

## GENETIC DIVERGENCE AND ASSOCIATION AMONG POLYGENIC CHARACTERS IN *GOSSYPIUM HIRSUTUM* L.

MARYAM BIBI<sup>1</sup>, NAQIB ULLAH KHAN<sup>1</sup>, FIDA MOHAMMAD<sup>1</sup>, ROZINA GUL<sup>1</sup>,  
ABDUL AZIZ KHAKWANI<sup>2</sup> AND OBAID ULLAH SAYAL<sup>2</sup>

<sup>1</sup>Department of Plant Breeding & Genetics, Khyber Pakhtunkhwa Agricultural University, Peshawar, Pakistan

<sup>2</sup>Faculty of Agriculture, Gomal University, Dera Ismail Khan, Pakistan

Corresponding author: maryam\_pbg@yahoo.com

### Abstract

Development of promising cotton populations with improved agronomic performance is primary objective of the cotton breeders. Genetic potential and variability in  $8 \times 8$  F<sub>1</sub> diallel hybrids versus their parental lines, traits correlation and heritability estimates were studied in *Gossypium hirsutum* L., during 2008-09 at Khyber Pakhtunkhwa Agricultural University, Peshawar, Pakistan. Highly significant variations were observed among the parental cultivars and their F<sub>1</sub> hybrids for all traits. Results indicated that F<sub>1</sub> hybrids CIM-506  $\times$  CIM-554, CIM-473  $\times$  CIM-554, CIM-446  $\times$  CIM-554 and CIM-446  $\times$  CIM-496 (its reciprocal) produced significantly higher seed cotton yield, bolls per sympodia, boll weight and seeds per boll. Most of the F<sub>1</sub> populations involving CIM-554 as maternal plant also revealed early maturity. Yield related traits revealed significant positive correlations with seed cotton yield. Heritability (broad sense) was high in magnitude for all traits. Results revealed that traits with high heritability and wide range of genetic variability in breeding material can work as a base population, and their significant contribution towards high yield can help in early segregating generations.

### Introduction

Cotton is the most important cash, fiber and industrial crop contributing about 2% to GDP and 8.2% of value added in Agriculture. In Pakistan, cotton is grown on 12% of the total cultivated area. Pakistan is the fourth largest cotton producer and plays a vital role in the national economy and contributes about 60% through export of raw cotton and its by-products. Its contribution in oil production is apparent from the fact that it contributes 60-70% to the local edible oil industry. Stable production of quality cotton is, therefore, crucial to the national interest of Pakistan (Arshad *et al.*, 1993; Baloch, 1997; Hassan *et al.*, 2006; Khan *et al.*, 2009b).

During 2009-10, cotton was grown on 3.106 million hectares and seed cotton yield was 12.70 million bales with average yield of 695 kg ha<sup>-1</sup> (FBS, 2010). Seed cotton yield in Pakistan is still low as compared to other cotton growing countries and need proper attention by Agriculturists. Seed cotton yield being a complex character, is the product of interaction between genotypes and varying environmental conditions. Knowledge about the nature of gene action, genetic potential and mean performance and correlation of yield with various agronomic characters are important for breeder to tackle the problem of yield increase successfully (Hassan *et al.*, 2006; Baloch, 2001; Khan *et al.*, 2009a; Bibi *et al.*, 2011).

However, cultivated cotton has a narrow genetic base and limited genetic variation available for use in the development of new high yielding cotton genotypes (Mohamed *et al.*, 2003). The information about available genetic diversity and relationships among breeding materials could have a significant influence in cotton improvement. Successful breeding program depends on the complete knowhow of the genetic diversity within and among genetic resources of the available germplasm, which facilitates the plant breeders to choose parental sources to generate more diverse populations for further selection (Esmail *et al.*, 2008).

Genetic diversity and variability among cotton genotypes reduces vulnerability of crop against epidemic attack of insects/diseases. In cotton, diversity is important

for long term improvement in lint yield and fiber quality (May *et al.*, 1995). Yield depends upon several yield contributing traits and direct selection for yield is often not effective. Thus, it is essential to study the association of yield components with yield to explore traits for indirect selection (Joshi *et al.*, 2006). Previous researchers i.e. Tariq *et al.*, (1992), Baloch (1997), Moser *et al.*, (2000), Baloch (2001), Prasad *et al.*, (2005), Hassan *et al.*, (2006), Shakeel *et al.*, (2008), Soomro *et al.*, (2008) and Bibi *et al.*, (2011) also evaluated the genetic variability in various cotton cultivars for yield and yield related traits and found significant variations among genotypes for traits. Therefore, the genetic disparity in  $8 \times 8$  F<sub>1</sub> diallel hybrids and their parental lines, and correlation among various morpho-yield traits were studied in upland cotton.

