large amount of variability was present among genotypes for this trait, therefore we can use this germplasm for further breeding program.

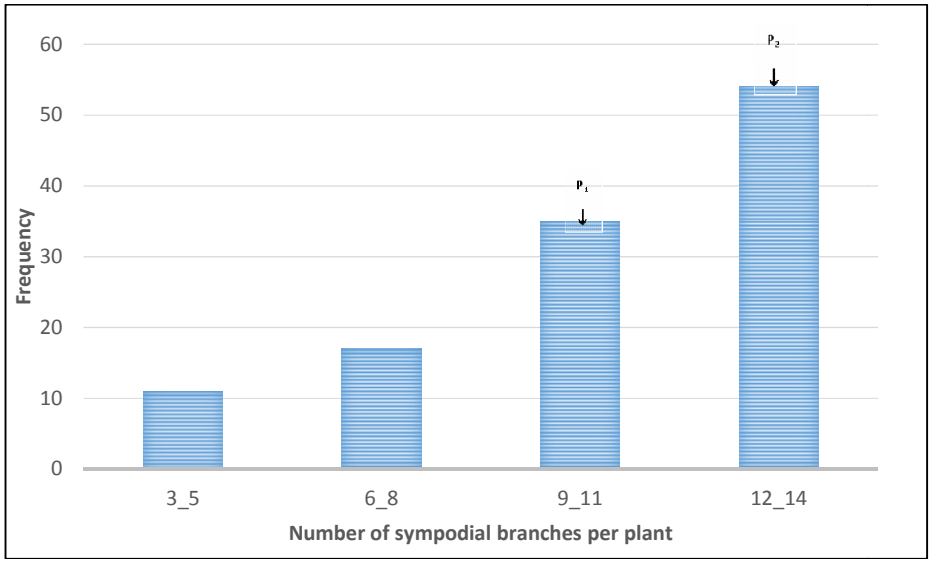

Fig. 3. Frequency distribution of F_2 for number of sympodial branches per plant

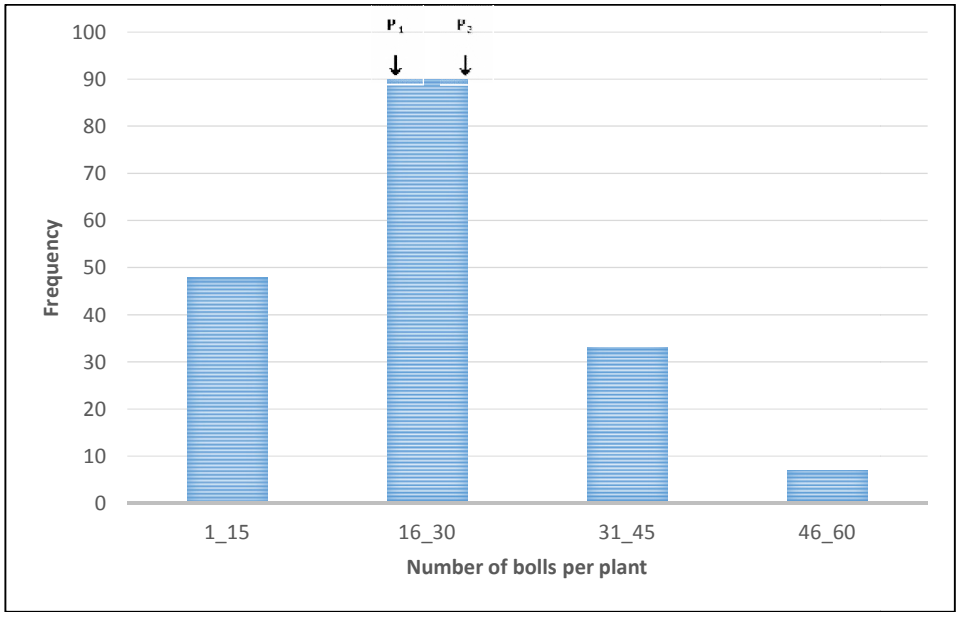

Fig. 4. Frequency distribution of F_2 for number of bolls per plant

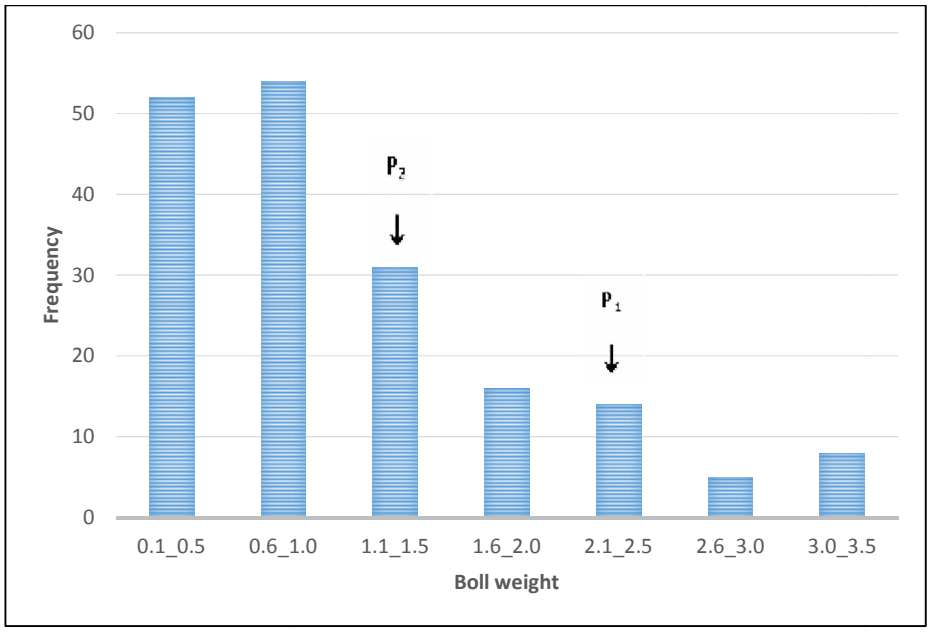

Fig. 5. Frequency distribution of F_2 for boll weight (g)

3.7 Bract Type

Two types of bracts were observed. Among the parental genotypes L.A. frego bract had frego bract and CIM-600 had normal bract. In case of F_2 population, both types of bracts were observed. Some plants of F_2 population had normal bracts while others had frego bract. Correlation analysis showed that frego bract type had association with oval boll shape, medium beak size and number of monopodial branches per plant.

3.8 Boll Shape

Two types of boll shapes round and oval were observed. Among the parental genotypes L.A. Frego bract had round boll shape and CIM-600

had oval boll shape. Both types of boll shapes were observed in F_2 population. Some plants of F_2 population had round boll shape while others had oval boll shape. Correlation matrix revealed that oval boll shape had positive association with frego bract type and medium beak size. Round boll shape had association with ginning out turn.

