

LEGACY STUDY OF COTTON SEED TRAITS IN UPLAND COTTON USING GRIFFING'S COMBINING ABILITY MODEL

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Abstract

Combining ability was studied for identification of potential cultivars and hybrids, and the nature of gene action involved for inheritance of cottonseed traits and oil content % in a 6x6 diallel cross in upland cotton (*Gossypium hirsutum* L.) during 2003-2005. Analysis of variance revealed highly significant ($p \leq 0.01$) differences among the genotypes for all the traits. Combining ability studies showed that the mean squares due to general combining ability (GCA) and specific combining ability (SCA) were mostly significant in F₁ and F₂ generations. Genetic components of variances due to GCA and SCA revealed that most of the traits were controlled by additive type of gene action in both generations because of greater GCA variances. However, seeds per boll and cottonseed oil % in F₁ generation gained preponderance of SCA variances having non-additive type of gene action. Cultivar CIM-1100 was found as leading general combiner in combination with other cultivars BH-36 and CIM-240, FH-682 and CRIS-9, and their hybrids (CIM-1100 x BH-36, CIM-240 x CIM-1100, FH-682 x BH-36, CIM-1100 x FH-682 & CIM-1100 x CRIS-9) showed prominent SCA and renowned mean performance for seeds per boll, seed index and cottonseed oil content %. Therefore, involvement of CIM-1100 in most of the hybrids resulted in the synthesis of superior genotypes for all the traits.

Introduction

Apart from the great economic importance of cotton (*Gossypium hirsutum* L.) as a fibre crop, its share in edible oil is obvious from the fact that it contributes 65-70% to the local oil industry (Khan *et al.*, 2008). Therefore, there is a dire need to pay emphasis to the cottonseed oil improvement. For recognition of potential parental cultivars on the basis of progeny performance requires large number of crosses, which is a very laborious and expensive job. Diallel analysis provides a mating design whereby the selected parents are crossed in all possible combinations; the mean values are used for predicting combining ability of the parents (GCA) and hybrids (SCA) to enlighten the nature of gene action involved in the inheritance of traits.

Combining ability (Griffing, 1956) is a statistical procedure used for analysis of diallel crosses in a universal theoretical form. It works as a principal method for screening of germplasm and to determine the ability of the different genotypes to be included or not in a future-breeding programme on the basis of their GCA, SCA and reciprocal effects. GCA is the real expression and performance ability of genotypes on individual basis. Predominance of GCA can direct the breeder to make effective selection in segregating

population, which can further be studied for more stability in the following generations for genetic gain and improvement in required traits. SCA is the cumulative effect of two genotypes in a specific hybrid, and preponderance of SCA can specify some hybrids having economic heterosis, which can be used for hybrid cotton production. So, combining ability is very contributive in selecting potential parents and their hybrids with desired heritable variances through GCA and SCA and in some cases also through maternal effects.

In quantitative genetics, genetic variance components and their estimation in form of expression are very important to understand the inheritance pattern of different traits. Significant inherent variances due to GCA and SCA were noticed by Baloch *et al.*, (1997 & 1999), Ali *et al.*, (2000), Hassan *et al.*, (2000), Khan (2003) and Khan *et al.*, (2008) for various traits in upland cotton. Non-additive type of gene action was involved in inheritance of yield components (Hassan *et al.*, 1999; Muthu *et al.*, 2005; Ahuja & Dhayal, 2007; Khan *et al.*, 2008). Additive type of gene action with partial dominance was noticed for most of the traits in upland cotton (McCarty *et al.*, 1996; Tang *et al.*, 1993a & b; Chinchane *et al.*, 2002; Khan *et al.*, 2005; Aguiar *et al.*, 2007). Such type of contradictions may be due to different genetic background of breeding material used and different environmental conditions under which the cotton crop is grown. In view of the economic importance of combining ability, and the importance of selected hybrids in segregating generations, a research project was undertaken to evaluate the genetic variances and effects due to GCA, SCA and reciprocals for seeds per boll, seed index and cottonseed oil content % in F₁ and F₂ generations in a set of 6x6 diallel cross experiment in upland cotton.