### Materials and Methods

**Plant material and experimental design:** The experiments to study the genetic variability and correlation comprised of a crossing block and F<sub>1</sub> population of  $8 \times 8$  diallel cross of cotton (*G. hirsutum* L.). Eight diverse genotypes (SLH-284, CIM-446, CIM-473, CIM-496, CIM-499, CIM-506, CIM-554 and CIM-707) varying in pedigree, year of release and morph-yield traits were hand sown during May, 2008 and crossed in a complete diallel fashion to generate 56 F<sub>1</sub> cross combinations at Khyber Pakhtunkhwa Agricultural University. During May 2009, eight parental genotypes and their F<sub>1</sub> hybrids were also hand sown in a randomized complete block (RCB) design with three replications. Each genotype was having one row with 5 m length (with no border effect as the spacing between the treatments was same). Plant and row spacing was 30 and 75 cm, respectively. Thinning was performed after 15 to 20 days when the plants gain the height around 10 to 15 cm to ensure single plant per hill. All the recommended cultural practices and inputs including fertilizer, hoeing, irrigation were applied same for all the entries from sowing till the harvesting and the crop was grown under uniform conditions to minimize environmental variations to the maximum possible extent. Different insecticides were also

sprayed for control of sucking and chewing insect pests time to time and as and when required. Pickings were made during the month of November on individual plant basis.

**Traits measurement and statistical analysis:** Data were recorded on days to flowering, monopodia per plant, bolls per sympodia, boll weight, seeds per boll and seed cotton yield per plant on individual plant basis. The data was analyzed through analysis of variance appropriate for RCB design as outlined by Steel & Torrie (1980). Mean values of the genotypes for each parameter were further compared by using least significant difference (LSD) test

at 5% level of probability. Simple correlation coefficient ( $r$ ) of seed cotton yield with all other traits was also worked out according to Kwon & Torrie (1964).

### Results and Discussion

Highly significant ( $p \leq 0.01$ ) differences were observed among parental cultivars and their  $F_1$  hybrids for days to flowering, monopodia per plant, bolls per sympodia, boll weight, seeds per boll and seed cotton yield per plant (Table 1). Thus,  $F_1$  hybrids and their parents indicated significant genetic variation for various morpho-yield traits.

**Table 1. Mean squares and CV for various traits in 8 × 8 diallel cross of upland cotton.**

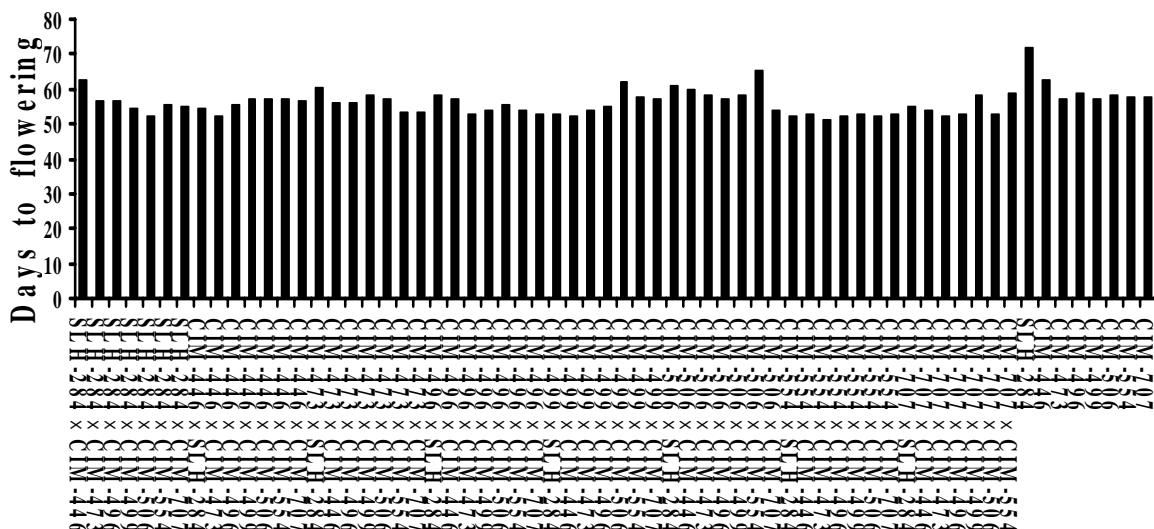
Parameters	Mean squares	CV%
Days to flowering	39.77**	4.83
Monopodia per plant	0.39**	12.94
Bolls per sympodia	1.15**	13.08
Boll weight	0.17**	8.56
Seeds per boll	21.60**	8.13
Seed cotton yield per plant	3652.93**	14.65

