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The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(4): 1469-1475

www.thepharmajournal.com
Received: 17-02-2022
Accepted: 23-03-2022

Deepak Panwar
Department of Genetics and Plant Breeding, Rajasthan College of Agriculture, MPUAT, Udaipur, Rajasthan, India

Hemlata Sharma
Department of Genetics and Plant Breeding, Rajasthan College of Agriculture, MPUAT, Udaipur, Rajasthan, India

Dalip
Department of Genetics and Plant Breeding, Rajasthan College of Agriculture, MPUAT, Udaipur, Rajasthan, India

Sanjay Kumar
Department of Genetics and Plant Breeding, Rajasthan College of Agriculture, MPUAT, Udaipur, Rajasthan, India

Bhavna Goswami
Department of Genetics and Plant Breeding, Rajasthan College of Agriculture, MPUAT, Udaipur, Rajasthan, India

Vikas Khandelwal
ICAR-AICRP on Pearl Millet, PC Unit, Mandor, Agriculture University, Jodhpur, Rajasthan, India

Vandna
Department of Horticulture, Rajasthan College of Agriculture, MPUAT, Udaipur, Rajasthan, India

Corresponding Author:
Deepak Panwar
Department of Genetics and Plant Breeding, Rajasthan College of Agriculture, MPUAT, Udaipur, Rajasthan, India

Analysis of heterosis in barley (*Hordeum vulgare* L.) for yield, its attributing and quality traits

Deepak Panwar, Hemlata Sharma, Dalip, Sanjay Kumar, Bhavna Goswami, Vikas Khandelwal and Vandna

Abstract
For the present experiment assessed the magnitude of heterosis by using 9 parents were crossed in diallel (without reciprocals) mating design to obtain 36 crosses during *rabi* 2017-18. The experimental material thus consisted of 9 Parents 36 crosses and 2 checks *viz.*, RD 2899 and BH 946, total of 47 entries, were evaluated during *rabi* 2018-19 in Randomized Block Design (RBD) with 3 replications, the observations were recorded for 13 characters to study the magnitude of relative heterosis (RH), heterobeltiosis (HB), economic heterosis (EH). One cross RD 2786 × BH 959 depicted positive significant economic heterosis (8.82%) for grain yield per plant over the best check BH 946 and also exhibited positive economic heterosis for flag leaf area, spike length, 1000-grain weight. Heterobeltiosis for grain yield per plant was exhibited by cross RD 2035 × DWRB 92 and maximum relative heterosis exhibited by the cross DWRB 91 × BH 959. Parents RD 2786, RD 2715 and BH 959 could be recommended for utilizing in varietal development.

Keywords: Diallel without reciprocals, economic heterosis, grain yield, heterobeltiosis, relative heterosis

Introduction
Barley (*Hordeum vulgare* L., 2n= 2x =14) is the world's 4th very most important cereal crop after Wheat (*Triticum aestivum* L.), Maize (*Zea mays* L.) and Rice (*Oryza sativa* L.). It belongs to family Poaceae. Barley is popularly known as "Jau" in Hindi and one of the most important cereal grain crops in India. It is cultivated as a *rabi* season crop in India and sowing is done from October to December and harvesting from March to May. Barley is most paramount cereal crop and considered as the 1st cereal crop domesticated for use by man as food and feed (Potla *et al.* 2013). This crop requires temperature of 12°C to 16°C at growing stage and about 30 °C to 32 °C at maturity. It is very susceptible to frost at any stage of its growth and has very good tolerance to drought conditions. It is grown under marginal to sub marginal land and mostly under rain fed conditions. It is an essential crop of North India and three spp. of barley *viz.*, two-row barley (*H. distichum*), four-row barley (*H. tetrastichum*), six-row barley (*H. vulgare*) and husk & huskless barley are available. Barley is utilized almost 60 per cent as animal feed, around 30 per cent for malt production, 7 per cent for seed production and only 3 per cent for human food (Baik *et al.* 2008) [2]. It is produced primarily as animal feed, while it has same nutritive value as corn. Barley has most importance in neutraceutical diets and has potential health benefit. It contains high amounts of carbohydrates, moderate amounts of protein, calcium, phosphorus and small amount of the vitamin B. By-products of the brewing process and malt sprouts are also used as livestock feed. Barley is also used in liquor industry and breakfast foods. In Rajasthan, principle cereal crops *viz.*, Maize, Wheat and Barley are grown and their average yield is higher in Rajasthan. The places where soil is light, irrigation is scanty or saline are being replaced by barley. Improvement of high yielding crop cultivars requires a thorough acquaintance of the existing genetic variation for grain yield and its component traits (Raikwar *et al.* 2014) [10]. Till nowadays availability of desirable genotypes with better yielding is not enormously satisfactory. Hence, efforts are being made to develop the desirable genotypes which also can be adopted widely. Desirable attributes along with higher yield from two or more genotypes could be brought together through hybridizations. To create an efficient breeding programme for development of superior genotypes and to breed varieties with high yielding potential with higher malting requirement and greater stability for industrialized utilization is the ultimate objective of plant breeders.

