COMBINING ABILITY EFFECTS OF SOME PHENOLOGICAL TRAITS IN BREAD WHEAT

NADIA HUSSAIN AHMAD, GHULAM SHABBIR, ZAHID AKRAM and M. KAUSAR NAWAZ SHAH

Department of Plant Breeding and Genetics, Pir Mehr Ali Shah Arid Agriculture University, Rawalpindi, - Pakistan.
E-mail: drgshabbir@gmail.com

ABSTRACT

Five wheat varieties/lines viz. Chakwal-97, Inqlab-91, GA-2002, 6C001 and 6C002 were crossed in 5 x 5 diallel cross to estimate combining ability at PMAS Arid Agriculture University, Rawalpindi, Pakistan during 2007-2008 and 2008-2009. GCA effects for days to heading (7.81), flag leaf area (22.07), plant height (82.18), number of tiller metre^{-2} (2997.21), days to maturity (9.59) and grain yield plant^{-1} (47.76) were non-significant indicating the preponderance of non additive type of gene action for these traits. SCA effects were highly significant for days to heading (26.81), flag leaf area (365.11), plant height (141.05), number of tillers metre^{-2} (8639.21), days to maturity (18.85) and grain yield plant^{-1} (93.70) which indicated that these traits are being controlled by non-additive type of gene action. RCA effects were also highly significant for all the traits studied suggesting selection can be effective in later generations. Chakwal-97 proved to be the best general combiner for all the characters under study except plant height. Among hybrids, Chakwal-97 x 6C002 proved better having maximum SCA for days to heading, number of tillers metre^{-2} and days to maturity while hybrid Chakwal-97 x Inqlab-91 had higher SCA for 1000 grain yield plant^{-1}. Hence it can be concluded that Chakwal-97 may be used in breeding programmes to develop high yielding wheat cultivars.

Key Words: ***Triticum Aestivum*** **L., Phenological Traits, Yield, Diallel, Combining Ability, Gene Action**

Citation: Ahmad, N.H., G. Shabbir, Z. Akram and M.K.N. Shah. 2013. Combining ability effects of some phenological traits in bread wheat. Sarhad J. Agric. 29(1): 15-20.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is an important food crop with the largest cropped area of the world devoted to its cultivation. It occupies 70 % of Rabi (winter season) and 37 % of total cropped area in Pakistan (Anon., 2010). Wheat is the staple food of 35% of the world's population (Kronstad, 1998). To meet the ever increasing demand of food grains for rapidly growing population, it is imperative to develop genotypes possessing desirable phenological traits along with better yield potential per unit area. This could be achieved only by exploring maximum genetic potential from available germplasm. Among wheat traits, yield is one of the most complex and economically important characters (Akram *et al.,* 2008). An efficient crop improvement programme demands an understanding of the genetic mechanism involved in the expression of yield and other phenological traits of the plant material to be used in the hybridization (Rabbani *et al.,* 2009). Diallel cross designs are frequently being used in plant breeding research to ascertain information on genetic effects for a fixed set of parental lines or estimates of general combining ability (GCA) and specific combining ability (SCA) variance components and heritability for a population from randomly chosen parental lines. The combining ability analysis developed by Griffing (1956) provides useful information regarding the genetic effects of various parameters in any crop plant. Good combining ability implies to the capacity of a parent to produce superior progeny when combined with another parent. General combining ability (GCA) provides an assessment of the degree of mainly additive gene action, while specific combining ability (SCA) refers to the performance of two particular lines in a specific cross and it thus reflects non-additive types of gene interaction (Nazim-Uddin *et al.,* 2009). Furthermore the analyses reveal the nature and magnitude of various types of gene actions involved in the expression of quantitative characters The additive type of gene action was reported in wheat for days to maturity and flag leaf area (Akram *et al.,* 2008), fertile tiller plant^{-1} (Liu and Wei, 2006), while non-additive type of gene action was observed for plant height (Esmail *et al.,* 2002; Akram *et al.,* 2008), flag leaf area (Senapati *et al.,* 2000; Rabbani *et al.,* 2009), days to maturity (Faisal *et al.,* 2005; Akram *et al.,* 2008) number of tillers metre^{-2} (Inamullah *et al.,* 2006; Akram *et al.,* 2008) and grain yield plant^{-1} (Sangwan *et al.,* 1999; Iqbal and Khan, 2006; Rabbani *et al.,* 2009).

