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Heterosis for yield and yield component traits in F_1 and F_2 generation of winter and spring wheat derivatives (line x tester)

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Abstract
Introgression of winter wheat gene pool in spring wheat is one of the potential approaches to break the yield barrier. The presence of heterosis indicates the ability of parents to combine well in hybrid combination. To assess the heterosis of yield and yield contributing traits, ten diverse winter wheat or their derivatives were crossed with three spring wheat testers in line x tester fashion to generate 30 cross combinations. The thirty F_1 hybrids were advanced to generate 30 F_2 s. 30 F_1 s, 30 F_2 s along with the 13 parents (10 lines and 3 testers) were evaluated in randomized block design during rabi 2016-17 at university Research Farm of Sher-e- Kashmir university of Agricultural Sciences and Technology, Jammu (SKUAST, J) Main campus, Chatha. Heterotic pattern estimation revealed that none of the cross combination had significant heterosis for all the traits. However, on individual trait basis, some of the crosses revealed significant heterosis. The crosses showing desirable heterosis (10 or more percent) were for yield attributing traits were Nordresprez x PBW 175, WW21 x PBW 175, Diana x PBW 175, WW12 x PBW 175, WW25 x PBW 175, Diana NS 720 x PBW 175, respectively for both in F_1 and F_2 generation of crosses. Significant desirable heterosis for many traits was revealed suggesting the possibility of yield improvement through heterosis breed.

Keywords: Heterosis, winter wheat, spring wheat, yield components, line x tester

1. Introduction
Wheat (*Triticum aestivum* L.), self-pollinated crop of the Poaceae family and of the genus *Triticum*, is the world's largest cereal crop (Dumato *et al.*, 2015). It is popularly known as 'Stuff of life or King of the cereals' because of the acreage occupied, high productivity and the prominent position it holds in the international food grain trade. Wheat (*Triticum* spp.), is the most important cereal crop and occupies prominent position in Indian agriculture after rice. India is now the second largest producer of wheat in the world with the production hovering around 75 million tonnes during the last decade). The area and production of wheat in India during year 2016-17 was recorded 30.97 million ha with 97.44 million tonnes production and with an average productivity of 3172 kg ha-1 (Director's Report, IIWBR, Karnal, 2016-17). The problem of drought is in the soil with low water holding capacity especially in the rain fed areas of mountainous and sub-mountainous regions. Therefore, there is an urgent need for genetic improvement of wheat in such environments. One of the ways by which this can be achieved is by the incorporation of genes from winter wheat. The importance of winter wheat for the improvement of spring wheat under rainfed conditions was highlighted as early as in 1949 by Ackerman and Mackey. The success of winter x spring hybridization depends upon the ability of these two physiologically different ecotypes to combine well with each other. In order to formulate a sound breeding strategy, information on the relative magnitude of genetic variance, heterosis study for grain yield and its related traits is essential. Such information is useful for the selection of parental lines having superior performance and isolation of potential combination for their further use in the breeding programmes. The technique of line x tester analysis tends itself to the detailed genetic analysis and identifies superior parents and cross combinations on the basis of the best heterotic crosses. Thus this strategy of commercial production of hybrid varieties will be helpful to overcome the yield plateau. Further, the winter wheat when facultative in nature, flower under condusive environmental conditions and can be utilized in hybridization programme.

2. Materials and methods
The breeding material, represented ten winter wheat and their derivatives that were used as females (lines) and three of spring wheat, used as males (Testers). The above selected ten winter wheat lines used as females were crossed with three spring wheat lines used as males

