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RESEARCH ARTICLE

Genetic Studies in Different F_2 Segregating Population for Yield and Fiber Quality Traits in Cotton (*Gossypium hirsutum* L.)

Urooj Fatima Chaudhry[1], Muhammad Nouman Khalid[1*], Shahan Aziz[2], Ifrah Amjad[1], Ayesha Khalid[1], Hafsa Noor[1], Hamza Bin Sajid[1]

[1]Department of Plant Breeding and Genetics, University of Agriculture Faisalabad, Pakistan.

[2]Department of Agriculture & Agribusiness Management, University of Karachi.

Edited by:

K. Ashokkumar, Ph.D.,
Department of Crop Improvement, GRI-DU, Gandhigram, Dindigul, Tamil Nadu, India.

Reviewed by:
Tafere Mulualem. Ph.D.,
EIAR, Pawe Research Center, Ethiopia.

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*Corresponding author e-mail address: noumankhalidpbg@gmail.com (Muhammad Nouman Khalid)

ABSTRACT

The present research was conducted for the assessment of six F_2 population and their six parents for various yield and fiber contributing attributes. F_2 segregating population have more variability with a greater adaptation against stress. Analysis of variance results indicated that genotypes for all traits were significant except number of monopodial branches and total nodes per plant. Highest value of heritability was calculated for seed cotton yield while lowest value was observed for first fruiting branch node. Correlation matrix for overall F_2 populations along with their parents manifested that yield was significantly and positively associated with plant height, height to node ratio, first fruiting branch node, total bolls per plant, ginning out turn %, lint index and short fiber index. Path analysis results showed that yield was directly and positively influenced by number of sympodial branches per plant, height to node ratio, total bolls per plant, seed index, fiber uniformity, short fiber index, micronaire value and fiber strength. The variety Mubarak showed maximum mean values for yield contributing and fiber related trait like sympodial branches, boll weight, GOT% and lint index, BS80 for bolls per plant and seed cotton yield, CM595 for seeds per boll, fiber strength and fiber length and FH142 for fiber uniformity. F_2 cross combination MNH886×Mubarak followed by CM595×MNH886 showed maximum value of ranges for the different attributes and succeeding generations of these two populations may be used for selection of potential genotypes for development of high yielding varieties.

Keywords: cotton, correlation, F_2 population, heritability, path analysis, variability

INTRODUCTION

Cotton is famous for its name known as white gold. American cotton (*Gossypium hirsutum* L.), is a predominant cotton species mainly cultivated for its fiber in more than 80 countries in the world (Reddy et al*.,* 2015). Cotton (*Gossypium spp.)* supplied raw material for the textile industry (Deshmukh et al*.,* 2019). World biggest textile industry is running on the bases of cotton fiber having annual income impact about $600 billion worldwide (Ashraf et al*.,* 2018). It provides livelihood to 6 million farmers directly and 40 to 50 million people indirectly that are involved in cotton processing and trade (Kumar et al*.,* 2019). India is leading country in world for the production of cotton by producing 5770 thousand metric tons, USA at 2nd with 3999 thousand metric tons, China at 3rd 3500 thousand metric tons, Brazil at 4th 2787 thousand metric tons and Pakistan ranked 5th position in the world with 1655 thousand metric tons production.

Cotton belongs to genus Gossypium having more than 50 species containing cultivated and wild species. 45 species are diploid (2n=2x=26) and remaining are allotetraploid (2n=2x=52) with (A-G, K) and AD genomes respectively. Cultivated species of cotton are *G. herbaceum*, *G. arboreum*, *G. barbadence* and *G. hirsutum*. The *G. hirsutum* is a tetraploid specie of cotton and its origin is south Mexico. It is cultivated on more than 90% area of world for cotton production. (Abdullah et al*.,* 2016).

Cotton seed oil is generally considered as healthy vegetable oil. It is cholesterol free and hence termed as "Heart oil" (Ashokkumar and Ravikesavan, 2011 & 2013). The processed cotton seed oil is the fifth leading vegetable oil in the world. In India nearly entire cotton seed oil being utilized for edible purpose and mostly for Vanaspati, only small quantity (5-10 %) is used for manufacturing soaps (Ashokkumar and Ravikesavan, 2008 & 2010). The percentage of seed oil content varies from 10.2-26.1 in *G. hrisutum* (Ashokkumar and Ravikesavan, 2009). Cotton seed oil makes major contribution in the national oil industry (Shuli et al*.,* 2018). Cotton also provides raw material in the form of cotton seed for the oil extraction to the oil mills. Cotton is 2nd major oilseed crop after soybean (Khan et al*.,* 2010). Pakistan compensates 17.7% cooking oil requirement from the cottonseed oil (Nizamani et al*.,* 2016).

Pakistan is an agricultural country and major part of the economy of the country is directly and indirectly depend upon the agriculture. Cotton is famous as lifeline of the economy of Pakistan. Its share 0.8 percent in the GDP and contribute 4.5% in agriculture value addition. During 2018-19 and 2017-18 the cotton production was 9.86, 11.946 million bales. 17.5% decrease last year due to biotic and abiotic factors. Cotton ginning is also declined by 12.74% due to decline in production (Anonymous, 2018-19). Pakistan cotton yield have been reduced in the last few years due to many reasons. Our production is very low as compared to other cotton growing countries. Main reason behind this low production is too much rains at sowing time, fluctuation in temperature, high temperature at flowering stage, late harvesting of wheat, delay cotton sowing, reduction in the area of cotton, improper use of production technology and insect pest attack especially CLCuV attack and lack of resistant varieties (Panni et al*.,* 2012).

Cotton production commercially increased by growing segregating (F_2) population in many countries, main reason behind that F_2 have maximum variability and gave more chance of selection (Khan, 2011). F_2 have more variability with a greater adaptation against stress. F_2 segregating population of cotton have been reported for the improvement of disease resistant, seedling vigor and cotton yield (Dever and Gannaway, 1992). Cotton breeding program, needed genetic diversity in the germplasm that should be exploited to make improvement in the genetics of cotton crop. It helps us to select the parents with desirable attributes that may be crossed to bring the broaden diversity in the germplasm. The evaluation of diversity in the morphological attributes mainly helps us to develop a superior genotype that may be used in future different breeding program (Rathinavel, 2017). In F_2 segregating population every plant is different from all the remaining plants so therefore selection for the desirable traits is easier.

The correlation analysis forecast the change take place in one attribute by the change in the other attribute (Dahiphale and Deshmukh, 2018) Correlation analysis is an effective tool to identify the association between the different attributes in genetically diverse F_2 segregating population that will be used in the future breeding program for crop improvement (Dahiphale et al*.,* 2015) In plant breeding, the correlation analysis measures the mutual relationship among the different attributes and identify the traits on which selection can be based for the high yielding genetic improvement program. Magnitude and direction of correlation among yield and yield related attributes must be considered for the selection of the superior genotypes for the highly diverse genetic breeding program (Deshmukh et al. 2019). It is may not be possible to select the genotype just only on the basis of yield because yield is a complex multigenic trait and it is controlled by many components of traits. The relationship between yield and yield contributing attributes are estimated by the correlation analysis and provide information for the selection. (Kumar et al., 2019)

Path analysis is used for the estimation of relationship among the independent and dependent variables (Kumar et al., 2019). For the calculation of the direct and indirect effects of the independent variable on dependent one, the path coefficient analysis is used. It is helpful to measure the direct and indirect effects on yield separately. This analysis is helpful to set selection criteria for the future breeding program to enhance seed cotton yield (Ashokkumar and Ravikesavan, 2011; Deshmukh et al., 2019). Heritability estimates the inheritance of attributes that is used for the selection of better plants (Soomro et al., 2008). High heritability gave clear image for the selection in the breeding program (Ahmad et al., 2019). Keeping in view the importance of F_2 population in cotton breeding program, the research was designed to study correlation and path coefficient analysis to set selection criteria in different F_2 population of cotton. This study was helpful for selection of different plant in segregating population.