\*\* Significant at 1% level of probability

### Genetic variation among parental and $F_1$ genotypes:

Days to flowering showed that parental genotypes varied from 57.00 to 71.67 days and their  $F_1$  hybrids took 51.33 to 65.33 days to flowering (Fig. 1). The less days to flowering were observed in progenies of cultivar CIM-554 as maternal parent i.e. CIM-554 × CIM-473 (51.33 days) and 52.00 days each in  $F_1$  hybrids CIM-554 × CIM-446, CIM-554 × CIM-496, SLH-284 × CIM-506, CIM-446 × CIM-473. Maximum days to flowering were recorded in parental genotype SLH-284 (71.67) and hybrid CIM-506 × CIM-554 (65.33) and were closely followed by two parental cultivars and three  $F_1$  hybrids ranged from 59.67 to 62.67 days. Other  $F_1$  populations and parental genotypes have medium days to flowering. The existing genetic variability among parental lines and  $F_1$  hybrids for

days to flowering may be useful to develop early maturing cotton genotypes through selection in segregating populations, and the same also discussed by Shakeel *et al.*, (2008). Iqbal *et al.*, (2003) and Alishah *et al.*, (2008) by having significant genetic variability among different cotton genotypes for earliness. Breeders are mostly interested in earliness of cotton genotypes as to readily fit in the cropping system and to have wheat sowing in time after harvesting of cotton. Early maturity in cotton is also preferred because of decreasing pressure of inputs i.e. fertilizer, irrigation, crop protection and to provide proper time for rotation of the other crops (Basbag *et al.*, 2007). Iqbal *et al.*, (2006) also mentioned that earliness enables the cotton crop to develop during more favorable season and to escape from losses of late season insects attack.



### 8 x 8 Diallel crosses of upland cotton

Fig. 1. Mean performance for days to flowering in 8 × 8 diallel cross of upland cotton.

Monopodia per plant varied from 0.30 to 1.13 among parents while 0.22 to 1.59 in F<sub>1</sub> hybrids. Minimum number of monopodia per plant was recorded in F<sub>1</sub> hybrids i.e. CIM-496 × CIM-499 (0.22), CIM-496 × CIM-506 (0.31) and parent cultivar SLH-284 (0.30), and were found statistically at par with two parental cultivars and 15 other F<sub>1</sub> hybrids with range of 0.33 to 0.66 (Fig. 2). However, the maximum monopodia were observed in F<sub>1</sub> hybrid CIM-506 × CIM-499 (1.59) which was also found equal with 13 F<sub>1</sub> genotypes ranged from 1.18 to 1.57. Other genotypes showed medium number of monopodia per plant. Khan *et al.*, (1991), Arshad *et al.*, (1993), Akbar

*et al.*, (1994), Hussain *et al.*, (2000), Iqbal *et al.*, (2006) and Ahmad *et al.*, (2008) observed greater genetic variability for vegetative branches, and mentioned that like other yield contributing traits, the vegetative branches also played positive role in managing seed cotton yield. However, Iqbal *et al.*, (2003), Alishah *et al.*, (2008) and Batool *et al.*, (2010) mentioned the variation for monopodia among various cotton populations but negative impact on yield. Therefore, the direct effect and role of monopodial branches could not be recognized in increased yield (Rauf *et al.*, 2004).

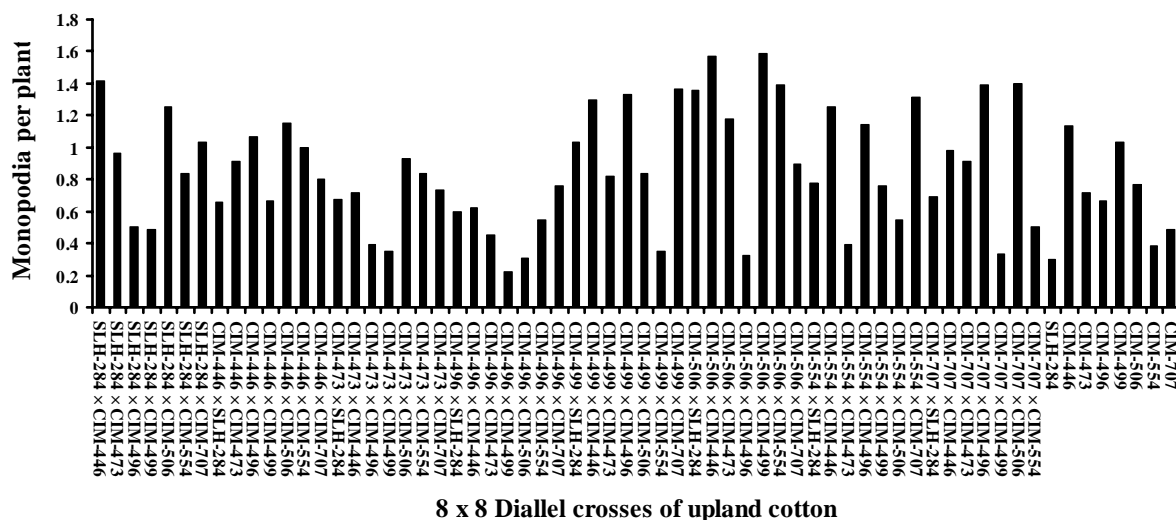


Fig. 2. Mean performance for monopodia per plant in 8 × 8 diallel cross of upland cotton.

