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GENETIC DISPARITY AND RELATIONSHIP AMONG QUANTITATIVELY INHERITED YIELD RELATED TRAITS IN DIALLEL CROSSES OF UPLAND COTTON

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Abstract

In quantitative genetics, development of high yielding genotypes from parental cultivars of same ancestry is some what confusing as compared to genetically diverse parents. However, sufficient recombinations through allelic variations in mating of closely-related populations result in superior agronomic performance. Development of improved cotton genotypes is one of the prime objectives of any cotton breeding programmes. Genetic divergence and yield potential of parental cotton genotypes versus their diallel hybrids, relationship of yield with various morpho-yield traits and their heritability were studied in 8 × 8 F_1 diallel hybrids and their parental cultivars in *Gossypium hirsutum* L. during 2008-09 at Khyber Pakhtunkhwa Agricultural University, Peshawar, Pakistan. Highly significant ($p\leq 0.01$) differences were observed among parental genotypes and F_1 populations for all the traits. Results revealed that F_1 hybrids i.e., CIM-506 × CIM-554, CIM-473 × CIM-554, CIM-446 × CIM-496 and CIM-446 × CIM-554 produced significantly higher number of sympodia, bolls per plant and seed cotton yield. Some F_1 populations showed incredible performance for plant height, locules per boll and seeds per locule. Seed cotton yield manifested positive association with morpho-yield traits which also accounted for greater genetic variations to yield being dependent trait. Heritabilities (broad sense) were moderate to high in magnitude for all traits. Results revealed that F_1 populations with larger genetic potential, positive relationship between yield and yield contributing traits and moderate to high heritability can guide intensive selection and improvement *per se* in segregating populations.

Introduction

Cotton is world's leading natural fiber crop. Upland cotton accounts for 90% of world lint production (Preetha & Raveendren, 2008) and is sixth largest source of vegetable oil in world (Alishah *et al*., 2008), however, in Pakistan its contribution in edible oil production is apparent from the fact that it contributes 65-70% to local edible oil industry (Batool *et al*., 2010). Ultimate objective of a cotton breeder is to develop high yielding cultivars, through different breeding techniques by utilizing the existing crop genetic resources. To achieve this aim, a breeder must exploit genetic variability of quantitatively based characters already present in germplasm. Final product of cotton plant i.e., seed cotton yield is the outcome interplay between genetic and non-genetic components and due to its complex nature owing to interaction of these components, the harmonious combination of desirable characters becomes difficult. Thus, for development of promising genotypes, cotton breeder is obliged to study breeding material regarding genetic variability, nature of gene action and degree of correlation of yield with yield related traits (Alam & Islam, 1991; Azhar *et al*., 2000; Hussain *et al*., 2000; Naveed *et al*., 2004; Ahmad *et al*., 2008; Alishah *et al*., 2008; Batool *et al*., 2010).

Maintenance of crop germplasm is direly needed for constant supply of genetic variability for crop improvement and identification of genetic relatedness of available genetic resources. The existing cultivated cotton presents low levels of genetic diversity, and the morpho-agronomic traits in cotton have traditionally been used to differentiate cultivars and provide useful information to the end users. However, the expression of majority of these characters is extensively influenced by environment causing problems for consistent identification (Kumar, 1999). The narrow genetic diversity in available germplasm has led genetic vulnerability and hindrances in cotton production because of insect pests attack, diseases, low yield and poor fibre quality (Lukonge & Ramadhani, 1999).

For expression of morpho-yield traits, heritability in traits and genetic potential basis of various genotypes is earnestly needed for assortment of promising population for breeding programme (Khan *et al*., 2010). Considerable genetic variances and high heritability estimates implied that characters could be improved through intensive selection in a population in segregating generations (Baloch, 2004; Khan *et al*., 2009b). Heritability estimates were generally found to be high in magnitudes in intraspecific crosses of *G. hirsutum* L. (Khan & Azhar, 2000; Naveed *et al*., 2004; Hu *et al*., 2001) as comparative to *Gossypium barbadense* L. crosses (Esmail, 2007).

Generally it has been observed that large number of genes control yielding capacity of the cotton plant. Correlation of one phenotypic character with another is dependent upon the cause and effect relationship. The observation is either positive or negative and its degree varies according to the environment involved. There are certain characters that are consequently associated in a definite manner throughout the varying environmental conditions (Memon *et al*., 2002). Naveed *et al*., (2004) carried out correlation studies and reported that plant height and bolls per plant were positively associated with yield. Soomro (2000) found more and heavier bolls, and yield in F_1 hybrids as compared to conventional cultivars. Keim *et al*., (2000) recorded increase in yield by early season new cultivars and full season *G. hirsutum* L. cultivars. Ji *et al*., (2000) characterized the high yielder cultivars as strong boll setting capability, medium boll weight and high lint percentage. Afiah & Ghoneim (1999) also observed an increased yield in Egyptian cotton cultivars due to higher number of bolls per plant and boll weight.

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Positive correlation between yield and morpho-yield traits was also mentioned by Tariq *et al*., (1992), Tyagi (1994), Memon *et al*., (2002), Mustafa *et al*., (2007), Makhdoom *et al*., (2010) and Salahuddin *et al*., (2010). Seed cotton yield had positive correlation with plant height and bolls, and also assessed genetic variability for plant height, sympodia, bolls and yield (Satange *et al*., 2000; Soomro, 2000; Soomro *et al*., 2008; Khan *et al*., 2009a; Batool *et al*., 2010; Khan *et al*., 2010). If correlation between traits is very high, then selection for one trait will simultaneously result in changes in other trait. This association may be either harmful or beneficial, depending upon the direction of association and objectives of the breeder. Therefore, the present studies were carried out to determine the genetic divergence among 8 × 8 F_1 diallel hybrids and their parental cultivars, and correlation for various morpho-yield traits in upland cotton.

