Received: 30 Mar 2023 | Revised: 16 May 2023 | Accepted: 28 May 2023

Electronic Journal of Plant Breeding

Research Article

Assessment of heterotic potential and association analysis in direct and reciprocal hybrids for seed cotton yield and fiber quality traits involving lintless – fuzzless genotypes in upland cotton (*Gossypium hirsutum*. L)

L. Ananda Lekshmi[1], M. Kumar[2*], S. Rajeswari[3], M. Raveendran[4], D. Uma[5] and S. Manickam[6]

[1]Department of Genetics and Plant Breeding, Tamil Nadu Agricultural University, Coimbatore 641003, India
[2]Oilseeds Research Station, Tindivanam
[3]Department of Cotton, Tamil Nadu Agricultural University, Coimbatore 641003, India
[4]Department of Plant Biotechnology, Centre for Plant Molecular Biology and Biotechnology, Tamil Nadu Agricultural University, Coimbatore, 641003, India.
[5]Department of Plant Biochemistry, Centre for Plant Molecular Biology and Biotechnology, Tamil Nadu Agricultural University, Coimbatore, 641003, India.
[6] Central Institute for Cotton Research Regional Station, Coimbatore-641004
[*]**E-Mail**:kumarmahadevan@rediffmail.com

Abstract
The present investigation focused on studying heterosis for yield and fibre quality traits among nine parents and their 36 hybrids developed through hybridization between six elite varieties as females and three fuzzless genotypes as pollen parent, along with their reciprocal crosses. Analysis of variance indicated the presence of substantial variability among the experimental materials for yield and fibre quality traits. The study indicated that the direct cross-hybrids generated using elite cultivars as female parents performed better than the reciprocal hybrids. The hybrids CO17 / AKH98-81, CO17 / TCH1646, CO14 / TCH1646 and MCU 5 / AKH 98-81 had recorded significant positive heterosis for a majority of traits including seed cotton yield and fibre quality. An association analysis revealed that seed cotton yield exhibited a positive and highly significant correlation with number of sympodia, number of bolls, boll weight, lint index, ginning out turn and all fibre quality traits. The analysis of the direct effect of various traits on seed cotton yield revealed that the traits like number of bolls, boll weight, number of seeds per boll, ginning out turn, fibre length, fibre strength, uniformity index, micronaire value and elongation percentage had expressed very high positive direct effects.

Keywords: Correlation, Cotton, Fuzzless, Heterosis, Path analysis.

INTRODUCTION

Cotton, the king of fibre, is one of the most significant and chief cash crops of the country. It is the most important commercial crop contributing towards the total raw material needs of the textile industry in our country. Understanding the type and extent of gene action affecting yield traits is crucial in order to develop an effective breeding strategy for enhancing cotton through heterosis breeding. According to the reports, nonadditive or dominant effects genetically influence the amount of yield heterosis in cotton crops (Marani, 1967). Although cotton has historically benefited from heterosis, a hybrid plant needs to outperform the best commercial cultivar currently in the market. This suggests that the hybrid would yield more and produce fibre of higher quality. Researchers have long sought to use heterosis to increase cotton yield and fibre quality. The cotton seeds have two types of fibres, the lint and the fuzz which arise at varied points after fertilization from the outer surface (Fang *et al.,* 2018). There is also a possibility that seeds without fuzz or lint or both can be recovered. Thus, this study aims to investigate the heterotic potential of hybrids generated from naked seeded types for the fuzz and lint bearing capacity. In order to enhance the yield potential of cotton varieties, an understanding on relationship among different characters is more important (McCarty *et al.,* 2008).

As correlation research establishes the relationship between yield and quality traits, correlation study is crucial in cotton breeding programmes. Additionally, it measures the association between various traits and identifies the constituent characters that may be employed as the basis for selection to improve the genetics of seed cotton and lint yield (Salahuddin *et al*., 2010). It is possible to select superior genotypes from a variety of genetic backgrounds using the correlation between yield and contributing traits, but this method lacks information about the direct and indirect effects of independent variables on the dependent variable, necessitating path coefficient analysis (Erande *et al*., 2014). Path analysis categorises the impact of a correlation coefficient into direct and indirect effects. The dependent variable, which is the average yield of seed cotton per plant, is the subject of a path coefficient analysis in order to examine the direct and indirect effects of each component character on the dependent variable. With the study of path coefficients, breeders are able to concentrate on the variables that have a significant direct impact on the production of seed cotton. The present study aims to examine heterosis in terms of genetic components and understand the association between seed cotton yield and yield contributing traits in upland cotton (*Gossypium hirsutum.* L).

MATERIALS AND METHODS

Nine parents involving six elite cultivars *viz*., SVPR4, SVPR6, MCU5, MCU7, CO14 and CO17 and three fuzzless seed genotypes, namely TCH1646, MCU5 Lintless and AKH98-81 were hybridized to generate 18 direct cross and 18 reciprocal cross hybrids. The hybrids were evaluated along with parents and local check (CO14) at the Department of Cotton, TNAU, Coimbatore. The experiment was conducted in Randomized Block Design (RBD) with two replications during *Rabi* 2022. Standard agronomical practices were followed during the entire crop growth period. Observations on 12 biometrical traits were recorded in five tagged plants of each replication and for fibre quality two plants of each replication was analyzed in High Volume Instrument (HVI). The traits include days to fifty per cent flowering (DFF), days to first boll opening (DFP), plant height (PH), number of monopodia (NM), number of sympodia (NS), number of bolls per plant (NB), boll weight (BW), number of seeds per boll (NSB), seed index (SI), lint index (LI) ginning percentage (GP), seed cotton yield (SCY), upper half mean length (UHML), fibre strength (STR), uniformity index (UI), micronaire value (MIC) and elongation percentage (EL). The mean data were subjected to Analysis of Variance (ANOVA) as per Panse and Sukathme (1985), character association studies (Snedecor and Cochran, 1967) and heterosis analysis (Fonseca and Patterson, 1968).
The standard heterosis and better parent heterosis were calculated using the following formula:

$$\text{BH}\ (\%) = \frac{F_1\text{-BP}}{\text{BP}} \times 100$$

$$\text{SH}\ (\%) = \frac{F_1\text{-SP}}{\text{SP}} \times 100$$

Where, BH – better parent heterosis (%), SH- Standard heterosis (%), F_1 – mean value of hybrid and BP – mean value of better parent. The estimation of heterosis was done using TNAU STAT software and correlation and path analysis was carried out using R software (4.0.2) using the packages “corrplot” and “RColorBrewer”. Genotypic correlation coefficients were further partitioned into direct and indirect effects by path analysis as suggested by Dewey and Lu (1959).