Bolls per sympodia ranged from 1.54 to 3.02 among parent cultivars, while in F<sub>1</sub> hybrids the range was 1.52 to 4.48 (Fig. 3). Highest number of bolls per sympodia was recorded in F<sub>1</sub> hybrids i.e. CIM-506 × CIM-554 (4.48), SLH-284 × CIM-506 (3.67), CIM-496 × CIM-446 (3.54) and its reciprocal (3.50). The later three F<sub>1</sub> hybrids were also at par with seven F<sub>1</sub> cross combinations with range of 3.02 to 3.45 bolls sympodia<sup>-1</sup>. Minimum bolls per sympodia were manifested by F<sub>1</sub> hybrids CIM-499 × CIM-707 (1.52) and CIM-707 × CIM-506 (1.53) and were also found at par with three parent cultivars and 21 F<sub>1</sub>

hybrids with range of 1.54 to 2.19. Other genotypes have medium bolls per sympodia. Hassan *et al.*, (2006) and Khan *et al.*, (2009a) obtained similar results and indicated larger genetic variability among various cotton genotypes for bolls per sympodia. However, Ahmad *et al.*, (2008) noticed non-significant differences in means values for bolls per sympodia. Azhar *et al.*, (1998), Djaboutou *et al.*, (2005) and Naveed *et al.*, (2004) mentioned in their findings that bolls per sympodia/plant have major role in yield protection, and during selection such important characters should not be evaded.

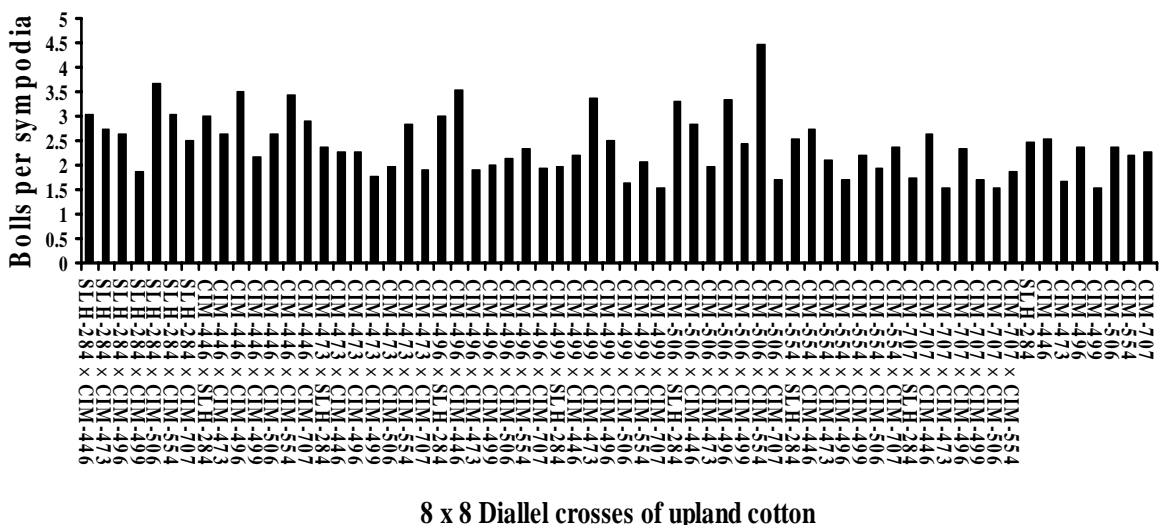
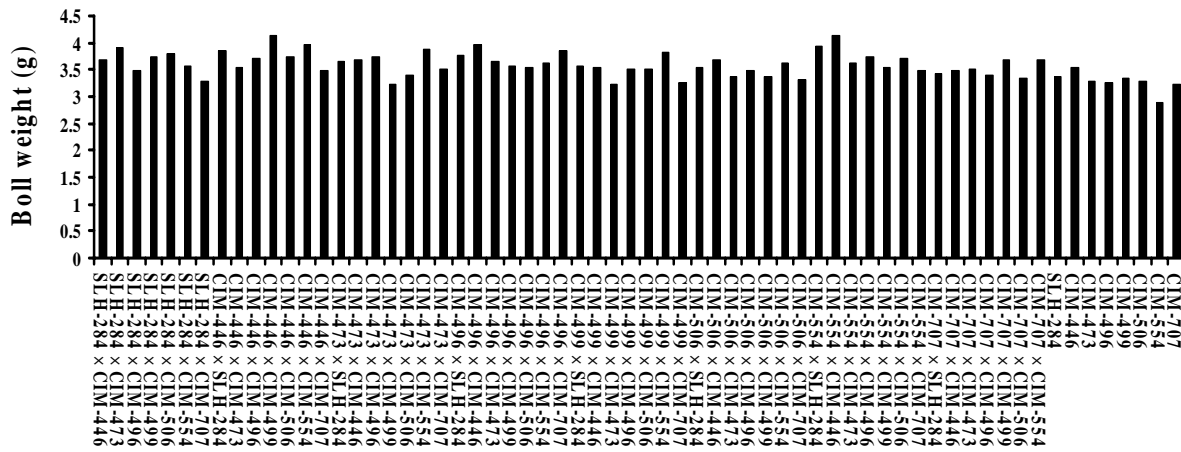