Materials and Methods

Breeding material and field procedure: Eight diverse genotypes (SLH-284, CIM-446, CIM-473, CIM-496, CIM-499, CIM-506, CIM-554 and CIM-707) of upland cotton varying in pedigree, year of release and morpho-yield traits were hand sown during May, 2008 at Khyber Pakhtunkhwa Agricultural University, Peshawar, Pakistan (Table 1) and were crossed in a complete diallel fashion to generate 56 F_1 cross combinations. Peshawar lies between 34°, 02′ North latitude and 71°, 37′ East longitude. During May 2009, the parent cultivars and their F_1 hybrids were also hand sown in a randomized complete block (RCB) design with three replications. Each genotype was having one row with five meter length (with no border effect as the spacing between the treatments was same). Plants and rows were spaced at 30 and 75 cm, respectively. Thinning was performed after 15 to 20 days when the plants gained the height of 10 to 15 cm to ensure single plant per hill. All recommended cultural practices and inputs including fertilizer, hoeing, irrigation, insecticides were applied same for all entries from sowing till harvesting and the crop was grown under uniform conditions to minimize environmental variation to the maximum possible extent. Pickings were made during the month of November on single plant basis.

Table 1. Breeding material used in 8 × 8 F_1 diallel crosses.

Cultivars	Parentage	Breeding Centre	Release (year)	Seed cotton yield (kg ha^{-1})	GOT (%)	Staple length (mm)
CIM-446	CP-15/2 × S-12	CCRI, Multan	1998	3,000	36.1	27.0
CIM-473	CIM-402 × LRA 5166	CCRI, Multan	2002	3,000	39.7	29.5
CIM-496	CIM-425 × 755-6/93	CCRI, Multan	2005	3,000	41.1	29.7
CIM-499	CIM-433 × 755-6/93	CCRI, Multan	2003	3,000	40.0	29.6
CIM-506	CIM-360 × CP 15/2	CCRI, Multan	2004	3,000	38.6	28.7
CIM-554	2579-04/97 × W-1103	CCRI, Multan	2009	4,241	41.5	28.5
CIM-707	CIM-243 × 738-6/93	CCRI, Multan	2004	3,000	39.0	32.2
SLH-284	Not yet released	CRS, Sahiwal	-	3,707	39.0	28.5

Traits measurement and statistical analysis: Data were recorded on 10 randomly selected plants for plant height, sympodia per plant, bolls per plant, locules per boll, seeds per locule, and seed cotton yield per plant on individual plant basis. Data were subjected to analysis of variance appropriate for RCB design to compare mean differences among various cotton populations for different morpho-yield traits as outlined by Steel & Torrie (1980). Mean values of 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 morpho-yield traits was also worked out according to Kwon & Torrie (1964).

Results and Discussion

Significant (*$p \leq 0.01$*) differences were observed among genotypes for plant height, sympodia per plant, bolls per plant, locules per boll, seeds per locule and seed cotton yield per plant (Table 2), indicating greater genetic variations among F_1 populations and their parents for various traits.

Table 2. Mean squares and CV for various traits in 8 × 8 diallel cross of upland cotton.

Parameters	Mean squares	CV %
Plant height	999.75**	10.55
Sympodia per plant	43.66**	10.20
Bolls per plant	176.46**	10.80
Locules per boll	0.03**	2.41
Seeds per locule	0.78**	4.99
Seed cotton yield per plant	3652.93**	14.65

** Significant at 1% level of probability

Genetic variations among F_1 populations and parental cultivars

Plant height: Plant height ranged from 75.84 to 119.80 cm for parental genotypes, while in F_1 hybrids ranged between 81.69 and 148.30 cm. Tallest plants were noticed in F_1 hybrids i.e., CIM-554 × CIM-446 (148.3 cm) SLH-284 × CIM-506 (145.50 cm) and SLH-284 × CIM-446 (144.90 cm) which were also found at par with 12 other cross combination with range of 124.30 to 143.90 cm (Fig. 1). Minimum plant height was expressed by parental genotype CIM-499 (75.84 cm) and F_1 hybrids CIM-506 × CIM-473 (81.69 cm) and CIM-499 × CIM-506 (83.50 cm). All other genotypes showed medium plant height. Khan *et al*., (1991), Elsiddig *et al*., (2007), Khan *et al*., (2009a & b) and Batool *et al*., (2010) also indicated greater genetic variability among upland cotton populations for plant height. Plant height was found positively correlated (r = 0.63) with seed cotton yield (Table 3). Results revealed that increase in plant height resulted in increased number of sympodia and bolls, which in turn increased seed cotton yield. However, cotton breeders are mostly interested in short stature plants due to lodging threat and also suitable for mechanical picking. Plant height positively correlated with fruiting branches, number of bolls and seed cotton yield. Had there not been lodging, plant height would have positive association with bolls per plant. Significant and positive association was reported between plant height and seed cotton yield (Arshad *et al*., 1993; Azhar *et al*., 1998 & 2000; Hussain *et al*., 2000; Baloch *et al*., 2001; Naveed *et al*., 2004; Ahmad *et al*., 2008; Khan *et al*., 2009a & 2010). Plant height contributed 70% of total variability to seed cotton yield and showed positive correlation with seed cotton yield (Tyagi, 1994). Plant height and sympodia per plant gave positive relationship and had greater contribution in variations of seed cotton yield (Preetha & Raveendren, 2008). However, the direct effect of plant height on seed cotton yield was negative; therefore height cannot be used as selection criteria for yield improvement in cotton (Rauf *et al*., 2004). Negative associations of plant height with number of bolls and seed cotton yield had been reported (Tariq *et al*., 1992; Elsiddig *et al*., 2007; Makhdoom *et al*., 2010), which might be due to lodging of cotton plants due to worse environmental conditions.

