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Assessment of residual useful heterosis for grain yield and yield component traits in the bread wheat (*Triticum aestivum* L.)

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Abstract
A field experiment was conducted at the Dr. P. D. K. V., Akola, during Rabi 2018-19 seasons, to study yield and its components of full diallel wheat bread crosses. A Randomize Block Design (RBD) with three replications was used for the experiment. The experimental material comprised of 145 genotypes including 132 F_2 crosses (Direct and reciprocal crosses), 12 parents and one check (WB-2). Analyses of Variance for all the treatment showed highly significant differences for nine characters indicated the presence of extensive amount of genetic variability. The result of residual heterosis over check for grain yield per plant revealed that the cross combinations WB-2 x GW-322, MACS-6222 x WB-2, HPBW-01 x WB-2, MACS-6222 x HPBW-01, MACS-6222 x GW-322 direct crosses and GW-322 x WB-2, GW-322 x AKAW-4925, GW-322 x K-307 reciprocal crosses were good along with the combined range of -47.37 (AKAW-5017 x HPBW-01) to 57.89% (WB-2 x GW-322). The above crosses were seen to perform stably for all the characters studied. Hence can be exploited for further wheat breeding programs.

Keywords: Randomize block design, *Triticum aestivum* L., MACS-6222 x WB-2, HPBW-01 x WB-2

Introduction
Wheat (*Triticum* spp.) is counted among the 'big three' cereal crops. Wheat, maize, and rice account for more than 85% of total grain production worldwide and more than half of the total food calories. Wheat cultivation started 5000 years ago in India (Feldman, 2001) [4] and is the staple food of millions of people particularly in the northern and northwestern regions of India. Nutritive content of the wheat consist of 70% carbohydrates, 22% crude fiber, 12% protein, 12% water, 2% fat and 1.8% minerals (Kumar *et al.* 2017) [11]. There is urgent need to develop wheat genotypes having high yield potential to feed the ever increasing world population. Grain yield is basically a complex trait being the consequence of several genes and their interaction in a particular environment. The main effort of the wheat breeder is the detection of genes and to merge them in a particular genotype using the most suitable combination (Nassar *et al.* 2020) [8]. The study of heterosis is important tool in interpreting genetic parameters in most of the crops including wheat (Jaiswal *et al.* 2018) [5]. Therefore, the present study was conducted to deduct the magnitude of the residual heterosis and identify superior crosses and parents that can be successfully utilized in development of high yielding stable lines.

Material and Methods
Present investigation comprised of twelve genetically diverse bread wheat (*Triticum aestivum* L.) varieties, *viz.* AKAW-5017, AKAW-5014, AKAW-4924, AKAW-4925, AKAW-4627, AKW-1071, AKAW-4210-6, K-307, MACS-6222, HPBW-01, GW -322, and WB-2. Final materials consist of 132 F_2 crosses, 12 parents and one check that were evaluated in the Rabi 2018-19 at Dr. P.D.K.V., Akola, Wheat research Unit. The genotypes were planted in randomize complete block design (RCBD) with three replications per entry and five rows (2m) per replication. Plant-to-plant spacing of 10cm and row-to-row spacing of 18cm was maintained. Standard agronomic practices were used for raising and maintenance of the plants.
The observations were recorded randomly from the ten competitive plants in parents and 30 plants from F_2 progenies for all the following traits *viz.*, days to 50% flowering, days to maturity, plant height, effective tillers per plant, grains per earhead, grain weight per plant, 1000 grain weight, harvest index and grain weight per plot.

Relative heterosis was estimated following methods suggested by Hays *et al.* (1955).

