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GENETIC ANALYSIS OF F_1 AND F_2 GENERATIONS FOR EARLY MATURE, YIELD AND FIBRE TRAITS IN UPLAND COTTON (*GOSYPIUM HIRSUTUM* L.)

GHULAM MURTAZA CHANNA[1,2*], ZAHOOR AHMED SOOMRO[2] AND TANWEER FATAH ABRO[2]

[1]*Agriculture Research Sind, Tandojam, Agriculture Supply & Prices Department, Sindh, Pakistan*
[2]*Department of Plant Breeding & Genetics, Sindh Agriculture University, Tandojam, Sindh, Pakistan*
**Corresponding author email: gmcchanna@gmail.com*

Abstract

The Current study was conducted to genetically analysis the F_1 and F_2 generation for early mature, yield and fibre traits in upland cotton. During the studied parents, F_1 and F_2were highly significant confirming the presence of variation among the genotypes. The parents MNH-886 and CRIS-342 recorded with highest mean performance. In F_1 and F_2, generally, it could be concluded that the parent IR-3701 and MNH-886 were the best combiners for many traits. The Specific Combining Ability (SCA) effects showed the excellent combinations for direct and reciprocal crosses i.e. plant height MNH-886 x CRIS-342; for no. of nodes to first fruiting branch IR-3701 x CRIS-342; for no. of days to first square MNH-886 x Bakhtawar; no. of days to 1st flower Bakhtawar x CRIS-342; for no. of sympodia plant^{-1}Bakhtawar x CRIS-342; for earliness index IR-3701 x Bakhtawar; for days to 1st open bolls MNH-886 x Bakhtawar; Boll maturation period (BMP) Sindh-1 x CRIS-342; no. of boll at 90 days MNH-886 x Sindh-1; for no. of bolls plant^{-1} IR-3701 x CRIS-342; for seed yield plant^{-1} Sindh-1 x CRIS-342; for GOT% MNH-886 x IR-3701; staple length IR-3701 x Bakhtawar. Thus, these parents, and hybrids for selection of early and yield-related traits in later generations could be utilized to the improvement of yield-related traits in short duration seasons in the cotton breeding programs under variable weather conditions for maximizing cotton production.

Key words: Upland cotton, Hybrids, Combining ability, Climate change, Mean performance.

Introduction

The cotton fiber plant (*G. hirsutum* L.) is an allotetraploid perennial plant (2n=4x=52) of the family *Malvaceae* of indeterminate growth. The genus *Gossypium* comprises about 50 species including 45 diploids (2n=2x=26) and 5 tetraploids (2n=4x=52). The cultivated types of cotton include two diploids, *G. arboretum* L. and *G. herbaceum* L., tetraploidi, *G. hirsutum* L. *G. barbadense* L. upland cotton(*G. hirsutum* L.) is the most widely cultivated tetraploid cotton species and accounts for 95% of the world's cotton production.

The Cotton is an important exportable crop of Pakistan, and played a vital role in boost up the economy. In 2020-21, the crop was cultivated over 2,079,000 hectares, with a reduction of 17.4% as compared to last year's of 2,517 thousand hectares (Khalid *et al.*, 2022).

Pakistan ranked 6thin the major producer of Cotton lint (Anon., 2022) due to massive decline of non-availability of improved varieties of cotton crop production, and increase prices of cost of production, as major challenges. Beside this the crop also facing pests, and diseases, biotic stresses of whitefly and pink bollworm, abiotic stresses like climate change, heat stress and extreme rainfalls; poor agricultural practices, and excess uses of pesticides.

In Pakistan wheat crop is delayed due to cotton crop. It is grown over 2.8 million hectares which covers 33% (Anonymous, 2014). Due to delayed of cropping of wheat crop after 15th November, causing 42 Kg ha^{-1} loss of wheat day per day (Khan, 2003). The early mature varieties promote in double cropping pattern, especially in Cotton cropping zones of the country assists more favorable conditions, escape losses occurred by late-season insect infestation, reduce minimum use irrigation water, fertilizer, and chemical pesticide. Short-lived cotton cultivars can avoid yield losses due to disease and pest complexes. Therefore, taking into account the suggestions of another possibility of saving the cotton crop is through breeding early maturing varieties. Growing such cultivars will not only reduce pesticide use, but expenses incurred for other inputs such as irrigation water and fertilizers will also be reduced.

The plant breeder makes extensive use of diallel analysis for the selection of parents, and their hybrids in combining ability in early generations. Suitable selection of parents and their hybrids by the plant breeder, also leads early generation by the plant breeders which is determined by the combining, and diallel analysis. Meteorological data suggested cotton yield can be affected significantly due to irregular precipitation, temperature, humidity and wind velocity.

The agricultural sector in Pakistan is vulnerable due to un-precedent of climate change especially in cotton growing areas (Ali and Erenstein, 2017). The cotton crop is continuously shifted in vegetative, and reproductive phases due to its indeterminate growth pattern, as well as extreme weather with management techniques (Zhang *et al.*, 2008; Amin *et al.*, 2018).

Material and Methods

Current research was conducted at CRI, Agriculture Research Centre, Tandojam by using five (05) parents i.e., MNH-886, Sindh-1, IR-3701, CRIS-342, and Bakhtawar collected from a reputable institutes of country (Pakistan) in full diallel mating design with 20 genotypes. The analysis of variance for different morphological traits including i.e. plant height (cm), no. of node first fruiting branch, no. of days to 1st square, no. of days to 1st flower, no. of sympodia plant^{-1}, earliness index, days to 1st open boll (DFOB), BMP, no. of bolls to open at 90 days, no. of bolls to open at 120 days, no. of bolls plant^{-1}, seed yield plant^{-1} (g), ginning outturn (GOT) (%), seed Index /100-seed weight (g), lint index /100-seed weight (g), staple length (mm).

Parents:

Name of variety	Year of release	Centre of release
MNH-886	2012	*CRI, Multan
Sindh-1	2010	*CRI, Tandojam
IR-3701	2010	Nuclear Institute of Biotechnology and Genetic Engineering (NIBGE), Faisalabad
CRIS-342	2010	Central Cotton Research Institute (CCRI), Sakrand
Bakhtawar	2016	*CRI, Tandojam

*Cotton Research Institute

Statistical analysis: The collected data of $F_1$and F_2 generation were analyzed for analysis of variance (ANOVA) using the formula of Gomez & Gomez (1984), and the mean of genotypes are compared with Ducan Multiple Range Test (DMRT). Genetic analysis of parents and their F_1& F_2 genotypes were carried out for determining GCA, and SCA according to Griffing's numerical approach (1956) Method-I (Model-I).

Estimating genetic variance components:

Variance Components	Model-I
σ^2_{gca}	$\frac{1(MS_{gca}-MS_e)}{2rp}$
σ^2_{sca}	$\frac{1(MS_{Sca}- MS_e)}{2r}$
σ^2_m	$\frac{1(MS_m- MS_e)}{2rp}$
σ^2_r	$\frac{1(MS_r- MS_e)}{2r}$
σ^2_p	$2\sigma^2_{gca}+\sigma^2_{sca}+\frac{2\sigma^2_m}{R}+\sigma^2_r+\sigma^2_e$
σ^2_A	$2\sigma^2_{gca}$
σ^2_D	$2\sigma^2_{sca}$
σ^2_b	$\frac{\sigma^2_A+\sigma^2_D}{\sigma^2_p}$
h^2_n	$\frac{\sigma^2_A}{\sigma^2_p}$

Where,
gca = general combining ability effects
sca = specific combining ability effects
r = residual effects
p = phenotypic effects
D= dominant effects
A= additive effects

The meteorological data for three years (2018, 2019, and 2020) were collected from the Regional Agromet Centre (RAMC), Tandojam for temperature (ºC); relative humidity (%); wind speed(knots), and rainfall (mm).

Estimation of morphological traits

Plant height (cm): Plant height was measured as the distance between the base of the plant and the apex of the plant at maturity using the meter rule.

No. of node first fruiting branch: The number of the main stem node at which the first fruiting branch arises has been determined by counting nodes consecutively up the stem above the cotyledonary node.

No. of days to 1st square: The number of days from planting to appearances of 1st square of size was easily observed by the naked eye.

No. of days to 1st flower: The no. of days to 1st flower was observed as the number of days from planting to the appearance of the first flower.

No. of sympodia plant^{-1}: The number of sympodia plant^{-1} was recorded as the number of branches that are extra auxiliary in position and normally horizontal with a zig-zag pattern of the fruiting point at maturity. The numbers of such sympodia on the main stem were counted and recorded at maturity.

Earliness index: The earliness index was observed with the number of days from sowing to completion of flowering at the 1st 30 primary sites.

Days to first open boll (DFOB): The number of days from planting to the opening of the 1st boll based on periodic observation has been observed.

Boll maturation period (BMP): The boll maturation period was recorded with a length of time between flower opening and opening of the mature boll or time from anthesis of the flour until the resulting boll is sufficiently open to see the lint.

No. of days to open bolls at 90 days: The number of days from planting to 90 days opening of the bolls based on periodic observation were recorded.

No. of days to open bolls at 120 days: The number of days from planting to 120 days opening of the bolls based on periodic observations were recorded.

No. of bolls plant^{-1}: The number of boll plant^{-1} was recorded as the number of bolls that contributed to seed cotton yield at the time of harvest.

Seed yield plant (g): The total weight of the seed cotton, lint, or the number of bolls plant^{-1}, harvested at a specified date during a sequential harvest period, was expressed as seed cotton yield.

Ginning outturn (GOT) (%): Ginning out turn (GOT%) was recorded as the weight of the lint, and expressed as a percentage of the weight of seed cotton.

