https://doi.org/10.56093/ijas.v90i2.99007

Indian Journal of Agricultural Sciences **90** (2): 307–11, February 2020/Article

Heterosis and inbreeding depression for yield and its components traits in barley (*Hordeum vulgare*)

R S RAIKWAR[1]

Jawaharlal Nehru Krishi Vishwa Vidyalaya, College of Agriculture, Tikamgarh, Madhya Pradesh 472 001, India

Received: 24 October 2018; Accepted: 19 July 2019

ABSTRACT

Heterosis and inbreeding depression was analysed using a set of diallel crosses involving 10 diverse parents (excluding reciprocals). Heterosis over standard parent for grain yield per plant ranged from -9.65–45.45 (%) and -14.78–12.05 (%) under normal and late sown conditions, respectively and heterosis over better-parent for grain yield per plant ranged from -26.43–70.77(%) and -32.16–12.05(%) respectively. Nature and magnitude of heterosis and inbreeding depression varied across crosses, characters as well as environments. Considering the very high degree of heterosis in desirable direction, the importance of non-additive components of genetic variance was observed for yield and most of the yield contributing components. Cross II (K 603 × Azad) and cross IV (RD 2618 × PL 708) revealed better specific cross combinations to be used for heterosis. The study revealed good scope for commercial exploitation of heterosis as well as isolation of pure lines among the progenies of heterotic F_1 for improvement of yield levels in barley.

Key words: Heterosis over standard parent, Heterosis over better-parent, Inbreeding depression

Barley (*Hordeum vulgare* L., 2n=2x=14) is the worlds' fourth most important cereal crop after wheat, maize and rice. It is a staple food in several regions of the world, i.e. in some areas of North Africa and the Near East, highlands of Central Asia, Horn of Africa, Andean countries and Baltic States. These regions are characterized by harsh living conditions and home to some of the poorest farmers in the world who depend on the low productive systems. It is considered as the first cereal domesticated for use by man as food and feed (Potla *et al*. 2013). In India, it is grown in 693 thousand ha with average grain productivity 2580 kg/ha and total production of 1788 thousand tonnes (Anonymous 2016-17), whereas in Rajasthan, it is grown in 276 thousand ha with average grain productivity 3297 kg/ha and total production of 910 thousand tonnes (Anonymous 2016-17). This productivity is far below to most of developed countries such as Germany (5425 kg/ha), France (6685 kg/ha) and the United Kingdom (5931 kg/ha) (FAO 2016). Barley cultivation in India is now becoming oriented towards industrial utilization. Though, presently only 12–15% of total produce is being utilised for malting/brewing, but it is projected that by 2020 the demand will be more than double. 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 (Lal *et al*. 2018). In a self-pollinated crop, the utilization of heterosis depends mainly upon the direction and magnitude of heterosis. However, grain yield as well as component character are highly influenced by environmental fluctuation, which challenge the breeders to breed varieties with high yield potential along with high malt requirement and greater stability for industrial utilisation. However, grain yield as well as component characters are highly influenced by environmental fluctuations thus the study based on solitary environment may not be much useful because of genotype × environment interactions.

MATERIALS AND METHODS

The present investigation aimed to gather information on the genetic basis of yield and its contributing traits in 10 diverse genotypes of barley, viz. DL-88, K 560, K 603, Azad, RD 2552, NDB 1020, RD 2618, PL 708, NDB 1173 and Lakhan (Lakhan use as standard parent) selected from the germplasm on the basis of a broad range of genetic diversity for major yield components. These selected genotypes were planted at JNKVV, College of Agriculture, Tikamgarh (MP), for hybridization in diallel fashion excluding reciprocals. The 10 parents and their resulting F_1's and F_2's were grown in a randomized block design with three replications under normal (20th November) and late (5th December)

[1]Scientist (rudrasen_singh@rediffmail.com), Plant Genetics and Breeding, Jawaharlal Nehru Krishi Vishwa Vidyalaya, College of Agriculture Tikamgarh, Madhya Pradesh, India.

