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Identification of Superior Parents and Hybrids from Diallel Crosses of Bread Wheat (*Triticum aestivum* L.)

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Abstract. Five parents of bread wheat (*Triticum aestivum* L.) viz. TD-1, SKD-1, Marvi, Moomal and Mehran were crossed in a half diallel design; hence 10 F_1 hybrids were developed. Parents alongwith hybrids were evaluated for combining ability and heterosis for tillers/plant, spike length, spike density, grains/spike, grain yield/plant and seed index. The experiment was conducted in a randomized complete block design with four replications at Botanical Garden, Department of Plant Breeding & Genetics, Sindh Agriculture University, Tandojam, during 2010. The analysis of variance due to genotypes, parents, hybrids and parents vs. hybrids was significant for all the characters which revealed presence of significant amount of genetic variability in the material. The results also indicated significant differences among the parents for their general combining ability (GCA) and hybrids for specific combining ability (SCA) suggesting the importance of both additive and non-additive genes in the expression of traits studied. The greater magnitude of SCA variances over GCA were recorded for tillers/plant, grains/spike and grain yield/plant which indicated the importance of additive gene action while the involvement of non-additive genes was evident in the inheritance of spike length, spike density and seed index. Among the parents, generally TD-1, Mehran, Moomal and Marvi were the best general combiners for tillers/plant, spike length, spike density, grains/spike, grain yield/plant and seed index. Whereas, the hybrids like SKD-1 × Mehran, Marvi × Mehran, Marvix Moomal and TD-1 × SKD-1 were the best specific combiners for majority of yield traits. Positive heterosis was expressed by the hybrid SKD-1 × Moomal for tillers per plant; TD-1 × Moomal for spike length; TD-1 × SKD-1 for grains per spike; Marvi × Mehran for spike density and Marvi × Moomal for seed index. The best parents and hybrids could be effectively utilized in hybridization and selection programmes and also for hybrid crop development, respectively.

Keywords: diallel analysis, combining ability, heterosis, wheat genotypes

Introduction

Contributions of both i.e. nature and selective process of man have made tremendous genetic improvements in wheat plant. Increasing crop yield has still remained main concern to wheat breeders. The knowledge regarding the genetic basis of yield and its components helped wheat breeders to sort out promising parents to be used in hybridization and selection programmes. A diallel technique is one of the most powerful quantitative genetic analysis by which plant breeders estimate combining ability and heterotic potential of fixed lines or varieties. Among various diallel forms, the half-diallel provides maximum information about genetic architecture of a trait, potentiality of parents in crosses and type of gene action controlling traits (Griffing, 1956).

The combining ability was further partitioned into general combining ability (GCA) and specific combining ability (SCA) effects; hence components of gene action were obtained. The average performance of a genotype in a series of hybrid combinations is called GCA and is used to measure additive variances and additive genes. Whereas, the performance of genotypes in crosses is determined by SCA and measures non-additive gene action (Sprague and Tatum, 1942). Importance of general combining ability for grain yield per plant was observed by Akram *et al*. (2011) and Khan *et al*. (2007) and suggested additive type of gene action for this trait. While, Shabbir *et al*. (2011) and Akbar *et al*. (2009) believed that non-additive genetic effects were high for grain yield, revealing the prevalence of SCA effects. Additive type gene action with high values of general combining ability for tillers per plant (Mahpara *et al*., 2008; Rahim *et al*., 2006), spike length (Yucel *et al*., 2009), spike density (Mahpara *et al*., 2008), grains per spike (Shabbir *et al*., 2011; Yucel *et al*., 2009) and 1000-grains weight (Dhadhal *et al*., 2008 and Mahpara *et al*., 2008) were recorded. On the contrary, substantial specific

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combining ability effects were recorded for spike length, grains/spike, 1000 grain weight (Akram *et al*., 2011; Shabbir *et al*., 2011; Cifci and Yagdi, 2010) and spike density (Iqbal and Khan, 2006).

Proper choice of parents for hybrid wheat development is an important factor to enhance grain yield potential in existing germplasm. Nagarajan (2001) suggested the use of wheat hybrid varieties at commercial scale because of its higher production. Utilization of heterotic effects for more yield were largely attributed to cross-pollinated crops, yet evidences are now available to prove the presence of such effects in self-pollinated crops like wheat. Several plant breeders worked on heterosis in wheat and reported that grain yield can be maximized from 6% (Borghi *et al*., 1986) to as high as 41% (Zehr *et al*., 1997). Maximum and positive heterosis was found in spike length (Jaiswal *et al*., 2010); grains per spike (Khattab *et al*., 2010); 1000-grain weight and grain yield per plant (Abdel-Moneam, 2009). The objective of present investigation was to explore general combiners and mark crosses with better specific combining ability for wheat yield and its related traits by employing diallel genetic analysis.