Results and Discussion

Analysis of variance for nine characters in a 12 parents diallel crosses (including reciprocal cross) indicated significant differences among the parents, and F_2s for most of the characters indicating the presence of considerable genetic variability in the material studied (Table.1). Heterosis was calculated in per cent over economic parent (WB-2) for all nine characters (Table. 2). The nature and magnitude of residual useful heterosis that most of the crosses exhibited significant and negative relative heterosis for days to 50% flowering varied from -1.52 to 22.73%. None of the crosses from the direct and reciprocal crosses were found to have desirable negative residual useful heterosis over the check (WB-2) for days to 50% flowering. The range of the residual useful heterosis for the days to maturity was recorded from -9.40 to 3.42% including direct and reciprocal crosses. The crosses AKAW-4627 x WB-2 and K-307 x MACS-6222 (-9.40%) showed maximum negative desirable residual useful heterosis among the direct crosses followed by the crosses AKAW-4925 x K-307 and AKAW-4627 x HPBW-01 (-8.55%). Only three crosses AKAW-5014 x AKAW-5017 (-9.40%), GW-322 x MACS-6222 (-8.55%) and K-307 x AKAW-4210-6 (-7.69%) were seen to have significant desirable negative residual useful heterosis among the reciprocal crosses for the days to maturity. For the plant height of F_2 generation, none of the crosses from the direct and reciprocal crosses were seen to have significant desirable negative residual useful heterosis for the plant height. The range of the residual useful heterosis for the effective tillers per plant was recorded from -42.37 to 22.14% including direct and reciprocal crosses. Among the 66 direct crosses, only two crosses were seen to have significant positive residual useful heterosis as follows WB-2 x GW-322 (22.14%) and HPBW-01 x WB-2 (19.36%), while, for the reciprocal crosses, the only cross showing significant positive residual useful heterosis was GW-322 x WB-2 (19.41%). For grains per earhead, seven direct crosses were found to have significant positive residual useful heterosis as follows WB-2 x GW-322 (23.62%), HPBW-01 x WB-2 (22.35%), MACS-6222 x WB-2 (22.12%), MACS-6222 x HPBW-01 (18.73%), MACS-6222 x GW-322 (18.59%), AKAW-4924 x MACS-6222 (16.39%), and AKAW-4924 x AKAW-4210-6 (13.97%). Similarly among the reciprocal crosses, seven crosses were found to have significant positive residual useful heterosis as follows GW-322 x WB-2 (21.50%), MACS-6222 x AKW-1071 (18.63%), K-307 x AKAW-5014 (18.59%), GW-322 x AKAW-4925 (18.21%), GW-322 x K-307 (16.21%), MACS-6222 x AKAW-4627 (12.66%), and HPBW-01 x AKAW-5017 (12.60%). For the grain weight per plant, among 66 direct crosses, five crosses have recorded highest significant positive residual useful heterosis as follows MACS-6222 x HPBW-01 (47.69%), MACS-6222 x WB-2 (46.86%), MACS-6222 x GW-322 (38.42%), AKAW-4924 x MACS-6222 (24.38%), and AKAW-4924 x AKAW-4210-6 (23.67%). For the reciprocal crosses, the cross GW-322 x WB-2 (46.86%) was seen to have highest significant positive residual useful heterosis followed by the crosses MACS-6222 x AKW-1071 (38.46%), GW-322 x AKAW-4925 (34.56%), GW-322 x K-307 (23.79%) and MACS-6222 x AKAW-4210-6 (23.20%). Out of 66 direct crosses, seven crosses showed significant positive residual useful heterosis for 1000 grain weight. The cross WB-2 x GW-322 (22.43%) recorded highest significant positive residual useful heterosis among the direct crosses followed by the crosses HPBW-01 x WB-2 (21.16%), MACS-6222 x WB-2 (19.85%), MACS-6222 x HPBW-01 (16.47%), and MACS-6222 x GW-322 (14.93%). Out of 66 reciprocal crosses, eight crosses recorded positive residual useful heterosis for the 1000 grain weight. The cross GW-322 x WB-2 (18.31%) showed maximum significant positive residual useful heterosis among the reciprocal crosses followed by the crosses MACS-6222 x AKW-1071 (15.77%), MACS-6222 x K-307 (15.57%), GW-322 x K-307 (13.41%), and MACS-6222 x AKAW-4627 (11.53%). Out of 66 direct crosses, seven crosses showed significant positive residual useful heterosis for harvest index. The crosses WB-2 x GW-322 and HPBW-01 x WB-2 (23.26%) recorded highest significant positive residual useful heterosis for the harvest index among the direct crosses followed by the crosses MACS-6222 x WB-2 (20.93%), MACS-6222 x HPBW-01 (18.60%), MACS-6222 x GW-322 (16.28%). Out of 66 reciprocal crosses, eight crosses showed significant positive residual useful heterosis. The cross GW-322 x WB-2 (18.60%) exhibited maximum significant positive residual useful heterosis for the harvest index among the reciprocal crosses followed by the crosses MACS-6222 x AKW-1071 (16.28%), GW-322 x AKAW-4925 and GW-322 x K-307 (13.95%). Desale and Mehta (2013) [3] recorded substantial amount of heterosis for grain yield plant^{-1}, harvest index and protein content. For grain weight per plot, the range of the residual useful heterosis was from -47.37 to 57.89% including both the direct and reciprocal crosses. Out of 66 direct crosses, seven crosses showed significant positive residual useful heterosis. Among the direct crosses, the cross WB-2 x GW-322 (57.89%) showed highest significant positive residual useful heterosis followed by the crosses MASC-6222 x WB-2, HPBW-01 x WB-2 (52.63%), MASC-6222 x HPBW-01 (37.66%), and MASC-6222 x GW-322 (36.84%). Among 66 reciprocal crosses, six crosses showed significant positive residual useful heterosis as follows GW-322 x WB-2 (42.11%), MASC-6222 x AKW-1071, GW-322 x AKAW-4925 (36.84%), GW-322 x K-307 (31.58%), MACS-6222 x AKAW-4627 and HPBW-01 x AKAW-5017 (26.32%). Raj Preeti and Kandalkar (2013) [10] recorded significant favorable heterosis for days to heading, days to maturity, plant height, number of productive tillers plant^{-1}, number of grains earhead^{-1}, grain weight earhead^{-1}, grain weight plant^{-1}, 1000 grain weight, grain yield plant^{-1} and harvest index. Above results were in agreement with Nagar *et al.* (2019) [7], Adhikari *et al.* (2020) [1], Kumar P. *et al.* (2020), Nassar *et al.* (2020) [8], and Chauhan and Pandey (2021) [2]. Heterosis breeding lays the foundation for the positive selection of genotypes. The positive and negative expressions indicated the role of dominant and recessive genes in inheritance of the characters. Henceforth, from the present study, it can be concluded that the selected crosses should be used for further improvement in the wheat crop through the traits of interest of the breeder.