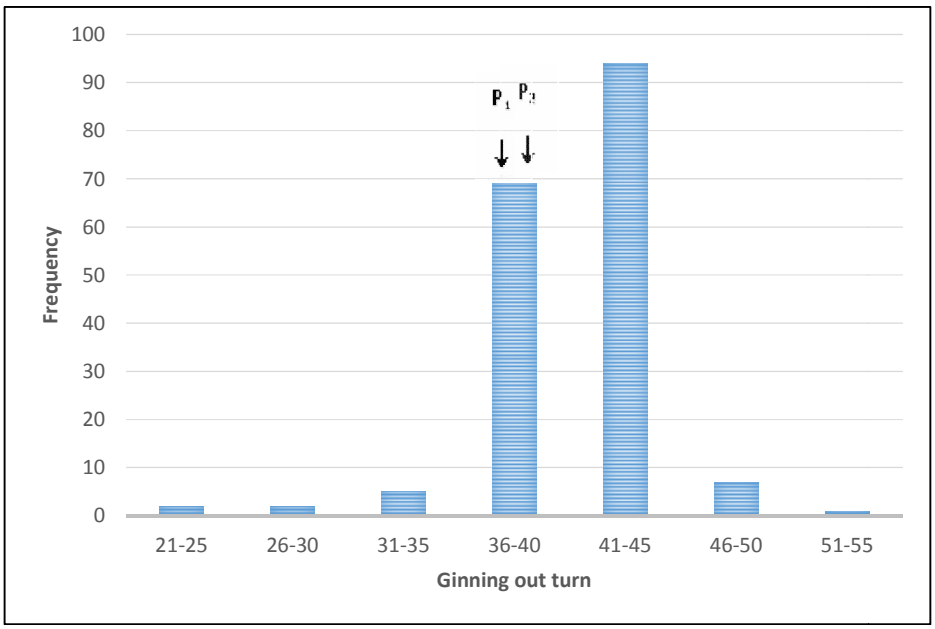

Fig. 6. Frequency distribution of F_2 for Ginning out turn %age

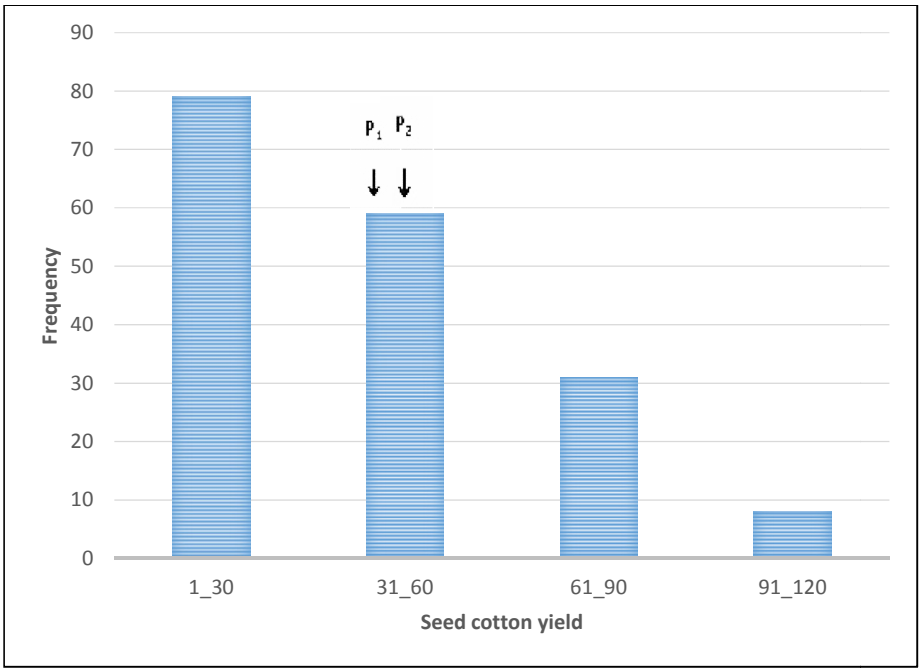

Fig. 7. Frequency distribution of F_2 for Seed cotton yield per plant (g)

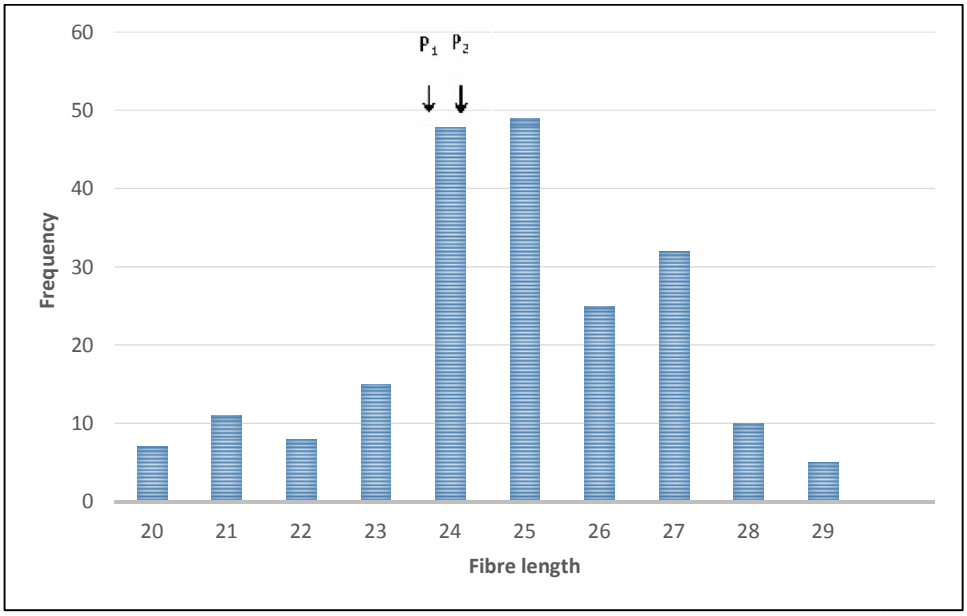

Fig. 8. Frequency distribution of F_2 for fiber length (mm)