The study was conducted to determine the type of gene action governing various traits for advance lines in wheat. Such information can be useful in designing and executing an efficient breeding programme to achieve the maximum genetic gain

MATERIALS AND METHODS

The present research studies were carried out in the research area of the Department of Plant Breeding and Genetics, PMAS Arid Agriculture University Rawalpindi during 2007-09. Five wheat genotypes; three varieties viz. Chakwal-97, Inqlab-91 and GA-2002 and two advance lines viz. 6C001 and 6C002 were sown in the field during Rabi 2007-08 and crossed in diallel fashion. The emasculation and crossing was done during the month of March, 2008. After emasculation, the respective spikes were bagged, pollinated in the next morning and bagged again. Seeds of F_{1S} along with parents were sown following Randomized Complete Block Design with three replications during November, 2008 under field conditions. Uniform agronomic practices were performed for all the treatments as per requirements. Data were recorded for the traits like: days to heading, days to maturity, flag leaf area, plant height, number of tillers metre^{-2} and grain yield plant^{-1}. Data were statistically analyzed following method described by Griffing (1956) Method-1, Model-II.

RESULTS AND DISCUSSION

Knowledge of the nature of inheritance and the manner in which parent can transmit favourable alleles for desired trait to their progeny enhances breeder's ability to select genetically superior parents and practice selection within segregating population. Results in Table 1 depicted highly significant differences among the genotypes for all the traits under study. Total variation for various traits under study have been partitioned into general combining ability and specific combining ability and discussed separately for each trait studied as follows.

Table 1. ***Analysis of variance for mean squares of yield components in a 5x5 diallel cross of wheat***

Source of variation	df	Days to heading	Flag leaf area (cm^2)	Plant height (cm)	Number of tillers m^{-2}	Days to maturity	Grain yield plant^{-1} (g)
Replications	2	11.57	28.27	0.57	37557.24	24.41	13.52
Genotypes	24	26.11**	140.16**	148.90**	8769.27**	19.96**	69.10**
Error	48	3.99	2.49	3.71	174.86	3.00	2.07

** =Highly Significant ($P \leq 0.01$)

Days to Heading

Days to heading determines number of days from sowing till 50 % plants show heading. The minimum days for heading were observed for genotype Inqlab-91 with 108.7 days closely followed by Chakwal-97 with 110 days (Table 2). Among cross combinations, the earliest flowering (108.7) was observed for Chakwal-97 x 6C002, whereas the very late flowering i.e. 116.7 days was observed for 6C002 x 6C001 (Table 2). Combining ability analysis revealed that SCA mean square and reciprocal mean square were highly significant (Table 3). The estimate of general combining ability effects of parents indicated that Chakwal-97 showed lowest (-0.77) for days to heading (Table 4). The specific combining ability indicated negative value of -2.94 for Chakwal-97 x 6C002 and positive effects of 2.11 for cross (6C001 x 6C002). Reciprocal effects were negative (-5.17) for 6C002 x 6C001 and positive (1.5) for cross 6C001 x Chakwal-97 (Table 4). It was observed that Chakwal-97 is early maturing parent and can be used in breeding programmes for escaping late season biotic and abiotic stresses. Results showed that RCA variance for the cross (6C002 x 6C001) was larger than GCA and SCA variances suggesting the importance of reciprocal genetic effects. These results are according to those obtained by Hennawy (1996), Esmail *et al*. (2002) and Akram *et al.* (2008) who reported similar finding while working in different wheat genotypes for these traits.

Flag Leaf Area (cm^2)

The relevance of flag leaf area to grain yield is due to its role in photosynthetic activity. At spike development, flag leaf is the major contributor towards the grain yield (Dickson, 1991; Kozlowski, 1992). The mean values for flag leaf area ranged from 39.33-53.8 cm^2 (Table 2). Among cross combinations, the highest mean value of 53.8 was shown by Chakwal-97 x 6C001 (Table 2). Combining ability analysis revealed that GCA mean square was non-significant while SCA and reciprocal mean squares were highly significant (Table 3). The GCA estimate was highest and positive (1.07) for Chakwal-97 among parents suggesting that Chakwal-97 and Inqlab-91 appeared to be good parents for having maximum flag leaf area. The specific combining ability effects were positive for

Inqlab-91 x GA-2002 i.e. 5.57. Reciprocal effects were maximum and positive in the cross 6C001 x Inqlab-91 i.e. 7.92 (Table 4). Results revealed that SCA effects were larger than GCA suggesting the importance of non-additive genetic effects for flag leaf area. These results are according to those obtained by Akram *et al.* (2008) and Rabbani *et al*. (2009).

