The Pharma Innovation Journal 2022; 11(12): 3250-3254

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(12): 3250-3254

www.thepharmajournal.com
Received: 02-10-2022
Accepted: 06-11-2022

Kaveri Chawan
Department of Genetics and Plant Breeding, Dr. P. D. K. V., Akola, Maharashtra, India

NV Kayande
Associate Professor, Department of Genetics and Plant Breeding, Dr. P. D. K. V., Akola, Maharashtra, India

Swati G Bharad
Senior Research Scientist (Wheat), Wheat Research Unit, Dr. P. D. K. V., Akola, Maharashtra, India

Corresponding Author:
Kaveri Chawan
Department of Genetics and Plant Breeding, Dr. P. D. K. V., Akola, Maharashtra, India

Estimating heterosis in wheat for yield and yield component characteristics using line x tester mating design (*Triticum aestivum* L.)

Kaveri Chawan, NV Kayande and Swati G Bharad

Abstract
Wheat is one of the world's most important cereal crops. Wheat contains 8-11 percent protein and also provides dietary fibre, vitamins, minerals, and phytochemicals to the human diet. However, the current wheat scenario is not favorable due to more susceptible diseases affecting wheat yield and resulting in lower yield. Therefore, heterosis in wheat crops can be used to solve these issues. Heterosis is the superiority of progeny from both parents. In a line x tester mating fashion, four lines of bread wheat were crossed with eight testers to produce 32 F1 hybrids, which were evaluated with parents and one standard check during Rabi 2018–2019. The experiment was carried out in a Randomized Blocks Design with three replications at the Wheat Research Unit by Dr. PDKV Akola. The study revealed the detailed understanding of the extent of useful heterosis observed within the available genetic variability and an idea about the combining ability of the parents for various characters studied. The study would help in determining the breeding strategy for further improvement in wheat.

Keywords: Heterobeltiosis, heterosis, line × tester, standard heterosis, wheat

1. Introduction
Wheat is a widely cultivated grass whose seed is a cereal grain that is used as a staple food all over the world. The most important wheat varieties are common wheat (*Triticum aestivum*), durum wheat (*Triticum Durum*), and club wheat (*Triticum compactum*). Over the past few decades, particularly since the green revolution, the situation of wheat production has undergone tremendous transformation. India is currently the world's second-largest producer of bread wheat after China, with a massive production of 101.20 million tons in 2018-19. With population growth, there is an urgent need to increase wheat production potential, as crop acreage cannot be extended beyond a certain limit. In response to this challenge, there is a strong breeding interest in developing superior high-yielding crop cultivars.

Exploiting heterosis and hybrid vigour is one of the critical methods for creating high yielding cultivars. In contrast to hybrids with lower heterosis, crossovers with greater heterotic values can offer a better potential for the isolation of preferred purelines in later generations (Sharif *et al*., 2001) [18]. A breeder can thus reject less productive cross combinations in the F1 generation itself by analysing heterosis (Ibrahim *et al*., 2020) [10]. The capacity of the lines to be used as parents to nick each other and have genetic divergence is crucial for the exploitation of heterosis. Compared to the other crosses, some parents will perform better and have better nicking ability.

Therefore, one of the most crucial phases in creating better, high-yielding hybrids is accurate parent identification. By choosing better cross combinations, the breeder will be able to concentrate on parents that will produce superior offspring and will be able to take into account more fruitful progenies. Solomon *et al*. (2007) [20], Bilgin *et al*. (2011) [5], Devi *et al*. (2013) [6], Singh *et al*. (2013) [19], Pankaj *et al*. (2015) [15], Jaiswal *et al*. (2018) [12], Hussain *et al*. (2019) [9] and Adhikari *et al*. (2020) [2] have all previously noted the exploitation of heterosis in wheat. The current research investigation was carried out to determine the degree of heterosis for yield and yield attributes in 32 F1s developed by mating four lines with eight testers in a line x tester mating system.

2. Material and Methods
The study was carried out during the rabi season of 2018-2019 at the experimental field of Dr. PDKV Wheat Research Unit in Akola.