sown conditions during 2016–17 and 2017–18. The whole experiment was performed for fifteen metric traits in barley with best five crosses, viz. DL 88 × K 560 (cross I), K 603 × Azad (cross II), RD 2552 × NDB 1020 (cross III), RD 2618 × PL 708 (cross IV) and NDB 1173 × Lakhan (cross V). The experiment plot comprised two rows each of parent and F_1 and six rows of F_2 of 3-m length. Row to row and plant to plant spacing was maintained at 30 cm and 10 cm. Observations were recorded on 20 randomly selected competitive plants of each parent and F_1's and 60 plants in F_2's in every replication for following traits, viz. days to ear emergence, plant height (cm), number of effective tillers per plant, length of the main spike (cm), days to maturity, weight of grains per main spike (g), number of grains/spike, 1000-grain weight (g), grain yield/plant (g), flour recovery (g), husk content (%), protein content (%), lysine content (mg/g), amylose content (%) and pelshenke value (min.). In case of maturity traits (days to heading and days to maturity), the data was recorded on the whole plot basis. For quality analysis, the total nitrogen was estimated by the micro-Kjeldahl method. Total nitrogen was then used for estimation of protein by multiplying with a factor of 6.25. Lysine content was estimated by the method of Felker *et al*. (1978) and amylose content was determined by Juliano (1979). The mean of each plot used for statistical analysis. The data were first subjected to the usual analysis followed for a randomized block design for individual environment (Panse and Sukhatme 1967). The heterosis (H%) and heterobeltiosis (HB%) were estimated as deviation of F_1 value from the mid-parent and the better-parent values (Martinez *et al*. 1998) and Fonseca and Patterson (1968), respectively. The heterosis and heterobeltiosis in each environment for all the characters were estimated as:

$$\text{Heterosis over mid parent (H \%)} = [(F_1 - MP)/MP \times 100]$$

$$SE\ (F_1 - MP) = (3Me/2r)1/2$$

$$\text{Heterosis over better parent (HB \%)} = [(F_1-BP)/BP \times 100]$$

$$SE\ (F_1 - BP) = (2Me/r)1/2$$

where Me, error mean squares for parents and F_1s data of individual environment; MP, mean mid parent value = (P1 + P2)/2; P1, mean performance of parent one; P2, mean performance of parent two; BP, mean better parent value; R, number of replications; inbreeding depression (ID %) = $[(F_1-F_2)/F_1 \times 100]$

$$SE\ (F_1-F_2) = (2Me/r)1/2$$

where Me, error mean square from the ANOVA of individual environment. Significance of heterosis and heterobeltiosis and inbreeding depression were tested by 't' test using SE values in all the characters under each environment, separately.

RESULTS AND DISCUSSION

Heterosis refers to the developmental stimulation resulting by mechanism from the union of different gametes while hybrid vigour denotes the manifestation of effects of heterosis. The exploitation of heterosis for developing high yielding cultivars in barley has been limited due to its autogamous nature. For a successful hybrid breeding programme it is essential that significant heterosis is available in F_1 population and that is a method available for commercial seed production economically. In present study, the estimates of heterosis over standard parent (NDB 1173) and better parent were calculated for five F_1s in timely sown and late sown to assess their genetic potential as breeding material. Significant heterosis over standard-parent (Table 1) was observed for all traits in timely sown except number of effective tillers per plant (cross IV), days to maturity (cross II), 1000-grain weight (cross V), flour recovery (cross I and IV) and pelshenke value in cross III and IV while in late sown for plant height (cross V), number of grains per spike (cross I), 1000-grain weight (cross II), lysine content (cross II) and pelshenke value (cross III and V). On the other hand heterosis over standard parent ranged from -0.20% (flour recovery in cross I) to 48.45% (amylose content in cross IV) in timely sown, while in late sown it ranged from 0.29% (pelshenke value in cross III) to 47.88% (number of grains per spike in cross IV). In the present study, the standard parent heterosis for grain yield per plant ranged from -9.65% (cross IV) to 46.68% (cross II) in timely sown. The maximum heterosis of 46.68% was shown by the cross II, followed by cross V (45.45%), cross III (36.76%) in timely sown, while maximum positive standard-parent heterosis was observed for cross V (12.05%). Rest of crosses showed negative heterosis. Maximum standard-parent heterosis was also reported for other characters in timely sown in the crosses (cross II (4.55%) for days to ear emergence, cross IV (-5.68%) for plant height. Cross III (15.97%) for number of effective tillers per plant, cross IV (48.45%) for amylose content and cross II (13.19%) for pelshenke value. The results in different environments for grain yield per plant are in conformity with the previous findings in varying environments for different characters by Saad *et al.* (2013), Mansour (2016), Pesaraklu *et al.* (2016) and Ram and Shekhawat (2017).