Materials and Methods

Plant material and experimental design: The research work comprised of a crossing block, F₁ and F₂ population experiments of cotton (*Gossypium hirsutum* L.), was conducted and maintained over a three years period (2003-2005) at the Agricultural Research Institute, Dera Ismail Khan, Pakistan. Six diverse genotypes viz. CIM-109, CIM-240, CIM-1100, FH-682, BH-36 & CRIS-9 of upland cotton varied by pedigree, morphological characters, yield potential and yield contributing traits were sown in a non-replicated crossing block (F₀) by dibbling (hand sowing) during May 2003. Plots consisting of 5 rows, each 27 m in length, with a plant and row spacing of 60 and 100 cm, respectively were used to facilitate hand emasculation and crossing. All the cultivars were crossed in all possible combinations following complete diallel fashion. The F₁ and F₂ population having 30 hybrids (direct & reciprocals) along with 6 parents of a 6x6 complete diallel cross were sown by dibbling with randomized complete block (RCB) design during May 2004 and 2005, respectively. In F₁'s, each genotype was planted in a single row measuring 3.30 m, with three replications, while in F₂'s the plant population was increased and each genotype was planted in four rows, each of 6.30 m length, with four replications. The row and plant spacing were 75 and 30 cm, respectively. All the cultural practices were carried out as per recommended package for cotton production and the crop grown under uniform conditions to minimize environmental variability to the maximum possible extent. Picking was done in the months of November-December every year on single plant basis and ginning was done with eight saw-gins.

Traits measurement and statistical analyses: The data were recorded for seed per boll,

seed index and cottonseed oil percentage. For seeds per boll in each genotype, 50 bolls were separated and after counting the number of seeds in each boll, the average number of seeds per boll was calculated. For seed index, after ginning the hundred cottonseeds free from lint, disease or any other insect pest were weighed on electronic balance and the hundred seed weight in gram (g) was treated as seed index. For cottonseed oil content %, the seed samples were acid-delinted and were oven dried at 40°C for 24 hours and oil analysis was carried out by wide line Nuclear Magnetic Resonance (NMR, 4000). All the data were subjected to analysis of variance (ANOVA) technique using Mstatc computer software to test the null hypothesis of no differences between various F_1 's, F_2 's and their parental lines. The data were further subjected to combining ability analysis as outlined by Griffing (1956) Method-I, based on Eisenhart's Model-II to assess the genetic variances due to GCA and SCA and maternal effects.

Result and Discussion

Genetic variability: Analysis of variance revealed highly significant ($P \leq 0.01$) differences among all the 30 F_1 and F_2 hybrids along with parents for all the traits. The trait wise means variation is given as follows.

Seeds per boll: In F_1 generation, the seeds per boll varied from 16.67 (CIM-240) to 22.33 (BH-36) among the parents and 18.33 (CIM-240 x CRIS-9) to 26.33 (CIM-1100 x BH-36) among the hybrids (Fig. 1). Maximum seeds per boll were produced by hybrid CIM-1100 x BH-36 (26.33). It was statistically at par with 9 other crosses (24.00 to 25.33), among them 6 were the CIM-1100 derivatives. Generally more than 2/3 of F_1 hybrids surpassed their respective parental values. Lowest seeds per boll were exhibited by parent cultivars CIM-240 (16.67), CIM-1100 (18.67) and F_1 hybrid CIM-240 x CRIS-9 (18.33). In F_2 generation (Fig. 1), the seeds per boll varied from 17.95 (CIM-240) to 21.98 (BH-36) among the parents and 17.72 (CIM-109 x CIM-240) to 22.48 (BH-36 x FH-682) among the hybrids. Highest seeds per boll (21.98 to 22.48) were possessed by two derivatives of CIM-1100, cultivar BH-36 and one other F_2 hybrid. These were also found statistically at par with 7 other crosses ranged from 20.35 to 21.02, and amongst them 3 hybrids were having CIM-1100 as one parent. The lowest and at par seeds per boll were produced by cultivar CIM-240 and its crosses with CIM-109 and CRIS-9 (17.72 to 17.95).

Seed index: The seed index assorted from 7.86 g (BH-36) to 9.35 g (CIM-1100) among the parents and 7.71 g (BH-36 x CRIS-9) to 10.55 g (CIM-240 x CIM-1100) among the hybrids in F_1 generation (Fig. 1). Maximum seed index was exhibited by the hybrid CIM-240 x CIM-1100 (10.55 g). It was followed by five crosses and two parents (CIM-1100 & CIM-240) having seed index of 9.31 to 9.88 g. In F_2 generation, overall the seed index diverse from 7.53 g (BH-36) to 9.35 g (CIM-240) among the parents and 7.46 g (BH-36 x CRIS-9) to 9.48 g (CIM-240 x CIM-1100) among the hybrids (Fig. 1). Lowest seed index was obtained by cultivar BH-36 (7.86 g) and F_1 hybrid BH-36 x CRIS-9 (7.71). Maximum seed index (9.48 g) was attained by the same F_2 hybrid as mentioned in F_1 (CIM-240 x CIM-1100) and it was found statistically at par with 6 other hybrids and one parent cultivar (CIM-240) with the magnitude of 9.07 g to 9.35 g. The lowest seed index was possessed by cultivar BH-36 (7.53 g) and its cross with CRIS-9 (7.46 g).