MATERIALS AND METHODS

This research was carried out in the field experimental area of Department of Plant Breeding and Genetics, University of Agriculture Faisalabad, during *kharif* season 2019. Experimental material was consisting of 6 parents (BS-80, MNH-886, CIM-595, FH-142, IUB-75, and Mubarak) and their 6 F_2 populations (MNH-886 × Mubarak, BS-80 × Mubarak, FH-142 × Mubarak, FH-142 × MNH-886, CIM-595 × MNH-886, IUB-75×FH-142). The seeds of parents and their F_2 population were sown during the growing season of cotton in June 2019 by using randomized complete block design with 2 replications. Each F_2 population was sown in 5 rows, each have 10 plants and parent were sown in single row in each replication. Keeping row to row 75cm and plant to plant 30cm distance. All cultural and agronomic practices were done as usual such as irrigation, fertilizers, hoeing, thinning and plant protection measures according to the requirement of crop to maintain their proper health.

Yield related traits

Yield related traits; monopodial branches, sympodial branches, plant height(cm), bolls per plant, boll weight(g), seed index(g), seed per boll, height to node ratio, total nodes per plant, first fruiting branch node, GOT%, lint index(g), seed cotton yield(g) were measured at maturity.

Fiber traits

Fiber length (mm), fiber uniformity percentage, short fiber index, micronaire value (µg/inch), fiber strength (g/tex), reflectance (Rd), maturity index with the help of Uster HVI-900 S. A. Mean was value calculated for further analysis.

Statistical analysis

The obtained data was analyzed for analysis of variance followed by Steel et al. (1997) and simple correlation coefficients was computed following by Kwon and Torrie (1964). Heritability was computed following by Burton and Devane (1953). Categorization of heritability was estimated according to Johnson et al. (1955). Path coefficient analysis was carried out to check the indirect and direct effects of different genotype traits on yield with the help of "R" statistical software. This method was followed as given by Dewey and Lu (1959).

RESULTS

Analysis of Variance

Analysis of variance manifested that F_2 population and their parents exhibited significant variation for all the attributes like bolls plant^{-1}, boll weight, lint index, sympodial branches plant^{-1}, plant height, seed index, ginning out turn (%), height to node ratio, seed boll^{-1}, first fruiting branch node, maturity index, fiber length, fiber uniformity, short fiber index, reflectance, fiber strength, micronaire value while seed cotton yield were highly significant. The monopodial branches per plant and total nodes per plant were non-significant (table 1).

Table 1. Mean Square value from analysis of variance for yield contributing and fiber related attributes of six F_2 populations and their six parents

Source	DF	NMP	NSP	PH	NBP	BW	SI	SPB	HNR	FFBN	NP
Block	1	0.02	6.87	2.99	1.00	0.04	0.00	36.57	0.01	0.02	38.46

Genotype	11	0.22^{NS}	3.54*	141.38*	14.66*	0.21*	0.36*	26.72*	0.21*	1.15*	32.8^{NS}
Error	11	0.09	1.10	34.57	3.82	0.06	0.09	7.86	0.047	0.39	14.31
Source	DF	GOT%	LI	SCY	UHML	UI	SF	MIC	STR	RD	MAT
Block	1	0.28	0.19	4.18	0.00	1.97	0.12	0.00	0.05	0.39	7.51
Genotype	11	3.41*	0.24*	172.26**	0.64*	1.62*	0.27*	0.06*	1.50*	5.64*	1.89*
Error	11	0.94	0.06	27.51	0.15	0.53	0.06	0.01	0.43	1.58	4.41

(α 5%) P<0.01=**(Highly Significant) P<0.05=*(Significant) P>0.05=NS(Non-Significant)

NMP (Number of monopodial plant-1), NSP(Number of sympodial plant-1), PH (Plant height), NBP (Number of bolls plant-1), BW (Boll weight), SI (Seed index), SPB (Seed boll-1), HNR (Height to node ratio), FFBN (First fruiting branch node), NP (Number of nodes plant-1), GOT% (Ginning out Turn %), LI (Lint index), SCY (Seed cotton yield), UHML (Fiber length), UI (Fiber uniformity), SF (Short fiber index), MIC (Micronaire value), STR (Fiber strength), RD (Reflectance), MAT (Maturity index)

Basic statistics of six F_2 population of Gossypium hirsutum

Basic statistics (Range, mean, standard deviation, variance, coefficient of variation and SE-mean) is exploited to summarize the large data of different plant traits. It provides quick simple description of data. Summary of basic statistics of yield contributing attributes for the F_2 crosses are given in table 2 to 7.

Mean performances of six F_2 population and their six parents for different plant attributes in Gossypium hirsutum

Yield related traits

Mean performance of six F_2 population and their six parents indicated that parent Mubarak showed highest sympodial branches (10.45) while F_2 cross combination FH142×MNH886 revealed 2nd highest value (9.9). IUB75 exhibited lowest value (5.5) for this attribute. Maximum plant height was recorded for the parent Mubarak (99.46) followed by F_2 cross combination FH142×Mubarak (97.09) and FH142×MNH886 (96.84) while parent FH142 depicted lowest value (73.23) for this trait. Parent BS80 manifested highest bolls per plant (18.3) followed by F_2 cross FH142×MNH886 (17.14) and FH142×Mubarak (15.73) among all genotypes while parent FH142 inferred lowest bolls per plant (9.25). Highest boll weight was recorded for the parent Mubarak (3.35) followed by CIM595 (3.31). F_2 population MNH886×Mubarak (7.30) and parent MNH886 (7.18) revealed highest value for the seed index and parent FH142 manifested lowest value (6) for this attribute.

Highest seeds per boll were counted for the parent CIM595 (29.16) and IUB75 (26.25) whilst lowest seeds per boll were calculated for the F_2 population IUB75×FH142 (15.76) (Fig. 4.6). Highest height to node ratio was calculated for the parent BS80 (3.13) followed by Mubarak (3.01) and F_2 cross BS80×Mubarak (2.45) while CIM595 exploited lowest value (2.06). Parent BS80 (12.95) followed by Mubarak (12.08) and F_2 population MNH886×Mubarak (11.97) revealed highest value for the first fruiting branch node while IUB75 inferred lowest value (10.25) for this attribute. Maximum GOT% was recorded for the parent Mubarak (40.88) and BS80 (40.48) while MNH886 exhibited lowest value (36.58) for this trait (Fig. 4.9). Parent Mubarak (5.25) and BS80 (4.46) inferred maximum Lint index value while MNH886 depicted lowest value (3.82) for this trait. Parent BS80 (56.42), Mubarak (46.19), F_2 population FH142×Mubarak (45.42) and FH142×MNH886 (43.85) exploited the highest seed cotton yield while MNH886 inferred lowest value (21.09).

Fiber traits

Maximum value of fiber length was estimated for the parent CIM595 (27.59) and F_2 cross FH142×Mubarak (27.13) while lowest value (25.71) was calculated for parent BS80. Highest value of fiber uniformity was depicted for the parent FH142 (85.41) and F_2 cross combination FH142×Mubarak (83.99) whilst the lowest value for this attribute was estimated for the MNH886 (81.62). Parent Mubarak (8.29) and F_2 cross combination FH142×Mubarak (8.19) exhibited highest value for the short fiber index while MNH886 manifested lowest value (7.15) for this attribute (Fig.

4.14). Parent IUB75 (4.59) and Mubarak (4.57) recorded for the highest value for the micronaire whilst MNH886 showed lowest value (4.08) for this trait.

Parent CIM595 (31.3), Mubarak (30.19) and IUB75 (29.82) recorded for the highest value for the fiber strength while F_2 population IUB75×FH142 manifested lowest value (28.29) for this trait. Maximum value of reflectance was measured for the parent IUB75 (77.55) and MNH886 (77.29) whilst the lowest value (73.74) was estimated for the FH142. Highest value of maturity index was recorded for the parent MNH886 (0.84) followed by F_2 cross combination FH142×Mubarak (0.84), BS80×Mubarak (0.84), CIM595×MNH886 while lowest value was calculated for the parent FH142 (0.80).

