International Journal of Agriculture, Environment and Biotechnology
Citation: IJAEB: 13(2): 119-128, June 2020
DOI: 10.30954/0974-1712.02.2020.1

ASSOCIATION OF AGRICULTURE, ENVIRONMENT AND BIOTECHNOLOGY

GENETICS AND PLANT BREEDING

Genetic Analysis of Yield and Yield Contributing Traits in Bread Wheat

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Paper No. 826 **Received:** 14-01-2020 **Revised:** 17-04-2020 **Accepted:** 27-05-2020

ABSTRACT

Ten wheat genotypes were crossed in diallel manner excluding reciprocals. The crosses along with parents were analysed for combining ability and significant variation was found amongst genotypes for various yield and yield contributing traits. ANOVA revealed that mean square for general combining ability was significant for all the traits studied except for spike length. Mean square for SCA was also non significant for spike length while for all other characters it was significant. Out of total 45 crosses 5, 8, 4, 7, 8, 3, 3, 11, 11, 13, 8 and 11 crosses showed significant SCA effects in desirable direction for days to 75% heading, days to maturity, flag leaf area, number of productive tillers per plant, plant height, spike length, number of spikelets/spike, number of grains/ spike, 1000 grain weight, biological yield/plant, grain yield/plant and harvest index, respectively. Two cross combinations viz., HD 2967 × NIAW 1594 and KFA/2*KACHU × WH 1187 were identified as good crosses due to them having higher per se performance and significant SCA effects for three yield and yield contributing traits so these crosses presents an opportunity for commercial exploitation either in form of hybrid varieties or as base material for selection of potential homozygous lines from transgressive segregants for improvement of yield levels of bread wheat.

Highlights

- Half diallel mating between ten wheat genotypes.
- Assessment of general combining ability of parents and specific combining ability of crosses.
- Identifying best general combiners and best cross combinations for different yield and yield contributing traits.

Keywords: wheat, combining ability, GCA, SCA, gene action

Bread wheat (*Triticum aestivum* L. em. Thell) is an allohexaploid (2n=6x=42, AABBDD) originally belonging to the Levant region. It is widely cultivated throughout the world and covers an area of 220.40 million hectares globally with a production of 729.01 million tonnes and 3307.4 kg/ha productivity (FAO, 2014). On a global level it acts as a major provider of digestible sugar contributing 55% carbohydrate and 20% of the total food calories (Breiman and Graur 1995). The highest wheat production in world comes from China followed by India. Under Indian context wheat is an important staple food crop for many states and is grown over an area of 20.23 million hectares contributing 30% to the Indian food basket (Anonymous 2016). Being one of the most important crop of the *rabi* season in India wheat gives a mammoth production of 93.50 million tonne and 3093 kg/ha productivity. The major wheat producing states in India are Uttar Pradesh (26.9 million tonne), Punjab (16.11 million tonne) and Haryana (11.14 million tonne).

In India three wheat species are cultivated i.e., *Triticum aestivum*, *T. durum* and *T. dicoccum.* The largest area under wheat cultivation i.e., 95% is occupied by *Triticum aestivum* also called as common wheat or bread wheat. It is grown in all six agroclimatic zones of the country viz., Northern Hill Zone (NHZ), North West Plain Zone (NWPZ), North East Plain Zone (NEPZ), Central Zone (CZ), Peninsular Zone (PZ) and Southern Hill Zone (SHZ) and is used for a variety for purpose including making of bread, biscuit, chapatti, cookies, noodles, cakes etc. Four percent area under wheat production in India is occupied by *T. durum or macroni wheat.* It is adapted to Central and Peninsular Zone and used for production of macaroni, vermicelli and spaghetti. *T. dicoccum* covers only 1% area of India and is grown only in Peninsular Zone of the country and is used for making chapatti, macaroni, spaghetti and also has medicinal value.

Wheat is a staple food crop for nearly two billion people i.e., 36% of the world population. With the increase in population the demand of wheat is increasing continuously (Joshi *et al.* 2018b). India is expected to surpass China by the year 2022 in terms of number of individual residing in the country, with its population reaching 1.7 billion by 2050. The production of wheat is 93.50 million tonnes in 2015-2016. With a population growth rate of 1.2%, the production of wheat must increase at the rate of 1.8 percent per year to meet the demand of increasing population. By the year 2035 the production must increase by 42 million tonnes. Global demand for wheat is growing at approximately 2% per year, twice the current rate of gain in genetic yield potential (Skovmand and Reynolds 2000). The first tremendous increase in wheat production from 11 million tons in 1966-67 to 17 million tons in 1967-68 owing to the influx of quality seeds, new equipment and technologies, new methods for production was the driver of green revolution in India. Further increase in production of wheat is only possible by increasing the production per unit area of wheat as further increase in area under wheat cultivation is not possible due to limited land and the production practices of wheat have already been optimized. Imrovement of wheat quality is also an important need of present times (Joshi *et al.* 2018a, Joshi *et al.* 2019 and Joshi *et al.* 2020). For yield enhancement input responsive and high yielding varieties must be produced. In order to achieve this target it is essential to know the type of gene action involved in controlling different yield contributing traits of wheat so as to determine the required breeding programme in order to breed superior varieties. Also for achieving improvement by means of hybridisation identification of good general combiner and superior cross combinations is necessary. Combining ability analysis developed by Griffing (1956) provides a clear idea about the performance of the F_1 developed by them and is helpful in choosing of superior parents for hybridisation programme. Therefore present investigation was conducted to identify suitable parents for hybridization on the basis of combining ability and per se performance and also to determine superior cross combinations for various yield and yield contributing traits which can be used for isolation of superior transgressive segregants and development of improved variety to further enhance food security.

MATERIAL AND METHODS

The experiment was conducted at Norman E. Borlaug Crop Research Centre, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, India. Crossing of 10 parental lines namely, KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUITES, QLD 39, UP 2762, KFA/2*KACHU, RAJ 4419, PBW 729, WH 1187, HD 2967, DBW 50 and NIAW 1594 in half diallel fashion excluding reciprocals to produce 45 hybrids was done during Rabi 2015-16 and the F1 progenies generated along with parental lines and checks (UP 2628 and WH 1105) were planted for evaluation during Rabi 2016-17 in randomized block design with three replications. The row to row spacing was 20 cm and plant to plant distance was 10 cm. Each entry was planted in two rows of 1m in each replication.