Fig. 3. Mean performance for bolls per sympodia in 8 × 8 diallel cross of upland cotton.

Boll weight varied from 2.89 to 3.53 g among the parental lines, while 3.21 to 4.14 g in F<sub>1</sub> hybrids (Fig. 4). The bigger bolls were noticed in F<sub>1</sub> hybrids i.e. CIM-554 × CIM-446 (4.14 g) and its reciprocal (3.96 g), CIM-446 × CIM-499 (4.12 g) and its reciprocal (3.96 g) and CIM-554 × SLH-284 (3.94 g). In series 35 other F<sub>1</sub> hybrids and two parent cultivars were also at par with above five promising F<sub>1</sub> populations and ranged from 3.49 to 3.91 g. Most of the parent cultivars showed smallest bolls ranged from 2.89 (CIM-554) to 3.37 g (SLH-284) and that range also included seven F<sub>1</sub> hybrids. All other genotypes showed medium boll weight. During selection in these F<sub>1</sub>

hybrids, there are greater chances of improvement in the said trait which may increase the yield. Boll weight is the fundamental yield component after bolls per plant and both traits have greater contribution in variation and enhancement of seed cotton yield. Ahmad *et al.*, (2008), Khan *et al.*, (2009a) and Batool *et al.*, (2010) reported similar proportion and variation for boll weight in relation to seed cotton yield in various upland cotton genotypes. Ali *et al.*, (1998), Elsiddig *et al.*, (2007), Soomro *et al.*, (2008) and Makhdoom *et al.*, (2010) observed genetic variability and its positive impact on seed cotton yield after bolls per plant among various cotton populations.

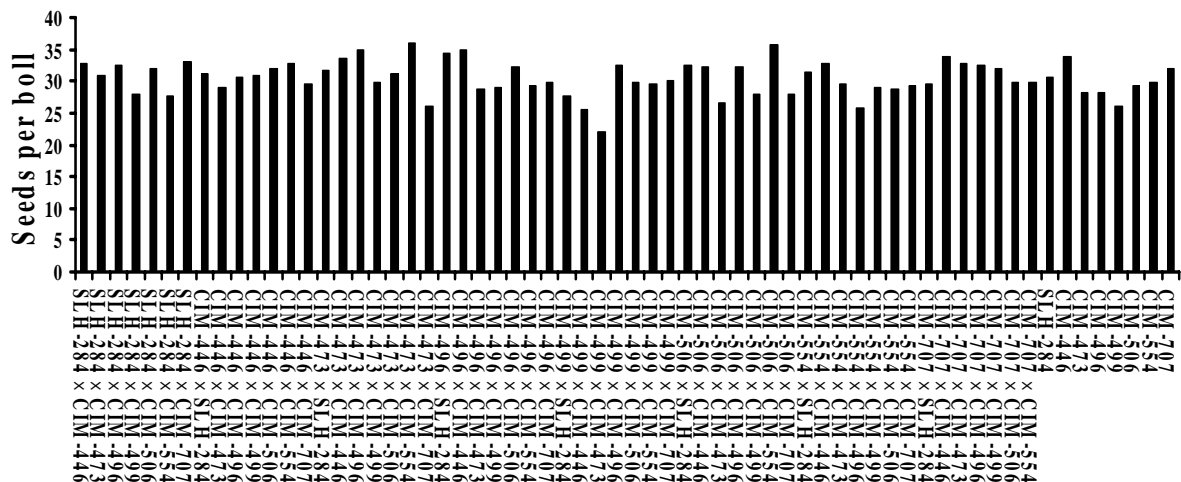


8 x 8 Diallel crosses of upland cotton

Fig. 4. Mean performance for boll weight in 8 × 8 diallel cross of upland cotton.