Assessment of heritability in G. hirsutum for various attributes

It measures the degree of variation in a population's phenotypic trait due to the genetic variation of the individuals in that group. Expect 1st fruiting branch node all traits have high heritability. Seed cotton yield exhibited highest value for heritability. (Table 8).

Correlation matrix studies

Correlation matrix for all yield and fiber contributing attributes for six F_2 population and their six parents (combined data) is given in the table 9. Sympodial branches inferred the positive association with plant height, first fruiting branch node and GOT% while it showed negative linkage with seed per bolls. Plant height positively linked with total bolls per plant, fiber maturity and yield while it depicted negative association with micronaire value. Height to node ratio exhibited positive correlation with first fruiting branch node, total bolls per plant, GOT% lint index and yield. First fruiting branch node manifested positive linkage with GOT%, short fiber and yield while seed per bolls negatively associated with this trait.

Total bolls per plant positively linked with GOT%, fiber maturity and yield while micronaire value negatively associated with this attribute. Boll weight inferred positive linkage with fiber strength. GOT% exhibited positive relationship with lint index, fiber uniformity, short fiber and yield while seed per boll inferred negative linkage with this trait. Lint index exploited positive linkage with short fiber and yield. Seed index manifested positive relationship with fiber maturity while fiber uniformity and micronaire value exhibited negative linkage for this attribute. Seed per boll positively associated with fiber strength. Reflectance negatively correlated with fiber length. Fiber uniformity negatively associated with fiber maturity. Short fiber positively linked with yield. Micronaire value negatively correlated with fiber maturity (Table 9).

Correlation table for the F_2 cross combination MNH886×Mubarak is given in the table 10. Sympodial branches manifested positive linkage with plant height, total bolls per plant and yield. Plant height positively associated with fiber maturity. Height to node ratio positively associated with fiber uniformity. First fruiting branch node positively linked with total bolls per plant. Total bolls per plant positively correlated with seed per boll and yield. Boll weight positively associated with seed per boll, fiber uniformity and yield. Lint index positively linked with seed index and negatively linked with micronaire value. Seed per boll positively associated with fiber uniformity index, micronaire value and yield. Fiber uniformity positively associated with yield. Fiber strength inferred positive association with yield (Table 10).

Correlation analysis for the F_2 population BS80×Mubarak is given in the table 11. Sympodial branches positively linked with total bolls per plant and yield while negatively linked with first fruiting branch node and lint index. Height to node ratio manifested positive association with seed index while negatively associated with total bolls per plant and yield. First fruiting branch node positively linked with lint index. Total bolls per plant exhibited positive association with yield. Boll weight exploited positive relationship with seed per boll and yield while fiber maturity negatively linked (Table 11).

Correlation table for the segregating F_2 population FH142×Mubarak is given in the table 12. Sympodial branches inferred positive linkage with plant height, total bolls per plant, lint index and yield. Total bolls per plant exhibited positive relationship with yield. Boll weight manifested positively correlated with seed per boll, fiber maturity and yield while negatively correlated with short fiber (Table 12).

Correlation matrix for the F_2 segregating population FH142×MNH886 is given in the table 13. Sympodial branches exhibited positive correlation with plant height, total bolls per plant, fiber maturity and yield. Plant height manifested positive association with height to node ratio, bolls per plant and yield while negatively correlated with reflectance. Height to node ratio manifested positive linkage with bolls per plant, seed per boll, short fiber and yield. First fruiting branch node negatively correlated with micronaire value.

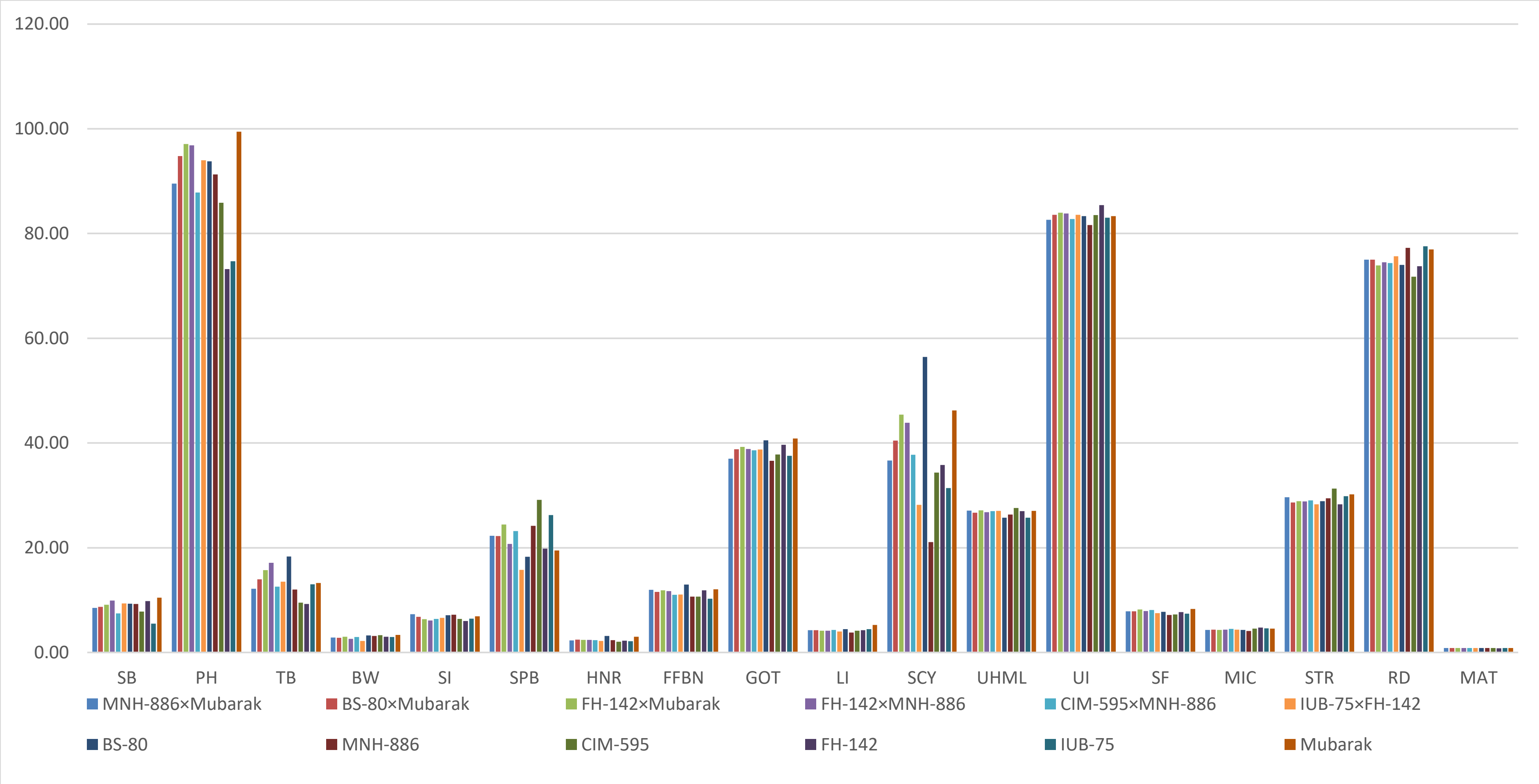

Figure 1. Mean performances of six F_2 population and their six parents for different plant attributes in *Gossypium hirsutum*

NMP (Number of monopodial plant-1), NSP (Number of sympodial plant-1), PH (Plant height), NBP (Number of bolls plant-1), BW (Boll weight), SI (Seed index), SPB (Seed boll-1), HNR (Height to node ratio), FFBN (First fruiting branch node), NP (Number of nodes plant-1), GOT% (Ginning out Turn %), LI (Lint index), SCY (Seed cotton yield), UHML (Fiber length), UI (Fiber uniformity), SF (Short fiber index), MIC (Micronaire value), STR (Fiber strength), RD (Reflectance), MAT (Maturity index)

Table 2. Basic measures of variability for various attributes of F_2 population MNH886×Mubarak