In late sown, maximum standard-parent heterosis was observed for other characters in the crosses, viz. cross V (1.60%) for days to ear emergence; cross I (-24.28%) for plant height, cross II (17.48%) for number of effective tillers per plant, cross II (24.22%) for length of main spike; cross IV (16.72%) weight of grains per main spike; cross V (37.21%) for number of grains per spike; cross III (33.69%) for 1000-grain weight; cross V (07.58%) for flour recovery; cross V (-41.80%) for husk content; cross IV (29.89%) for protein content cross I (14.29%) for lysine content; cross V (16.86%) for amylose content and cross II (15.40%) over standard-parent for pelshenke value. In timely sown, heterosis over better parent for grain yield per plant varied from 20.69% (cross I) to 70.77% (cross II). The maximum heterobeltiosis was displayed by the cross V (45.45%) followed by cross III (38.82%) and cross I (20.69%) for grain yield per plant. Under late sown situation, heterobeltiosis for weight of grains per main spike ranged

Table 1 Heterosis over standard-parent (%) and better-parent (%) for 15 metric traits in cross I-V in timely sown and late sown conditions

Character	Timely sown										Late sown									
	Cross I		Cross II		Cross III		Cross IV		Cross V		Cross I		Cross II		Cross III		Cross IV		Cross V	
	SP(%)	BP(%)	SP(%)	BP(%)	SP(%)	BP(%)	SP(%)	BP(%)	SP(%)	BP(%)	SP(%)	BP(%)	SP(%)	BP(%)	SP(%)	BP(%)	SP(%)	BP(%)	SP(%)	BP(%)
Days to ear emergence	13.13**	1.63**	4.55**	6.97**	9.55**	-11.57**	22.73**	18.42**	10.45**	10.46**	12.50**	10.45**	7.40**	-7.40**	12.04**	9.50**	20.83**	7.41**	1.60**	11.59**
Plant height (cm)	8.37**	5.71**	10.51**	10.51**	29.23**	-10.82**	-5.68**	-15.94**	12.95**	12.94**	-24.28**	-5.14**	10.15**	2.99*	-22.86**	-11.71**	-6.13**	4.25**	-7.67	-7.67**
No. of effective tillers/ plant	12.06**	36.24**	12.06**	15.13**	15.97**	31.62**	0.53	-6.85**	-4.15**	-4.17**	-29.32**	-8.64**	17.48**	0.24	0.96*	7.52**	-12.13**	-0.33	10.51**	10.51**
Length of main spike (cm)	-25.64**	8.75**	-19.27**	-2.30**	-17.09**	-13.31**	-32.29**	-32.92**	-5.70**	-5.70**	-7.15**	7.25**	24.22**	-4.80**	-11.29**	6.61**	-4.64**	-14.93**	3.26**	3.26**
Days to maturity	-3.74**	4.31**	0.24	-1.38	-6.79	3.11**	5.15**	0.49	3.05**	1.93*	14.05**	3.04**	6.53**	1.23	13.79**	2.09	15.61**	1.36	2.88**	3.11**
Weight of grains/ main spike (g)	1.83**	-6.54**	-14.37**	27.27**	-30.58**	-9.20**	-10.19**	-16.19**	-2.14**	-2.04**	-40.25**	-6.76**	14.24**	-13.44**	-0.93**	18.52**	16.72**	63.73**	-4.02**	-4.12**
No. of grains/ spike	-4.93**	6.96**	-44.07**	12.15**	-29.18**	-32.18**	-8.35**	-8.34**	-48.56**	-48.55**	1.15	11.14**	30.50**	-21.11**	44.54**	11.20**	47.88**	51.20**	37.21**	37.21**
1000-grain weight (g)	12.47**	-9.92**	15.55**	19.70**	-1.23*	-11.06**	9.11**	-4.90**	0.00	0.00	14.30**	-1.72	0.76	-7.34**	33.69**	13.88**	17.73**	10.08**	17.49**	16.87**
Grain yield/ plant (g)	12.63**	20.69**	46.68**	70.77**	36.76**	38.82**	-9.65**	-26.43**	45.45**	45.45**	-7.95**	9.18**	-14.78**	-32.16**	-6.72**	-6.39**	-7.06**	10.70**	12.05**	12.05**
Flour recovery (g)	-0.20	-0.90*	4.00**	1.18	2.98**	2.46**	0.20	1.96	2.16**	2.16**	3.22**	2.62**	1.77*	-0.20	0.71**	0.23	6.01**	5.02**	7.58**	7.58**
Husk content (g)	0.19	6.02**	24.84**	-10.85**	-25.29**	-18.94**	-3.92**	-10.32**	-5.23**	-5.23**	-15.13**	-13.96**	-3.33**	12.11**	3.80**	6.84**	-32.47**	-26.59**	-41.80**	-41.80**
Protein content (%)	-11.45**	-9.57**	-2.08**	-14.31**	-21.15**	30.67**	21.88**	3.27**	-14.27**	-14.28**	-12.06**	-7.58**	-4.12**	-12.26**	16.49**	21.89**	29.89**	11.18**	5.88**	5.84**
Lysine content (mg/g)	20.38**	9.05**	7.69**	21.73**	-18.08**	-33.33**	12.69**	-1.45**	26.92**	26.92**	14.29**	9.22**	0.00	9.09**	-21.43**	-25.00**	-28.36**	1.52**	-10.71**	-10.71**
Amylose content (%)	34.52**	25.97**	13.09**	-1.04*	22.27**	-27.67**	48.45**	46.96**	2.02**	-2.02**	4.10**	15.49**	-6.67**	-0.68**	-0.67**	-26.35**	16.86**	43.19**	-17.43**	-17.43**
Pelshenke value (min)	-8.88**	-12.88**	13.19**	17.22**	-0.56	-0.57	0.29	-1.69	2.01**	2.01**	-9.30**	-10.34**	15.40**	17.16**	0.29	0.00	9.01**	0.00	2.62	2.62