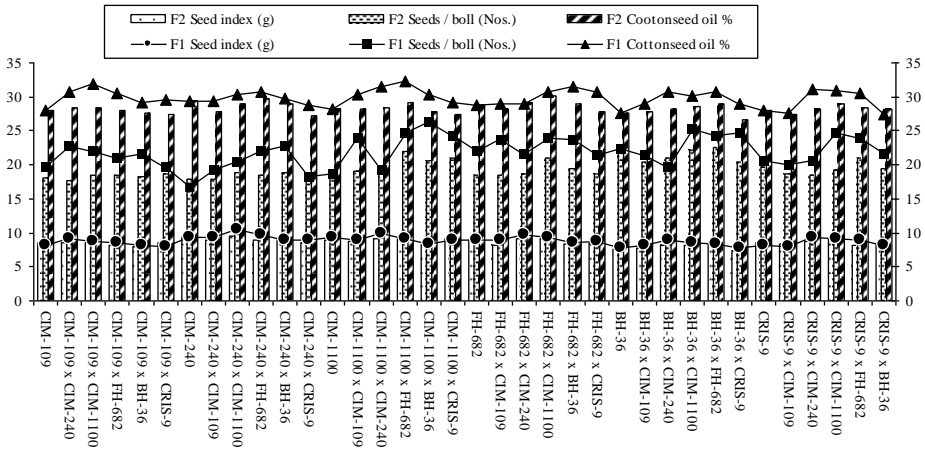


Fig. 1. Means performance of F_1 and F_2 hybrids along with six parental cultivars in a 6×6 F_1 and F_2 diallel cross of upland cotton.

Cottonseed oil %: In F_1 generations (Fig. 1), oil content % varied from 27.55% (BH-36) to 29.32% (CIM-240) among the parents and 27.49% (CRIS-9 x BH-36) to 32.34% (CIM-1100 x FH-682) among the hybrids. Maximum oil content was obtained in the cross combination CIM-1100 x FH-682 (32.34%) and was found statistically at par with three hybrids in which two were the derivatives of CIM-1100 i.e. CIM-109 x CIM-1100 (31.96%), CIM-1100 x CIM-240 (31.50) and FH-682 x BH-36 (31.55%). The low and at par percentage of oil content (27.49 to 28.13%) was noted in 4 cultivars (BH-36, CRIS-9, CIM-109 and CIM-1100) and 2 hybrids of CRIS-9 with CIM-109 and BH-36. In F_2 generation, the oil content varied from 27.55% (BH-36) to 29.32% (CIM-240) among the parents and 26.64% (BH-36 x CRIS-9) to 30.12% (FH-682 x CIM-1100) among the hybrids (Fig. 1). Maximum oil content was shown by FH-682 x CIM-1100 (30.12%) which was reciprocal of F_1 top scoring hybrid. However, it was found statistically at par with 9 other genotypes having 3 derivatives of CIM-1100 (28.89 to 29.76%) for oil content. The lowest oil content was recorded in the hybrid BH-36 x CRIS-9 (26.64%) and the other F_2 's were having medium percentages of oil content.

Combining ability: The total genetic variability observed in F_1 and F_2 generations was further partitioned into its components i.e., mean squares, components of genetic variances due to GCA, SCA and reciprocals and their individual effects shown by genotypes for cottonseed traits and oil content, as defined by Griffing (1956) Method I, Model II. Mean squares due to GCA were significant for seeds per boll (16.47, 7.76), seed index (2.37, 1.29) and oil content (2.86, 2.09) in F_1 and F_2 generations, respectively (Table 1). This indicates stability of additive factors. Significant mean squares due to GCA reported by Voitenok *et al.*, (1983), Dani (1989 & 1991), Tang *et al.*, (1993 a & b), Ali *et al.*, (2000), Khan (2003) and Khan *et al.*, (2007 & 2008). The F_1 SCA mean squares were significant (Table 1) for seeds per boll (4.41), seed index (0.10) and oil content (1.93). Significant mean squares due to SCA were also noticed in F_1 hybrids by Hassan *et al.*, (1999), Khan (2003) and Ahuja & Dhayal (2007). In case of F_2 SCA, seed