	NSP	PH	NBP	BW	SI	SPB	HNR	FFBN	GOT%	LI	SCY	UHML	UI	SF	MIC	STR	RD	MAT
R	3-18	35.1-142.7	2-26	1.59-4.11	5.21-8.56	11-34	1.51-4.61	6-16	31.23-41.23	2.83-5.61	4.5-85.76	24.67-29.75	77.5-89.3	6.6-9.7	3.37-5.2	23.9-33.5	67.6-81.3	0.8-0.88
M	8.42	90.28	11.92	2.82	7.27	22.06	2.30	11.97	36.92	4.22	36.12	27.06	82.59	7.86	4.31	29.52	75.12	0.84
V	11.34	360.22	29.74	0.38	0.88	32.97	0.31	6.60	7.28	0.59	383.11	1.57	6.94	0.76	0.22	6.16	13.72	0.00
SD	3.37	18.98	5.45	0.62	0.94	5.74	0.56	2.57	2.70	0.77	19.57	1.25	2.64	0.87	0.47	2.48	3.70	0.02
CV	40.00	21.02	45.76	21.97	12.87	26.03	24.23	21.46	7.31	18.16	54.20	4.63	3.19	11.07	10.89	8.40	4.93	2.62

Table 3. Basic measures of variability for various attributes of F_2 population BS80×Mubarak

	NSP	PH	NBP	BW	SI	SPB	HNR	FFBN	GOT%	LI	SCY	UHML	UI	SF	MIC	STR	RD	MAT
R	3-16	54.1-123.9	5-33	1.40-3.86	5.29-8.67	11-33	1.92-3.3	6-16	30.45-44.56	3.01-5.70	9.84-114.72	24.9-28.9	79.2-87.6	6.4-9.6	3.4-5.2	24.7-34.7	68.1-81.2	0.81-0.88
M	8.54	95.58	13.80	2.78	6.77	22.40	2.46	11.63	38.69	4.29	40.85	26.75	83.45	7.82	4.36	28.78	74.85	0.84
V	13.02	261.04	41.75	0.46	0.61	33.89	0.10	7.77	12.01	0.35	551.64	1.33	5.58	0.64	0.17	6.70	11.40	0.00
SD	3.61	16.16	6.46	0.68	0.78	5.82	0.31	2.79	3.47	0.59	23.49	1.15	2.36	0.80	0.41	2.59	3.38	0.02
CV	42.24	16.90	46.82	24.45	11.54	25.99	12.53	23.97	8.96	13.74	57.49	4.30	2.83	10.23	9.46	9.00	4.51	2.07
SE	0.61	2.73	1.09	0.12	0.13	0.98	0.05	0.47	0.59	0.10	3.97	0.20	0.40	0.14	0.07	0.44	0.57	0.00

Table 4. Basic measures of variability for various attributes of F_2 population FH142×Mubarak

	NSP	PH	NBP	BW	SI	SPB	HNR	FFBN	GOT%	LI	SCY	UHML	UI	SF	MIC	STR	RD	MAT
R	2-17	44.2-150.4	3-37	1.82-3.81	4.21-8.78	13-32	1.93-2.95	6-16	28.09-44.85	2.00-5.71	7.5-95.13	24.6-30.1	78.2-89.3	6.7-9.5	3.4-4.9	24.1-32.8	67.6-79.7	0.8-0.88
M	9.03	96.70	15.56	3.01	6.40	24.53	2.38	11.82	39.14	4.11	45.16	27.14	84.03	8.18	4.28	28.80	73.93	0.84
V	14.09	381.37	70.44	0.37	0.71	21.29	0.07	6.21	17.65	0.72	586.60	1.50	9.69	0.75	0.17	4.67	10.37	0.00
SD	3.75	19.53	8.39	0.61	0.84	4.61	0.27	2.49	4.20	0.85	24.22	1.22	3.11	0.87	0.41	2.16	3.22	0.02
CV	41.57	20.19	53.94	20.30	13.12	18.81	11.35	21.08	10.74	20.68	53.63	4.51	3.71	10.62	9.66	7.50	4.36	2.42
SE	0.64	3.35	1.44	0.11	0.14	0.79	0.05	0.43	0.72	0.15	4.15	0.21	0.53	0.15	0.07	0.37	0.55	0.00

Table 5. Basic measures of variability for various attributes of F_2 population FH142×MNH886

	NSP	PH	NBP	BW	SI	SPB	HNR	FFBN	GOT%	LI	SCY	UHML	UI	SF	MIC	STR	RD	MAT
R	3-17	47.5-133.4	1-45	1.17-3.75	4.71-8.64	6-33	1.4-3.4	7-16	24.25-46.95	1.79-5.41	3.2-102.3	24.6-28.9	79.2-87.8	5.8-10.2	3.37-5.2	23.6-35.1	68.1-80.7	0.8-0.88
M	9.84	96.74	17.11	2.62	6.11	20.67	2.39	11.71	38.87	4.15	43.66	26.79	83.89	7.92	4.36	28.84	74.52	0.84
V	18.13	367.60	84.06	0.34	0.84	28.59	0.16	6.44	19.66	0.57	644.06	1.37	6.13	0.86	0.18	9.94	12.81	0.00
SD	4.26	19.17	9.17	0.59	0.92	5.35	0.41	2.54	4.43	0.75	25.38	1.17	2.48	0.93	0.43	3.15	3.58	0.02
CV	43.26	19.82	53.58	22.38	14.99	25.87	16.94	21.67	11.41	18.16	58.13	4.37	2.95	11.73	9.80	10.93	4.80	2.47
SE	0.64	2.86	1.37	0.09	0.14	0.80	0.06	0.38	0.66	0.11	3.78	0.17	0.37	0.14	0.06	0.47	0.53	0.00

Table 6. Basic measures of variability for various attributes of F_2 population CIM595×MNH886

	NSP	PH	NBP	BW	SI	SPB	HNR	FFBN	GOT%	LI	SCY	UHML	UI	SF	MIC	STR	RD	MAT
R	1-15	41.8-132.7	1-31	1.66-4.09	4.49-8.76	13-34	1.4-3	1-16	30.27-46.96	2.24-6.40	3-120.91	24.5-30.1	76.7-87.6	6.5-9.6	3.42-5.4	24.1-33.5	67.6-81.3	0.8-0.88
M	7.35	87.20	12.51	2.94	6.42	23.08	2.33	11.11	38.56	4.35	37.22	26.89	82.68	8.12	4.52	29.11	74.37	0.84
V	13.96	510.31	70.87	0.60	0.84	23.80	0.14	9.54	19.30	0.86	626.47	2.13	6.12	0.74	0.23	4.49	15.33	0.00
SD	3.74	22.59	8.42	0.78	0.91	4.88	0.38	3.09	4.39	0.93	25.03	1.46	2.47	0.86	0.48	2.12	3.92	0.02
CV	50.82	25.91	67.27	26.39	14.25	21.14	16.23	27.81	11.39	21.28	67.24	5.43	2.99	10.61	10.60	7.28	5.27	2.45
SE	0.61	3.71	1.38	0.13	0.15	0.80	0.06	0.51	0.72	0.15	4.12	0.24	0.41	0.14	0.08	0.35	0.64	0.00

Table 7. Basic measures of variability for various attributes of F_2 population IUB75×FH142

	NSP	PH	NBP	BW	SI	SPB	HNR	FFBN	GOT%	LI	SCY	UHML	UI	SF	MIC	STR	RD	MAT
R	3-17	70.1-138.4	3-30	1.33-3.77	5.09-8.67	9-30	1.35-2.92	7-15	30.37-45.92	3.00-5.98	4.32-85.81	25.2-28.9	79.6-86.7	6.6-9.2	3.8-4.86	23.9-34.7	68.8-80.7	0.81-0.88
M	8.44	96.59	12.38	2.14	6.69	16.27	2.25	11.16	38.30	4.12	30.16	27.06	83.09	7.57	4.36	28.19	75.18	0.84
V	22.49	403.76	48.60	0.40	1.01	30.09	0.15	4.38	20.99	0.64	465.16	1.19	4.21	0.56	0.09	7.25	10.18	0.00
SD	4.74	20.09	6.972	0.63	1.00	5.48	0.39	2.09	4.58	0.80	21.57	1.09	2.05	0.75	0.30	2.69	3.19	0.02
CV	56.16	20.80	56.27	29.64	15.06	33.70	17.42	18.74	11.96	19.47	71.50	4.03	2.47	9.91	6.76	9.55	4.24	2.33
SE	1.11	4.73	1.64	0.15	0.23	1.29	0.09	0.49	1.08	0.19	5.08	0.26	0.48	0.18	0.07	0.64	0.75	0.01