Materials and Methods

Five bread wheat cultivars of diverse origin *viz*. TD-1, SKD-1, Marvi, Moomal and Mehran were crossed in half-diallel design. The seeds of parent and their 10 F_1 hybrids were sown in randomized complete block design with four replications in the experimental field, Department of Plant Breeding and Genetics. The sowing was done during mid December, 2010 with drill method and the distance between plant to plant and row to row was kept at 6 and 9 cm, respectively. The inorganic fertilizer like one bag (50 kg) of DAP per hectare was applied at the time of sowing whereas two bags of urea, one with third irrigation and second dose was applied at the time of grain formation. The crop was harvested in April, 2010. To reduce the intensity of harmful weeds, weedicide like Buctril Super at the rate of 1000cc was applied after first irrigation. The analysis of variance was carried out according to statistical methods developed by Gomez and Gomez (1984). Diallel analysis was carried out according to Griffing's Method-11, Model-1 (Griffing, 1956) by numerical approach as adopted by Singh and Choudhary (1979). Heterotic effects in F_1 hybrids were determined as the percent increase (+) or decrease (-) of F_1 hybrids over mid or better parents according to Fehr (1987) as under:-

$$\text{Mid parent heterosis \%} = \frac{F_1 - MP}{MP} \times 100$$

$$\text{Better parent heterosis \%} = \frac{F_1 - BP}{BP} \times 100$$

Where, F_1 = hybrid performance, M.P. = mid parent value (the mean of both parents) B.P. = Better parent value (the mean of better parent). Ten plants per replication from each F_1 hybrid and parent were randomly selected and treated as index plants to record the data. The traits studied were tillers/plant, spike length (cm), spike density, grains/ spike, grain yield/plant and seed index (1000-grain weight in g).

Results and Discussion

The present experiment was conducted so as to estimate the combining ability and heterotic effects in F_1 hybrids developed from five parent half diallel of bread wheat. The characters studied were tillers/plant, spike length, spike density, grains/spike, grain yield/plant and seed index. The mean squares due to genotypes, parents, hybrids and parents vs. hybrids were significant for all the characters indicating the presence of considerable amount of variability in the breeding material (Table 1). These results further suggested that the parental lines and their hybrids were quite variable in their performance and presence of overall heterosis for most of the characters. The significant mean squares due to general combining ability (GCA) and specific combining ability (SCA) suggested that additive as well as non-additive genes were advocating the traits under study (Baloch *et al*., 2008). The magnitude of GCA variances was higher than the SCA variances indicating preponderance of additive gene effects for spike length, spike density and seed index. While high SCA variances over GCA for tillers/plant, grains/spike and grain yield/plant confirmed the prevalence of non-additive genetic effects for these traits. Importance of general combining ability variance for grain yield per plant was also observed by Akram *et al*. (2011) and Baloch *et al*.(2011) who suggested that additive type of gene action was advocating grain yield per plant, while Shabbir *et al*. (2011) believed that non-additive genetic effects were high for grain yield, revealing the prevalence of SCA effects. For other traits, additive type gene action with high values of general combining ability for tillers per plant was reported by Mahpara *et al*. (2008); spike length by

Yucel *et al*. (2009); spike density by Mahpara *et al*. (2008); grains per spike by Shabbir *et al*. (2011) and 1000-grains weight by Dhadhal *et al*. (2008) and Mahpara *et al*. (2008). On the contrary, substantial specific combining ability effects rather than general combining ability were recorded for spike length and seed index (Akram *et al*., 2011; Shabbir *et al*., 2011; Cifci and Yagdi, 2010); spike density (Iqbal and Khan, 2006) and grains per spike (Baloch *et al*., 2011).

With respect to average performance, the parents TD-1 developed maximum tillers/plant, gave maximum grain yield/plant and recorded maximum seed index. While Mehran set maximum grains/spike and Marvi measured longer spikes and also recorded maximum spike density (Table 2). It is quite interesting to note that parents like TD-1 and Marvi which performed well as *per se* also performed well for GCA effects. These results therefore suggested that both the parents could reliably be used in hybridization and selection programmes to improve various yield traits. Regarding F_1 hybrids' performance, cross TD-1 × SKD-1 set highest grains per spike and at the same time produced maximum grain yield/plant. Hybrid TD-1 × Mehran developed maximum tillers per plant and Marvi × Moomal measured longest spikes; Marvi × Mehran recorded

Table 1. Mean squares from diallel analysis for various yield traits in bread wheat (*Triticum aestivum* L.)