index (0.07) showed significant, but seeds per boll and oil content manifested non-significant mean squares. However, F_1 SCA mean squares for above traits were significant, which is a clear indication of segregation, inbreeding depression and predominance of additive gene action in F_2 generation as also mentioned by Chinchane *et al.*, (2002) and Tuteja *et al.*, (2003). Dever & Gannaway (1992), Baloch *et al.*, (1996) and Galanopoulou & Roupakias (1999) were also of opinion that F_2 hybrids even by having inbreeding depression offer more heterogeneous population along with their different effects as compared to their F_1 hybrids and parents. The mean squares due to reciprocals were found significant for seeds per boll (1.87) and oil content (1.00) in F_1 's and for seed index (0.07) in F_2 generation. Hassan *et al.*, (1999 & 2000) and Khan *et al.*, (2005) also achieved reciprocal effects for various cottonseed traits.

According to genetic components of variance (%), the F_1 GCA variances (Table 2) were greater in magnitude and more important for seed index (73.36%). Quite analogous results and additive type of variances have been also reported by Khan (2003) and Khan *et al.*, (2007) for seed index. Additive genetic effects with enough genetic variability were noticed for most of the yield traits having effective selection (Chinchane *et al.*, 2002; Aguiar *et al.*, 2007). However, the present results are in contrast with the findings of Irfanullah *et al.*, (1993), Hassan *et al.*, (1999), Muthu *et al.*, (2005) and Ahuja & Dhayal (2007) who advocated appreciable amount of variance due to SCA for various characters, whereas the variance due to GCA was much smaller in magnitude. Such deviation might be due to different breeding materials and agro-climatic conditions under which the experiments were conducted.

Table 1. Mean squares for ANOVA and combining ability in a 6x6 F_1 and F_2 diallel cross of upland cotton.

Source of variation	D.F.	Seeds / boll	Seed index	Cotton seed oil %
F_1 generation				
Replications	2	6.028	0.252	0.062
Genotypes	35	15.131**	1.199**	4.985**
Error	70	2.152	0.133	0.346
G.C.A.	5	16.47**	2.37**	2.86**
S.C.A.	15	4.41**	0.10*	1.93**
Reciprocals	15	1.87**	0.04 N.S.	1.00**
Error	70	0.72	0.04	0.12
F_2 generation				
Replications	3	6.502	0.544	6.404
Genotypes	35	7.478**	0.978**	2.126
Error	105	2.598	0.097	0.818
G.C.A.	5	7.76**	1.28**	2.09**
S.C.A.	15	0.71 N.S.	0.07**	0.24 N.S.
Reciprocals	15	1.07 N.S.	0.07**	0.30 N.S.
Error	105	0.65	0.02	0.20

*, ** Significant at 5% and 1% probability level, respectively.

N.S. Non-significant, D.F. Degree of Freedom

Table 2. Estimates of components of variance due to GCA, SCA and reciprocal

effects in a 6x6 F₁ and F₂ diallel cross of upland cotton.

Components of variation	Seeds / boll	Seed index	Cotton seed oil %
F₁ generation			
G.C.A.	1.02 (22.87)	0.19 (73.36)	0.08 (4.73)
S.C.A.	2.14 (47.98)	0.03 (11.58)	1.05 (62.13)
Reciprocals	0.58 (13.01)	-0.001 (-0.38)	0.44 (26.04)
Error	0.72 (16.14)	0.04 (15.44)	0.12 (7.10)
Total	4.46 (100)	0.259 (100)	1.69 (100)
F₂ generation			
G.C.A.	0.59 (39.86)	0.10 (58.83)	0.15 (35.71)
S.C.A.	0.03 (2.03)	0.03 (17.65)	0.02 (4.76)
Reciprocals	0.21 (14.19)	0.02 (11.76)	0.05 (11.91)
Error	0.65 (43.92)	0.02 (11.76)	0.20 (47.62)
Total	1.48 (100)	0.17 (100)	0.42 (100)

Components of variance.

Percentages of components of variance: left side values (in parenthesis).

