*Plant Archives* Vol. 17 No. 2, 2017 pp. 813-820 ***ISSN 0972-5210***

# HETEROSIS AND COMBINING ABILITY OF INDIGENOUS AND EXOTIC CROSSES OF BARLEY

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## Abstract

The present investigation was conducted at Banaras Hindu University, Varanasi (U.P.) during *Rabi* seasons of 20014-15 and 2015-16. The experimental material included 30 genotypes and data were recorded on the following characters *viz*., days to 75 per cent flowering, days to maturity, number of effective tillers/plant, number of grains/main ear, ear length (cm), awn length (cm), biological yield/plant (gm), harvest index (%), grain weight (1000-grain weight) and grain yield/plant. The line × tester interaction was significant for all the traits under study. Plant height showed highest narrow sense heritability followed by 1000 grain weight, on the contrary, only awn length and harvest index exhibited moderate narrow sense heritability. Out of 15 $F_1$'s studied, twelve crosses expressed desirable heterosis over BP (Better Parent) and one desirable heterosis over SV (Standard Variety). Among the genotypes, HUBL 09-17, IBYT 04-177, IBYT 04-09 and Moroc 09-75 showed significant negative *GCA* effects for days to 50% flowering and days to maturity (considering negative effects as desirable). Positive significant *GCA* effects were recorded for spike length, awn length and harvest index by IBYT 04-10 and IBYT 04-09. BYT(LRA)12 and IBYT 04-10 had shown preferred negative SCA for days to 50% flowering and days to maturity in more crosses. IBYT(LRA)12 had also shown preferrred *SCA* for number of effective tillers, grain yield per plant and biological yield. The cross Moroc 09-95 × IBYT(LRA)12 had highest *SCA* for biological yield along with preferred *SCA* for number of effective tillers, number of grains per spike, 1000 grain weight and grain yield per plant.

***Key words :*** Barley, exotic cross, heterosis, combining ability.

## Introduction

Barley (*Hordeum vulgare* L. 2n = 14, sub family *Poaceae*) is an important crop of present era ranks fourth after wheat, rice and maize (FAO, 2005 and Raikwar, 2013). Since, time immemorial, barley is considered as crop of rainfed and problematic soil conditions *i.e.* saline alkaline, drought and diara, marginal/coastal area of river as well. Barley flourishes well under less resource of irrigation and fertilizers. Thus, this crop has great elasticity of adaptation under various stress situations.

The sound understanding of nature and magnitude of gene effects involved in inheritance of important plant characters is essential for laying the foundation of a successful crop improvement program. Such understanding not only helps in selection of appropriate breeding approach but also in determining the type of variety to be developed in a given situation. For characterizing the nature and magnitude of gene effects for yield and its components, a number of genetical models particularly second degree statistical models like covariance of half-sib and full-sib families (Comstock and Robinson, 1952), combining ability analysis (Griffin, 1961b) and partial diallel (Kempthorn and Kurnow, 1961) have been suggested.

Heterosis has been frequently exploited for the development and isolation of promising hybrids for further utilization in conventional as well as heterosis breeding program. The $F_1$ hybrids in cross fertilized as well as self-fertilized crops are known to exhibit hybrid vigour, but effective exploitation of this phenomenon for commercial cultivation has been limited in case of self-pollinated crops. Information on heterosis and combining ability for yield and its components traits in barley will prove very useful in selection of desirable parents for the development of superior hybrids. The line × tester analysis is one which is employed in the study of genetic variability,

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heritability and genetic advance of yield attributes. It is also used in estimating *GCA* of the parents and *SCA* of the hybrids and their effects. The exploitation of heterosis over better parent and standard variety is considered to be one of the outstanding works in several crops. Till date it has been employed in many cross and self-pollinated crops.

## Materials and Methods

The present investigation was conducted at the Genetics and Plant Breeding, Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (U.P.) during *Rabi* seasons of 20014-15 and 2015-16. Geographically, Banaras Hindu University is situated between 25º18' N latitude, 83º 03´E longitudes and at an altitude of 128.93 meters above the mean sea level in the North Gangetic plain of eastern part of Uttar Pradesh. The experimental materials comprised of 30 genotypes (15 $F_1$s, & 15 $F_2$s) developed by crossing 5 lines {HUBL09-17, IBYT (LRA) 04-177, IBYT (MRA) 04-10, IBYT (LRA)-12, IBYT (MRA) 04-09} with 3 testers V-MORLES, HUB113, MORAC-09-75. These were laid in Randomized Block Design with three replications for the investigation. Each treatment (genotype) was sown in line having 2.75 m length. The row to row and plant to plant distance was followed 25 cm and 10 cm, respectively. All the recommended agronomic practices for respective experimental conditions were followed to raise a good normal crops.

Five competitive plants, in each plot of parents, $F_1$s and F,s were randomly selected and tagged well in advance for recording the observations. Data were recorded on the following characters *viz*., days to 75 per cent flowering, days to maturity, number of effective tillers/ plant, number of grains/main ear, ear length (cm), awn length (cm), biological yield/plant (gm), harvest index (%), grain weight (1000-grain weight) and grain yield/plant. The analysis of variance for the design of experiment was carried out according to the procedure outlined by Panse and Sukhatme (1967). Genetic advance (GA) was estimated by using the formula given by Johnson *et al.* (1955). After testing the significance among the treatments and crosses, line × tester analysis for estimation of combining ability was done. For the estimation of general and specific combining ability variances, procedure outlined by Kempthorne (1957) was followed.

## Results and Discussion

Results of the present study are discussed under the following heads.