Table 1: Analysis of Variance for various among nine characters in a diallel cross (with reciprocals) of 12 parents and their F_2s

Sources of variation	Df	Mean Sum of Squares								
		Days to 50% flowering	Days to maturity	Plant height (cm)	Effective tillers per plant	Grain per ear head	Grain weight per plant (g)	1000 grain weight (g)	Harvest index	Grain Yield per plot (kg)
		F_2								
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Replications	2	0.1	1.465	1.567	0.529	0.088	0.372	0.063	0.00005	0
Treatments	143	48.536 **	37.678 **	108.697 **	2.687 **	99.314 **	11.140 **	66.845 **	0.01**	0.0052**
Parents	11	12.182	12.614	55.463	5.973 **	71.166 **	6.806 **	119.454 **	0.017**	0.0059**
Crosses	131	51.677 **	37.972 **	113.993 **	2.319 **	99.756 **	11.575 **	62.544 **	0.0095**	0.0051**
Parents Vs. Crosses	1	36.945 *	274.926 **	0.575	14.691 **	351.053 **	1.741	51.583 **	0.00023	0.0057**
F_2's	65	41.675 **	45.900 **	74.449 **	2.270 **	94.844 **	12.496 **	44.718 **	0.0086**	0.0051**
Reciprocals	65	56.775 **	29.505	154.786 **	2.380 **	106.136 **	10.579 **	77.646 **	0.0102**	0.0051**
F_2's Vs. Reciprocals	1	370.427 **	72.98	32.824	1.542	4.358	16.499 **	239.680 **	0.015**	0.0074**
Error	286	9.26	26.295	43.762	0.523	12.259	0.791	6.898	0.0007	0.0006

Table 2: Estimation of residual useful heterosis in percentage for 9 attributes in 12 x 12 diallel crosses of wheat