(Testers) in Line x Tester fashion during 2015-2016 at university Research Farm of Sher-e- Kashmir university of Agricultural Sciences and Technology, Jammu (SKUAST, J) Main campus, Chatha, Jammu to generate 30 F_1s. These were advanced in off-season nursery to generate 30 F_2 s. Thirty F_1 crosses then 30 F_2 crosses and 13 Parents (10 lines + 3 testers) were evaluated in Randomized Block Design replicated thrice at the Research Farm of Sher-e- Kashmir university of Agricultural Sciences and Technology, Jammu (SKUAST,J) Main campus, Chatha, Jammu during the rabi season of 2016. Experimental Plot in each replication consisted of a single row of 1.5 m length spaced 25 cm apart for number of such rows. For proper growth the seedling – seedling spacing was maintained at 5 cm. The observation were recorded on five competent for different traits namely: tillers per plant, spike length, grains per plant, 1000 grain weight, Biological yield per plant, grain yield per plant and harvest index. The per cent increase (+) or decrease (-) of F_1 cross over mid-parent as well as better parent was calculated to observe heterotic effects for all the traits related to drought tolerance. The estimate of heterosis over the mid-parent and better parent (heterobeltiosis) was calculated using the procedure of Matzinger *et al.* (1962).

$$\text{Heterosis (\%)} = \frac{F_1 - MP}{MP} \times 100$$

$$\text{Heterobeltiosis (\%)} = \frac{F_1 - BP}{BP} \times 100$$

MP = mid parent value of the particular F_1 cross $(P_1 + P_2)/2$
BP = better parent value in the particular F_1 cross

3. Results and discussion

Manifestation of hybrid vigour has been concentrated more in cross-pollinated crops wherein higher level of heterozygosity can be maintained to exploit this vigour. In the present study heterosis in the F_1 an F_2 generations was estimated to examine the overall behavior of cross combination for economic traits. The heterosis was measured against the performance of better parent of a cross (table1-3). Heterosis to the extent of 10.0 or more percent in F_1 for all the traits (except maturity traits where 5.0 or more percent) was considered good in the present study. Retention of this heterosis in F_2 or exceeding the F_1 value was also considered favourable. Mention about such cross combination has been made neither to. Heterosis for productive tillers per plant per plant in F_1 was exhibited by 4 cross combination viz: Blue boy x PBW 175 (22.62%); WW21 x PBW 175 (10.7%); and Nordresprez x PBW 175 (17.9%). For spike length only one cross combination viz; WW21 x PBW 175 releaved significant heterosis in F_1 (11.25%) and F_2 (13.82). For grain per plant the significant desirable crosses showing heterosis were Arkaan x PBW 175 (11.85% in F_1 and 9.4 in F_2); Diana NS 720 x PBW175 (20.9% in F_1 and 20.2% in F_2); Diana NS 720 x PBW 644 (11.8% in F_2) and WW 25 x PBW 175 (13.6% in F_1 and 14.4 % in F_2). For 1000 grain weight none of the crosses revealed heterosis in F_1 (23.9%) and F_2 (25.5%), while as the cross WW25 x PBW175 exhibited 10.1% heterosis in F_2.

The most important trait i.e grain yield per plant exhibited significant (11.2 %), Diana NS 720x PBW 175 (14.2 %) and WW21 x PBW 175 (10.2 %). In the F_2 generation the crosses showing significant desirable were Blue boy x PBW 175 (10.3%); China x PBW 644 (10.7%); Diana NS 720 x PBW 175 (17.3 %); WW21 x PBW 175 (12.2 %); WW12 x PBW 644 (11.6%); Diana x PBW 644 (10.2%) and Diana x PBW 175 (10.1%). Some of the crosses revealed higher heterosis in F_2 generation than F_1 generation. None of the cross combination revealed desirable significant heterosis for harvest index in the F_1 generation with highest heterosis in F_2 (9.5) exhibited by WW12 x PBW 175.

