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Study of Heterosis for Yield and Grain Quality Traits in Barley (*Hordeum vulgare* L.)

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ABSTRACT

Twenty-nine barley genotypes including fifteen crosses, commercial cultivars and elite (exotic) lines were evaluated to estimate the magnitude of heterosis. Significant mean square due to genotype were observed for days to maturity, effective tillers per plant, spike length, no. of grains per spike, grain yield per plant, hectoliter weight (kg/hl), grain bold grain %, husk content (%), protein content (%) and starch content (%). Crosses IBON HI 19-94 x RD 2899 followed by IBON HI 19-110 x RD 2786 and IBON HI 19-82 x RD 2035 exhibited desirable positive significant heterosis, heterobeltiosis, economic heterosis for grain yield, tillers per plant, spike length, no. of grains per spike and bold grain (%). Therefore, above crosses may be observed as promising types for tangible advancement for yield potential and bold grain. IBON HI 19-82 x RD 2035 revealed significant economic heterosis for hectoliter weight, bold grains, husk content and protein content along with grain yield. The study revealed good scope for commercial exploitation of heterosis as well as isolation of transgressive segregants among the progenies of heterotic F_1 for improvement of yield and grain quality.

Keywords: *- Barley, Grain protein, Heterobeltiosis, Bold grain, Hectoliter weight.*

Introduction

Barley (*Hordeum vulgare* L.) is one of the ancient cereal crops, currently ranking fourth after rice, wheat and maize in the world production (USDA, 2020). It can be grown in wide range of environments than any other cereals, including extremes of latitude, longitude and altitude (Kishore *et al.,* 2016). The crop requires around 12-15 °C temperature during growing period and around 30-32 °C at maturity. Barley is hardy crop more tolerant to drought, heat and salt affected soils (Baik and Ullrich 2008).

Barley is a nutri-rich cereal and occupies an area of 0.62 million hectare with a production and productivity of 1.59 million tones and 25.73 q/ha (Anonymous, 2020). In the global context, only 2-5 per cent of barley is used as human food, while nearly 20-25 percent of the produce is consumed by malting and brewing industry and 70-75 percent is used for livestock feed purpose (Caterina, *et al.*,

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2018). The malt is used for brewing, distillation, nutraceutical/baby foods and medicinal purpose, *etc*. Barley cultivation requires less input in the form of fertilizer, irrigation and other chemicals and it has potential to grow under drought and saline conditions (Baik and Ullrich, 2008). The productivity of barley is low in India, which is below the world barley productivity on account of its cultivation mainly under marginal lands, with minimum input application and slow varietal replacement rate. The production of barley can be increased either by bringing more area under cultivation or by developing new high yielding cultivars

Beside food and nutrition value, barley malt is also used in distillation and brewing industry for preparing beer, whisky, malt vinegar, malted shakes, flavored malt energy drink (such as Horlicks, Maltova, milo) baked products such as malt loaf and bagels. To determine the malting quality of barley, diastatic power, hot water extract, Kolbach index, β-glucan, protein content, starch content, malt friability are the major biochemical traits are responsible for malting quality (Fincher, 1989; Fox *et al.,* 2003). For high malt yield, low protein (9-11 %) and low β-glucan content (< 4%) and high starch content are required, while higher hot water extract and diastatic power are desirable.

The study of heterosis has a direct bearing on the breeding methodology to be employed for varietal improvement and also provides information about usefulness of the parents in breeding programs (Singh *et al*., 2012). The superiority of hybrids particularly over better parent (heterobeltiosis) is more important and useful in determining the feasibility of commercial exploitation of heterosis and also indicating the parental combinations capable of producing the highest level of transgressive segregants. The success of this approach will depend on the degree of heterosis besides the availability of suitable mechanism of production of hybrid seeds. Study of heterosis also useful for eliminating the less productive crosses in early generations. Utilization of heterosis through hybrid barley is better than conventional plant breeding methods, which obtain lower yield gain (1% per year) in the north-western plains zone. Allard (1960) reported that the ability of parents to combine well depends on complex interaction among genes for trait of interest which cannot be adjusted by mere yield and yield adaptation of the parents. However, grain yield as well as component character are highly influenced by environmental fluctuation. Efforts are needed to develop high yielding *vis a vis* quality assessing trait to be used in breeding the crop.