Seed index/100-seed weight (g): Seed index was recorded as the absolute weight of lint obtained from 100 seeds in grams.

Lint index/100-seed weight (g): Lint index was recorded as the absolute weight of lint obtained from 100 seeds in grams.

Staple length (mm): Staple length was recorded as the distance spanned by a specified percentage of fibers in the specimen being tested and expressed in millimeters.

Table 1. Analysis of variance (ANOVA) due to GCA & SCA for various morphological traits in 5 x 5 F_1 diallel cross of *Gossypium hirsutum* L.

Source of variation	d.f.	Plant height (cm)	No. of node first fruiting branch	No. of days to 1st square	No. of days to 1st flower	No. of sympodia $plant^{-1}$	Earliness index	Days to first open boll (DFOB)	Boll maturation period (BMP)	No. of bolls to open at 90 days
Replication	3	84.77	0.402	0.05	1.12	13.68	2.40	1.65	0.16	71.47
Genotypes	24	881.52	2.56	16.42	28.26	113.34	18.18	52.19	15.52	29.84
GCA	4	1079.45	1.35	3.19	13.76	81.30	23.80	16.24	17.16	52.38
SCA	10	602.81	3.28	22.82	26.84	79.78	16.72	54.60	14.73	15.49
Reciprocal	10	1081.06	2.32	15.32	35.47	159.71	17.38	64.16	15.65	35.17
Error	72	11.50	0.68	1.31	2.36	2.86	1.80	4.02	0.74	1.58

Table 2. Analysis of variance (ANOVA) due to GCA & SCA for various morphological traits in 5 x 5 F_1 diallel cross of *Gossypium hirsutum* L.

Source of variation	d.f.	No. of bolls to open at 120 days	No. of bolls $plant^{-1}$	Seed yield plant (g)	Ginning outturn (GOT) (%)	Seed index /100-seed weight (g)	Lint index /100-seed weight (g)	Staple length (mm)
Replication	3	14.65	10.096	69.66	0.88	0.29	0.08	0.02
Genotypes	24	675.83	403.89	2753.59	12.95	6.55	0.76	6.92
GCA	4	1536.12	539.05	4118.14	20.70	5.34	0.42	10.35
SCA	10	213.13	160.31	1490.38	7.11	4.39	0.79	5.21
Reciprocal	10	794.42	593.42	3470.98	15.69	9.20	0.87	7.26
Error	72	4.15	6.68	31.78	1.69	0.15	0.03	0.56

Table 3. Analysis of variance (ANOVA) due to GCA & SCA for various morphological traits in 5 x 5 F_2 diallel cross of *Gossypium hirsutum* L.

Source of variation	d.f.	Plant height (cm)	No. of node first fruiting branch	No. of days to 1st square	No. of days to 1st flower	No. of sympodia $plant^{-1}$	Earliness index	Days to first open boll (DFOB)	Boll maturation period (BMP)	No. of bolls to open at 90 days
Replication	3	88.34	0.66	2.483	0.95	17.40	0.86	0.93	0.76	0.03
Genotypes	24	828.69	2.99	56.47	46.32	86.89	29.67	58.04	15.04	21.64
GCA	4	1374.09	3.10	43.40	25.62	27.79	22.34	22.77	20.42	50.06
SCA	10	625.20	2.15	38.97	45.82	85.33	39.05	64.74	11.52	5.73
Reciprocal	10	814.01	3.77	79.19	55.09	112.10	23.22	65.45	16.41	26.17
Error	72	6.54	0.19	2.95	1.37	2.95	2.17	1.60	5.80	0.09

Table 4. Analysis of variance (ANOVA) due to GCA & SCA for various morphological traits in 5 x 5 F_2 diallel cross of *Gossypium hirsutum* L.

Source of variation	d.f.	No. of bolls to open at 120 days	No. of bolls $plant^{-1}$	Seed yield plant (g)	Ginning outturn (GOT) (%)	Seed index /100-seed weight (g)	Lint index /100-seed weight (g)	Staple length (mm)
Replication	3	22.47	25.53	46.06	0.84	0.254	0.03	0.030
Genotypes	24	607.79	449.73	3108.98	8.97	7.09	0.90	4.77
GCA	4	1419.42	762.59	5465.94	14.44	15.39	1.32	6.41
SCA	10	182.83	210.99	2318.31	5.06	5.46	0.85	4.09
Reciprocal	10	708.09	563.32	2956.87	10.69	5.40	0.79	4.79
Error	72	3.76	8.09	34.86	1.62	0.09	0.02	0.52

Results and Discussion

Analysis of variance (ANOVA): The ANOVA for five parents and twenty (20) genotypes for early mature, yield and fiber-related traits are highly significant resulted in deviation of genotypes for morphological traits in F_1& F_2 generation (Tables 1-4), respectively.

Mean performance: The results for mean performance for GCA, and SCA for parents, and hybrids in F_1, and F_2 is shown in Figs.1-16, respectively indicating that parents MNH-886, recorded with high performance for no. of sympodia $plant^{-1}$ (34.56; 33.35; 35.00), earliness index (69.20%; 69.65, 71.38), no. of bolls open at 90 days (31.82; 28.28; 25.81) , No. of bolls open at 120 days (52.19; 68.26; 61.68) , no. of bolls $plant^{-1}$ (72.59; 76.65; 78.67) seed cotton yield $plant^{-1}$ (160.97 g; 171.06 g; 167.51g), Seed index/100 seed weight (8.01g; 8.20 g; 8.85g), respectively. Whereas, only high lint index /100-seed weight (3.26 g; 4.38 g), were reported during 1st and 2nd year of experiments. Furthermore, the parent MNH-886 also showed significant over minimum number of nodes to first fruiting branch (4.88; 4.11; 3.69), no. of days to 1st square (30.69; 29.95; 30.10), no of days to 1st flower (38.94; 37.80; 38.12), days to 1st open boll (68.64; 70.66; 70.16), respectively during 1st, 2nd and 3rd year. While only minimum BMP 38.44 and 39.80 were recorded during the 1st and 2nd year, respectively. For CRIS-342, the highest mean performance for plant height (128.55 cm; 129.29; 132.76 cm), and staple length (29.87 mm; 29.87 mm; 29.56 mm) were recorded by 1st, 2nd year and 3rd year respectively also reported maximum lint index 100-seed weight (4.02), staple length (29.56 mm), and minimum days to BMP (39.98) were recorded during the 3rd year of experiment. During the 1st, 2nd and 3rd year in Sindh-1 with high GOT% (41.35%) in 1st year. Mokadem *et al.*, 2016, Carvalho *et al.*, 2018, Swetha *et al.*, 2018, Munir *et al.*, 2018, Khokhar *et al.*, 2018, Rajeev *et al.*, 2018, Aref *et al.*, 2019, Mokadem *et al.*, 2019, Sirisha *et al.*, 2019 and Yehia *et al.*, 2019 reported significant mean performance due to GCA and SCA for these traits.

In F_1 direct crosses recorded better performance over the reciprocal crosses for all the traits studied. However, hybrid MNH-886 x Bakhtawar showed better mean values for no. of nodes to first fruiting branch (4.41), No. of days to 1st square (29.85), No. of days to 1st flower (38.01), earliness index (72.11), days to 1st open boll (69.12), BMP (38.30), no. of bolls to open boll at 90 days (34.07) and no. of bolls to open at 120 days (77.46). Whereas, highest means values for plant height were recorded by MNH-886 x CRIS-342 (148.38 cm) and MNH-886 x IR-3701 was observed maximum sympodia plant^{-1} (44.75). While MNH-886 x Sindh-1 showed maximum no. of boll plant^{-1} (85.59) increases highest seed yield plant^{-1} (186.86 g), seed index /100 seed weight (9.68 g), and staple length (30.33 mm). The highest GOT% was recorded by MNH-886 x IR-3701 (41.73%). While, IR-3701 x Bakhtawar showed maximum lint index/100 seed weight (4.54 g). The results are also in general agreement with those reported by Mokadem *et al.*, 2016, Carvalho *et al.*, , 2018, Swetha *et al.*, , 2018, Munir *et al.*, 2018, Khokhar *et al.*, 2018, Rajeev *et al.*, 2018, El-Aref *et al.*, 2019, Mokadem *et al.*, 2019, Sirisha *et al.*,2019, Yehia *et al.*, 2019. For F_2 hybrids direct crosses also showed better performance over reciprocal crosses in many traits under studied except days to 1st square, days to 1stflower and ginning outturn%. However, among twenty genotypes MNH-886 x IR-3701 and MNH-886 x Bakhtawar recorded better performances for no. of nodes to first fruiting branch (4.39; 5.71), No. of days to first square (27.61; 28.03), no. of days to 1stflower (36.93; 37.27), earliness index (74.00%; 73.52%) respectively.In F_2 hybrids MNH-886 x Bakhtawar was also showed better performance for days to 1st square (67.38), BMP (38.05), No. of boll to open at 90 days (31.07), no. of bolls opens at 120 days (67.70), no. of boll plant^{-1} (93.14) followed by MNH-886 x CRIS-342 (83.42) increase seed yield plant^{-1} (195.45 g; 191.37 g), respectively. Similar findings are in accordance with those obtained by Mokadem *et al.*, 2016, Carvalho *et al.*, 2018, Swetha *et al.*, 2018, Munir *et al.*, 2018, Khokhar *et al.*, 2018, Rajeev *et al.*, 2018, Aref *et al.*, 2019, Mokadem *et al.*, 2019, Sirisha *et al.*, 2019, and Yehia *et al.*, 2019.

