

ASSESSMENT OF BEST PARENTS AND SUPERIOR CROSS COMBINATIONS FOR EARLINESS RELATED TRAITS IN UPLAND COTTON (*Gossypium hirsutum* L.)

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ABSTRACT

A genetic analysis was conducted to determine the combining ability potential of six diverse *Gossypium hirsutum* L. genotypes and their 15 crosses for days to squaring, days to flowering, vertical flowering interval, horizontal flowering interval, days to first boll opening, boll maturity period, node number for first fruiting branch, height of first fruiting branch, mean maturity date and earliness index. Out of the six parents CIM-448 was found to be best general combiner followed by FH-945 and MNH-93 while CIM-496 was found to be poorest general combiner among the six parents. FH-945 × NIAB-78 proved to be best cross combination for various earliness traits followed by FH-945 × CIM-496, MNH-93 × CIM-446, MNH-129 × CIM-496. There is inference of predominant presence of non-additive type of gene action for all of the traits except DFF and HFFD. The plant material studied here is might be best suitable for hybrid breeding experiments.

Key words: Cotton, specific combining ability, general combining ability, gene action.

INTRODUCTION

Cotton is an important cash crop of Pakistan. It holds an eminent position in the crop husbandry of Pakistan and contributes significantly towards boosting the economy of the country by way of exporting raw fiber as well as finished products. Short duration and high yielding varieties are always required for better quality and production. Early maturing crops avoid disease and insect pest epidemics due to which Plant breeders have positioned adequate pressure on the development of early maturing crop plants (Sing, 2004).

Term earliness is particular to crop production that refers to harvest the crop as early as possible without incurring significant yield losses. Average vegetative growth period of cotton throughout the world is found to be 135-150 days (Kassianenko, 2003). Early maturing crop varieties are top suitable for farming culture and textile industry also as it can bump up cotton production by diminishing late-season risks allied to insect intimidation and adverse weather conditions along with save of water in critical conditions of Pakistan (Neil, 1991).

Richmond and Radwan conducted an experiment during the year 1962 suggesting several dimensions to evaluate earliness of cotton i.e., found significant correlation between phenological aspects (first square, flower, and open boll) and product-quantity measurements (ratio of fractions relative to total yield) while most tactical method for measuring maturity is, examining the ratio of weights in early harvests to total

seed cotton harvested. Date of peak flower and node at which first sympodial is borne are index of earliness as well, lower such node earlier is crop variety. Similar criteria were followed by (Iqbal *et al.*, 2003 Basbag *et al.*, 2007 and Shakeel *et al.*, 2008) in their genetic studies of cotton.

In cotton and wheat crop rotation of Pakistan considerable wheat's yield losses occur when it is planted after November and this decline in production continues with each day delay in wheat planting (Chattha *et al.*, 1995, Chaudhary *et al.*, 1995). Delay in sowing of wheat after 10 November may cause 42 kg/ha/day loss in yield (Khan, 2003) and late maturity of cotton causes poor development of all fibre quality characters (Salam *et al.*, 1993). Moreover short duration varieties are economical regarding crop production and protection measures because early maturing varieties of cotton sidesteps from biotic and abiotic hazards (Rehana *et al.*, 2001).

Combining ability is incredibly contributive in sorting prospective parents and their hybrids with preferred inherited variations during GCA and SCA and in some cases also through maternal effects (Griffing, 1956). Nadeem *et al.*, (1998), Baloch *et al.*, (2000) and Azhar *et al.*, (2007), Karademir E. and O. Gencer (2010) conducted various combining ability experiments to study earliness and earliness component traits. Present study was conducted to generate detailed information about the genetic parameters of earliness related traits, seed cotton yield along with its constituents and fiber excellence characters in 6 × 6 half diallel crosses under local condition, so that new genotypes may be developed having all these desirable characters. Evolution of such

new early maturing genotypes could lead to reduce the usage of pesticides, saving of foreign exchange being spent on import of pesticide, minimizing the environmental pollution caused by excessive use of harmful pesticides in cotton fields. These genotypes would ultimately increase the earnings of farmer through increase in their yield and decrease in cost of production.