Observation was recorded for twelve different yield and yield contributing traits as Days to 75% heading, Days to maturity, Flag leaf area (cm^2), Plant height at maturity (cm), Number of productive tillers/plant, Spike length (cm), Number of spikelets/spike, Number of grains/spike, 1000 grain weight, Biological yield/plant, Grain yield/plant and Harvest index (HI). For characters as Days to 75% heading, Days to maturity, Flag leaf area (cm^2), Plant height at maturity (cm), Number of productive tillers/plant, Spike length (cm), Number of spikelets/spike, Number of grains/spike, 1000 grain weight, Biological yield/plant, Grain yield/plant observations were taken on five randomly selected competitive plants for each entry. The mean value of five plants was used for analysis. While observations were taken on whole plot basis for characters as days to 75 % heading and days to maturity. Harvest index for each entry was calculated by utilising the value of biological yield/plant and grain yield/plant as per the following formula

$$HI\ (\%) = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

Analysis of combining ability was done using OP Stat software (Sheoron *et al*. 1998) according to Griffing's (1956) method 2 model 1.

RESULT AND DISCUSSION

Analysis of variance for combining ability was done for twelve yield and yield contributing traits. The estimates revealed that mean square for general combining ability was significant for all the traits studied except for spike length. Significant mean square for GCA for spike length, spikelets/spike, plant height, tillers per plant, flag leaf area and grains per spike was also reported by Kashif and Khaliq (2003). Mean square for SCA was also non significant for spike length while for all other characters it was significant (Table 1). Non significant SCA mean squares for spike length was also reported by Chowdhary *et al.* (2005). The presence of significant SCA and GCA mean squares for the traits studied suggest the presence of both additive and non additive gene effects in controlling the inheritance of these traits as reported by Seboka *et al.* 2009. The existence of higher MS due to GCA compared to MS due to SCA for traits as days to maturity, flag leaf area, plant height, number of spikelets per spike, number of grains per spike, 1000 grain weight and harvest index shows that these traits are mostly governed by additive gene action. The involvement of additive gene effects in controlling flag leaf area, plant height, number of grains per spike and 1000 grain weight was previously reported by Chowdhary *et al.* (2005), Khan *et al.* (2007) and Dagustu (2008). While for days to 75% heading, number of productive tillers/plant, biological yield/plant and grain yield/plant the SCA mean square were significant and higher than GCA mean squares indicating that these traits were mostly controlled by non additive gene action and therefore heterosis breeding can be a suitable strategy for improvement of these traits. Preponderance for non additive gene action for controlling number of productive tillers/plant was reported by Khan *et al.* (2007).

The mean value of parents along with their GCA effects for different traits (Table 2) indicates a close relationship between mean performance and GCA effects. On the basis of high per se performance and significant GCA effects in desirable direction parental line KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUITES was identified as best general combiner for number of grains per spike and thousand grain weight. KFA/2*KACHU was responsible for greater number of spikelets per spike. For biological yield per plant and harvest index Raj 4419 acted as superior general combiner. The results obtained for biological yield are in general agreement to the findings of Singh *et al.* (2012). While PBW 729 and WH 1187 showed superior combining ability for grain yield per plant. For flag leaf area WH 1187 showed superior combining ability. DBW 50 acted as superior combiner for plant height and NIAW 1594 was responsible for early heading and early

Table 1: Analysis of variance for general combining ability (GCA) and specific combining ability (SCA) for different characters in wheat

Source of variation	d.f.	Mean sum of squares of various characters											
		Days to 75% heading	Days to maturity	Flag leaf area (cm^2)	No. of productive tillers/plant	Plant height (cm)	Spike length (cm)	No. of spikelets/spike	No. of grains/spike	1000 grain weight (g)	Biological yield/plant (g)	Grain yield/plant (g)	Harvest index (%)
GCA	9	13.606**	16.748**	235.777**	48.250**	216.807**	1.690	17.131**	250.055**	132.741**	1870.058**	432.658**	77.314**
SCA	45	18.523**	15.673**	54.774**	123.322**	85.593**	1.405	10.666**	154.815**	57.422**	2848.025**	463.868**	40.353**
Error	108	3.946	2.881	37.305	34.869	17.276	0.994	3.971	19.129	4.734	201.483	45.506	4.979

*** Significant at 1% probability level.*

Table 2: Estimates of general combining ability (GCA) effects of parents for different traits in wheat

Parents	Days to 75% heading		Days to maturity		Flag leaf area (cm²)		No. of productive tillers/ plant		Plant height (cm)		Spike length (cm)	
	GCA effect	Parent mean	GCA effect	Parent mean	GCA effect	Parent mean	GCA effect	Parent mean	GCA effect	Parent mean	GCA effect	Parent mean
KAUZ/ALTAR84/3/MILAN/ KAUZ/4/HUITES	0.094	93.3	0.372	140.3	-1.749	28.4	-0.066	27.2	0.610	91	0.289	13.4
UP 2762	-0.378	93.3	0.567*	141.3	-3.740**	23.4	-0.621	22.3	-0.508	84.2	-0.149	12.6
KFA/2*KACHU	-0.711*	98	-1.156**	141.3	-1.084	21.5	1.059	21.3	2.466**	87.9	-0.231	11.9
Raj 4419	0.206	95	0.011	139	2.044*	27.2	-0.333	20.1	2.371**	90.8	0.007	11.8
PBW 729	0.956**	99	-0.544*	141.7	-1.557	28.2	1.739	28	-2.306**	86.4	0.236	12.3
WH 1187	-0.461	94.3	-0.072	141.3	3.897**	34.7	0.775	15.3	-2.572**	85.6	-0.249	11.5
HD 2967	0.650*	93.3	0.456	140	0.175	24.7	0.614	23.2	2.595**	97.2	-0.237	11.9
DBW 50	0.456	937	1.094**	144	-2.307*	24.8	-2.407*	23.6	-3.855**	72.4	-0.070	12.8
NIAW 1594	-0.961**	92.3	-0.822**	136	3.618**	32.4	0.043	19.1	2.546**	93.9	0.237	13.1
QLD 39	0.150	93	0.094	141.7	0.702	28.5	-0.804	21.9	-1.344*	92.3	0.166	14.3
SE (gi)	0.314		0.268		0.966		0.934		0.657		0.158	
SE (gi-gj)	0.468		0.400		1.440		1.392		0.980		0.235	