The variances due to F₁ SCA (Table 2) was much higher in magnitude than GCA and were more important for seeds per boll (47.98%), oil content (62.13%), indicating non-additive type of genes. Irfanullah *et al.*, (1993), Hassan *et al.*, (1999) and Khan *et al.*, (2007) also observed non-additive control of seed traits. However, Echenkwu & Alabi (1994 & 1995), McCarty *et al.*, (1996), Baloch *et al.*, (1997), Tang *et al.*, (1993 a & b) had observed additive type of gene action for most of the traits. Such contradictions may be due to different genetic background of the cultivars used and different environmental conditions. The mean squares due to GCA, SCA in F₂ generation for all the traits (Table 1), were not coinciding in magnitude with F₁ and manifested a clear decline in all the values due to segregation and inbreeding depression. Therefore, the selection of promising lines should be based on the average performance of F₁ and F₂ hybrids. Galanopoulou & Roupakias (1999) also suggested that F₁ hybrids did not predict the yield of the bulks in the following generations; however the combined performance of the F₁ and F₂ hybrids could be a good indicator to identify the most promising populations to be utilized either as F₂ hybrids or as a source population for further selection.

Genetic variances due to F₂ GCA (Table 2) were greater than SCA for all the traits (seeds per boll 39.86; seed index 58.83; oil content 35.71). From results it can be concluded that the major portion of genetic variance of these traits was due to genes with additive effects and through simple selection in F₂ the seed traits can be improved. Regarding GCA significant variances in F₂ studies were in agreement with the findings of Voitenok *et al.*, (1983) and Khan (2003) for cottonseed traits and oil content. However, Tang *et al.*, (1996) and Muthu *et al.*, (2005) observed dominance variance for some traits indicating that hybrids should have an advantage for these traits as compared to other lines but low proportion of additive variance for seed traits indicated a lack of substantial useful additive genetic variability for seed traits which suggest that selection within these F₂ population should have limited success in improving the traits. In comparison to F₁ studies, the seed index was additively controlled in both generations, however after transgressive segregation the two traits (seeds per boll and oil content) jumped from non-additive to additive; hence, the seed traits and oil content can be improved through simple selection in F₂ generation.

In F₁ and F₂ reciprocal variances (Table 2), seed traits exhibited smaller values of

variances due to reciprocals as compared to GCA and SCA; except F_1 oil content (26.04%) showing second ranking values of reciprocal variances to SCA but were greater than GCA. Kohel (1980) and Khan (2003) also reported a maternal influence on oil content in the cottonseed and suggested that the single cross performance could be composited with their reciprocal effects in view of cotton seed traits. It is relevant that maternal effects for above traits were due to plasma gene action which is found rarely in such diallel studies.

General combining ability: In F_1 generation (Table 3), the cultivar CIM-1100 superseded all the cultivars and manifested highest GCA effects for oil content (0.54), CIM-240 for seed index (0.60) and BH-36 for seeds per boll (1.08). The second ranking cultivars having maximum GCA effects were FH-682 for seeds per boll (0.99) and oil content (0.48), and CIM-1100 for seed index (0.36). The results revealed that the best general combiner (CIM-1100) and its hybrids in diallel crossing with other commercial cultivars viz., CIM-109, FH-682 and CRIS-9 showed economic improvement in oil content. Further confirmation was also made in F_2 studies after segregation in which CIM-1100 showed stability as second general combiner for all the traits. Therefore, in future preference will be given to CIM-1100 for inclusion in breeding programme for improvement cottonseed traits and oil content. Like F_1 's, in F_2 generation the seeds per boll and seed index also administered by BH-36 (1.14) and CIM-240 (0.36), respectively (Table 3). However, for cottonseed oil content, FH-682 obtained the leading position with highest GCA (0.53). So the former two cultivars showed sustainability in both generations. In F_1 's, FH-682 was also having second GCA effects for oil content. In case of mean values (Fig. 1), the cultivars having maximum GCA also showed appreciable mean values for the said traits.

These results got support from the findings of Galanopoulou & Roupakias (1999) that genotypes in F_1 did not predict the yield of the bulk in the following generations but the combined performance of the F_1 and F_2 hybrids could be a good indicator to identify the promising population. Dani (1991), Irfanullah *et al.*, (1993), Raveendhran *et al.*, (1996), Tang *et al.*, (1996), Baloch *et al.*, (1997) and Hassan *et al.*, (2000) also concluded that parents with high GCA manifested best performance. However, Baloch *et al.*, (1999), Khan (2003) and Khan *et al.*, (2005) opined that the higher GCA hybrids did not predict higher SCA, and GCA and SCA of different traits were independent. However, Dani (1989) and Voitenok *et al.*, (1983) reported prominent GCA as compared to SCA effects and concluded that best yielding parents having high GCA produced best yielding combinations for cottonseed oil content.