Source of variation	D.F.	Mean squares					
		Tillers/plant	Spike length	Spike density	Grains/spike	Grain yield/plant	Seed index
Genotype	14	20.05**	9.052**	334.39**	129.69**	18.03**	33.57**
Parents	4	11.20**	10.92**	185.44**	113.30**	12.12**	52.05**
Hybrids	9	4.82**	8.74**	430.21**	28.36**	10.62**	16.40**
Parents vs. hybrids	1	192.53**	4.38**	67.72**	1106.56**	108.3**	114.15**
GCA	4	14.40**	22.89**	764.14**	34.18**	17.40**	36.95**
SCA	10	22.31**	3.52**	162.49**	167.83**	18.28**	32.21**
Error	42	0.477	0.524	34.901	0.780	0.676	0.763

** = significant at 1% probability level

Table 2. Mean performance of parents and F_1 hybrids for various yield traits in bread wheat (*Triticum aestivum* L.)

Parents	Mean performance					
	Tillers/plant (cm)	Spike length (%)	Spike density	Grains/spike (g)	Grain yield/plant	Seed index (g)
TD-1	9.50	11.38	75.85	52.75	19.25	45.50
SKD-1	6.00	12.50	70.21	57.25	15.50	38.75
Marvi	5.50	15.75	87.05	60.75	14.75	35.50
Moomal	7.50	14.00	81.42	64.75	16.00	40.00
Mehran	8.50	13.00	72.71	65.50	17.00	39.87
F_1 Hybrids						
TD-1 × SKD-1	12.50	11.90	61.51	73.60	21.50	42.00
TD-1 × Marvi	11.50	13.50	85.79	70.50	20.75	41.25
TD-1 × Moomal	11.00	14.75	90.99	66.75	19.00	44.00
TD-1 × Mehran	12.75	13.50	75.69	71.50	19.00	40.50
SKD-1 × Marvi	9.50	14.50	85.80	68.00	17.00	42.50
SKD-1 × Moomal	11.25	12.00	72.36	69.00	17.50	44.00
SKD-1 × Mehran	12.00	12.75	67.41	71.00	21.50	42.00
Marvi × Moomal	10.75	16.50	86.63	66.75	18.75	45.25
Marvi × Mehran	11.25	15.50	92.55	71.00	20.50	40.50
Moomal × Mehran	9.50	14.00	81.12	65.00	18.00	46.50
L.S.D (5%)	0.986	0.974	8.42	1.26	1.17	1.247

maximum spike density; Moomal × Mehran gave higher seed index. It is generally assumed that F_1 hybrid performance is reflected in specific combining ability, but such assumption did not hold true (Baloch and Bhutto, 2003). These results suggested that F_1 performance may not be taken as granted for specific combining ability of such hybrids. Concerning GCA effects, TD-1 expressed maximum positive GCA effects for tillers/plant and grain yield/plant. Cultivar Marvi manifested maximum positive GCA effects for spike length and spike density; Mehran for grains/spike (1.694); Moomal for seed index. These results therefore suggested that parents TD-1, Marvi, Mehran and Moomal may be preferred for hybridization and selection programmes so as to improve majority of the characters studied. The results for specific combining ability (SCA) effects revealed that maximum positive SCA effect was displayed by hybrid SKD-1 × Mehran for tillers/plant and grain yield/plant; TD-1 × Moomal for spike length and spike density; TD-1 × SKD-1 for grains/spike and Moomal × Mehran for seed index (Table 2). These results suggested that various hybrids may be considered for hybrid crop development to improve above traits.

The GCA effects presented in Table 3 revealed that for tillers/plant, TD-1 demonstrated highest positive GCA effects of 1.021 while, Mehran ranked next (0.414), yet Marvi manifested maximum negative GCA effects of -0.800. As far as SCA effect is concerned, hybrids, SKD-1 × Mehran (2.09), SKD-1 × Moomal (2.05) and Marvi × Moomal (2.01), respectively were among the top three rankers for tillers per plant (Table 4). With respect to spike length, Marvi and Moomal established maximum positive GCA effects of 1.299 and 0.406, respectively while SKD-1 exhibited highly negative GCA effect of -0.894. Eight hybrids manifested positive SCA effects while other two crosses gave negative SCA effects for spike length (Table 4). Nonetheless, top three rankers in SCA effects were; TD-1 × Moomal (1.58), Marvi × Moomal (1.19) and TD-1 × Mehran (0.83).