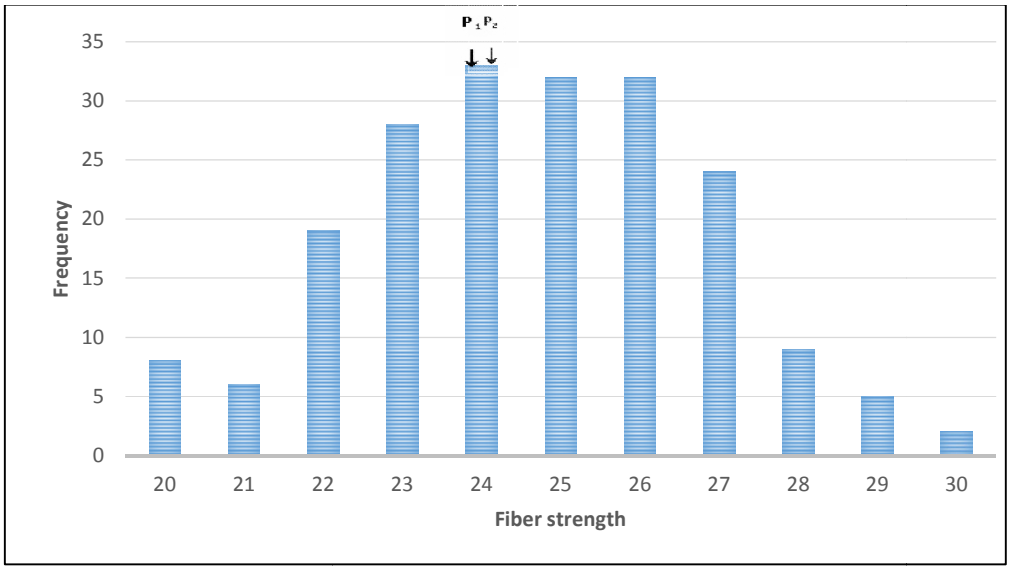

Fig. 9. Frequency distribution of F_2 for fiber strength (g/tex)

3.9 Beak Size

Two types of beak sizes were observed. Among the parental genotypes L.A. Frego bract had short beak size and CIM-600 had medium beak size. Both types of beak size were observed in F_2 population. Some plants of F_2 population had short beak size while others had medium beak size. Correlation matrix showed that medium beak size had positive association with number of bolls per plant, sympodial branches per plant, frego bract type and oval boll shape. Short beak size had association with boll weight.

3.10 Seed Cotton Yield

It was predicted from mean performance of both parents and F_2 population that highest seed cotton yield was observed in parent CIM-600 as 65.42 while parent L. A. Frego bract and F_2

population produced lower number of bolls per plant as 31.85 and 48.70 respectively.

The correlation study indicated that seed cotton yield associated positively with number of sympodial branches per plant, boll weight and fiber fineness. Broad sense heritability was found for this trait 78%.

Seed cotton yield had positive association with boll weight and number of bolls per plant [20]. Seed cotton yield had positive association with number of sympodial branches per plant, number of bolls per plant and boll weight [13]. They concluded that broad sense heritability for this trait was 95.45%. Range showed that large amount of variability was present among genotypes for this trait, therefore we can use this germplasm for further breeding program. Similar finding that boll weight and fiber fineness had positive genotypic association with seed cotton yield [25].

3.11 Fiber Length

The correlation study showed that fiber length associated positively with fiber strength and fiber fineness. So it means simultaneous increase in fiber length and strength is possible. It had negative correlation with boll weight. Broad sense heritability was found for this trait 73%.

Broad sense heritability for this trait fiber length was 97.89% [26]. Fiber length had positive association with fiber strength [27]. Heritability value showed it was suitable for breeding program. Range showed that large amount of variability was present among genotypes for this trait, therefore we can use this germplasm for further breeding program.

3.12 Fiber Strength

The correlation coefficient showed that fiber strength associated positively with fiber length and negatively associated with fiber fineness. Iqbal et al. reported that fiber strength had positive association with fiber length [28, 17, 15].

For this trait heritability value was 71%. Heritability estimates showed it was suitable for breeding program. Range showed that large amount of variability was present among genotypes for this trait, therefore we can use this germplasm for further breeding program.

3.13 Fiber Fineness

Correlation studies revealed that fiber fineness had positive association with boll weight, fiber length and seed cotton yield. It had negative association with fiber strength. Fiber fineness positively associated with seed cotton yield. Imran et al. [29] found that fiber