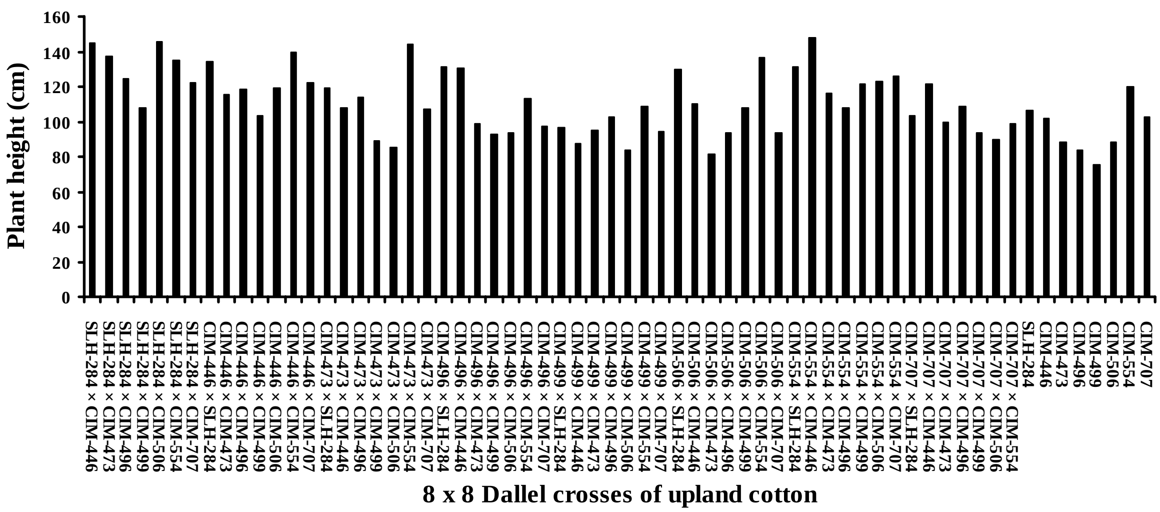

Fig. 1. Mean performance for plant height in 8 × 8 diallel cross of upland cotton.

Table 3. Correlation of seed cotton yield with various traits in 8 × 8 diallel cross of upland cotton.

Parameters	Correlation with seed cotton yield	Std. Error
Plant height	0.63**	0.10
Sympodia per plant	0.71**	0.01
Bolls per plant	0.79**	0.20
Locules per boll	0.15*	19.06
Seeds per locule	0.36**	4.28
Seeds per boll	0.41**	0.72

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

Sympodia per plant: Sympodia per plant ranged between 11.09 and 18.51 among parental genotypes, while 11.59 to 27.00 in F_1 cross combinations (Fig. 2). Maximum number of fruiting branches was observed in hybrids SLH-284 × CIM-506 (27.00), CIM-446 × SLH-284 (24.64), CIM-506 × CIM-554 (24.55) and CIM-446 × CIM-554 (24.13). The least number of fruiting branches was revealed by parental genotype CIM-499 (11.09), F_1 hybrids CIM-496 × CIM-446 (11.59) and CIM-496 × CIM-499 (12.00), and were found at par with two parents and 14 other cross combinations ranged from 12.03 to 14.56. Other genotypes had medium sympodia per plant. Mustafa *et al*., (2007), Ahmad *et al*., (2008) and Batool *et al*., (2010) also obtained similar results for sympodia per plant with larger genetic variability among various upland cotton genotypes. Sympodia per plant were positively correlated (r = 0.49) with seed cotton yield because boll bearing branches directly affect seed cotton yield (Table 3). Hussain *et al*., (2000) also reported positive genetic correlation using F_2 families and their eight parents of *G. hirsutum* L. While making selection for promising lines, the fruiting branches must be kept in mind as secondary selection criteria after bolls per plant and boll weight. Greater genetic variability and positive relationship between sympodia and seed cotton yield contributed significantly in addition to fruiting branches towards yield improvement (Arshad *et al*., 1993; Azhar *et al*., 1998; Memon *et al*., 2002; Djaboutou *et al*., 2005; Ahmad *et al*., 2008; Soomro *et al*., 2008). However, correlation between sympodial branches and seed cotton yield was mainly due to boll number, which was high and positive. Hence, the sympodial branches could not be regarded as a reliable source of getting high yields in cotton (Rauf *et al*., 2004). The conflicting views might be due to genetic background of the cotton populations used under various environmental conditions.