Therefore, the present investigation was made to find out the magnitude of heterosis, heterobeltiosis and economic heterosis in barley and identified superior crosses that would be gainfully utilized in further barley improvement programmes.

Materials and Methods

The experimental materials used for the present study was developed by crossing of genetically diverse lines of six rowed exotic barley with indigenous lines during *Rabi 2019-20*. The materials received from AICRP, Wheat and Barley, Department of Genetics and Plant Breeding, RCA, Udaipur.

A total of twenty-nine genotypes including successfully attempted 15 F_1s, 12 parents and 2 checks were sown in Randomized Block Design with three replications during *Rabi*, 2020-21 at Instructional Farm, Rajasthan College of Agriculture, MPUAT, Udaipur. Each genotype was grown in single row plot of two meter length with a spacing of 30 cm and plant to plant distance 10 cm maintained. The experimental materials were evaluated under timely sown condition. The recommended cultural practices were carried out to raise the healthy crop. The data were recorded for days to maturity, effective tillers per plant, spike length (cm), grains per spike, grain yield per plant (g), hectolitre weight (kg/hl), bold grain (%), husk content (%), protein content (%) and starch content (%). The days to maturity and quality traits were recorded on plot basis, whereas the rest of the characters were recorded on five randomly selected plants per plot per replications. Analysis of variance for all the characters was done as suggested by Panse and Sukhatme. The heterosis, heterobeltiosis and economic heterosis were calculated as per the method suggested by Shull (1914); Fonesca and Patterson (1968) and Meredth and Bridge (1972).

To calculate heterobeltiosis and economic heterosis, higher mean value were considered for parents and check for all the characters except days to maturity and husk content, where lower mean value was considered and both were calculated in desirable direction only.

Results and Discussion

The analysis of variance revealed significant differences among the parents and their F_1 hybrids for all the traits studied viz., days to maturity, tillers per plant, spike length, number of grains per spike, grain yield per plant, hectoliter weight, bold grain, husk content, protein content and starch content. The significant variation between parents v/s crosses indicated the presence of sufficient magnitude of heterosis. Similar results were reported by Lodhi *et al*. (2015), Patial *et al.* (2018) and Swati *et al*. (2018).

This study may also be helpful in identification of promising cross combination for conventional breeding programme. Mackey (1976) described genetic principles of expression of heterosis superior to the better parent, which may result from one or two of the following situations: (i) the accumulated action of favourable dominant or semi-dominant genes dispersed amongst two parents, i.e. dominance; (ii) the complementary interaction of additive dominant on recessive genes at different loci i.e. non-allelic interaction or epistasis; (iii) favourable interaction between two alleles at the same locus i.e. intra locus or inter allelic interactions referred to as over dominance. It will be possible to recover homozygous lines as good as heterotic hybrids if either or both of the first two situations are cause heterosis, although the case with which such lines can be recovered will depend on linkage relationship of the genes involved and the ability to identify the recombinants as and when they arise. This will be particularly difficult with close linkage and when heterosis is expressed by a slight improvement in each of main yield components. If the heterosis is due to inter-allelic interactions of dominant types, it is not possible to fix such heterosis in homozygous condition in subsequent generations. The commercial utilization of heterosis is regarded as magnificent implementation of genetics in the plant breeding. The magnitude of heterosis in a crop relies on its exploitation, utilization and practicability of hybrid seed production. The superiority of hybrids particularly over better parent (heterobeltiosis) is more important and useful in determining the feasibility of commercial exploitation of heterosis and also indicating the parental combinations capable of producing the highest level of transgressive segregants.