RESULTS AND DISCUSSION

Analysis of variance indicated highly significant differences due to treatments fulfilling the basic requirement to take the study forward. Results suggest that there was enough variability in the genetic material (**Table1**). The hybrids obtained in the present investigation were studied for the *per se* performance and heterosis over local check CO14. Negatively significant values were considered for the traits days to fifty per cent flowering, days to first boll opening and number of monopodia for mean performance and heterosis.

The mean performance serves as the primary criterion for choosing better hybrids because it exposes their real value. The mean performance of direct and reciprocal hybrids are furnished in **Table 2**. When comparing the trait means, direct cross hybrids outperformed their respective reciprocal crosses for the majority of the traits evaluated. Direct cross hybrids were found to be early for flowering than reciprocal hybrids. The prime trait, seed cotton yield per plant, ranged from 64.94 - 121.92 g and 65.79 -120.21g in direct and reciprocal crosses respectively. Significant variation in hybrid performance was observed for plant height, number of sympodia, boll weight and number of bolls among direct and reciprocal hybrids where the direct hybrids surpassed the reciprocal hybrids. For fibre quality characters, the mean and ranges were nearly the same for both sets of hybrids. These results were found to be in accordance with the findings of Giri *et al.* (2021).

Table 1. Analysis of variance for various yield components and fibre quality traits

SOURCE	df	DFF	DFP	PH	NM	NS	NB	BW	NSPB
Replication	1	2.0336	4.0934	0.1270	0.0010	0.0152	1.0752	0.0001	0.4673
Hybrids	17	7.5460**	75.9533**	150.5357**	0.0552**	23.7286**	19.7848**	0.4824**	8.5176**
Checks	2	46.5175**	189.4761**	73.5709**	1.1941**	25.9260**	2.7691	0.3874**	6.2218**
Check vs hydrids	1	21.6597**	15.7750**	1494.94**	0.8183**	315.9520**	620.1504**	0.2244**	0.9620
Error	20	2.1088	8.2504	7.8197	0.0004	0.3184	0.7154	0.0114	0.5029

Table 1. Continued

SOURCE	df	SI	LI	GOT	SCY	UHML	STR	UI	MIC	EL
Replication	1	0.1524	0.0002	0.0003	0.5372	0.2867	0.0780	1.0752	0.0031	0.0060
Hybrids	17	4.5005**	0.9120**	31.3354**	247.9793**	5.8096**	5.8512**	3.2358**	0.4979**	0.0737
Checks	2	3.9615**	0.8065**	0.4161*	44.7549**	28.5683**	41.4314**	5.4859*	3.6721**	0.2208
Check vs hydrids	1	2.3800**	0.3395**	33.7115**	13.5281**	23.9452**	2.9705**	6.8739**	0.9931**	0.0004**
Error	20	0.1033	0.0170	0.7575	37.2445	0.7366	0.4357	1.5154	0.0107	0.0292

(DFF- Days to fifty per cent flowering, DFFP- Days to first boll opening, PH – Plant height, NM – Number of monopodia, NS- Number of sympodia, NB-Number of bolls, BW – Boll weight, NSPB – Number of seeds per boll, SCY- Seed cotton yield, SI- Seed index, LI- Lint index, GOT- Ginning out turn, UHML- Upper Half Mean Length, STR- Fibre strength, UI- Uniformity index, MIC-Micronaire value, EL- Elongation percentage * and ** indicates significance at 5 % and 1 % level)

Table 2. Trait mean of direct and reciprocal crosses for various yield components and fibre quality traits

CHARACTERS	DIRECT CROSS		RECIPROCAL CROSS	
	Trait mean (± SE)	Range	Trait mean (± SE)	Range
Days to fifty per cent flowering	56.44 ± 1.08	53.00-60.00	57.28± 0.98	53.00-63.00
Days to first boll opening	95.44± 1.95	83.00-104.00	98.94± 1.56	90.00-112.00
Number of Monopodia	0.46± 0.01	0.16-0.67	0.51± 2.09	0.00-1.00
Plant height (cm)	111.10± 2.08	95.50-126.00	90.67± 0.01	71.50-107.00
Number of sympodia	26.33± 0.39	19.00-32.50	18.50± 0.38	12.50-23.00
Number of bolls	34.60± 0.63	28.00-38.83	19.78± 0.35	13.25-24.75
Boll weight (g)	4.00± 0.07	2.75-4.65	3.56± 0.06	2.75-5.25
Number of seeds per boll	24.83± 0.47	22.25-30.25	24.49± 0.52	18.00-30.25
seed cotton yield (g)	90.12± 1.35	64.94-121.92	87.06± 0.54	65.79-120.21
seed index	10.30± 0.24	7.95-12.90	9.83± 0.16	6.85-12.39
lint index	4.65± 0.09	3.05-5.65	4.04± 0.08	2.45-5.08
Ginning out turn (%)	31.23± 0.64	25.96-38.46	29.23± 0.71	25.51-35.38
Upper half mean length (mm)	28.45± 0.56	25.20-31.30	28.08± 0.48	25.40-33.00
Fibre strength (g/tex)	23.59± 0.48	21.30-28.20	23.39± 0.47	19.50-30.50
Uniformity index (%)	47.15± 0.80	45.80-49.60	46.78± 0.88	45.10-49.10
Micronaire value (µg/inch)	4.05± 0.06	3.05-5.12	3.90± 0.053	2.81-5.05
Elongation percentage (%)	5.80± 0.13	5.50-6.20	5.69± 0.10	5.10-6.40

The potential for utilizing hybrid vigour depends on the high *per se* performance of the hybrids compared to the standard variety or the local check, the degree of heterosis, and the biological viability of large-scale hybrid seed production (Swaminathan *et al.,*1971). Overdominance is linked to heterobeltiosis, although the hybrid's commercial superiority can be determined by using a normal commercial check. Among the three types of heterosis, the interpretation of test hybrids based on standard heterosis reflects the actual superiority of it over the best current cultivar to be replaced and appears to be more pertinent and beneficial. Thus, heterosis over the elite cultivars CO14 was accounted to judge the best hybrid in the current investigation.