Table 1: Estimates of Heterosis over (B.P) and per se performance on the basis of F_1 and F_2 generation of crosses

Cross combination	No.of tillers per plant				Spike length			
	Mean of the Cross	Mean of B.P	F_1 Heterosis (%)	F_2 Heterosis (%)	Mean of the Cross	Mean of B.P	F_1 Heterosis (%)	F_2 Heterosis (%)
1 Arkaan*PBW 175	28.3	28.0	1.19	10.00	10.4	11.0	-5.22	-11.25
2 Arkaan*PBW 644	19.0	27.0	-29.63	-22.50	8.37	9.8	-15.22	-1.72
3 Arkaan*WH1080	19.3	26.6	-27.50	-31.25	10.3	9.8	4.93	8.60
4 Blue boy*PBW 175	31.3	28.0	11.90	30.26	11.5	11.0	4.62	4.62
5 Blue boy*PBW 644	21.6	27.0	-19.75	-3.95	9.0	10.1	-10.69	-1.84
6 Blue boy*WH1080	18.6	25.3	-26.32	-22.37	8.9	10.1	-11.61	-13.74
7 China*PBW 175	31.6	30.6	3.26	-3.26	10.6	11.0	-3.89	-6.27
8 China*PBW 644	17.6	30.6	-42.39	-45.65	7.9	10.6	-25.53	-22.40
9 China*WH1080	20.6	30.6	-32.61	-31.52	8.2	10.6	-22.37	-16.11
10 WW 23*PBW 175	26.0	30.6	-15.22	-11.96	11.0	11.0	0.06	10.02
11 WW 23*PBW 644	20.0	30.6	-34.78	-34.78	8.4	9.9	-15.35	-4.65
12 WW 23*WH1080	18.0	30.6	-41.30	-40.22	7.5	9.9	-24.08	-20.70
13 DianaNS 72*PBW 175	34.3	28.0	22.62	6.25	10.6	11.0	-4.01	-4.95
14 DianaNS 72*PBW 644	21.6	27.0	-19.75	-27.50	8.1	10.0	-18.52	-15.86
15 DianaNS 72*WH1080	24.0	26.6	-10.00	-2.50	8.0	10.0	-19.59	-14.26
16 WW21*PBW 175	32.3	28.0	15.48	17.72	12.2	11.0	11.25	13.82
17 WW21*PBW 644	28.6	27.0	6.17	-11.39	8.6	9.8	-12.27	-11.73
18 WW21*WH1080	24.6	26.3	-6.33	-21.52	9.3	9.8	-4.80	-2.20
19 WW25*PBW 175	30.0	28.0	7.14	16.67	11.5	11.0	4.10	3.80
20 WW25*PBW 644	19.6	27.0	-27.16	-18.06	7.3	9.2	-20.66	-13.83
21 WW25*WH1080	24.3	24.0	1.39	1.39	8.2	9.3	-11.50	-7.92
22 WW12*PBW 175	30.6	30.0	2.22	0.00	10.7	11.0	-3.02	4.37
23 WW12*PBW 644	20.0	30.0	-33.33	-31.11	8.4	11.0	-23.59	-21.65
24 WW12*WH1080	17.6	30.0	-41.11	-40.00	7.8	11.0	-29.15	-23.20
25 Nordresprez*PBW 175	32.3	28.0	15.48	23.75	11.3	11.0	2.35	2.84

26 Nordresprez*PBW 644	19.3	27.0	-28.40	-32.50	8.8	10.4	-14.64	-16.41
27 Nordresprez*WH1080	18.6	26.6	-30.00	-23.75	8.4	10.4	-18.65	-20.25
28 Drina*PBW 175	34.0	34.0	0.00	-4.90	11.3	11.2	0.86	5.26
29 Drina*PBW 644	21.3	34.0	-37.25	-34.31	7.8	11.2	-30.18	-24.24
30 Drina*WH1080	20.3	34.0	-40.20	-43.14	7.3	11.2	-34.51	-27.35

Table 2: Estimates of Heterosis over (B.P) and per se performance on the basis of F_1 and F_2 generation of crosses

