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# ESTIMATION OF COMBINING ABILITY AND HETEROSIS FOR GRAIN YIELD AND ITS ATTRIBUTES IN BARLEY (*HORDEUM VULGARE* L.)

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**ABSTRACT**

Barley is a nutri-rich rabi season cereal grain crop, known for its low input requirement even under harsh environments. The current study was carried out at CCS Haryana Agricultural University, Hisar (Haryana) during the crop season 2019-20 and 2020-21 with the objective to estimate the combining ability and heterosis relates to grain yield and its contributing traits. The experimental material comprised of sixteen barley genotypes consisting twelve lines (female) and four testers (male), crossed in line x tester design in order to obtained 48 crosses ($F_{1s}$). The analysis of variance revealed significant difference due to treatments, parents vs. crosses, crosses and line x tester for all the ten studied traits. Among the parents, three lines namely BBM 797, IBON-HI-2018-19-12, IBON-HI-2018-19-45 and one tester i.e. BH 885 exhibited positive significant GCA effects for grain yield. However, among crosses, IBON-HI 2018-19-12/ BH 902 showed highest positive and significant SCA effects followed by IBON-HI 2018-19-16/ BH 959 and IBON-HI 2018-19-119/ BH 885 for grain yield. Combining ability analysis elucidated higher magnitude of variance due to SCA than the GCA variances and higher estimates of dominance variance to additive indicated prevalence of non-additive gene action in almost all the traits. The average heterosis for grain yield was recorded highest in the cross IBON-HI 2018-19-12/ BH 902 followed by IBON-HI 2018-19-45/ BH 885 and BBM 797/ BH 946. Similarly, the crosses, IBON-HI 2018-19-45/ BH 885, IBON-HI 2018-19-12/ BH 902 and IBON-HI 2018-19-119/ BH 885 elucidated desirable heterobeltiosis for grain yield. The relative contribution of lines x testers' component was higher than the lines and testers for almost all the traits, confirming predominant role of non-additive gene effects in the inheritance of the characters. Consequently, one could plan for heterosis breeding availing information on combining ability effects, type of variances and magnitude of heterosis aimed to enhance grain yield in barley.
***Keywords*:** Barley, combining ability, heterosis, yield traits

## Introduction

Barley (*Hordeum vulgare* L.) ranks fourth in terms of total production and area cultivated after wheat, rice and maize in the world with annual production over 142.29 million tonnes (USDA, 2023). In India, it occupies around 0.62 mha area that produces 1.69 mt with the productivity of 27.33 q/ha. Barley was cultivated on 15,300 hectares with a production of 53,300 tons in Haryana state that ranked second in average productivity (34.86 q/ha) after Punjab (36.54 q/ha) during 2022-23 (ICAR-IIWBR, 2023). It has been widely utilized for different purposes such as, stable health food for mankind, cheap ingredient in whisky and beer production industry and as animal feed and fodder (Bornare *et al.*, 2014). It is a hardy crop, has enormous elasticity of adaptation to various stresses. This crop can flourish well and gives good returns even under less resource of irrigation and fertilizers.

It is of immense important to understand the nature and magnitude of gene effects controlling the inheritance of important traits for laying the foundation of a targeted crop improvement program (Singh *et al*., 2017). These studies facilitate the breeder to select the appropriate breeding approach for deciding the type of variety to be developed for a particular situation. Combining ability analysis is one of the powerful tools to evaluate the comparative performance of different parental lines involved in hybrid combinations and provides useful information to select the suitable parent and crosses for exploitation of heterosis (Kakani *et al*., 2007). Based *per se* performance of parent, it is not possible to know their combining ability, hence the information on nature of gene action and their expression in terms of combining ability is necessary (Patial *et al*., 2016). Potla *et al.* (2013); Bornare *et al.* (2014) and Zhang *et al*. (2015) have also delineated combining ability analysis for selection of rewarding parents and crosses in barley breeding. The heterosis breeding has been employed and is being exploited for the development promising hybrids more frequently in cross pollinated and limited in self pollinated crops. The cost of production and magnitude of heterosis are known to limit the exploitation of hybrid vigour commercially in case of self pollinated crops. And if the magnitude of heterosis is found to be desirable, the attempts towards exploitation of hybrid vigour will be very encouraging. Line x Tester mating design suggested by Kempthorne (1957) is one of the efficient methods to evaluate the combining ability that also facilitated to test large number of inbred lines.

In the present study an attempt has been made to estimate the extent of heterosis and combining ability of parents and hybrids to find out gene action controlling the inheritance of characters for generating hybrids through line x tester system of mating.

## Materials and Methods

The current study was carried out at Barley Research Area of Department of Genetics and Plant Breeding, CCS, Haryana Agricultural University, Hisar (Haryana). The crosses were attempted in line × tester fashion involving twelve lines (female) and four testers (male) to generate 48 crosses of barley during *rabi* 2019-20. These crosses alongwith their parents were sown in randomized block design with three replications during 2020-21 crop season. Each genotype was planted in a single row of 1.5 m length, spaced at 25cm apart. All the agronomic practices recommended were accordingly followed to raise the crop.

The observations on yield and its contributing traits *viz*., days to heading, days to maturity, number of effective tillers per meter row, plant height (cm), spike length (cm), number of grains per spike, 1000-grain weight (g), biological yield per plot (g), harvest index (%) and grain yield per plot (g) were recorded at appropriate stages of the crop growth. Analysis of variance for line x tester was carried out as described by Kempthorne (1957) and detailed by Singh and Chaudhary (1985). Heterosis expressed as percentage increase or decrease of $F_1$s' over mid parent (average heterosis) and better parent (heterobeltiosis) was also calculated according to the methods suggested by Kempthorne (1957). INDOSTAT software version 8.1 was used for statistical analysis of the recorded data.

## Results and Discussion

The perusal of ANOVA as depicted in Table 1 revealed highly significant mean squares due to treatments for all the traits. The further partitioning of treatment mean squares *i.e.* due to parents, parents vs. crosses and crosses are similarly indicating the highly significant variations for all characters under study. The mean squares due to lines were highly significant for number of effective tillers per meter row and number of grains per spike and significant for harvest index, while for testers, it was significant for number of grains per spike. The estimates of mean squares due to lines were observed higher over the testers mean squares with exception of grain yield per plot, indicating their higher variability compared to testers. Similarly, the interactions due to lines and testers were also exhibited highly significant variance for all the traits. These findings are in congruence with earlier reports by Potla *et al.* (2013) and Singh *et al*. (2017).