Table. 3 Better parent heterosis of crosses for yield and fibre quality traits

GENOTYPES	DFF	DFFP	PH	NM	NS	NB	BW	NSPB	SCY	SI	LI	GOT	UHML	STR	UI	MIC	EL
SVPR4/TCH1646	-11.79**	-11.18**	17.00**	-39.27**	15.34**	57.37**	-4.25	-31.63**	-5.96*	-24.30**	18.96**	6.84*	-0.87	6.56*	-2.61	18.05**	1.87
SVPR4/MCU5LL	-10.74**	-6.96*	11.23**	-68.95**	6.79*	37.12**	8.85**	-19.78**	2.62	-21.46**	22.95**	5.34*	-3.82	8.25**	1.28	25.27**	-2.22
SVPR4/AKH98-81	-7.61**	-8.04**	27.37**	-54.79**	31.12**	91.54**	-8.26**	9.69*	-7.16**	8.27**	16.30**	3.75	11.47**	22.86**	-8.08**	-18.32**	8.44*
MCU7/TCH1646	-10.45**	-14.51**	4.55	-58.58**	5.61	29.21**	-2.08	-32.50**	-8.69**	-34.87**	25.81**	21.79**	7.44*	12.63**	-3.28	12.13**	2.99
MCU7/MCU5LL	3.53	-12.74**	22.34**	-57.74**	33.86**	47.32**	-3.42	-27.42**	3.82	-34.34**	12.67**	11.39**	15.35**	22.99**	-6.49*	14.30**	6.35*
MCU7/AKH98-81	8.80**	-20.17**	38.50**	-71.55**	61.82**	69.26**	4.88	11.40**	-23.65**	-8.68**	7.84**	6.39*	5.46	10.12**	-4.73	0.00	7.53*
CO17/TCH1646	-8.81**	-11.18**	25.59**	-83.50**	40.89**	68.00**	-4.59	-32.00**	33.66**	-23.50**	-31.03**	-22.81**	-1.86	21.16**	3.27	-26.26**	3.73
CO17/MCU5LL	1.55	5.32	11.82**	1.0**	52.88**	58.90**	-6.35*	-9.37**	32.30**	-46.89**	-9.71**	11.35**	-4.14	8.58*	2.96	-24.51**	-1.09
CO17/AKH98-81	4.95	-4.99	35.44**	-82.91**	46.08**	64.24**	-1.29	-2.33	11.17**	-26.79**	-11.42**	12.66**	14.92**	15.13**	-8.63**	-35.02**	5.82
SVPR6/TCH1646	-15.36**	-7.18*	5.70	-58.75**	15.27**	75.58**	22.46**	-36.81**	14.76**	-17.78**	-10.89**	-4.81	-0.82	-5.66*	-0.50	3.00	-2.63
SVPR6/MCU5LL	-13.57**	-6.97*	18.10**	-58.33**	1.37	33.33**	-6.33	-25.72**	-14.59**	-41.03**	-38.15**	-10.01**	0.31	-4.46	0.58	2.35	-0.76
SVPR6/AKH98-81	-22.64**	-19.85**	4.99	-45.00**	0.76	59.07**	-3.17	7.83*	-5.82*	-27.27**	-22.28**	4.02	4.16	-5.11	-7.44**	0.91	-3.14
CO14/TCH1646	-8.10**	-5.82	10.51**	-55.03**	38.13**	56.36**	-1.3	-35.62**	49.10**	-14.64**	0.20	-14.02**	-14.65**	-12.24**	3.76	35.76**	-4.31
CO14/MCU5LL	-2.72	7.43*	8.33*	-66.11**	35.80**	48.69**	-9.55**	-14.24**	48.01**	-21.76**	-9.63**	-17.58**	-15.15**	-19.98**	4.86	16.99**	-10.41**
CO14/AKH98-81	0.98	3.62	20.09**	-65.77**	48.46**	57.12**	-22.80**	-9.59**	25.48**	10.29**	-10.03**	-13.81**	-6.12*	-1.28	-8.24**	17.81**	-0.73
MCU5/TCH1646	-13.39**	-10.22**	16.31**	-39.09**	46.83**	34.99**	14.34**	-38.41**	2.86	-38.46**	16.32**	6.72**	-8.02**	-5.31*	5.51	101.74**	-1.67
MCU5/MUC5LL	-9.48**	-10.75**	13.42**	-54.55**	44.71**	45.63**	-19.17**	-22.65**	10.31**	-31.35**	-4.31	-18.65**	-12.17**	-7.89**	6.88*	46.51**	0.88
MCU5/AKH98-81	-10.78**	-16.32**	9.21**	-54.09**	32.59**	38.6**	24.14**	19.98**	13.59**	25.32**	30.89**	-8.71**	-10.26**	-4.8	-6.97**	5.80	2.72
TCH1646/SVPR4	-8.97**	-14.03**	-39.27**	-26.77**	-33.85**	-39.96**	-33.85**	-41.17**	35.04**	-28.51**	-26.31**	-16.00**	-1.84	5.93	-7.20**	-11.96**	-2.98
TCH1646/MCU7	1.38	-12.51**	-71.61**	-18.88**	-13.46**	-20.31**	-26.01**	-30.80**	-11.57**	-34.39**	-10.95**	-7.61*	5.36	33.58**	0.98	-28.39**	-3.90
TCH1646/CO17	-8.74**	-10.67**	-100.00**	-7.25*	6.79*	6.48**	-32.69**	-16.01**	4.37**	-37.17**	-29.90**	-10.58**	7.03**	6.77	-1.88	-27.25**	2.80
TCH1646/SVPR6	-5.53*	-2.55	-57.87**	-23.5**	-29.03**	-21.97**	-2.15	-31.29**	-9.55**	-37.10**	-31.97**	-10.61**	-7.00**	-10.33**	-0.27	-15.50**	-5.64*
TCH1646/CO14	-4.42	-5.86*	-43.73**	2.83	8.56**	-1.54	-5.95**	-26.85**	50.95**	-19.29**	0.50	-9.92**	-15.07**	-5.00*	5.84*	37.62**	1.01
TCH1646/MCU5	-9.28**	-6.45*	-69.27**	-17.44**	-4.76	-8.90**	-19.07**	-29.49**	5.10**	-34.01**	-15.60**	-16.9**	-10.90**	-6.66*	8.83**	32.65**	1.10
MCU5LL/SVPR4	-7.80**	-8.21**	-38.36**	4.38	-12.28**	-15.78**	-32.54**	-16.22**	26.39**	-40.89**	-17.73**	-3.95	-2.98	-0.57	-6.46*	4.03	-8.30**
MCU5LL/MCU7	-5.99*	-14.32**	-57.63**	5.19	-31.68**	-21.39**	32.04**	-43.37**	-12.35**	-31.74**	6.14*	0.15	-1.25	2.41	1.65	14.96**	1.86
MCU5LL/CO17	0.81	1.14	1.0**	3.11	-15.05**	-5.48*	-32.81**	-35.53**	-14.18**	-33.68**	-36.86**	-25.88**	4.25	6.41	-5.97*	-37.7**	-8.03**
MCU5LL/SVPR6	-9.19**	0.04	-57.45**	-17.03**	-44.33**	-18.57**	36.50**	-14.16**	-13.27**	-40.92**	-1.33	19.59**	2.16	3.84	-0.66	28.59**	0.67
MCU5LL/CO14	-1.59	3.51	-54.58**	10.11**	17.29**	-10.70**	-40.54**	-36.31**	8.64**	-55.16**	-26.41**	5.71*	-21.28**	-26.70**	7.19**	48.73**	-8.14**
MCU5LL/MCU5	-9.17**	-7.16**	-39.91**	-1.37	10.92**	-19.29**	2.25	-28.03**	15.89**	-33.85**	17.23**	-2.03	-17.61**	-21.56**	11.20**	66.42**	-7.08**
AKH98-81/SVPR4	-13.07**	-2.4	-84.47**	-6.57*	-14.24**	-8.73**	-16.33**	14.08**	8.71**	-3.86	11.59**	10.84**	6.07*	5.81	-6.97**	16.76**	7.21**
AKH98-81/MCU7	2.49	-8.44**	-72.03**	8.25**	19.37**	-23.05**	10.30**	-9.22*	1.89	-16.64**	6.50*	14.74**	12.53**	14.93**	-5.48*	-8.31**	6.96**
AKH98-81/CO17	8.24**	-0.66	-82.65**	4.45	2.27	2.04	-21.03**	12.05**	17.74**	-6.44*	-30.35**	-19.35**	13.92**	22.76**	-6.42*	-8.20**	7.85**
AKH98-81/SVPR6	-11.90**	-13.13**	-57.87**	-17.34**	-21.12**	3.05	-0.53	7.73*	26.35**	0.76	-50.05**	-43.88**	4.16	5.52	-6.72**	8.39**	0.93
AKH98-81/CO14	-0.69	15.44**	-54.24**	4.71	12.75**	0.54	-13.08**	12.94**	9.52**	2.52	-14.76**	-11.89**	-3.61	11.30**	-9.77**	-0.14	6.88**
AKH98-81/MCU5	-12.54**	-11.49**	-8.26**	-0.99	3.85	-27.77**	9.61***	-0.10	-2.91*	7.65*	9.90**	-10.49**	-4.49*	-0.35	-7.12**	-15.80**	-1.18

