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COMBINING ABILITY STUDIES FOR SOME YIELD CONTRIBUTING TRAITS OF BREAD WHEAT UNDER NORMAL AND LATE SOWING CONDITIONS

Muhammad Kashif and Abdus Salam Khan
Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad

A 7 × 7 diallel analysis involving seven wheat genotypes was conducted under normal and late sowing conditions to determine the combining ability of these genotypes for yield related traits i.e. plant height, tillers per plant, spikelets per spike, grains per spike, 1000-grain weight and grain yield per plant. Preponderance of non-additive effects was observed for tillers per plant, spikelets per spike, grains per spike, 1000-grain weight and grain yield per plant under both normal and late sowing conditions. Plant height showed high additive variance and over dominance variance under both sowing conditions. GA-2002 was the best general combiner for tillers per plant, spikelets per spike, grains per spike and grain yield per plant under both plantings, while SH-2002 for 1000-grain weight under late sowing. Chenab 2002 was the best combiner for 1000-grain weight under normal planting. Cross combinations involving GA-2002 and SH-2002 proved to be useful in selecting high yielding genotypes for normal as well as late sowing conditions.

Keywords: Combining ability, Gene action, wheat, sowing time, yield.

INTRODUCTION

Late sowing is among the main reasons for lower yield of wheat per unit area in Pakistan and it is doomed. Wheat is planted in a diverse cropping system following rice, cotton, maize, sugarcane, fodders and vegetables. Especially in wheat-cotton cropping system short duration early maturing wheat varieties have become a prime importance. Some of the previous scientists like Mahmood and Chowdhry (2002) studied traits like tillers per plant, 1000-grain weight and grain yield per plant under both normal and late sown conditions, to determine the combining ability of 6 wheat genotypes. They reported that additive variance was greater than dominance variance for the above traits. Saeed *et al.* (2005) evaluated the performance of wheat cultivars and found that mean squares for GCA were highly significant for number of spikelets per spike. Specific combining ability (SCA) mean squares were highly significant for grains per spike, 1000-grain weight and grain yield per plant and significant for the spikelets per spike. They reported additive gene effects for spikelets per spike and grains per spike as evident by greater mean squares for general combining ability, and non-additive effects for grains per spike, 1000-grain weight and grain yield per plant. Iqbal and Chowdhry (2000) performed combining ability studies for plant height, spikelets per spike, grains per spike and 1000-grain weight in a set of diallel crosses involving five spring wheat genotypes. GCA, SCA and reciprocal effects were significant. Additive gene action was found for the characters. Mahantashivayogayya *et al.* (2004) studied 10 quantitative characters in dicoccum wheat and reported that GCA magnitude was much higher than that of SCA for all the characters. High SCA variance indicated non-additive effects for plant height, tillers per plant and 1000-grain weight was reported by Farooq *et al.* (2006) in their 5 × 5 diallel experiment in wheat, while additive gene effect were observed for spikelets per spike and grains per spike.

The present study was carried out to obtain information on the nature and magnitude of the types of genes controlling the expression of the various agronomic and yield characters under two sowing dates i.e., normal and late. The main objective was to study the impact of external conditions on the genetic behaviour which ultimately results in phenotypic variations between normal and late sown wheats for various yield contributing traits.

MATERIALS AND METHOD

The present research was conducted in the experimental area of the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad. The experimental material consisted of seven wheat varieties viz., SH-2002, Menthar-3, GA-2002, Chenab-2000, Iqbal-2000, Uqab-2000 and Bhakkar-02. These varieties were crossed in a 7 × 7 complete diallel fashion, during February, 2005. Care was taken to avoid the contamination of genetic material. The hybrids alongwith their parents were sown in the experimental area on November 8, 2006 under normal sowing. The experiment was laid out in a triplicated randomized complete block design. The experimental unit comprised of a single row of 5 meter length. Inter-row and inter-plant distances were kept as 30 and 15 cm, respectively. Two to three seeds per hole were sown with the help of a dibble and after germination thinning was done to have a single healthy seedling per site. Similar practice was followed for the conduct of late sown experiment on December 10, 2006.

Identical cultural practices like irrigation, fertilizer, hoeing, etc. were carried out for all treatments. At maturity ten guarded plants from each treatment were selected randomly and data on the plant traits viz., plant height, tillers per plant, spikelets per spike, grains per spike, 1000-grain weight and grain yield per plant were recorded on individual plant basis. The data recorded on all the traits were subjected to analysis of variance (Steel *et al.* 1997) to determine the significant differences among genotypes. Combining ability studies were conducted according to Method I, Model II of Griffing (1956).