Seeds per boll were having ranges of 25.93 to 33.70 and 21.98 to 36.06 among parental genotypes and F<sub>1</sub> hybrids, respectively (Fig. 5). Maximum and at par seeds per boll were recorded in F<sub>1</sub> hybrids viz; CIM-473 × CIM-554 (36.06), CIM-506 × CIM-554 (35.75) and 34.79 seeds each in CIM-473 × CIM-496 and CIM-496 × CIM-446. However, these hybrids were also at par with 24 other F<sub>1</sub> populations and two parental genotypes with range of 30.84 to 34.47 seeds per boll. Minimum seeds per boll were produced by hybrid CIM-499 × CIM-473 (21.98) and it was also found at par with one parent and four F<sub>1</sub>

hybrids having range of 25.38 to 26.62 seeds per boll. All other genotypes showed medium seeds per boll. Results revealed that seed per boll is an important yield contributing trait and playing major indirect positive role in protecting the boll weight and eventually seed cotton and lint yields as the fiber directly emerging from seeds. Akbar *et al.*, (1994), Khan and Azhar (2000), Iqbal *et al.*, (2003), Khan *et al.*, (2010) and Makhdoom *et al.*, (2010) also reported same genetic variation for seeds per boll and its positive role in managing boll weight and seed cotton and lint yields.



8 x 8 Diallel crosses of upland cotton

Fig. 5. Mean performance for seeds per boll in 8 × 8 diallel cross of upland cotton.

Seed cotton yield per plant was produced 40.48 to 117.50 g among parental cultivars, while 42.11 to 243.10 g in F<sub>1</sub> hybrids (Fig. 6). Highest seed cotton yield was noticed in F<sub>1</sub> hybrid CIM-506 × CIM-554 (243.1 g). It was closely followed by three other F<sub>1</sub> hybrids i.e., CIM-446 × CIM-554 (153.60), CIM-446 × CIM-496 (155.70) and CIM-473 × CIM-554 (170.80). Lowest seed cotton yield was observed in parent cultivar CIM-499 (40.48 g) and its hybrid CIM-499 × CIM-707 (42.22 g) and were found at par with three parental cultivars and 14 F<sub>1</sub> genotypes with range of 55.08 to 70.45 g. All other

genotypes showed medium seed cotton yield. Results revealed that selection for a capable genotype may be made with some compromise between bolls per plant, boll weight, seeds per boll and plant height. Khan *et al.*, (1991), Ali *et al.*, (1998), Baloch (2001), Hassan *et al.*, (2006), Alishah *et al.*, (2008), Soomro *et al.*, (2008), Batool *et al.*, (2010), Khan *et al.*, (2009a & 2010) and Bibi *et al.*, (2011) findings also revealed greater variability in yield and its dependency on yield contributing traits in various upland cotton genotypes and their F<sub>1</sub> populations.

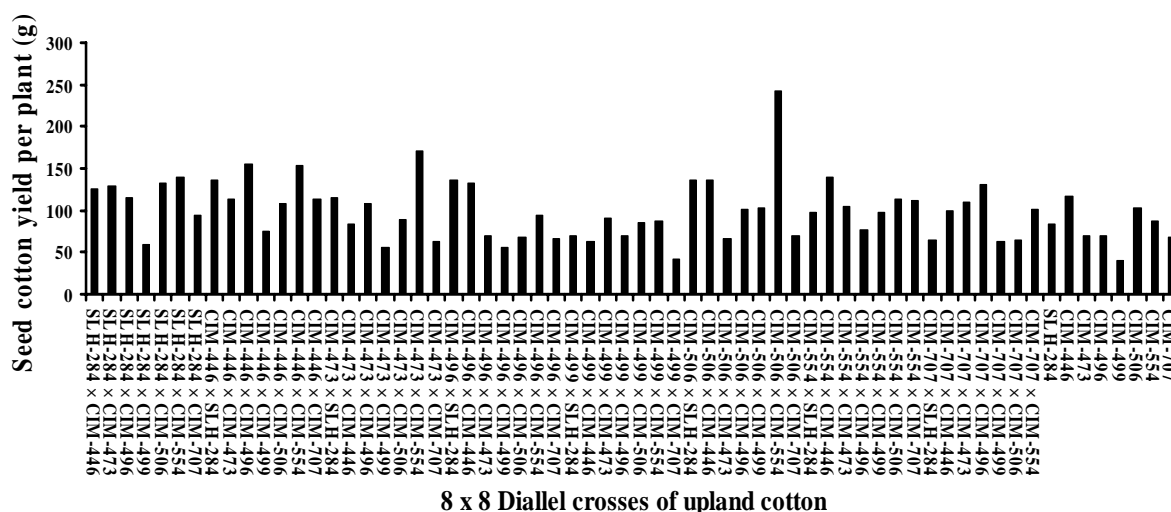


Fig. 6. Mean performance for seed cotton yield plant<sup>-1</sup> in 8 × 8 diallel cross of upland cotton.