### General Combining Ability (GCA) effects of parents

The results presented in Table 3 showed the estimates of general combining ability effects of parents used in the study. The perusal of data revealed both positive and negative estimates of GCA effect, of which negative estimates for days to heading and maturity and plant height exhibited by parents indicated their superiority for these traits. Consequently, the parents with highly significant GCA effects found to be good combiners. Among the lines, 6$^{th}$ GSBON-2018-19-27 was found good combiner for plant height; 6$^{th}$ GSBON-2018-19-32 for days to heading and 1000-garin weight; 6$^{th}$ GSBON-2018-19-132 for number of grains per spike; IBON-HI-2018-19-12 for days to heading and maturity, number of tillers per meter row, grain and biological yield and harvest index; IBON-HI-2018-19-16 and IBON-HI-2018-19-122 for days to heading and maturity; IBON-HI-2018-19-45 for spike length, 1000-grain weight, grain and biological yield; IBON-HI-2018-19-75 and IBON-HI-2018-19-119 for 1000-garin weight; 6$^{th}$ GSBYT-2018-19-15 for number of tillers per meter row, spike length, number of grains per spike and biological yield; BBM797 for number of grains per spike, grain and biological yield and harvest index; and BBM814 for number of grains per spike and harvest index. Likewise, among the testers, BH 946 was identified as a good general combiner for plant height and harvest index; BH 902 for days to maturity; BH 885 for spike length, 1000-grain weight, grain and biological yield; and BH 959 for days to heading. The negative GCA of plant height is in consensus with reports of Li HongTao *et al.* (2015). The general combining ability effects were also estimated and reported in barley (Verma *et al*., 2007; Singh *et al*., 2013; Lal *et al*., 2018c; Madakemohekar *et al*., 2018; Swati *et al*., 2018; Kumari *et al*., 2020) for the identification of good combiners.

**Specific Combining Ability (SCA) effects of crosses**

Table 3 accounted for specific combining ability effect of 48 different cross combinations. The crosses with high significant SCA effects for the traits indicated their superior performance for the concerned traits. Some crosses possessed better SCA effects for many traits. Such crosses identified were 6th GSBON 2018-19-32/ BH 885 for days to maturity, number of grains per spike and biological yield; IBON-HI 2018-19-12/ BH 902 for number of tillers per meter row, grain and biological yield; IBON-HI 2018-19-16/ BH 959 for spike length, and grain and biological yield; IBON-HI 2018-19-45/ BH 885 for spike length, number of grains per spike and biological yield; IBON-HI 2018-19-45/ BH 959 for days to heading, maturity and plant height; IBON-HI 2018-19-75/ BH 946 for number of tillers per meter row, grain and biological yield; IBON-HI 2018-19-119/ BH 885 for days to heading, number of tillers per meter row, grain and biological yield; and 6th GSBYT 2018-19-15/ BH 959 for days to heading, plant height, number of grains per spike and harvest index. Some findings were also deciphered the specific combining ability effects in finding out the best parental combinations in barley (Pawar and Singh, 2013; Zhang *et al*., 2015; Lal *et al*., 2018c; Swati *et al*., 2018; Jalata *et al*., 2019; Kumari *et al*., 2020).

**Components of Genetic Variance**

The components of genetic variance *i.e.* variance due to GCA ($\sigma^2$GCA), SCA ($\sigma^2$SCA), additive ($\sigma^2$A), dominance ($\sigma^2$D) and Degree of dominance ($\sqrt{\sigma^2 D/\sigma^2 A}$) were estimated and are illustrated in Table 4. The estimates of genetic component of variance due to SCA were found to be highly significant and higher in magnitude compared to GCA variances for all the traits. And their ratios were found lesser than unity. Similarly, the dominance variance for all the characters were observed higher than the respective additive variance, consequently having degree of dominance greater than unity with the exception for number of grains per spike. These findings indicated the control of non-additive gene effects and the predominant role of dominance gene action on the expression of the traits. Previous findings of Potla *et al.* (2013) and Singh *et al.* (2017) also delineated the role of non-additive gene effects in the expression of various traits in barley.

**Heterosis**

The magnitude of heterosis over the mid parent (average heterosis) in 48 $F_{1's}$ for ten traits were estimated as shown in Table 5. Manifestation of heterosis was observed in both positive and negative directions. The negative values of heterosis were considered for the traits *viz*., days to heading, maturity and plant height as desirable for these traits. A total of 23 out of 48 crosses exhibited significant negative heterosis for early heading; among them superior crosses found were 6th GSBON 2018-19-32/ BH 946, IBON-HI 2018-19-122/ BH 946, IBON-HI 2018-19-122/ BH 902 and IBON-HI 2018-19-122/ BH 959. Likewise, the desirable crosses showing negative and significant heterobeltiosis for days to maturity were IBON-HI 2018-19-122/ BH 946, IBON-HI 2018-19-75/ BH 902 and IBON-HI 2018-19-122/ BH 946. The cross, 6th GSBON 2018-19-27/ BH 946 was found promising for plant height revealed by highly significant negative heterosis. The desirable positive significant heterosis for number of tillers per meter row were found in crosses, IBON-HI 2018-19-12/ BH 902, 6th GSBYT 2018-19-15/ BH 902 and 6th GSBYT 2018-19-15/ BH 946. Out of 48 crosses, high manifestation of significant positive heterosis for spike length was exhibited by IBON-HI 2018-19-45/ BH 885, IBON-HI 2018-19-122/ BH 946, IBON-HI 2018-19-45/ BH 959 and IBON-HI 2018-19-122/ BH 959. Positively significant heterotic effects for number of grains per spike were found in 6th GSBON 2018-19-132/ BH 885, IBON-HI 2018-19-75/ BH 885 and IBON-HI 2018-19-45/ BH 885 crosses. Four crosses *viz*., 6th GSBYT 2018-19-15/ BH 946, BBM 814/ BH 959, IBON-HI 2018-19-45/ BH 885 and IBON-HI 2018-19-122/ BH 959 depicted significant heterosis for 1000-grain weight. The magnitude of average heterosis for grain yield ranged from 8.56 to 83.65 % and was illustrated highest by the cross IBON-HI 2018-19-12/ BH 902 followed by IBON-HI 2018-19-45/ BH 885 and BBM 797/ BH 946. The highest significant positive heterosis for biological yield was evidenced by the cross IBON-HI 2018-19-45/ BH 885 followed by 6th GSBYT 2018-19-15/ BH 885 and 6th GSBYT 2018-19-15/ BH 902.

The crosses exhibiting highly positive significant heterosis for harvest index in the study portrayed by 6th GSBON 2018-19-132/ BH 902, IBON-HI 2018-19-12/ BH 902 and IBON-HI 2018-19-12/ BH 885.