Regarding GCA effects of spike density, Marvi and Moomal expressed maximum positive effects of 7.158 and 2.714, respectively. Whereas SKD-1 (-6.751) and Mehran (-1.795) demonstrated negative GCA effects (Table 3). Concerning SCA effects, six hybrids manifested positive SCA effects and four crosses gave negative SCA effects (Table 4). Nonetheless, three top rankers in SCA effects were TD-1 × Moomal (11.25), Marvi × Mehran (8.92) and SKD-1 × Marvi (7.10). GCA effects of grains/spike (Table 3) revealed that Mehran and Marvi genotypes expressed positive GCA effects of 1.694 and 0.016, respectively, while TD-1 (-1.399), SKD-1 (-0.220) and Moomal (-0.091) displayed negative GCA effects. With respect to SCA effects, the top three scoring hybrids were TD-1 × SKD-1 (9.62),

Table 3. The GCA effects of various yield traits in bread wheat (*Triticum aestivum* L.)

Parents	Tillers/ plant	Spike length	Spike density	Grains/ spike	Grain yield/ plant	Seed index
TD-1	1.021	-0.787	-1.326	-1.399	1.193	1.072
SKD-1	-0.336	-0.894	-6.751	-0.220	-0.271	-0.464
Marvi	-0.800	1.299	7.158	0.016	-0.557	-1.535
Moomal	-0.300	0.406	2.714	-0.091	-0.736	1.215
Mehran	0.414	-0.023	-1.795	1.694	0.371	-0.287
S.E. (gi.)	0.014	0.015	0.99	0.02	0.02	0.02

Table 4. The SCA effects of F_1 hybrids for various yield traits in bread wheat (*Triticum aestivum* L.).

F1 hybrids	Tillers/plant	Spike length	Spike density	Grains/spike	Grain yield/plant	Seed index
TD-1 × SKD-1	1.99	0.03	-8.79	9.62	2.37	-0.05
TD-1 × Marvi	1.45	-0.55	1.66	6.28	1.91	0.27
TD-1 × Moomal	0.45	1.58	11.25	2.64	0.33	0.28
TD-1 × Mehran	1.49	0.83	0.46	5.61	-0.77	-1.72
SKD-1 × Marvi	0.80	0.48	7.10	2.61	-0.39	3.04
SKD-1 × Moomal	2.05	-1.13	-1.95	3.72	0.29	1.81
SKD-1 × Mehran	2.09	0.11	-2.39	3.94	3.19	1.30
Marvi × Moomal	2.01	1.19	-1.52	1.23	1.82	4.12
Marvi × Mehran	1.80	0.69	8.92	3.71	2.47	0.87
Moomal × Mehran	-0.44	0.07	1.88	-2.18	0.15	4.13
S.E. (si.)	0.06	0.06	4.15	0.09	0.08	0.09

Table 5. Heterotic effects of F_1 hybrids over their mid and better parents for various traits in bread wheat (*Triticum aestivum* L.)

F_1 hybrids	Tillers per plant		Spike length		Spike density		Grains per spike		Grain yield per plant		Seed index	
	R.H. (%)	B.P. (%)	R.H (%)	B.P. (%)	R.H. (%)	B.P. (%)	R.H. (%)	B.P. (%)	R.H. (%)	B.P. (%)	R.H. (%)	B.P. (%)
TD-1 × SKD-1	61.29	31.58	-0.31	-4.80	-15.77	-18.90	33.82	28.56	23.74	11.69	-0.30	-7.69
TD-1 × Marvi	53.33	21.05	-0.46	-14.29	5.33	-1.44	24.23	16.05	22.06	7.79	1.85	-9.34
TD-1 × Moomal	29.41	15.79	16.26	5.36	15.72	11.76	13.62	3.09	7.80	-1.30	2.92	-3.30
TD-1 × Mehran	41.67	34.21	10.77	3.85	1.92	-0.19	20.93	9.16	4.83	-1.30	-5.12	-10.99
SKD-1 × Marvi	65.22	58.33	2.65	-7.94	9.13	-1.43	15.25	11.93	12.40	9.68	14.48	9.68
SKD-1 × Moomal	66.67	50.00	-9.43	-14.29	-4.55	-11.13	13.11	6.56	11.11	9.38	11.75	10.00
SKD-1 × Mehran	65.52	41.18	0.00	-1.92	-5.66	-7.28	15.68	8.40	32.31	26.47	6.84	5.34
Marvi × Moomal	65.38	43.33	10.92	4.76	2.84	-0.48	6.37	3.09	21.95	17.19	19.87	13.13
Marvi × Mehran	60.71	32.35	7.83	-1.59	15.87	6.32	12.48	8.40	29.13	20.59	7.47	1.58
Moomal × Mehran	18.75	11.76	3.70	0.00	5.27	-0.37	-0.19	-0.76	9.09	5.88	16.44	16.25