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

Parents	No. of spikelets/ spike		No. of grains/ spike		1000 grain weight (g)		Biological yield/ plant (g)		Grain yield/ plant (g)		Harvest index (%)	
	GCA effect	Parent mean	GCA effect	Parent mean	GCA effect	Parent mean	GCA effect	Parent mean	GCA effect	Parent mean	GCA effect	Parent mean
KAUZ/ALTAR84/3/MILAN/ KAUZ/4/HUITES	0.251	23.3	3.722**	74.5	1.194**	50.7	-6.451**	145.4	-0.098	59.3	1.677**	40.6
UP 2762	0.060	23.2	-2.63**	63.3	-2.187**	40.7	-5.254*	154.7	-2.827**	61.0	-0.810*	39.3
KFA/2*KACHU	0.875**	23.1	3.194**	72.7	1.555**	41.2	6.979**	91.4	4.734**	35.6	1.586**	38.9
Raj 4419	0.462	21.2	-0.306	57.2	2.219**	46.5	-6.719**	109.9	-0.982	52.1	1.378**	47.3
PBW 729	0.246	23.8	-0.203	64.5	0.594	45.5	9.389**	176.6	2.209*	66.0	-1.326**	37.3
WH 1187	-1.497**	17.1	1.980**	76.5	0.888**	44.7	4.626*	135.8	3.315**	57.2	0.908*	42.0
HD 2967	-0.594	22.5	-2.667**	63	-0.673	44.8	-1.443	107.5	-0.799	43.2	-0.719*	39.8
DBW 50	-0.478	23.9	-2.409**	63.4	-3.023**	42.3	-9.415**	135.8	-4.841**	50.4	-0.372	37.2
NIAW 1594	0.586	24.5	2.338**	69.1	1.808**	45.9	10.051**	107.7	4.323**	47.6	0.085	44.1
QLD 39	0.088	24	-3.014**	50.2	-2.376**	32.9	-1.762	116.6	-4.146**	35.0	-2.947**	30.1
SE (gi)	0.315		0.692		0.344		2.244		1.067		0.353	
SE (gi-gj)	0.470		1.031		0.513		3.346		1.590		0.526	

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

maturity. These lines having significant estimates of GCA in desirable direction along with higher per se performance can be used as parental line in crosses effected with the main aim of accessing improvement of these traits.

The crosses with SCA effects and mean performance have been depicted in table 3. The crosses having higher SCA effects in desirable direction for different traits can be utilized to produce superior transgressive segregant for these traits. The involvement of parents with good general combining ability for specific traits in certain crosses can be attributed to superior SCA effects of these crosses for these traits. Out of total 45 crosses 5, 8, 4, 7, 8, 3, 3, 11, 11, 13, 8 and 11 crosses showed significant SCA effects in desirable direction for days to 75% heading, days to maturity, flag leaf area, number of productive tillers per plant, plant height, spike length, number of spikelets/spike, number of grains/ spike, 1000 grain weight, biological yield/plant, grain yield/plant and harvest index, respectively. The ranking of specific cross combinations on the basis of their per se performance and SCA effects were computed in Table 4. Grain yield is considered as one of the most important trait from breeding point of view as it decides the success of a particular breeding programme. Five crosses namely, WH 1187 x HD 2967, KFA/2*KACHU x NIAW 1594, KFA/2*KACHU × PBW 729, WH 1187 × QLD 39 and HD 2967 × NIAW 1594 showed significant positive SCA effects for grain yield. Crosses with significant and positive SCA effects for grain yield were also

Table 3: Specific combining ability effects of crosses for various traits in wheat