The perusal of Table 6 indicated the estimates of heterosis over the better parent (heterobeltiosis) estimated for 48 $F_{1's}$ obtained from line x tester analysis. The negative values of heterosis as desirable for days to heading, maturity and plant height, were considered accordingly. The crosses exhibited desirable heterobeltiosis for days to heading observed were 6th GSBON 2018-19-32/ BH 946, 6th GSBON 2018-19-132/ BH 959, IBON-HI 2018-19-122/ BH 946, IBON-HI 2018-19-122/ BH 902, IBON-HI 2018-19-122/ BH 885, IBON-HI 2018-19-122/ BH 959 and 6th GSBYT 2018-19-15/ BH 959. Similarly, the crosses exhibiting negative and significant heterobeltiosis desirable for days to maturity recorded were IBON-HI 2018-19-16/ BH 902, IBON-HI 2018-19-75/ BH 902 and IBON-HI 2018-19-122/ BH 946. Among all, four crosses *i.e.* 6th GSBON 2018-19-27/ BH 946, 6th GSBON 2018-19-27/ BH 959, 6th GSBON 2018-19-132/ BH 902 and IBON-HI 2018-19-75/ BH 902 exhibited their superiority for plant height over the better parent. The crosses namely IBON-HI 2018-19-12/ BH 902, 6th GSBYT 2018-19-15/ BH 902 and 6th GSBYT 2018-19-15/ BH 946 explained their superiority among all crosses for number of tillers per meter row. The crosses manifested highly significant positive heterobeltiosis for spike length were IBON-HI 2018-19-45/ BH 885 and IBON-HI 2018-19-45/ BH 959. The cross IBON-HI 2018-19-75/ BH 885 possessed highest positive significant heterobeltiosis for number of grains per spike, followed by 6th GSBON 2018-19-132/ BH 885 and IBON-HI 2018-19-45/ BH 885. Five crosses showed significant heterobeltiosis for 1000-grain weight, *viz*., 6th GSBYT 2018-19-15/ BH 946, BBM 814/ BH 959, 6th GSBON 2018-19-32/ BH 885, IBON-HI 2018-19-122/ BH 959 and 6th GSBON 2018-19-32/ BH 902. The heterosis study also revealed the desirable heterobeltiosis for grain yield as elucidated by the crosses, IBON-HI 2018-19-45/ BH 885, IBON-HI 2018-19-12/ BH 902 and IBON-HI 2018-19-119/ BH 885. A total of eleven crosses showed significant positive heterobeltiosis for biological yield, ranging from 6.04 (IBON-HI 2018-19-12/ BH 902) to 80.24 % (IBON-HI 2018-19-45/ BH 885).The heterobeltiosis for harvest index was observed as its maximum and desirable in cross 6th GSBON 2018-19-132/ BH 902. Many researchers have also identified the potential cross combinations for different traits in barley (Ram and Shekawat, 2017; Lal *et al*., 2018a; Lal *et al*., 2018b; and Jalata *et al*., 2019).

The proportional contribution of lines, testers and their interaction for different characters are presented in Table 7. The proportional contribution of lines was observed maximum for number of grains per spike (68.40) followed by number of tillers per meter row (55.72) and harvest index (38.97). Similarly, the contribution of testers towards total variance was recorded maximum for grain yield (11.49) followed by number of grains per spike (7.86) and days to heading (7.72). Likewise, the interaction of lines and testers contributed highest through plant height (70.87) to total variance, followed by 1000-grain weight (69.94) and spike length (64.43). The relative contribution of parents and their interactions to the total variance has also been discerned by Singh *et al.* (2017) and Katiyar *et al.* (2021) in barley.

## Conclusion

The analysis of variance revealed significant mean squares due to treatments, parents vs. crosses, crosses as well as for line x tester for all the traits. Based on desirable GCA effects, BBM797, IBON-HI-2018-19-12, IBON-HI-2018-19-45 among the lines and BH 885 among tester were identified as superior donors for grain yield. The crosses, IBON-HI 2018-19-12/ BH 902, IBON-HI 2018-19-16/ BH 959 and IBON-HI 2018-19-119/ BH 885 exhibited highly positive and significant SCA effects for grain yield, indicating the preponderance of non-additive gene action. Higher estimates of SCA variance over the GCA as well as higher dominance variance to additive in almost all the traits also indicated control of non-additive gene effects. The average heterosis was recorded highest in the cross IBON-HI 2018-19-12/ BH 902 followed by IBON-HI 2018-19-45/ BH 885 and BBM 797/ BH 946 for grain yield. Similarly, the crosses viz., IBON-HI 2018-19-45/ BH 885, IBON-HI 2018-19-12/ BH 902 and IBON-HI 2018-19-119/ BH 885 elucidated desirable heterobeltiosis for grain yield. The lines, testers and their interaction contributed highly towards total variance through number of grains per spike, grain yield and plant height, respectively. Consequently, the findings concluded pointed to the parents identified as good donors / combiners be exploited for other cross combinations. Additionally, the crosses recorded with superior performance for multi traits could be advanced for further selection intended to develop promising barley cultivars.

**Table 1:** Analysis of variance for combining ability of different traits in barley

| Source | d.f. | DH | DM | T/M | PH | SL | G/S | TGW | GY | BY | HI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Replications** | 2 | 3.02 | 4.02 | 81.08 | 51.06 | 0.09 | 0.75 | 1.99 | 380.60 | 5213.02 | 0.35 |
| **Treatments** | 63 | 65.48** | 26.71** | 2347.19** | 173.28** | 3.67** | 482.79** | 273.67** | 59728.54** | 831562.73** | 174.54** |
| **Parents** | 15 | 72.79** | 24.89** | 730.87** | 182.24** | 3.99** | 625.22** | 102.52** | 32481.91** | 457483.89** | 117.20** |
| **Parents vs. Crosses** | 1 | 32.11** | 11.39* | 12460.14** | 689.06** | 25.25** | 413.44** | 3054.87** | 201002.78** | 977214.63** | 135.12** |
| **Crosses** | 47 | 63.86** | 27.61** | 2647.86** | 159.44** | 3.11** | 438.81** | 269.12** | 65418.44** | 947850.62** | 193.68** |
| **Lines** | 11 | 86.32 | 36.00 | 6303.74** | 165.24 | 3.76 | 1282.41** | 280.00 | 81992.60 | 1236638.05 | 322.50* |
| **Testers** | 3 | 77.27 | 27.08 | 1147.17 | 121.75 | 3.56 | 540.33* | 240.65 | 117771.01 | 1136622.40 | 227.59 |
| **Lines x Testers** | 33 | 55.15** | 24.86** | 1565.66** | 160.94** | 2.86** | 148.37** | 268.09** | 55134.39** | 834427.07** | 147.66** |
| **Error** | 126 | 2.67 | 2.02 | 27.90 | 30.28 | 0.12 | 2.25 | 1.65 | 460.63 | 2029.29 | 5.64 |

DH: Days to heading; DM: Days to maturity; TM: Number of effective tillers per meter row; PH: Plant height; SL: Spike length; GS: Number of grains per spike; TGW: 1000- grain weight; GY: Grain yield per plot; BY: Biological yield per plot; HI: Harvest index; *, ** Significant at p=0.05 and 0.01, respectively