*, ** Significant at 5% and 1% level of probability, respectively.

Table 2 Inbreeding depression (%) in F_2 over F_1 for 15 metric traits in cross I-V in timely sown and late sown conditions

Character	Timely sown					Late sown				
	Cross I	Cross II	Cross III	Cross IV	Cross V	Cross I	Cross II	Cross III	Cross IV	Cross V
Days to ear emergence	-0.72**	0.86	3.73	4.44**	-8.15**	1.46	4.07**	3.72**	10.34**	3.69**
Plant height (cm)	-5.28**	15.70**	25.95**	-11.01**	13.69**	-5.84**	7.82**	-28.63**	1.30	-7.48**
No. of effective tillers/ plant	7.39**	-0.27	38.05**	0.00	10.95**	-44.59**	24.27**	-14.20**	-7.97**	11.42**
Length of main spike (cm)	6.38**	-11.78**	18.70**	-50.93**	-6.71**	-2.70**	-6.67**	-15.09**	-22.37**	-7.69**
Days to maturity	-0.24	-0.71	-10.05**	12.47**	0.12	1.93	-1.60	1.37	2.24	-10.12**
Weight of grains/main spike (g)	16.00**	7.23**	-33.88**	-9.09**	-3.12**	-5.17**	21.43**	0.94**	28.32**	12.90**
No. of grains/spike	15.49**	-21.09**	4.36**	9.63**	-62.05**	21.99**	-25.40**	12.28**	28.66**	-3.62**
1000-grain weight (g)	15.98**	13.75**	5.18**	12.93**	2.97**	-9.02**	13.01**	13.77**	9.63**	-11.51**
Grain yield/plant (g)	-32.42**	-93.99**	2.08**	-51.92**	-2.21	-16.19**	46.67**	29.52**	-11.39**	-1.83*
Flour recovery (g)	-0.87*	2.39**	1.97**	0.35	3.00**	2.70**	4.11**	-0.51	6.34**	8.59**
Husk content (g)	5.07**	-10.34**	-31.23**	-4.31**	-4.60**	-14.14**	-32.17**	8.99**	-46.38**	-71.76**
Protein content (%)	-9.80**	16.49**	0.52**	3.99**	-18.22**	-15.23**	-0.35*	-7.96**	10.85**	-9.42**
Lysine content (mg/g)	3.19**	-28.57**	-3.28**	2.94**	24.24*	28.13**	10.71**	0.00	1.49**	4.00**
Amylose content (%)	14.65**	-27.89**	-9.75**	24.33**	-47.08**	12.20**	-31.93**	-9.27**	24.46**	-42.69**
Pelshenke value (min)	-7.55**	10.08**	-24.78**	0.00	-3.93**	-8.97**	8.61**	-28.70**	5.60**	0.00

*, ** Significant at 5% and 1% level of probability, respectively.

from -4.12% (cross I) to 63.73% (cross V) followed by cross III (18.52%). Under late sown situation heterosis over better parent was observed for other characters in the crosses, viz. cross II (-7.40%) for days to ear emergence; cross III (-11.71%) for plant height; cross V (10.51%) for number of effective tillers per plant; cross I (7.25%) for length of main spike; cross IV (63.73%) for weight of grains per main spike. These crosses may provide transgressive segregants in segregating generations. Seed yield and other characters mentioned above in normal and late sown expressed high heterosis and mean performance.