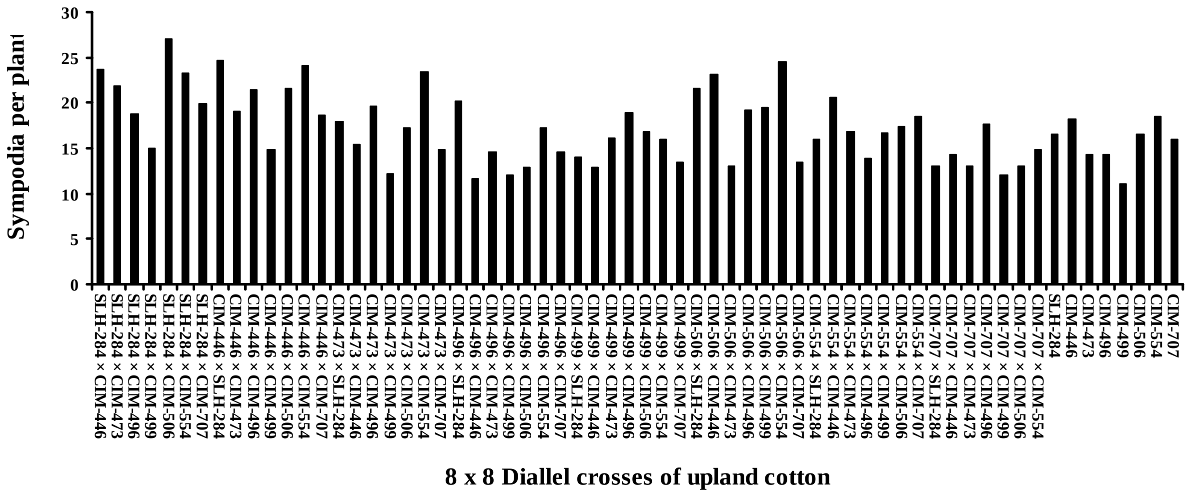

Fig. 2. Mean performance for sympodia per plant in 8 × 8 diallel cross of upland cotton.

Bolls per plant: Bolls per plant varied from 11.75 to 34.71 among the parental genotypes and 13.30 to 47.33 in F_1 cross combinations (Fig. 3). Maximum bolls per plant were observed in cross CIM-473 × CIM-554 (47.33) and were also found at par with three F_1 hybrids SLH-284 × CIM-554 (40.81), CIM-446 × CIM-496 (37.18) and CIM-446 × CIM-554 (36.73). Minimum bolls per plant were exhibited by parental genotype CIM-499 (11.75) and were also found at par with three parents and 22 F_1 genotypes (13.30 to 22.20). Other genotypes provided medium bolls per plant. Larger genetic variations were observed among various upland cotton genotypes for bolls per plant (Ali *et al*., 1998; Elsiddig *et al*., 2007; Ahmad *et al*., 2008; Makhdoom *et al*., 2010). Bolls per plant have direct influence and major role in managing seed cotton yield and the said trait was found positively correlated (r = 0.79) with seed cotton yield (Table 3), as also reported by Azhar *et al*., (1998). The findings of Alam & Islam (1991), Hussain *et al*., (2000) and Khan & Azhar (2000) also revealed larger genetic variability for bolls per plant among upland cotton populations and found positively correlated with seed cotton yield. Number of bolls per plant had maximum positive direct effect on seed cotton yield per plant followed by boll weight (Rauf *et al*., 2004). Results revealed that bolls per plant should be given greater importance in cotton improvement programmes as it contributes significantly. Therefore selection should be made for larger number of bolls per plant and high lint % for breeding cotton with high seed cotton and lint yields. For identifying potential populations, preference should be given to increased and bigger bolls.

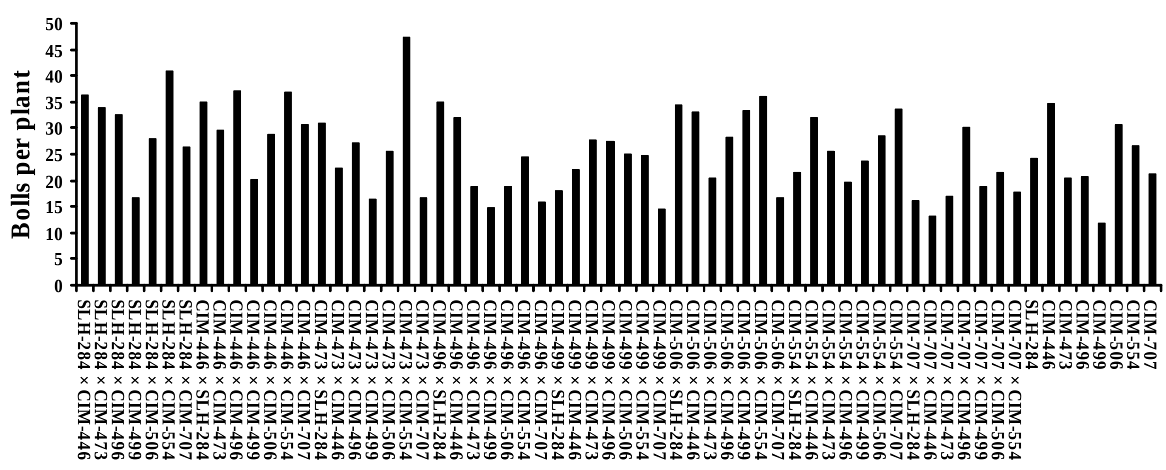

Fig. 3. Mean performance for bolls per plant in 8 × 8 diallel cross of upland cotton.