RESULTS AND DISCUSSION

Plant height

It was revealed from Table 1 that GCA mean squares were greater and highly significant for plant height under normal as well as late planting, showing the importance of additive genetic effects. Mean squares due to SCA and reciprocal effects were also significant. These results are in agreement with those of Rehman *et al.* (2002), Kashif and Khaliq (2003) and Chandrashekhar and Kerketta (2004) who also reported significant mean squares due to both GCA and SCA. Higher GCA and additive variance for plant height (Table 1) was also indicated by variance components in both plantings. Additive genetic effects were also reported by Chowdhry *et al.* (1999b) and Iqbal and Chowdhry (2000). However, importance of non-additive effects for plant height was indicated by Chowdhry *et al.* (1999a), Shoran *et al.* (2003) and Chowdhry *et al.* (2005).

Negative combining ability effects are desirable in case of plant height. Under normal planting, combining ability analysis (Table 2) depicted that highest negative GCA effects were displayed by Menthar-3 followed by Chenab-02, Iqbal-2000 and Bhakkar 02 while Uqab-02, GA-2002 and SH-2002 displayed positive GCA effects in descending order. Similarly, negative SCA effects were recorded in 6 of the crosses while 15 crosses had positive SCA effects. Cross combination having highest negative SCA effects was Chenab-02 × Uqab-02 followed by the cross Menthar-3 × GA-2002. Reciprocal differences became obvious as more crosses displayed negative reciprocal effects. However, the cross Chenab-02 × Uqab-02 having highest SCA effects displayed highest positive reciprocal effects.

Under late planting, the parental genotypes showed similar performance. Genotypes showing negative GCA effects under normal planting also showed negative GCA effects under late planting except Bhakkar 02 which showed positive GCA effects under late planting. Maximum negative GCA effects were observed in Menthar-3 followed by Chenab-02 and Iqbal-2000. Nine of the crosses showed negative SCA effects being maximum in the cross SH-2002 × Uqab-02 followed by Menthar-3 × Iqbal-2000. However, this cross showed highest positive reciprocal effects. Reciprocal effects were negative in 10 crosses being highest in the cross Bhakkar 02 × SH-2002.

Table 1. Analysis of variance of combining ability for grain yield and its attributes and components of variance under normal (N) and Late (L) planting in wheat

Traits		Mean Squares				Variance components					
		GCA	SCA	Reciprocal	Error	σ^2g	σ^2s	σ^2r	σ^2e	σ^2A	σ^2D
Plant height	N	111.25**	4.82**	2.71*	1.40	7.85	3.42	0.65	1.40	15.69	3.42
	L	117.44**	4.59**	2.94**	0.92	8.32	3.66	1.01	0.92	16.64	3.66
Tillers per plant	N	2.56**	1.91**	0.96**	0.28	0.16	1.63	0.34	0.28	0.32	1.63
	L	1.32**	0.65**	0.46	0.28	0.07	0.37	0.09	0.28	0.14	0.37
Spikelets per spike	N	34.79**	28.14**	14.02**	3.82	0.08	1.02	0.21	0.15	0.16	1.02
	L	18.22**	7.80**	5.54*	3.08	0.12	0.52	0.15	0.33	0.24	0.52
Grains per spike	N	0.19**	0.11**	0.06**	0.02	2.21	24.31	5.10	3.82	4.42	24.31
	L	0.28**	0.09**	0.12**	0.04	1.08	4.72	1.23	3.08	2.16	4.72
1000-grain wt	N	40.70**	4.14**	2.02**	0.32	2.88	3.82	0.85	0.32	5.76	3.82
	L	9.47**	3.25*	2.15	1.60	0.56	1.65	0.28	1.60	1.12	1.65
Yield	N	7.99**	6.50**	3.21**	0.88	0.51	5.62	1.17	0.88	1.02	5.62
	L	19.58**	8.25**	5.88*	3.18	1.17	5.07	1.35	3.18	2.34	5.07

* = $P \leq 0.05$ ** = $P \leq 0.01$

Table 2. GCA (diagonal) and SCA (above diagonal) and reciprocal effects yield of some yield contributing traits in wheat under normal (N) and late planting