The main objectives of this study were to identify superior parents and their cross combinations from half diallel mating design to obtain high grain yield. The analysis of heterosis has a straight manner on the breeding methodology to be employed for varietal enhancement and provides most valuable genetic informations. Development of potential varietal hybrids also requires knowledge of combining ability of the breeding materials and selection based on this has been used as an important breeding approach in crop enhancement. (Amiruzzaman *et al.* 2011) [1]

Materials and Methods

The experimental material thus consisted of 9 genetically diverse parents namely RD 2035, RD 2552, RD 2786, RD 2715, DWRB 91, BH 959, DWRB 92, DWRB 64, and BH 393. parents were crossed in diallel (without reciprocals) mating design to obtain 36 crosses during rabi 2017- 18. Nine parents 36 crosses and 2 checks *viz.*, RD 2899 and BH 946, total of 47 entries, were evaluated during *rabi* 2018-19 in Randomized Block Design (RBD) with 3 replications, the observations were recorded for 13 characters to study the magnitude of relative heterosis (RH), heterobeltiosis (HB), economic heterosis (EH). The experiment carried out at the research farm, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur (Rajasthan) during rabi 2018-2019. The observations recorded for thirteen characters *viz.*, days to 50 per cent heading, days to 75 per cent maturity, plant height, flag leaf area, number of effective tillers per plant, spike length, number of grains per spike, number of spikelets per plant, 1000- grain weight, grain yield per plant, biological yield per plant, harvest index and protein content. The data were subjected for analysis of variance for all the characters studied as per the method suggested by Panse and Sukhatme (1985). Estimation of relative heterosis/mid parent (MP) heterosis, heterobeltiosis/better parent (BP) heterosis and economic/standard check (SC) heterosis suggested by (Shull 1908), (Fonesca and Patterson 1968) [5], (Briggle 1963) [4], respectively.

Results and Discussion

The analysis of variance revealed that mean squares due to genotypes, parents and crosses were significant for all the traits except days to 75 per cent maturity. While mean squares due to for parents v/s crosses were significant for flag leaf area, number of grains per spike, grain yield per plant and protein content.

Out of 36 crosses, 2 crosses *viz.*, DWRB 64 × BH 393 (-6.84%) and DWRB 92 × BH 393 (-6.67%) showed negative significant relative heterosis for days to 50 per cent heading while none of the cross showed negative significant heterobeltiosis and economic heterosis for this trait. relative heterosis for days to 75 per cent maturity revealed that none of the cross showed negative significant relative heterosis, heterobeltiosis and economic heterosis. the negative significant relative heterosis for plant height was expressed by 2 crosses *viz.*, DWRB 91 × BH 959 (-7.91%) and RD 2715 × BH 959 (-9.66%). While one cross RD 2715 × BH 959 (-7.05%) showed negative significant heterobeltiosis and one cross BH 959 × DWRB 64 (-7.53%) exhibited economic heterosis for plant height. These similar resultant also reported by Madhukar *et al.* (2018) [7].

A perusal of estimates of heterosis for flag leaf area revealed that 9 crosses exhibited positive significant relative heterosis. It ranged from 9.03 per cent (DWRB 64 × BH 393) to 38.00 per cent (RD 2552 × DWRB 92). Whereas two crosses *viz.*, RD 2786 × DWRB 64 (16.95%) and RD 2552 × DWRB 92 (37.47%) showed positive heterobeltiosis for this trait. five crosses showed positive significant economic heterosis which varied from 10.52 per cent (DWRB 91 × BH 959) to 18.71 per cent (RD 2035 × RD 2786) for this trait.5 crosses exhibited positive significant relative heterosis out of 36 crosses. The magnitude of heterosis ranged from 10.17 per cent (RD 2035 × RD 2786) to 31.31 per cent (RD 2715 × BH 959). Only single cross RD 2715 × BH 959 (25.32%) exhibited positive significant heterobeltiosis for this trait.