MATERIALS AND METHODS

Plant Material: The genetic material comprised of 6 divergent varieties of *Gossypium hirsutum* L. namely FH-945, MNH-93, MNH-129, CIM-496, NIAB-78 and CIM-446. Selection of the parents was made on the basis of variability of characters regarding the traits under study. Maximum numbers of direct crosses were made following half diallel mating fashion to generate sufficient amount of fifteen F₁ hybrid's seeds along with six self crosses. Recommended agronomic practices were sustained for maintaining healthy plant populations. Essential safety measures were reserved at the time of emasculation and pollination to avoid foreign contamination of the genetic material: (1) Emasculation was done at immature anther's stage before the stigma became receptive to minimize self-pollination. (2) Flowers one day prior to maturity were selected for emasculation (3) Complete elimination of anther was ensured (4) Gynoecium was kept safe from all types of damages (5) Emasculated buds were wrapped before and after pollination.

The F₁ seed of 15 hybrids and 6 parents were planted in the field. Each genotype was sown in triplicate form by, Randomized Complete Block Design (RCBD). In order to make sure standardized plant seeds were dibbled in single row with eleven plants keeping plant to plant and row to row distance of 30 and 75 cm respectively. Observations were recorded on the central five competitive plants for nine traits. At maturity, self and crossed bolls were picked and ginning was done with single roller ginning machine. For measuring the characters 5 guarded plants in each row were used as experimental unit to collect the data regarding above mentioned characters.

Statistical analysis of the data: In order to verify the genetic differences among 21 genotypes, mean values of ten traits in each replication were analyzed as suggested by Steel and Torrie (1997). Before assessment of combining ability effects, characters showing significant genotypic differences were subjected to genetic analysis by combining ability technique (Griffing, 1956) using 'Method II', 'Model II'. The GCA: SCA ratio representing that whether the trait is restricted by additive or non-additive gene action (dominant) was calculated using ratios of the mean squares for GCA and SCA.

RESULTS AND DISCUSSION

Data were subjected to analysis of variance (Table 1) for each trait which allowed the detection of highly significant differences ($P \sim 0.05, 0.01$) among 21 genotypes i.e. 15 crosses and 6 parent, for days to first boll opening, boll maturity period, node number for first fruiting branch, height of first fruiting branch, mean maturity date, and earliness index and significant differences ($P \sim 0.05$) for days to squaring, days to flowering and horizontal flowering interval. For vertical flowering interval genotypes did not showed any statistical differences ($P \sim 0.01$) and ($P \sim 0.05$), due to the involvement of environmental effects thereby inhibiting further analysis for this trait. Genetic variability among nine characters was dissected by GCA, SCA analysis according to (Griffing, 1956) using 'Method II', 'Model II' combining ability analysis except non-significant trait, vertical flowering interval and result are depicted in Table 2.

Each of the parents was compared for its general combining ability and among six parents CIM-446 was found to be best general combiner, as it executed positive general combining ability in case of DFS (0.8), DFF (0.55), HFI (0.12), DFOB (0.36), HFFD (0.68), MMD (0.2) and Earliness index (2.52), while negative general combining ability was observed in case of BMP (-1.06) and NNFFB (-0.51) respectively. MNH-93 × CIM-446 was best combinations for most of the traits studied (Table 2). It is advocated that parents having good general combining ability may have the ability to manifest excellent performance in their specific combination for particular trait under study (Ayub *et al.*, 1991; Khan *et al.*, 1991; Irfanullah *et al.*, 1994) and similar behavior of CIM446 was found in the present study.

FH-945 showed best GCA performance for six traits (Table 2) and FH-945 × NIAB-78 was found to be best combination for seven of the nine traits studied leaving behind rest of the combinations due to lack of potential to perform equivalently (Table 2). Also FH-945 in combination with CIM496 depicted awesome performance for controlling the BMP, NNFFB coinciding earlier studies of Ayub *et al.*, 1991; Khan *et al.*, 1991; Irfanullah *et al.*, 1994). Similarly MNH-93 having conspicuous GCA performance depicted its overwhelming performance in combination with CIM-446 as mentioned earlier. Combination of FH-945 × MNH-93 in contrast to their awesome GCA performance did not proved to be healthy combination thereby manifested poor SCA performance for the studied traits.