**Table 2:** GCA effects of lines and testers for different characters in barley

| Parents/Variables | DH | DM | T/M | PH | SL | G/S | TGW | GY | BY | HI |
|---|---|---|---|---|---|---|---|---|---|---|
| **Lines** | | | | | | | | | | |
| **6th GSBON-2018-19-27** | 1.49** | -0.77 | 5.15** | -10.23** | 0.07 | -11.03** | 0.20 | -47.05** | -260.24** | 1.59* |
| **6th GSBON-2018-19-32** | -1.51** | 0.98* | 4.65** | -0.23 | 0.12 | -10.03** | 5.91** | -114.13** | -260.24** | -4.88** |
| **6th GSBON-2018-19-132** | 2.90** | 1.73** | -12.02** | 0.02 | 0.40** | 17.97** | -6.60** | -0.38 | -362.74** | 9.61** |
| **IBON-HI-2018-19-12** | -1.51** | -2.27** | 32.81** | -1.06 | -1.17** | -9.53** | -3.32** | 115.45** | 216.01** | 2.96** |
| **IBON-HI-2018-19-16** | -4.26** | -2.19** | -2.94 | 4.35** | -0.18 | -8.36** | -5.26** | 21.28** | 192.26** | -3.88** |
| **IBON-HI-2018-19-45** | 0.57 | 0.65 | 5.48** | 2.52 | 0.77** | -8.36** | 4.80** | 96.28** | 343.09** | 0.22 |
| **IBON-HI-2018-19-75** | -0.85 | -0.35 | -16.69** | -0.56 | -0.12 | -8.69** | 6.35** | -77.05** | -169.41** | -4.22** |
| **IBON-HI-2018-19-119** | 3.40** | -0.69 | -12.19** | 3.52* | 0.16 | 3.31** | 4.16** | -31.63** | -129.41** | -0.53 |
| **IBON-HI-2018-19-122** | -5.01** | -1.85** | -13.85** | 2.27 | -0.63** | 5.97** | 1.07** | -62.88** | -148.16** | -0.43 |
| **6th GSBYT-2018-19-15** | 1.15* | -0.10 | 46.98** | 0.85 | 0.87** | 8.47** | 2.65** | -7.88 | 644.34** | -9.61** |
| **BBM797** | 1.90** | 1.40** | 3.06* | -0.15 | -0.28** | 9.81** | -4.36** | 154.20** | 267.67** | 5.01** |
| **BBM814** | 1.74** | 3.48** | -40.44** | -1.31 | -0.01 | 10.47** | -5.60** | -46.22** | -333.16** | 4.17** |
| **Testers** | | | | | | | | | | |
| **BH 946** | -0.15 | 0.67** | -8.41** | -2.34** | -0.29** | 1.08** | -2.69** | -44.27** | -201.77** | 2.72** |
| **BH 902** | 0.29 | -1.19** | 3.73** | 1.72 | -0.07 | 1.36** | 0.04 | -31.08** | -71.63** | -1.15** |
| **BH 885** | 1.71** | 0.62* | 2.42** | 1.19 | 0.45** | -5.64** | 3.48** | 82.67** | 212.53** | 1.33** |
| **BH 959** | -1.85** | -0.10 | 2.26* | -0.56 | -0.09 | 3.19** | -0.84** | -7.33* | 60.87** | -2.91** |