Three crosses showed positive significant economic heterosis which varied from 18.03 per cent (RD 2035 × RD 2786) to 31.54 per cent (RD 2035 × BH 959).These resultant are in accordance with the results obtained by Madhukar *et al.* (2018) [7].

A perusal of data indicated that out of 36 crosses, 4 crosses exhibited positive significant relative heterosis for this character. Relative heterosis ranged from 10.60 per cent (RD 2786 × BH 959) to 22.17 per cent (DWRB 91 × DWRB 92). In case of heterobeltiosis 2 crosses namely DWRB 64 × DWRB 92 (13.03%) and DWRB 91 × DWRB 92 (15.71%) showed positive significant heterobeltiosis for spike length. Only one cross namely RD 2786 × BH 959 (14.39%) exhibited positive significant economic heterosis.

Significant relative heterosis in positive direction was observed in 7 crosses for this trait. The magnitude of heterosis varied from 5.59 per cent (RD 2035 × DWRB 64) to 47.38 per cent (DWRB 91 × BH 959). In case of heterobeltiosis, none of crosses expressed positive significant estimates. In case of economic heterosis, out of 36 crosses, 6 crosses showed positive significant estimates which ranged from 11.16 per cent (RD 2035 × RD 2715) to 20.55 per cent (RD 2715 × BH 959). Pesaraklu *et al.* (2016) [9] also reported the same results.

Eleven crosses showed positive significant relative heterosis among 36 crosses. The analysis of heterosis ranged from 9.70 per cent (RD 2715 × DWRB 91) to 37.81 per cent (RD 2715 × BH 959). Only 4 crosses expressed positive significant heterobeltiosis for number of spikelets per plant which varied from 11.41 per cent (RD 2786 × BH 393) to 35.09 per cent (RD 2715 × BH 959). Four crosses expressed positive significant economic heterosis which ranged from 21.09 per cent (DWRB 91 × BH 959) to 36.45 per cent (RD 2035 × RD 2786 and RD 2715 × BH 959) for this trait.

Out of 36 crosses, positive significant relative heterosis for 1000-grain weight was expressed by eleven crosses. Relative heterosis varied from 5.81 per cent (RD 2786 × BH 959) to 8.16 per cent (DWRB 91× BH 959). In case of heterobeltiosis, none of crosses expressed positive significant estimates. Only one cross RD 2786 × BH 959 (9.87%) showed positive significant economic heterosis for this trait. The results of this study are in agreement with Pesaraklu *et al.* (2016) [9].

The perusal of estimates of relative heterosis revealed that out of 36 crosses, 15 crosses exhibited significant positive relative heterosis for grain yield per plant and the magnitude varied from 8.30 per cent (RD 2035 × BH 959) to 20.06 per cent (DWRB 91 × BH 959). Three crosses showed significant positive heterobeltiosis for grain yield per plant and the magnitude of heterobeltiosis ranged from 9.91 per cent (RD

2715 × DWRB 64) to 14.56 per cent (RD 2035 × DWRB 92). Only one cross namely RD 2786 × BH 959 (8.82%) showed positive significant economic heterosis for this trait. Potla *et al.* (2013), Bornare *et al.* (2014) [3], Madakemohekar *et al.* (2015) [6] and Ram and shekhawat (2017) [11] also reported the similar findings for grain yield with respect to economic heterosis.

The perusal of estimates of heterosis for this trait revealed that out of 36 crosses, five crosses exhibited positive significant relative heterosis. It ranged from 16.47 per cent (RD 2035 × DWRB 92) to 43.72 per cent (RD 2035 × BH 393). While another cross RD 2035 × BH 393 (31.47%) expressed positive significant heterobeltiosis. Only one cross RD 2035 × BH 393 (20.35%) showed positive significant economic heterosis for biological yield per plant.

Three crosses exhibited positive significant relative heterosis out of 36 crosses, magnitude of heterosis ranged from 15.92 per cent (RD 2715 × DWRB 91) to 43.34 per cent (RD 2715 × BH 959). Only single cross RD 2715 × BH959 (34.40%) exhibited positive significant heterobeltiosis for this trait. The positive significant economic heterosis was expressed by the cross RD 2715 × BH 959 (36.86%).