Another interesting observation is, MNH-93 and MNH-129, both revealed top GCA performances for DFS, DFF but SCA performance of their cross combination was totally reverse, i.e., DFF and DFS illustrate negative numerical values. Similarly varieties

having superb GCA for MMD and EI did not performed well in their cross combination illustrating poor SCA for MMD and EI following similar combining behavior as mentioned earlier. This shows that it is not always necessary to have fabulous SCA performance as expected from the marvelous performance of the parents and vice versa for the trait under study. Similar outcomes have been stated by Khan *et al.*, (1991), Punitha *et al.*, (1991), Khan and Idris (1995), Baloch *et al.*, (1997), Hassan *et al.*, (1999), Kalwar and Babar (1999), Kumaresan *et al.*, (1999), Hassan *et al.*, (2000), Shakeel *et al.*, (2001) and Ahuja and Dhayal (2007).

On the other hand CIM-496 revealed poorest general combining ability as it showed negative GCA values for seven out of nine traits (Table 2). NIAB-78 and MNH-129 (Table 2) were remaining poor general combiners showing negative general combining ability values for six and five out of the nine studied traits. These poor GCA parents did provided poor SCA performance in combinations CIM-496 × NIAB-78 and MNH-93 × MNH-129 (Table 2), as these combinations produced negative SCA values for the seven out of nine studied traits, similar results were presented by (Shakeel *et al.*, 2001).

Individual performance of each parent was different for each of the trait studied such as for days to squaring and days to flowering FH-945, MNH-129, MNH-93 and CIM-446 clearly showed better general combining ability potential while CIM-496 and NIAB-78 attained negative numerical values and displayed to be the worst general combiners for DFS and DFF. FH-945 × NIAB78 showed positive SCA values for DFS & DFF (1.87 & 0.77) respectively, highly significant GCA mean square values for DFS & DFF showed the presence pronounced effect of additive type of gene action (Table 3) as has been reported by (Ali *et al.*, 2000, Hassan *et al.*, 2000).

GCA effects on controlling horizontal flowering interval (HFI) exposed that, FH-945, MNH-93, MNH-129 and NIAB-78 attained negative numerical values (-0.040, -0.0094, -0.21 and -0.034) respectively and CIM-496 (0.17) and CIM-446 (0.12) attained positive values (Table 2). Mean squares for general combining ability were highly significant ($P < 0.01$) for HFI while mean squares due to SCA were non-significant, σ^2 GCA 0.014 - σ^2 SCA ratio (0.029) showed the involvement of additive gene action for its control as reported by (Baloach *et al.*, 1999).

GCA effects for days to first boll opening (DFOB) revealed that, FH-945, CIM-496 and NIAB-78 attained negative values while MNH-129, MNH-93 and CIM-446 attained positive GCA values. Mean squares due to SCA were significant indicating the presence of non-additive type of gene action while variance resulting from GCA was lower than variance resulting from SCA there by confirming the prevalence of non-additive type of gene action in the control of the trait. Effects of general combining ability on controlling boll maturation period uncovered that FH-945, MNH-93 and CIM-496 attained positive GCA values and had proved to be the best general combiner for the character. Remaining parents attained negative GCA values (Table 2) indicating that those were poor general combiners for boll maturation period.

Possessions of general combining ability on controlling node number for first fruiting branch revealed that most of parents attained negative GCA values and had expressed as the immoral general combiner for the character except FH-945 and MNH-93 (Table 2). General combining ability studies of height of first fruiting branch concluded that, three partmens MNH-129, CIM-496 and NIAB-78 attained negative GCA values, while FH-945, MNH-93 and CIM-446 attained positive GCA values (Table 2). GCA of mean maturity date showed that, MNH-93, MNH-129 and CIM-496 attained negative values (-0.47, -0.07 and -0.23), remaining parents attained positive GCA values (Table 2). Effects of general combining ability on controlling earliness index revealed that, FH-945, MNH-93, CIM-496 and CIM-446 attained negative values while MNH-129 and NIAB-78 showed positive GCA values (Table 2).