In present investigation, wide range of average heterosis, heterobeltiosis and economic heterosis were observed for grain yield and its related traits (Table 2). The ranges of heterosis -1.93 % (GSBYT-19-1 x RD 2035) to 10 .68 % (IBON HI-19-94 x RD 2552) for days to maturity, -31.58 % (IBON HI 19-110 x RD 2552) to 62 .47 % (IBON HI-19-82 x RD 2035) for tillers per plant, 9.20 % (IBON HI 19-110 x RD 2552) to 66 .32 % (IBON HI 19-110 x RD 2899) for spike length, -16.81 % (IBON HI 19-111 x RD 2035) to 48.47 % (IBON HI 19-94 x RD 2899) for number of grains per spike, -16.81 % (IBON HI 19-111 x RD 2035) to 48.47 % (IBON HI 19-94 x RD 2899) for number of grains per spike, -13.36 % (IBON HI 19-94 x RD 2552) to 150.39 % (IBON HI 19-94 x RD 2899) for grain yield per plant, -10.07 % (IBON HI 19-94 x RD 2786) to 2.47 % (IBON HI 19-111 x RD 2715) for hectoliter weight, -4.91 (GSBYT 19-6 x RD 2715) to 31.33 % (IBON HI 19-82 x RD 2035) for bold grain %, -22.09 % (GSBYT 19-1 x RD 2715) to 27.37 % (IBON HI 19-82 x RD 2035) for husk content, -15.86 % (IBON HI 19-94 x RD 2552) to 14.50 % (IBON HI 19-111 x RD 2715) for protein content and -3.86 % (GSBYT 19-1 x RD 2715) to 0.89 % (IBON HI 19-82 x

Table 1. Analysis of variance showing mean square for yield and its contributing traits.

Characters	Replication [2]	Genotypes [28]	Parents [11]	Crosses [14]	Parents v/s Crosses [1]	Error [28]
Days to Maturity	4.59	92.49**	10.01**	56.93**	82.76**	1.60
Effective tillers per plant	0.17	7.89**	2.37**	3.92**	7.04**	0.64
Spike length (cm)	0.00	8.52**	2.79**	1.44**	8.14**	0.09
Number of grains per spike	7.24	205.40**	49.79**	106.34**	201.08**	11.45
Grain yield per plant (g)	1.77	345.52**	29.71**	265.19**	339.63**	3.69
Hectoliter weight (kg/hl)	3.02	13.57**	4.46**	4.31**	13.56**	0.97
Bold grain (%)	4.35	258.30**	165.03**	38.10**	249.10**	19.82
Husk content (%)	0.01	10.07**	3.44**	4.42**	8.21**	0.38
Protein Content (%)	0.01	2.76**	2.13**	0.49**	2.67**	0.07
Starch Content (%)	0.06	3.36**	1.27**	0.87**	3.28**	0.11

* Significant at 5% level and ** significant at 1% level.

RD 2715) for starch content. Magnitudes of average heterosis (%) for grain yield and grain quality traits are presented in Figure 1. The results are in conformity with the findings of other obtained for different characters such as Medimagh and El Felah (2019), Jalata *et al.* (2019); Lal *et al.* (2018) and Singh *et al.* (2017).

Increase of grain yield per plant is the important trait for improvement of crop productivity, hence an overall study of heterosis for grain yield per plant

Table 2a. Extent of heterosis (H), Heterobeltiosis (HB) and economic heterosis (EH) for days to maturity, effective tillers per plant and spike length.