Table 2. ***Mean values for yield components of wheat parents and crosses in a 5x5 diallel cross of wheat***

Parents and crosses	**Days to heading**	**Flag leaf area (cm^2)**	**Plant height (cm)**	**Number of tillers metre^{-2}**	**Days to maturity**	**Grain yield plant^{-1} (g)**
Chakwal-97	110.0	39.3	101.0	216.0	177.0	21.7
Inqlab-91	108.7	46.2	92.6	252.3	176.7	22.8
GA-2002	118.0	45.1	94.5	166.0	180.7	15.5
6C001	111.0	48.1	91.7	234.0	178.0	18.0
6C002	113.0	43.3	99.1	246.8	183.0	13.4
Chakwal-97 x Inqlab-91	111.7	37.9	98.3	218.7	178.0	19.4
Chakwal-97 x GA-2002	114.0	47.3	102.4	234.0	180.0	16.4
Chakwal-97 x 6C001	114.3	53.8	98.7	249.0	181.0	17.5
Chakwal-97 x 6C002	108.7	46.9	90.4	330.0	175.0	17.7
Inqlab-91 x Chakwal-97	113.0	29.5	91.3	189.3	180.0	14.2
Inqlab-91 x GA-2002 Inqlab-	112.0	52.6	93.2	201.7	172.0	11.7
91 x 6C001	112.0	48.2	97.4	305.7	180.0	15.5
Inqlab-91 x 6C002	114.0	48.4	100.5	221.7	183.0	13.3
GA-2002 x Chakwal-97	114.0	48.6	98.3	249.0	179.0	12.4
GA-2002 x Inqlab-91	113.0	46.9	94.0	295.7	180.0	15.7
GA-2002 x 6C001	112.0	35.7	88.6	234.0	177.0	15.9
GA-2002 x 6C002	114.0	44.0	97.7	160.0	179.0	12.3
6C001 x Chakwal-97	112.0	40.5	94.0	185.4	180.0	14.9
6C001 x Inqlab-91	112.0	45.6	88.1	216.0	178.7	16.5
6C001 x GA-2002	110.3	34.6	93.7	165.3	176.0	14.5
6C001 x 6C002	116.0	36.5	93.6	156.0	180.0	17.7
6C002 x Chakwal-97	114.0	51.7	91.6	188.0	180.0	14.5
6C002 X Inqlab-91	115.0	42.2	87.4	191.6	178.0	13.9
6C002 X GA-2002	114.0	36.8	88.6	222.8	181.0	17.2
6C002 X 6C001	116.7	42.3	101.5	177.6	176.0	17.5

Plant Height (cm)

Generally plant height is considered as an indirect criterion of selection. The plant height for parental genotypes ranged from 91.70 cm to101.02 cm (Table 2). Results further revealed that the cross Chakwal-97 x GA-2002 showed the maximum mean value of 102.35 and the lowest mean value of 87.40 was observed for cross 6C002 x Inqlab-91. (Table 3) showed that mean squares for specific combining ability and reciprocal combining ability were highly significant. General combining ability effects for plant height displayed that variety Chakwal-97 had the maximum positive value of 2.74 whereas the maximum negative value (-2.54) was shown by the genotype 6C002 among parents (Table 4). Negative combining ability effects are preferred for plant height in wheat because short stature varieties are preferred due to less lodging and being more responsive to fertilizers. Therefore, genotype 6C002 could be an asset in any breeding programme as dwarfing gene source. (Table 4) revealed the highest positive SCA effects of 5.69 by the cross Chakwal-97 x GA-2002 while the cross GA-2002 x 6C002 showed the highest negative SCA effects with the value of -5.20. The maximum positive reciprocal effects for plant height for cross 6C002 x Inqlab-91 with the value of 4.39 and the cross which showed the maximum negative reciprocal effects was 6C002 x 6C001 (-3.64). The results clearly indicated that non-additive type of gene action was responsible for the expression of plant height as SCA variance was higher than GCA. Singh *et al*. (2000), Bakhsh *et al*. (2003), Iqbal and Khan (2006) and Khan and Ali (1998) reported that there was preponderance of non-additive genetic variance for plant height in wheat.