A perusal of estimates of heterosis for protein content revealed that out of 36 crosses, 14 crosses exhibited positive significant relative heterosis, magnitude of which ranged from 3.96 per cent (DWRB 64 × DWRB 92) to 17.78 per cent (RD 2035 × RD 2786). Six crosses exhibited positive significant heterobeltiosis with magnitude varied from 4.05 per cent (RD 2786 × BH 959) to 15.35 per cent (RD 2035 × RD 2786). While two crosses *viz.*, RD 2715 × BH 959 (4.50%) and DWRB 91 × BH 959 (9.00%) exhibited positive significant economic heterosis for protein content.

Table 1: Mean squares for thirteen characters in Barley (*Hordeum vulgare* L.)

S.N.	Characters	Replication	Genotype	Parent	crosses	Parent v/s crosses	Error
		[2]	[44]	[8]	[35]	[1]	[88]
1	Days to 50 per cent heading	2.81	22.17**	34.26**	20.02**	0.74	9.81
2	Days to 75 per cent maturity	26.34	27.38	28.42	26.88	36.30	18.22
3	Plant height (cm)	9.45	52.83**	47.09**	55.17**	16.81	13.80
4	Flag leaf area (cm^2)	0.33	52.04**	88.32**	44.68**	19.47**	1.15
5	Number of effective tillers per plant	0.05	10.51**	13.96**	10.02**	0.05	0.78
6	Spike length (cm)	2.94	10.62**	8.98**	11.22**	2.60	1.66
7	Number of grains per spike	0.25	825.74**	960.36**	806.61**	418.35**	5.15
8	Number of spikelets per plant	57.28	4089.12**	5309.08**	3926.98**	3.99	111.96
9	1000-Grain weight (g)	9.51*	11.49**	25.26**	8.64**	1.17	3.05
10	Grain yield per plant (g)	0.52	11.33**	17.36**	9.95**	11.50**	0.94
11	Biological yield per plant (g)	5.69	38.52**	65.46**	32.13**	46.50	12.48
12	Harvest index (%)	3.69	24.74**	29.35**	24.39**	0.00	4.83
13	Protein content (%)	0.05	1.34**	1.35**	1.35**	1.08**	0.07

*, ** Significant at 5% and 1% level of significance, respectively

Table 2: Percent relative heterosis (RH), heterobeltiosis (HB) and economic heterosis (EH) for Days to 50 per cent heading, Days to 75 per cent maturity and Plant height

S.N.	Crosses	Days to 50 per cent heading			Days to 75 per cent maturity			Plant height		
		RH	HB	EH	RH	HB	EH	RH	HB	EH
1.	RD 2035 × RD 2552	1.67			-1.92	0.00		-2.30		
2.	RD 2035 × RD 2786	-2.65	-0.98	-2.42	-3.06	-2.24	-0.85	-5.41	-2.46	-3.32
3.	RD 2035 × RD 2715	5.61			2.25			7.78**		
4.	RD 2035 × DWRB 91	2.19			3.85			-0.17		-0.52
5.	RD 2035 × BH 959	4.08			1.69			1.45		
6.	RD 2035 × DWRB 92	5.77			1.39			0.29		-0.02
7.	RD 2035 × DWRB 64	4.06			3.35			3.81		-0.05
8.	RD 2035 × BH 393	-3.62			3.00			0.85		
9.	RD 2552 × RD 2786	-1.41	-0.47		1.91			0.72		
10.	RD 2552 × RD 2715	-3.42	-1.40		0.28			-0.12		
11.	RD 2552 × DWRB 91	0.95			2.10			1.70		
12.	RD 2552 × BH 959	4.67			1.39			-2.42	-0.85	
13.	RD 2552 × DWRB 92	9.60**			0.27			-4.98	-2.06	-1.79
14.	RD 2552 × DWRB 64	0.00			2.19			2.13		
15.	RD 2552 × BH 393	1.99			3.51			-0.53		
16.	RD 2786 × RD 2715	-2.07			-0.56			1.79		
17.	RD 2786 × DWRB 91	2.39			1.56			0.34		
18.	RD 2786 × BH 959	5.19			-2.52	-0.85	-1.14	-1.20	-0.15	
19.	RD 2786 × DWRB 92	-0.71	-0.47		1.10			0.39		
20.	RD 2786 × DWRB 64	-0.94	-0.00		-0.83	-0.28		4.75		
21.	RD 2786 × BH 393	-3.79			5.25*			-2.10		
22.	RD 2715 × DWRB 91	6.73*			1.58			-0.74		
23.	RD 2715 × BH 959	-0.69			-1.70	-1.42	-1.70	-9.66**	-7.05*	-4.15
24.	RD 2715 × DWRB 92	-0.46			-0.28			4.73		
25.	RD 2715 × DWRB 64	-2.96	-0.93		-3.37	-2.55	-2.27	0.27		
26.	RD 2715 × BH 393	-1.73			3.88			2.07		