The mean squares for general combining ability were highly significant ($P < 0.01$) for all of the traits except EI and BMP and were significant ($P < 0.05$) for MMD, while mean squares due to SCA were significant for all of traits except EI and BMP which were Highly significant, but were non-significant for HFI respectively (Table 3). The variance resulting from general combining ability was lower than variance due to specific combining ability and EI while GCA variance was higher than SCA variance in case of DFF and HFFD thereby revealed the predominance of additive type of gene action similar to Hassan *et al.*, (1999), Muthu *et al.*, (2005) and Ahuja and Dhayal (2007), thereby allowing mass selection under pedigree method at early stages of segregating material. It is suggested that non-additively controlled characters may have low heritability Falconer and Mackey, (1996)

Table 1. Mean squares obtained from partitioned analysis of variance of earliness traits in cotton

SOV	d.f	DFS	DFF	VFI	HFI	DFOB	BMP	NNFFB	HFFD	MMD	EI
Replications	2	41.24*	2.20 ^{NS}	0.32*	0.90**	3.9 ^{NS}	16.3*	0.11 ^{NS}	0.96 ^{NS}	1.76*	2.51 ^{NS}
Genotypes	20	32.42*	23.9*	0.03 ^{NS}	0.19*	35.5**	40.7**	6.8**	12.5**	5.01**	249.**
Error	40	21.11	14.0	0.04	0.19	9.7	19.7	1.71	5.63	2.36	18.9

Table 2. Means, general and specific combining ability effects of various earliness traits of cotton