General combining ability effects (GCA) & specific combining ability (SCA) estimates: The GCA, and SCA effects of the parents, and Hybrids F_1 and F_2 generation for earliness and yield component traits are shown in Tables 5-8, respectively. In F_1 and F_2, generally concluded that the parent IR-3701 was a best combiner for plant height (-7.49; -10.19), BMP (-0.68; -0.84), Seed yield (8.41; 11.38) and lint index /100 seed weight (0.15; 0.15), respectively, except Seed index/100 seed weight (0.38) in F_1 and no. of boll plant^{-1} (4.03) and lint index/100 seed weight (0.15) in F_2. However, Bakhtawar was the best combiner for no. of nodes to first fruiting branch (-0.29), earliness index (-0.71) was also recorded same by MNH-886 as well as stable length (0.48) in F_1 and Bakhtawar was found best combiner for no. of sympodia (0.96) in F_2 population. Whereas, Sindh-1 was the best combiner for days to 1st square (-0.48; -1.55), no. of days to 1st flower (-0.99; -1.06), days to 1st open bolls (-0.87; -0.86), GOT% (0.81; 0.57) in F_1 and F_2 population, respectively. While, no. of bolls plant^{-1} (3.01)only in F_1; seed index/100 seed weight (0.61), staple length (0.54) only in F_2 population. Beside this, CRIS-342 was recorded best combiner for no. of bolls to open 90 days (-1.18; -0.97) and no. of bolls open at 120 days (-8.62; -8.44) were recorded as best general combiner in F_1 and F_2 population, respectively. SCA effects showed the excellent specific combinations for direct and reciprocal crosses in F_1 population which were as follow; for plant height MNH-886 x CRIS-342 (-14.58) and CRIS-342 x MNH-886 (-16.37); for no. of nodes to first fruiting branch IR-3701 x CRIS-342 (-0.69) and Bakhtawar x MNH-886 (-1.14); for no. of days to 1st square MNH-886 x Bakhtawar (-1.62) and IR-3701 x MNH-886 (-2.36); no. of days to 1st flower Bakhtawar x CRIS-342 (-1.40) and IR-3701 x MNH-886 (-4.14); for no. of sympodia plant^{-1} Bakhtawar x CRIS-342 (3.46) and Bakhtawar x Sindh-1 (8.18); for earliness index IR-3701 x Bakhtawar (-2.01) and Sindh-1 x MNH-886 (-3.99); for days to 1st open bolls MNH-886 x Bakhtawar (-2.19); IR-3701 MNH-886 (-5.01); BMP Sindh-1 x CRIS-342 (-1.42) and IR-3701 x MNH-886 (-2.47); no. of boll at 90 days MNH-886 x Sindh-1 (-2.25) and Sindh-1 x MNH-886 (-4.62); no. of bolls at 120 days MNH-886 x Sindh-1 (-5.20) and Sindh-1 x MNH-886 (-12.44); for no. of bolls plant^{-1} IR-3701 x CRIS-342 (5.70) and CRIS-342 x Sindh-1 (11.83); for seed yield per plant Sindh-1 x CRIS-342 (12.93) and IR-3701 x Sindh-1 (21.71); for GOT% MNH-886 x IR-3701 (1.85) and IR-3701 x MNH-886 (2.13); Seed index /100 seed weight MNH-886 x Bakhtawar (0.41) and IR-3701 x Sindh-1 (0.89); Sindh-1 x CRIS-342 (0.29); IR-3701 x Sindh-1 (0.4); staple length IR-3701 x Bakhtawar (0.69) and CRIS-342 x IR-3701 (1.69), respectively. An excellent SCA was showed by both direct and reciprocal crosses in F_2 population are as follow; for plant height MNH-886 x CRIS-342 (-14.87) and IR-3701 x Sindh-1 (-11.30); for no. of nodes to first fruiting branch Sindh-1 xIR-3701 (-0.38) and CRIS-342 x Bakhtawar (-1.31); for no. of days to 1st square and no. of days to 1st flower Bakhtawar x CRIS-342 (-1.74 and -2.05); for no. of sympodia plant^{-1} Sindh-1 x IR-3701 (2.27) and Sindh-1 x MNH-886 (4.11); for earliness index IR-3701 x Bakhtawar (-3.60) and IR-3701 x Sindh-1(-1.65); for days to 1st open bolls MNH-886 x Bakhtawar (-2.50); Sindh-1 x MNH-886 (-3.60); BMP Sindh-1 x CRIS-342 (-2.21) and Bakhtawar x Sindh-1 (-1.56); no. of boll at 90 days IR-3701 x Bakhtawar (-1.09) and Bakhtawar x MNH-886 (-3.55); no. of bolls at 120 days Bakhtawar x CRIS-342 (-5.16) and Bakhtawar x Sindh-1 (-13.37); for no. of bolls plant^{-1} MNH-886 x Bakhtawar (4.70) and Sindh-1 x MNH-886 (10.11); for seed yield plant^{-1} Sind-1 x CRIS-342 (16.80) and Sindh-1 x MNH-886 (33.75); for GOT% Bakhtawar x CRIS-342 (0.93) and Sindh-1 x MNH-886 (2.08); for seed index /100 seed weight MNH-886 x Bakhtawar (0.83) and CRIS_342 x MNH-886 (1.22); for lint index /100 seed weight Sindh-1 x CRIS-342 (0.83) and CRIS-342 x MNH-886 (0.24); for staple length MNH-886 x Sindh-1 (0.40 and 0.76) (Table 6 and 8).

This findings indicating the present of a considerable genetic variability between genotypes, hence subsequent analysis for combining ability were performed by Swetha *et al.*, 2018, Khokhar *et al.*, 2018, Rajeev *et al.*, 2018, Aref *et al.*, 2019, Mokadem *et al.*, 2019, Sirisha *et al.*, 2019, Yehia *et al.*, (2019).

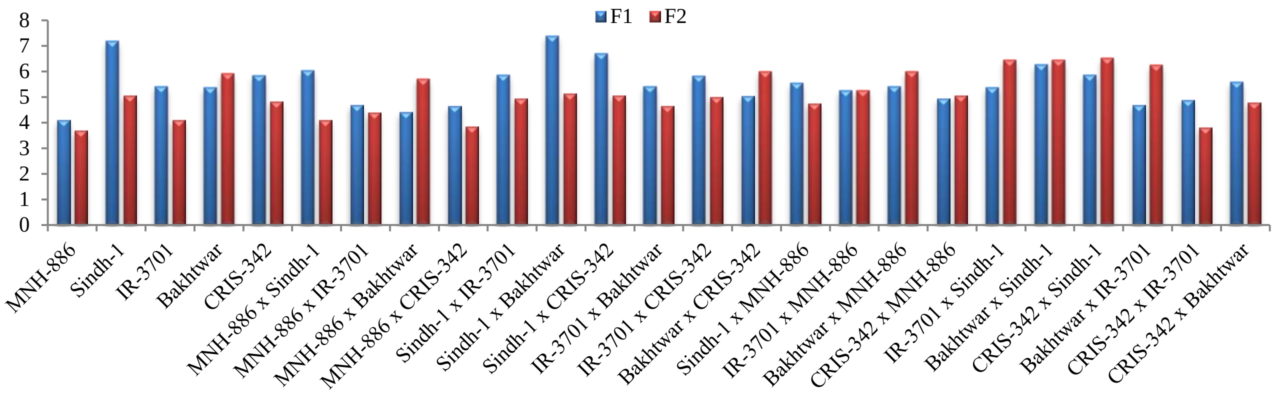

Fig. 1. Mean performance of F_1 and F_2 for no. of node first fruiting branch.

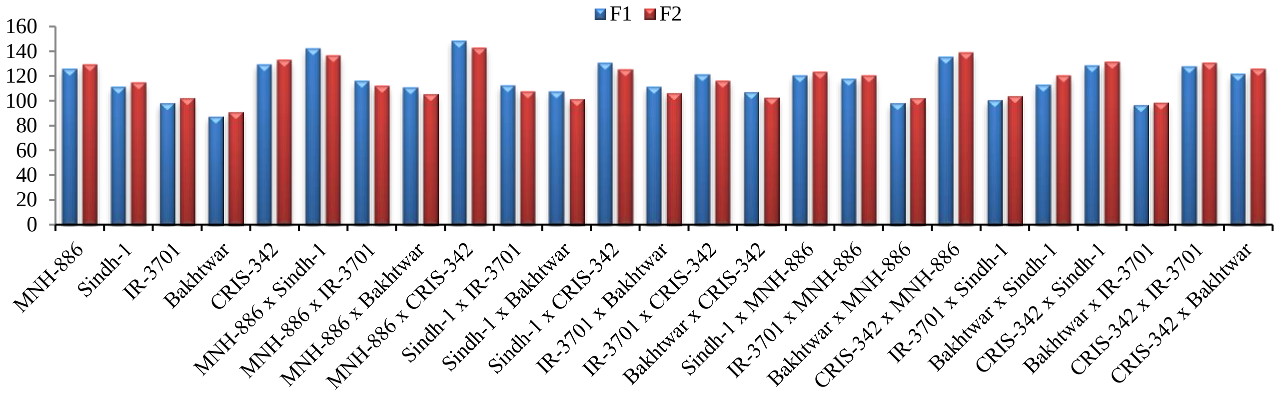

Fig. 2. Mean performance of F_1 and F_2 for plant height (cm).