Number of Tillers Metre^{-2}

Grain yield is comprised of the combined production of the main stem and number of tillers metre^{-2} contributes significantly towards the increase in yield. Among parents, the maximum tillers (252.3) were produced by genotype Inqlab-91 whereas least number of tillers (166) were produced by GA-2002 (Table 2). Among hybrids, the highest average value (330) was observed in Chakwal-97 x 6C002 and the lowest value (156) by 6C001 x 6C002. Combining ability analysis indicated that mean squares for specific combining ability and reciprocal combining ability were highly significant (Table 3). Estimates of general combining ability effects were positive for the parent Chakwal-97 with the value of 19.30 and negative with the value of -13.99 for 6C002 (Table 4) suggesting that Chakwal-97 can be used in breeding programme for improvement of tiller production. Estimates of specific combining ability effects showed the maximum positive value of 45.60 for the cross Chakwal-97 x 6C002. Reciprocal combining ability effects were maximum and positive (85) for 6C002 x 6C001 (Table 4). From results it was clear that there is predominance of non-additive type of gene action for number of tillers metre^{-2}. The findings of Aslam *et al*. (2007) and Inamullah *et al*. (2006) are in agreement with these results.

Table 3. ***Combining ability analysis for mean squares of yield component traits in a 5x5 diallel cross of wheat***

Source of variation	df	Days to heading	Flag leaf area (cm^2)	Plant height (cm)	Number of tillers metre^{-2}	Days to maturity	Grain yield plant^{-1} (g)
General combining ability	4	7.81^{NS}	22.07^{NS}	82.18^{NS}	2997.21^{NS}	9.59^{NS}	47.76^{NS}
Specific combining ability	5	26.81**	365.11**	141.05**	8639.21**	18.85**	93.70**
Reciprocal combining effects	10	28.53**	72.46**	175.89**	8567.62**	25.17**	61.35**

NS=Non-significant * =Significant (P<0.05) ** =Highly Significant (P<0.01)

Days to Maturity

Early maturity is associated with higher yield (Cox *et al*. 1988 and Khalil *et al*. 1995). Among parents, the genotype Inqlab-91 was earliest with respect to days to maturity (176.7) followed by the parent Chakwal-97 i.e. 177 days (Table 2). Among hybrids, the minimum days to maturity (172 days) was observed for the cross combination Inqlab-91 x GA-2002. Results in (Table 3) revealed that specific combining ability and reciprocal effects were significant for this trait. Estimates of general combining ability effects for days to maturity were positive (0.77) for Chakwal-97 and negative (-1.07) GCA effects for GA-2002 (Table 4), suggesting that GA-2002 could be used as parent in hybridization programme. The maximum positive value for SCA estimates were (1.67) for GA-2002 x 6C002 and maximum negative (-1.67) for both Inqlab-91 x GA-2002 and Chakwal-97 x 6C002. Reciprocal effects were maximum and positive (2.5) for the cross 6C002 x GA-2002 and the maximum negative effects (-4.5) for 6C001 x Inqlab-91 for this trait (Table 4). Specific combining ability effects were larger than general ability effects indicating that non-additive gene action was more important for expression of this trait. Akram *et al.* (2008), Faisal *et al*. (2005) and Esmail *et al*. (2002) also reported similar findings.

Grain Yield Plant^{-1} (g)

The grain yield plant^{-1} is a complex trait affected by many traits of a plant. The genotype (Inqlab-91) had the maximum mean value of 22.8 closely followed by Chakwal-97 (21.7) while the minimum (13.4) was recorded for the genotype i.e. 6C002 among parents (Table 2). Among cross combinations, the maximum value of 19.4 was observed for Chakwal-97 x Inqlab-91. Mean squares due to specific combining ability effects and reciprocal effects were highly significant (Table 3). The estimates of general combining ability for parents indicated that it was maximum and positive for Chakwal-97 i.e. 1.66 (Table 4) showing that Chakwal-97 is a good parent for grain yield plant^{-1}. The maximum positive value for specific combining ability effects were 4.93 observed for Chakwal-97 x Inqlab-91. Reciprocal effects were maximum and positive for the cross Inqlab-91 x Chakwal-97 (2.58) and the maximum negative effects (-2.48) for the cross 6C002 x GA 2002 for grain yield plant^{-1} (Table 4). Results showed that SCA effects were larger than GCA effects suggesting the importance of non-additive genetic effects for the manifestation of grain yield plant^{-1}. Earlier researchers Iqbal and Khan (2006), Mann *et al*. (1995), Inamullah *et al*. (2006) and Rabbani *et al.* (2009) also reported greater SCA effects for grain yield plant^{-1} in wheat.