	DFS		DFE		HFI		DFOB			
Parents	Means	GCA	Means	GCA	Means	GCA	Means	GCA		
FH-945	38.87	0.06	51.33	0.01	3.95	-0.04	91.330	-0.97		
MNH-93	38.40	0.85	54.67	1.68	4.30	-0.01	104.00	-2.15		
MNH-129	37.67	0.94	50.67	0.59	4.07	-0.21	102.67	0.99		
CIM-496	28.40	-2.16	45.00	-2.69	4.58	0.17	95.330	-0.56		
CIM-446	36.70	0.80	55.33	0.55	4.31	0.12	99.000	0.36		
NIAB-78	32.90	-0.50	50.00	-0.15	4.03	-0.03	92.330	-1.97		
		1.33		1.08		0.13		0.9		
Crosses	Means	SCA	Means	SCA	Means	SCA	Means	SCA		
FH-945 × MNH-93	31.93	-2.62	5.000	-1.72	4.27	0.04	95.33	-1.58		
FH-945 × MNH-129	31.93	-2.7	50.00	-0.64	4.12	0.09	93.33	-2.41		
FH-945 × CIM-496	30.73	-0.79	49.67	2.31	4.57	0.15	99.00	4.79		
FH-945 × CIM-446	28.50	-5.99	47.33	-3.26	4.48	0.12	98.00	2.88		
FH-945 × NIAB-78	35.07	1.87	50.67	0.77	4.29	0.09	94.00	1.21		
MNH-93 × MNH-129	32.53	-2.89	50.33	-1.97	3.94	-0.12	95.00	-3.87		
MNH-93 × CIM-496	35.03	2.71	50.00	0.98	4.40	-0.04	95.00	-2.33		
MNH-93 × CIM-446	33.73	-1.55	51.00	-1.26	4.44	0.05	99.33	1.09		
MNH-93 × NIAB-78	32.20	-1.79	53.00	1.44	4.23	-0.01	94.67	-1.24		
MNH-129 × CIM-496	34.83	2.42	49.00	1.065	3.99	-0.25	96.00	-0.16		
MNH-129 × CIM-446	35.43	0.056	52.67	1.48	4.30	0.11	93.00	-4.08		
MNH-129 × NIAB-78	32.90	-1.18	51.67	1.19	3.78	-0.25	95.33	0.59		
CIM-496 × CIM-446	33.00	0.73	44.67	-3.22	4.50	-0.08	92.00	-3.54		
CIM-496 × NIAB-78	27.70	-3.27	45.33	-1.85	4.72	0.31	93.00	-0.20		
CIM-446 × NIAB-78	37.77	3.83	48.33	-2.1	4.58	0.22	92.67	-1.45		
S.E.(sij-sik)		3.51		2.85		0.34		2.38		
	BMP		NNFFB		HFFD		MMD		EI	
Parents	Means	GCA	Means	GCA	Means	GCA	Means	GCA	Means	GCA
FH-945	44.00	0.28	12.0	1.07	31.33	1.38	131.33	0.51	39.21	-3.61
MNH-93	52.67	1.82	11.3	0.48	28.67	0.51	127.69	0.47	42.87	-0.17
MNH-129	50.67	-0.43	8.67	-0.30	26.33	-1.23	127.48	-0.07	53.88	3.22
CIM-496	50.33	1.57	9.33	-0.30	25.00	-1.19	128.85	-0.23	51.17	-0.98
CIM-446	43.67	-1.06	8.67	-0.43	32.67	0.68	128.49	0.20	34.77	2.52
NIAB-78	42.33	-2.18	8.33	-0.51	27.33	-0.15	128.76	0.06	61.85	4.07
		1.28		0.37		0.68		0.44		1.25
Crosses	Means	SCA	Means	SCA	Means	SCA	Means	SCA	Means	SCA
FH-945 × MNH-93	46.67	-1.88	11.00	-0.57	29.33	-0.79	128.75	0.02	60.04	6.17
FH-945 × MNH-129	43.33	-2.96	11.00	0.22	27.33	-1.04	127.85	-1.28	65.04	7.78
FH-945 × CIM-496	49.33	1.041	11.00	0.22	30.67	2.25	128.36	-0.6	51.53	-1.52
FH-945 × CIM-446	54.00	8.33	9.330	-1.33	30.00	-0.29	129.08	-0.32	56.63	5.12
FH-945 × NIAB-78	46.00	1.46	12.33	1.76	28.67	-0.79	128.24	-1.02	62.98	4.87
MNH-93 × MNH-129	46.00	-1.83	10.67	0.47	27.00	-0.50	126.98	-1.15	63.42	2.72
MNH-93 × CIM-496	49.00	-0.83	10.00	-0.19	28.67	1.12	129.29	1.31	60.44	3.94
MNH-93 × CIM-446	49.00	1.79	12.00	1.92	28.67	-0.75	129.13	0.72	65.81	10.9
MNH-93 × NIAB-78	43.67	-2.45	7.670	-2.32	30.67	2.08	127.45	-0.81	66.70	5.15
MNH-129 × CIM-496	47.00	-0.58	11.33	1.92	27.00	1.20	129.71	1.33	63.05	3.16
MNH-129 × CIM-446	40.33	-4.63	8.330	-0.95	26.00	-1.67	129.44	0.62	68.23	9.89
MNH-129 × NIAB-78	43.67	-0.17	9.000	-0.2	27.67	0.833	131.26	2.59	61.79	-3.15
CIM-496 × CIM-446	44.00	-2.96	8.000	-1.28	25.00	-2.70	127.39	-1.25	60.23	6.09
CIM-496 × NIAB-78	47.67	1.83	8.670	-0.53	26.67	-0.20	126.42	-2.08	58.09	-2.64
CIM-446 × NIAB-78	42.00	-1.21	11.67	2.6	28.00	-0.75	130.35	1.41	62.85	3.66
S.E.(sij-sik)		3.38		0.99		1.81		1.17		3.31

Table 4 Combining ability analysis of various traits of 21 genotypes of *Gossypium hirsutum* L.