S.	Crosses	Days to Maturity			Effective tillers per plant			Spike length (cm)		
No.		AH (%)	HB (%)	EH (%)	AH (%)	HB (%)	EH (%)	AH (%)	HB (%)	EH (%)
1	IBON HI 19-94 x RD 2552	10.68**	13.35**	17.35**	-21.05*	-31.19**	-11.76	34.55**	8.82**	17.09**
2	IBON HI 19-94 x RD 2786	6.72**	8.06**	14.41**	8.11	-3.85	17.65**	38.98**	7.89**	29.75**
3	IBON HI 19-94 x RD 2899	7.10**	7.99**	15.29**	34.42**	21.65**	43.12**	59.19**	38.45**	24.43*
4	IBON HI 19-110 x RD 2552	7.91**	10.51**	14.41**	-31.58**	-31.97**	-11.76	9.20	-13.76	-7.22
5	IBON HI 19-110 x RD 2786	6.72**	8.06**	14.41**	3.48	0.54	30.41**	50.16**	14.00**	37.09**
6	IBON HI 19-110 x RD 2899	7.56*	7.44**	14.71**	-12.01	-16.10	8.82	66.32**	40.85**	26.58**
7	IBON HI 19-82 x RD 2035	-0.83	0.28	5.00**	62.47**	38.01**	51.00**	29.64**	18.09**	40.51**
8	IBON HI 19-82 x RD2715	3.01**	5.28**	5.59**	-9.75	-10.81	-0.06	15.67**	15.21**	37.09**
9	IBON HI 19-111 x RD 2035	0.70	1.97**	6.47**	43.39**	18.30*	39.18**	38.15**	34.15**	39.24**
10	IBON HI 19-111 x RD 2715	5.75**	7.92**	8.24**	10.12	7.50	26.47**	22.68**	15.28**	36.08**
11	IBON HI 19-81 x RD 2715	6.98**	7.92**	8.24**	23.50*	21.16**	41.12**	18.42**	12.55**	32.85**
12	GSBYT 19-6 x RD 2715	-0.87	0.29	0.59	17.55	3.20	15.65**	14.62**	10.78**	30.76**
13	GSBYT 19-6 x RD 2035	1.82	4.01**	6.76**	52.04**	44.65**	22.53**	34.92**	27.36**	40.25**
14	GSBYT 19-1 x RD 2035	-1.93*	-1.39	4.41**	39.41**	21.19**	25.47**	34.00**	25.11**	22.34**
15	GSBYT 19-1 x RD 2715	-1.28	1.47*	1.76**	16.34	11.92	25.41**	18.56**	1.88	20.25**

* Significant at 5% level and ** significant at 1% level.
AH= Average heterosis, HB= Heterobeltiosis, EH= Economic heterosis

Table 2b. Extent of heterosis (H), Heterobeltiosis (HB) and economic heterosis (EH) for number of grains per spike, grain yield per plant and hectoliter weight.

S.	Crosses	Number of grains per spike			Grain yield per plant (g)			Hectoliter Weight (k/h)		
No.		AH (%)	HB (%)	EH (%)	AH (%)	HB (%)	EH (%)	AH (%)	HB (%)	EH (%)
1	IBON HI 19-94 x RD 2552	13.92	3.34	-6.17*	-13.36	-31.44**	-15.47**	-4.42*	-4.72**	-2.01
2	IBON HI 19-94 x RD 2786	46.81**	24.33**	32.51**	10.73	-12.04**	7.34	-10.07**	-10.31**	-7.76**
3	IBON HI 19-94 x RD 2899	48.47**	38.70**	18.10**	150.39**	102.10**	136.36**	-5.61**	-4.99**	-2.90*
4	IBON HI 19-110 x RD 2552	10.36	3.42	-6.11	-7.03	-20.05**	-1.42	-8.13**	-9.66**	-4.49**
5	IBON HI 19-110 x RD 2786	27.70**	11.40**	18.73**	136.92**	104.63**	149.72**	-7.82**	-9.31**	-4.12**
6	IBON HI 19-110 x RD 2899	2.06	-1.40	-16.04**	24.27*	9.30**	27.82**	-7.36**	-8.60**	-3.37**
7	IBON HI 19-82 x RD 2035	1.77	-1.90	10.27**	135.88**	88.10**	123.16**	-0.34	-3.97**	3.48**
8	IBON HI 19-82 x RD 2715	10.43	-1.62	10.58**	27.11**	6.90*	26.84**	1.96	1.17	1.08
9	IBON HI 19-111 x RD 2035	-16.81**	-19.09**	-10.72**	12.56	-6.37	-0.42	-4.62*	-10.05**	-3.06*
10	IBON HI 19-111 x RD 2715	-13.39**	-22.21**	-14.16**	-9.50	-20.32**	-15.25**	2.47	0.98	-0.67
11	IBON HI 19-81 x RD 2715	25.63**	21.14**	14.65**	1.15	-9.84*	-6.78	-0.65	-1.79*	-1.12
12	GSBYT 19-6 x RD 2715	30.49**	23.79**	21.23**	36.81**	23.56**	0.00	-4.13*	-5.48**	-4.33**
13	GSBYT 19-6 x RD 2035	25.47**	21.65**	26.87**	58.06**	52.11**	7.34	-4.17*	-7.08**	0.13
14	GSBYT 19-1 x RD 2035	21.88**	13.54**	18.41**	32.81**	14.70**	11.30**	-9.46**	-11.93**	-5.09**
15	GSBYT 19-1 x RD 2715	37.36**	35.74**	22.17**	22.23*	12.09**	8.76*	-2.43	-4.12**	-2.32