Cross combination	No.of grains per spike				Grain yield			
	Mean of the Cross	Mean of B.P	F_1 Heterosis (%)	F_2 Heterosis (%)	Mean of the Cross	Mean of B.P	F_1 Heterosis(%)	F_2 Heterosis (%)
1 Arkaan*PBW 175	47.3	42.3	11.81	9.45	67.6	65.6	3.05	4.06
2 Arkaan*PBW 644	41.0	40.6	0.90	3.36	44.5	54.1	-17.68	-11.52
3 Arkaan*WH1080	36.1	41.2	-12.52	-7.43	48.0	54.1	-11.21	-22.92
4 Blue boy*PBW 175	47.1	48.6	-3.22	-3.01	71.1	65.6	8.27	10.30
5 Blue boy*PBW 644	34.6	48.6	-28.77	-26.03	55.3	52.0	6.41	3.21
6 Blue boy*WH1080	38.0	48.6	-21.92	-16.51	47.0	52.6	-10.70	-20.20
7 China*PBW 175	50.4	49.3	2.16	2.16	73.0	65.6	11.17	13.71
8 China*PBW 644	38.5	49.3	-21.96	-14.53	53.0	50.9	4.19	10.74
9 China*WH1080	38.0	49.3	-22.97	-25.74	44.8	52.6	-14.81	-12.28
10 WW 23*PBW 175	48.6	46.6	4.29	6.00	65.0	65.6	-1.02	1.52
11 WW 23*PBW 644	38.3	46.6	-17.86	-20.00	39.8	58.5	-31.99	-23.45
12 WW 23*WH1080	43.0	46.6	-7.86	-14.29	35.4	58.6	-39.44	-30.90
13 Diana NS 72*PBW 175	52.0	43.0	20.93	20.16	75.0	65.6	14.21	17.26
14 Diana NS 72*PBW 644	44.0	43.0	2.33	11.78	48.3	50.9	-5.63	-9.56
15 Diana NS 72*WH1080	39.6	43.0	-7.75	-4.65	52.0	52.6	-1.20	-3.10
16 WW21*PBW 175	41.3	46.0	-10.14	-8.04	72.3	65.6	10.15	12.18
17 WW21*PBW 644	33.5	46.0	-27.03	-19.78	45.7	51.0	-10.39	-6.47
18 WW21*WH1080	34.7	46.0	-24.49	-11.59	54.8	52.6	4.24	-1.14
19 WW25*PBW 175	50.0	44.0	13.64	14.39	66.2	65.6	0.86	-10.51
20 WW25*PBW 644	41.1	44.0	-6.52	-9.85	42.4	50.9	-16.63	-13.36
21 WW25*WH1080	39.2	44.0	-10.83	-16.82	53.7	52.6	2.09	-1.08
22 WW12*PBW 175	40.6	42.3	-4.09	-8.03	72.1	65.6	9.80	11.57
23 WW12*PBW 644	34.2	42.3	-19.06	-13.54	57.5	63.2	-9.02	-13.24
24 WW12*WH1080	42.6	42.3	0.79	2.83	45.7	63.2	-27.64	-31.86
25 Nordresprez*PBW 175	51.0	46.6	9.29	10.71	68.3	65.6	4.06	7.36
26 Nordresprez*PBW 644	40.6	46.6	-12.86	-12.86	45.3	60.3	-24.92	-33.20
27 Nordresprez*WH1080	42.3	46.6	-9.29	-19.29	44.3	60.3	-26.52	-21.55
28 Drina*PBW 175	47.6	46.0	3.62	8.70	69.6	65.6	6.09	10.15
29 Drina*PBW 644	31.5	46.0	-31.52	-26.45	52.5	59.7	-12.00	-6.42
30 Drina*WH1080	40.3	46.0	-12.32	-13.04	46.0	59.7	-22.94	-15.68

Table 3: Estimates of Heterosis over (B.P) and per se performance on the basis of F_1 and F_2 generation of crosses