Traits	Genotypes	SH-02		Menthar-3		GA-02		Chenab-02		Iqbal-2000		Uqab-02		Bhakkar 02	
		N	Late	N	Late	N	Late	N	Late	N	Late	N	Late	N	Late
Plant height	SH-02	**1.11**	**0.69**	0.44	1.28	0.22	0.56	1.06	-1.18	1.38	2.15	-0.22	-2.95	-0.52	0.90
	Menthar-3	-0.48	-0.58	**-4.08**	**-4.70**	-1.56	2.08	0.97	-0.20	-0.30	-2.02	2.58	1.03	0.26	-0.42
	GA-02	1.17	0.12	-1.97	-0.55	**3.23**	**2.93**	-0.37	-0.44	0.13	0.42	2.05	-0.66	2.34	-0.53
	Chenab-02	-0.19	1.06	0.17	-0.56	-1.28	0.94	**-2.80**	**-2.41**	0.08	-0.39	-2.55	0.89	0.09	2.24
	Iqbal-2000	0.04	0.23	-1.29	-1.11	-0.34	1.39	-1.29	0.76	**-0.42**	**-0.39**	0.56	2.25	2.20	0.90
	Uqab-02	-0.56	0.54	-1.73	-2.15	1.02	2.02	2.48	0.87	0.78	1.10	**3.35**	**3.62**	1.92	3.00
	Bhakkar 02	0.31	-2.35	-0.45	-0.80	0.89	-0.59	0.66	-2.13	1.40	1.17	-1.79	-0.87	**-0.39**	**0.26**
Tillers per plant	SH-02	**0.24**	**0.18**	1.48	0.90	-0.27	-0.51	0.31	0.46	-0.05	-0.02	0.41	-0.26	0.26	0.09
	Menthar-3	0.38	0.01	**-0.82**	**-0.57**	-0.20	-0.43	0.75	0.75	0.19	-0.37	0.28	0.33	0.26	-0.22
	GA-02	0.32	0.32	-1.15	-0.29	**0.54**	**0.32**	-0.50	-0.66	1.26	0.61	1.10	0.87	1.04	1.01
	Chenab-02	0.19	-0.11	0.12	-0.01	-0.20	0.11	**-0.02**	**-0.13**	-0.13	-0.17	-0.50	-0.39	-0.02	0.05
	Iqbal-2000	0.18	0.33	0.28	-0.21	0.30	-0.12	-0.16	-0.24	**0.11**	**0.04**	0.28	0.18	-0.30	-0.57
	Uqab-02	0.25	0.43	-0.57	-0.89	0.22	0.24	-0.49	-0.57	0.65	0.06	**-0.21**	**-0.13**	0.08	-0.36
	Bhakkar 02	1.34	1.29	1.16	0.51	-0.75	-0.59	-0.04	-0.21	0.48	0.15	-1.78	-0.82	**0.15**	**0.28**
Spikelets per spike	SH-02	**0.21**	**0.22**	1.10	1.17	-0.25	-0.62	0.34	0.48	-0.06	0.04	0.50	-0.06	0.11	0.03
	Menthar-3	0.16	-0.13	**-0.60**	**-0.69**	-0.17	-0.43	0.76	0.85	-0.01	-0.62	0.22	0.33	0.30	-0.25
	GA-02	0.23	0.25	-0.80	-0.20	**0.37**	**0.42**	-0.27	-0.78	0.91	0.69	0.64	0.87	0.92	1.16
	Chenab-02	0.27	-0.10	0.22	-0.07	-0.11	0.12	**-0.04**	**-0.20**	-0.21	-0.01	-0.33	-0.35	-0.22	-0.12
	Iqbal-2000	0.04	0.48	0.23	-0.12	0.27	-0.33	-0.06	-0.25	**0.09**	**0.03**	0.15	0.28	-0.18	-0.49
	Uqab-02	0.20	0.40	-0.49	-0.98	0.11	0.13	-0.07	-0.73	0.64	0.35	**-0.08**	**-0.09**	0.25	-0.34