NMP (Number of monopodial plant-1), NSP (Number of sympodial plant-1), PH (Plant height), NBP (Number of bolls plant-1), BW (Boll weight), SI (Seed index), SPB (Seed boll-1), HNR (Height to node ratio), FFBN (First fruiting branch node), NP (Number of nodes plant-1), GOT% (Ginning out Turn %), LI (Lint index), SCY (Seed cotton yield), UHML (Fiber length), UI (Fiber uniformity), SF (Short fiber index), MIC (Micronaire value), STR (Fiber strength), RD (Reflectance), MAT (Maturity index)

Table 8. Heritability values for F_2 population and their parents

Attributes	h^2(b.s)	Classification	Attributes	h^2(b.s)	Classification
NSP	0.525	High	LI	0.569	High
PH	0.607	High	SCY	0.724	High
NBP	0.586	High	UHML	0.615	High
BW	0.524	High	UI	0.503	High
SI	0.574	High	SF	0.603	High
SPB	0.545	High	MIC	0.563	High
HNR	0.632	High	STR	0.554	High
FFBN	0.488	Moderate	Rd	0.560	High
GOT %	0.567	High	MAT	0.621	High

NMP (Number of monopodial plant-1), NSP (Number of sympodial plant-1), PH (Plant height), NBP (Number of bolls plant-1), BW (Boll weight), SI (Seed index), SPB (Seed boll-1), HNR (Height to node ratio), FFBN (First fruiting branch node), NP (Number of nodes plant-1), GOT% (Ginning out Turn %), LI (Lint index), SCY (Seed cotton yield), UHML (Fiber length), UI (Fiber uniformity), SF (Short fiber index), MIC (Micronaire value), STR (Fiber strength), RD (Reflectance), MAT (Maturity index)

Bolls per plant positively linked with yield. Boll weight inferred positive relationship with seed per boll and yield. GOT% manifested positive linkage with lint index. Lint index exploited positive linkage with fiber uniformity while negatively correlated with seed per boll. Seed per boll positively associated with yield (Table 13). Correlation matrix for the CIM595×MNH886 is given in the table 14. Sympodial branches exhibited positive correlation with plant height, bolls per plant and yield. Plant height manifested positive linkage with height to node ratio, bolls per plant and yield. Height to node ratio revealed positive relationship with lint index and yield. Bolls per plant positively associated with yield. Boll weight negatively correlated with lint index. GOT% positively linked with fiber uniformity index. Lint index inferred positive association with seed index and short fiber. Seed index positively linked with reflectance and micronaire value. Fiber length positive correlated with fiber uniformity. Short fiber exhibited positive linkage with micronaire value (Table 14).

Analysis of correlation for IUB75×FH142 is given in the table 15. Sympodial branches positively linked with fiber uniformity. Height to node ratio inferred positive linkage with short fiber and yield. 1st fruiting branch node exhibited positive linkage with boll weight and seeds per boll. Bolls per plant negatively correlated with seed index. Boll weight positively associated with seed per boll. Lint index exploited negative relationship with reflectance. Seed per boll manifested positive association with yield (Table 15).

Path analysis

Path analysis offers information on the effect of certain attributes on the resulting variable that is yield. It describes direct and indirect effect of certain trait on yield. This technique is helpful in selecting the best performing trait that contributes more to increase the yield potential of the crop plant in the breeding range. Path analysis value is given in table 16.

Path analysis inferred that sympodial branch, height to node ratio, bolls per plant, seed index, fiber uniformity, short fiber index, micronaire value, boll weight and fiber strength executed direct positive effects on yield while plant height, first fruiting branch node, GOT%, lint index, seeds per boll, reflectance, fiber length and fiber maturity had direct negative effects. Indirect positive effects of sympodial branches effected yield through plant height, height to node ratio, first fruiting branch node, bolls per plant, GOT%, lint index, seed index, fiber length, fiber uniformity and short fiber. Plant height is indirectly contributing to yield positively through seeds per boll, fiber uniformity, micronaire value and fiber strength. Height to node ratio had positive indirect influence on yield through sympodial branches, plant height, first fruiting branch node, bolls per plant, boll weight, GOT%, lint index, seed index, reflectance, short fiber index and fiber maturity.First fruiting branch node had indirect positive impact on yield via seeds per boll, reflectance, micronaire value and fiber strength. Bolls per plant indirectly effect in positive direction on yield via sympodial branches, plant height, height to node ratio, first fruiting branch node, GOT%, lint index, seed index, short fiber and fiber maturity. Boll weight influenced yield indirectly in a positive way via sympodial branches, plant height, bolls per plant, reflectance, fiber length, fiber uniformity and fiber maturity.

Table 9. Correlation matrix for various attributes for F_2 population and their parents

	NSP	PH	HNR	FFBN	NBP	BW	GOT	LI	SI	SPB	RD	UHML	UI	SF	MIC	STR	MAT
PH	0.411*																
HNR	0.285	0.377															
FFBN	0.468*	0.340	0.568**														
NBP	0.323	0.491*	0.469*	0.311													
BW	0.039	-0.090	0.205	0.059	-0.169												
GOT	0.512*	0.19	0.65**	0.478*	0.464*	0.04											
LI	-0.035	0.071	0.469*	0.332	0.041	0.293	0.437*										
SI	-0.039	0.287	0.386	0.052	0.174	0.201	-0.183	0.172									
SPB	-0.532**	-0.294	-0.336	-0.502*	-0.311	0.359	-0.451*	-0.086	-0.088								
RD	-0.029	0.039	0.147	-0.289	0.167	-0.142	-0.055	0.048	0.326	-0.106							
UHML	0.226	0.219	-0.272	-0.15	-0.345	-0.015	0.004	-0.011	-0.224	0.231	-0.455*						
UI	0.348	-0.241	-0.072	0.095	0.09	-0.076	0.557**	0.031	-0.455*	-0.306	-0.311	0.243					
SF	0.221	0.350	0.377	0.492*	0.34	-0.081	0.531**	0.539**	-0.066	-0.116	-0.023	0.203	0.148				
MIC	-0.091	-0.412*	-0.269	0.038	-0.415*	0.186	0.188	0.397	-0.571**	0.029	-0.193	0.153	0.365	0.152			
STR	-0.198	-0.054	-0.089	-0.146	-0.246	0.501*	-0.186	0.315	0.122	0.468*	-0.119	0.161	-0.273	-0.221	0.191		
MAT	0.141	0.598**	0.087	-0.024	0.585**	-0.089	-0.099	-0.231	0.431*	-0.005	0.181	-0.057	-0.404*	0.067	-0.629**	0.071	
SCY	0.284	0.417*	0.54**	0.728*	0.515*	0.254	0.574**	0.461*	-0.057	-0.181	-0.339	-0.043	0.208	0.631**	0.145	-0.057	0.073

**= P>0.01, *=P>0.05

Table 10. Correlation matrix for various attributes for F_2 cross combination MNH886×Mubarak