Cross combination	1000 grain weight				Biological yield per plant				Harvest Index			
	Mean of the Cross	Mean of B.P	Mean of the Cross	Mean of B.P	F_1 Heterosis (%)	Residual heterosis in F_2	F_1 Heterosis (%)	F_2 Heterosis (%)	Mean of the Cross	Mean of B.P	F_1 Heterosis (%)	F_2 Heterosis (%)
1 Arkaan*PBW 175	45.9	60.4	47.3	48.7	-2.81	-5.20	-24.04 **	-27.89	135.3	129.3	4.61	-6.61
2 Arkaan*PBW 644	39.4	60.4	33.9	50.6	-33.09	-31.98	-34.84 **	-34.45	123.3	113.1	9.05	11.19
3 Arkaan*WH1080	36.6	60.4	40.6	47.8	-15.04	-9.33	-39.42 **	-33.08	97.1	138.4	-29.83	-18.18
4 Blue boy*PBW 175	40.4	55.5	48.3	48.7	-0.75	2.84	-27.21 **	-21.62	140.6	129.3	8.73	7.78
5 Blue boy*PBW 644	30.8	55.5	39.0	50.6	-23.03	-22.36	-44.50 **	-27.09	108.5	108.1	0.34	0.85
6 Blue boy*WH1080	29.5	55.5	36.0	47.0	-23.51	-22.92	-46.79 **	-25.23	102.3	138.4	-26.10	-26.47
7 China*PBW 175	37.4	52.6	51.0	49.3	2.68	5.17	-28.86 **	-28.86	133.6	129.3	3.32	-19.94
8 China*PBW 644	30.5	52.6	34.3	50.6	-32.24	-26.32	-42.09 **	-28.29	110.0	123.6	-11.05	-10.22
9 China*WH1080	31.8	52.6	32.6	49.3	-34.23	-33.36	-39.56 **	-18.23	121.3	138.4	-12.37	
10 WW 23*PBW 175	49.4	51.0	51.3	50.0	2.53	3.36	-3.07	-9.35	141.3	129.3	9.25	-0.59
11 WW 23*PBW 644	38.2	51.0	34.6	50.0	-31.58	-27.72	-25.03 **	-12.88	106.3	127.8	-16.81	-15.97
12 WW 23*WH1080	39.0	51.0	33.0	50.0	-34.07	-34.86	-23.40 **	-16.86	121.6	138.4	-12.13	-5.18
13 Diana NS 72*PBW 175	35.9	50.1	47.8	48.7	-1.85	3.63	-28.32 **	-28.32	136.0	129.3	5.13	0.28
14 Diana NS 72*PBW 644	30.5	50.1	37.0	50.6	-26.97	-24.90	-39.16 **	-25.86	118.1	124.3	-4.99	-4.75
15 Diana NS 72*WH1080	36.1	50.1	31.5	47.0	-32.99	-34.30	-27.86 **	-21.21	118.6	138.4	-14.30	-12.30
16 WW21*PBW 175	47.7	50.0	51.0	48.7	4.72	7.94	-4.60	-5.93	122.6	129.3	-5.18	-3.50
17 WW21*PBW 644	30.1	50.0	37.3	50.6	-26.32	-28.29	-39.67 **	-33.00	88.0	125.3	-29.73	-29.73
18 WW21*WH1080	33.7	50.0	34.2	48.2	-29.14	-29.70	-32.60 **	-28.27	108.8	138.4	-21.40	-23.71
19 WW25*PBW 175	49.1	49.0	37.3	49.1	-24.01	-17.10	0.20	0.20	141.6	129.3	9.51	10.05
20 WW25*PBW 644	32.0	49.0	31.3	50.6	-38.16	-25.66	-34.69 **	-27.21	120.3	127.4	-5.60	-4.94
21 WW25*WH1080	31.3	49.0	35.6	49.1	-27.40	-6.37	-36.12 **	-25.24	117.0	138.4	-15.50	-16.20
22 WW12*PBW 175	49.0	48.6	50.6	48.7	4.04	9.51	0.75	-1.99	160.3	129.3	23.94	25.49
23 WW12*PBW 644	36.5	48.6	37.6	50.6	-25.66	-13.82	-24.88 **	-27.90	126.0	129.2	-2.48	-2.50
24 WW12*WH1080	34.6	48.6	30.6	47.0	-34.84	-34.84	-28.72 **	-20.77	109.6	138.4	-20.85	-21.86
25 Nordresprez*PBW 175	46.3	48.0	44.2	48.7	-9.10	-21.36	-3.47	2.08	115.0	129.3	-11.11	-7.51