The experimental material consists of four lines: AKAW-3717, AKAW-2865, AKAW-2956, and HI-1418, and eight testers. AKAW-4630, AKAW-4739, AKAW-4731, AKAW-4498, AKAW-4800, AKAW-4730, AKAW-507, AKAW-4924. According to Kempthorne's line tester mating design, four lines and eight testers were crossed to create 32 F1 hybrids. In a randomized block design with three replications, F1 plants were sown in the field along with their parents. Each plot comprised one row of 2.5 m length with space of 30 cm between rows and seeds were placed 15 cm apart.

Recommended cultural practices were followed to raise a good crop. Monoammonium phosphate (52% P2O5 + 12% N) with 80 kg ha−1 was applied just before sowing and 75 kg ha−1 of Sulfate (26% N + 35% SO3) was spread at tillering stage. Weeds were controlled by application of 12 g ha−1 of Granstar [Methyl Triberunon] herbicide mixed with water. Five competitive plants (excluding border plants) were tagged before heading and data were recorded for the days to heading, days to maturity, plant height, effective tillers per plant, spike length, grains per spike, 1000 grain weight, grain weight per spike, and grain yield per plant. Data recorded were subjected to analysis of variance according to Steel and Torrie (1980) to determine significant differences among genotypes.

3. Results and Discussion

For all of the characters under evaluation, the analysis of variance (Table 1) revealed a significant genotype effect. This indicated that the genotypes studied had a high level of genetic variability for these traits. The comparison of mean squares due to parent vs. cross indicated the presence of overall heterosis for all characters except days to heading and plant height, indicating that hybrid performance differed from that of the parents for the majority of the characters.

With regard to heterosis (Table 2) nine crosses showed significant and negative average heterosis over the mid parent while fourteen crosses showed significant and negative heterosis over the better parent in terms of days to heading. Significant and negative heterosis was found in the crosses HI 1418x AKAW 4924 (-12.56 percent over mid parent) and HI 1418x AKAW 4498(-15.99 percent over better parent). Over check HI 1418, the largest standard heterosis was recorded in AKAW 2865 x AKAW 4800 (- 17.81 percent). Ashutosh *et al.*, (2011) and Singh *et al.*, (2011) [4] both found similar findings (2013).

In HI 1418 x AKAW 4498, the average heterosis and heterobeltiosis in the desired direction were recorded for days to maturity (-11.58 percent over mid parent and -13.73 percent over better parent). Over check HI 1418, the standard heterosis was likewise recorded in HI 1418 x AKAW 4498 (-13.73 percent). In AKAW 2956 x AKAW 4739, heterosis and heterobeltiosis in the desired direction were recorded (-13.60 percent over mid parent and -13.99 percent over better parent) for plant height. Over check HI 1418, the standard heterosis was reported in AKAW 2956 x AKAW 4739 (-17.60 percent). Abdullah *et al.,* (2002) [1] and Rasul *et al.,* (2002) [16] reported similar findings (2002).

Out of 32 crosses, seventeen showed significant and positive average heterosis over the mid parent and ten showed significant and positive heterosis over the better parent in terms of the number of effective tillers per plant. Positive heterosis was found in the cross AKAW 3717 x AKAW 4731 (61.02 percent over mid parent and 41.68 percent over better parent). Over check HI 1418, the largest standard heterosis was recorded in AKAW 2956 x AKAW 4739 (24.91 percent). In terms of spike length, twelve crosses showed significant and positive average heterosis over the mid parent, while four crosses showed significant and positive heterosis over the better parent. Significant positive heterosis was found in the crosses AKAW 2956 x AKAW 5077 (50.62 percent over mid parent) and AKAW 2956 x AKAW 4800 (39.81 percent over better parent). The maximum standard heterosis (24.32 percent) was found in AKAW 2956 x AKAW 5077 over check HI 1418. Akbar *et al*., (2007) [3], Ilker *et al*., (2010) [11], and Mahpara *et al*., (2010) [14] all reported similar findings (2015). In terms of number of grains per spike, four crosses showed significant and positive average heterosis over mid parent, while two crosses showed significant and positive heterosis over better parent. The cross AKAW 2956 x AKAW 4739 (48.99 percent over mid parent and 47.92 percent over better parent) revealed significant positive heterosis out of 32 crosses.