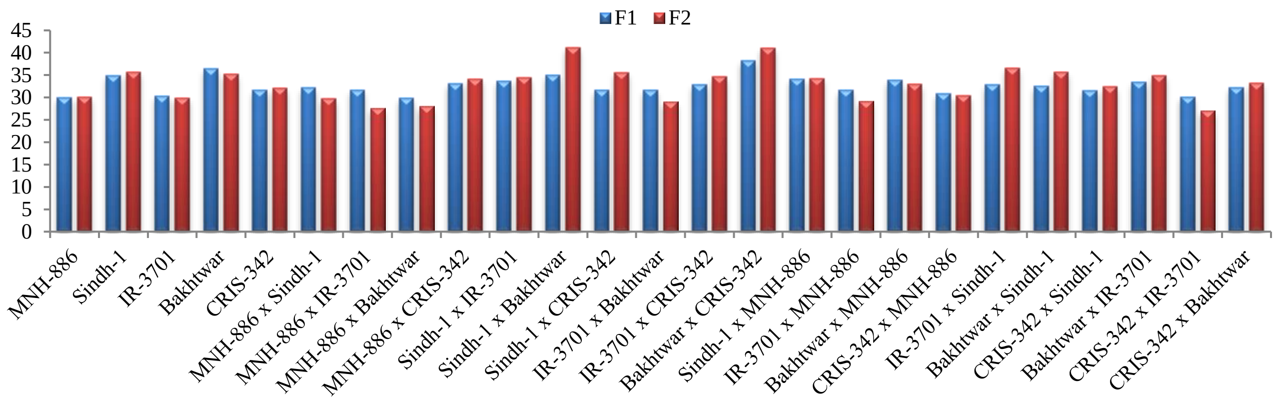

Fig. 3. Mean performance of F_1 and F_2 for no. of days to 1st square.

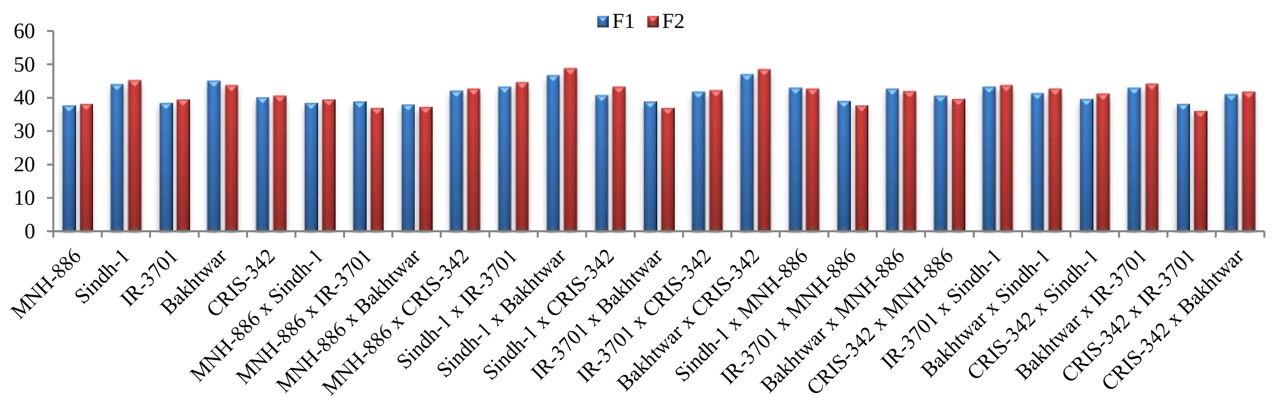

Fig. 4. Mean performance of F_1 and F_2 for no. of days to 1st flower.

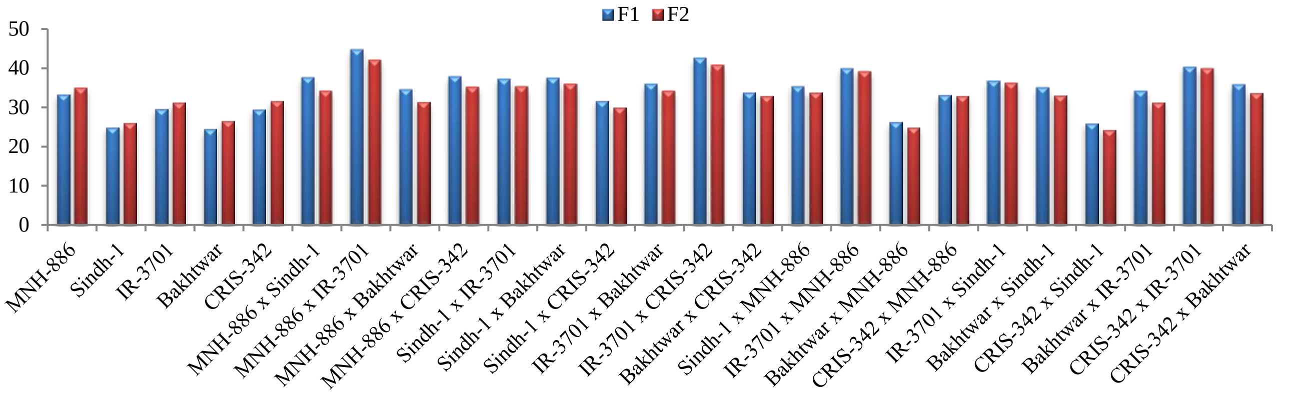

Fig. 5. Mean performance of F_1 and F_2 for no. of sympodia plant^{-1}.

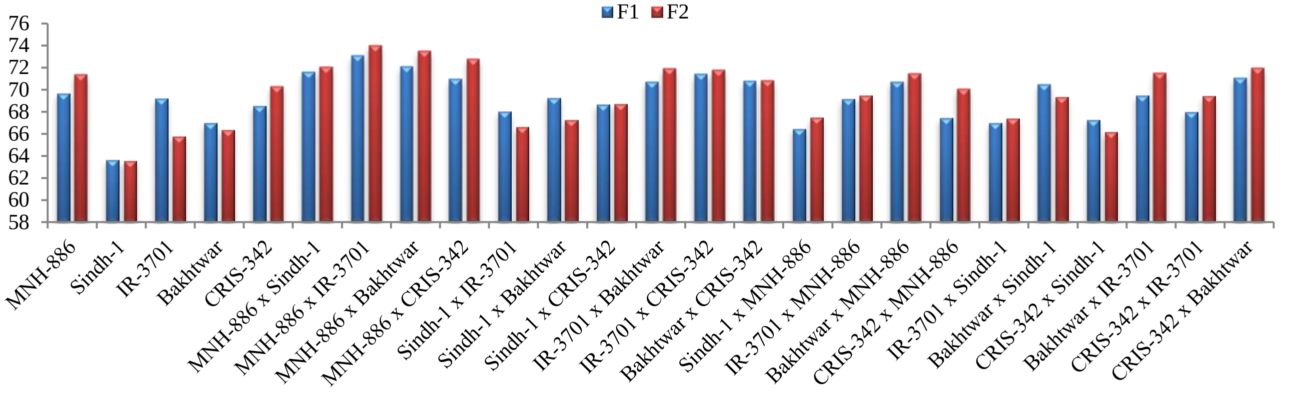

Fig. 6. Mean performance of F_1 and F_2 for earliness index (%).

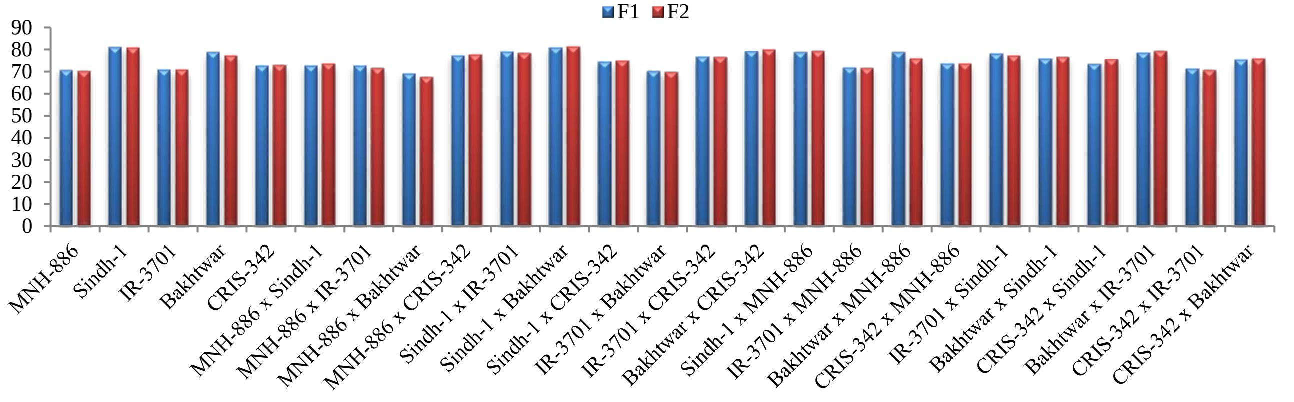

Fig. 7. Mean performance of F_1 and F_2 for days to first open boll (DFOB).