S.N.	Genotypes	Days to 50% flowering	Days to maturity	Plant height (cm)	Effective tillers per plant	Grains per earhead	Grain weight per plant (g)	1000 grain weight	Harvest Index	Grain weight per plot (kg)
Direct Crosses										
1	AKAW-5017 X AKAW-5014	4.55	0	14.25	-7.22	4.54	11.83	5.12	2.33	10.53
2	AKAW-5017 X AKAW-4924	18.18**	3.42	1.09	-1.22	-0.3	13.49	7.92	4.65	15.79*
3	AKAW-5017 X AKAW-4925	18.18**	3.42	7.11	-7.26	-1.8	-12.78	-17.27 **	-20.93 **	10.53
4	AKAW-5017 X AKAW-4627	15.15**	-0.85	-1.49	-0.93	-0.26	11.83	3.68	2.33	10.53
5	AKAW-5017 X AKAW-4210-6	16.67**	-1.71	-8.26	-27.35 **	-2.38	-45.84 **	-13.77 **	-25.58 **	5.26
6	AKAW-5017 X AKW-1071	12.12**	-1.71	9.96	-22.53 *	-2.26	-53.96 **	-10.17*	-25.58 **	-42.11**
7	AKAW-5017 X MACS-6222	10.61**	-1.71	3	-14.87	-7.93	-44.93 **	-15.22 **	-20.93 **	-21.05
8	AKAW-5017 X GW-322	16.67**	-2.56	11.27	-15.21	-1.53	0	2.29	0	-5.26
9	AKAW-5017 X K-307	13.64**	-0.85	0.26	-8.87	-1.76	-31.95 **	-7.09	-4.65	-15.79*
10	AKAW-5017 X HPBW-01	9.09**	-0.85	-1.19	-13.16	-28.11 **	-46.00 **	-14.08 **	-27.91 **	-47.37**
11	AKAW-5017 X WB-2	13.64**	-1.71	8.51	-15.6	-18.40 **	-22.17 *	-2.62	0	5.26
12	AKAW-5014 X AKAW-4924	1.52	-0.28	13.21	-7.56	-6.61	10.3	3.08	-9.3	0
13	AKAW-5014 X AKAW-4925	13.64**	-7.69*	6.94	-5.61	-2.2	1.22	-13.54 **	-13.95 **	-21.05
14	AKAW-5014 X AKAW-4627	7.58*	-5.98	15.44 *	-20.77 *	-0.85	8.52	-0.3	-9.3*	5.26
15	AKAW-5014 X AKAW-4210-6	3.03	-0.85	18.81 *	-9.31	-9.93	1.85	-14.73 **	-4.65	-5.26
16	AKAW-5014 X AKW-1071	13.64**	-7.69*	14.14	-10.48	-13.95 **	-13.37	-7.66	-9.3*	-21.05
17	AKAW-5014 X MACS-6222	12.12**	-5.13	7.06	-18.14 *	-15.88 **	-9.94	-15.05 **	-2.33	-10.53
18	AKAW-5014 X GW-322	13.64**	-2.56	15.31	-9.9	-4.44	6.75	-3.99	0	5.26
19	AKAW-5014 X K-307	10.61**	-5.98	12.59	-27.30 **	-0.63	-20.08 *	2.48	0	0
20	AKAW-5014 X HPBW-01	13.64**	0.85	7.21	-7.7	-12.49 **	-47.06 **	-6.32	-13.95 **	-31.58**