Locules per boll: The locules per boll varied from 4.43 to 4.70 among the parental genotypes, while 4.51 to 4.94 in F_1 populations (Fig. 4). Highest number of locules per boll was noticed in F_1 hybrids CIM-499 × CIM-554 (4.94) and 4.90 each in CIM-473 × SLH-284 and CIM-707 × SLH-284, and was also found at par with one parent and 39 F_1 cross combinations with range of 4.70 to 4.87. Minimum locules per boll were recorded in parental genotype CIM-499 (4.43) and were also found equal with seven parents and 10 F_1 hybrids (4.51 to 4.67). All other genotypes showed medium number of locules per boll. The locules per boll was found positively correlated (r = 0.15) with seed cotton yield (Table 3). Morphological traits like locules per boll and sympodia also have indirect positive impact on seed cotton yield. Results revealed that increasing the number of locules and seeds per boll would increase the boll weight and lint per boll. Locules per boll were found positively correlated with seeds per boll and boll weight (Brown & Ware, 1958; Afzal & Ali, 1969; Ahmad *et al*., 2008) and concluded that locules per boll would increases lint yield. Hence, improvement of boll weight would improve the seed cotton yield. Singh *et al.*, (1968) also reported that cotton yield basically dependent on bolls, boll weight and locules per boll. However, Tyagi (1994) and Khan *et al*., (2009a) observed the association of different morphological and yield traits and noticed that locules per boll were negatively correlated with seed cotton yield. Plant type characteristics play important role and consideration should be paid to such type of traits during selection. Contradictory views of various researchers about the said trait might be due to genotypic and environmental variances and due to different genetic background of the cotton populations tested under various environmental conditions.

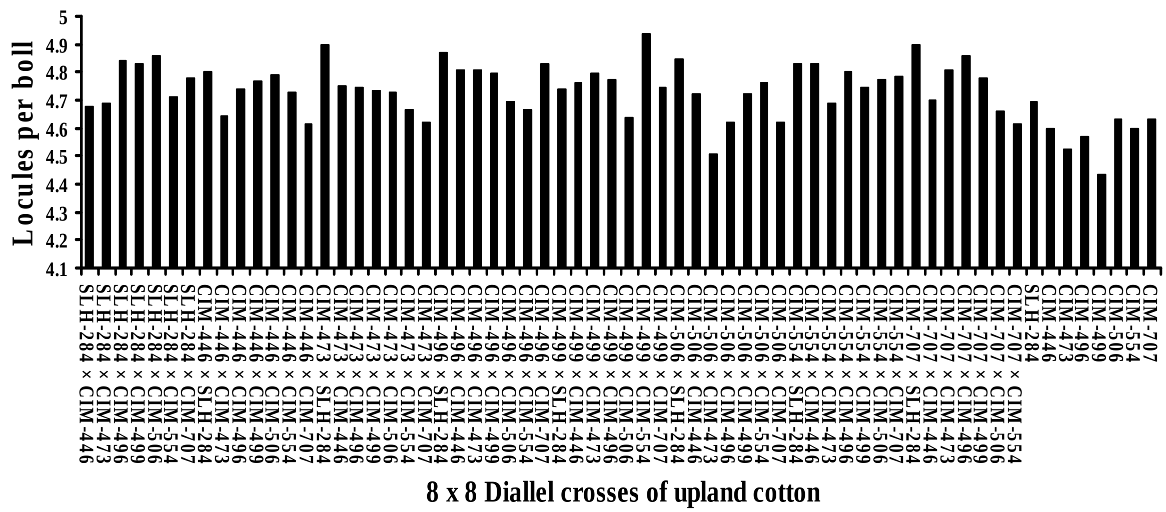

Fig. 4. Mean performance for locules per boll in 8 × 8 diallel cross of upland cotton.

Seeds per locule: Seeds per locule ranged from 6.46 to 7.35 among parental cultivars, while 6.02 to 8.11 in F_1 hybrids (Fig. 5). Highest number of seeds per locule was observed in F_1 hybrids CIM-499 × CIM-496 (8.11), CIM-473 × CIM-496 (8.04) and CIM-506 × CIM-554 (8.01) and these hybrids were also found at par with 13 other F_1 genotypes with range of 7.36 to 7.95. Minimum seeds per locule were noticed in cross combinations CIM-554 × CIM-506 (6.02), CIM-473 × CIM-446 (6.12) and CIM-554 × CIM-499 (6.17) and were also found at par with five parental cultivars and 13 F_1 cross combinations with range of 6.26 to 6.74. All other genotypes showed medium seeds per locule. Ahmad *et al*., (2008), Khan *et al*., (2009a & 2010) observed significant variations for seed traits and observed that any improvement in seed traits would have a positive effect on seed cotton yield. Seeds per locule were found positively correlated (r = 0.36) with seed cotton yield (Table 3). Tyagi (1994), and Makhdoom *et al*., (2010) also found significant positive association between seeds per locule and seed cotton yield, however, Khan *et al*., (2010) observed negative association for the said traits. Contradictory vision of past researchers might be due to different breeding material used under inconsistent environmental conditions.