Crosses	Days to 75% heading		Days to maturity		Flag leaf area (cm²)		No. of productive tillers/ plant		Plant height (cm)		Spike length (cm)	
	SCA effect	mean	SCA effect	mean	SCA effect	mean	SCA effect	mean	SCA effect	mean	SCA effect	mean
KAUZ/ALTAR84/3/MILAN/ KAUZ/4/HUITES × UP 2762	-0.462	94.3	0.104	141.3	-2.129	20.2	-2.587	19.3	-1.017	86.5	-0.483	12.5
KAUZ/ALTAR84/3/ MILAN/KAUZ/4/HUITES × KFA/2*KACHU	-1.462	93.0	0.492	140	2.656	27.6	0.909	24.5	1.675	92.2	-0.285	12.6
KAUZ/ALTAR84/3/MILAN/ KAUZ/4/HUITES × Raj 4419	-0.045	95.3	-0.674	140	-2.316	25.8	2.348	24.5	3.547	93.9	0.148	13.3
KAUZ/ALTAR84/3/MILAN/ KAUZ/4/HUITES × PBW 729	4.538**	100.7	1.881*	142	-0.262	24.2	-3.734	20.5	0.171	85.9	-0.135	13.2
KAUZ/ALTAR84/3/MILAN/ KAUZ/4/HUITES × WH 1187	-1.712	93.0	0.076	140.7	5.431	35.4	7.374*	30.7	-1.683	83.8	0.287	13.2
KAUZ/ALTAR84/3/MILAN/ KAUZ/4/HUITES × HD 2967	-0.157	95.7	-0.452	140.7	-7.270*	18.9	0.968	24.1	-7.063	83.6	-0.439	12.4
KAUZ/ALTAR84/3/MILAN/ KAUZ/4/HUITES × DBW 50	4.371**	100	2.242*	144	0.705	24.4	-5.945	14.2	9.930**	94.1	0.391	13.4
KAUZ/ALTAR84/3/MILAN/ KAUZ/4/HUITES × NIAW 1594	1.788	96	2.492**	142.3	-0.150	29.5	-1.918	20.6	-5.147*	85.4	0.941	14.3
KAUZ/ALTAR84/3/MILAN/ KAUZ/4/HUITES × QLD 39	-2.990**	92.3	-4.758**	136	-4.887	21.8	-6.958*	14.8	-5.125*	81.6	-0.355	12.9
UP 2762 × KFA/2*KACHU	-0.323	93.7	-0.035	139.7	-3.520	19.4	-2.033	21	-4.150	85.2	0.381	12.8
UP 2762 × Raj 4419	0.427	95.3	0.131	141	8.855**	34.9	4.589	26.2	3.869	93.1	0.400	13.1
UP 2762 × PBW 729	-1.657	94	1.354	141.7	2.719	25.2	-7.279*	16.4	-4.611*	80	0.347	13.3
UP 2762 × WH 1187	-0.240	94	0.881	141.7	-2.611	25.3	-0.749	22	-0.731	83.6	0.649	13.1
UP 2762 × HD 2967	-0.684	94.7	-2.980**	138.3	-4.469	19.7	1.079	23.7	13.098**	102.6	-1.407**	11.4
UP 2762 × DBW 50	-0.490	94.7	0.048	142	-3.570	18.2	8.890**	28.4	-0.518	82.5	0.543	13.2
UP 2762 × NIAW 1594	1.593	95.3	-0.369	139.7	0.451	28.1	-0.684	21.3	2.771	92.2	-0.964	12
UP 2762 × QLD 39	3.816**	98.7	1.048	142	-1.885	22.9	-3.073	18.1	-4.230	81.3	0.040	12.9
KFA/2*KACHU × Raj 4419	-1.907	92.7	0.854	140	-1.794	26.9	9.243**	32.6	-2.586	89.7	0.591	13.2
KFA/2*KACHU × PBW 729	-0.990	94.3	-0.924	137.7	1.947	27.1	6.618*	32	-5.075*	82.5	1.245*	14.1
KFA/2*KACHU × WH 1187	-1.573	92.3	0.270	139.3	-2.270	28.3	-1.785	22.6	0.251	87.6	-0.362	12
KFA/2*KACHU × HD 2967	0.316	95.3	0.409	140	3.039	29.9	-3.157	21.1	0.747	93.2	-0.309	12.1
KFA/2*KACHU × DBW 50	-1.823	93	-4.563**	135.7	3.914	28.3	0.420	21.7	6.130**	92.2	0.431	13
KFA/2*KACHU × NIAW 1594	-1.073	92.3	-0.646	137.7	5.799	36.1	0.613	24.3	5.407*	97.8	0.048	12.9
KFA/2*KACHU × QLD 39	0.149	94.7	-2.563**	136.7	-1.488	25.9	-4.087	18.8	6.562**	95.1	-0.778	12
Raj 4419 × PBW 729	3.427**	99.7	2.909**	142.7	-5.278	23	-7.390*	16.6	-5.757**	81.7	0.368	13.4
Raj 4419 × WH 1187	3.843**	98.7	0.437	140.7	-3.622	30.1	0.197	23.2	-5.211*	82	0.010	12.6
Raj 4419 × HD 2967	-0.601	95.3	-0.758	140	5.327	35.3	1.025	23.9	7.676**	100.1	0.280	12.9
Raj 4419 × DBW 50	-2.407*	93.3	-0.396	141	0.759	28.3	1.255	21.1	7.036**	93	0.497	13.3
Raj 4419 × NIAW 1594	-0.323	94	1.187	140.7	-0.110	33.3	-6.195*	16.1	-2.452	89.9	-0.400	12.7
Raj 4419 × QLD 39	-1.434	94	-1.063	139.3	7.544*	38.1	-1.461	20	-3.342	85.1	0.161	13.2
PBW 729 × WH 1187	-3.573**	92	-3.674**	136	-4.244	25.9	-3.798	21.3	1.333	83.9	0.147	13
PBW 729 × HD 2967	-1.351	95.3	0.465	140.7	3.701	30.1	0.430	25.4	0.296	88	0.918	13.8

PBW 729 × DBW 50	-3.490**	93	-6.174**	134.7	-0.624	23.3	-3.826	18.1	3.079	84.3	-0.242	12.8
PBW 729 × NIAW 1594	-0.073	95	2.409**	141.3	-4.725	25.1	20.057**	44.4	2.569	90.2	0.218	13.5
PBW 729 × QLD 39	-0.851	95.3	-3.174**	136.7	-0.325	26.6	-5.019	18.5	0.735	84.5	-0.789	12.4
WH 1187 × HD 2967	0.399	95.7	0.659	141.3	6.644*	38.5	3.527	27.5	-2.601	84.8	1.043*	13.4
WH 1187 × DBW 50	4.927**	100	0.020	141.3	0.893	30.3	0.704	21.7	3.405	84.4	0.430	12.9
WH 1187 × NIAW 1594	-2.990**	90.7	-3.396**	136	7.521*	42.8	-2.313	21.1	1.395	88.8	-0.454	12.4
WH 1187 × QLD 39	0.566	95.3	2.354**	142.7	-5.902	26.5	14.444**	37	-0.829	82.7	-0.083	12.7
HD 2967 × DBW 50	4.816**	101	3.159**	145	-4.042	21.6	-15.791**	5.0	-13.988**	72.2	-1.526**	11
HD 2967 × NIAW 1594	0.232	95	1.076	141	-1.917	29.7	6.025	29.3	-1.122	91.4	1.307*	14.1
HD 2967 × QLD 39	3.121**	99	0.826	141.7	5.943	34.6	7.072*	29.5	-6.233**	82.4	0.604	13.4
DBW 50 × NIAW 1594	-0.573	94	0.104	140.7	-2.619	26.5	-1.564	18.7	-1.972	84.1	-0.056	12.9
DBW 50 × QLD 39	-0.684	95	2.520**	144	1.411	27.6	4.159	23.5	1.440	83.7	-0.729	12.2
NIAW 1594 × QLD 39	3.066**	97.3	2.437**	142	1.003	33.1	-6.857*	15	-4.170	84.4	-0.246	13
SE (ij)	1.056		0.903		3.248		3.140		2.210		0.530	