27.	DWRB 91 × BH 959	-4.76	-3.38	-3.38	-1.87	-0.87	-3.13	-7.91**	-6.56	-6.38
28.	DWRB 91 × DWRB 92	1.67			2.98			11.76**		
29.	DWRB 91 × DWRB 64	-1.90	0.00	0.00	-0.71		-0.85	3.66		
30.	DWRB 91 × BH 393	2.47			1.46		-1.14	0.80		
31.	BH 959 × DWRB 92	-0.71	-0.47		3.93			6.14*		
32.	BH 959 × DWRB 64	-0.00			1.13			-5.92	-1.05	-7.53*
33.	BH 959 × BH 393	-2.44			1.30		-0.28	1.46		
34.	DWRB 64 × DWRB 92	-0.23			2.78			19.70**		
35.	DWRB 92 × BH 393	-6.67*	-0.94		-1.85		-1.99	1.57		
36.	DWRB 64 × BH 393	-6.84*	-1.86		4.14			3.56		

*, ** Significant at 5% and 1% level of significance, respectively

Table 3: Percent relative heterosis (RH), heterobeltiosis (HB) and economic heterosis (EH) for Flag leaf area, Number of effective tillers per plant and Spike length

S.N.	Crosses	Flag leaf area			No. of effective tillers per plant			Spike length		
		RH	HB	EH	RH	HB	EH	RH	HB	EH
1.	RD 2035 × RD 2552	-25.05**			-22.11**			5.67	2.77	
2.	RD 2035 × RD 2786	21.17**		18.71**	10.17*		18.03**	6.76	3.45	6.55
3.	RD 2035 × RD 2715	-5.13		11.92**	-26.06**			1.66	1.36	
4.	RD 2035 × DWRB 91	-29.61**			-17.19**			1.41		
5.	RD 2035 × BH 959	-34.88**			16.55**	4.26	31.54**	-3.06		
6.	RD 2035 × DWRB 92	-23.81**			-29.61**			-6.69		
7.	RD 2035 × DWRB 64	0.25			-26.52**			-11.26*		
8.	RD 2035 × BH 393	-10.50**		0.83	-20.07**			1.37		
9.	RD 2552 × RD 2786	-4.78			3.50			-8.18		
10.	RD 2552 × RD 2715	-24.81**			-7.34			-9.87		
11.	RD 2552 × DWRB 91	-17.13**			12.03	11.57		-21.91**		
12.	RD 2552 × BH 959	-14.23**			7.31			-6.54		
13.	RD 2552 × DWRB 92	38.00**	37.47**		-0.35			7.63	4.48	
14.	RD 2552 × DWRB 64	-11.55*			-4.58			-2.58		
15.	RD 2552 × BH 393	27.27**	0.66		6.18			-3.58		
16.	RD 2786 × RD 2715	-4.65			3.07	1.71		0.77		0.28
17.	RD 2786 × DWRB 91	-23.89**			12.56	8.21		-17.81**		
18.	RD 2786 × BH 959	28.28**	4.63	14.99**	5.83			10.60*	10.14	14.39*
19.	RD 2786 × DWRB 92	12.30*	2.29		-3.08			-13.60**		
20.	RD 2786 × DWRB 64	19.69**	16.95**		6.71	4.06		-17.40**		
21.	RD 2786 × BH 393	-14.16**			12.75			-6.38		
22.	RD 2715 × DWRB 91	-17.08**			4.57			-11.52*		
23.	RD 2715 × BH 959	3.39	3.16	13.37**	31.31**	25.32**	24.77**	0.94		0.88
24.	RD 2715 × DWRB 92	-9.44*			-12.99			0.67		
25.	RD 2715 × DWRB 64	-10.09*			8.82	7.52		-10.69*		
26.	RD 2715 × BH 393	-8.67*			-1.16			-1.62		
27.	DWRB 91 × BH 959	15.31**	0.56	10.52*	18.94**	8.03	7.56	11.68*		0.92
28.	DWRB 91 × DWRB 92	-11.13*			-2.18			22.17**	15.71*	
29.	DWRB 91 × DWRB 64	-7.63			-4.54			8.52	4.08	
30.	DWRB 91 × BH 393	-10.76**			-4.54			6.52	1.24	
31.	BH 959 × DWRB 92	7.20			-12.78			-3.40		
32.	BH 959 × DWRB 64	-22.73**			-1.41			-27.53**		
33.	BH 959 × BH 393	-4.94			3.52			-0.45		
34.	DWRB 64 × DWRB 92	2.69			28.97**	6.70		14.53*	13.03*	
35.	DWRB 92 × BH 393	16.10**			-4.86			7.29	6.88	
36.	DWRB 64 × BH 393	9.03*			6.64			7.81	6.80	