*, ** Significant at p=0.05 and 0.01, respectively

**Table 3:** SCA effects of crosses for different characters in barley

| Crosses/Variables | DH | DM | T/M | PH | SL | G/S | TGW | GY | BY | HI |
|---|---|---|---|---|---|---|---|---|---|---|
| 6th GSBON 2018-19-27/ BH 946 | 2.07* | 0.49 | -23.09** | -12.49** | -1.35** | -1.75* | -9.15** | 60.52** | -93.65** | 10.3** |
| 6th GSBON 2018-19-27/ BH 902 | -1.38 | 0.69 | 24.77** | 7.78* | 0.71** | -0.03 | 5.55** | 78.99** | 202.88** | 1.07 |
| 6th GSBON 2018-19-27/ BH 885 | 1.87 | -0.12 | 19.41** | 11.65** | 0.78** | 8.31** | 5.88** | -63.09** | 137.05** | -8.20** |
| 6th GSBON 2018-19-27/ BH 959 | -2.57** | -1.06 | -21.09** | -6.94* | -0.15 | -6.53** | -2.27** | -76.42** | -246.28** | -3.17* |
| 6th GSBON 2018-19-32/ BH 946 | -9.26** | 1.08 | 20.08** | -1.83 | 0.17 | -1.42 | 3.43** | -0.73 | 9.69 | -5.97** |
| 6th GSBON 2018-19-32/ BH 902 | -0.04 | 1.60 | -29.4** | -1.88 | 0.22 | -2.36** | 6.90** | 16.08 | 226.22** | -4.85** |
| 6th GSBON 2018-19-32/ BH 885 | 4.54** | -4.53** | 17.91** | 5.31 | 0.73** | 7.97** | 6.59** | 85.66** | 543.72** | -1.77 |
| 6th GSBON 2018-19-32/ BH 959 | 4.76** | 1.85* | -8.59** | -1.60 | -1.13** | -4.19** | -16.92** | -101.01** | -779.62** | 12.59** |
| 6th GSBON 2018-19-132/ BH 946 | 2.65** | 3.66** | -20.59** | 9.59** | 0.16 | -5.42** | -8.59** | -161.15** | -364.48** | -6.73** |
| 6th GSBON 2018-19-132/ BH 902 | -1.79 | -2.15* | 13.94** | -6.47* | 0.38* | 0.97 | 0.51 | -52.67** | -299.62** | 9.87** |
| 6th GSBON 2018-19-132/ BH 885 | 1.46 | 0.72 | -4.09 | -1.60 | -0.27 | 6.64** | -3.16** | 171.91** | 496.22** | -1.31 |
| 6th GSBON 2018-19-132/ BH 959 | -2.32* | -2.23** | 10.74** | -1.52 | -0.27 | -2.19* | 11.23** | 41.91** | 167.88** | -1.83 |
| IBON-HI 2018-19-12/ BH 946 | -5.26** | -2.01* | -15.42** | -1.66 | 0.73** | -1.92* | 4.33** | 39.69** | 123.44** | -1.35 |
| IBON-HI 2018-19-12/ BH 902 | -3.04** | 0.52 | 35.10** | 5.62 | -0.72** | -2.86** | -4.44** | 261.49** | 613.30** | 5.06** |
| IBON-HI 2018-19-12/ BH 885 | 3.54** | 3.72** | -19.59** | -9.85** | -1.01** | 7.47** | -13.64** | -127.26** | -602.53** | 5.24** |
| IBON-HI 2018-19-12/ BH 959 | 4.76** | -2.23** | -0.09 | 5.90 | 1.00** | -2.69** | 13.75** | -173.92** | -134.20** | -8.95** |
| IBON-HI 2018-19-16/ BH 946 | 3.82** | -0.42 | 6.66* | 2.26 | 0.90** | 0.25 | 15.30** | -82.81** | 268.85** | -11.83** |
| IBON-HI 2018-19-16/ BH 902 | 3.04** | -2.56** | 6.19* | -2.47 | -0.41* | -4.69** | 3.27** | -151.01** | -639.62** | -1.55 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| IBON-HI 2018-19-16/ BH 885 | -5.04** | -0.70 | -20.51** | -6.6* | -1.63** | 7.64** | -12.2** | -19.76 | -337.12** | 6.42** |
| IBON-HI 2018-19-16/ BH 959 | -1.82 | 3.69** | 7.66* | 6.81* | 1.14** | -3.19** | -6.38** | 253.58** | 707.88** | 6.96** |
| IBON-HI 2018-19-45/ BH 946 | 3.65** | -0.26 | -33.42** | -4.58 | -0.98** | -3.75** | -0.65 | -131.15** | -660.31** | 2.42 |
| IBON-HI 2018-19-45/ BH 902 | 1.88 | 0.94 | 19.44** | 5.70 | -0.39* | -4.03** | 1.71* | -31.01** | 114.55** | -4.22** |
| IBON-HI 2018-19-45/ BH 885 | 1.46 | 3.47** | 5.74 | 8.56** | 1.12** | 7.64** | 4.04** | 110.24** | 520.38** | -1.70 |
| IBON-HI 2018-19-45/ BH 959 | -6.99** | -4.15** | 8.24** | -9.69** | 0.25 | 0.14 | -5.10** | 51.91** | 25.38 | 3.50* |
| IBON-HI 2018-19-75/ BH 946 | 0.4 | 1.08 | 27.41** | 2.17 | -0.22 | -4.08** | 7.02** | 165.52** | 960.52** | -5.41** |
| IBON-HI 2018-19-75/ BH 902 | -5.04** | -4.06** | -28.40** | -5.88 | -0.63** | -2.36** | -15.51** | -71.01** | -471.28** | 2.58 |