**Traits relationship and heritability:** Correlation is used to describe the intensity/ratio of association between various variables. Correlation measures the interdependence between a pair of characters and a change in one trait escorted by a change in another variable. In breeding programmes, the knowledge of correlation is required to obtain the anticipated response of other traits when intensive selection is applied to the variable of interest. Correlation can be either positive, when both variables advance in same direction, and negative when both traits proceed in opposite directions.

Days to flowering was found positively correlated (r = 0.18) with seed cotton yield (Table 2). Rauf *et al.*,

(2005) also obtained positive association for said traits. Kohel & Benedict (1987) found that earliest crop produce lowest yield per plant, and days to flowering have positive correlation with yield. Seed cotton yields were positively correlated with days to first open boll, and highest yields were shown by the least determinate and slowest-maturing genotypes; however, yields generally decreased as determinacy increased and rate of maturity accelerated (Anderson *et al.*, 1976; Godoy & Palomo, 1999). In contradiction, the negative association between these traits has been mentioned by Iqbal *et al.*, (2003). Batool *et al.*, (2010) and reported that highest yield was obtained with medium maturing genotypes.

**Table 2. Correlation of seed cotton yield with various traits in 8 × 8 diallel cross of upland cotton.**

Parameters	Correlation with seed cotton yield plant <sup>-1</sup>	Std. Error
Days to flowering	0.18*	0.62
Monopodia per plant	0.28**	6.91
Bolls per sympodia	0.74**	2.69
Boll weight	0.28**	7.47
Seeds per boll	0.41**	0.72

\*\* , \* Significant at 1% and 5% level of probability, respectively

Monopodia were found positively correlated (r = 0.28) with seed cotton yield (Table 2). Khan *et al.*, (1991), Azhar *et al.*, (1998), Hussain *et al.*, (2000) and Iqbal *et al.*, (2006) observed positive association between vegetative branches and yield. Previous studies of Arshad *et al.*, (1993) and Akbar *et al.*, (1994) also reported positive correlation of seed cotton yield with monopodial and sympodial branches. However, Iqbal *et al.*, (2003)

mentioned the direct negative effects of vegetative branches on yield. Alishah *et al.*, (2008) found non-significant relationship between yield and monopodial branches, as the vegetative branches induce negative impact due to delay in maturity and more square shedding. The correlation between monopodial branches and yield was mainly due to boll number and was negative, which showed that selection for the monopodial

branches would not be realized in increased seed cotton yield (Rauf *et al.*, 2004). Batool *et al.*, (2010) findings also revealed that most of the upland cotton cultivars having less monopodia exhibited higher seed cotton yield, and in breeding for higher yield, preference should be given to less vegetative branches in cotton plant. Present results also revealed that relationship between vegetative branches and seed cotton yield was very weak and not dependable. Therefore, it may not be a criterion for selection because in previous findings the monopodia were also found negatively correlated with yield. That's why mostly the breeders are interested in less vegetative branches, with no bushy structure and to have erect cotton plants. The contradictory findings may be due to different genetic makeup of the breeding material used under various environments.

Number of bolls per sympodia was found positively correlated ( $r = 0.74$ ) with seed cotton yield (Table 2). Khan *et al.*, (2009a) also reported positive correlation between bolls per sympodia and yield. Bolls per sympodia/plant were found significantly positively correlated with yield (Azhar *et al.*, 1997 & 1998; Djaboutou *et al.*, 2005) and have major role in managing seed cotton yield. The traits plant height, bolls per sympodia and bolls per plant also showed significant positive association with yield at phenotypic and genotypic levels (Naveed *et al.*, 2004). Being a yield contributing trait, the upland cultivars having maximum number of bolls per sympodia also showed increased seed cotton yield because of positive association (Ahmad *et al.*, 2008). Therefore, during selection of promising populations preference should be given to more fruiting branches with good boll setting.

Boll weight was also found positively correlated ( $r = 0.28$ ) with seed cotton yield (Table 2). Boll weight and boll number had immense positive influence on seed cotton yield and direct selection for bigger bolls might increase seed cotton yield, and the same was also suggested by Azhar *et al.*, (1997). Greater genetic variability for boll weight, and its direct positive effect (after bolls per plant) on seed cotton yield was observed (Alam & Islam, 1991; Moser *et al.*, 2000; Khan *et al.*, 2009a). The findings of Tariq *et al.*, (1992), Azhar *et al.*, (1997), Batool *et al.*, (2010) and Makhdoom *et al.*, (2010) also enunciated that boll weight was found positively associated with yield and has greater contribution in enhancement of yield in upland cotton.