21	AKAW-5014 X WB-2	12.12**	-0.85	8.7	-17.02	-20.38 **	-22.56 **	3.23	0	5.26
22	AKAW-4924 X AKAW-4925	16.67**	0.85	5.57	-27.65 **	-0.44	-34.56 **	-3.45	-13.95 **	5.26
23	AKAW-4924 X AKAW-4627	7.58*	-6.84	12.74	-28.62 **	-0.28	-23.27 **	-3.55	0	5.26
24	AKAW-4924 X AKAW-4210-6	7.58*	0	4.14	6.34	13.97 **	23.67 **	13.31 *	13.95 **	26.32*
25	AKAW-4924 X AKW-1071	13.64**	-0.85	1.39	-28.86 **	-0.67	-32.90 **	-9.94	-6.98	-5.26
26	AKAW-4924 X MACS-6222	9.09**	0	8.38	7.36	16.39 **	24.38 **	13.64 **	13.95 **	31.58**
27	AKAW-4924 X GW-322	0	-3.42	8.29	-7.85	-5.93	4.85	1.29	-4.65	5.26
28	AKAW-4924 X K-307	15.15**	-0.85	2.92	-22.43 *	-1.31	-18.78 *	-13.54 *	0	0
29	AKAW-4924 X HPBW-01	4.55	-7.69*	24.16 **	-32.91 **	-4.49	4.26	-2.55	-2.33	5.26
30	AKAW-4924 X WB-2	9.09**	-6.84	15.61 *	-29.89 **	-23.50 **	-34.48 **	-5.95	-27.91 **	5.26
31	AKAW-4925 X AKAW-4627	9.09**	-2.56	-1.17	-18.97 *	-1.35	-18.74 *	-6.21	0	5.26
32	AKAW-4925 X AKAW-4210-6	7.58*	-5.13	-0.08	-7.7	-2.68	4.85	-14.03 **	0	0
33	AKAW-4925 X AKW-1071	16.67**	0.85	1.47	-16.19	-2.48	10.3	-1.74	0	0
34	AKAW-4925 X MACS-6222	12.12**	0.85	0.11	-11.31	-4.62	-0.91	-8.7	-2.33	-5.26
35	AKAW-4925 X GW-322	16.67**	1.71	1.09	-20.43 *	-0.4	8.99	2.01	-6.98*	-5.26
36	AKAW-4925 X K-307	-1.52	-8.55*	15.76 *	-29.01 **	-7.91	-34.36 **	1.47	0	0
37	AKAW-4925 X HPBW-01	10.61**	0.85	1.42	-11.8	-0.63	-20.20 *	-16.57 **	-6.98*	-10.53
38	AKAW-4925 X WB-2	15.15**	0.85	-1.54	-16.14	-0.22	7.93	2.91	0	-10.53
39	AKAW-4627 X AKAW-4210-6	21.21**	0.85	-2.93	-17.84 *	-0.06	-8.88	-0.6	-16.28 **	5.26
40	AKAW-4627 X AKW-1071	18.18**	-0.85	11.57	-4.83	-1.51	-18.70 *	0.37	-2.33	0
41	AKAW-4627 X MACS-6222	13.64**	-0.85	5.86	-17.31 *	-1.76	-20.32 *	-0.92	0	5.26
42	AKAW-4627 X GW-322	16.67**	-0.85	17.06 *	-7.7	-30.07 **	-34.40 **	-13.61 *	-27.91 **	-47.37**
43	AKAW-4627 X K-307	21.21**	0	-9.56	-20.09 *	-0.67	-7.81	1.86	-4.65	5.26
44	AKAW-4627 X HPBW-01	10.61**	-8.55*	14.26	-29.55 **	-6.21	-32.03 **	-7.11	-11.63 *	-5.26