* Significant at 5% level and ** significant at 1% level.
AH= Average heterosis, HB= Heterobeltiosis, EH= Economic heterosis

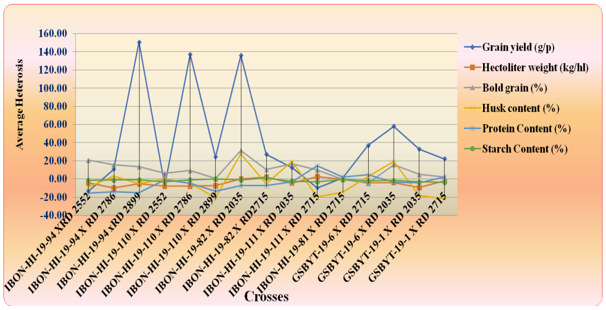

Fig. 1. Magnitude of average heterosis (%) for grain yield per plant and grain quality traits.

revealed that out of 15 crosses, eleven crosses exhibited significant positive average heterosis, nine crosses showed heterobeltiosis and economic heterosis. Crosses IBON HI 19-94 x RD 2899 followed by IBON HI 19-110 x RD 2786, IBON HI 19-82 x RD 2035 exhibited highest positive significant value of average heterosis, heterobeltiosis and economic heterosis for grain yield per plant, thus these crosses were observed most desirable cross combination.

The majority of barley is used for animal feed or malting. High protein barleys are generally valued for food and feeding barley, though in recent times high protein barley are being preferred for malting to ensure the enzymes free brewing (Anonymous 2021). Plump and uniform kernels are desirable as plump kernels contain higher levels of starch, which will produce more beer from a given weight of malt. Bold grain > 80% in six row barley and hectoliter weight > 62 % is desirable value for grain quality. Barley is a good livestock feed and is a good source of protein. Improvement of grain quality traits also play important role for food, animal feed and malting industry. None of the crosses were exhibited significant positive heterosis, heterobeltiosis and economic heterosis for hectoliter weight. Highest magnitude of significant desirable positive heterosis (30.25 %) and heterobeltiosis (29.77 %) were observed in cross IBON HI 19-82 x RD 2035 for bold grain, while negative significant desirable heterosis (-22.09 %) and heterobeltiosis (-17.36 %) were observed in crosses GSBYT 19-1 x RD 2715 and IBOH HI 19-111x RD 2715 for husk content. Significant average positive heterosis was found in IBON HI 19-94 x RD 2552, IBON HI 19-111 x RD 2035, GSBYT 19-6 x RD 2035 and IBON HI 19-94 x RD 2786 for bold grain. IBON-HI 19-111 x RD 2715 exhibited highest positive average heterosis (14.10 %), heterobeltiosis (10.63 %) and economic heterosis (15.08 %) for protein content and negative significant heterosis (-19.95 %) heterobeltiosis (-17.36 %) and economic heterosis (-32.39 %) for husk content, which is desirable for food and feed barley while, cross IBON-HI-19-94 x RD 2552 showed maximum negative significant heterosis (-15.86 %), heterobeltiosis (-28.46%) and economic heterosis (-4.02%) for protein content, which is desirable for malting industry. IBON HI 19-82 x RD 2715 was showed significant economic heterosis (0.97) for starch content. For high malt yield, low protein (9-11 %) and high starch content are required (Fincher 1989; Fox *et al.,* 2003). Gupta and Singh (1999) reported positive heterosis for grain protein and husk content. Heterosis and heterobeltiosis reported by Medimagh and El Felah (2019) for 1000-kernel weight (TKW) and protein content.