*, ** Significant at 5% and 1% level of significance, respectively

Table 4: Percent relative heterosis (RH), heterobeltiosis (HB) and economic heterosis (EH) for Number of grains per spike, Number of spikelets per plant and 1000-Grain weight

S.N.	Crosses	Number of grains per spike			Number of spikelets per plant			1000-Grain weight		
		RH	HB	EH	RH	HB	EH	RH	HB	EH
1.	RD 2035 × RD 2552	-9.64**			-20.67**			4.69	2.75	
2.	RD 2035 × RD 2786	8.37**	1.08	11.49**	25.03**	1.24	36.45**	-0.92		
3.	RD 2035 × RD 2715	-2.56		11.16**	-27.02**			-0.12		
4.	RD 2035 × DWRB 91	-43.18**			-15.90**			7.36*	3.72	
5.	RD 2035 × BH 959	1.06		15.69**	13.97**		34.35**	8.09**	4.42	4.71
6.	RD 2035 × DWRB 92	-43.27**			-26.95**			3.81	2.17	
7.	RD 2035 × DWRB 64	5.59*	5.29	16.14**	-29.93**			7.05*	4.79	2.25
8.	RD 2035 × BH 393	-4.64			-25.82**			-2.01		

9.	RD 2552 × RD 2786	-1.53			28.17**	21.68**	1.59	-3.29		
10.	RD 2552 × RD 2715	-7.50**			-14.13**			4.84	0.11	
11.	RD 2552 × DWRB 91	-28.07**			15.36**	4.57		6.20	4.50	
12.	RD 2552 × BH 959	-3.92			12.13**			-0.01		
13.	RD 2552 × DWRB 92	-35.11**			-11.05*			7.56*	7.27	
14.	RD 2552 × DWRB 64	1.21			4.48			4.11	0.07	
15.	RD 2552 × BH 393	8.56**	4.10		3.32			-4.43		
16.	RD 2786 × RD 2715	-6.93**			-0.32			-5.09		
17.	RD 2786 × DWRB 91	-28.10**			11.61**	6.29		-7.24*		
18.	RD 2786 × BH 959	-4.68		2.04	4.00			5.81*	2.31	9.87**
19.	RD 2786 × DWRB 92	-30.66**			12.90**	8.32		-1.85		
20.	RD 2786 × DWRB 64	-12.06**			-0.34			-6.12*		
21.	RD 2786 × BH 393	1.22			27.42**	11.41*		-7.76**		
22.	RD 2715 × DWRB 91	-52.92**			9.70*	7.03	3.84	-3.98		
23.	RD 2715 × BH 959	1.96	1.62	20.55**	37.81**	35.09**	36.45**	3.25	2.56	2.84
24.	RD 2715 × DWRB 92	-42.67**			-0.23			-4.43		
25.	RD 2715 × DWRB 64	-19.31**			-1.51			-2.87		
26.	RD 2715 × BH 393	-8.05**			-3.93			-3.38		
27.	DWRB 91 × BH 959	47.38**		18.63**	25.29**	19.89**	21.09**	8.16**	1.07	1.35
28.	DWRB 91 × DWRB 92	-7.41			-9.47*			5.43	3.47	
29.	DWRB 91 × DWRB 64	23.13**			-4.84			-0.28		
30.	DWRB 91 × BH 393	36.71**	0.63		-5.85			1.07		
31.	BH 959 × DWRB 92	-49.95**			-9.37*			6.16*	0.98	1.26
32.	BH 959 × DWRB 64	-25.35**			-2.30			-1.56		
33.	BH 959 × BH 393	1.66		5.89	8.47			-2.47		
34.	DWRB 64 × DWRB 92	-39.14**			7.80			1.38		
35.	DWRB 92 × BH 393	46.43**	4.73		-11.44*			0.85		
36.	DWRB 64 × BH 393	-4.00			5.58			-2.82		