All the five crosses showed highly significant inbreeding depression (Table 2) along with highly significant standard parent heterosis and heterobeltiosis for length of main spike, weight of grains per main spike, number of grains per spike, protein content and amylose content in both environments. The occurrence of high inbreeding depression in highly heterotic crosses indicated predominant role of non-fixable (non-additive) gene action representing dominance and epistatic components in manifestation of heterosis for these traits. Under timely sown situation, positive and highly significant standard parent heterosis, heterobeltiosis and inbreeding depression were recorded for number of tillers per plant (cross III), 1000-grain weight (cross III), grain yield per plant (cross III), flour recovery (cross II, III and V), protein content (cross IV), lysine content (cross I and V), amylose content (cross I and IV) and pelshenke value (cross II).

For number of effective tillers per plant (cross III and V), 1000-grain weight (cross III and IV), flour recovery (cross I, III and V), husk content (cross V), protein content (cross IV), lysine content (cross I), amylose content (cross I and IV) and pelshenke value (cross II), had significant or highly significant and positive heterobeltiosis, standard parent heterosis and inbreeding depression in late sown condition. It was also noted that the expression of heterosis and heterobeltiosis was influenced by the environments for almost all the characters possibly due to significant G × E interaction. The results in varying environments for different characters are in harmony with the findings of Potla *et al.* (2013), Saad *et al.* (2013), Mansour (2016) and Ram and Shekhawat (2017) who also reported maximum heterosis for grain yield per plant.

Overall appraisal of the results in the present study, advocated that reciprocal recurrent selection (Hull 1945), diallel selective mating, use of multiple crosses and bi-parental mating may be effective alternative approaches for tangible advancement of barley yield in the coming years.

REFERENCES

Anonymous. 2016-17. Progress report of All India Co-ordinated Wheat and Barley Improvement Project. Indian Inst. Wheat and Barley Research, Karnal, India.

FAO. 2016: http://www.fao.org/faostat/en/# data/QC

Felker C, Libanauskas C K and Wainer G. 1978. Estimation of lysine in foods. *Crops Science* **18**(3): 480–90.

Fonseca S and Patterson F L. 1968. Hybrid vigour in a seven parental diallelcross in common winter wheat (*Triticum aestivum* L.). *Crop Science* **51**(9): 623–26.

Hull F H. 1945. Recurrent selection for specific combining ability in corn. *American Society of Agronomy* **37**: 134–45.

Juliano B O. 1979. Amylose analysis in rice. A review. International Rice Research Institute, pp 251–60.

Lal C, Shekhawat A S, Singh J and Kumar V. 2018. Heterosis and inbreeding depression studies for yield and its contributing traits in barley (*Hordeum vulgare* L.) under normal and late sown condition. *International Journal of Current Microbiology and Applied Sciences* **7**(9): 2651–60

Mansour M. 2016. Genetical analysis of some quantitative traits in barley under saline soil conditions. Proceedings, The sixth field crops conference, FCRI, ARC, Giza, Egypt, 22-23 Nov. 2016. Page (99:107).

Martinez J H E and Foster A E. 1998. Genetic analysis of heading date and other agronomic characters in barley (*Hordeum vulgare* L.). *Euphytica* **99**(3): 145–53.

Panse V C and Sukhatme P V. 1967. *Statistical Methods for Agricultural Workers*. ICAR, New Delhi.

Pesaraklu S, Soltanloo H, Ramezanpour S S, Kalate Arabi M, Nasrollah Nejad and Ghomi A A. 2016. An estimation of the combining ability of barley genotypes and heterosis for some quantitative traits. *Iran Agricultural Research* **35**(1): 73–80.

Potla K R, Bornare S S, Prasad L C, Prasad R and Madakemohekar A H. 2013. Study of heterosis and combining ability for yield and yield contributing traits in barley (*Hordeum vulgare* L.). *Bioscan* **8**(4): 1231–35.

Ram M and Shekhawat A S. 2017. Genotypic variances and interactions with environments in barley genotypes for grain yield and its associated characters. *Bioscan* **11**(4): 3173–75.

Saad F F, MohenAbd El A A, ShafiAbd El M A and Soudan VIH. 2013. Genetic behavior of grain yield and its components in barley crosses under water stress and non-stress conditions. *Scientia Agriculturae* **1**(2): 45–55.