Seed cotton yield: Seed cotton yield per plant was 40.48 to 117.50 g among parental cultivars, while 42.11 to 243.10 g in F_1 hybrids (Fig. 6). Highest seed cotton yield was recorded in F_1 hybrid CIM-506 × CIM-554 (243.10 g). It was closely followed by three other F_1 cross combinations i.e. CIM-446 × CIM-554 (153.60), CIM-446 × CIM-496 (155.70) and CIM-473 × CIM-554 (170.80). The lowest seed cotton yield was observed in parent cultivar CIM-499 (40.48 g) and F_1 cross combination CIM-499 × CIM-707 (42.22 g) and was found equal with three parent cultivars and 14 F_1 genotypes with range of 55.08 to 70.45 g. All other genotypes showed medium seed cotton yield per plant. Khan *et al*., (1991), Ali *et al*., (1998) and Makhdoom *et al*., (2010) also observed significant differences among upland cotton genotypes and their hybrids for seed cotton yield. Seed cotton yield showed positive correlation with all other morpho-yield traits (plant height, sympodia per plant, bolls per plant, locules per boll and seeds per locule). Baloch *et al*., (2001), Baloch (2004) and Batool *et al*., (2010) evaluated different *G. hirsutum* L. cultivars for yield traits and observed significant genetic variations for bolls per plant and boll weight, and these traits contributed significantly to seed cotton yield. Afiah & Ghoneim (2000), Soomro *et al*., (2008) and Khan *et al*., (2010) mentioned that seed cotton yield has strong positive association with seed traits. Arshad *et al*., (1993) and Djaboutou *et al*., (2005) reported positive correlation of seed cotton yield with plant height, bolls per plant and fruiting branches.

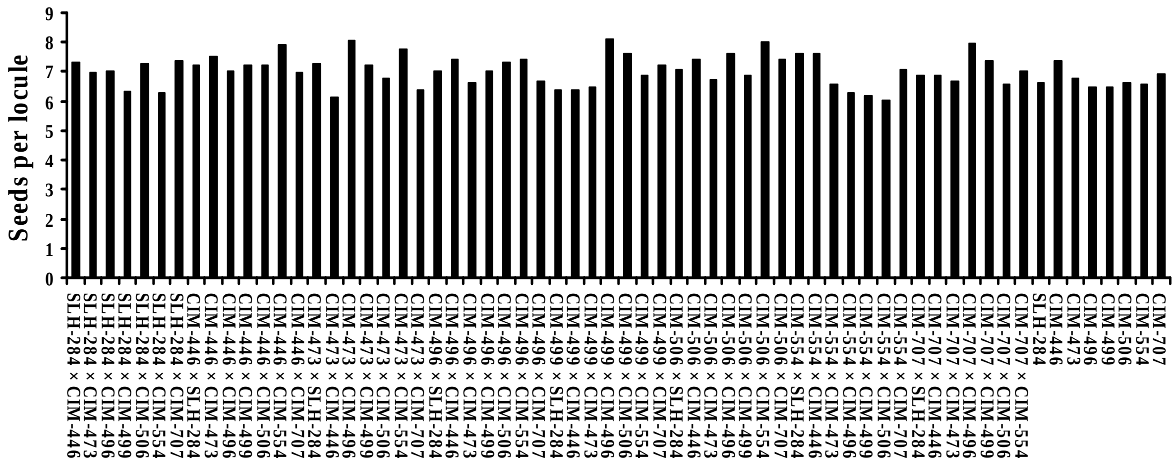

Fig. 5. Mean performance for seeds per locule in 8 × 8 diallel cross of upland cotton.

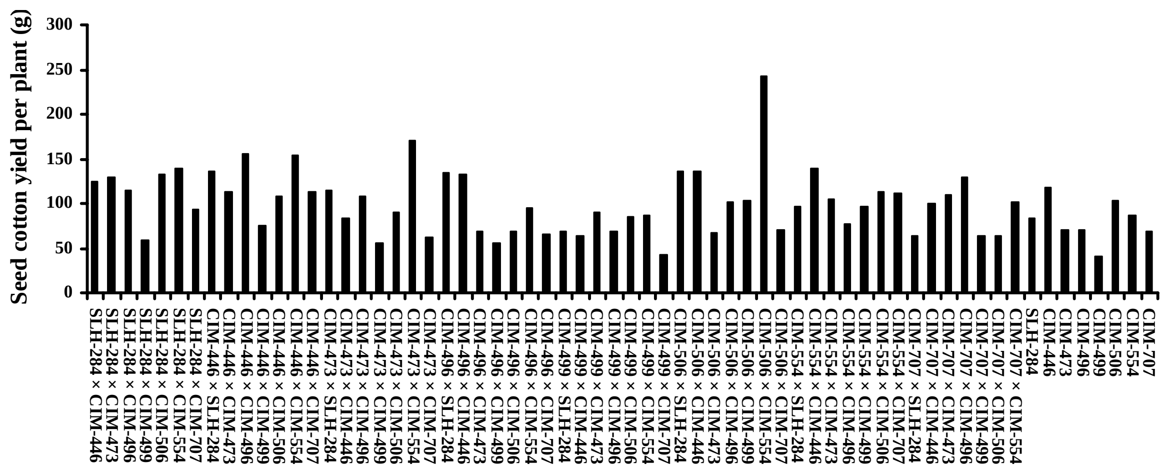

Fig. 6. Mean performance for seed cotton yield per plant in 8 × 8 diallel cross of upland cotton.

Heritability: The heritabilities (broad sense) for various traits were moderate to high in magnitude and most of the characters were highly heritable (Table 4) viz., plant height (0.86), sympodia per plant (0.63), bolls per plant (0.98), locules per boll (0.81), seeds per locule (0.94) and seed cotton yield per plant (0.98). Results revealed that magnitudes of heritabilities suggested that intensive selection in early generation for identifying the promising genotypes for the said traits cumulatively will be more effective as also mentioned by Ali *et al*., (1998), Khan & Azhar (2000), Naveed *et al*., (2004), Hu *et al*., (2001), Baloch *et al*., (2003), Elsiddig *et al*., (2007), Khan *et al*., (2009a & 2010) and Batool *et al*., (2010). However, Falconer & Mackey (1996) mentioned that heritability is mostly affected by environmental conditions, and therefore may be used with great care in plant improvement programme. However, in present studies the higher magnitude of heritabilities may result due to greater genetic variation hold by genes expression and a smaller environmental intervention.