| IBON-HI 2018-19-75/ BH 885 | -1.79 | -2.53** | 6.24* | -3.69 | -0.46* | 7.31** | 0.08 | -126.42** | -473.78** | -0.74 |
| IBON-HI 2018-19-75/ BH 959 | 6.43** | 5.52** | -5.26 | 7.4* | 1.31** | -0.86 | 8.41** | 31.91** | -15.45 | 3.58* |
| IBON-HI 2018-19-119/ BH 946 | 2.49* | 0.74 | -9.42** | 8.76** | 0.13 | 7.25** | -4.35** | 13.44 | -172.81** | 5.01** |
| IBON-HI 2018-19-119/ BH 902 | 2.38* | 2.94** | -28.9** | -4.63 | 1.08** | -1.69* | 0.91 | -138.09** | -664.62** | 2.62 |
| IBON-HI 2018-19-119/ BH 885 | -6.38** | -3.2** | 39.41** | -3.44 | -0.31 | -6.03** | 3.08** | 216.49** | 642.88** | 2.52 |
| IBON-HI 2018-19-119/ BH 959 | 1.51 | -0.48 | -1.09 | -0.69 | -0.9** | 0.47 | 0.36 | -91.84** | 194.55** | -10.15** |
| IBON-HI 2018-19-122/ BH 946 | -0.10 | -5.42** | -0.76 | -3.33 | 0.85** | 6.58** | -10.3** | 1.35 | -374.06** | 10.73** |
| IBON-HI 2018-19-122/ BH 902 | -2.21* | 1.44 | -3.23 | -6.38* | -1.29** | -3.03** | 4.47** | 43.16** | 404.13** | -6.76** |
| IBON-HI 2018-19-122/ BH 885 | 2.38* | 0.30 | -21.92** | -4.52 | 0.12 | -9.36** | 2.03** | -132.26** | -590.03** | -0.09 |
| IBON-HI 2018-19-122/ BH 959 | -0.07 | 3.69** | 25.91** | 14.23** | 0.32 | 5.81** | 3.79** | 87.74** | 559.97** | -3.88** |
| 6th GSBYT 2018-19-15/ BH 946 | -0.60 | 1.83* | 21.08** | 4.42 | 1.52** | 0.08 | 10.35** | -30.31* | 266.77** | -7.83** |
| 6th GSBYT 2018-19-15/ BH 902 | 3.63** | -1.31 | 4.94 | 3.03 | 0.57** | 3.81** | -4.48** | 16.49 | 356.63** | -2.27 |
| 6th GSBYT 2018-19-15/ BH 885 | 2.21* | 0.22 | -12.09** | 2.23 | -0.52** | -13.19** | 3.92** | 4.41 | 32.47 | 0.35 |
| 6th GSBYT 2018-19-15/ BH 959 | -5.24** | -0.73 | -13.92** | -9.69** | -1.58** | 9.31** | -9.79** | 9.41 | -655.87** | 9.75** |
| BBM 797/ BH 946 | -4.01** | -2.01* | 33.99** | -2.24 | -1.06** | 3.42** | -7.50** | 199.27** | 390.10** | 2.84* |
| BBM 797/ BH 902 | 1.21 | 1.52 | -17.81** | 4.37 | 0.52** | 8.47** | 8.37** | -23.92* | 71.63** | -2.92* |
| BBM 797/ BH 885 | -1.21 | 2.38** | -26.51** | 3.90 | 0.87** | -10.53** | 8.67** | -217.67** | -759.20** | 1.56 |
| BBM 797/ BH 959 | 4.01** | -1.9* | 10.33** | -6.02 | -0.33 | -1.36 | -9.54** | 42.33** | 297.47** | -1.48 |
| BBM 814/ BH 946 | 4.15** | 1.24 | -6.51* | -1.08 | -0.86** | 0.75 | 0.11 | -73.65** | -354.06** | 7.82** |
| BBM 814/ BH 902 | 1.38 | 0.44 | 3.35 | 1.20 | -0.04 | 7.81** | -7.29** | 51.49** | 85.80** | 1.38 |
| BBM 814/ BH 885 | -3.04** | 0.30 | 15.99** | -1.94 | 0.57** | -13.86** | -5.29** | 97.74** | 389.97** | -2.28 |
| BBM 814/ BH 959 | -2.49* | -1.98* | -12.84** | 1.81 | 0.34 | 5.31** | 12.46** | -75.59** | -121.70** | -6.92** |

*, ** Significant at p=0.05 and 0.01, respectively

**Table 4:** Estimates of genetic components of variances for various characters in barley

| Variance/Variables | DH | DM | T/M | PH | SL | G/S | TGW | GY | BY | HI |
|---|---|---|---|---|---|---|---|---|---|---|
| **$\sigma^2$ GCA** | 3.30** | 1.23* | 154.06*** | 4.72 | 0.15* | 37.88*** | 10.78 | 4142.55** | 49358.37* | 11.23** |
| **$\sigma^2$ SCA** | 17.49*** | 7.62*** | 512.59*** | 43.55*** | 0.91*** | 48.71*** | 88.81*** | 18224.59*** | 277465.93*** | 47.34*** |
| **$\sigma^2$ GCA/ $\sigma^2$ SCA** | 0.19 | 0.16 | 0.30 | 0.11 | 0.16 | 0.78 | 0.12 | 0.23 | 0.18 | 0.24 |
| **$\sigma^2$ A** | 6.59 | 2.46 | 308.13 | 9.43 | 0.30 | 75.76 | 21.56 | 8285.10 | 98716.74 | 22.45 |
| **$\sigma^2$ D** | 17.49 | 7.62 | 512.59 | 43.55 | 0.91 | 48.71 | 88.81 | 18224.59 | 277465.93 | 47.34 |
| **Degree of dominance ($\sqrt{\sigma^2 D/\sigma^2 A}$)** | 1.63 | 1.76 | 1.29 | 2.15 | 1.74 | 0.80 | 2.03 | 1.48 | 1.68 | 1.45 |