(DFF- Days to fifty per cent flowering, DFFP- Days to first boll opening, PH – Plant height, NM – Number of monopodia, NS- Number of sympodia, NB-Number of bolls, BW – Boll weight, NSPB – Number of seeds per boll, SCY- Seed cotton yield, SI- Seed index, LI- Lint index, GOT- Ginning out turn, UHML- Upper Half Mean Length, STR- Fibre strength, UI- Uniformity index, MIC-Micronaire value, EL- Elongation percentage * and ** indicates significance at 5 % and 1 % level)

Table 4. Standard heterosis of crosses for yield and fibre quality traits over standard check CO14

GENOTYPES	DFF	DFFP	PH	NM	NS	NB	BW	NSPB	SCY	SI	LI	GOT	UHML	STR	UI	MIC	EL
SVPR4/TCH1646	-2.43	9.18**	23.94**	-55.37**	22.54**	50.41**	-11.94**	-8.77**	-16.31**	9.70**	8.71**	-1.61	-20.13**	-22.75**	4.75	42.88**	-6.75*
SVPR4/MCU5LL	-1.27	14.37**	17.82**	-77.18**	13.46**	31.45**	0.11	-5.74*	-8.67**	19.25**	12.36**	-3.00	-22.50**	-21.53**	8.93**	51.62**	-10.50**
SVPR4/AKH98-81	2.18	13.04**	34.91**	-66.78**	39.30**	66.09**	-15.64**	-6.35*	-17.38**	13.85**	6.28*	-4.46	-10.18**	-5.87*	0.80	-1.13	-0.73
MCU7/TCH1646	-8.43**	-1.41	1.43	-66.78**	-5.87*	23.50**	-12.92**	-9.94**	-3.57	-5.61	5.67*	8.38**	-18.08**	-22.29**	4.81	42.07**	-7.57*
MCU7/MCU5LL	0.55	0.62	18.68**	-66.11**	31.77**	41.22**	-14.12**	-14.72**	9.63**	-0.30	-5.37	-0.87	-12.05**	-15.14**	1.33	44.82**	-4.56
MCU7/AKH98-81	0.03	-7.94*	34.36**	-77.18**	36.87**	58.01**	-6.73**	-9.05**	-19.37**	-5.41	-9.42**	-5.32	-17.59**	-15.63**	4.48	26.70**	-2.36
CO17/TCH1646	-6.75*	2.42	17.90**	-88.93**	47.34**	68.40**	-11.94**	-9.27**	49.06**	10.86**	-22.29**	-20.96**	-22.93**	-17.07**	8.80**	22.65**	-7.24*
CO17/MCU5LL	-1.38	8.85*	4.97	-88.59**	59.88**	59.28**	-13.57**	6.48*	47.55**	-19.35**	1.72	14.02**	-24.72**	-25.68**	8.47**	25.57**	-11.55**
CO17/AKH98-81	-1.54	-1.80	27.14**	-88.59**	52.76**	64.63**	-8.90**	-15.02**	23.98**	-19.91**	-0.20	15.36**	-9.75**	-11.80**	0.20	8.09*	-3.91
SVPR6/TCH1646	0.12	16.30**	12.09**	-66.78**	28.06**	67.81**	-13.57**	-15.68**	9.87**	19.15**	-11.25**	-18.53**	-13.78**	-20.37**	1.43	27.83**	-6.75*
SVPR6/MCU5LL	2.24	16.56**	25.24**	-66.44**	12.61**	27.81**	-38.98**	-12.73**	-18.22**	-10.46**	-38.40**	-22.98**	-12.79**	-19.36**	2.52	27.02**	-4.96
SVPR6/AKH98-81	-8.48**	0.42	11.34**	-55.70**	11.94**	38.57**	-20.30**	-11.71**	-9.83**	-8.34*	-22.59**	-10.98**	-9.45**	-19.91**	1.50	25.24**	-7.24*
CO14/TCH1646	-6.02*	8.60*	10.51**	-55.03**	38.13**	56.36**	-1.30	-14.09**	49.10**	23.70**	0.20	-14.02**	-14.65**	-12.24**	3.76	35.76**	-4.31
CO14/MCU5LL	-2.72	7.43*	8.33*	-66.11**	35.80**	48.69**	-9.55**	0.76	48.01**	18.80**	-9.63**	-17.58**	-15.15**	-19.98**	4.86	16.99**	-10.41**
CO14/AKH98-81	0.98	3.62	20.09**	-65.77**	48.46**	57.12**	-22.80**	-9.59**	25.48**	14.25**	-10.03**	-13.81**	-6.12*	-1.28	0.63	41.26**	-0.73
MCU5/TCH1646	-4.43	7.80*	24.20**	-55.03**	30.87**	47.13**	-7.38**	-17.82**	9.99**	-10.81**	1.11	9.24**	-12.35**	-14.55**	3.84	68.45**	-8.79**
MCU5/MUC5LL	-0.10	7.16*	21.11**	-66.44**	42.44**	58.73**	-34.53**	-9.12**	17.96**	4.24	-16.82**	-16.72**	-16.30**	-16.88**	5.19	22.33**	-6.43*
MCU5/AKH98-81	-1.54	0.47	16.62**	-66.11**	12.14**	51.07**	2.17	11.05**	21.46**	29.81**	13.78**	-6.54*	-14.48**	-14.09**	2.02	26.86**	-4.72
TCH1646/SVPR4	3.19	4.39	-54.92**	-25.38**	-29.84**	-43.26**	-39.57**	-19.27**	21.27**	6.23*	-33.63**	-23.48**	-21.96**	-20.19**	-1.35	0.48	-9.66**
TCH1646/MCU7	6.51*	-0.5	-77.29**	-20.81**	-21.10**	-24.68**	-36.32**	-5.03	-7.48**	-2.5	-25.70**	-16.71**	-21.15**	-8.48**	7.48*	-11.11**	-13.18**