Table 4. ***Estimate of general, specific and reciprocal combining ability effects for yield associated traits in a 5x5 diallel cross of wheat***

Genotypes	Days to heading	Flag leaf area (cm^2)	Plant height (cm)	Number of tillers metre^{-2}	Days to maturity	Grain yield plant^{-1} (g)
GCA						
Chakwal-97	-0.77	1.07	2.74	19.3	0.77	1.66
Inqlab-91	-0.27	1.01	0.29	5.59	-0.07	-2.65
GA-2002	-0.16	-0.43	-1.67	-3.53	-1.07	-0.18
6C001	0.18	-1.60	1.18	-7.36	-0.23	0.83
6C002	1.01	-0.04	-2.54	-13.99	0.60	0.35
SCA						
Chakwal-97 x Inqlab-91	0.33	-11.80	-1.78	-43.94	-0.50	4.93
Chakwal-97 x GA-2002	1.89	3.66	5.69	7.67	1.00	-1.98
Chakwal-97 x 6C001	0.72	3.54	-1.16	-9.34	1.17	-4.17
Chakwal-97 x 6C002	-2.94	4.60	-2.74	45.60	-1.67	1.23
Inqlab-91 x GA-2002	-0.11	5.57	1.42	8.55	-1.67	-1.39
Inqlab-91 x 6C001	-0.94	5.50	-2.26	44.56	1.00	0.94
Inqlab-91 x 6C002	0.72	0.73	2.26	-9.16	1.17	-4.48
GA-2002 x 6C001	-1.89	-6.47	-1.91	-7.50	-1.00	1.68
GA-2002 x 6C002	0.11	-2.76	-5.20	-8.72	1.67	1.69
6C001 x 6C002	2.11	-2.57	5.33	-27.72	-1.17	1.56
RCA						
6C002 x Chakwal-97	-1.17	-5.28	-1.06	-1.50	-2.5	1.63
6C002 x Inqlab-91	-1.00	5.37	4.39	39.00	0.5	-0.34
6C002 x GA-2002	-0.84	5.74	-1.39	35.73	2.5	-2.48
6C002 x 6C001	-5.17	1.41	-3.64	85.00	-2.0	0.11
6C001 x Chakwal-97	1.50	-2.54	-1.21	12.00	2.0	1.29
6C001 x Inqlab-91	-1.00	7.92	2.36	-10.55	-4.5	-0.47
6C001 x GA-2002	-1.00	-0.21	-0.43	28.34	0.5	0.67
GA-2002 x Chakwal-97	0.50	0.68	2.95	39.84	1.0	2.04
GA-2002 x Inqlab-91	-1.50	-3.26	0.61	21.2	-0.5	-1.99
Inqlab-91 x Chakwal-97	-2.50	- 5.58	1.19	-1.32	-1.0	2.58

CONCLUSION AND RECOMMENDATIONS

The analysis of variance revealed that differences among the genotypes were highly significant for all characters suggesting that the parents differ significantly and could be used efficiently for improvement of traits. SCA effects were highly significant for all the traits under study indicating presence of non-additive type of gene action hence selection should be done in later generations. Chakwal-97 proved to be the best general combiner for all the characters under study except plant height. Among hybrids, Chakwal-97 x 6C002 proved better having maximum SCA for days to heading, number of tillers metre^{-2} and days to maturity while hybrid Chakwal-97 x Inqlab-91 had higher SCA for 1000 grain yield plant^{-1}. So it could be concluded that Chakwal-97 may be used in breeding programmes to develop high yielding wheat cultivars. Whereas Chakwal-97 x 6C002 and Chakwal-97 x Inqlab-91 may be used as advance lines for future testing at different locations and which could be released as varieties after thorough evaluation.

REFERENCES

Akram, Z., S.U. Ajmal, M. Munir and G. Shabbir. 2008. Genetic determination of yield related attributes in bread wheat. Sarhad J. Agric. 24(3): 431-437.

Anonymous. 2010. Agricultural Statistics of Pakistan, 2009-2010. Federal Bureau of Statistics, Islamabad, Pakistan

Aslam, M.C., M. Sajad and M.I. Ashraf. 2007. Analysis on combining ability of metric traits in bread wheat (*Triticum aestivum* L.). J. Agric. Res. 45(1): 7-9.