*, ** Significant at 5% and 1% level of significance, respectively

Table 5: Percent relative heterosis (RH), heterobeltiosis (HB) and economic heterosis (EH) for for grains yield per plant, biological yield per plant and harvest index

S.N.	Crosses	Grains yield per plant			Biological yield per plant			Harvest index		
		RH	HB	EH	RH	HB	EH	RH	HB	EH
1.	RD 2035 × RD 2552	-0.78			8.96			-6.81		
2.	RD 2035 × RD 2786	13.09**		3.62	4.90			5.41	4.65	9.19
3.	RD 2035 × RD 2715	3.64			5.25			-2.25		
4.	RD 2035 × DWRB 91	11.61*	6.00		3.49			4.32		
5.	RD 2035 × BH 959	8.30*			11.10			-1.58		0.71
6.	RD 2035 × DWRB 92	17.91**	14.56**		16.47*	6.45		0.12		
7.	RD 2035 × DWRB 64	4.14	2.79		20.59*	17.57		-9.37*		
8.	RD 2035 × BH 393	14.32**	2.66	1.70	43.72**	31.47**	20.35**	-15.61**		
9.	RD 2552 × RD 2786	-5.36			-0.03			-3.15		
10.	RD 2552 × RD 2715	10.65**	7.79		-2.96			9.62	7.78	
11.	RD 2552 × DWRB 91	-11.09*			-3.51			-5.76		
12.	RD 2552 × BH 959	-0.41			0.99			-0.46		
13.	RD 2552 × DWRB 92	5.08			2.11	0.02		2.19		
14.	RD 2552 × DWRB 64	14.19**	11.13*		17.85*	3.37		-3.18		
15.	RD 2552 × BH 393	-1.31			1.49			-2.64		
16.	RD 2786 × RD 2715	-1.52			-4.45			1.96		
17.	RD 2786 × DWRB 91	-9.06*			-1.28			-5.08		
18.	RD 2786 × BH 959	4.93	4.24	8.82*	5.12	4.16	4.11	0.13		3.22
19.	RD 2786 × DWRB 92	5.46			-3.21			7.02		2.11
20.	RD 2786 × DWRB 64	-19.52**			11.89			-21.00**		
21.	RD 2786 × BH 393	-2.58			5.30	1.77		-5.94		
22.	RD 2715 × DWRB 91	15.91**	3.53		-5.79			15.92**	11.16	
23.	RD 2715 × BH 959	6.77	0.13	3.15	-38.77**			43.34**	34.40**	36.86**
24.	RD 2715 × DWRB 92	3.15			-4.65			5.63	4.06	
25.	RD 2715 × DWRB 64	15.84**	9.91*		9.24			2.27		1.20
26.	RD 2715 × BH 393	0.37			6.13		5.09	-5.09		
27.	DWRB 91 × BH 959	20.06**	1.37	4.42	-3.15			16.96**	5.47	7.40
28.	DWRB 91 × DWRB 92	11.85*	9.26		-1.00			8.62	5.69	
29.	DWRB 91 × DWRB 64	12.97**	5.98		9.83			0.50		
30.	DWRB 91 × BH 393	-8.49*			0.04			-6.76		
31.	BH 959 × DWRB 92	-4.61			-4.29			0.37		
32.	BH 959 × DWRB 64	13.58**	1.42	4.48	12.38			0.07		5.37

33.	BH 959 × BH 393	-1.27			2.63			-3.59		0.99
34.	DWRB 64 × DWRB 92	9.16*	4.72		11.57			-2.81		
35.	DWRB 92 × BH 393	12.90**			4.31	4.21		4.74		1.68
36.	DWRB 64 × BH 393	-4.97			18.68*	6.11		-15.48**		

*, ** Significant at 5% and 1% level of significance, respectively

Table 6: Percent relative heterosis (RH), heterobeltiosis (HB) and economic heterosis (EH) for protein content