	Bhakkar 02	0.91	1.58	0.98	0.60	-0.82	-0.62	-0.21	-0.32	0.34	0.20	-1.26	-0.90	**0.05**	**0.30**
Grains per spike	SH-02	**0.95**	**0.61**	5.89	3.69	-1.21	-1.94	1.80	1.30	-0.37	-0.10	2.08	-0.21	0.42	0.17
	Menthar-3	0.22	-0.22	**-2.93**	**-2.09**	-0.98	-1.17	3.11	2.52	0.12	-1.62	0.71	0.71	1.28	-0.80
	GA-02	1.16	1.06	-3.99	-1.17	**2.12**	**1.32**	-1.77	-2.20	5.09	2.13	3.88	2.80	4.38	3.50
	Chenab-02	1.29	-0.07	0.75	-0.50	-0.50	0.78	**-0.14**	**-0.61**	-0.83	-0.14	-1.96	-1.26	-0.45	0.09
	Iqbal-2000	0.89	1.25	1.30	-0.87	1.04	-0.78	-0.71	-1.02	**0.21**	**0.19**	0.93	0.67	-1.70	-1.54
	Uqab-02	1.28	0.93	-2.64	-2.98	0.68	0.43	-1.62	-1.81	3.44	0.67	**-0.76**	**-0.31**	0.32	-1.00
	Bhakkar 02	4.79	4.58	4.92	1.79	-3.75	-1.79	-0.34	-1.02	1.48	0.30	-6.02	-2.94	**0.55**	**0.90**
1000-grain weight	SH-02	**0.60**	**0.68**	1.98	2.33	-0.54	-0.05	0.02	0.52	0.24	-1.03	-0.55	0.32	-0.08	-0.41
	Menthar-3	-0.60	0.04	**-2.62**	**-1.71**	1.40	0.65	0.02	0.96	-1.61	-1.67	0.96	0.28	0.15	-0.79
	GA-02	-0.41	0.99	0.89	-0.42	**-1.70**	**-0.18**	1.31	-0.70	1.29	1.76	-0.46	1.82	-0.92	0.49
	Chenab-02	-0.27	-0.07	0.54	-0.51	-0.12	0.69	**2.27**	**0.66**	0.73	0.69	1.36	-0.30	-0.45	-0.30
	Iqbal-2000	-2.17	0.22	0.24	-0.26	-0.31	-0.41	-0.17	-1.88	**-0.45**	**0.24**	-0.61	0.16	0.25	-0.57
	Uqab-02	1.30	0.64	-1.41	-1.90	-0.13	0.16	-0.06	-1.62	0.66	0.42	**1.25**	**-0.08**	1.58	-0.56
	Bhakkar 02	1.83	1.83	-0.82	-0.16	-0.60	-0.68	0.60	-0.87	-0.30	0.45	-2.38	-2.30	**0.64**	**0.38**
Grain yield	SH-02	**0.44**	**0.65**	2.84	3.66	-0.59	-2.02	0.80	1.33	-0.15	-0.12	0.94	-0.34	0.27	0.40
	Menthar-3	0.15	-0.17	**-1.41**	**-2.13**	-0.56	-1.24	1.51	2.53	0.04	-1.64	0.32	0.74	0.61	-0.81
	GA-02	0.56	1.19	-1.94	-1.32	**1.01**	**1.42**	-0.82	-2.32	2.51	2.20	1.89	2.94	2.08	3.68
	Chenab-02	0.61	-0.08	0.36	-0.48	-0.27	0.72	**-0.06**	**-0.60**	-0.47	-0.20	-0.93	-1.18	-0.22	0.10
	Iqbal-2000	0.45	1.17	0.58	-0.87	0.58	-0.76	-0.24	-1.01	**0.12**	**0.12**	0.48	0.78	-0.78	-1.76
	Uqab-02	0.62	0.97	-1.30	-3.10	0.35	0.40	-0.82	-1.89	1.56	0.57	**-0.37**	**-0.39**	0.18	-1.12
	Bhakkar 02	2.37	4.70	2.26	1.76	-1.81	-1.96	-0.14	-0.87	0.70	0.22	-2.89	-3.10	**0.26**	**0.94**