Specific combining ability: The F_1 hybrid FH-682 x BH-36 (Table 4) was the leading and best specific combination for exhibition of highest SCA effects for cottonseed oil % (1.27). The F_1 hybrid (CIM-109 x CIM-1100) was having second ranking GCA value for oil content (1.15). In above two crosses, FH-682 and CIM-1100 have a prominent GCA effects for oil content, but the cultivar BH-36 and CIM-109 were not in a position to have even positive value for the said trait. It is concluded that intra-hirsutum crosses with high x low and low x high GCA parents performed well in SCA determination for cottonseed oil %. Irfanullah *et al.*, (1993) and Khan *et al.*, (2003 & 2005) also referred that when a parent with the best GCA was used as pollen parent produced better combinations.

Table 3. Estimates of GCA effects in a 6x6 F_1 and F_2 diallel cross of upland cotton.

Cultivars	Seeds / boll	Seed index	Cotton seed oil%
F₁ generation			
CIM-109	-0.69	-0.32	-0.36
CIM-240	-1.92	0.60	0.28
CIM-1100	0.78	0.36	0.54
FH-682	0.94	0.18	0.48
BH-36	1.08	-0.53	-0.38
CRIS-9	-0.19	-0.29	-0.56
CD _(gi-gi)	0.69	0.17	0.28
F₂ generation			
CIM-109	-0.91	-0.19	-0.35
CIM-240	-0.89	0.36	0.34
CIM-1100	0.53	0.31	0.22
FH-682	0.20	0.09	0.53
BH-36	1.14	-0.51	-0.24
CRIS-9	-0.07	-0.06	-0.50
CD _(gi-gi)	0.65	0.13	0.37

Table 4. Estimates of SCA effects in a 6x6 F₁ and F₂ diallel cross of upland cotton.

Hybrids	F ₁ generation			F ₂ generation		
	Seeds/ boll	Seed index	Cotton seed oil %	Seeds/boll	Seed index	Cotton seed oil %
CIM-109 x CIM-240	1.69	0.10	0.37	0.18	0.05	-0.15
CIM-109 x CIM-1100	0.00	-0.10	1.15	-0.28	-0.09	0.07
CIM-109 x FH-682	0.17	0.13	-0.16	-0.27	-0.33	-0.37
CIM-109 x BH-36	-0.81	0.22	0.05	-0.33	0.02	0.001
CIM-109 x CRIS-9	-1.19	-0.24	-0.35	0.15	0.09	0.05
CIM-240 x CIM-1100	-0.94	0.43	0.32	-0.23	0.05	-0.11
CIM-240 x FH-682	0.89	0.06	-0.74	-0.13	-0.001	0.26
CIM-240 x BH-36	0.08	0.10	0.54	0.25	0.04	0.11
CIM-240 x CRIS-9	-0.31	0.05	0.52	-0.36	-0.19	-0.44
CIM-1100 x FH-682	0.69	-0.07	0.75	1.36	0.20	0.60
CIM-1100 x BH-36	2.06	-0.23	0.23	0.24	-0.14	-0.06
CIM-1100 x CRIS-9	2.00	0.17	0.28	0.25	0.30	0.11
FH-682 x BH-36	0.06	-0.10	1.27	0.20	0.19	0.38
FH-682 x CRIS-9	0.00	0.13	0.89	0.29	-0.24	-0.22
BH-36 x CRIS-9	0.36	-0.07	-0.63	-0.63	-0.09	-0.16
CD _(sij-sik)	1.54	0.38	0.62	1.46	0.28	0.82
CD _(sij-skl)	1.38	0.34	0.55	1.30	0.25	0.73

In the same F₁ generation (Table 4), hybrid CIM-1100 x BH-36 manifested highest SCA effects for seeds per boll (2.06). The hybrid CIM-1100 x CRIS-9 was also second ranking specific combination for seeds per boll (2.00). It may be noted that cultivar BH-36 had highest GCA, CIM-1100 has medium GCA, but cultivar CRIS-9 was noted with negative GCA effects for seeds per boll. It revealed that medium x high and high x low GCA parents performed well in SCA conviction. Baloch *et al.*, (1996 & 1997) and Khan *et al.*, (2007) mentioned that per se performance of F₁ hybrids for yield components was found to be correlated with SCA but the parents that displayed larger GCA effects did not necessarily exhibit higher SCA effects.