Conclusion

The sufficient magnitude of average heterosis, heterobeltiosis and economic heterosis were observed for grain yield and its related traits. Crosses IBON HI 19-94 x RD 2899 followed by IBON HI 19-110 x RD 2786, IBON HI 19-82 x RD 2035 exhibited desirable positive significant heterosis, heterobeltiosis and economic heterosis for grain yield and most of grain related traits (Table 3). IBON HI 19-110 x RD 2786 was showed the sufficient magnitude of heterosis, heterobeltiosis and economic heterosis for bold grain, husk content and economic heterosis for protein content. Economic heterosis for hectoliter weight, bold grain, husk content and protein content were exhibited in IBON HI 19-82 x RD 2035. Therefore, above crosses may be observed as promising types for tangible advancement for yield potential and grain quality in barley. An overall evaluation of heterosis for grain yield per plant revealed that the maximum magnitude of relative heterosis (150.39 %) followed by (136.92 %) and (135.88 %) were observed in IBON HI 19-94 x RD 2899, IBON HI 19-110 x RD 2786 and IBON HI 19-82 x RD 2035. Similarly, heterobeltiosis (104.63 %) and economic heterosis (149.72 %) were observed IBON HI 19-110 x RD 2786. Therefore, these crosses were observed highest magnitude of heterosis for grain yield per plant.

The maximum magnitude of relative heterosis (14.10 %), heterobeltiosis (10.63 %) and economic heterosis (15.08 %) for protein content were ob-

Table 2c. Extent of heterosis (H), Heterobeltiosis (HB) and economic heterosis (EH) bold grain, protein content, starch content.