R.H. = relative heterosis; B.P. = better parent heterosis.

TD-1 × Marvi (6.28) and TD-1 × Mehran (5.61). For grain yield/plant**,** TD-1 and Mehran expressed maximum positive GCA effects of 1.193 and 0.371, respectively whereas Moomal (-0.736), Marvi (-0.557) and SKD-1 (-0.271) demonstrated negative GCA effects (Table 3). Concerning the SCA effects for grain yield/plant, eight crosses manifested positive SCA effects while remaining two hybrids showed negative SCA effects (Table 4). Seed index (1000-grain weight in g) results revealed that Moomal and TD-1 expressed maximum positive GCA effects of 1.215 and 1.072, respectively whereas other parents such as Marvi (-1.535), SKD-1 (-0.464) and Mehran (-0.287) displayed negative GCA effects (Table 3). From 10 crosses, eight hybrids manifested positive SCA effects yet, top three hybrids were Moomal × Mehran (4.13), Marvi × Moomal (4.12) and SKD-1 × Marvi (3.04) (Table 4).

Heterotic effects revealed that hybrids SKD-1 × Moomal exhibited maximum positive heterobeltiosis for tillers per plant; TD-1 × Moomal for spike length; Marvi × Mehran for spike density; TD-1 × SKD-1 for grains/spike; SKD-1 × Mehran for grain yield/plant; Marvi × Moomal for seed index (Table 5). Regarding heterobeltiosis, maximum positive heterobeltiosis was displayed by hybrids SKD-1 × Marvi for tillers per plant; TD-1 × Moomal for spike length and spike density; TD-1 × SKD-1 for grains/spike; SKD-1 × Mehran for grain yield/plant and Moomal × Mehran for seed index. These crosses revealed good scope for their commercial exploitation of heterosis as well as isolation of promising progenies in later segregating generations. Analogous to our heterotic effects, Jaiswal *et al*. (2010) obtained mid parent and better parent heterosis for tillers per plant; Akbar *et al*. (2009) for spike length; Chowdhry *et al*. (2005) for spike density, Moneam (2009) for grain yield per plant and Akbar *et al*. (2009) for seed index.

Conclusion

The overall findings revealed the importance of both additive and non-additive genetic variances and effects which suggested that the use of integrated breeding strategies can efficiently utilize both gene actions. Among the parents, TD-1, Mehran, Moomal and Marvi were found as best general combiners hence can be regarded potential parents for hybridization and selection programmes to improve yield traits under study. Furthermore, if hybrid wheat becomes feasible, the better parent heterosis could be of practical value and hybrids like SKD-1 × Mehran, Marvi × Mehran, Marvi × Moomal and TD-1 × SKD-1 may be more meaningful for improving yield in wheat.

References

Abdel-Moneam, M.A. 2009. Heterosis in some crosses of bread wheat under irrigation and drought conditions. *Pakistan Journal of Biological Sciences*, **12:** 486-491.

Akbar, M., Anwar, J., Hussain, M., Qureshi, M.H., Khan, S. 2009. Line × tester analysis in bread wheat (*Triticum aestivum* L.). *Journal of Agriculture Research*, **47:** 21-30.

Akram, Z., Ajmal, S.U., Khan, K.S., Qureshi, R., Zubair, M. 2011. Combining ability estimates of some yield and quality related traits in spring wheat (*Triticum aestivum* L.). *Pakistan Journal of Botany*, **43:** 221-231.

Baloch, M.J., Mallano, I.A., Baloch, A.W., Jatoi, W.A., Veesar, N.F. 2011. Efficient methods of choosing potential parents and hybrids: Line × Tester analysis of spring wheat (*Triticum aestivum* L.) cultivars. *Pakistan Journal of Scientific and Industrial Research*, **54:** 117-121.