It further elucidated that F₁ cross combination CIM-240 x CIM-1100 possessed maximum SCA effects for seed index (0.43). The hybrid CIM-109 x BH-36 ranked second hybrid for seed index (0.22). In the former cross both cultivars (CIM-240 & CIM-

1100) have prominent GCA for said trait, but in second cross both cultivars (CIM-109 & BH-36) were having negative GCA effects for seed index in both generations. Therefore high x high and low x high GCA parents performed better in SCA determination. It concluded that the parent with best GCA on their utilization as one of the parent produces good hybrid combinations. In case of mean values (Fig. 1), the hybrids having maximum SCA also showed appreciable mean values for the said traits. Parents with high GCA were found more effective to produce high yielding hybrids (Baloch *et al.*, 1997; Hassan *et al.*, 2000). No doubt the present results were in contrast with the findings of Baloch *et al.*, (1999) and Khan (2003) who reported that GCA and SCA were independent and GCA is not the criterion for predicting the SCA. The deviation between the research findings may be due to different factors like breeding material used and peculiar climatic conditions under which the experiments were conducted.

In F₂ generation, the hybrid CIM-1100 x FH-682 was the best hybrid by having maximum SCA effects for seeds per boll (1.36), cottonseed oil % (0.60) and the same hybrid also ranked second for seed index SCA (0.20). The cultivars CIM-1100 and FH-682 were having highest GCA for oil content and medium GCA for seeds per boll in both generations. Therefore, high x high and high x low GCA parents produced the best cross combination for cottonseed traits and oil content. In F₁'s, the said hybrid was third ranking for these traits, but due transgressive segregation it gained the maximum SCA effects in F₂ generation. For the above traits, the second ranking cross for SCA effects were FH-682 x BH-36 (0.38); FH-682 x CRIS-9 (0.29) for cottonseed oil and seeds per boll, respectively. Dever & Gannaway (1992) and Galanopoulou & Roupakias (1999) also opined that F₂ hybrids despite of by inbreeding depression offer more heterogeneous population as compared to their F₁ hybrids and parents. Of the remaining F₂ hybrids, CIM-1100 x CRIS-9 (0.30) has shown maximum SCA value for seed index and in this cross CIM-1100 has second ranked GCA values for seed index in both generation, while CRIS-9 was having negative GCA effects. It is concluded that high x low GCA parent performed well in SCA determination. In case of mean values (Fig. 1), the hybrids having highest SCA also showed appreciable mean values for the said traits.

From the above results (Table 4) its concluded that F₂ hybrids CIM-1100 x FH- 682 and CIM-1100 x CRIS-9 even after segregation exhibited highest and second ranked SCA values for most of the traits and by artificial selection the cottonseed traits and oil content can be improved to a significant level. In comparison to F₁ generation, the said hybrids were having leading position for said parameters and their best performance has also been confirmed by F₂ generation even after inbreeding depression. The F₁ hybrids having maximum SCA effects for some traits attained the second and third position in F₂ generation for SCA due to high magnitude of inbreeding depression suggesting dominant genes were functioning for these traits which will require repeated selection. The F₁ hybrids having 2nd and third position for SCA gave transgressive segregates by having lower magnitude of inbreeding depression and additive genes were responsible for these traits which can be improved through simple selection. Similar results have been also reported by Baloch *et al.*, (1996) and Galanopoulou & Roupakias (1999). The results in F₂ obtained by Raveendhran *et al.*, (1996) and Tang *et al.*, (1996) showed that the parents with high GCA effects were found to produce high yielding hybrids. No doubt, the present results are at divergence from the findings of Tang *et al.*, (1993 a & b) and Khan *et al.*, (2007 & 2008) who reported that GCA is not the criterion for predicting the SCA and that variation may be due to different factors like breeding material used under distinct environmental conditions.

Table 5. Estimates of reciprocal effects in a 6x6 F₁ and F₂ diallel cross of upland cotton.