S. No.	Crosses	Bold Grain (%)			Husk content (%)			Protein Content (%)			Starch Content (%)		
		AH(%)	HB(%)	EH(%)	AH(%)	HB(%)	EH(%)	AH(%)	HB(%)	EH(%)	AH(%)	HB(%)	EH(%)
1	IBON HI 19-94 x RD 2552	20.69**	-0.38	0.32	-9.09*	10.09	-18.87**	-15.86**	-28.46**	-4.02**	-1.49*	-3.10**	-1.61**
2	IBON HI 19-94 x RD 2786	15.58*	-4.42	-4.21	3.09	6.42	-21.58**	-14.10**	-24.72**	1.01	-1.48*	-1.64**	-3.38**
3	IBON HI 19-94 x RD 2899	13.47	-5.73*	-6.62**	-5.19	8.26	-20.23**	-15.57**	-25.84**	-0.50	-1.05	-2.24**	-1.61**
4	IBON HI 19-110 x RD 2552	6.17	-0.60	0.09	-0.31	15.32**	-8.00*	-1.38	-13.65**	8.04**	-3.11**	-4.84**	-3.38**
5	IBON HI 19-110 x RD 2786	9.03	2.30	2.52	-5.14	-4.34	-24.96**	-4.89	-14.06**	7.54**	-0.99	-0.99**	-3.06**
6	IBON HI 19-110 x RD 2899	0.18	-5.49*	-6.37**	-20.93**	-13.59**	-31.07**	-13.53**	-21.69**	-2.01	-0.24	-1.60**	-0.97**
7	IBON HI 19-82 x RD 2035	31.33**	30.06**	2.41	27.37**	31.29**	-4.68	-7.73**	-17.81**	2.01	-1.20	-1.44**	-0.48
8	IBON HI 19-82 x RD 2715	10.46	-3.42	-0.40	-5.43	0.56	-26.99**	-7.50**	-10.63**	-7.04**	0.89	0.00	0.97**
9	IBON HI 19-111 x RD 2035	16.49*	10.45**	-13.03**	19.14**	26.89**	-2.21	-3.18	-13.77**	7.04**	-2.64**	-2.95**	-1.85**
10	IBON HI 19-111 x RD 2715	9.96	-7.40**	-4.50	-19.95**	-17.36**	-32.39**	14.50**	10.63**	15.08*	-3.38**	-4.30**	-3.22**
11	IBON HI 19-81 x RD 2715	-0.69	-6.49**	-3.56	-14.65**	-14.30**	-30.46**	1.75	-1.93	2.01	-0.53	-1.05**	-0.81**
12	GSBYT 19-6 x RD 2715	-4.91	-16.08**	-13.45**	2.34	11.64*	-8.68*	4.37	3.86**	8.04**	-2.41**	-3.42**	-2.18**
13	GSBYT 19-6 x RD 2035	15.83*	15.95**	-8.70**	18.97**	34.09**	3.34	-3.98	-12.15**	9.05**	-2.00**	-2.39**	-1.13**
14	GSBYT 19-1 x RD 2035	4.97	-0.69	-12.35**	-18.52**	-3.51	-25.63**	-4.52	-14.57**	6.03**	-3.52**	-4.91**	-1.61**
15	GSBYT 19-1 x RD 2715	1.97	-5.39*	-2.42	-22.09**	-10.82*	-27.05**	1.99	-0.97	3.02*	-3.86**	-5.84**	-2.58**

* Significant at 5% level and ** significant at 1% level.
AH= Average heterosis, HB= Heterobeltiosis, EH= Economic heterosis

Table 3. Crosses possessing high heterosis, heterobeltiosis and economic heterosis for grain yield per plant (g) along with desirable (+) heterotic expression for grain yield related and grain quality characters.

Particulars	Crosses possessing high heterosis, heterobeltiosis and economic heterosis for grain yield per plant (g)	DM	TP	SL (cm)	G/S	Hect. Wt. (kg/hl)	Bold Grain (%) (%)	Husk content	Protein Cont. (%)	Starch Content (%)
Heterosis	IBON HI 19-94 x RD 2899	-	+	+	+	-	+	+	-	-
	IBON HI 19-110 x RD 2786	-	+	+	+	-	+	+	-	-
	IBON HI 19-82 x RD 2035	+	+	+	+	-	+	-	-	-
Heterobeltiosis	IBON HI 19-94 x RD 2899	-	+	+	+	-	-	-	-	-
	IBON HI 19-110 x RD 2786	-	+	+	+	-	+	+	-	-
	IBON HI 19-82 x RD 2035	+	+	+	-	-	+	-	-	-
Economic Heterosis	IBON HI 19-94 x RD 2899	-	+	+	+	-	-	+	-	-
	IBON HI 19-110 x RD 2786	-	+	+	+	-	+	+	+	-
	IBON HI 19-82 x RD 2035	-	+	+	+	+	+	+	+	-

DM=Days to maturity; TP= Tillers per plant; SL= Spike Length; G/S= Number of grains per spike served IBON-HI-19-111 x RD 2715. The present investigation revealed that an ample scope for exploitation of hybrid vigour as well as isolation of superior pure lines from transgressive segregants among the progenies of heterotic F_1 for tangible advancement of grain yield as well as grain quality traits in barley.

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