Over check HI 1418, the cross AKAW 2956 x AKAW 4739 (16.67 percent) showed significant standard heterosis for grains per spike. For 1000 grain weight, four crosses showed significant and positive average heterosis over the mid parent, while only one cross showed significant and positive heterosis over the better parent. The cross AKAW 3717 x AKAW 4731 showed significant positive heterosis (30.82 percent over mid parent and 24.78 percent over better parent) out of 32 crosses. For 1000 grain weight over check HI 1418, no cross recorded significant standard heterosis. In terms of grain weight per spike, seventeen crosses showed significant and positive average heterosis over the mid parent, while thirteen crosses showed significant and positive heterosis over the better parent.

Significant positive heterosis was found in the cross AKAW 2865 x AKAW 4630 (78.24 percent over mid parent and 74.58 percent over better parent). There was no significant standard heterosis for grain weight per spike when compared to check HI 1418. Nineteen crosses had significant and positive average heterosis over the mid parent and twelve crosses had substantial and positive heterosis over the better parent in terms of grain yield per plant. Significant positive heterosis was found in the cross AKAW 3717 x AKAW 4731 (176.99 percent over mid parent and 129.08 percent over better parent). Over check HI 1418, the maximum standard heterosis was likewise recorded in cross AKAW 3717 x AKAW 4731 (86.77 percent). Akbar *et al*., (2007) [3], Singh *et al*., (2013) [19], and Garg *et al*., (2013) [7] all found similar findings (2016).

Table 1: Analysis of variance for parents and hybrids for seed yield and its component characters in wheat

Sources	DF	Days to heading	Days to maturity	Plant height (cm)	Effective tillers per plant	Spike length(cm)	Grains per spike	1000 grain weight (g)	Grain weight per spike (g)	Grain yield per plant (g)
		1	2	3	4	5	6	7	8	9
Replications	2	6.33	15.46	14.88	0.95	1.06	3.29	12.76	0.08	6.88
Treatments	43	43.34*	163.66*	145.32**	6.81**	2.58**	121.25**	58.31**	0.86**	313.67**
Parents	11	48.59	49.55	75.72	9.45**	2.55**	62.27*	49.26	0.58**	34.29**
Parents vs. Crosses	1	259.90**	356.68	132.20	125.68**	16.98**	369.21**	355.18**	8.98**	2072.10**
Crosses	31	34.49**	197.93**	62.32**	8.98**	2.13**	134.18**	51.94*	0.69**	356.09**
Error	86	25.84	92.09	76.08	1.85	0.60	32.65	31.56	0.12	9.72

Note: * Significant at 5% level of significance
** Significant at 1% level of significance

Table 2: Estimation of heterosis (%) over mid-parent (H_1), better parent (H_2) and standard checks (H_3) for yield and other yield contributing traits