TCH1646/CO17	-4.12	0.45	-100.00**	-14.85**	14.50**	4.25	-39.46**	15.26**	14.12**	-6.64*	-22.09**	-7.62*	-16.76**	-24.49**	2.41	18.25**	-4.37
TCH1646/SVPR6	12.39**	18.86**	-66.44**	-18.85**	-21.91**	-26.25**	-31.24**	-5.71*	-14.63**	-6.54*	-33.13**	-22.66**	-20.14**	-23.40**	2.06	5.56*	-5.88*
TCH1646/CO14	0.42	5.85*	-43.73**	2.83	8.56**	-1.54	-5.95*	0.38	50.95**	19.93**	0.50	-9.92**	-15.07**	-5.00	5.84*	37.62**	1.01
TCH1646/MCU5	5.27*	13.14**	-77.29**	-13.42**	-13.17**	-1.44	-33.95**	-3.24	10.87**	-1.94	-27.21**	-16.06**	-17.12**	-15.01**	4.74	12.22**	0.76
MCU5LL/SVPR4	4.51	11.45**	-54.24**	6.37*	-6.95*	-20.82**	-38.38**	0.32	13.51**	-8.18**	-25.90**	-12.51**	-22.86**	-25.09**	-0.56	18.73**	-14.61**
MCU5LL/MCU7	-6.51*	-2.55	-66.10**	2.69	-32.62**	-25.91**	13.62**	-32.19**	-8.29**	6.03*	-11.45**	-9.71**	-26.09**	-29.84**	8.19**	42.7**	-7.98**
MCU5LL/CO17	0.25	-0.05	-53.90**	-5.34	-8.91**	-7.46**	-39.57**	-22.80**	-6.16**	3.01	-29.82**	-23.42**	-18.92**	-24.74**	-1.85	1.27	-14.44**
MCU5LL/SVPR6	8.04**	22.02**	-66.10**	-11.99**	-38.75**	-23.44**	-11.46**	2.79	-18.14**	-8.23**	-3.01	3.48	-12.28**	-11.30**	1.66	60.63**	0.42
MCU5LL/CO14	-1.59	3.51	-54.58**	10.11**	17.29**	-10.70**	-40.54**	-23.74**	8.64**	-30.35**	-26.41**	5.71	-21.28**	-26.70**	7.19*	48.73**	-8.14**
MCU5LL/MCU5	5.40*	12.27**	-55.59**	3.43	9.39**	-12.67**	-16.54**	-13.82**	22.25**	2.76	1.10	-1.04	-23.35**	-28.58**	7.02*	40.79**	-7.39**
AKH98-81/SVPR4	-1.46	18.52**	-88.47**	-4.79	-9.03**	-23.14**	-23.57**	-2.53	-2.37	3.01	0.50	0.96	-15.67**	-18.65**	1.23	34.92**	-0.17
AKH98-81/MCU7	-3.71	4.14	-77.63**	5.68	2.06	-27.47**	-5.08**	-24.29**	6.60**	-13.75**	-11.14**	3.45	-13.45**	-11.64**	2.84	13.81**	-0.67
AKH98-81/CO17	5.09*	-1.83	-88.47**	-4.1	9.66**	-0.11	-28.97**	1.49	28.74**	3.12	-22.59**	-16.68**	-11.40**	-5.61*	1.82	49.21**	0.34
AKH98-81/SVPR6	4.82	5.95*	-66.44**	-12.32**	-13.20**	-10.08**	-18.27**	-10.15**	19.26**	28.05**	-50.90**	-51.44**	-10.56**	-9.86**	1.49	35.4**	0.67
AKH98-81/CO14	-0.69	15.44**	-54.24**	4.71	12.75**	0.54	-13.08**	12.94**	9.52**	6.08*	-14.76**	-11.89**	-3.61	11.3**	-1.82	15.4**	6.88**
AKH98-81/MCU5	1.49	7.04**	-32.2**	3.83	-11.22**	-21.85**	-9.95**	-6.17*	2.42	11.39**	-5.22*	-9.59**	-11.15**	-9.27**	1.06	-2.7	-1.51

(DFF- Days to fifty per cent flowering, DFFP- Days to first boll opening, PH – Plant height, NM – Number of monopodia, NS- Number of sympodia, NB-Number of bolls, BW – Boll weight, NSPB – Number of seeds per boll, SCY- Seed cotton yield, SI- Seed index, LI- Lint index, GOT- Ginning out turn, UHML- Upper Half Mean Length, STR- Fibre strength, UI- Uniformity index, MIC-Micronaire value, EL- Elongation percentage * and ** indicates significance at 5 % and 1 % level)

The analysis revealed that among the 36 hybrids, TCH1646 / CO14, CO14 / TCH1646, CO17 / TCH1646, CO14 / MCU5LL, MCU5LL / MCU5 exhibited significant *per se* performance and significant positive heterosis over the CO14 for seed cotton yield. Similarly, four hybrids, *viz*., MCU 5 / AKH98-81, TCH1646 / CO17, AKH98-81 / CO14, and CO17 / MCU5 LL expressed significant *per se* performance and positive heterosis for number of seeds per boll. For boll weight, MCU5LL / MCU7 showed significant *per se* performance and desirable positive heterosis. Most of the hybrids showed better parent heterosis for nearly all the characteristics. These results were found to be in line with the findings of Unay *et al*. (2019) and Yehia *et al*. (2023) (**Table 3**).