*, **, *** Significant at p=0.05, 0.01 and, 0.001 respectively

**Table 5:** Estimates of average heterosis for different characters in barley

| Crosses/Variables | DH | DM | T/M | PH | SL | G/S | TGW | GY | BY | HI |
|---|---|---|---|---|---|---|---|---|---|---|
| 6th GSBON 2018-19-27/ BH 946 | 3.39** | -0.50 | -15.60** | -16.12** | -0.59 | -31.25** | -5.15* | -31.28** | -43.46** | 27.02** |
| 6th GSBON 2018-19-27/ BH 902 | -0.71 | -3.08** | 53.87** | 3.63 | 22.29** | -21.67** | 28.13** | -17.84** | -12.72** | -3.93 |
| 6th GSBON 2018-19-27/ BH 885 | 7.27** | -1.61* | 28.31** | 17.77** | 26.73** | 18.07** | 33.88** | -19.39** | 22.11** | -32.50** |
| 6th GSBON 2018-19-27/ BH 959 | -2.17 | -2.37** | -4.99 | -7.05 | 17.30** | -36.00** | 16.8** | -54.29** | -32.09** | -30.47** |
| 6th GSBON 2018-19-32/ BH 946 | -10.99** | 0.87 | 27.91** | 1.28 | 17.19** | -31.34** | 37.32** | -68.40** | -39.10** | -47.25** |
| 6th GSBON 2018-19-32/ BH 902 | -1.43 | -1.47* | -2.67 | 1.08 | 16.67** | -28.57** | 41.95** | -58.9** | -16.74** | -50.43** |
| 6th GSBON 2018-19-32/ BH 885 | 8.09** | -3.96** | 27.84** | 17.91** | 26.02** | 12.36** | 45.93** | -5.48 | 48.26** | -35.80** |
| 6th GSBON 2018-19-32/ BH 959 | 3.65** | 0.75 | 7.82* | 5.21 | 5.53 | -31.30** | -6.86** | -82.4** | -81.31** | -4.61 |
| 6th GSBON 2018-19-132/ BH 946 | 0 | 2.47** | -34.86** | 7.98* | 17.11** | 0 | -17.86** | -81.15** | -81.70** | 3.05 |
| 6th GSBON 2018-19-132/ BH 902 | -4.86** | -4.51** | 15.17** | -6.65 | 18.45** | 17.95** | 4.16 | -51.66** | -70.39** | 63.60** |
| 6th GSBON 2018-19-132/ BH 885 | 2.58* | -0.37 | -15.11** | 6.47 | 14.86** | 51.26** | 1.38 | 36.53** | 9.54** | 22.54** |
| 6th GSBON 2018-19-132/ BH 959 | -5.64** | -2.59** | 1.80 | 1.25 | 15.77** | 11.80** | 37.66** | -23.08** | -27.33** | 5.05 |
| IBON-HI 2018-19-12/ BH 946 | -7.66** | -2.40** | 32.48** | -2.48 | 0.18 | -32.85** | 8.36** | 8.56* | -18.44** | 24.17** |
| IBON-HI 2018-19-12/ BH 902 | -5.65** | -3.24** | 117.36** | 4.02 | -15.59** | -30.23** | -11.06** | 83.65** | 13.39** | 57.04** |
| IBON-HI 2018-19-12/ BH 885 | 5.82** | 1.26 | 30.05** | -1.63 | -14.63** | 8.70* | -24.57** | 13.61** | -33.87** | 55.63** |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| IBON-HI 2018-19-12/ BH 959 | 2.53* | -3.28** | 57.50** | 8.20* | 6.38* | -28.36** | 34.00** | -34.15** | -16.62** | -26.84** |
| IBON-HI 2018-19-16/ BH 946 | 1.09 | -1.39 | 6.62 | 5.86 | 18.79** | -23.31** | 35.95** | -60.36** | 2.45 | -61.34** |
| IBON-HI 2018-19-16/ BH 902 | -0.18 | -5.72** | 26.82** | 1.34 | 3.13 | -29.60** | 6.46** | -70.68** | -54.74** | -34.91** |
| IBON-HI 2018-19-16/ BH 885 | -4.64** | -2.26** | -15.35** | 6.51 | -6.33* | 18.18** | -21.64** | -9.64** | -5.16* | -5.31 |
| IBON-HI 2018-19-16/ BH 959 | -5.71** | 1.01 | 15.91** | 13.84** | 25.14** | -24.62** | -10.42** | 27.38** | 54.83** | -17.86** |
| IBON-HI 2018-19-45/ BH 946 | 4.10** | 2.43** | -20.35** | -1.25 | 15.85** | -31.82** | 37.56** | -42.92** | -36.13** | -7.30 |
| IBON-HI 2018-19-45/ BH 902 | 1.77 | 0.51 | 59.55** | 7.95* | 21.65** | -27.42** | 39.89** | -6.47 | 37.37** | -31.72** |
| IBON-HI 2018-19-45/ BH 885 | 5.82** | 4.58** | 23.40** | 20.72** | 42.86** | 19.54** | 50.62** | 81.72** | 131.47** | -20.11** |
| IBON-HI 2018-19-45/ BH 959 | -7.94** | -1.28 | 31.96** | -2.54 | 34.98** | -16.28** | 31.29** | 26.03** | 56.67** | -17.75** |
| IBON-HI 2018-19-75/ BH 946 | -0.18 | 1.39 | 9.76** | -1.65 | 6.84* | -32.31** | 37.85** | -31.05** | 26.29** | -45.32** |
| IBON-HI 2018-19-75/ BH 902 | -6.41** | -5.24** | -27.40** | -8.67* | 1.48 | -22.95** | -12.83** | -75.86** | -67.33** | -25.86** |
| IBON-HI 2018-19-75/ BH 885 | 1.47 | -2.01** | -6.31 | 1.42 | 7.25** | 20.00** | 24.97** | -60.84** | -41.96** | -32.72** |
| IBON-HI 2018-19-75/ BH 959 | 5.82** | 4.04** | -13.03** | 6.56 | 28.08** | -18.11** | 45.76** | -47.91** | -22.30** | -33.01** |
| IBON-HI 2018-19-119/ BH 946 | 8.39** | 2.18** | -19.87** | 6.51 | 6.01* | -12.22** | 22.88** | -52.10** | -59.96** | 14.19* |
| IBON-HI 2018-19-119/ BH 902 | 7.78** | 1.01 | -21.82** | -5.28 | 15.12** | -23.26** | 33.20** | -80.15** | -81.55** | 4.93 |
| IBON-HI 2018-19-119/ BH 885 | 2.79* | -1.53* | 29.77** | 4.05 | 4.39 | -27.41** | 43.44** | 31.37** | 16.21** | 6.38 |
| IBON-HI 2018-19-119/ BH 959 | 6.84** | 0.51 | -3.19 | 1.51 | -1.79 | -18.64** | 40.56** | -64.31** | -22.6** | -56.21** |
| IBON-HI 2018-19-122/ BH 946 | -10.96** | -6.57** | -7.77* | -5.19 | 35.15** | 7.19** | 5.59* | -57.31** | -66.55** | 27.92** |
| IBON-HI 2018-19-122/ BH 902 | -13.38** | -4.16** | 10.04* | -7.71* | 5.03 | -6.21** | 41.94** | -41.46** | -8.66** | -35.48** |
| IBON-HI 2018-19-122/ BH 885 | -4.81** | -2.96** | -23.87** | 2.03 | 27.62** | -11.11** | 41.13** | -53.28** | -49.66** | -7.81 |
| IBON-HI 2018-19-122/ BH 959 | -11.60** | -0.50 | 28.26** | 14.03** | 32.41** | 12.00** | 50.16** | -23.87** | 19.34** | -36.38** |
| 6th GSBYT 2018-19-15/ BH 946 | -4.26** | 0.87 | 83.60** | 5.77 | 26.48** | -15.08** | 64.32** | -46.24** | 70.07** | -67.48** |
| 6th GSBYT 2018-19-15/ BH 902 | -0.34 | -4.19** | 93.46** | 4.20 | 15.59** | -4.09* | 21.59** | -26.32** | 76.31** | -58.18** |
| 6th GSBYT 2018-19-15/ BH 885 | 2.43* | -0.99 | 48.84** | 13.01** | 8.00** | -31.34** | 47.78** | 10.17* | 101.77** | -44.71** |
| 6th GSBYT 2018-19-15/ BH 959 | -9.66** | -1.75* | 54.28** | -3.97 | -2.82 | 5.68** | 15.30** | -20.65** | 14.46** | -29.14** |
| BBM 797/ BH 946 | -2.15 | 0.76 | 46.02** | 0.16 | -11.31** | -9.29** | -0.74 | 38.46** | 26.72** | 10.79* |
| BBM 797/ BH 902 | 3.02* | 0.63 | 12.85** | 6.10 | 4.81 | 4.00* | 39.22** | -4.88 | 5.50* | -9.16 |
| BBM 797/ BH 885 | 4.94** | 3.40** | -11.79** | 15.58** | 11.82** | -24.64** | 45.31** | -18.78** | -24.34** | 7.69 |
| BBM 797/ BH 959 | 5.99** | 0.13 | 29.83** | 0.16 | -0.36 | -12.22** | -0.79 | 18.52** | 42.97** | -16.39** |
| BBM 814/ BH 946 | 7.61** | 4.69** | -45.51** | -6.78* | -2.21 | -7.51** | 18.80** | -73.84** | -81.19** | 34.77** |
| BBM 814/ BH 902 | 4.13** | 1.25 | -19.04** | -4.69 | 6.09* | 10.30** | -2.64 | -42.5** | -49.72** | 13.30* |
| BBM 814/ BH 885 | 3.88** | 3.27** | -18.80** | 0.62 | 16.20** | -25.00** | 8.84** | -1.73 | -7.19** | 1.58 |
| BBM 814/ BH 959 | -0.18 | 1.52* | -42.45** | -0.90 | 14.55** | 5.88** | 59.66** | -64.53** | -50.76** | -30.35** |