Sl. No.	Crosses	Days to heading			Days to maturity			Plant height (cm)		
		(H_1)	(H_2)	(H_3)	(H_1)	(H_2)	(H_3)	(H_1)	(H_2)	(H_3)
1	AKAW 3717 × AKAW 4630	-10.98 *	-14.19 **	-15.75 **	-2.24	-3.56	-5.72	6.19	5.75	1.27
2	AKAW 3717 × AKAW 4739	-1.82	-4.79	-6.51	-1.41	-2.79	-2.24	9.44	7.19	6.16
3	AKAW 3717 × AKAW 4731	-9.53 *	-11.92 *	-13.52 *	-1.47	-2.79	-2.35	-13.58 *	-13.97 *	-17.56 *
4	AKAW 3717 × AKAW 4498	-4.44	-10.58 *	-12.20 *	-1.25	-2.58	-4.76	8.53	4.71	-0.55
5	AKAW 3717 × AKAW 4800	1.25	-4.53	-6.27	0.3	-2.87	-5.04	5.36	4.14	1.24
6	AKAW 3717 × AKAW 4730	-1.25	-4.2	5.94	3.23	0	-2.24	10.74	8.15	7.75
7	AKAW 3717 × AKAW 5077	-2.77	-10.16	-11.79 *	-0.8	-1.58	-2.24	6.86	5.95	2.38
8	AKAW 3717 × AKAW 4924	-9.97 *	-10.58 *	-12.20 *	0.09	0	-2.07	1.65	-3.24	1.69
9	AKAW 2865 × AKAW 4630	-6.45	-7.36	-13.93 **	4.46	2.77	-2.24	2.71	-1.8	3.1
10	AKAW 2956 × AKAW 4630	5.61	5.24	-2.23	-4.02	-8.08	-7.57	4.23	1.28	6.33
11	AKAW 2865 × AKAW 4731	-2.71	-2.75	-9.56	-0.87	-5.02	-4.6	-1.23	-5.54	-0.83
12	AKAW 2865 × AKAW 4498	2.26	-1.77	-8.74	1.77	0.12	-4.76	14.34 *	5.25	10.5
13	AKAW 2865 × AKAW 4800	-8.62	-11.54 *	-17.80 **	3.6	3.35	-4.88	-1.43	-5.08	-0.34
14	AKAW 2865 × AKAW 4730	-1.65	-1.95	-8.9	6.32	6.09	-2.35	0.61	-1.97	2.93
15	AKAW 2865 × AKAW 5077	4.35	-1.06	-8.08	2.17	-1.58	-2.24	-0.84	-4.79	-0.03
16	AKAW 2865 × AKAW 4924	-12.08 *	-13.87 *	-16.57 **	-2.69	-5.61	7.57	-1.49	-1.54	3.48
17	AKAW 2956 × AKAW 4630	-6.49	-7.45	-13.93 **	1.42	0.11	-2.24	10.71	6.79	2.27
18	AKAW 2956 × AKAW 4739	3.87	3.46	-3.79	-1.36	-2.79	-2.24	-13.60 **	-13.99**	-17.60**
19	AKAW 2956 × AKAW 4731	-2.13	-2.13	-8.99	1.36	-0.06	0.39	19.95 **	15.66 *	10.84
20	AKAW 2956 × AKAW 4498	-3.6	-7.45	-13.93 **	-9.04	-10.22	-12.33	16.16 *	15.71	2.96
21	AKAW 2956 × AKAW 4800	-7.74	-10.73	-16.98 **	-3.2	-6.2	-8.41	8.49	3.9	1
22	AKAW 2956 × AKAW 4730	-11.30 *	-11.61 *	-17.81 **	3.29	0.11	-2.24	8.41	2.63	2.24
23	AKAW 2956 × AKAW 5077	-2.34	-7.45	-13.93 **	-10.98	-11.74	-12.33	2.52	-1.53	-4.85
24	AKAW 2956 × AKAW 4924	-9.34	-11.15 *	-13.93 **	-10.35	-10.48	-12.33	3.37	-4.55	0.31
25	HI 1418 × AKAW 4630	-11.82 *	-15.75 **	-15.75 **	0.2	-2.24	-2.24	-2.41	-4.48	-4.48
26	HI 1418 × AKAW 4739	-2.92	-6.68	-6.68	-0.95	-1.23	-0.67	-2.77	-3.24	-3.24
27	HI 1418 × AKAW 4731	-10.81 *	-13.93 **	-13.93 **	-7.21	-7.42	-7.01	0.72	-1.38	-1.38
28	HI 1418 × AKAW 4498	-9.46	-15.99 **	-15.99 **	-11.58	-13.73 *	-13.73 *	3.51	-2.55	-2.55
29	HI 1418 × AKAW 4800	-9.88 *	-15.75 **	-15.75 **	-8.78	-12.61	-12.61	-0.47	-1.86	-1.86
30	HI 1418 × AKAW 4730	-6.13	-9.73	-9.73	-4.42	-8.41	-8.41	7.43	7.23	7.23
31	HI 1418 × AKAW 5077	-3.73	-11.79 *	-11.79 *	-1.9	-1.9	-2.12	0.35	-1.34	-1.34
32	HI 1418 × AKAW 4924	-12.56 **	-13.93 **	-13.93 **	-11.47	-12.39	-12.39	-10.54	-12.71	-8.26
	SE(D)±	3.59	4.15	4.15	6.78	7.83	7.83	6.16	7.12	7.12
	CD 5%	7.18	8.29	8.29	13.56	15.66	15.66	12.32	14.23	14.23
	CD 1%	9.55	11.03	11.03	18.03	20.82	20.82	16.39	18.92	18.92