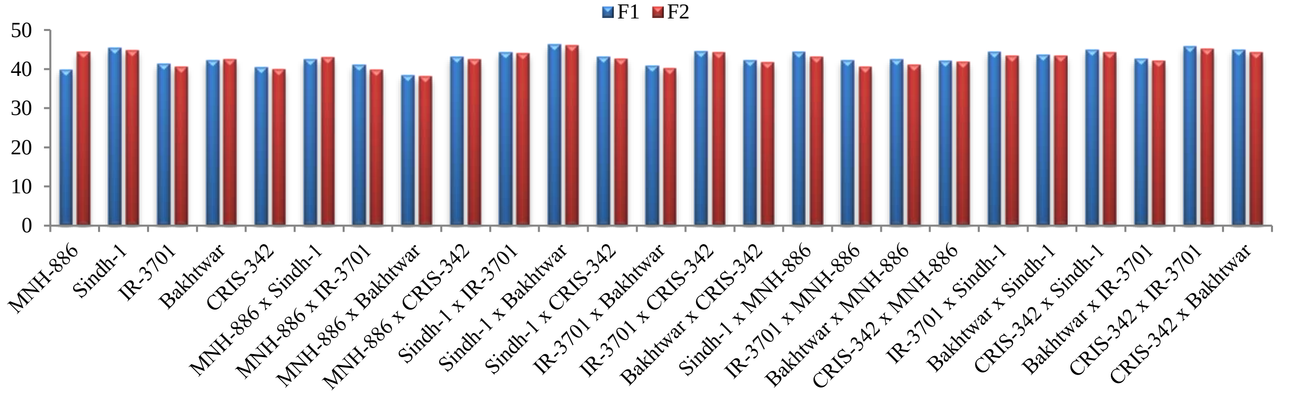

Fig. 8. Mean performance of F_1 and F_2 for boll maturation period (BMP)

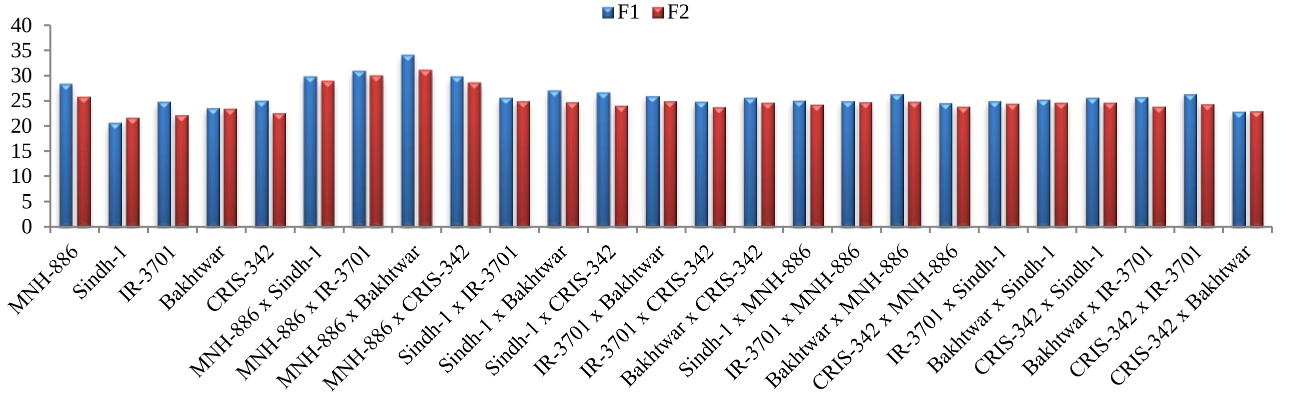

Fig. 9. Mean performance of F_1 and F_2 for no. of bolls to open at 90 days.

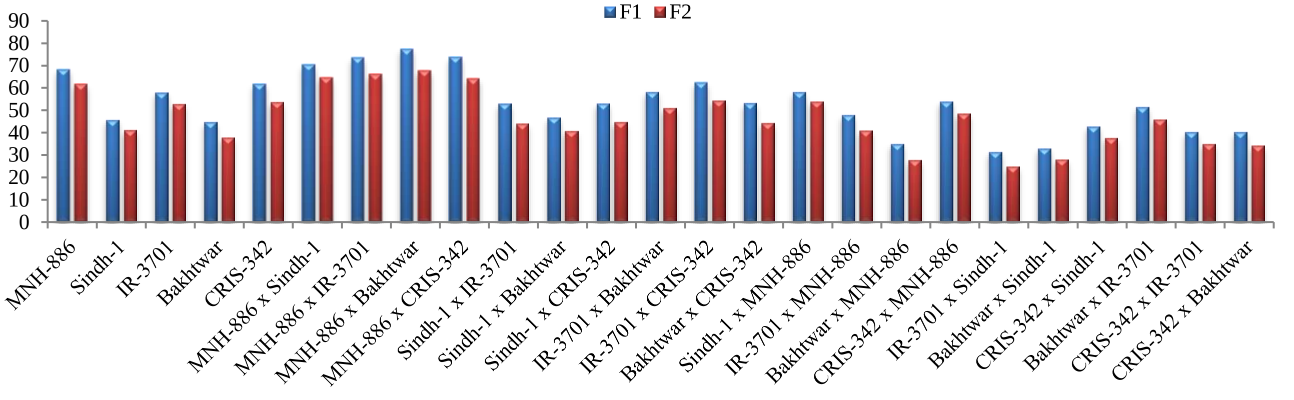

Fig. 10. Mean performance of F_1 and F_2 for no. of bolls to open at 120 days.

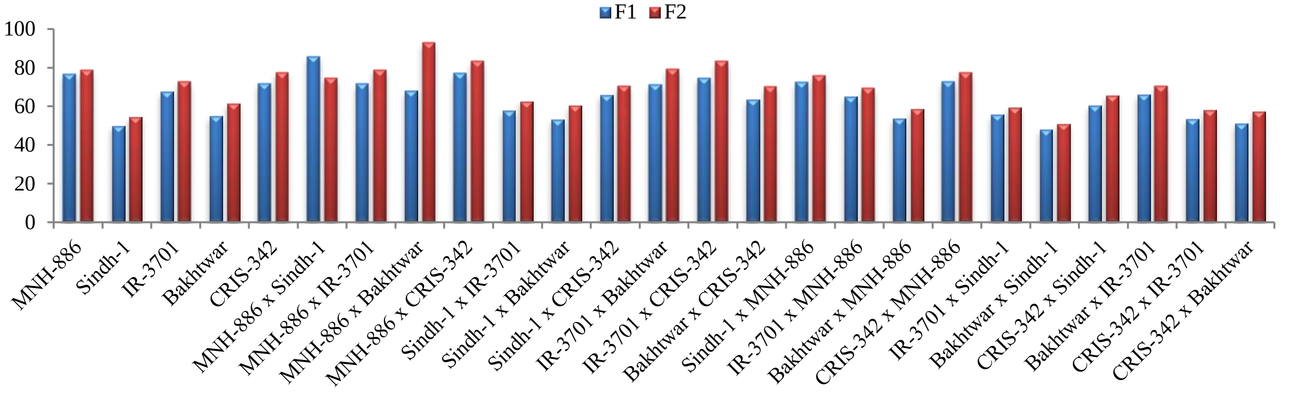

Fig. 11. Mean performance of F_1 and F_2 for no. of Bolls plant^{-1}.

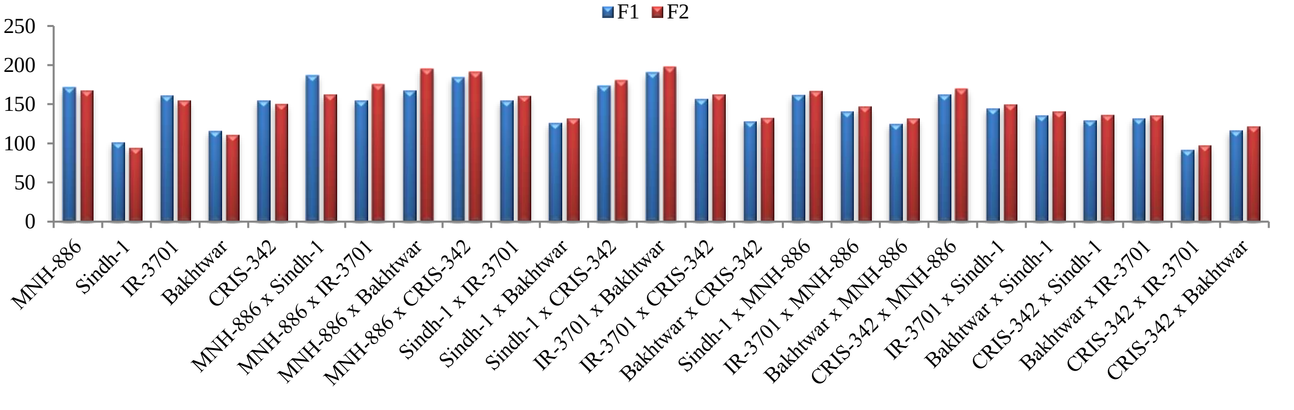

Fig. 12. Mean performance of F_1 and F_2 for seed yield plant (g).

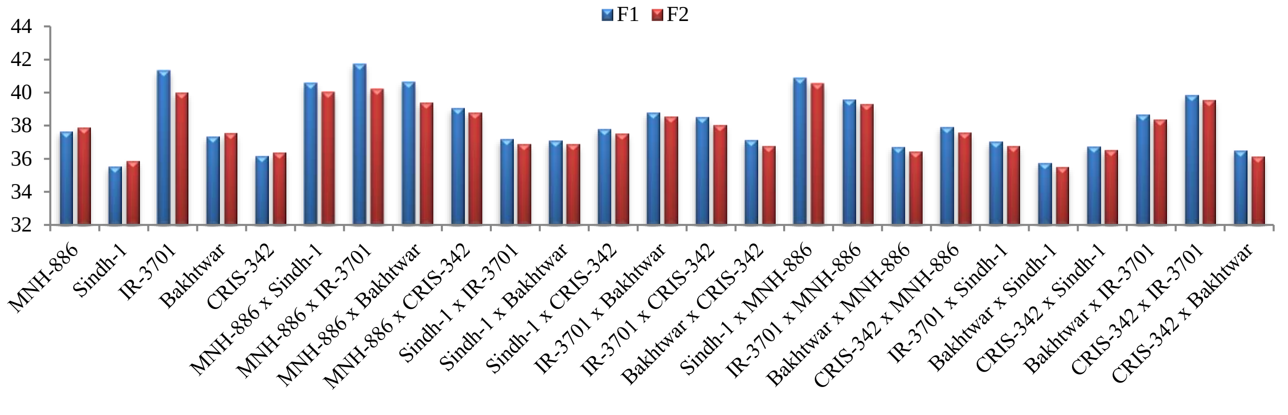

Fig. 13. Mean performance of F_1 and F_2 for ginning outturn (GOT) (%).