Table 4. Genetic, environmental and phenotypic variances with heritability (bs) for various traits in upland cotton.

Parameters	Vg	Ve	Vp	H^2
Plant height	287.90	136.06	333.25	0.86
Sympodia per plant	36.39	21.80	58.19	0.63
Bolls per plant	168.71	7.75	171.30	0.98
Locules per boll	0.02	0.01	0.02	0.81
Seeds per locule	0.65	0.12	0.69	0.94
Seed cotton yield plant^{-1}	3440.93	211.99	3511.66	0.98

Vg = Genetic variance, Ve = Environ. variance, Vp = Phonotypic variance, H^2 = Heritability (bs)

Conclusion

Highest genetic variability was observed among parental cultivars and their F_1 hybrids for all traits. Seed cotton yield was positively correlated with yield contributing traits, which can be used as ready reference in future breeding programme. Based on the results of F_1 hybrids i.e. CIM-506 × CIM-554, CIM-473 × CIM-554, CIM-446 × CIM-496 and CIM-446 × CIM-554 could yield potential segregants for seed cotton yield. Comparative performance of F_1 hybrids, heritability estimates and association among traits could offer useful guidance in selection process.

References

Afiah, S. and E.M. Ghoneim. 1999. Evaluation of some Egyptian cotton (*G. barbadense* L.) varieties under desert conditions*, Annals Agric. Sci. Cairo,* 44(1): 201-211.

Afzal, M. and M. Ali. 1969. *Cotton plant in Pakistan*. Islami Aiwan-i-Science, Sharah-i-Romi, Lahore, Pakistan: 252.

Ahmad, W., N.U. Khan, M.R. Khalil, A. Parveen, U. Aimen, M. Saeed, Samiullah and S.A. Shah. 2008. Genetic variability and correlation analysis in upland cotton. *Sarhad J. Agric*., 24(4): 573-580.

Alam, A.K.M.R. and H. Islam. 1991. Correlation and path coefficient analysis of yield and yield contributing characters in upland cotton (*G. hirsutum* L.) in Bangladesh. *Annals of Bangladesh Agric*., 1(2): 87-90.

Ali, B., I.A. Khan and K. Aziz. 1998. Study pertaining to the estimation of variability, heritability and genetic advance in upland cotton. *Pak. J. Biol. Sci.,* 1(4): 307-308.

Alishah, O., M.B. Bagherieh-Najjar and L. Fahmideh. 2008. Correlation, path coefficient analysis of some quantitative and agronomic traits in cotton (*G. hirsutum* L.). *Asian J. Biol. Sci.,* 1(2): 61-68.

Arshad, M., M. Hanif, N. Ilahi and S.M. Shah. 1993. Correlation studies on some commercial cotton varieties of *G. hirsutum* L. *Sarhad J. Agric.,* 9(1): 49-53.

Azhar, F.M., A.I. Khan and I. Mahmood. 1998. Path coefficient analysis of some advanced generation progenies of *G. hirsutum* L. *Int. J. Agric. Biol*., 1(3): 85-87.

Azhar, F.M., S.S. Hussain and A.I. Khan. 2000. Association of seed cotton yield with other quantitative plant characters of *G. hirsutum* L. *Pak. J. Biol. Sci*., 2: 700-701.

Baloch, M.J. 2004. Genetic variability and heritability estimates of some polygenic traits in upland cotton. *Pak. J. Sci. Indus. Res*., 42: 451-454.

Baloch, M.J., A.R. Lakho, H. Bhutto and M.Y. Solangi. 2001. Path coefficient analysis for assessing direct and indirect effects of yield components on seed cotton yield in *G. hirsutum* L. *J. Biol. Sci*., 1: 354-355.

Batool, S., N.U. Khan, K. Makhdoom, Z. Bibi, G. Hassan, K.B. Marwat, Farhatullah, F. Mohammad, Raziuddin and I.A. Khan. 2010. Heritability and genetic potential of upland cotton genotypes for morpho-yield traits. *Pak. J. Bot*., 42(2): 1057-1064.

Brown, H.B. and J.O. Ware. 1958. Cotton by Brown. pp. 116. Mc - Grawhill Book Company.

Djaboutou, C.M., S.O. Alabi, C.A. Echewku and F.C. Orakwue. 2005. Variability and interrelationship of some agronomic and fibre quality traits in multi-adversity cotton (*G. hirsutum* L.). *Agric. Trop. Subtrop*., 38(3-4): 7-13.

Elsiddig, A.A., M.M.S. Ahmed and A.E. Ibrahim. 2007. Variability, heritability and association of some characters in upland cotton (*G. hirsutum* L.). *Univ. of Khartoum J. Agril. Sci. Sudan*, 15(2): 191-203.

Falconer, D.S. and T.F.C. Mackey. 1996. *Introduction to Quantitative Genetics*. 3rd Ed. Longman, London.

Hu, S.L., Y.J. Mei, P. Gong, X.C. Cao, C. Zeng and L.R. He. 2001. Genetic analysis of the yield and morphological characters of F_2 of Upland cotton. *China Cottons*, 28: 9-10.

Hussain, S.S., F.M. Azhar and I. Mahmood. 2000. Path coefficient and correlation analysis of some important plant traits of *G. hirsutum* L. *Pak. J. Biol. Sci.*, 3(9): 1399-1400.