SN.	Crosses	Protein content		
		RH	HB	EH
1.	RD 2035 × RD 2552	-1.59	-	-
2.	RD 2035 × RD 2786	17.78**	15.35**	1.48
3.	RD 2035 × RD 2715	-1.35	-	-
4.	RD 2035 × DWRB 91	10.13**	6.83**	-
5.	RD 2035 × BH 959	5.14**	-	-
6.	RD 2035 × DWRB 92	14.04**	14.04**	-
7.	RD 2035 × DWRB 64	6.81**	4.19	-
8.	RD 2035 × BH 393	3.48	-	-
9.	RD 2552 × RD 2786	12.23**	7.39**	3.40
10.	RD 2552 × RD 2715	-4.98**	-	-
11.	RD 2552 × DWRB 91	3.31	-	-
12.	RD 2552 × BH 959	-5.92**	-	-
13.	RD 2552 × DWRB 92	-6.99**	-	-
14.	RD 2552 × DWRB 64	-1.05	-	-
15.	RD 2552 × BH 393	0.54	-	-
16.	RD 2786 × RD 2715	-10.33**	-	-
17.	RD 2786 × DWRB 91	1.44	0.45	-
18.	RD 2786 × BH 959	9.05**	4.05*	0.78
19.	RD 2786 × DWRB 92	1.80	-	-
20.	RD 2786 × DWRB 64	2.94	2.52	-
21.	RD 2786 × BH 393	-3.52	-	-
22.	RD 2715 × DWRB 91	0.29	-	-
23.	RD 2715 × BH 959	5.53**	3.27	4.50*
24.	RD 2715 × DWRB 92	-8.86**	-	-
25.	RD 2715 × DWRB 64	-5.87**	-	-
26.	RD 2715 × BH 393	-10.13**	-	-
27.	DWRB 91 × BH 959	16.84**	12.53**	9.00**
28.	DWRB 91 × DWRB 92	6.69**	3.50	-
29.	DWRB 91 × DWRB 64	-1.25	-	-
30.	DWRB 91 × BH 393	3.17	1.54	-
31.	BH 959 × DWRB 92	10.88**	3.72	0.46
32.	BH 959 × DWRB 64	-1.33	-	-
33.	BH 959 × BH 393	4.43*	2.16	-
34.	DWRB 64 × DWRB 92	3.96*	1.41	-
35.	DWRB 92 × BH 393	6.66**	1.88	-
36.	DWRB 64 × BH 393	-2.43	-	-

*, ** Significant at 5% and 1% level of significance, respectively

References

1. Amiruzzaman M, Islam MA, Pixley KV, Rohman MM. Heterosis and combining ability of CIMMYT's tropical × subtropical quality protein maize germplasm. International Journal Sustainable Agriculture. 2011;3(3):76-81.
2. Baik BK, Ullrich SE. Barley for food characteristics, improvement and renewed interest. Journal of cereal science. 2008;48:233-242.
3. Bornare SS, Prasad LC, Lal JP, Madakemohekar AH, Prasad R, Singh J, *et al*. Exploitation of heterosis and combining ability for yield and its contributing traits in crosses of two-row and six-row barley (*Hordeum vulgare* L.) under rainfed environment. Vegetos, Society for Plant Research. 2014;27(3):40-46.
4. Briggle LW. Heterosis in wheat a review. Crop Science. 1963;3:407-412.
5. Fonseca S, Patterson FL. Hybrid vigour in seven-parental diallel crosses in common winter wheat (*Triticum aestvum* L.). Crop Science. 1968;8:85-88.
6. Madakemohekar AH, Prasad LC, Lal JP, Bornare SS, Prasad R. Study of heterosis and combining ability in exotic and indigenous crosses of barley (*Hordeum vulgar* L.) under rainfed environment. The Bioscan. 2015;10(2):751-756.
7. Madhukar K, Prasad LC, Lal JP, Chandra K, Thakur P. Heterosis and mixing effects in barley (*Hordeum vulgare* L.) for yield and drought related traits. Journal of Pharmacognosy and Phytochemistry. 2018;7(2):2882-2888.
8. Panse VG, Sukhatme PV. Statistical method for agricultural workers. ICAR Publication, New Delhi, 1985, 97-151p.
9. Pesaraklu S, Soltanloo H, Ramezanpour SS, Kalate Arabi M, Nejad Ghomic, Nasrollah AA. An estimation of the combining ability of barley genotypes and heterosis for

some quantitative traits. Iran Agricultural Research. 2016;35(1):73-80.
10. Raikwar RS, Upadhyay AK, Tyagi PK. Heritability and genetic variability for yield components under two regimes of soil in barley (*Hordeum vulgare* L.). The Bioscan. 2014;9(4):1613-1617.
11. Ram M, Shekhawat AS. Heterosis, inbreeding depression and combining ability analysis for yield and its component traits in barley (*Hordeum vulgare* L.). Plant Archives. 2017;17(2):851-860.