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

Crosses	No. of spikelets/ Spike		No. of grains/ Spike		1000 grain weight (g)		Biological yield/ plant (g)		Grain yield/ plant (g)		Harvest index (%)	
	SCA effect	Mean	SCA effect	Mean	SCA effect	mean	SCA effect	Mean	SCA effect	mean	SCA effect	mean
KAUZ/ALTAR84/3/MILAN/ KAUZ/4/HUITES × UP 2762	1.363	24.2	3.472	66.5	-3.208**	40.5	0.562	102.6	3.113	45.0	2.608*	43.7
KAUZ/ALTAR84/3/MILAN/ KAUZ/4/HUITES × KFA/2*KACHU	-1.806	21.9	-4.822*	64.0	1.151	48.6	19.495**	133.8	7.085*	56.5	-1.402	42.1
KAUZ/ALTAR84/3/MILAN/ KAUZ/4/HUITES × Raj 4419	-1.216	22.1	6.411**	71.8	-1.280	46.9	29.827**	130.4	9.735**	53.4	-2.335*	40.9
KAUZ/ALTAR84/3/MILAN/ KAUZ/4/HUITES × PBW 729	0.597	23.7	-9.558**	55.9	-1.355	45.2	-32.881**	83.8	-14.023**	32.9	-1.350	39.2
KAUZ/ALTAR84/3/MILAN/ KAUZ/4/HUITES × WH 1187	1.050	22.4	-2.408	65.2	-2.616*	44.2	-14.552	97.4	-9.162*	38.8	-2.751*	40.8
KAUZ/ALTAR84/3/MILAN/ KAUZ/4/HUITES × HD 2967	-0.199	22.1	3.106	66.1	3.021**	48.3	12.184	118.1	6.085	50.0	0.833	42.5
KAUZ/ALTAR84/3/MILAN/ KAUZ/4/HUITES × DBW 50	-0.152	22.2	-0.119	63.1	-4.038**	38.9	-30.311**	67.6	-6.540	33.3	7.359**	48.9
KAUZ/ALTAR84/3/MILAN/ KAUZ/4/HUITES × NIAW 1594	-0.043	23.4	0.367	68.4	0.998	48.7	-38.477**	78.9	-21.337**	27.0	-6.788**	35.2
KAUZ/ALTAR84/3/MILAN/ KAUZ/4/HUITES × QLD 39	-0.098	22.8	-6.681**	56.0	0.114	43.7	-34.897**	70.7	-6.168	34.4	9.724**	48.7
UP 2762 × KFA/2*KACHU	-2.464*	21.0	4.333	66.8	-1.736	42.4	-33.602**	81.9	-10.810**	36.8	4.152**	45.1
UP 2762 × Raj 4419	1.206	24.3	-4.000	55.0	12.067**	56.8	-12.470	89.3	-1.793	40.1	4.169**	44.9
UP 2762 × PBW 729	-0.255	22.6	5.797*	64.9	4.292**	47.4	-36.345**	81.6	-13.751**	31.3	0.007	38.1
UP 2762 × WH 1187	0.058	21.2	-3.786	57.5	1.164	44.6	-9.049	104.1	-8.923*	37.2	-4.661**	35.6
UP 2762 × HD 2967	-1.354	20.7	-18.339**	38.3	-7.874**	34.0	0.687	107.8	-4.543	37.5	-4.640**	34.6
UP 2762 × DBW 50	1.666	23.8	8.736**	65.6	-1.024	38.5	6.592	105.7	-0.968	37.0	-3.831**	35.2
UP 2762 × NIAW 1594	-0.478	22.7	-1.878	59.8	-5.955**	38.4	15.159*	133.7	9.602**	56.8	2.983*	42.5
UP 2762 × QLD 39	-0.733	22	-7.592**	48.7	1.595	41.8	-34.461**	72.3	-13.829**	24.9	-2.189	34.3
KFA/2*KACHU × Raj 4419	0.703	24.6	4.872*	69.7	-3.841**	44.7	9.663	123.7	5.213	54.6	0.876	44.0
KFA/2*KACHU × PBW 729	0.200	23.9	-2.964	62.0	0.617	47.5	37.821**	168.0	13.021**	65.6	-1.456	39.0
KFA/2*KACHU × WH 1187	2.759**	24.7	-7.547**	59.6	7.623**	54.8	-5.883	119.5	6.782	60.5	7.686**	50.4
KFA/2*KACHU × HD 2967	1.817	24.7	-9.467**	53.0	4.917**	50.5	3.753	123.1	1.496	51.1	-0.123	41.5
KFA/2*KACHU × DBW 50	0.917	23.9	-2.092	60.6	1.834	45.1	3.159	114.5	2.538	48.1	0.786	42.2
KFA/2*KACHU × NIAW 1594	1.859	25.9	2.628	70.1	1.703	49.8	33.392**	164.2	12.707**	67.4	-0.787	41.1