26 Nordresprez*PBW 644	32.0	48.0	35.6	50.66	-29.74	-3.95	-33.33 **	-29.86	111.0	123.6	-10.19	-10.68
27 Nordresprez*WH1080	30.0	48.0	31.9	47.0	-32.03	-3.70	-37.50 **	-36.67	108.3	138.4	-21.76	-11.84
28 Drina*PBW 175	48.0	47.5	49.6	48.7	2.01	4.06	1.05	1.19	138.2	129.3	6.88	8.40
29 Drina*PBW 644	31.0	47.5	40.7	50.6	-19.59	-5.11	-34.74 **	-22.95	117.2	125.0	-6.24	-4.91
30 Drina*WH1080	31.6	47.5	39.17	47.0	-16.78	4.47	-33.33 **	-36.07	111.6	138.4	-19.35	-21.33

Heterosis in bread wheat was first reported by Freeman (1919) [9] in durum x spring wheat crosses, whereas Engledow and Pal (1934) [8] reported it for the first time for grain yield in F_1 and F_2 generations. Similarly, heterosis for spike length per plant, grains per plant and grain weight was reported by Boyce (1948) [4] in bread wheat, and suggested that total yield depended upon the product of yield components, which individually may or may not reveal heterosis. Heterosis for many traits in bread wheat has been reported by several workers. Singh and Kandola (1968) [21] for grain yield components Singh and singh (1970) for grain yield, spike number and grain weight. Paroda and joshi (1972) [15] for grain yield; Popov and Stankov (1972) [17] for grain yield and grain weight. Chawas and Abel Halim (1973) [5] reported negative heterosis for productive tillers, spike length, grain number, grain weight and grain yield in most of the crosses. Significant heterosis for spike number and spike length was also reported. Krishna and Ahmad (1992) [12] reported significant heterosis for 1000 grain weight, grain yield and harvest index by Chaudhary *et al* (1993) [6]. Nehvi *et al.* (2000) [14] found higher magnitude of heterosis over mid parent than better parent in cross combinations. Salgotra *et al* (2002) [19] observed significant heterosis over standard check in 2 crosses involving winter x spring genotypes for grain yield, grain number and harvest index. Baric *et al* (2004) [3] recorded significant heterosis for grains per plant and 1000 grain weight in winter x spring crosses. Innamullah *et al* (2006) [10] reported heterosis in several crosses of bread wheat for maturity traits, tillers per plant, flag leaf area, plant height, spike length, grains per plant, 1000 grain weight and seed protein content. Prakash (2006) [18] reported heterosis for grain yield and yield components in wheat as manifestation of dominant gene action.

4. Conclusion

Heterotic pattern estimation revealed that none of the cross combination had significant heterosis for all the traits. However, on individual trait basis, some of the crosses revealed significant heterosis, WW21 x PBW 175 for productive tillers per plant; WW21 x PBW 175 for spike length, Arkaan x PBW 175 for grains per plant, WW12 x PBW 175 for biological yield and for grain yield the cross was Diana NS 720 x PBW 175 for both the generations, none of the crosses in F_1 or F_2 revealed desirable heterosis (10% or more) for 1000 grain weight and harvest index. Accordingly, for population improvement of wheat for rainfed ecosystem of Jammu regions from the present set of material, multiline crossing programme is needed to introgress allelic resources from elite genotypes and the progenies showing better early generation performance are further crossed through bi-parental procedure to increase chances of generation of hidden latent variability in heterozygous polygenic blocks. Use of recurrent selection procedure for the identification of superior transgressive segregants before fixation of alleles in homozygous condition.