Sl. No.	Crosses	Effective tillers per plant			Spike length (cm)			Grains per spike		
		(H_1)	(H_2)	(H_a)	(H_1)	(H_2)	(H_a)	(H_1)	(H_2)	(H_a)
1	AKAW 3717 × AKAW 4630	44.24**	40.24**	15.76*	8.16	1.42	-2.4	11.52	8.36	-11.51
2	AKAW 3717 × AKAW 4739	17.15*	11.49	-7.96	12.19	7.01	-0.68	5.83	4.02	-15.05 *
3	AKAW 3717 × AKAW 4731	61.02**	41.68**	16.94*	8.79	0.69	-0.34	19.54 *	15.03	1.61
4	AKAW 3717 × AKAW 4498	27.66**	17.15*	15.76*	0.95	-5.65	-8.56	-18.52 *	-21.79 *	-36.13 **
5	AKAW 3717 × AKAW 4800	20.40**	19.67	0	19.48 **	12.2	-5.48	-17.80 *	-22.43 **	-28.60 **
6	AKAW 3717 × AKAW 4730	42.03*	37.91**	20.84**	-0.19	-5.13	-11.3	7.9	6.06	-13.39
7	AKAW 3717 × AKAW 5077	7.40	-1.20	-2.88	-3.65	-8.73	-14.04 *	-8.23	-10.61	-23.01 **
8	AKAW 3717 × AKAW 4924	9.10	-1.16	0.50	3.24	-2.87	-7.19	11.16	8.89	-11.08
9	AKAW 2865 × AKAW 4630	20.63*	16.30*	-9.32	13.92 *	10.68	6.51	13.31	8.26	-8.44
10	AKAW 2956 × AKAW 4630	-4.44	-10.75	-19.83*	9.33	8.12	0.34	-10.59	-13.6	-26.94 **
11	AKAW 2865 × AKAW 4731	19.69*	11.70	-19.15*	-5.78	-9.69	-10.62	15.05	12.6	-0.54
12	AKAW 2865 × AKAW 4498	43.78**	-1.71	-2.88	5.47	2.12	-1.03	12.59	6.29	-10.11
13	AKAW 2865 × AKAW 4800	-5.86	-12.17	-26.61**	16.42 *	5.66	-4.11	12.82	8.24	-0.38
14	AKAW 2865 × AKAW 4730	50.42**	37.33**	20.33**	5.95	4.4	-2.4	4.74	1.21	-14.41
15	AKAW 2865 × AKAW 5077	-15.19**	-26.37**	-27.62**	6.67	4.73	-1.37	2.8	1.87	-12.26
16	AKAW 2865 × AKAW 4924	10.41	-5.5	-3.89	7.35	4.66	0	17.16 *	12.84	-4.57
17	AKAW 2956 × AKAW 4630	33.33**	24.52**	11.86	20.49 **	4.63	0.68	8.72	8.23	-15.86 *
18	AKAW 2956 × AKAW 4739	51.95**	39.05**	24.91**	44.77 **	27.68 **	18.49 **	48.99 **	47.92 **	16.67 *
19	AKAW 2956 × AKAW 4731	21.55**	3.20	-7.28	20.56 **	3.46	2.4	7.67	1.22	-10.59
20	AKAW 2956 × AKAW 4498	-25.78**	-29.15**	-30**	19.18 **	3.18	0	6.86	5.05	-18.33 *
21	AKAW 2956 × AKAW 4800	43.30**	38.30**	24.23**	42.79 **	39.81 **	3.42	14.82	5.9	-2.53
22	AKAW 2956 × AKAW 4730	25.50**	27.07**	11.35	32.08 **	16.12 *	8.56	45.62 **	44.58 **	14.03
23	AKAW 2956 × AKAW 5077	9.90	5.17	3.38	50.62 **	32.00 **	24.32 **	6.76	1.56	-12.53
24	AKAW 2956 × AKAW 4924	3.18	-2.83	-1.18	16.05 *	1.08	-3.42	17.26 *	16.82	-8.49
25	HI 1418 × AKAW 4630	5.01	-11.81	1.18	-10.65	-12.33	-12.33	5.19	-6.88	-6.88
26	HI 1418 × AKAW 4739	1.52	-16.24*	-3.89	-11.90 *	-15.07 *	-15.07 *	13.01	1.08	1.08
27	HI 1418 × AKAW 4731	3.72	-19.79*	-7.96	-0.52	-1.03	-1.03	-9.28	-14.57	-14.57
28	HI 1418 × AKAW 4498	21.74**	13.29	23.02	9.91	8.22	8.22	-1.32	-13.6	-13.6
29	HI 1418 × AKAW 4800	20.17**	3.84	19.15**	25.98 **	9.59	9.59	-9.63	-13.23	-13.23
30	HI 1418 × AKAW 4730	5.52	-6.94	6.77	-0.18	-3.42	-3.42	-7.36	-17.15 *	-17.15 *
31	HI 1418 × AKAW 5077	-5.64	-12.40	0.50	1.23	-1.71	-1.71	-10.05	-16.29 *	-16.29 *
32	HI 1418 × AKAW 4924	3.36	-2.51	11.86	-7.88	-9.93	-9.93	1.06	-9.89	-9.89
	SE(D)±	0.48	0.26	0.26	0.54	0.63	0.63	4.04	4.66	4.66
	CD 5%	0.50	0.59	0.59	1.09	1.26	1.26	8.07	9.32	9.32
	CD 1%	0.70	0.80	0.80	1.45	1.68	1.68	10.73	12.39	12.39