SOV	DFS	DFE	HFI	DFOB	BMP	NNFFB	HFFD	MMD	EI
MS ^{GCA}	11.52**	17.24**	0.15 *	17.40**	19.1**	3.23**	9.1**	0.95 *	75.8**
MS ^{SCA}	10.13*	4.86 *	0.04 ^{NS}	9.96 *	11.73**	1.95 *	2.54 *	1.91 *	85.8**
σ^2 GCA	0.17	1.55	0.014	0.93	0.91	0.16	0.8	-0.11	-1.24
σ^2 SCA	3.09	0.19	-0.029	6.72	5.18	1.38	0.66	1.12	79.4
V _A	0.35	3.09	0.028	1.86	1.83	0.32	1.61	-0.23	-2.48
V _D	3.09	0.19	0.029	6.72	5.18	1.38	0.66	1.12	79.4
V _A /V _D	0.11	1.84	0.97	0.28	0.35	0.23	2.44	-0.21	-0.31

therefore could not be subjected to selection process at their earlier stages of segregating population.

The obtained information of the general and specific combining ability studies of twenty one genotypes will surely provide guide line to the plant breeder for planning the breeding experiment. Because of the manifestation of additively controlled genetic variation thereby having high heritability of DFF and HFFD, F₂ segregating population could be integrated to breeding program for improvement of these two traits. Traits having low heritability and non-additive genetic variation need to have keen observation and imaginative decision for the selection of plants for their improvement. The genetic nature of the plant material implies that such type of plant material is extremely useful for hybrid breeding programs.

REFERENCES

- Ahuja, L. S. and L. S. Dhayal (2007). Combining ability estimates for yield and fibre quality traits in 4 - 13 line tester crosses of *Gossypium hirsutum* L. *Euphytica* 153: 87-98.
- Ali M., M. S. Kalwar, M. G. Baloch and M. K. Baloch (2000). Breeding implications from a diallel analysis for yield and yield components in cotton. *Pakistan. J. Agric. Agri. Eng. Vet. Sci.* 16: 14-18.
- Ayub M., S. Rahman, and M. Amin (1991). Combining ability analysis of some quality characters in various crosses of cotton (*Gossypium hirsutum* L.). *Sarhad J. Agric* 7: 707-716.
- Azhar F.M., A. Hussain, and A. Shakeel (2007). Combining ability for plant characters related to earliness in *Gossypium hirsutum* L. *J. Agri Soc. Sci.* 3: 63-66.
- Baloch M. J., A. R. Lakho, and H. U. Bhutto (1999). Line-tester analysis for estimating genetic components of some quantitative traits in *G. hirsutum*. *Sindh Bal. J. Plant Sci.* 1, 28-34.
- Baloch M. J., H. U. Bhutto, and A. R. Lakho (1997). Combining ability estimates of highly adapted tester lines crossed with pollinator inbreds of cotton (*G. hirsutum*). *Pakistan J. Sci. Ind. Res.* 40, 95-98.
- Baloch, M. J., A. R. Lakho, H. U. Bhutto, A. M. Memom, G. N. Panhwar and A. H. Soomro (2000). Estimates of combining ability and genetic parameters for yield and fiber traits in upland cotton. *Pakistan J. Biol. Sci.* 3, 1183-1186.
- Basbag S., Ekinçi R. and Gencer O. (2007). Combining ability and heterosis for earliness characters in line \times tester population of *Gossypium hirsutum* L. *Hereditas* 144: 185-190
- Chattha, A. A., H. M. Akram, A. Ali, A. Yar, and M. A. Shehzad (1995). Yield performance of new wheat genotypes at different planting dates. *J. Agri. Res.* 33, 97-101.
- Chaudhary M. H., J. Anwar, F. Hussain, and F. A. Khan (1995). Yield performance of new wheat genotypes at different planting dates. *J. Agri. Res.* 33,102-108.
- Falconer D. S. and T. F. C. Mackey (1996). Introduction to Quantitative Genetics, 3rd edition. Longman, London.
- Griffings, B. (1956). Concept of general and specific combining ability in relation to diallel crossing systems. *Aust. J. Biol. Sci.* 9, 463-493.
- Hassan G., G. Mahood, A. Razzaq, and Hayatullah (2000). Combining ability in inter-varietal crosses of Upland cotton (*Gossypium hirsutum* L.). *Sarhad J. Agri*; 16,407-410.
- Hassan, G., G. Mahood, N. U. Khan, and A. Razzaq (1999). Combining ability and heterobeltiotic estimates in a diallel cross of cotton. *Sarhad J. Agri.* 15, 563-568.
- Iqbal, M., Chang, M. A., Jabbar, and M. Z. Iqbal (2003). Inheritance of earliness and other characters in upland cotton. *J. Biol. Sci.* 3: 585-590.
- Irfanullah, M., A. Khan, H. A. Sadaqat, and A. A. Khan (1994). Potentials of combining ability for yield and lint quality traits in cotton (*Gossypium hirsutum* L.). *J. Agric. Res.* 32, 363-367.
- Kalwar, M. S. and S.B. Babar (1999). Estimates of combining ability in upland cotton (*Gossypium hirsutum* L.). *The Pakistan Cot.* 43, 25-30.