The hybrids CO17 / AKH98-81, CO17 / TCH1646, CO14 / TCH1646 and MCU 5 / AKH 98-81 recorded significant heterosis for a majority of the traits including seed cotton yield and fibre quality (**Tables 4**). MCU5 / AKH98-81 recorded significant heterosis for plant height, number of monopodia, number of sympodia, number of bolls, number of seeds per boll, seed cotton yield, seed index, lint index and micronaire value over CO14. Among the reciprocal hybrids, TCH 1646 / CO14 was found to have better potential with heterosis for five traits over CO14.

Positive and significant heterosis was reported for yield and fibre quality traits by Baloch *et al*. (2015), Khokhar *et al*. (2018), Gnanasekaran *et al*. (2019), Thiyagu *et al*. (2019), Chakholoma *et al*. (2021), Giri *et al*. (2021) and Mudhalvan *et al*. (2021). Based on the results from heterosis study, it could be concluded that direct crosses exhibited high heterotic performance than reciprocal hybrids. The hybrids *viz.,* CO17 / AKH98-81, CO17 / TCH1646, CO14 / TCH1646 and MCU 5 / AKH 98-81 demonstrated significantly desired standard heterosis for seed cotton yield and the component traits. The use of non-additive components in breeding programmes was thus found to be promising for improving yield in these crosses. These crosses can therefore be used to increase heterotic responsiveness.

Genotypic correlation for seed cotton yield exhibited positive and highly significant correlation with number of sympodia, number of bolls, boll weight, lint index, ginning out turn and for all fibre quality traits (**Fig. 1**). Similar findings were also reported by Chaudhari *et al*. (2017), Khokhar *et al*. (2017), Jarwar *et al.* (2019), Manonmani *et al.* (2019), Kumbhar *et al*.(2020) and Nisar *et al*. (2022). On the contrary, Amer *et al.* (2020) reported a negative correlation among seed cotton yield and fibre quality

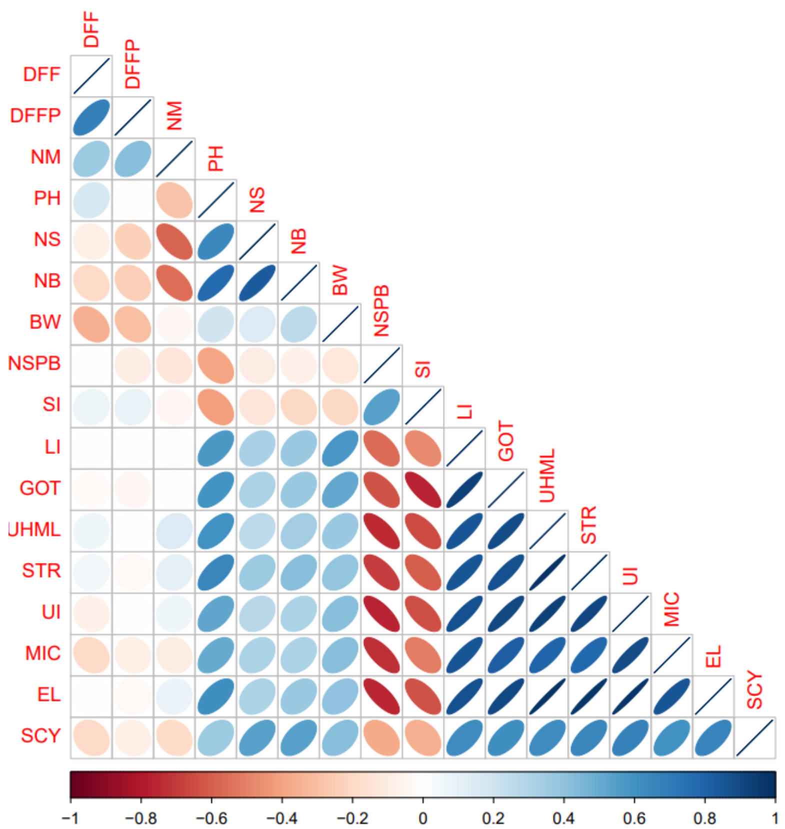

Fig. 1. Genotypic correlation between seed cotton yield and yield components and fibre quality traits

https://doi.org/10.37992/2023.1402.052

Table 5. Path coefficients between seed cotton yield with yield components and fibre quality traits

	DFF	DFFP	PH	NM	NS	NB	BW	NSPB	SI	LI	GOT	UHML	STR	UI	MIC	EL	SCY
DFF	**-0.0804**	0.2251	-0.0193	-0.1111	-0.0175	-0.0728	-0.0604	0.0019	0.2151	-0.0394	-0.1403	-0.0257	0.0105	0.0189	-0.0824	-0.013	-0.1908
DFFP	-0.0552	**0.3281**	-0.0228	0.0087	-0.0484	-0.0928	-0.0511	-0.0336	0.2686	0.0221	-0.316	0.0033	-0.007	0.0011	-0.0354	-0.0533	-0.0836
PH	-0.029	0.1399	**-0.0534**	0.1792	-0.1211	-0.208	-0.0073	-0.049	-0.1242	0.1058	-0.0627	-0.0661	0.0208	-0.0163	-0.044	0.1474	-0.188
NM	-0.014	-0.0045	0.015	**-0.6366**	0.1328	0.2899	0.0341	-0.1451	-1.1485	-3.1201	3.9467	-0.2531	0.1198	-0.1357	0.217	1.0693	0.367
NS	0.0068	-0.0769	0.0313	-0.4092	**0.2066**	0.3131	0.0261	-0.0382	-0.3845	-1.7554	2.0595	-0.1108	0.0661	-0.0698	0.137	0.5443	0.546
NB	0.0157	-0.0815	0.0297	-0.4941	0.1731	**0.3736**	0.0454	-0.0282	-0.5672	-2.0356	2.4654	-0.1449	0.0774	-0.0808	0.1372	0.6568	0.5421
BW	0.0285	-0.0985	0.0023	-0.1275	0.0316	0.0996	**0.1703**	-0.0459	-0.5582	-3.1868	3.4209	-0.1572	0.0714	-0.108	0.1836	0.6988	0.4249
NSPB	-0.0004	-0.0296	0.007	0.2486	-0.0212	-0.0283	-0.021	**0.3717**	1.5127	3.0324	-4.1901	0.3087	-0.1265	0.1968	-0.3165	-1.323	-0.3787
SI	-0.0063	0.0319	0.0024	0.2647	-0.0287	-0.0767	-0.0344	0.2035	**2.7628**	2.5873	-5.0508	0.2722	-0.1103	0.1656	-0.2217	-1.1125	-0.351
LI	-0.0006	-0.0013	0.001	-0.3674	0.0671	0.1406	0.1004	-0.2085	-1.322	**-5.4072**	6.1448	-0.3547	0.1551	-0.224	0.3679	1.5339	0.6251
GOT	0.0017	-0.0157	0.0005	-0.3803	0.0644	0.1394	0.0882	-0.2358	-2.112	-5.0289	**6.6072**	-0.3705	0.1587	-0.2305	0.3567	1.5732	0.6162
UHML	-0.005	-0.0026	-0.0085	-0.3873	0.055	0.1301	0.0643	-0.2759	-1.8073	-4.6105	5.8842	**-0.416**	0.179	-0.2401	0.3478	1.7141	0.6214
STR	-0.0047	-0.0126	-0.0061	-0.4188	0.0749	0.1587	0.0668	-0.2581	-1.6736	-4.6032	5.7557	-0.409	**0.1821**	-0.2348	0.3387	1.6984	0.6545
UI	0.0059	-0.0014	-0.0034	-0.3372	0.0563	0.1178	0.0718	-0.2856	-1.786	-4.7286	5.9474	-0.3901	0.1669	**-0.2561**	0.3862	1.7081	0.6721
MIC	0.0153	-0.0268	0.0054	-0.3198	0.0655	0.1186	0.0724	-0.2723	-1.4173	-4.6043	5.4541	-0.3349	0.1428	-0.2289	**0.4321**	1.5003	0.6023
EL	0.0006	-0.01	-0.0045	-0.3902	0.0644	0.1406	0.0682	-0.2819	-1.7618	-4.7539	5.9578	-0.4087	0.1773	-0.2508	0.3716	**1.7447**	0.6634