Tillers per plant

Highly significant mean squares due to both GCA and SCA (Table 1) displayed the importance of additive and dominance genetic effects for tillers per plant under normal as well as late planting. Similar results have also been reported by Mahmood and Chowdhry (2002) and Srivastava (2005). Reciprocal differences were significant under normal planting while these were non-significant under late planting. Significant reciprocal differences were also observed by Chowdhry *et al.* (1999a) and Farooq *et al.* (2006).

A perusal of variance components (Table 1) indicated a much greater SCA variance displaying importance of dominance variation for tillers per plant under both plantings. Similar results were reported by Chowdhry *et al.* (1999a & b), Shoran *et al.* (2003) and Farooq *et al.* (2006). However, importance of additive variation was indicated by Mahmood and Chowdhry (2002) and Kashif and Khaliq (2003). The genotype GA-2002 turned up to be the best general combiner for tillers per plant under normal planting (Table 2) with highest GCA effects. While Menthar-3 was the poorest combiner. Rest of the genotypes had lower GCA effects. The best specific performance was indicated by the cross SH-2002 × Menthar-3 with highest positive SCA effects followed by the crosses GA-2002 × Iqbal-2000 and GA-2002 × Uqab-02. Performance of all the direct crosses was not maintained in reciprocate combinations. The cross Uqab-02 × Bhakkar 02 having positive SCA effects showed maximum negative reciprocal effects. The cross Menthar-3 × Bhakkar 02 having low positive SCA effects showed highest positive reciprocal effects.

Under late planting, the performance of parental genotypes was similar to that under normal planting. The genotype GA-2002 maintained its status as the best general combiner and Menthar-3 as the poorest combiner. However, cross combinations showed some variations. The best cross with highest SCA effects was GA-2002 × Bhakkar 02 while the lowest SCA effects were recorded in the cross GA-2002 × Chenab-02. Change in direction (positive to negative and vice versa) and magnitude (low to high or high to low) of combining ability was observed in most of the crosses in reciprocal combination. The reciprocal cross Bhakkar 02 × SH-2002 had the highest reciprocal effect as compared to negligible SCA effects in direct combination.

Spikelets per spike

Analysis of variance for combining ability (Table 1) revealed significant differences due to both GCA and SCA under both plantings which indicated the importance of both additive and dominance genetic effects for number of spikelets per spike. These results are in agreement with those of Rehman *et al.* (2002) and Saeed *et al.* (2005) who also observed significant mean squares due to GCA and SCA for spikelets per spike. Reciprocal differences were also found significant. Significant reciprocal effects were also observed by Chowdhry *et al.* (1999a). Components of variance (Table 1) in both plantings, indicated that SCA variance was greater than GCA variance which ultimately resulted in a greater dominance variance, similar results were also reported by Chandrashekhar and Kerketta (2004). Combining ability studies (Table 2) for spikelets per spike revealed a very similar performance of parental genotypes. GA-2002 was the best general combiner while Menthar-3 had the lowest GCA under both plantings. Similarly, SCA effects were maximum in the cross SH-2002 × Menthar-3 followed by GA-2002 × Bhakkar 02 hybrid under both plantings. Reciprocal effects were positive in thirteen and nine crosses under normal and late plantings, respectively.

Grains per spike

The results revealed that differences due to GCA and SCA were highly significant (Table 1) for number of grains per spike under normal as well as late planting. Reciprocal differences were also significant. The results are in conformity with those of Chowdhry *et al.* (1999a), Arshad and Chowdhry (2002) and Kashif and Khaliq (2003)who also observed significant mean squares due to GCA and SCA for grains per spike. Significant reciprocal differences were also reported by Saeed *et al.* (2005) and Farooq *et al.* (2006). Variance components (Table 1) revealed a much greater SCA variance and highlighted the importance of dominance due to greater dominance variance under both plantings. Thus, non-additive effects were involved in the inheritance of grains per spike as reported by Chowdhry *et al.* (1999a), Shoran *et al.* (2003) and Saeed *et al.* (2005). While Hassani *et al.* (2005) and Farooq *et al.* (2006) indicated high ratio GCA to SCA variance for this trait.

Positive GCA effects for number of grains per spike under normal planting (Table 2) were indicated in GA-2002, SH-2002, Bhakkar 02 and Iqbal-2000 in respective order while the remaining three genotypes showed negative GCA effects. The best specific combination with high SCA effects was SH-2002 × Menthar-3 followed by GA-2002 × Iqbal-2000, GA-2002 × Bhakkar 02 and GA-2002 × Uqab-02. The cross Chenab-02 × Uqab-02 was the poorest specific combiner. Positive reciprocal effects were recorded in thirteen crosses being maximum in Bhakkar 02 × Menthar-3.

General combining ability of the genotypes under late planting remained almost similar to that under normal planting. GA-2002 was the best and Menthar-3 was the lowest general combiner. In case of crosses, the cross SH-2002 × Menthar-3 was again the best specific cross followed by GA-2002 × Bhakkar 02, GA-2002 × Uqab-02, Menthar-3 × Chenab-02 and GA-2002 × Iqbal-2000. Nine crosses showed positive reciprocal effects which were maximum in the cross Bhakkar 02 × SH-2002.