- Karademir E. and O. Gencer (2010). Combining Ability and Heterosis for Yield and Fiber Quality Properties in Cotton (*G. hirsutum* L.) obtained by Half Diallel Mating Design. Not. Bot. Hort. Agrobot. Cluj 38 : 222-227.
- Kassianenko, V.A. (2003). Genetic Analysis of the Duration of Vegetative Period in Cotton *Gossypium hirsutum* L. on Soil with Different Nitrogen Content. Russian J. Gen. 39, 1400-1404. Translated from Genetika, 39, 1651-1655.
- Khan, M. A. (2003). Wheat crop management for maximization. Wheat Res. Int. Faisalabad. pp 733.
- Khan, M. A., K. L. Cheema, A. Massod and H.A. Sadaqat (1991). Combining ability in cotton (*Gossypium hirsutum* L.). J. Agric. Res. 29, 311-318.
- Khan T. M. and M. A. Idris (1995). Inheritance of boll weight, boll number and yield of seed cotton in upland cotton (*Gossypium hirsutum* L.). Sarhad J. Agric. 11, 599-605.
- Kumaresan, D., P. Senthilkumar and J. Ganesan (1999). Combining ability studies for quantitative traits in cotton (*Gossypium hirsutum* L.). Madras Agric. J. 18, 430-432.
- Muthu, R., G. Kandasamy, T. S. Raveendran, R. Ravikesavan, and M. Jayaramachandran (2005). Combining ability and Heterosis for yield traits in Cotton (*G. hirsutum*). Madras Agric. J. 92, 17-22.
- Nadeem, A., D. K. Munir, M. A. Khan, A. Mushtaq, N. Austain, and M. Ahmad (1998). Genetic studies of cotton (*Gossypium hirsutum* L.) combining ability and heterosis studies in yield and yield components. Pakistan J. Sci. Ind. Res. 41, 54-56.
- Neil, F. (1991). Strategies for prevision of development pesticide resistance. Proc. ICAC-CCRIReg.Consult. On Insecticide Resist. Manage. in Cotton. June 28- July 1.
- Punitha D., T. S. Raveendran, and M. Kavitha (1991). Combining ability studies for yield and quality traits in interspecific coloured linted cotton (*Gossypium hirsutum* L. *Gossypium barbadense* L.). PKV Res. J. 23, 14-16.
- Rehana, A. R., Soomro, and M. A. Chang (2001). Measurement of earliness in upland cotton. Pakistan J. Biol. Sci. 4, 462-463.
- Salam, C. A., M. Arshad and M. Afzal (1993). Effect of picking dates on fiber character of different commercial cotton varieties of *G. hirsutum* L. The Pakistan Cottons. 37, 75-80.
- Shakeel, A., F. M. Azhar and I. A. Khan (2008). Assessment of earliness in *Gossypium hirsutum* L. Pakistan J. Agri. Sci., 45, 80-87.
- Shakeel A., I. A. Khan, and F. M. Azhar (2001). Study pertaining to the estimation of gene action controlling yield and related traits in upland cotton. J. Biol. Sci. 1, 6.
- Singh, P. (2004). Cotton breeding. Kalyani Pub., New Dehli. India.
- Steel, R. G. D., J. H. Torrie and D. A. Dickey (1997). Principles and procedures of statistics: A biometrical approach, 3rd ed. McGraw Hill Book Co., New York.