Crosses	No. of spikelets/ Spike		No. of grains/ Spike		1000 grain weight (g)		Biological yield/ plant (g)		Grain yield/ plant (g)		Harvest index (%)	
	SCA effect	mean	SCA effect	mean	SCA effect	Mean	SCA effect	Mean	SCA effect	Mean	SCA effect	mean
KFA/2*KACHU × QLD 39	-1.559	22	6.314**	68.4	0.953	44.9	4.939	123.9	1.110	47.4	-0.752	38.1
Raj 4419 × PBW 729	-0.760	22.5	-6.064**	55.4	-2.713*	44.8	-38.930**	77.5	-17.596**	29.3	-2.665*	37.6
Raj 4419 × WH 1187	1.063	22.6	1.219	64.8	1.559	49.4	3.349	115.0	-1.235	46.8	-2.433*	40.1
Raj 4419 × HD 2967	2.880**	25.3	6.133**	65.1	-2.047	44.2	-25.115**	80.5	-12.854**	31.0	-2.942*	38.5
Raj 4419 × DBW 50	0.704	23.3	3.942	63.2	1.537	45.5	36.324**	134.0	10.421**	50.3	-3.696**	37.5
Raj 4419 × NIAW 1594	-0.977	22.6	-4.006	60.0	-3.194**	45.6	-10.076	107.0	-6.843	42.2	-2.350*	39.3
Raj 4419 × QLD 39	0.884	24	-0.319	58.3	3.256**	47.8	-11.629	93.7	-1.840	38.7	2.669*	41.3
PBW 729 × WH 1187	-0.681	20.6	-1.017	62.7	-5.083**	41.1	-36.926**	90.9	-15.626**	35.6	-0.692	39.1
PBW 729 × HD 2967	1.329	23.5	12.031**	71.1	-0.588	44.1	5.744	127.5	8.488*	55.6	4.715**	43.4
PBW 729 × DBW 50	-0.357	22	-6.294**	53.0	1.562	43.9	-5.618	108.1	0.129	43.2	1.281	39.8
PBW 729 × NIAW 1594	-0.111	23.3	-2.975	61.1	5.464**	52.6	27.616**	160.8	8.299*	60.5	-1.482	37.5
PBW 729 × QLD 39	-1.520	21.4	5.111*	63.8	-1.286	41.7	-8.504	112.9	-0.698	43.0	2.157	38.1
WH 1187 × HD 2967	2.802**	23.3	-1.019	60.2	3.251**	48.2	44.506**	161.5	19.449**	67.6	0.991	41.9
WH 1187 × DBW 50	-0.767	19.8	-3.278	58.2	2.467*	45.1	-23.188**	85.8	-9.510**	34.6	-0.163	40.6
WH 1187 × NIAW 1594	-0.285	21.4	0.175	66.4	-3.963**	43.5	-25.722**	102.7	-11.640**	41.7	-0.613	40.6
WH 1187 × QLD 39	-1.130	20	-3.539	57.4	-0.780	42.5	41.992**	158.6	20.129**	65.0	2.635*	40.8
HD 2967 × DBW 50	-8.213**	13.3	-18.964**	37.9	-9.238**	31.8	-81.352**	21.6	-30.529**	9.5	4.404**	44.1
HD 2967 × NIAW 1594	-1.281	21.3	6.489**	68.1	0.964	46.8	24.714**	147.1	11.640**	60.8	1.185	41.3
HD 2967 × QLD 39	-0.066	22	7.308**	63.6	4.848**	46.5	21.662**	132.2	2.577	43.3	-4.427**	32.7
DBW 50 × NIAW 1594	-0.117	22.6	-5.536*	56.3	1.448	45.0	15.087*	129.5	6.749	51.9	0.100	40.0
DBW 50 × QLD 39	1.811	24	11.117**	67.6	-1.836	37.5	-2.466	100.1	-1.182	35.5	-1.635	35.3
NIAW 1594 × QLD 39	-0.017	23.2	-0.231	61.0	7.367**	51.5	10.734	132.8	4.321	50.2	0.269	37.6
SE (ij)	1.060		2.326		1.157		7.549		3.588		1.187	

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

Table 4: Ranking of good cross combination on the basis of per se performance and their SCA effect in a 10 × 10 diallel cross of wheat

Character	Parent with higher per se performance	Good cross combination	Superior common cross combination
Days to 75% heading	1. WH 1187 × NIAW 1594 2. PBW 729 × WH 1187 3. KFA/2*KACHU × NIAW 1594 4. KFA/2*KACHU × WH 1187 5. KAUZ/ALTAR84/3/MILAN/KAUZ/4/ HUITES × QLD 39	1. PBW 729 × WH 1187 2. PBW 729 × DBW 50 3. WH 1187 × NIAW 1594 4. KAUZ/ALTAR84/3/MILAN/KAUZ/4/ HUITES × QLD 39 5. Raj 4419 × DBW 50	PBW 729 × WH 1187 WH 1187 × NIAW 1594 KAUZ/ALTAR84/3/MILAN/KAUZ/4/ HUITES × QLD 39
Days to maturity	1. PBW 729 × DBW 50 2. KFA/2*KACHU × DBW 50 3. PBW 729 × WH 1187 4. WH 1187 × NIAW 1594 5. PBW 729 × QLD 39	1. PBW 729 × DBW 50 2. KAUZ/ALTAR84/3/MILAN/KAUZ/4/ HUITES × QLD 39 3. KFA/2*KACHU × DBW 50 4. PBW 729 × WH 1187 5. WH 1187 × NIAW 1594	PBW 729 × DBW 50 KFA/2*KACHU × DBW 50 PBW 729 × WH 1187 WH 1187 × NIAW 1594
Flag leaf area	1. WH 1187 × NIAW 1594 2. WH 1187 × HD 2967 3. Raj 4419 × QLD 39 4. KFA/2*KACHU × NIAW 1594 5. KAUZ/ALTAR84/3/MILAN/KAUZ/4/ HUITES × WH 1187	1. UP 2762 × Raj 4419 2. Raj 4419 × QLD 39 3. WH 1187 × NIAW 1594 4. WH 1187 × HD 2967	Raj 4419 × QLD 39 WH 1187 × NIAW 1594 WH 1187 × HD 2967
Productive tillers/plant	1. PBW 729 × NIAW 1594 2. WH 1187 × QLD 39 3. KFA/2*KACHU × Raj 4419 4. KFA/2*KACHU × PBW 729 5. KAUZ/ALTAR84/3/MILAN/KAUZ/4/ HUITES × WH 1187	1. PBW 729 × NIAW 1594 2. WH 1187 × QLD 39 3. KFA/2*KACHU × Raj 4419 4. UP 2762 × DBW 50 5. KAUZ/ALTAR84/3/MILAN/KAUZ/4/ HUITES × WH 1187	PBW 729 × NIAW 1594 WH 1187 × QLD 39 KFA/2*KACHU × Raj 4419 KAUZ/ALTAR84/3/MILAN/KAUZ/4/ HUITES × WH 1187