	NSP	PH	HNR	FFBN	NBP	BW	GOT	LI	SI	SPB	RD	UHML	UI	SF	MIC	STR	MAT
PH	0.368*																
HNR	0.078	-0.056															
FFBN	0.266	0.228	-0.188														
NBP	0.503**	0.236	0.135	0.33*													
BW	0.275	0.287	0.117	-0.225	0.269												
GOT	-0.186	-0.036	-0.177	-0.328	-0.182	0.01											
LI	-0.076	-0.315	0.044	-0.106	0.033	-0.174	0.212										
SI	-0.03	-0.184	0.004	0.039	-0.102	0.076	-0.08	0.477**									
SPB	0.237	0.281	0.193	0.076	0.356*	0.711**	0.027	-0.214	-0.176								
RD	-0.013	0.118	0.124	0.07	-0.048	-0.123	-0.105	0.258	0.032	0.091							
UHML	0.161	0.144	0.121	0.045	0.127	0.028	-0.073	-0.045	0.19	0.115	-0.149						
UI	0.131	0.088	0.348*	-0.005	0.296	0.468**	0.092	-0.21	-0.058	0.365*	-0.029	0.071					
SF	-0.15	-0.041	-0.092	0.125	-0.147	-0.127	-0.053	-0.088	-0.228	-0.068	-0.124	-0.079	0.039				
MIC	0.144	0.272	0.325	-0.002	-0.03	0.105	-0.135	-0.332*	-0.319	0.37*	0.211	0.113	0.023	-0.171			
STR	-0.317	-0.198	0.138	0.019	-0.254	-0.058	0.076	-0.146	0.139	0.132	0.053	0.303	0.206	0.146	0.174		
MAT	0.098	0.34*	0.179	-0.051	0.209	0.301	0.075	0.046	0.024	0.2	0.07	0.184	0.204	0.209	0.167	-0.002	
SCY	0.609**	0.278	-0.039	0.144	0.751**	0.429**	-0.017	-0.035	-0.099	0.337*	-0.287	0.055	0.352*	-0.302	-0.061	-0.378*	-0.021

**= P>0.01, *=P>0.05

Table 11. Correlation matrix for various attributes for F_2 cross combination BS80×Mubarak

	NSP	PH	HNR	FFBN	NBP	BW	GOT	LI	SI	SPB	RD	UHML	UI	SF	MIC	STR	MAT
PH	0.065																
HNR	-0.114	-0.074															
FFBN	-0.336*	0.079	-0.248														
NBP	0.391*	0.054	-0.468**	0.252													
BW	0.183	0.22	-0.174	0.05	0.141												
GOT	-0.015	-0.035	0.121	0.042	-0.029	-0.002											
LI	-0.382*	0.208	-0.157	0.456*	0.082	-0.136	0.078										
SI	0.088	-0.034	0.354**	-0.084	0.163	0.031	-0.037	0.186									
SPB	0.024	0.183	0.026	0.296	0.155	0.657**	0.051	-0.031	-0.208								
RD	0.027	0.062	-0.124	0.113	0.217	0.125	0.016	0.01	-0.011	0.279							
UHML	0.103	-0.239	0.178	0.251	0.1	-0.004	-0.031	-0.021	-0.039	0.224	0.066						
UI	-0.188	-0.198	0.094	0.178	-0.032	-0.099	0.101	0.06	-0.112	-0.038	0.07	-0.174					
SF	0.026	0.081	0.205	-0.216	-0.138	0.117	-0.199	-0.18	0.031	0.049	-0.042	-0.258	-0.283				
MIC	0.042	-0.187	0.008	0.127	-0.022	0.126	0.045	0.282	0.056	0.218	0.266	0.262	-0.049	-0.329			
STR	0.072	0.095	0.289	-0.157	-0.093	-0.113	-0.038	0.222	-0.212	0.194	-0.115	0.195	-0.076	0.076	0.119		
MAT	-0.246	0.131	0.2	-0.058	-0.149	-0.383*	0.052	0.28	-0.073	-0.26	0.244	-0.31	0.076	-0.017	0.04	-0.03	
SCY	0.338*	0.189	-0.459**	0.262	0.82**	0.39*	-0.216	0.135	0.397*	0.263	0.051	0.134	-0.096	-0.13	0.045	-0.131	-0.305

**= P>0.01, *=P>0.05

Table 12. Correlation matrix for various attributes for F_2 cross combination FH142×Mubarak

	NSP	PH	HNR	FFBN	NBP	BW	GOT	LI	SI	SPB	RD	UHML	UI	SF	MIC	STR	MAT
PH	0.369*																
HNR	-0.033	0.032															
FFBN	0.276	0.198	-0.122														
NBP	0.466**	0.106	-0.038	0.187													
BW	0.042	0.185	0.234	-0.106	0.252												
GOT	-0.181	-0.121	-0.132	-0.216	0.268	0.191											
LI	0.344*	0.229	0.227	0.276	0.305	0.323	0.229										
SI	-0.178	-0.178	-0.055	0.031	0.324	-0.063	0.106	-0.157									
SPB	0.255	0.2	0.08	-0.11	0.153	0.364*	0.289	0.095	0.071								
RD	0.087	-0.224	-0.176	-0.123	0.115	-0.229	0.21	0.197	-0.071	-0.072							
UHML	-0.109	-0.052	-0.025	0.057	0.123	0.264	0.034	0.09	0.224	0.028	-0.269						
UI	-0.036	-0.037	-0.258	-0.075	-0.126	-0.032	-0.058	-0.001	-0.081	-0.013	0.001	-0.112					
SF	0.086	-0.011	-0.005	0.169	0.032	-0.377*	-0.131	0.008	-0.15	-0.26	-0.173	0.111	0.003				
MIC	-0.016	-0.124	-0.054	0.141	-0.123	-0.237	0.163	0.273	-0.33	-0.313	0.173	-0.12	0.187	0.306			
STR	0.093	0.039	-0.31	-0.018	0.006	-0.014	-0.144	0.05	-0.224	0.007	-0.029	0.094	0.026	-0.1	0.079		
MAT	0.138	-0.019	0.118	-0.086	0.225	0.471*	0.099	0.328	-0.26	0.043	-0.018	0.14	-0.234	-0.052	0.064	0.119	
SCY	0.465**	0.191	-0.025	0.077	0.882**	0.416*	0.264	0.275	0.195	0.308	0.012	0.063	0.094	-0.177	-0.135	0.074	0.191

**= P>0.01, *=P>0.05

Table 13. Correlation matrix for various attributes for F_2 cross combination FH142×MNH886

	NSP	PH	HNR	FFBN	NBP	BW	GOT	LI	SI	SPB	RD	UHML	UI	SF	MIC	STR	MAT
PH	0.485**																
HNR	0.241	0.361*															
FFBN	0.114	0.11	0.058														
NBP	0.507**	0.644**	0.356*	0.278													
BW	0.14	0.033	0.206	0.113	0.109												
GOT	0.104	-0.189	0.026	0.07	-0.027	0.046											
LI	0.1	-0.254	-0.035	-0.231	0.064	-0.037	0.471**										
SI	-0.021	0.089	0.186	-0.153	0.029	0.29	-0.094	0.25									
SPB	0.249	0.253	0.384**	0.261	0.197	0.521*	-0.069	-0.404**	-0.082								
RD	-0.027	-0.307*	0.012	0.019	-0.233	0.086	0.227	0.094	-0.079	0.053							
UHML	0.022	-0.014	-0.064	0.004	-0.052	0.135	0.206	0.083	0.159	-0.119	0.177						
UI	-0.076	-0.11	-0.216	-0.001	0.043	-0.034	0.292	0.38**	0.033	-0.103	0.032	0.112					
SF	0.187	0.206	0.318*	0.019	0.265	0.01	0.229	0.021	-0.193	0.059	-0.165	0.025	0.147				
MIC	0.124	0.008	0.205	0.375*	-0.159	-0.184	0.098	0.003	-0.116	0.037	0.131	-0.003	-0.014	0.053			
STR	-0.061	-0.039	-0.015	-0.128	0.183	0.216	0.039	-0.019	-0.029	0.02	0.077	0.053	0.111	0.106	0.01		
MAT	0.395**	-0.015	-0.125	0.05	0.255	0.019	0.068	0.144	-0.085	0.096	-0.103	0.058	0.181	-0.144	-0.005	0.008	
SCY	0.489**	0.59**	0.511**	0.25	0.816**	0.483*	0.001	0.005	0.107	0.463**	-0.096	0.033	-0.034	0.232	-0.096	0.223	0.211

**= P>0.01, *=P>0.05

Table 14. Correlation matrix for various attributes for F_2 cross combination CIM595×MNH886