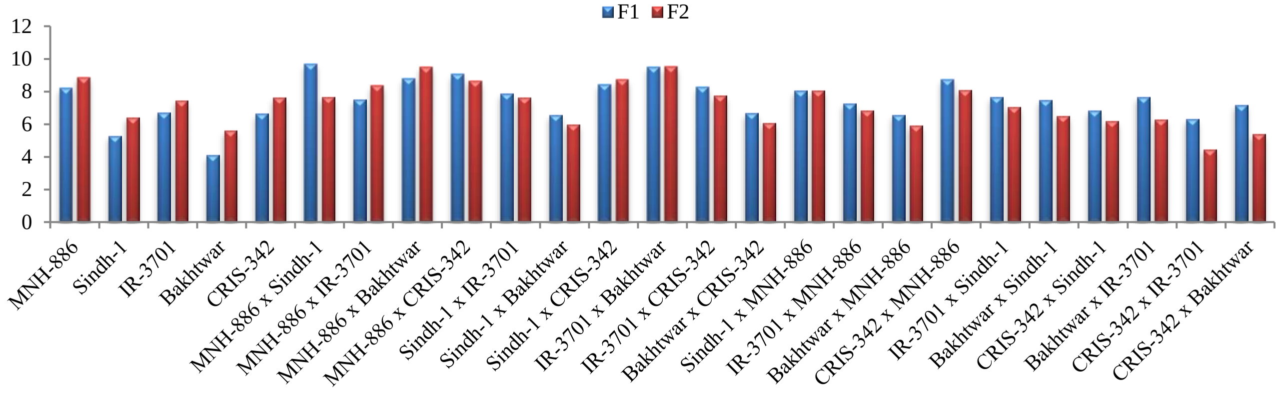

Fig. 14 Seed Index /100-seed weight (g).

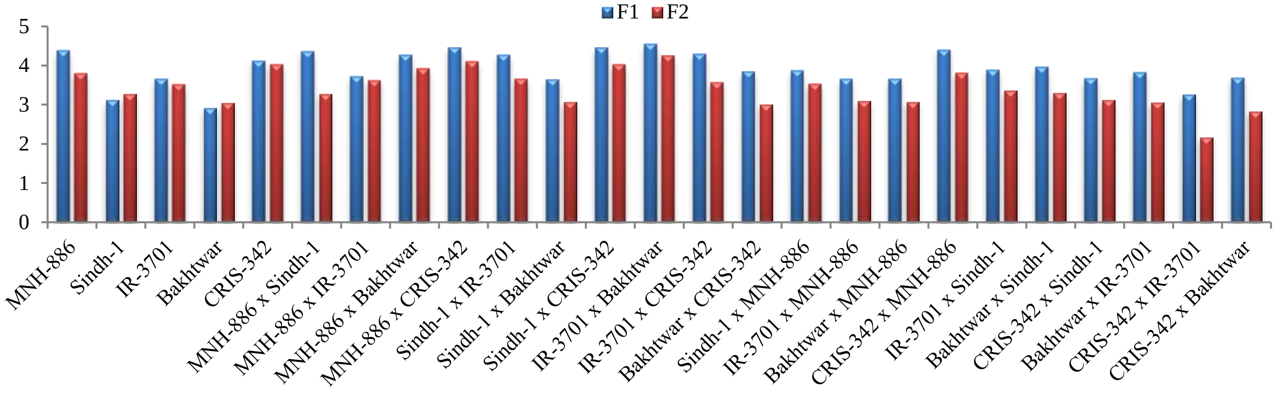

Fig. 15. Mean performance of F_1 and F_2 for lint index /100-seed weight (g).

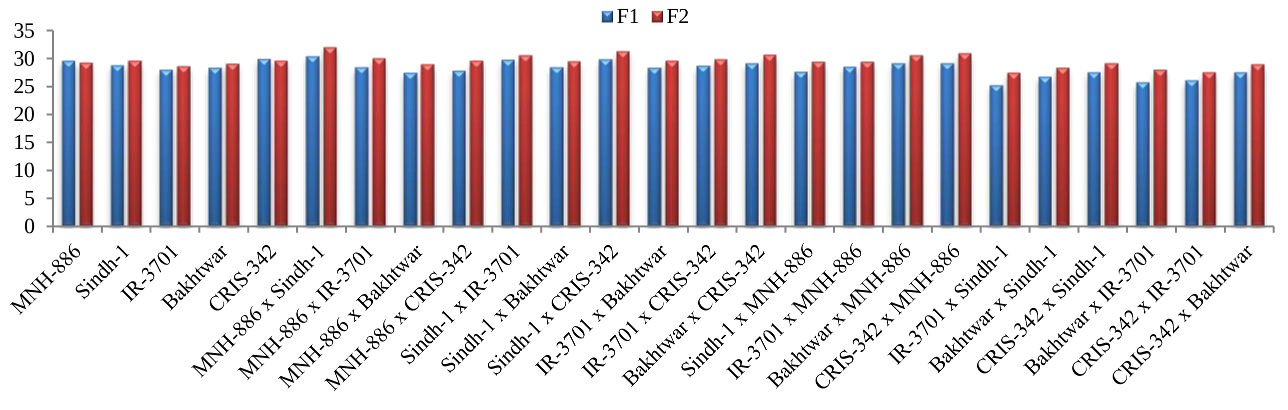

Fig. 16. Mean performance of F_1 and F_2 for staple length (mm).

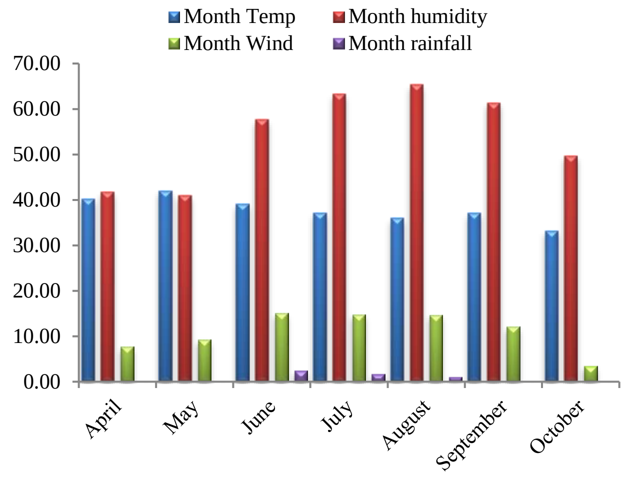

Fig. 17. Meteorological estimates, 2018-19.

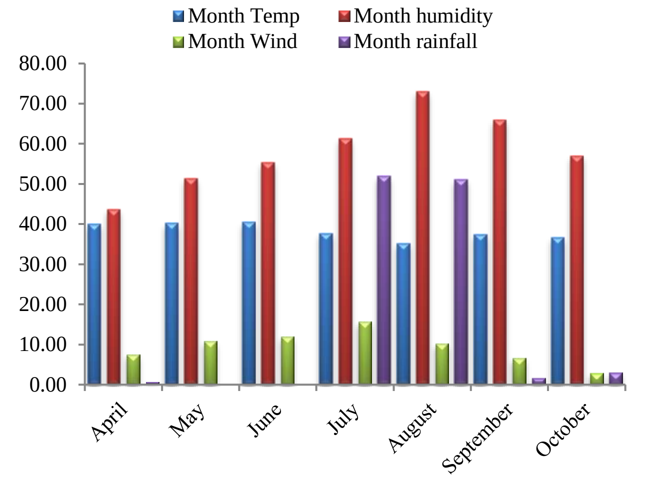

Fig. 18. Meteorological estimates, 2019-20.

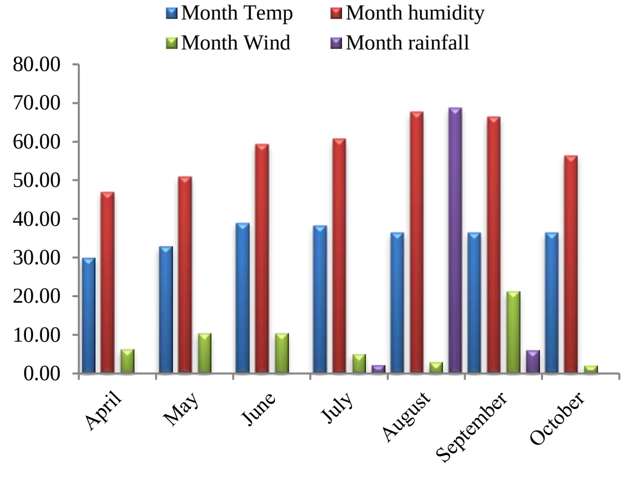

Fig. 19. Meteorological estimates, 2020-21.

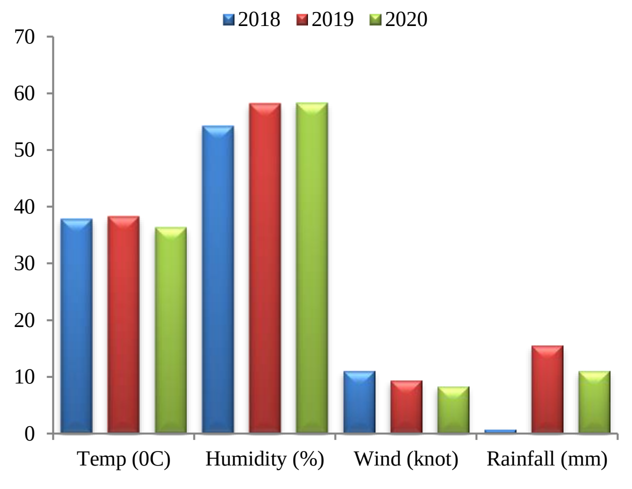

Fig. 20. Meteorological estimates, (2018-19 to 2020-21).