Residual effect - 0.3011

(DFF- Days to fifty per cent flowering, DFFP- Days to first boll opening, PH – Plant height, NM – Number of monopodia, NS- Number of sympodia, NB-Number of bolls, BW – Boll weight, NSPB – Number of seeds per boll, SCY- Seed cotton yield, SI- Seed index, LI- Lint index, GOT- Ginning out turn, UHML- Upper Half Mean Length, STR- Fibre strength, UI- Uniformity index, MIC-Micronaire value, EL- Elongation percentage) traits. The seed cotton yield also showed strong negative correlation with number of seeds per boll and seed index. Seed index was found to have a high negative correlation with ginning outturn, lint index, plant height as well as with all fibre quality traits, found on par with the findings of Nawaz *et al*. (2019). The lint index and ginning out turn had a significant positive correlation with all the fibre quality traits as well as with boll weight and plant height. Similar results were reported by Jarwar *et al*.(2019).

The interrelationships between the significant component traits are also crucial in determining which feature to be given more weight during selection. Analysis of the direct effect of various traits on seed cotton yield revealed that the traits like days to first boll opening, number of bolls, number of seeds per boll, ginning out turn and microniare value had expressed positive direct effects (**Table 5**). The traits *viz.,* days to fifty percent flowering, plant height, number of monopodia, lint index, fibre length and uniformity index registered negative direct effects on seed cotton yield. Similar results were reported by Reddy *et al*. (2015), Chaudhari *et al.* (2017), Nawaz *et al*. (2019) and Manonmani *et al.* (2019). On the contrary, Abdullah *et al.* (2016) reported a negative inter correlation among various yield and fibre quality traits.

Based on the study, the superior hybrids identified *viz.*, MCU5 / AKH98-81, CO17 / AKH98-81, CO17 / TCH1646 and CO14 / TCH1646 could be exploited for the production of better hybrids with better yield and fibre quality. Based on the study for trait association, number of sympodia, number of bolls, boll weight, lint index and ginning out turn were identified as selection indices which could be banked on for yield improvement in cotton. The study indicated the utilization of hybrids developed from fuzzless genotypes, which requires a lesser amount of energy and effort for ginning process, thus making the separation of fibres from seed faster and more cost-effective. Moreover, the proportion of fuzz to lint fibre per seed also determines the value of a cultivar on a commercial scale and these hybrids are with less amount of fuzz on seed coat. These seeds are more preferable for oil extraction, a by-product from cotton seed, as it eliminates the task of fuzz removal from seed coat before oil extraction. Considering all these facts the hybrids developed from the study will increase productivity and profitability for cotton farmers.

REFERENCES

Abdullah, M., Numan, M., Shafique, M. S., Shakoor, A., Rehman, S. and Ahmad, M. I. 2016. Genetic variability and interrelationship of various agronomic traits using correlation and path analysis in cotton (*Gossypium hirsutum* L.). *Academia Journal of Agricultural Research*, **4**(6): 315-318.

Amer, E. A., El-Hoseiny, H. A. and Hassan, S. S. 2020. Seed oil content, yield and fiber quality traits in some Egyptian cotton genotypes. *Journal of Plant Production,* **11**(12): 1469-1467. [Cross Ref]

Babu, B. Jaishankar, Satish, Y., Lal Ahamed, M. and Srinivasa Rao, V. 2018. Studies on heterosis in cotton (*Gossypium hirsutum* L.) for yield and fibre quality traits. *International Journal of Chemical Studies,* **6**(4): 1013-1018.

Baloch, A. W., Solangi, A. M., Baloch, M., Baloch, G. M. and Abro, S. 2015. Estimation of heterosis and heterobeltiosis for yield and fiber traits in F_1 hybrids of upland cotton (*Gossypium hirsutum* L.) genotypes. *Pakistan Journal of Agriculture, Agricultural Engineering and Veterinary Sciences,* **31**(2): 221-228.

Bilwal, B. B., Vadodariya, K. V., Rajkumar, B. K., Lahane, G. R. and Shihare, N. D. 2018. Combining ability analysis for seed cotton yield and its component traits in cotton (*Gossypium hirsutum* L.). *International Journal of Current Microbiology and Applied Sciences,* **7** (7): 3005-3010. [Cross Ref]

Chakholoma, M. A., Nimbal, S.O., Sangwan, O. M., Mor, V. and Jain, A. S. 2021. Studies on economic heterosis for yield and fibre quality traits in American cotton (*Gossypium hirsutum* L.). *Journal of Cotton Research and Development*, **35**(2):185-92.

Chaudhari, M., Faldu, G. and Ramani, H. J. A. I. B. 2017. Genetic variability, correlation and path coefficient analysis in cotton (*Gossypium hirsutum* L.). *Advanced Biomedical Research,* **8**(6): 226-233.