5. References

1. Akbar M, Anwar J, Hussain M, Iqbal MM, Sabir W. Heterosis and heterobeltiosis for grain yield improvement in bread wheat. Journal of Agricultural Research. 2010; 48(1):15-23
2. Barot HG, Patel MS, Sheikh WA, Patel LP, Allam CR. Heterosis and combining ability analysis for yield and its component traits in wheat (*Triticum aestivum* L.). Electronic Journal of Plant Breeding. 2014; 5(3):350-359.
3. Baric M, Sarcevic H, Keresa S. Analysis of yield components of F1 hybrids of crosses between spring and winter, 2004.
4. Boyce SW. A note on heterosis in a *Triticum vulgare* cross. New Zealand J Sci. Technol. 1948; 30:23.
5. Chawas MI, Abel-Halim AAA. Genetic studies of yield components in wheat. Egyptian J Bot. 1973; 16:465-482.
6. Chaudhary HK, Kapoor AS, Walia DP. Manifestation of heterosis in winter x spring wheat crosses. In heterosis breeding in crop plant-Theory and Applications; short communications symposium, Ludhiana, 1993, 23-24.
7. Desale CS, Mehta DR. Heterosis and combining ability analysis for grain yield and quality traits in bread wheat (*Triticum aestivum* L.). Electronic Journal of Plant Breeding. 2013; 4(3):1205-1213.
8. Engledow FL, Pal BP. Investigations on yield in cereals 1: VIII. Hybrid vigour in wheat. The Journal of Agricultural Science. 1934; 24(3):390-409.
9. Freeman GF. The heredity of quantitative characters in wheat. Genetics. 1919; 4(1):1-93.
10. Inamullah Ahmad H, Mohammadi F, Siraj-Ud-Din. Evaluation of the heterotic and heterobeltiotic potential of wheat genotypes for improved yield. Pakistan Journal of Botany. 2006; 38(4):1159-1167.
11. Kant L, Mahajan V, Gupta HS. Mid-Parent Advantage and Heterobeltiosis in F 1 Hybrids from Crosses of winter and Spring Wheat. Sabrao Journal of Breeding & Genetics. 2011; 43(2).
12. Krishna R, Ahmad Z. Heterosis for yield components and developmental traits in spring wheat, 1992.
13. Mahmood Q, Lei WD, Qureshi AS, Khan MR, Hayat Y, Jilani G *et al*. Heterosis, correlation and path analysis of morphological and biochemical characters in wheat [*Triticum aestivum* (L.) em. Thell]. Agricultural Journal. 2006; 1(3):180-185.
14. Nehvi FA, Wani A, Zargar GH. Heterosis in bread wheat (*Triticum aestivum* L.). Applied Biological Research. 2000; 2(1-2):69-74.
15. Paroda RS, Joshi AB. Genetic architecture of yield and components of yield in wheat. Indian Journal of Genetics. 1972; 30:298-314.
16. Parakasa Rao VS. Heterosis, combining ability and gene action for yield and its components in wheat. Biovigayanam, 1980; 3:81-96.
17. Popov P, Stankov I. Studies on heterosis in soft winter wheat. Gen Selek, 1972.
18. Prakash V, Saini DD, Pancholi SR. Genetic basis of heterosis for grain yield and its traits in wheat [*Triticum aestivum* (L.) em. Thell] under normal and late so. Crop Research. 2006; 31:245-249.
19. Salgotra RK, Thakur KS, Sethi GS, Sharma JK. Heterosis in winter x spring wheat crosses. Indian Journal of Genetics and Plant Breeding. 2002; 62(2):104-106.

20. Singh KB, Singh JK. Potentialities of heterosis breeding in wheat. Euphytica. 1971; 20(4):586-590.
21. Singh KB, Kandola HS. Heterosis in wheat. Indian Journal of Genetics and Plant Breeding (The). 1968; 29(1):53-61.
22. Singh MK, Sharma PK, Tyagi BS, Singh G. Heterosis for yield component traits and protein content in bread wheat under normal and heat stress environment. Cereal Research Communications. 2014; 42(1):151-162.
23. Singh V, Krishna R, Singh S, Vikram P. Combining ability and heterosis analysis for yield traits in bread wheat (*Triticum aestivum*). Indian Journal of Agricultural Sciences. 2012; 82(11):254-258.
24. Zykin AG. Ways of shortening the time of growing elite seed tubers, variety renovation and replacement of potatoes. Biulleten', 1976.