45	AKAW-4627 X WB-2	15.15**	-9.40**	8.66	-27.89 **	-12.39 **	-45.96 **	-7.07	-20.93 **	-10.53
46	AKAW-4210-6 X AKW-1071	16.67**	2.56	1.55	-8.73	-28.16 **	-31.72 **	-16.88 **	-23.26 **	-26.32*
47	AKAW-4210-6 X MACS-6222	12.12**	-0.85	5.64	-30.38 **	-4.21	-33.89 **	-0.99	-18.60 **	-47.37**
48	AKAW-4210-6 X GW-322	21.21**	0.85	-2.88	-27.55 **	-16.20 **	-8.64	-0.75	-18.60 **	-5.26
49	AKAW-4210-6 X K-307	1.52	-1.71	5.71	-18.97 *	-13.64 **	-44.50 **	-0.99	-9.3*	-36.84**
50	AKAW-4210-6 X HPBW-01	13.13**	-0.85	8.6	-33.93 **	-16.36 **	-23.27 **	-11.52 *	0	-5.26
51	AKAW-4210-6 X WB-2	4.55	-0.85	-0.12	-4.24	-0.63	0	-1.86	0	5.26
52	AKW-1071 X MACS-6222	16.67**	0.85	6.99	-15.11	-22.86 **	1.81	-4.74	-18.60 **	-10.53
53	AKW-1071 X GW-322	6.06	-6.84	11.29	-7.7	-13.67 **	-43.63 **	0.12	-6.98*	0
54	AKW-1071 X K-307	22.73**	2.56	-6.8	-31.20 **	-2.32	-42.56 **	-6.02	-18.60 **	0
55	AKW-1071 X HPBW-01	21.21**	1.71	-5.72	-7.85	-2.81	-12.54	-3.68	-11.63 *	-5.26
56	AKW-1071 X WB-2	15.15**	-0.85	-1.45	-28.72 **	-3.88	3.27	-1.63	-20.93 **	-42.11**
57	K-307 X MACS-6222	3.03	-9.40**	9.91	-22.87 *	-3.85	-13.21	-13.88 **	0	5.26
58	K-307 X GW-322	12.12**	0	15.69 *	-22.53 *	-15.91 **	-31.05 **	-4.6	-20.93 **	-5.26
59	K-307 X HPBW-01	19.7**	0.85	1.51	-8.14	-0.22	8.99	-1.44	-18.60 **	-5.26
60	K-307 X WB-2	15.15**	0.85	12.78	-17.75 *	-2.21	-32.98 **	-13.51**	0	5.26
61	MACS-6222 X GW-322	21.21**	0	12.52	10.29	18.59 **	38.42 **	14.93 **	16.28 **	36.84**
62	MACS-6222 X HPBW-01	19.7**	-0.85	1.52	11.9	18.73 **	47.69 **	16.47 **	18.60 **	42.11**
63	MACS-6222 X WB-2	18.18**	0.85	13.09	12.34	22.12 **	46.86 **	19.85 **	20.93 **	52.63**
64	HPBW-01 X GW-322	12.12**	-7.69*	11.36	-9.17	-1.53	-31.72 **	-16.33 **	-11.63 *	0
65	HPBW-01 X WB-2	13.64**	0	7	19.36 *	22.35 **	-56.06 **	21.16 **	23.26 **	52.63**
66	WB-2 X GW-322	13.64**	0	10.11	22.14 *	23.62 **	-32.39 **	22.43 **	23.26 **	57.89**
	Reciprocal crosses									
67	AKAW-5014 X AKAW-5017	4.55	-9.40**	31.23 **	-30.86 **	-1.97	-33.53 **	-2.78	-9.3*	5.26
68	AKAW-4924 X AKAW-5017	13.64**	0	9.8	0.49	11.89 *	20.83 *	11.30 *	11.63 *	21.05
69	AKAW-4924 X AKAW-5014	10.61**	-0.85	13.07	-9.36	-4.84	-34.08 **	-2.09	-6.98*	5.26
70	AKAW-4925 X AKAW-5017	10.61**	-1.71	12.84	-10.48	1.35	-0.63	-11.04 *	-9.3*	-10.53
71	AKAW-4925 X AKAW-5014	13.64**	3.42	11.61	-7.7	-24.22 **	-21.18 *	-13.55 *	-18.60 **	-10.53
72	AKAW-4925 X AKAW-4924	-1.52	-1.71	-7.14	-21.94 *	-9.53*	-32.62 **	-1.42	-11.63 *	-47.37**
73	AKAW-4627 X AKAW-5017	15.15**	-0.57	3.03	-17.50 *	-22.96 **	-55.74 **	-8.8	0	-10.53
74	AKAW-4627 X AKAW-5014	3.03	-2.56	15.76 *	-7.85	-6.08	4.18	-19.59 **	-2.33	-5.26
75	AKAW-4627 X AKAW-4924	18.18**	0	10.03	-7.56	-7.93	0	0.42	0	-10.53
76	AKAW-4627 X AKAW-4925	18.18**	-1.71	14.53	-7.75	-12.64 **	0.95	-1.52	-6.98*	-21.05
77	AKAW-4210-6 X AKAW-5017	22.73**	-0.85	4.93	-7.85	-4.73	0	-34.91 **	-9.3*	-21.05