Plant height	1. HD 2967 × DBW 50 2. UP 2762 × PBW 729 3. UP 2762 × QLD 39 4. KAUZ/ALTAR84/3/MILAN/KAUZ/4/ HUITES × QLD 39 5. Raj 4419 × PBW 729	1. HD 2967 × DBW 50 2. HD 2967 × QLD 39 3. Raj 4419 × PBW 729 4. Raj 4419 × WH 1187 5. KAUZ/ALTAR84/3/MILAN/KAUZ/4/ HUITES × NIAW 1594	HD 2967 × DBW 50 Raj 4419 × PBW 729
Spike length	1. KAUZ/ALTAR84/3/MILAN/KAUZ/4/ HUITES × NIAW 1594 2. KFA/2*KACHU × PBW 729 3. HD 2967 × NIAW 1594 4. PBW 729 × HD 2967 5. PBW 729 × NIAW 1594	1. HD 2967 × NIAW 1594 2. KFA/2*KACHU × PBW 729 3. WH 1187 × HD 2967	HD 2967 × NIAW 1594 KFA/2*KACHU × PBW 729
Number of spikelets/spike	1. KFA/2*KACHU × NIAW 1594 2. Raj 4419 × HD 2967 3. KFA/2*KACHU × WH 1187 4. KFA/2*KACHU × HD 2967 5. KFA/2*KACHU × Raj 4419	1. Raj 4419 × HD 2967 2. WH 1187 × HD 2967 3. KFA/2*KACHU × WH 1187	Raj 4419 × HD 2967 KFA/2*KACHU × WH 1187
Number of grains/spike	1. KAUZ/ALTAR84/3/MILAN/KAUZ/4/ HUITES × Raj 4419 2. KFA/2*KACHU × NIAW 1594 3. KFA/2*KACHU × Raj 4419 4. HD 2967 × NIAW 1594 5. KFA/2*KACHU × QLD 39	1. PBW 729 × HD 2967 2. DBW 50 × QLD 39 3. UP 2762 × DBW 50 4. HD 2967 × QLD 39 5. HD 2967 × NIAW 1594	HD 2967 × NIAW 1594
1000 grain weight	1. UP 2762 × Raj 4419 2. KFA/2*KACHU × WH 1187 3. PBW 729 × NIAW 1594 4. NIAW 1594 × QLD 39 5. KFA/2*KACHU × NIAW 1594	1. UP 2762 × Raj 4419 2. KFA/2*KACHU × WH 1187 3. NIAW 1594 × QLD 39 4. PBW 729 × NIAW 1594 5. KFA/2*KACHU × HD 2967	UP 2762 × Raj 4419 KFA/2*KACHU × WH 1187 NIAW 1594 × QLD 39 PBW 729 × NIAW 1594
Biological yield/plant	1. HD 2967 × DBW 50 2. KAUZ/ALTAR84/3/MILAN/KAUZ/4/ HUITES × DBW 50 3. KAUZ/ALTAR84/3/MILAN/KAUZ/4/ HUITES × QLD 39 4. UP 2762 × QLD 39 5. Raj 4419 × PBW 729	1. HD 2967 × DBW 50 2. Raj 4419 × PBW 729 3. PBW 729 × WH 1187 4. KAUZ/ALTAR84/3/MILAN/KAUZ/4/ HUITES × NIAW 1594 5. KAUZ/ALTAR84/3/MILAN/KAUZ/4/ HUITES × QLD 39	HD 2967 × DBW 50 Raj 4419 × PBW 729 KAUZ/ALTAR84/3/MILAN/KAUZ/4/ HUITES × QLD 39
Grain yield/ plant	1. WH 1187 × HD 2967 2. KFA/2*KACHU × NIAW 1594 3. KFA/2*KACHU × PBW 729 4. WH 1187 × QLD 39 5. HD 2967 × NIAW 1594	1. WH 1187 × QLD 39 2. WH 1187 × HD 2967 3. KFA/2*KACHU × PBW 729 4. KFA/2*KACHU × NIAW 1594 5. HD 2967 × NIAW 1594	WH 1187 × QLD 39 WH 1187 × HD 2967 KFA/2*KACHU × PBW 729 KFA/2*KACHU × NIAW 1594 HD 2967 × NIAW 1594
Harvest index	1. KFA/2*KACHU × WH 1187 2. KAUZ/ALTAR84/3/MILAN/KAUZ/4/ HUITES × DBW 50 3. KAUZ/ALTAR84/3/MILAN/KAUZ/4/ HUITES × QLD 39 4. UP 2762 × KFA/2*KACHU 5. UP 2762 × Raj 4419	1. KAUZ/ALTAR84/3/MILAN/KAUZ/4/ HUITES × QLD 39 2. KFA/2*KACHU × WH 1187 3. KAUZ/ALTAR84/3/MILAN/KAUZ/4/ HUITES × DBW 50 4. PBW 729 × HD 2967 5. HD 2967 × DBW 50	KAUZ/ALTAR84/3/MILAN/KAUZ/4/ HUITES × QLD 39 KFA/2*KACHU × WH 1187 KAUZ/ALTAR84/3/MILAN/KAUZ/4/ HUITES × DBW 50

identified by Joshi *et al.* (2016). However on the basis of both per se performance and significant positive SCA effect crosses WH 1187 × QLD 39, WH 1187 × HD 2967, KFA/2*KACHU × PBW 729, KFA/2*KACHU × NIAW 1594 and HD 2967 × NIAW 1594 were identified as superior crosses for producing desirable trangressive segregant for grain yield. Similarly on basis of good mean performance and significant SCA effect common superior crosses for days to 75% heading were PBW 729 x WH 1187, WH 1187 × NIAW 1594, KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUITES × QLD 39, for days to maturity were PBW 729 × DBW 50, KFA/2*KACHU × DBW 50, PBW 729 × WH 1187, WH 1187 × NIAW 1594, for flag leaf area were Raj 4419 × QLD 39, WH 1187 × NIAW 1594, WH 1187 × HD 2967, for number of productive tillers/plant were PBW 729 x NIAW 1594, WH 1187 x QLD 39, KFA/2*KACHU x Raj 4419, KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUITES x WH 1187, for plant height were HD 2967 × DBW 50, Raj 4419 × PBW 729, for spike length were HD 2967 × NIAW 1594, KFA/2*KACHU × PBW 729, for number of spikelets/spike were Raj 4419 × HD 2967, KFA/2*KACHU × WH 1187, for number of grains/ spike were HD 2967 × NIAW 1594, for 1000 grain weight were UP 2762 × Raj 4419, KFA/2*KACHU × WH 1187, NIAW 1594 × QLD 39, PBW 729 × NIAW 1594, for biological yield/plant were HD 2967 × DBW 50, Raj 4419 x PBW 729, KAUZ/ALTAR84/3/ MILAN/KAUZ/4/HUITES × QLD 39, for grain yield per plant were WH 1187 × QLD 39, WH 1187 × HD 2967, KFA/2*KACHU × PBW 729, KFA/2*KACHU × NIAW 1594, HD 2967 × NIAW 1594 and for harvest index were KAUZ/ALTAR84/3/MILAN/KAUZ/4/ HUITES × QLD 39, KFA/2*KACHU × WH 1187, KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUITES × DBW 50. Some crosses had significant SCA effect and superior per se performance for more than one characters as PBW 729 x WH 1187 acted as good cross combination for two traits i.e., days to 75% heading and days to maturity, WH 1187 × NIAW 1594 for three traits viz. days to 75% heading, days to maturity and flag leaf area. KAUZ/ALTAR84/3/ MILAN/KAUZ/4/HUITES × QLD 39 was good specific combiner for three traits namely, days to 75% heading, biological yield and harvest index, WH 1187 × HD 2967 for two trait i.e. flag leaf area and grain yield/plant, PBW 729 × NIAW 1594 for two trait i.e., plant tillers/plant and thousand grain weight, WH 1187 × QLD 39 for two trait productive tillers/plant and grain yield/plant, HD 2967 × DBW 50 for two trait plant height and biological yield/ plant, Raj 4419 × PBW 729 for two traits viz., plant height and biological yield/plant, KFA/2*KACHU × PBW 729 for two traits spike length and grain yield/plant, HD 2967 × NIAW 1594 for three traits i.e., spike length, grain yield/plant and number of grains/spike and KFA/2*KACHU × WH 1187 for three traits viz., (Number of spikelets/spike, thousand grain weight and harvest index.