Ji, C., J. Yu, Y.L. Liu, Y. Wu, C.L. Ji, J. Yu, Y.L. Liu and Y. Wu. 2000. Characteristics of yield constitution of high-yielding cotton varieties. *Jiangsu. J. Agric. Sci*., 16(1): 25-30.

Keim, D.L., L. Burdett., K.R. Jones, P. Dugger and D. Richter. 2000. Yield progress in delta pine conventional varieties grown in the Midsouth. *Proceedings Beltwide Cotton Conf., San Antonio*, USA, 1: 545-547.

Khan, A.I. and F.M. Azhar. 2000. Estimates of heritabilities and pattern of association among different characters of *G. hirsutum* L. *Pak. J. Agric. Sci.,* 37(1-2): 7-10.

Khan, M.A., M. Hussain, M.A. Khan and R.A. Kainth. 1991. Estimation on heritable variation in four crosses of upland cotton (*G. hirsutum* L.). *J. Agric. Res*., 29(3): 305-310.

Khan, N.U., G. Hassan, K.B. Marwat, Farhatullah, S. Batool, K. Makhdoom, I. Khan, I.A. Khan and W. Ahmad. 2009a. Genetic variability and heritability in upland cotton. *Pak. J. Bot.,* 41(4): 1695-1705.

Khan, N.U., G. Hassan, K.B. Marwat, M.B. Kumbhar, I. Khan, Z.A. Soomro, M.J. Baloch and M.Z. Khan. 2009b. Legacy study of cottonseed traits in upland cotton using Griffing's combining ability model. *Pak. J. Bot*., 41(1): 131-142.

Khan, N.U., K.B. Marwat, G. Hassan, Farhatullah, S. Batool, K. Makhdoom, W. Ahmad and H.U. Khan. 2010. Genetic variation and heritability for cottonseed, fiber and oil traits in *G. hirsutum* L. *Pak. J. Bot*., 42(1): 615-625.

Kumar L.S. 1999. DNA markers in plant improvement. An overview. *Biotechnol. Adv*., 17: 143-182.

Kwon, S.H. and J.H. Torrie. 1964. Heritability and interrelationship among traits of two soybean population. *Crop Sci.,* 4: 194-198.

Lukonge, E. and O.S. Ramadhani. 1999. Review of plant breeding and agrobiodiversity in the Lake Zone. In: Breeding and Agrobiodiversity Workshop Proceedings pp. 6-11. *Agric. Res*. & Dev. Ukiriguru, Mwanza, Tanzania, pp 6-11.

Makhdoom, K., N.U. Khan, S. Batool, Z. Bibi, Farhatullah, S. Khan, F. Mohammad, D. Hussain, Raziuddin, M. Sajjad and N. Khan. 2010. Genetic aptitude and correlation studies in *G. hirsutum* L. *Pak. J. Bot*., 42(3): 2011-2017.

Memon, A.M., A.R. Soomro, R. Anjum and S. Bano. 2002. Correlation studies in four commercial upland cotton varieties. *Indus J. Plant Sci.,* 1(1): 49-52.

Mustafa, A., Y.M.A. Elsheikh and E.A. Babiker. 2007. Genetic variability and character association and selection criteria in cotton (*G. hirsutum* L.). *Sudan J. Agric. Res.*, 8: 43-50.

Naveed, M., F.M. Azhar and A. Ali. 2004. Estimates of heritabilities and correlations among Seed cotton yield and its components in *G. hirsutum* L. *Int. J. Agric. Biol.*, 6(4): 712-714.

Preetha, S. and T.S. Raveendren. 2008. Genetic appraisal of yield and fiber quality traits in cotton using interspecific F_2, F_3, and F_4 population. *Int. J. Integ. Biol.*, 3(2): 136-142.

Rauf, S., T.M. Khan, H.A. Sadaqat and A.I. Khan. 2004. Correlation and path coefficient analysis of yield components in cotton (*G. hirsutum* L.). *Int. J. Agric. Biol.*, 6(4): 686-688.

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

Satange, I.V., P.W. Khorgade, M.R. Wandhare, B.R. Patil and S.R. Golhar, 2000. Studies on genetic variability and correlation coefficient in American cotton. *J. Soils Crops,* 10: 94-97.

Singh, R.B., M.P. Gupta, B.R. Mar and D.K. Jain. 1968. Variability and correlation studies in yield and quality characters in *G. hirsutum* L. *Ind. J. Genetica*, 28: 216- 222.

Soomro, A.R. 2000. Assessment of *Gossypium hirsutum* F_1 against commercial varieties. *Pak. J. Sci. Ind. Res.* 43(3): 184-187.

Soomro, Z.A., A.S. Larik, N.U. Khan, M.J. Baloch, S. Mari, S. Memon and N.A. Panwar. 2008. Genetic variability studies on quantitative traits in upland cotton. *Sarhad J. Agric.*, 24(24): 587-591.

Steel, R.G.D and J.H Torrie. 1980. *Principles and procedures of statistics, a biological approach*, 2^{nd} ed. Mc Graw Hill, Inc. New York, Toronto, London.

Tariq, M., M.A. Khan and G. Idress. 1992. Correlation and path coefficient analysis in Upland cotton. *Sarhad J. Agric*., 8: 335-341.

Tyagi, A.P. 1994. Correlation coefficients and selection indices in upland cotton. *Indian J. Agric. Res.,* 28(3): 189-196.

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