Sl. No.	Crosses	1000 grain weight (g)			Grain weight per spike (g)			Grain yield per plant (g)		
		(H_1)	(H_2)	(H_3)	(H_1)	(H_2)	(H_3)	(H_1)	(H_2)	(H_3)
1	AKAW 3717 × AKAW 4630	-4.29	-8.79	-16.28 *	-10.29	-18.75 *	-32.87 **	110.39 **	80.94 **	73.93 **
2	AKAW 3717 × AKAW 4739	17.09 *	9.96	0.94	24.58 **	14.58	-5.34	83.72 **	63.72 **	44.84 **
3	AKAW 3717 × AKAW 4731	30.82 **	24.78 **	14.55	45.57 **	33.44 **	10.24	176.99 **	129.08 **	86.77 **
4	AKAW 3717 × AKAW 4498	1.08	0.55	-7.69	-0.21	-1.98	-19.02 *	35.61 **	23.02	4.55
5	AKAW 3717 × AKAW 4800	15.1	9.9	0.89	6.15	6.15	-12.31	13.36	4.79	-14.56
6	AKAW 3717 × AKAW 4730	3.67	-0.06	-8.26	41.58 **	25.73 **	3.87	113.58**	105.17**	81.57**
7	AKAW 3717 × AKAW 5077	-13.25	-17.13 *	-16.45 *	-12.55	-13.23	-28.31 **	115.71 **	101.91 **	39.75 **
8	AKAW 3717 × AKAW 4924	8.09	1.85	-6.51	9.06	0.31	-17.13 *	107.83 **	103.62**	73.11**
9	AKAW 2865 × AKAW 4630	11.01	10.16	-6.96	78.24 **	74.58 **	17.04 *	84.63 **	83.07 **	75.97 **
10	AKAW 2956 × AKAW 4630	5.68	3.28	-12.78	3.28	-0.5	-30.98 **	56.71 **	51.72 **	43.36 **
11	AKAW 2865 × AKAW 4731	12.58	11.83	-5.55	39.50 **	34.87 **	-7.14	1.74	1.45	-4.14
12	AKAW 2865 × AKAW 4498	17.49 *	13.36	2.98	42.02 **	28.29 **	2.24	-23.35 *	-27.20 *	-31.21 **
13	AKAW 2865 × AKAW 4800	14.89	14.24	-3.52	47.98 **	31.56 **	8.69	14.2	6.37	0.51
14	AKAW 2865 × AKAW 4730	12.75	12.26	-4.36	31.10 **	30.92 **	-15.83 *	64.17 **	48.08 **	39.92 **
15	AKAW 2865 × AKAW 5077	0.55	-7.61	-6.85	25.89 **	12.7	-8.35	99.73 **	63.66 **	54.64 **
16	AKAW 2865 × AKAW 4924	17.11 *	14.84	-3.01	46.43 **	41.07 **	-2.15	16.1	2.27	-3.36
17	AKAW 2956 × AKAW 4630	11.3	9.06	-5.49	53.80 **	45.31 **	-2.58	53.06 **	19.1	14.48
18	AKAW 2956 × AKAW 4739	6.18	2.48	-11.2	36.62 **	27.05 *	-11.88	41.38 **	13.42	0.34
19	AKAW 2956 × AKAW 4731	8.8	6.71	-7.53	35.43 **	26.37 *	-12.99	124.75 **	76.33 **	65.66 **
20	AKAW 2956 × AKAW 4498	7.25	4.79	-4.82	17.73	2.92	-17.99 *	55.53 **	26.69 *	7.67
21	AKAW 2956 × AKAW 4800	-2.19	-3.97	-16.78 *	-4.54	-17.81	-32.10 **	33.65 *	10.65	-9.78
22	AKAW 2956 × AKAW 4730	6.96	6.06	-8.09	56.33 **	50.87 **	-3.27	-2.88	-17.27	-37.15 **
23	AKAW 2956 × AKAW 5077	2.08	-5.1	-4.31	28.57 **	11.43	-9.38	4.81	-1.17	-40.35 **
24	AKAW 2956 × AKAW 4924	6.22	2.87	-10.86	31.95 **	22.70 *	-14.89 *	45.60 **	26.88	-8.68
25	HI 1418 × AKAW 4630	0.61	-7.86	-7.86	21.38 **	1.38	1.38	22.50 *	20.12	20.12
26	HI 1418 × AKAW 4739	-0.29	-9.95	-9.95	9.15	-7.57	-7.57	10.95	4.55	4.55
27	HI 1418 × AKAW 4731	6.3	-2.56	-2.56	-2.14	-17.38 *	-17.38 *	-42.61 **	-44.34 **	-44.34 **