Baloch, M.J., Kumbher, M.B., Jatoi, W.A., Fatima N. 2008. Estimates of genetic parameters from line × tester mating design for some quantitative traits in upland cotton, *Gossypium hirsutum* L. *Pakistan Journal of Scientific and Industrial Research*, **51:** 36-41.

Baloch, M.J., Bhutto, H.U. 2003. Design-11 analysis for estimating general and specific combining ability effects of cotton leaf curl virus resistant inbred parents. *Egypt Zagazig Journal of Agricultural Research*, **30:** 635-649.

Borghi, B., Corbellini, M., Cattaneo, M., Fornasari, M.E., Zucchelli, L. 1986. Modification of the sink/source relationships in bread wheat and its influence on grain yield and grain protein content. *Journal of Agronomy and Crop Science*, **157:** 245-247.

Chowdhry, M.A., Parveen, N., Khaliq, I., Kashif, M. 2005. Estimation of heterosis for yield and yield components in bread wheat. *Journal of Agriculture and Social Sciences*, **1:** 304-308.

Cifci, E.A., Yagdi, K. 2010. The research of the combining ability of agronomic traits of bread wheat in F_1 and F_2 generations. *Journal of Agricultural Faculty of Uludag University*, **24:** 85-92.

Dhadhal, B.A., Dobariya, K.L., Ponkia, H.P., Jivani, L.L. 2008. Gene action and combining ability over environments for grain yield and its attributes in bread wheat (*Triticum aestivum* L.). *Internal Journal of Agricultural Science*, **4:** 66-72.

Gomez, K.A., Gomez, A.A. 1984. *Statistical Procedurer for Agriculture Research*. 680 pp., 2^{nd} edition, John Wiley and Sons Inc., New York, USA.

Griffing, B. 1956. Concept of general versus specific combining ability in relation to diallel crossing system. *Australian Journal of Biological Sciences*, **9:** 463-493.

Iqbal, M., Khan, A.A. 2006. Analysis of combining ability for spike characteristics in wheat (*Triticum aestivum* L.). *International Journal of Agriculture and Biology*, **8:** 684-687.

Jaiswal, K.K., Pandey, P., Marker, S., Anurag, P.J. 2010. Heterosis studies for improvement in yield potential of wheat (*Triticum aestivum* L.). *Advances in Agriculture and Botanics*, **2:** 273-278.

Khan, M.A., Ahmad, N., Akbar, M., Rehman, A., Iqbal, M.M. 2007. Combining ability analysis in wheat. *Pakistan Journal of Agricultural Science*, **44:** 1-5.

Khattab, S.A.M., Esmail, R.M., Al-Ansary, A.M.F. 2010. Genetical analysis of some quantitative traits in bread wheat (*Triticum aestivum* L). *New York Scientific Journal*, **3:** 152-157.

Mahpara, S., Ali, Z., Ahsan, M. 2008. Combining ability analysis for yield and yield related traits among wheat varieties and their F1 hybrids. *International Journal of Agriculture and Biology*, **10:** 599-604.

Nagarajan, S. 2001. *Annual Report (2001)*. 55 pp., Directorate of Wheat Research, Karnal, India.

Rahim, M.A., Salam, A., Saeed, A., Shakeel, A., Abbas, G. 2006. Combining ability for flag leaf area, yield and yield components in bread wheat. *Journal of Agricultural Research*, **44:** 175-180.

Shabbir, G., Ahmad, N.H., Akram, Z., Tabassum, M.I. 2011. Genetic behavior and analysis of some yield traits in wheat (*Triticum aestivum* L.) genotypes. *Journal of Agricultural Research*, **49:** 1-9.

Singh, R.K., Choudhary, B.D. 1979. *Biometrical Methods in Quantitative Genetic Analysis*. pp. 191-200, Kalyani Publisher, New Delhi, India.

Sprague, G.F., Tatum, L.A. 1942. General *versus* specific combining ability in single crosses of corn. *Journal American Society of Agronomy*, **34:** 923-932.

Yucel, C., Baloch, F.S., Ozkan, H. 2009. Genetic analysis of some physical properties of bread wheat grain (*Triticum aestivum* L. em Thell). *Turkish Journal of Agriculture*, **33:** 525-535.

Zehr, B.E., Ratralikar, V.P., Reddy, L.M.M., Pandy, L.V. 1997. Strategies for utilizing heterosis in wheat, rice and oilseed Brassica in India, pp. 232-233, In: *Proceeding of Genetics and Exploitation of Heterosis in Crops*, Mexico City.