Bakhsh, A., A. Hussain and A.S. Khan. 2003. Genetic studies of plant height, yield and its components in bread wheat. Sarhad J. Agric. 19 (4): 529-534.

Cox, T.S., J.P. Shroyer, L. Ben-Hui, R.G. Sears and T.J. Martin. 1988. Genetic improvement in agronomic traits of hard red winter wheat cultivars from 1919 to 1987. Crop Sci. 28: 756-760.

Dere, S. and M.B. Yildrim. 2006. Inheritance of grain yield per plant, flag leaf width and length in an 8x8 diallel cross population of bread wheat. Turk. J. Agric. & Forestry. 30(5): 339-345.

Dickson, R.E. 1991. Assimilates distribution and storage. pp.51-58. *In* Raghavendra [ed.], *Physiology of stress*. John Wiley, New York.

Esmail, R.M. 2002. Estimation of genetic parameters in the F_1 and F_2 generations of diallel crosses of bread wheat (*Triticum aestivum* L.). Bullet. National Res. Centre, Cairo. 27(1): 85-106.

Faisal, M., A. Malik, S.I. Awan and S. Ali. 2005. Genetic behaviour and analysis of quantitative traits in five wheat genotypes. J. Agric. Soc. Sci. 1(4): 313-315.

Griffing, B. 1956. The concept of general and specific combining ability in relation to diallel crossing systems. Aust. J. Biol. Sci. 9: 463-493.

Hennawy, M.A. 1996. Heterosis and combining ability in diallel crosses of eight bread wheat varieties. Bullet. Faculty Agric. Univ. Cairo. 47(3): 379-392.

Liu, X. and Y. Wei. 2006. Genetic study on winter wheat yield character. Chinese J. Appl. Envir. Biol. 12(1): 1-4.

Ihsan, S.M., M. Jabeen and I. Ilahi. 2003. *In vitro* callus induction, its proliferation and regeneration in seed explants of wheat (*Triticum aestivum* L.) var. LU-26S. Pak. J. Bot. 35: 209-217.

Inamullah, H., A. Hussain, M. Faheem, G. Hassan and R. Gul. 2006. Diallel analysis of the inheritance pattern of agronomic traits of bread wheat. Pak. J. Bot. 38(4): 1169-1175.

Iqbal, M. and A.A. Khan. 2006. Diallel analysis of the inheritance pattern of agronomic traits of bread wheat. Pak. J. Bot. 38(4): 1169-1175.

Khalil, I.H., B.F. Carver and E.L. Smith. 1995. Genetic gains in two selection phases of a wheat-breeding program. Pl. Breed. 114: 117-120.

Khan, A.S. and Z. Ali. 1998. General and specific combining ability estimates for plant height and some yield components in wheat. J. Agric. Sci. 35(1-4): 4-7.

Krostand, W.E. 1998. Agricultural Development and wheat breeding in 20^{th} century. pp.1-10. *In*: H. J. Buran et al. (Eds.), Wheat Programme Global Improvement.

Mann, M.S., S.N. Sharma and V.K. Bhatnagar. 1995. Combining ability and nature of gene effects for grain yield and harvest index in macaroni wheat. Crop Improvement 22 (1): 65-68.

Nazim-Uddin, M., M.M. Hossain, M.M. Rahman, S. Ahmad and A.K.N. Quamruzzaman. 2009. Combining ability and gene action in cucumber (*Cucumis sativus* L.). SAARC J. Agric. 7(1): 64-72.

Rabbani, G., M. Munir, S.U. Ajmal, F. Hassan, G. Shabbir and A. Mahmood. 2009. Inheritance of yield related attributes in bread wheat under irrigated and rainfed conditions. Sarhad J. Agric. 25(3): 429-435

Sangwan,V.P. and B.D. Chaudhary. 1999. Diallel analysis in wheat (*Triticum aestivum* L.). Annals. Biol. Ludhiana. 15 (2): 181-183.

Senapati, N., S.K. Swain and M.C. Patnaik. 2000. Combining ability and nature of gene action in bread wheat. Environment Ecol. 18(1): 258-260.

Singh, B.D., D.K. Majumdar and K.K. Parsad. 2000. Combining ability for yield and its components in late sown wheat. J. Appl. Biol. 10(2): 119-126.