28	HI 1418 × AKAW 4498	11.59	6.48	6.48	-4.6	-14.29	-14.29	-13.9	-20.36	-20.36
29	HI 1418 × AKAW 4800	11.68	2.47	2.47	6.69	-2.58	-2.58	9.56	-0.56	-0.56
30	HI 1418 × AKAW 4730	-9.89	-16.56 *	-16.56 *	-8.86	-25.22 **	-25.22 **	-18.13	-27.97 *	-27.97 *
31	HI 1418 × AKAW 5077	-16.45 *	-16.80 *	-16.11 *	-16.66 *	-24.44 **	-24.44 **	19.92	-3.85	-3.85
32	HI 1418 × AKAW 4924	5.76	-4.19	-4.19	2.44	-13.25	-13.25	41.12 **	21.34	21.34
	SE(D)±	3.97	4.58	4.58	0.24	0.28	0.28	3.97	4.587	4.58
	CD 5%	7.94	9.16	9.16	0.49	0.57	0.57	7.94	9.16	9.16
	CD 1%	-4.29	-8.79	-16.28 *	0.65	0.75	0.75	10.55	12.18	12.18

Note: * Significant at 5% level of significance,
** Significant at 1% level of significance

4. Conclusions

The current study shows that there is a significant degree of genetic variation among the parental genotypes, which opens up a lot of potential for using these genotypes for heterosis for grain yield and other attributes. The cross combination of AKAW 3717 x AKAW 4731, AKAW 3717 x AKAW 4730, AKAW 2865 x AKAW 4630, AKAW 3717 x AKAW 4630, and AKAW 3717 x AKAW 4924, which had high positive heterosis over mid parent, better parent, and both the checks with high per se performance, is thought to be the best heterotic combination in terms of grain yield. Therefore, it would be best to continue using these hybrids in breeding programmes. For grain yield per plant, the cross AKAW 3717 x AKAW 4731 had the greatest significant average heterosis, heterobeltiosis, and standard heterosis, followed by the cross AKAW 3717 x AKAW 4730. This suggests that this cross may be further exploited in the future to increase grain yield.