*, ** Significant at p=0.05 and 0.01, respectively

**Table 6:** Estimates of heterobeltiosis for different characters in barley

| Crosses/Variables | DH | DM | T/M | PH | SL | G/S | TGW | GY | BY | HI |
|---|---|---|---|---|---|---|---|---|---|---|
| 6th GSBON 2018-19-27/ BH 946 | 3.20* | -1.24 | -23.74** | -24.33** | -3.44 | -50.00** | -11.04** | -51.10** | -54.98** | 8.77 |
| 6th GSBON 2018-19-27/ BH 902 | -1.40 | -3.68** | 47.64** | -9.39* | 22.05** | -41.25** | 27.21** | -39.86** | -33.23** | -9.93 |
| 6th GSBON 2018-19-27/ BH 885 | 4.98** | -1.74* | 10.32** | 11.55** | 24.18** | 13.95** | 30.24** | -38.52** | 2.24 | -40.02** |
| 6th GSBON 2018-19-27/ BH 959 | -3.56* | -2.98** | -15.47** | -14.77** | 12.60** | -52.94** | 9.05** | -66.32** | -45.05** | -38.62** |
| 6th GSBON 2018-19-32/ BH 946 | -11.79** | -0.25 | 14.24** | -5.93 | 13.21** | -47.73** | 26.87** | -75.24** | -47.80** | -52.70** |
| 6th GSBON 2018-19-32/ BH 902 | -3.16* | -1.72* | -7.77 | -9.12* | 16.23** | -43.75** | 40.68** | -66.67** | -31.78** | -51.07** |
| 6th GSBON 2018-19-32/ BH 885 | 6.91** | -4.43** | 8.73* | 15.18** | 24.18** | 8.70* | 44.23** | -19.46** | 34.39** | -40.12** |
| 6th GSBON 2018-19-32/ BH 959 | 3.27* | -0.25 | -5.16 | -0.62 | 0.75 | -47.06** | -14.33** | -85.61** | -83.70** | -11.66* |
| 6th GSBON 2018-19-132/ BH 946 | -5.13** | 0.48 | -36.80** | 4.45 | 10.39** | -6.82** | -20.70** | -84.01** | -82.43** | -15.58** |
| 6th GSBON 2018-19-132/ BH 902 | -8.97** | -5.08** | 11.36** | -12.71** | 15.05** | 15.00** | 0.38 | -57.39** | -70.81** | 45.92** |
| 6th GSBON 2018-19-132/ BH 885 | -4.49** | -1.69* | -21.96** | 4.44 | 13.62** | 18.42** | -4.21 | 27.24** | -0.96 | 3.92 |
| 6th GSBON 2018-19-132/ BH 959 | -11.54** | -4.36** | -2.87 | -0.31 | 7.89** | 5.88** | 32.27** | -31.58** | -31.63** | -11.46* |
| IBON-HI 2018-19-12/ BH 946 | -7.83** | -2.77** | 7.72* | -6.53 | -9.74** | -47.73** | -5.93** | -24.45** | -27.48** | -19.03** |
| IBON-HI 2018-19-12/ BH 902 | -6.32** | -4.90** | 86.15** | -3.59 | -21.75** | -43.75** | -17.60** | 31.27** | 6.04** | 7.86 |
| IBON-HI 2018-19-12/ BH 885 | 3.56* | 0.25 | 1.32 | -2.59 | -19.48** | 2.04 | -28.76** | -15.56** | -44.32** | 3.64 |
| IBON-HI 2018-19-12/ BH 959 | 1.07 | -3.77** | 26.36** | 5.54 | -5.19 | -43.53** | 15.86** | -52.63** | -27.21** | -51.47** |
| IBON-HI 2018-19-16/ BH 946 | -0.71 | -1.51 | -4.45 | 1.78 | 11.79** | -42.05** | 23.31** | -65.20** | 1.62 | -65.85** |
| IBON-HI 2018-19-16/ BH 902 | -2.81* | -7.11** | 20.61** | -5.80 | 0 | -45.00** | 3.42 | -73.20** | -57.45** | -36.80** |
| IBON-HI 2018-19-16/ BH 885 | -4.81** | -2.99** | -27.78** | 5.14 | -7.5* | 15.56** | -22.31** | -12.45** | -10.24** | -13.06* |
| IBON-HI 2018-19-16/ BH 959 | -6.23** | 0.75 | 2.29 | 11.38** | 16.43** | -42.35** | -19.10** | 17.54** | 52.82** | -25.09** |
| IBON-HI 2018-19-45/ BH 946 | 3.91** | 0.76 | -32.64** | -5.93 | 15.38** | -48.86** | 35.99** | -60.19** | -52.43** | -16.24** |
| IBON-HI 2018-19-45/ BH 902 | 1.05 | -2.45** | 42.57** | -0.55 | 17.49** | -43.75** | 28.95** | -32.99** | -1.24 | -32.03** |
| IBON-HI 2018-19-45/ BH 885 | 3.56* | 2.24** | -0.26 | 20.33** | 35.53** | 18.18** | 36.26** | 35.41** | 80.24** | -24.90** |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| IBON-HI 2018-19-45/ BH 959 | -9.25** | -3.02** | 10.03** | -5.54 | 33.88** | -36.47** | 30.42** | -9.12* | 18.36** | -23.23** |
| IBON-HI 2018-19-75/ BH 946 | -0.71 | 1.01 | 1.78 | -2.67 | 0.72 | -50.00** | 20.95** | -36.99** | 24.54** | -49.41** |
| IBON-HI 2018-19-75/ BH 902 | -7.72** | -6.86** | -28.38** | -12.71** | -1.43 | -41.25** | -18.31** | -76.98** | -69.46** | -27.43** |
| IBON-HI 2018-19-75/ BH 885 | 0 | -2.99** | -17.46** | -2.73 | 6.09* | 18.60** | 19.43** | -61.36** | -44.76** | -35.16** |
| IBON-HI 2018-19-75/ BH 959 | 5.05** | 3.52** | -20.63** | 5.76 | 19.35** | -38.82** | 27.36** | -49.82** | -22.86** | -35.9** |
| IBON-HI 2018-19-119/ BH 946 | 6.07** | 0.50 | -27.00** | 6.19 | -5.96* | -14.13** | 21.21** | -57.05** | -65.96** | -11.26* |
| IBON-HI 2018-19-119/ BH 902 | 4.56** | -1.96* | -24.32** | -8.29* | 5.02 | -28.26** | 25.70** | -81.44** | -83.55** | -11.82 |
| IBON-HI 2018-19-119/ BH 885 | 2.60 | -3.73** | 12.43** | -1.47 | -3.13 | -46.74** | 32.78** | 30.35** | -6.16** | -14.66* |
| IBON-HI 2018-19-119/ BH 959 | 5.86** | -1.26 | -13.18** | -0.59 | -13.79** | -21.74** | 37.99** | -66.32** | -35.33** | -65.07** |
| IBON-HI 2018-19-122/ BH 946 | -15.65** | -8.05** | -20.77** | -5.33 | 20.65** | -6.82** | 0.88 | -65.20** | -66.67** | 4.47 |
| IBON-HI 2018-19-122/ BH 902 | -17.25** | -4.39** | 0 | -10.77** | -8.75** | -15.00** | 26.76** | -50.52** | -13.77** | -42.65** |
| IBON-HI 2018-19-122/ BH 885 | -11.50** | -3.9** | -37.57** | -3.25 | 9.16** | -26.15** | 23.79** | -58.37** | -52.56** | -22.07** |
| IBON-HI 2018-19-122/ BH 959 | -17.25** | -1.95* | 8.60* | 11.83** | 19.5** | -1.18 | 44.12** | -35.09** | 17.25** | -46.55** |
| $6^{th}$ GSBYT 2018-19-15/ BH 946 | -8.47** | 0 | 52.82** | 0.59 | 11.01** | -16.48** | 59.28** | -60.82** | 32.87** | -70.53** |
| $6^{th}$ GSBYT 2018-19-15/ BH 902 | -3.91** | -4.66** | 69.93** | -4.14 | 4.28 | -9.89** | 10.05** | -44.67** | 32.51** | -58.22** |
| $6^{th}$ GSBYT 2018-19-15/ BH 885 | -3.91** | -1.24 | 18.52** | 12.83** | -0.92 | -49.45** | 31.33** | -13.62** | 65.48** | -47.86** |
| $6^{th}$ GSBYT 2018-19-15/ BH 959 | -14.66** | -2.48** | 26.65** | -7.08 | -15.6** | 2.20 | 12.29** | -40.00** | -9.18** | -33.64** |
| BBM 797/ BH 946 | -2.50 | 0 | 25.22** | -6.23 | -21.32** | -12.63** | -6.04* | 12.85** | 15.28** | -2.15 |
| BBM 797/ BH 902 | 1.75 | -1.47 | 2.36 | -3.87 | -4.39 | -4.21* | 23.28** | -19.59** | -8.59** | -11.82 |
| BBM 797/ BH 885 | 3.24* | 1.99* | -27.78** | 13.86** | 3.76 | -45.26** | 26.40** | -27.63** | -26.88** | -1.14 |
| BBM 797/ BH 959 | 5.04** | -0.75 | 9.74** | -4.62 | -12.54** | -16.84** | -5.66* | 1.05 | 32.61** | -23.77** |
| BBM 814/ BH 946 | 6.07** | 4.03** | -49.55** | -7.33 | -10.17** | -9.09** | 10.68** | -76.18** | -83.51** | 9.04 |
| BBM 814/ BH 902 | 1.75 | -0.74 | -20.27** | -7.46* | 0.34 | 7.06** | -15.04** | -45.36** | -53.66** | -0.34 |
| BBM 814/ BH 885 | 3.31* | 1.99* | -28.57** | -4.99 | 11.86** | -43.53** | -6.67** | -2.67 | -22.86** | -14.97** |
| BBM 814/ BH 959 | -0.37 | 0.75 | -47.56** | -3.23 | 4.07 | 5.88** | 49.43** | -65.96** | -57.59** | -42.05** |

*, ** Significant at p=0.05 and 0.01, respectively

**Table 7:** Proportional contribution of lines, testers and their interaction to total variance

| Sr. No. | Traits | Lines (%) | Testers (%) | Line x Tester (%) |
|---|---|---|---|---|
| 1 | Days to heading | 31.64 | 7.72 | 60.64 |
| 2 | Days to maturity | 30.52 | 6.26 | 63.22 |
| 3 | Number of effective tillers per meter row | 55.72 | 2.77 | 41.52 |
| 4 | Plant height (cm) | 24.26 | 4.87 | **70.87** |
| 5 | Spike length (cm) | 28.26 | 7.31 | 64.43 |
| 6 | Number of grains per spike | **68.40** | 7.86 | 23.74 |
| 7 | 1000-grain weight (g) | 24.35 | 5.71 | 69.94 |
| 8 | Grain yield/plot (g) | 29.33 | **11.49** | 59.18 |
| 9 | Biological yield/plot (g) | 30.54 | 7.65 | 61.81 |
| 10 | Harvest index (%) | 38.97 | 7.50 | 53.53 |

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## Conflict of interest

The authors declare no conflict of interest.

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