	NSP	PH	HNR	FFBN	NBP	BW	GOT	LI	SI	SPB	RD	UHML	UI	SF	MIC	STR	MAT
PH	0.542**																
HNR	0.189	0.495**															
FFBN	-0.049	0.056	-0.066														
NBP	0.676**	0.553**	0.277	0.102													
BW	0.041	-0.168	-0.069	-0.034	-0.15												
GOT	-0.041	0.094	0.032	0.095	0.217	0.028											
LI	-0.216	0.143	0.413*	0.257	-0.001	-0.384*	0.32										
SI	-0.269	0.108	0.24	0.135	-0.072	-0.049	0.234	0.378*									
SPB	0.114	0.139	-0.068	0.257	0.095	0.051	-0.148	-0.089	-0.262								
RD	-0.006	-0.169	-0.225	-0.068	-0.189	0.319	0.044	-0.129	0.338*	-0.103							
UHML	0.083	0.148	0.242	-0.292	0.068	0.18	-0.319	-0.263	-0.078	0.118	0.076						
UI	0.188	0.203	-0.125	0.051	0.158	0.152	0.457**	-0.097	0.216	0.214	0.152	-0.342*					
SF	-0.094	-0.026	0.168	-0.041	-0.201	-0.099	0.127	0.336*	0.17	-0.033	0.258	0.04	-0.183				
MIC	-0.076	-0.06	-0.036	-0.012	-0.062	0.076	-0.085	-0.087	0.379*	-0.123	0.144	-0.228	0.224	-0.462**			
STR	0.082	-0.169	-0.002	-0.059	0.025	-0.045	0.141	0.214	-0.027	-0.136	0.251	0.008	0.094	0.121	-0.317		
MAT	0.05	0.148	0.119	0.088	0.104	0.259	0.307	0.141	0.269	0.139	0.007	0.169	0.102	0.18	-0.108	0.01	
SCY	0.651**	0.556**	0.351*	0.078	0.792**	0.09	0.07	0.071	-0.015	0.161	-0.136	0.176	-0.001	-0.112	-0.068	-0.047	0.147

**= P>0.01, *=P>0.05

Table 15. Correlation matrix for various attributes for F_2 cross combination IUB75×FH142

	NSP	PH	HNR	FFBN	NBP	BW	GOT	LI	SI	SPB	RD	UHML	UI	SF	MIC	STR	MAT
PH	0.384																
HNR	0.219	0.392															
FFBN	0.075	-0.098	0.231														
NBP	0.416	0.005	-0.085	0.076													
BW	0.275	0.121	0.293	0.597*	0.216												
GOT	-0.006	0.173	-0.143	-0.207	0.18	-0.218											
LI	-0.178	0.231	0.236	0.21	-0.342	0.19	0.095										
SI	-0.239	-0.177	0.066	0.172	-0.594**	-0.027	-0.288	0.015									
SPB	0.321	0.298	0.467	0.534*	0.154	0.751*	-0.063	0.053	-0.183								
RD	0.027	-0.111	0.029	-0.315	0.008	-0.094	0.161	-0.494*	0.225	-0.128							
UHML	-0.082	0.363	-0.291	0.163	0.105	0.21	0.31	-0.011	0.166	0.123	0.117						
UI	0.479*	0.048	0.08	-0.071	0.083	0.029	0.317	0.036	0.059	-0.112	0.099	-0.319					
SF	0.072	0.213	0.484*	0.026	-0.037	0.136	-0.434	-0.17	0.281	0.211	0.232	-0.129	-0.034				
MIC	-0.042	-0.201	0.22	-0.062	0.374	-0.112	0.307	-0.242	0.108	-0.025	0.372	0.132	-0.126	0.12			
STR	0.161	-0.045	-0.196	-0.005	-0.063	-0.28	0.037	-0.255	-0.066	-0.23	0.165	0.045	-0.063	-0.364	-0.218		
MAT	0.252	-0.396	-0.183	0.077	0.169	-0.174	0.205	-0.237	-0.044	-0.197	0.176	-0.294	0.576	-0.176	0.1	0.12	
SCY	0.33	0.109	0.594**	0.33	0.344	0.431	-0.189	-0.245	-0.062	0.705**	0.082	-0.176	-0.046	0.499	0.386	-0.224	0.046

**= P>0.01, *=P>0.05.

Table 16. Path analysis of different attributes of F_2 population and their parents

	NSP	PH	HNR	FFBN	NBP	BW	GOT	LI	SI	SPB	RD	UHML	UI	SF	MIC	STR	MAT
NSP	**0.433**	-0.218	1.575	-0.423	0.055	0.030	-0.960	-0.138	0.097	0.311	0.249	-0.111	0.036	0.315	-0.575	-0.378	0.053
PH	0.339	**-0.278**	1.490	-0.256	0.896	0.053	-0.840	-0.138	0.171	0.118	-0.040	-0.041	-0.032	0.408	-1.201	-0.054	-0.214
HNR	0.355	-0.215	**1.920**	-0.498	0.837	-0.225	-1.446	-0.507	0.178	0.256	-0.133	0.117	-0.001	0.486	0.055	-0.050	-0.082
FFBN	0.421	-0.163	2.198	**-0.435**	1.028	-0.109	-1.895	-0.229	0.184	0.239	0.188	-0.033	0.093	0.562	-0.574	-0.446	-0.019
NBP	0.022	-0.229	1.481	-0.412	**1.086**	0.068	-0.498	-0.086	0.043	0.184	0.047	0.182	-0.038	0.310	-0.781	-0.380	-0.130
BW	-0.038	0.044	1.294	-0.142	-0.221	**0.334**	-0.711	-0.341	0.076	-0.188	0.050	0.059	-0.019	0.131	0.099	0.512	0.047
GOT	0.243	-0.137	1.627	-0.483	0.317	-0.139	**-1.706**	-0.497	-0.071	0.268	0.365	0.003	0.068	0.527	0.841	-0.286	0.134
LI	0.113	-0.072	1.841	-0.189	0.176	-0.216	-1.603	**-0.529**	0.030	0.084	-0.582	0.034	0.015	0.429	0.822	0.170	0.092
SI	0.134	-0.151	1.091	-0.254	0.149	-0.080	0.388	-0.052	**0.314**	0.061	-0.511	0.111	-0.127	-0.081	-0.898	0.206	-0.193
SPB	-0.398	0.097	-1.452	0.308	-0.590	-0.185	1.352	0.131	-0.056	**0.338**	0.269	-0.000	-0.032	-0.409	0.184	0.674	-0.002
RD	-0.117	-0.012	0.277	0.088	-0.056	0.018	0.674	-0.334	0.174	0.099	**0.923**	0.159	-0.096	-0.085	-0.214	0.012	-0.040
UHML	0.177	-0.042	-0.834	-0.054	-0.730	0.073	0.021	0.067	-0.129	-0.000	0.541	**-0.270**	0.036	0.189	0.428	0.211	0.082
UI	0.143	0.081	-0.021	-0.367	-0.382	0.058	-1.055	-0.074	-0.364	0.098	0.805	-0.089	**0.110**	0.279	1.399	-0.324	0.299
SF	0.204	-0.170	1.399	-0.367	0.505	-0.066	-1.349	-0.341	-0.038	0.208	0.117	-0.077	0.046	**0.666**	0.190	-0.192	0.024
MIC	-0.190	0.255	0.080	0.191	-0.647	-0.025	-1.095	-0.331	-0.215	-0.047	0.151	-0.088	0.117	0.096	**1.309**	0.076	0.317
STR	-0.259	0.024	-0.153	0.307	-0.653	-0.272	0.773	-0.142	0.102	-0.362	-0.018	-0.090	-0.056	-0.203	0.158	**0.631**	0.029
MAT	-0.092	-0.236	0.627	-0.034	0.5613	0.0634	0.9129	0.1951	0.241	-0.003	-0.146	0.088	-0.130	-0.063	-1.650	-0.073	**0.251**

NMP (Number of monopodial plant-1), NSP (Number of sympodial plant-1), PH (Plant height), NBP (Number of bolls plant-1), BW (Boll weight), SI (Seed index), SPB (Seed boll-1), HNR (Height to node ratio), FFBN (First fruiting branch node), NP (Number of nodes plant-1), GOT% (Ginning out Turn %), LI (Lint index), SCY (Seed cotton yield), UHML (Fiber length), UI (Fiber uniformity), SF (Short fiber index), MIC (Micronaire value), STR (Fiber strength), RD (Reflectance), MAT (Maturity index).