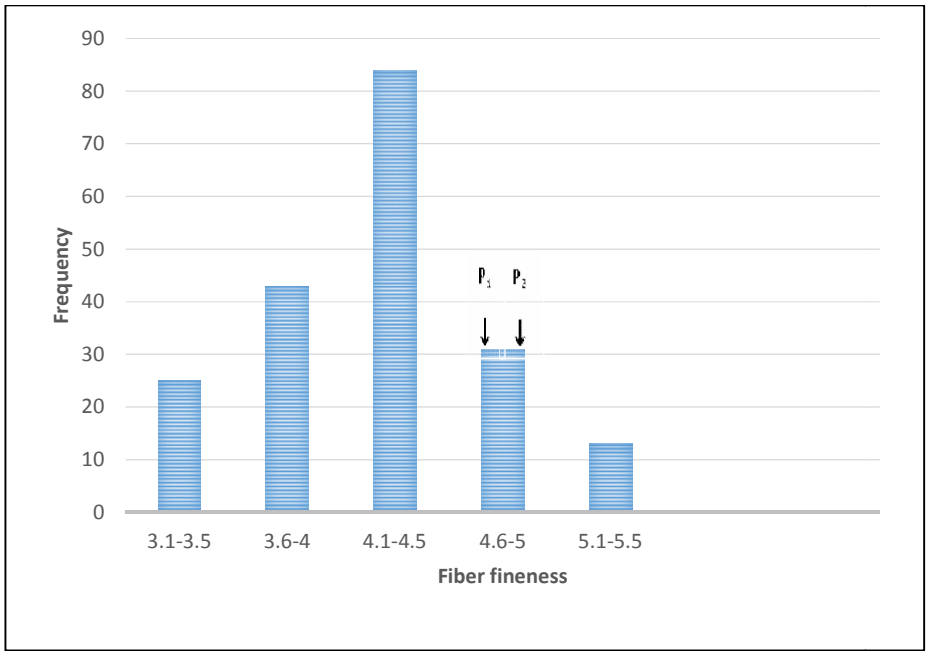

Fig. 10. Frequency distribution of F_2 for fiber fineness (µg/inch)

fineness associated negatively with fiber strength [20]. Broad sense heritability was higher for fiber fineness. For this trait heritability value was 50% Similar results that fiber fineness had positive genotypic association with seed cotton yield [9].

4. CONCLUSION AND RECOMMENDATION

Estimation of correlation revealed that plant height associated positively with number of monopodial branches per plant, number of sympodial branches per plant and number of bolls per plant. The trait had 79% broad sense heritability. Number of monopodial branches per plant linked negatively with boll weight and had positive association with number of bolls per plant and frego bract type. For this trait heritability value was 64%. Number of sympodial branches per plant showed positive association with number of bolls per plant, seed cotton yield, ginning out turn and medium beak size. It had negative association with boll weight. For this trait heritability value was 75%.

Number of bolls per plant showed positive association with plant height, number of monopodial branches, number of sympodial branches and medium beak size. It had negative association with boll weight. For this trait heritability value was 67%. Correlation analysis revealed that boll weight exhibited positive association with seed cotton yield and fiber fineness. It had negative association with medium beak size and fiber length. For this trait heritability value was 63%. Correlation studies showed that ginning out turn percentage positively associated with number of sympodial branches per plant. For this trait heritability value was 90%. Range showed that large amount of variability was present among genotypes for this trait. The correlation showed that frego bract type associated with oval boll shape, medium beak size and number of monopodial branches per plant. Normal bract type had association with ginning out turn.

Seed cotton yield associated positively with number of sympodial branches per plant, boll weight and fiber fineness. For this trait heritability value was 50%. The correlation study showed that fiber length associated positively with fiber strength and fiber fineness but negatively associated with boll weight. For this trait heritability value was 78%. So it means simultaneous increase in fiber length and strength is possible.

Fiber strength associated negatively with fiber fineness. For this trait heritability value is 73%. Correlation studies also revealed that fiber fineness had positive association with boll weight, fiber length and seed cotton yield. For this trait heritability value was 71%. The correlation study will be helpful to develop high yielding cotton cultivars with better quality fiber. High heritability estimates of ginning out turn, plant height and seed cotton yield showed that these characters are genetically determined and there is an ample scope for the genetic improvement of these both traits by selection and breeding provided most part of genetic variance is heritable.

All the parameters manifested positive correlation with seed cotton yield except plant height, monopodia per plant, bolls per plant, ginning out turn, boll shape, beak size, bract type, fiber length and fiber strength. Broad sense heritability was found maximum plant height, sympodial branches per plant, ginning out turn, seed cotton yield, fiber strength and fiber length. Thus during future breeding programme these traits should also kept in mind during making selection as those traits had major contribution in yield.

On basis of present findings, it is recommended while breeding for higher seed cotton yield:

- Selection of sympodial branches per plant, boll weight and fiber fineness should be practiced, as they were found positively associated with seed cotton yield.
- Higher plant height, monopodia per plant, bolls per plant, fiber length and fiber strength should be discouraged as they were found to be declining in seed cotton yield.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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