78	AKAW-4210-6 X AKAW-5014	13.64**	0	1.26	-8	-0.44	2.41	-1.79	0	-26.32*
79	AKAW-4210-6 X AKAW-4924	19.7**	0.85	4.49	-33.93 **	-30.96 **	-1.18	-4.05	-39.53 **	-47.37**
80	AKAW-4210-6 X AKAW-4925	10.61**	-1.71	9.93	-30.86 **	-0.85	-10.81	-0.97	-18.60 **	-36.84**
81	AKAW-4210-6 X AKAW-4627	12.12**	0	12.97	-7.7	-6.44	2.29	-11.00 *	-4.65	5.26
82	AKW-1071 X AKAW-5017	12.12**	-6.84	25.79 **	-42.08 **	-0.46	-34.79 **	-1.5	-6.98*	5.26
83	AKW-1071 X AKAW-5014	-1.52	-1.71	-7.16	-29.01 **	-16.55 **	-32.07 **	-11.29 *	-13.95 **	0
84	AKW-1071 X AKAW-4924	0	-1.71	-5.95	-22.53 *	-0.46	4.85	-6.62	-9.3*	5.26
85	AKW-1071 X AKAW-4925	18.18**	-1.71	20.00 **	-8.53	2.02	1.14	-18.25 **	0	5.26
86	AKW-1071 X AKAW-4627	18.18**	-2.56	11.6	-8.73	-5.42	1.66	-14.65 **	0	0
87	AKW-1071 X AKAW-4210-6	18.18**	-2.56	13.04	-14.77	2.03	-1.3	-46.29 **	-2.33	-5.26
88	K-307 X AKAW-5017	13.64**	0	3.29	-42.37 **	-33.58 **	-34.44 **	-0.35	-27.91 **	-15.79*
89	K-307 X AKAW-5014	13.64**	2.56	12.97	-23.99 **	18.59 **	0	0.65	-13.95 **	-10.53
90	K-307 X AKAW-4924	16.67**	-7.69	22.71 **	-33.45 **	6.3	15.5	-21.16 **	-2.33	5.26
91	K-307 X AKAW-4925	16.67**	3.42	7.01	-7.7	-23.92 **	-18.82 *	-8.35	-9.3*	5.26
92	K-307 X AKAW-4627	12.12**	-0.85	10.17	-8.43	6.24	2.17	-12.47 *	-13.95 **	0
93	K-307 X AKAW-4210-6	9.09**	-7.69*	28.48 **	-19.45 *	-1.58	-21.50 *	1.53	-2.33	-21.05
94	K-307 X AKW-1071	3.03	-2.56	-8.05	-19.45 *	-34.48 **	-55.27 **	-19.53 **	-46.51 **	-47.37**
95	MACS-6222 X AKAW-5017	6.06	2.56	-1.51	-8.14	-4	-23.39 **	-14.47 **	-18.60 **	5.26
96	MACS-6222 X AKAW-5014	1.52	0.85	-1.16	-15.31	-5.91	2.52	-1.44	-6.98*	0
97	MACS-6222 X AKAW-4924	15.15**	0	8.6	-7.7	-10.29	-42.49 **	-0.5	0	0
98	MACS-6222 X AKAW-4925	13.64**	-0.85	15.74 *	-17.65 *	-7.99	-33.77 **	-19.39 **	-18.60 **	5.26
99	MACS-6222 X AKAW-4627	12.12**	0	14.36	4.58	12.66 *	22.60 **	11.53 *	11.63 *	26.32*
100	MACS-6222 X AKAW-4210-6	12.12**	0	10.19	0.2	10.76*	23.20 **	11.03 *	11.63 *	21.05**
101	MACS-6222 X AKW-1071	13.64**	1.71	7.19	11.75	18.63 **	38.46 **	15.77 **	16.28 **	36.84**
102	MACS-6222 X K-307	7.58*	-1.71	15.82 *	0.05	9.67*	14.2	15.57 **	9.3*	15.79*
103	HPBW-01 X AKAW-5017	10.61**	-0.85	4.45	4	12.60 *	21.30 *	11.38 *	11.63 *	26.32*
104	HPBW-01 X AKAW-5014	12.12**	-0.85	-4.25	-17.21	-11.56 *	-10.45	-13.33 *	-11.63 *	0
105	HPBW-01 X AKAW-4924	-1.52	0	-10.07	-28.57 **	-9.89*	-33.61 **	-12.95 *	-16.28 **	-5.26
106	HPBW-01 X AKAW-4925	-1.52	-6.84	31.59 **	-17.75 *	-3.37	-10.3	0.58	-11.63 *	0
107	HPBW-01 X AKAW-4627	0	-0.85	13.03	-17.06	-11.82 *	-32.39 **	-3.94	-20.93 **	-42.11**
108	HPBW-01 X AKAW-4210-6	9.09**	0	2.94	-18.53 *	-4.44	2.52	-12.54 *	-6.98	0
109	HPBW-01 X AKW-1071	15.15**	0.85	4.48	-27.60 **	-3.17	-12.07	-13.77 *	-6.98	-5.26
110	HPBW-01 X K-307	16.67**	-0.85	8.62	-28.91 **	-0.2	-21.07 *	0.09	-9.3	-21.05**