5. References

1. Abdullah GM, Khan AS, Ali Z. Heterosis study of certain important traits in wheat. Int. J Agric. Biol. 2002;4(3):326-328.
2. Adhikari A, Ibrahim AM, Rudd JC, Baenziger PS, Sarazin JB. Estimation of heterosis and combining abilities of US winter wheat germplasm for hybrid development in Texas. Crop Science. 2020;60(2):788-803.
3. Akbar M, Khan MA, Rehman A, Ahmed N. Heterosis and heterobeltiosis for improvement of wheat grain yield. J Agric. Res., 2007;2(45):87-94.
4. Ashutosh K, Mishra VK, Vyas RP, Singh V. Heterosis and combining ability analysis in bread wheat (*Triticum aestivum* L.). J Plant Breed Crop Sci. 2011;3(10):209-217.
5. Bilgin O, Balkan A, Korkut KZ, Başer I. Heterotic and heterobeltiotic potentials of bread wheat (*Triticum aestivum* L.) hybrids for yield and yield components. Journal of Tekirdag Agricultural Faculty. 2011;8(2):133-142.
6. Devi EL, Swati GP, Singh M, Jaiswal JP. Heterosis studies for yield and yield contributing traits in bread wheat (*Triticum aestivum* L.). The Bioscan. 2013;8(3):905-909.
7. Garg M, Chawla M, Kumar R, Sharma S, Sharma NK, Kaur N, et al. Transfer of grain colors to elite wheat cultivars and their characterization. J cereal sci., 2016;71:138-144.
8. Hassan G, Mohammad FS, Afridi I. Combining ability in the F1 generations of diallel cross for yield and yield components in wheat. Sarhad J Agri. 2007;(4):937-942.
9. Hussain SB, Zahra S, Bakhsh A, Zubair M. Assessment of heterosis for morphological and yield donating traits in bread wheat by line x tester analysis. International Journal of Multidisciplinary Research and Studies. 2019;2(09):23-39.
10. Ibrahim AU, Yadav B, Anusha R, Magashi AI. Heterosis studies in durum wheat (*Triticum durum* L.). J Genet. Genom. Plant Breed. 2020;4(1):2-8.
11. Ilker E. Heterosis for yield and its components in bread wheat crosses among powdery mildew resistant and susceptible genotypes. Pak. J Bot. 2010;42(1):513-522.
12. Jaiswal R, Gaur SC, Jaiswal SK. Heterosis and inbreeding depression for grain yield and yield component traits in bread wheat (*Triticum aestivum* L.). Journal of Pharmacognosy and Phytochemistry. 2018;7(2):3586-3594.
13. Kempthorne O. An Introduction to Genetic Statistics, John Wiley & Sons, New York, NY, USA; c1957.
14. Mahpara S, Ali ZL, Farooq S, Hussain R. Heterosis and Heterobeltiosis analysis for spike and its attributes in different Wheat crosses. Pak. J Nutr. 2015;14(7):396-400.
15. Pankaj G, Saharan RP, Mamta G, Renu M. Heterosis studies for grain yield and its components in wheat (*Triticum aestivum* L. Em. Thell) under normal and drought conditions. The Bioscan. 2015;10(2):721-728.
16. Rasul I, Khan AK, Ali Z. Estimation of heterosis for yield and some yield components in bread wheat. Int. J Biol. Sci. 2002;4(2):214-216.
17. Seboka H, Ayana A and Zelleke H. Combining ability analysis for bread wheat (*Triticum aestivum* L.). East Afr. J Sci. 2009;3(1):87-94.
18. Sharif AF, Bakhsh A, Haqqani AM and Najma S. Identification of genetically superior hybrids in chickpea (*Cicer arietinum* L.). Pakistan Journal of Botany. 2001;33:403-409.
19. Singh MA, Devi EL, Aglawe S, Kousar N, Behera C. Estimation of heterosis in different crosses of bread wheat (*Triticum aestivum* L.). The Bioscan. 2013;8(4):1393-1401.
20. Solomon KF, Labuschagne MT, Viljoen CD. Estimates of heterosis and association of genetic distance with heterosis in durum wheat under different moisture regimes. The Journal of Agricultural Science. 2007;145(3):239-248.
21. Steel RGD, Torrie JH. Principles and procedures of statistics: A Biometrical Approach, McGraw Hill, New York, NY, USA; c1980.