GOT% indirectly effect on yield in a positively direction through seed index, seed per boll, reflectance, fiber length, fiber strength and maturity index. Indirect effect of lint index on yield was positive through seed per boll, fiber length and maturity index. Seed index indirect positive impact on yield through sympodial branches, plant height, height to node ratio, first fruiting branch node, bolls per plant, boll weight, lint index, seed index, fiber length, fiber strength and maturity index. Indirect effects of seed per boll on yield was positive through sympodial branches, plant height, height to node ratio, first fruiting branch node, bolls per plant, GOT%, lint index, seed index, reflectance, fiber uniformity and short fiber. Reflectance indirectly positively influenced on yield via sympodial branches, first fruiting branch node, bolls per plant, boll weight, GOT%, seed per boll, fiber length, fiber uniformity, short fiber and micronaire value.

Fiber length had indirect positive effect on yield through height to node ratio, bolls per plant, boll weight, GOT%, lint index, seed index, reflectance and maturity index. Indirect effect of fiber uniformity on yield was positive through sympodial branches, first fruiting branch node, GOT%, lint index, fiber length, short fiber index and micronaire value. Short fiber index had indirect effect on yield in a positive way through sympodial branches, plant height, height to node ratio, first fruiting branch node, bolls per plant, boll weight, GOT%, lint index, fiber length, fiber uniformity and micronaire value. Micronaire value positively indirectly effect on yield through height to node ratio, boll weight, GOT%, lint index, seed per boll, staple length, fiber uniformity, short fiber and fiber strength. Staple strength indirect positive influence on yield through boll weight, lint index, seed index, seed per boll, reflectance, fiber length and micronaire value. Maturity index had indirect positive effect on yield through sympodial branches, boll weight, GOT%, lint index, fiber length, fiber uniformity, short fiber, micronaire value and staple strength.

DISCUSSION

Pakistan is an agricultural country and major part of the economy of the country is directly and indirectly dependent on agriculture (Shuli et al., 2018). Cotton is famous as lifeline of the economy of Pakistan. Its share 0.8 percent in the GDP and contribute 4.5% in agriculture value addition. Cotton production decreased from the last decade due to many reasons. Cotton production had been commercially increased by growing segregating (F_2) population in many countries like China and India that's way the present research was designed to evaluate the potential of different F_2 populations for seed cotton yield and fiber quality traits.

Analysis of variance executed that all attributes like number of sympodial branches per plant, number of bolls per plant, boll weight, seed index, lint index, seed per boll, height to node ratio, ginning out turn %, first fruiting branch node, seed cotton yield, fiber length, fiber strength, fiber uniformity %, short fiber index, micronaire value, reflectance and maturity index inferred significant result whilst number of monopodial branches per plant and total nodes per plant were non-significant. Our results are in accordance with Shuli et al*.* (2018) who reported significant differences for plant height, number of sympodial branches, number of bolls, staple length and fiber fineness. Rehman et al*.* (2014) reported significant differences for number of sympodia per plant and ginning out turn. Nawaz et al*.* (2019) also reported significant differences for bolls number plant-1, weight of boll, ginning out turn and yield of seed cotton plant^{-1}.

Maximum value of ranges of traits were calculated for F_2 cross combination MNH886×Mubarak for sympodial branches, plant height, boll weight, height to node ratio, fiber uniformity, micronaire value reflectance and maturity index while 2nd maximum ranges for traits were calculated for CIM595×MNH886 for seed index, first fruiting branch node, seed cotton yield and fiber length. These results showed that maximum variation was present in MNH886×Mubarak followed by CIM595×MNH886. Succeeding segregating population of these two F_2 cross combination may be because ultimate goal of plant breeder is to find out more variation in genotypes to develop high yielding and resistant genotypes. Heritability measures the degree of variation in a population's phenotypic attributes due to the genetic variation of the individuals in that group. All the traits showed high value of heritability except first fruiting branch node which exhibited moderate heritability. Highest value of heritability was calculated for seed cotton yield. Gnanasekaran et al*.* (2020) also observed high heritability for the number of monopodia per plant, the number of bolls per plant, seed index, lint index, GOT, uniformity ratio, fiber fineness and seed cotton yield per plant.

Computation of correlation between yield and yield attributing traits is of considerable importance in plant selection (Ashokkumar and Ravikesavan, 2010). Correlation matrix for all yield and fiber contributing attributes for six F_2 population and their six parents showed that sympodial branches inferred the positive association with plant height, first fruiting branch node and GOT% while it showed negative linkage with seed per bolls. Plant height was positively linked with total bolls per plant, fiber maturity and yield while it depicted negative association with micronaire value. Height to node ratio exhibited positive correlation with first fruiting branch node, total bolls per plant, GOT% lint index and yield. First fruiting branch node manifested positive linkage with GOT%, short fiber and yield while seed per bolls negatively associated with this trait. Total bolls per plant positively linked with GOT%, fiber maturity and yield while micronaire value negatively associated with this attribute. Boll weight inferred positive linkage with fiber strength. Nikhil et al*.* (2018) also reported the significant positive correlation for seed cotton yield per plant with number of monopodia, number of bolls per plant, boll weight and lint index. Similar results were also observed by Gnanasekaran et al*.* (2020); Reddy et al*.* (2017). GOT% exhibited positive relationship with lint index, fiber uniformity, short fiber and yield while seed per boll inferred negative linkage with this trait. Monisha, (2018) revealed that seed cotton yield exhibited positive and highly significant correlation with boll weight, lint index and ginning out turn Lint index exploited positive linkage with short fiber and yield. Seed index manifested positive relationship with fiber maturity while fiber uniformity and micronaire value exhibited negative linkage for this attribute. These results are in accordance with Patil et al*.* (2017); Memon et al*.* (2017); Nawaz et al*.* (2019). Seed per boll positively associated with fiber strength. Reflectance negatively correlated with fiber length. Fiber uniformity negatively associated with fiber maturity. Short fiber positively linked with yield. Micronaire value negatively correlated with fiber maturity. Naik et al*.* (2019) lint index (g), micronaire value and uniformity ratio were found to have significant positive association with seed cotton yield plant^{-1}.

Path analysis exploited that seed index, number of sympodial branches per plant, number of bolls per plant, fiber uniformity, short fiber index, height to node ratio, boll weight, micronaire value and staple strength direct positive effects on yield while first fruiting branch node, plant height, GOT%, Lint index, seed per boll, reflectance, staple length and fiber maturity index direct negative effects. Direct positive effects give us a direction that we should more focus on these attributes during selection. Nikhil et al*.* (2018) showed that the path analysis indicated that boll weight and number of bolls per plant had highest direct effect on seed cotton yield per plant, whereas traits like plant height, UHML, fiber strength and lint index had direct negative effect on yield. Similar results were also observed by Patil et al*.* (2017); Memon et al*.* (2017); Tilak et al*.* (2017) and Reddy et al*.* (2017). Tonk et al*.* (2018) studied that seed cotton yield was not negatively associated with fiber quality properties. Dahiphale and Deshmukh (2018) observed that Lint kg/ha exhibited the highest magnitude of direct effects on seed cotton yield, followed by fiber length, plant height, bolls and sympodia/plant.

CONCLUSION

The results discussed above indicate that correlation and direct and indirect effect estimates vary for different traits with variation in genetic material based on yield component traits and fiber properties. Hence, correlations and direct and indirect effect estimation would provide useful information for planning a successful breeding program if the genetic material is grouped for yield and fiber quality characters and also it is essential to device suitable breeding methodologies for simultaneous improvement of both yield and quality parameters involving three-way crosses, modified back crosses or recurrent selection.

DISCLOSURE STATEMENT

No any potential conflict of interest was reported by Authors.

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