Hybrids	F ₁ generation			F ₂ generation		
	Seeds/ boll	Seed index	Cotton seed oil %	Seeds/boll	Seed index	Cotton seed oil %
CIM-240 x CIM-109	1.67	-0.07	0.69	-0.09	-0.20	0.34
CIM-1100 x CIM-109	-1.00	-0.09	0.85	-0.30	-0.08	0.08
FH-682 x CIM-109	-1.33	-0.17	0.84	-0.05	-0.004	-0.15
BH-36 x CIM-109	0.17	0.01	0.06	-1.13	0.10	-0.07
CRIS-9 x CIM-109	-0.17	0.06	0.96	0.00	0.11	0.01
CIM-1100 x CIM-240	0.50	0.33	-0.59	-0.05	0.20	0.32
FH-682 x CIM-240	0.17	0.01	0.87	-0.09	-0.08	0.34
BH-36 x CIM-240	1.50	0.003	-0.49	-1.09	0.39	0.38
CRIS-9 x CIM-240	-1.17	-0.21	-1.14	-0.28	-0.15	-0.40
FH-682 x CIM-1100	0.33	-0.07	0.79	0.53	-0.03	-0.48
BH-36 x CIM-1100	0.50	-0.14	0.08	-0.74	0.01	-0.33
CRIS-9 x CIM-1100	-1.17	-0.14	-0.84	0.85	-0.05	-0.77
BH-36 x FH-682	-0.33	0.11	0.41	-1.51	0.07	-0.05
CRIS-9 x FH-682	-1.33	-0.07	0.10	-1.15	0.20	-0.29
CRIS-9 x BH-36	1.50	-0.24	0.71	0.48	-0.46	-0.77
CD _(rij-rkl)	1.69	0.42	0.68	1.60	0.31	0.90

Maternal effects: In F₁ reciprocal effects (Table 5), CIM-1100 x CIM-240 had maximum reciprocal effects for seed index (0.33), CIM-240 x CIM-109 for seeds per boll (1.67) and CRIS-9 x CIM-109 for oil content (0.96). In case of F₂, the hybrid CRIS-9 x CIM-1100 had maximum reciprocal effects for seeds per boll (0.85) and BH-36 x CIM-240 for seed index (0.39) and oil content (0.38). Kohel (1980) and Khan (2003) also reported maternal influence on cottonseed oil content. The results are in contrast with the findings of Hassan *et al.*, (2000) and Khan *et al.*, (2005) as they noticed non-significant reciprocal effects for different parameters in their studies with the exception of one or two traits.

Most of the genetic studies designed to compare reciprocal differences have detected very few differences, and these maternal contributions to F₁ embryo consist of environments in which the embryo develops. However, the exceptions to the general rule are quite important, as they offer special opportunities to breeders. From the present investigation, it is suggested that the single cross performance could be composited with their reciprocal effects in view of cottonseed traits and oil content. As discussed earlier, all the above mentioned reciprocals having maximum reciprocal effects at F₂ level but were not so important due to negative or very low reciprocal values in F₁ generation for the said traits. Kohel (1980), Khan (2003) and Khan *et al.*, (2007) also supported same idea and noticed that even in F₂ population most of the traits exhibited reasonable variability and significant reciprocal effects.

Conclusion

In both generations, the mean squares due to GCA and SCA were highly significant for seeds per boll, seed index and cottonseed oil content except seed per boll and cottonseed oil have a non-significant SCA mean square in F₂ generation. In the F₁'s, SCA genetic components of variance were greater and more important for seeds per bolls and cottonseed oil, showing the predominance of dominance type of gene action, while in seed index the variation controlled by GCA. In the F₂, GCA components of variances

were greater than SCA and revealed the preponderance of additive gene action for inheritance of all the traits. Mostly smaller values of genetic variances with respect to GCA and SCA were obtained for reciprocals. For oil content, maximum GCA governed by CIM-1100 and FH-682 in F_1 's and F_2 's, respectively. Cultivars BH-36 and CIM-240 were found to be the best general combiner for seeds per boll and seed index, respectively in both generations. CIM-1100 was also found the second ranking best cultivar and showed appreciable GCA for all the traits in both generations. The F_1 hybrids i.e., CIM-1100 x BH-36, CIM-240 x CIM-1100 and FH-682 x BH-36 were found leading combinations for exhibition of highest SCA effects for seeds per boll, seed index and cottonseed oil %. While in F_2 's, CIM-1100 x FH-682 have maximum SCA for seeds per boll and oil content, however, seed index was better governed by CIM-1100 x CRIS-9. Therefore, involvement of CIM-1100 in most of the F_1 and F_2 hybrids resulted in the synthesis of superior genotypes for cottonseed traits.

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