111	HPBW-01 X MACS-6222	18.18**	3.42	10.15	-28.38 **	-3.92	-32.78 **	-20.06 **	-23.26 **	-36.84**
112	WB-2 X AKAW-5017	12.12**	0	11.55	-8.58	-7.71	-35.74 **	-28.22 **	-2.33	5.26
113	WB-2 X AKAW-5014	12.12**	0.85	31.31 **	-29.94 **	-3.33	-0.2	1.52	-41.86 **	-21.05**
114	WB-2 X AKAW-4924	12.12**	-0.85	4.46	-11.41	-0.4	-4.97	-8.51	-18.60 **	0
115	WB-2 X AKAW-4925	0	0	-5.46	-30.08 **	0.26	-0.95	-16.53 **	-17.05 **	-26.32**
116	WB-2 X AKAW-4627	-1.52	-0.85	-8.65	-18.97 *	-2.63	1.5	-4.38	-9.3	-42.11**
117	WB-2 X AKAW-4210-6	13.64**	-2.56	1.62	-18.04 *	-0.4	2.96	-18.70 **	-27.91 **	-42.11**
118	WB-2 X AKW-1071	7.58*	0	1.74	-9.17	-17.49 **	-34.67 **	1.56	-11.63 *	-15.79*
119	WB-2 X K-307	10.61**	1.71	6.99	-22.87 *	-3.55	0.71	-7.25	-18.60 **	-26.32*
120	WB-2 X MACS-6222	3.03	0	0.21	-22.48 *	-7.63	-21.07 *	-22.06 **	-16.28 **	-47.37**
121	WB-2 X HPBW-01	3.03	-3.42	5.56	-22.57 *	-5.57	-21.70 *	-0.97	-6.98	5.26
122	GW-322 X AKAW-5017	12.12**	-0.85	-1.14	-32.62 **	4.7	2.6	-13.92 **	-11.63 *	5.26
123	GW-322 X AKAW-5014	10.61**	-0.85	11.37	-9.36	-6.47	-34.64 **	-11.24 *	-6.98	-5.26
124	GW-322 X AKAW-4924	0	-8.55*	21.27 **	-20.23 *	-0.46	-10.93	-0.07	-4.65	5.26
125	GW-322 X AKAW-4925	13.64**	0.85	-2.7	10	18.21 **	34.56 **	14.58 **	13.95 **	36.84**
126	GW-322 X AKAW-4627	-1.52	-1.71	-10.91	-33.20 **	-20.45 **	-34.64 **	-14.59 **	-20.93 **	5.26
127	GW-322 X AKAW-4210-6	0	-3.42	-7.01	-31.20 **	-4.42	0.12	-29.21 **	-27.91 **	-5.26
128	GW-322 X AKW-1071	1.52	-2.56	-0.09	0.2	9.81*	14.2	10.13	9.3	15.79*
129	GW-322 X K-307	10.61**	0.85	-1.2	6.78	16.21 **	23.79 **	13.41 *	13.95 **	31.58**
130	GW-322 X MACS-6222	10.61**	0.85	-1.37	-25.94 **	-17.48 **	-32.98 **	-16.87 **	-32.56 **	-36.84**
131	GW-322 X HPBW-01	1.52	0	1.43	-16.67	-0.63	-9.47	-12.11 *	-6.98	0
132	GW-322 X WB-2	15.15**	2.56	10.05	19.41 *	21.50 **	46.86 **	18.31 **	18.60 **	42.11**
	SE(m)±	2.378	4.016	5.148	0.610	2.317	0.733	1.819	0.018	0.017

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

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