Table 5. Estimate of general and specific combining ability effects for various morphological traits in 5 x 5 F_1 diallel cross of *Gossypium hirsutum* L.

Parents	Plant height (cm)	No. of Node first fruiting branch	No. of days to 1st square	No. of days to 1st flower	No. of sympodia plant-1	Earliness index	DFOB	BMP
	General combining ability (GCA) effects							
MNH-886	-0.73	0.21	0.06	-0.07	-2.26	-0.71	0.04	-0.34
Sindh-1	6.65	0.02	-0.48	-0.99	1.59	0.49	-0.87	-0.31
IR-3701	-7.49	0.06	0.20	0.32	-0.10	1.04	-0.36	-0.68
Bakhtwar	2.47	-0.29	0.01	0.29	0.66	-0.71	0.57	0.43
CRIS-342	-0.89	-0.01	0.20	0.44	0.12	-0.10	0.63	0.91
	Specific combining ability (SCA) effects (Direct Crosses)							
MNH-886 x Sindh-1	3.90	0.85	1.30	0.98	-2.433	-1.42	2.40	1.65
MNH-886 x IR-3701	-5.83	0.61	-0.21	1.02	1.61	-0.34	0.92	1.86
MNH-886 x Bakhtwar	4.87	-0.03	-1.62	-1.26	-2.70	-0.41	-2.19	-1.20
MNH-886 x CRIS-342	-14.58	0.02	2.55	2.44	-2.83	-1.12	2.86	0.31
Sindh-1 x IR-3701	7.22	-0.29	0.16	-0.02	2.32	1.01	-0.44	-0.30
Sindh-1 x Bakhtwar	-2.11	0.33	0.52	0.31	-0.47	1.47	2.24	0.79
Sindh-1 x CRIS-342	6.03	0.33	-0.81	-0.99	0.08	1.06	-1.57	-1.42
IR-3701 x Bakhtwar	-2.02	0.33	0.22	0.71	-4.44	-2.01	1.12	1.09
IR-3701 x CRIS-342	-6.38	-0.69	2.76	2.88	-0.31	-0.06	3.35	-0.75
Bakhtwar x CRIS-342	-4.17	-0.07	-1.40	-1.40	3.46	-0.98	2.40	0.84
	Specific combining ability (SCA) effects (Reciprocal Crosses)							
Sindh-1 x MNH-886	-15.61	0.57	1.36	2.86	-6.37	-3.99	4.22	1.42
IR-3701 x MNH-886	-4.64	-0.98	-2.36	-4.14	-3.98	-0.04	-5.01	-2.47
Bakhtwar x MNH-886	-9.96	-1.14	-0.89	-1.36	1.45	1.72	-2.63	-2.41
CRIS-342 x MNH-886	-16.37	-0.09	1.13	0.99	-5.42	0.26	-0.03	-1.05
IR-3701 x Sindh-1	15.39	-0.31	0.75	1.48	-1.08	0.90	2.74	0.43
Bakhtwar x Sindh-1	11.66	0.20	-0.45	-0.49	8.18	0.35	-0.95	1.06
CRIS-342 x Sindh-1	8.24	-0.21	-0.42	-0.67	-2.78	-0.98	-1.59	-1.58
Bakhtwar x IR-3701	-8.12	-0.01	1.03	1.78	5.69	0.36	2.82	-0.36
CRIS-342 x IR-3701	5.15	0.18	2.37	1.92	-0.17	0.64	0.31	-0.21
CRIS-342 x Bakhtwar	-13.59	0.24	1.38	2.50	-1.83	-0.48	3.34	-0.71
S.E	0.47	0.11	0.16	0.21	0.23	0.18	0.28	0.12

Table 6. Estimate of general and specific combining ability effects for various morphological traits in 5 x 5 F_1 diallel cross of *Gossypium hirsutum* L.

Parents	No. of bolls to open at 90 days	No. of bolls to open at 120 days	No. of bolls plant^{-1}	Seed yield plant (g)	GOT %	Seed index /100-seed weight (g)	Lint index /100-seed weight (g)	Staple length (mm)
	General combining ability (GCA) effects							
MNH-886	-0.38	2.11	1.30	1.89	-0.25	-0.39	-0.07	0.48
Sindh-1	1.71	7.74	3.01	8.15	0.81	0.34	0.05	0.44
IR-3701	0.53	2.02	1.17	8.41	0.30	0.38	0.15	0.05
Bakhtwar	-0.68	-3.25	0.90	-2.13	0.23	-0.01	-0.03	-0.26
CRIS-342	-1.18	-8.62	-6.39	-16.32	-1.09	-0.33	-0.09	-0.72
	Specific combining ability (SCA) effects (Direct Crosses)							
MNH-886 x Sindh-1	-2.25	-5.20	-0.91	-12.63	-0.75	0.03	-0.15	0.40
MNH-886 x IR-3701	-0.37	-5.17	-6.54	-13.17	1.85	-0.84	-0.34	-0.60
MNH-886 x Bakhtwar	1.93	2.15	-1.44	7.08	0.91	0.41	0.23	-0.10
MNH-886 x CRIS-342	-0.78	-0.85	-2.88	-7.65	0.88	-1.01	-0.41	-0.48
Sindh-1 x IR-3701	0.14	2.93	2.84	9.94	0.03	0.33	0.12	-0.24
Sindh-1 x Bakhtwar	-0.45	-3.48	-2.21	-12.03	-1.16	-0.43	-0.07	0.90
Sindh-1 x CRIS-342	0.53	0.57	0.66	12.93	-0.94	0.30	0.29	0.33
IR-3701 x Bakhtwar	-1.11	-4.60	-1.81	3.68	-0.99	-0.13	0.09	0.69
IR-3701 x CRIS-342	0.18	5.58	5.70	-9.11	0.45	-0.38	-0.14	-0.18
Bakhtwar x CRIS-342	1.31	-5.64	-4.24	-10.01	1.04	-0.15	-0.20	-1.60
	Specific combining ability (SCA) effects (Reciprocal Crosses)							
Sindh-1 x MNH-886	-4.62	-12.44	-17.82	-42.69	-2.52	-2.20	-0.62	-0.77
IR-3701 x MNH-886	-1.05	5.70	7.24	17.52	2.13	0.06	0.01	-0.20
Bakhtwar x MNH-886	3.73	12.17	1.14	-2.96	1.41	0.18	-0.09	-1.19
CRIS-342 x MNH-886	-0.75	-6.74	-8.81	-22.98	-1.77	-1.97	-0.48	0.36
IR-3701 x Sindh-1	2.42	12.94	6.03	21.71	-0.26	0.89	0.4	-0.37
Bakhtwar x Sindh-1	-0.73	13.78	10.56	15.78	0.89	0.85	0.32	-0.23
CRIS-342 x Sindh-1	-0.11	14.42	11.83	9.45	0.20	-0.42	0.08	1.56
Bakhtwar x IR-3701	-0.01	5.11	-1.33	12.51	0.24	0.53	0.30	1.09
CRIS-342 x IR-3701	-0.02	0.90	-1.23	-1.68	-0.76	-0.49	0.01	1.69
CRIS-342 x Bakhtwar	-0.68	-4.41	1.05	26.50	-1.41	0.67	0.31	-0.41
S.E	0.17	0.28	0.36	0.79	0.18	0.05	0.02	0.10

Table 7. Estimate of general and specific combining ability effects for various morphological traits in 5 x 5 F_2 diallel cross of *Gossypium hirsutum* L.

Parents	Plant height (cm)	No. of node first fruiting branch	No. of days to 1st square	No. of days to 1st flower	No. of sympodia plant^{-1}	Earliness index	DFOB	BMP
	General combining ability (GCA) effects							
MNH-886	1.30	-0.34	0.38	0.32	-1.01	-1.15	0.175	0.66
Sindh-1	3.86	-0.18	-1.55	-1.06	0.69	0.44	-0.86	-0.61
IR-3701	-10.19	0.14	0.61	0.38	-0.56	0.82	-0.54	-0.84
Bakhtwar	3.97	0.01	-0.51	-0.57	0.96	-0.02	0.156	0.09
CRIS-342	1.04	0.37	1.06	0.91	-0.07	-0.09	1.08	0.70
	Specific combining ability (SCA) effects (Direct Crosses)							
MNH-886 x Sindh-1	3.56	-0.01	0.87	1.51	-2.83	-1.12	2.78	1.28
MNH-886 x IR-3701	-6.19	-0.29	1.53	1.85	1.92	-2.79	1.36	0.90
MNH-886 x Bakhtwar	4.94	0.31	-0.26	-0.63	-2.71	0.19	-2.50	-0.72
MNH-886 x CRIS-342	-14.87	0.55	1.85	1.89	-3.05	-1.56	2.79	-0.45
Sindh-1 x IR-3701	6.89	-0.38	0.75	0.24	2.27	1.06	0.15	-0.54
Sindh-1 x Bakhtwar	-1.41	0.23	0.68	0.66	-0.78	1.17	1.47	0.93
Sindh-1 x CRIS-342	7.60	0.49	-0.58	-1.14	0.16	1.42	-1.69	-2.21
IR-3701 x Bakhtwar	-2.54	0.42	0.93	1.39	-4.12	-3.60	1.56	1.49
IR-3701 x CRIS-342	-7.06	0.49	3.27	3.46	-0.54	0.80	3.97	-0.48
Bakhtwar x CRIS-342	-4.63	-0.35	-1.74	-2.05	3.93	-1.13	-2.42	0.89
	Specific combining ability (SCA) effects (Reciprocal Crosses)							
Sindh-1 x MNH-886	10.93	-0.48	-2.97	-2.83	4.11	4.25	-3.60	-0.89
IR-3701 x MNH-886	-0.32	0.53	5.67	4.70	2.40	0.74	5.26	2.72
Bakhtwar x MNH-886	9.82	-0.31	3.77	2.98	-0.69	-2.41	3.75	2.28
CRIS-342 x MNH-886	16.03	-0.57	-0.49	-0.49	3.68	0.55	1.03	0.30
IR-3701 x Sindh-1	-11.30	0.70	-2.47	-2.47	2.01	-1.65	-3.06	-0.95
Bakhtwar x Sindh-1	-7.08	0.50	-0.79	-0.06	-7.98	-0.16	-0.29	-1.56
CRIS-342 x Sindh-1	-6.11	0.81	1.84	1.03	0.71	-0.48	1.77	1.69
Bakhtwar x IR-3701	11.92	0.78	-1.06	-1.68	-5.55	-0.23	-1.32	0.10
CRIS-342 x IR-3701	-2.05	0.12	-3.07	-2.192	-0.77	0.35	-0.31	0.19
CRIS-342 x Bakhtwar	13.51	-1.31	-4.77	-3.82	1.91	1.01	-3.38	0.85
S.E	0.36	0.06	0.24	0.16	0.24	0.20	0.17	0.34