Dewey, D. R. and Lu, K. 1959. A correlation and path-coefficient analysis of components of crested wheatgrass seed production. *Agronomy journal*, **51**(9):515-518. [Cross Ref]

Erande, C. S., Kalpande, H. V., Deosarkar, D. B. Chavan., S. K., Patil, V. S., Deshmukh, J. D., Chinchane, V. N. , Anil Kumar, Utpal Dey and Puttawar, M. R. 2014. Genetic variability, correlation and path analysis among different traits in desi cotton (*Gossypium arboreum* L.).*African Journal of Agriculture Research,* **9**(29): 2278-2286. [Cross Ref]

Fang, D.D., Naoumkina, M. and Kim, H.J. 2018. Unraveling cotton fiber development using fiber mutants in the post-genomic era. *Crop Science*, **58**(6):2214-2228. [Cross Ref]

Fonseca, S. and Patterson, F. L. 1968. Hybrid vigour in seven parent diallel cross in common wheat (Triticum aestivum L.). Crop Sci., 8: 85-88. [Cross Ref]

Giri, R. K., Verma, S. K. and Yadav, J. P. 2021. Study of heterosis, combining ability and parental diversity for seed cottonyield and contributing traits using diallel data in cotton (*G. hirsutum* L.). *Indian Journal of Agricultural Research,* **55** (5): 556-562. [Cross Ref]

Gnanasekaran, M., Thiyagu, K. and Gunasekaran, M. 2019. Combining ability and heterosis studies for seed cotton yield and fibre quality traits in hirsutum cotton. *Electronic Journal of Plant Breeding,* **10**(4): 1519-1531. [Cross Ref]

Jarwar, A. H., Wang., X., Iqbal., M. S., Sarfraz., Z., Wang., L. Ma., Q. and Shuli, F. 2019. Genetic divergence on the basis of principal component, correlation and cluster analysis of yield and quality traits in cotton cultivars.*Pakistan Journal of Botony*, **51**(3): 1143-1148. [Cross Ref]

Khokhar, E. S., Shakeel, A., Maqbool, M. A., Abuzar, M. K., Zareen, S., Syeda, S. A. and Asadullah, M. 2018. Studying combining ability and heterosis in different cotton (*Gossypium hirsutum* L.) genotypes for yield and yield contributing traits. P*akistan Journal of Agricultural Research*, **31**(1):55-68. [Cross Ref]

Khokhar, E. S., Shakeel, A., Maqbool, M. A., Anwar, M. W., Tanveer, Z. and Irfan, M. F. 2017. Genetic study of cotton (*Gossypium hirsutum* L.) genotypes for different agronomic, yield and quality traits. *Pakistan Journal of Agricultural Research*, **30**(4): 363-372. [Cross Ref]

Kumbhar, Z. M., Jatoi, W. A., Sootaher, J. K., Baloch, M. I., Gadahi, A. A., Menghwar, K. K., Chang, M. S. and Kachi, M. 2020. Studies on correlation and heritability estimates in upland cotton (*Gossypium hirsutum* L.) genotypes under the agro-climatic conditions of Tandojam, Sindh, Pakistan. *Pure and Applied Biology*, **9** (4): 2272–8. [Cross Ref]

Manonmani, K., Mahalingam, L., Malarvizhi, D., Sritharan, N. and Premalatha, N. 2019. Genetic variability, correlation and path analysis for seed cotton yield improvement in upland cotton (*Gossypium hirsutum* L.). *Journal of Pharmacognosy and Phytochemistry*, **8** (4): 1358-1361.

Marani, A. 1967. Heterosis and combining ability in intraspecific and interspecific crosses of cotton1. *Crop Science*, **7**(5): 519-522. [Cross Ref]

McCarty, J. C., Wu, J. and Jenkins, J. N. 2008. Genetic association of cotton yield with its component traits in derived primitive accessions crossed by elite upland cultivars using the conditional ADAA genetic model. *Euphytica,* **161** (2): 337-352. [Cross Ref]

Mudhalvan, S., Rajeswari, S., Mahalingam, L., Jeyakumar, P., Muthuswami, M. and Premalatha, N. 2021. Combining ability estimates and heterosis analysis on major yield attributing traits and lint quality in American cotton (*Gossypium hirsutum* L.). *Electronic Journal of Plant Breeding*, **12** (4): 1111-1119. [Cross Ref]

Nawaz, B., Sattar, S. and Malik, T. A. 2019. Genetic analysis of yield components and fiber quality parameters in upland cotton. *International Multidisciplinary Research Journal*, **9** (9):13-19.

Nisar, S., Khan, T. M., Iqbal, M. A., Ullah, R., Bhutta, M. A., Ahmad, S. and Ishaq, M. Z. 2022. Assessment of yield contributing quantitative traits in upland cotton (*Gossypium hirsutum*.L). *Sarhad Journal of Agriculture*, **38**(1): 353-359. [Cross Ref]

Panse, V. G. and Sukhatme, P. V. 1985. Statistical method for agricultural workers. ICAR Publication, New Delhi, pp. 97-151.

Reddy, K. B., Chenga Reddy, V., Ahamed, M. L., Naidu, T. C. M. and Srinivasarao, V. 2015. Correlation and path coefficient analysis in upland cotton (*Gossypium hirsutum* L.). *Journal of Research ANGRAU,* **43** (2):25-35.

Salahuddin, S., Abro, S., Rehman, A. and Iqbal, K. 2010. Correlation analysis of seed cotton yield with some quantitative traits in upland cotton (*Gossypium hirsutum* L.). *Pakistan Journal of Botony*, **42**(6):3799-3805.

Sawarkar, M., Solanke, A., Mhasal, G. S. and Deshmukh, S. B. 2015. Combining ability and heterosis for seed cotton yield, its components and quality traits in *Gossypium hirsutum* L. *Indian Journal of Agricultural Research*, **49**(2): 154-159. [Cross Ref]

Snedecor, G. W. and Cochran, W. G. 1967. Statistical Methods. The Iowa State College Press, Ames, Iowa. U.S.A. 160-413.

Swaminathan, M. S., Siddiq, E. A. and Sharma, S. D. 1971. Outlook for hybrid rice in India.*Current Science,* **2** (1): 391-393.

Thiyagu, K., Gnanasekaran, M. and Gunasekaran, M. 2019. Combining ability and heterosis for seed cotton yield, its components and fibre quality traits in upland cotton (*Gossypium hirsutum* L.). *Electronic Journal of Plant Breeding*, **10** (4):1501-1511. [Cross Ref]

Unay, A., Nedim. O. and Cinar, V. M. 2019. Line x tester analysis for yield and fiber quality in cotton (*Gossypium hirsutum* L.). *Turkish Journal of Field Crops*, **24** (2): 215-220. [Cross Ref]

Yehia, W. M. B., Abdelbary, A. M., Mohamed, A. A., Kotb, H. M. K. and Sherif, M. M. 2023. Heterosis and estimation of general and specific combining ability as base for selected superior recombination of the some crossed cotton genotypes. *Asian Journal of Biochemistry, Genetics and Molecular Biology,* **13** (1): 1-10. [Cross Ref]