1000-grain weight

Significant mean squares due to both GCA and SCA displayed the significance of both additive and dominance genetic effects for 1000-grain weight under normal as well as late planting (Table 1). Reciprocal differences were significant under normal planting while these were non-significant under late planting. Similar findings have been reported by Arshad and Chowdhry (2002) and Mahantashivayogayya *et al.* (2004). Importance of dominance was also displayed by variance components which revealed a greater SCA variance for 1000-grain weight under both plantings. While the present results conflicted with early findings of Zalewski (2000) and Yao *et al.* (2004) and Chandrashekhar and Kerketta (2004) who reported additive gene action for the inheritance of 1000-grain weight.

Combining ability analysis (Table 2) for 1000-grain weight under normal planting indicated that the genotypes Chenab-02, Uqab-02, Bhakkar 02 and SH-2002 showed positive GCA effects in respective order. Menthar-3, GA-2002 and Iqbal-2000 displayed negative GCA effects. The cross SH-2002 × Menthar-3 was the best specific combination followed by Uqab-02 × Bhakkar 02, Menthar-3 × GA-2002, Chenab-02 × Uqab-02 and GA-2002 × Chenab-02. The cross Menthar-3 × Iqbal-2000 showed the lowest SCA effects. Positive reciprocal effects were indicated in only 7 crosses being maximum in Bhakkar 02 × SH-2002.

Under late planting, SH-2002 was identified as the best general combiner while Menthar-3 remained the poorest. The direction of GCA was changed in Iqbal-2000 and Uqab-02 as compared to that in normal planting. Eleven crosses showed positive SCA effects which were maximum in the hybrid SH-2002 × Menthar-3 followed by GA-2002 × Uqab-02 and GA-2002 × Iqbal-2000. Maximum positive reciprocal effects were recorded in the cross Bhakkar 02 × SH-2002.

Grain yield

Both GCA and SCA mean squares were significant for grain yield per plant (Table 1) under normal and late planting. Reciprocal differences were also found significant. Significant mean squares due to both GCA and SCA have also been reported by Mahmood and Chowdhry (2002) and Mahantashivayogayya *et al.* (2004). Estimation of variance components in Table 1 revealed a greater SCA and dominance variance under both plantings indicating the importance of dominance or non-additive genetic inheritance for grain yield per plant. Importance of non-additive genetic effects has also been highlighted by Chowdhry *et al.* (1999a), Kashif and Khaliq (2003), Saeed *et al.* (2005), Hassani *et al.* (2005) and Farooq *et al.* (2006).

Combining ability analysis (Table 2) under normal planting revealed that GCA effects for grain yield per plant were positive in four genotypes. GA-2002 was the best combiner while Menthar-3 was the poorest general combiner. SCA effects were positive in thirteen crosses and were maximum in the cross SH-2002 × Menthar-3 followed by GA-2002 × Iqbal-2000, GA-2002 × Bhakkar 02 and GA-2002 × Uqab-02. Thirteen crosses also showed positive reciprocal effects which were maximum in Bhakkar 02 × SH-2002 hybrid. GCA of parental genotypes was maintained under late planting with a little variation in the magnitude. GA-2002 and Menthar-3 maintained their positions as the best and poorest general combiners, respectively. SCA effects were maximum in the cross GA-2002 × Bhakkar 02 followed by SH-2002 × Menthar-3, GA-2002 × Uqab-02, Menthar-3 × Chenab-02 and GA-2002 × Iqbal-2000. The lowest SCA effects were indicated in the hybrid GA-2002 × Chenab-02. Maximum positive reciprocal effects were recorded in the cross Bhakkar 02 × SH-2002.

Combining ability studies revealed importance of both additive and non-additive genetic effects. Thus, possibility of utilizing integrated breeding strategies including pedigree selection, diallel hybridization and recurrent selection, etc. would be useful for utilizing additive as well as non-additive variation for the selection of transgressive genotypes and developing superior genotypes thereafter. The potential parental genotypes identified in the study were GA-2002 and SH-2002 which could be the better source material for synthesizing new high yielding genotypes for normal as well as late planting. Similarly, the best hybrids that can be studied further for transgressive segregants in latter generations include, SH-2002 × Menthar-3, GA-2002 × Iqbal-2000, GA-2002 × Uqab-2000 and GA-2002 × Bhakkar 02.

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