Table 8. Estimate of general and specific combining ability effects for various morphological traits in 5 x 5 F_2 diallel cross of *Gossypium hirsutum* L.

Parents	No. of bolls to open at 90 days	No. of bolls to open at 120 days	No. of bolls plant^{-1}	Seed yield plant (g)	GOT %	Seed index /100-seed weight (g)	Lint index /100-seed weight (g)	Staple length (mm)
	General combining ability (GCA) effects							
MNH-886	-0.54	2.98	-1.23	-5.82	-0.04	0.07	0.04	-0.05
Sindh-1	1.91	7.09	3.34	11.31	0.57	0.61	0.149	0.54
IR-3701	-0.05	1.418	4.03	11.38	0.15	0.45	0.15	0.12
Bakhtwar	-0.33	-3.05	0.69	-0.93	0.31	-0.17	-0.06	-0.04
CRIS-342	-0.97	-8.44	-6.83	-15.94	-0.99	-0.96	-0.28	-0.57
	Specific combining ability (SCA) effects (Direct Crosses)							
MNH-886 x Sindh-1	-1.00	-3.81	-7.27	-27.75	-0.47	-0.87	-0.33	0.76
MNH-886 x IR-3701	-0.94	-4.21	-5.93	-12.85	0.42	-1.03	-0.32	-0.54
MNH-886 x Bakhtwar	0.73	1.12	4.70	14.61	-0.17	0.83	0.25	-0.07
MNH-886 x CRIS-342	-0.16	-0.68	-0.56	-4.82	0.87	-0.29	-0.10	-0.20
Sindh-1 x IR-3701	0.15	1.83	2.57	8.28	0.24	0.07	0.09	-0.49
Sindh-1 x Bakhtwar	-0.28	-3.95	-3.51	-14.06	-1.12	-0.66	-0.19	0.56
Sindh-1 x CRIS-342	0.15	-0.36	2.43	16.80	-0.91	0.74	0.48	0.09
IR-3701 x Bakhtwar	-1.09	-4.44	-2.27	2.62	-0.76	0.03	0.09	0.38
IR-3701 x CRIS-342	0.33	5.56	3.40	-11.83	0.52	-0.53	-0.25	0.26
Bakhtwar x CRIS-342	0.71	-5.169	-4.79	-10.24	0.93	-0.32	-0.30	-1.37
	Specific combining ability (SCA) effects (Reciprocal Crosses)							
Sindh-1 x MNH-886	3.61	11.80	10.11	33.75	2.08	0.61	0.01	1.22
IR-3701 x MNH-886	1.27	-6.03	-6.30	-11.56	-1.55	-0.73	-0.21	0.44
Bakhtwar x MNH-886	-3.55	-11.42	-11.25	-7.58	-0.93	-0.39	0.04	1.18
CRIS-342 x MNH-886	0.38	8.02	7.38	28.10	1.49	1.22	0.24	0.15
IR-3701 x Sindh-1	-1.92	-11.62	-7.01	-22.14	0.24	-0.89	-0.50	-0.09
Bakhtwar x Sindh-1	0.53	-13.37	-12.27	-15.34	-0.79	-0.92	-0.24	0.34
CRIS-342 x Sindh-1	1.07	-12.81	-13.35	-4.93	-0.43	-0.55	-0.35	-0.61
Bakhtwar x IR-3701	-0.14	-3.19	1.48	-12.20	-0.18	-0.73	-0.27	-0.72
CRIS-342 x IR-3701	-0.38	0.85	0.17	1.35	0.80	0.10	0.02	-1.35
CRIS-342 x Bakhtwar	-0.07	5.00	-0.71	-25.97	1.38	-1.29	-0.60	0.05
S.E	0.04	0.27	0.40	0.83	0.18	0.04	0.02	0.10

Meteorological estimate (2018-19, 2019-20, and 2020-21): The data for meterological studied was carried out during the year 2018-19 to 2020-21 (Fig. 20) During the year 2018-19, the average mean high temperature was recorded during May (42.00ºC) followed by April 2018 (40.23ºC), whereas, the minimum mean temperature was recorded in October (33.13ºC) followed by August (35.97ºC). However, the high humidity was recorded in August (65.33%) followed by July (63.33%), wherein, low humidity was recorded in May (41.00%) followed by April (41.67%). Whereas, high wind velocity was shown in June and July with 15.07 knot and 14.83, respectively by showing high monthly average rain rainfall in both June and July month by 2.40 mm and 1.67 mm, respectively. In the year 2019-20, the maximum temperature were recorded in May (40.20ºC) and June (40.20ºC), and the minimum temperature were recorded in August and October by 35.17ºC& 36.67ºC, respectively. The high humidity 73% and 66% were observed during August and September, respectively. Wherein high wind velocity were recorded by June (11.97 knots) and July (15.63 knots). However, average record rainfall of 51.93 mm and 51.13 mm were observed during July and August, respectively and no rainfall was reported in May only during the cotton cropping season. The average maximum 38.90ºC and 38. 23^{0}C temperatures were recorded during June and July 2020, respectively. While the minimum temperature were recorded in April (30.00ºC) and May (32.97ºC). Simultaneously, high humidity 67.67% and 66.33% were reported during August and September, respectively and low humidity 46.93% and 50.83% were reported during April and May, respectively. However, high wind velocity 21.27 knot and 10.43 knot were reported during September and June, respectively and 2.90 knots and 2.00 knot were observed during August and October, respectively. The low temperature in August leads to high rainfall by 68.73 mm followed by 6.00 mm in September. The average mean annual temperature, humidity, wind velocity, and rainfall during three cropping years three years are shown graph-22, exhibited that maximum and minimum temperature were 38.22ºC and 35. 60ºC were recorded during the years 2019-20 and 2020-21, respectively. The annual mean high humidity were reported during the year 2020 (58.30%) followed by 2019 (58.23%) and 2018 (54.28%). However, maximum annual wind velocity were recorded during 2018 (11.00 knot) followed by 2019 (9.37 knot) and 2020 (8.32 knot). While 15.48 mm high annual rainfall were reported during the year 2019 followed by 10.99 mm and 0.72 mm in the year 2020 and 2018, respectively. However, the best performance was recorded by the parents MNH-886, CRIS-342, and Bakhtawar while the crosses IR-3701 x CRIS-342, and MNH-886 x Bakhtawar, MNH-886 x IR-3701; MNH-886 x Bakhtawar showed better performance. Thus, vulnerable changes in climate showed unpredictability impact on cotton maturity, yield and its attributing traits. However, these results are also in accordance with the findings of Ali and Erenstein, 2017; Amin *et al.*, 2018; Iqbal *et al.*, 2018 and Rahman *et al.*, 2018.

Conclusion

The aim of this study was to evaluate the best early mature genotypes on the growth and seed cotton yield of different cotton cultivars. According to the study, the parents of MNH-886 and CRIS-342 showed a significant number of nodes to first fruiting branch, no. of days to 1st square, no. of days to 1st flower, days to 1st opening boll, BMP, and plant height, staple length, respectively. SCA effects showed the excellent specific combinations for direct and reciprocal crosses in F_1 and F_2 populations. The cross IR-3701 x CRIS-342 showed better performance for no. of nodes to first fruiting branch, no. of bolls plant^{-1}, and seed yield plant^{-1}. Beside this MNH-886 x Sindh-1 showed significantly for early maturity of many traits especially for no. of boll at 90 days, no. of bolls at 120 days. Moreover, IR-3701 x CRIS-342 and MNH-886 x Bakhtawar showed better yield for no. of bolls plant-1, and seed yield per plant. These hybrids are considered as promising crossed to be used in breeding program for yield components. For fibre quality i.e. GOT% (MNH-886 x IR-3701 and Bakhtawar x CRIS-342); Seed index /100 seed weight (MNH-886 x Bakhtawar); staple length (IR-3701 x Bakhtawar and MNH-886 x Sindh-1), respectively. The overall response of parent MNH-886 and hybrids MNH-886 x IR-3701; MNH-886 x Bakhtawar under variable weather conditions also suggested good potential of early mature cotton genotypes for maximizing cotton production.

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