Seeds per boll were also found positively correlated ( $r = 0.41$ ) with seed cotton yield (Table 2). Akbar *et al.*, (1994), Khan & Azhar (2000) and Khan *et al.*, (2010) also reported genetic variability for seeds per boll among upland cotton genotypes and its positive relationship with yield. Positive association of yield with yield attributes including seeds per boll and genetic variability in upland cotton genotypes for said trait was also observed by Iqbal

*et al.*, (2003) and Wang *et al.*, (2004) and Khan *et al.*, (2009a & b). Past results of Ahamd *et al.*, (2008) revealed that seeds per boll has significant positive relationship with yield and have direct positive effect on yield through increased boll weight. However, the means for seeds per locule (sub-component of seeds per boll) were having nonsignificant variation and revealed no association with yield (Khan *et al.*, 2010). Therefore, during selection, the seeds per boll and locules per boll must keep in mind because of their direct and indirect affect on boll weight and yield, respectively.

Seed cotton yield exhibited positive relationship with yield contributing traits (days to flowering, monopodia per plant, bolls per sympodia, seeds per boll and boll weight) (Table 2), which indicated that any improvement in yield related traits would have a positive impact on seed cotton yield. Godoy & Palomo (1999), Hussain *et al.*, (2000), Naveed *et al.*, (2004), Basbag *et al.*, (2007), Elsiddig *et al.*, (2007), Ahmad *et al.*, (2008), Baloch *et al.*, (2001), Batool *et al.*, (2010) and Bibi *et al.*, (2011) also evaluated various cotton cultivars and observed significant genetic variation in yield contributing traits which donated considerably for variation to yield. Afiah & Ghoneim (2000) and Khan *et al.*, (2010) also mentioned that seed cotton yield has strong positive association with seed traits. Seed cotton yield was found with positive association with plant height, bolls per plant and sympodial branches (Arshad *et al.*, 1993; Akbar *et al.*, 1994; Baloch, 1997; Djaboutou *et al.*, 2005; Soomro *et al.*, 2008).

Heritability (broad sense) for various morpho-yield traits was being highest for days to flowering (0.81), monopodia per plant (0.99), bolls per sympodia (0.97), boll weight (0.71), seeds per boll (0.88) and seed cotton yield per plant (0.98) (Table 3). All the traits were heritable, with highest genetic variability among the parental cultivars and  $F_1$  populations which can be utilized in future breeding programmes for further improvement. Heritability estimates were prominent for bolls per plant, boll weight and yield thus suggesting that improvement for these traits can be made through intensive selection in early segregating generations (Akbar *et al.*, 1994; Ali *et al.*, 1998; Khan & Azhar, 2000; Bibi *et al.*, 2011). However, in moderate heritability the morpho-yield and earliness traits could be improved by making selections among the recombinants obtained through segregating populations (Basbag *et al.*, 2007). The low to moderate broad sense heritability suggested the rigorous plant selection to identify desirable plants in  $F_2$  generation (Naveed *et al.*, 2004; Elsiddig *et al.*, 2007). Batool *et al.*, (2010) and Khan *et al.*, (2009a & 2010) and reported greater genetic variances than environmental, revealed desirable broad sense heritability and all the traits were found highly heritable in upland cotton.

**Table 3. Genetic, environmental and phenotypic variances with heritability (bs) for various traits of upland cotton.**

Parameters	Vg	Ve	Vp	H <sup>2</sup>
Days to flowering	10.80	7.36	13.25	0.81
Monopodia per plant	0.379	0.012	0.383	0.99
Bolls per sympodia	1.05	0.010	1.08	0.97
Boll weight	0.08	0.09	0.11	0.71
Seeds per boll	15.46	6.15	17.50	0.88
Seed cotton yield per plant	3440.93	211.99	3511.66	0.98

Vg = Genetic variance, Ve = Environ. variance, Vp = Phenotypic variance, H<sup>2</sup> = Heritability (bs)

## Conclusion

Results indicated that promising  $F_1$  hybrids i.e., CIM-506  $\times$  CIM-554, CIM-473  $\times$  CIM-554, CIM-446  $\times$  CIM-554, CIM-446  $\times$  CIM-496 and its reciprocal produced significantly higher yield, bolls per sympodia, boll weight and seeds per boll and selection can be made in their early segregating populations for further improvement. The  $F_1$  genotypes of CIM-554 viz., CIM-554  $\times$  CIM-473, CIM-554  $\times$  CIM-496 and CIM-554  $\times$  SLH-284 showed early maturity and these genotypes can be used for development of some genotypes to easily fit in the cropping system to have timely cultivation of wheat crop.

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