CONCLUSION

The study revealed the existence of significant amount of variability amongst parental lines and crosses for almost all the traits studied except for spike length for which both GCA and SCA mean squares were insignificant. This shows that the improvement for all the traits except for spike length can be achieved by means of selection of genotypes with superior traits or by islolation of transgressive segregants. NIAW 1594 was best general combiner for both days to 75% heading and days to maturity, hence it can be used for development of lines with early maturity. For improvement of yield contributing traits as number of grains/spike and thousand grain weight KAUZ/ ALTAR84/3/MILAN/KAUZ/4/HUITES can be used as one of the parent in hybridisation programme. Two cross combinations viz., HD 2967 × NIAW 1594 and KFA/2*KACHU × WH 1187 were identified as good crosses due to them having higher per se performance and significant SCA effects for three yield and yield contributing traits so these crosses presents an opportunity for commercial exploitation either in form of hybrid varieties or as base material for selection of potential homozygous lines from transgressive segregants for improvement of yield levels of bread wheat.

REFERENCES

Anonymous, 2016. Progress Report of All India Coordinated Wheat and Barley Improvement Project, 2015-16, Director's Report. Ed. G.P. Singh, ICAR-Indian Institute of Wheat and Barley Research, Karnal, India. p 96.

Breiman, A. and Graur, D. 1995. Wheat evolution. Israel Journal of Plant Sciences, **43**(2): 85-98.

Chowdhry, M.A., Saeed, M.S., Khaliq, I. and Ahsan, M. 2005. Combining ability analysis for some polygenic traits in a 5 × 5 diallel cross of bread wheat (*Triticum aestivum* L. em. Thell). *Asian Journal of Plant Sciences,* **4**(4): 405-408.

Dagustu, N. 2008. Genetic Analysis of Grain Yield per Spike and Some Agronomic Traits in Diallel Crosses of Bread Wheat (*Triticum aestivum* L. em. Thell). *Turk. J. Agric. For.,* **32**: 249-258.

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

Habtamu, S., Amsalu, A. and Habtamu, Z. 2009. Combining Ability Analysis for Bread Wheat (*Triticum Aestivum* L.). *East Africa Journal of Sciences,* **3**: 87-94.

Joshi, A., Kumar, A., Budhlakoti, V., and Bhatt, N. 2019. Heterosis for quality traits in wheat. *International Journal of Chemical Studies,* **7**(6): 404-408.

Joshi, A., Kumar, A., Budhlakoti, V., and Bhatt, N. 2020. Genetic Analysis of Quality Traits in Bread Wheat. *International Journal of Current Microbiology and Applied Sciences,* **9**(2): 929-938.

Joshi, A., Kumar, A., Budhlakoti, V., Bhatt, N., and Prasad, B. 2018a. Analysis of variance and estimation of genetic variability parameters for quality traits in bread wheat (*Triticum aestivum* L. em. Thell) genotypes. *International Journal of Chemical Studies*, **6**(5): 369-372.

Joshi, A., Kumar, A., Budhlakoti, V., Bhatt, N., and Tabassum. 2018b. Estimation of genetic variability parameters for yield and its components in bread wheat (*Triticum aestivum* L. em. Thell) genotypes. *Journal of Pharmacognosy and Phytochemistry*, SP5: 87-90.

Joshi, S.K., Sharma, S.N., Singhania, D.L. and Sain, R.S. 2016. Genetic analysis of yield and its component traits in spring wheat. *Acta Agronomica Hungarica*, **51**(22): 178-195.

Khan, M.A., Ahmad, N., Akbar, M., Rehman, A., and Iqbal, M.M. 2007. Combining ability analysis in wheat. *Pak. J. Agri. Sci.*, **44**(1): 1-5.

Kumar, A., Mishra, V.K., Vyas, R.P. and Singh, V. 2011. Heterosis and combining ability analysis in bread wheat (*Triticum aestivum* L.). *Journal of Plant Breeding and Crop Science*, **3**(10): 209-217.

Sheoran, O.P., Tonk, D.S., Kaushik, L.S., Hasija, R.C. and Pannu, R.S. 1998. Statistical Software Package for Agricultural Research Workers. Recent Advances in information theory, Statistics & Computer Applications by D.S. Hooda & R.C. Hasija Department of Mathematics Statistics, CCS HAU, Hisar (139-143).

Singh, A., Kumar, A., Ahmad, E., Swati and Jaiswal, J. P. 2012. Combining ability and gene action studies for seed yield, its components and quality traits in bread wheat (*Triticum aestivum* L. em. Thell.). *Electronic Journal of Plant Breeding*, **3**(4): 964-972.

Skovmand, B. and Reynolds, M.P. 2000. Increasing yield potential for marginal areas by exploring genetic resources collections. The Eleventh Regional Wheat Workshop for Eastern, Central and Southern Africa. *Addis Ababa, Ethiopia*, **18**(22): 67-77.