### Variance for line × tester mating design

Treatment variations were highly significant for all the crosses (table 1). Variations due to treatment were partitioned into various components, such as parents, cross ($F_1$s) and parents *vs* crosses ($F_1$s). The mean squares due to parents *vs.* crosses showed significant differences for all the characters studied except 1000 grain weight. The mean squares due to testers were highly significant for harvest index and biological yield and significant for plant height and ear length, while for lines, it was significant for thousand grain weight and highly significant for harvest index and biological yield. The line × tester interaction was significant for all the traits under study.

### Estimation of general means, heritability, expected genetic advance and genetic advance as percent of mean

The values for general mean, heritability (narrow sense), expected genetic advance and genetic advance as percent of mean for individual traits were presented in table 2. The estimates of heritability are categorized as high (>30%), moderate (>10% and <30%) and low (<10%). In general, all the traits exhibited moderate to high heritability.

Plant height (69.89%) showed highest narrow sense heritability followed by 1000 grain weight (59.79%), spike length (54.36), days to maturity (45.39%), days to 50% flowering (45.01%), number of effective tillers (31.33), number of grains per spike (30.96), biological yield (30.95%) and grain yield per plant (30.93). Observations on higher estimates of heritability for these traits are in close agreement with the results of Akanksha *et al.* (2012). While only awn length (23.40) and harvest index (20.88%) exhibited moderate narrow sense heritability. Moderate estimates of heritability for these traits are in close agreement with the results of Raikwar *et al.* (2014). The estimations of heritability are more meaningful when it estimated along with genetic gain. The number of grains per spike (17.35%) and biological yield (17.35%) revealed highest value of genetic advance as per cent of mean followed by days to grain yield per plant (16.20), spike length (14.02), plant height (13.33). High genetic advance in per cent of mean coupled with high heritability have also been reported for grain yield per plant in earlier studies of Yadav *et al*. (1990) as found in present investigation.

### Components of genetic variance

The estimation of components of genetic variance *i.e*., variance due to lines (male $\sigma^2$gm), testers (female $\sigma^2$gf), GCA ($\sigma^2$GCA), SCA ($\sigma^2$SCA), additive ($\sigma^2$A),

**Table 1 :** Analysis of variance for L × T analysis of yield, its component traits of barley.

| Sources of variations | D.f. | Mean Sum of Squares | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Days to 50% flowering | Days to maturity | Plant height (cm) | Number of effective tillers | Spike length (cm) | Awn length (cm) | Number of grains per spike | 1000 grain weight (g) | Harvest Index | Grain yield per plant (g) | Biological yield |
| **Replicates** | 2 | 0.058 | 4.58* | 1.59 | 0.00251 | 0.04 | 0.14 | 2.16 | 2.26 | 6.53** | 9.39** | 12.67** |
| **Treatments** | 22 | 70.73** | 49.73** | 204.81** | 9.79** | 3.24** | 12.89** | 241.18** | 35.90** | 39.89** | 120.73** | 610.43** |
| **Parents** | 7 | 37.24** | 64.93** | 172.86** | 6.28** | 2.49** | 16.65** | 287.75** | 68.93** | 21.58** | 79.20** | 411.27** |
| **Crosses** | 14 | 87.56** | 40.93** | 205.28** | 5.98** | 2.31** | 9.39** | 198.68** | 21.79** | 46.54** | 73.25** | 407.47** |
| **Parents vs. Crosses** | 1 | 69.76** | 66.49** | 421.76** | 87.79** | 21.34** | 35.61** | 510.28* | 2.17 | 74.98** | 1076.18** | 4846.20** |
| **Lines (Male)** | 2 | 91.09 | 30.96 | 344.88 | 9.86 | 1.06 | 12.51 | 106.88 | 74.49* | 11.55** | 133.64 | 733.07** |
| **Testers (Female)** | 4 | 128.17 | 68.86 | 388.93* | 2.55 | 5.06* | 2.60 | 170.90 | 10.82 | 48.06** | 19.58 | 115.96** |
| **Lines x Testers** | 8 | 66.37** | 0.94** | 78.56** | 6.73** | 1.26** | 12.01** | 235.52** | 14.09** | 54.52** | 84.99** | 471.80** |
| **Error** | 44 | 0.99 | 16.83 | 2.17 | 0.07 | 0.06 | 0.22 | 0.76 | 0.73 | 1.03 | 0.47 | 1.65 |

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

dominance ($\sigma^2D$) and average degree of dominance $\sqrt{\sigma^2 D/\sigma^2 A}$ were estimated for all the traits during *Rabi* 2014-15 (table 3). The estimates of genetic components of variance due to female ($\sigma^2$gf) were found to be higher than due to male ($\sigma^2$gm) for number of effective tiller, awn length, thousand grain weight, grain yield per plant and biological yield per plant. Estimates of genetic component of variance due to male ($\sigma^2$gm) were comparatively higher than female ($\sigma^2$gf) for days to 50% flowering, days to maturity, plant height, spike length, number of grains per spike and harvest index. The variance due to $\sigma^2$s (specific combining ability) was found to be more than $\sigma^2$g (general combining ability) for each trait under investigation except for plant height. Values for the average degree of dominance showed presence of over-dominance to dominance for each of the trait except for plant height, spike length and 1000 grain weight.

**Extent of heterosis**

Heterosis is a complex biological phenomenon manifested in the superiority of hybrids over parents. Heterosis breeding added an advantage for obtaining jump in the production and productivity of barley. It has been extensively used in improving the yield potential through development of hybrid cultivar. Therefore, heterosis over better parent and best check were studied. The magnitude of heterosis in per cent over better parent (heterobeltiosis) and over standard check (standard heterosis) in fifteen $F_1$'s obtained from line x tester analysis for eleven traits were estimated (table 4). HUB 113, the variety released during year the 2014 was taken as standard check. Manifestation of heterosis was found in both positive and negative directions. In case of better parent and standard heterosis, only positive values are described for all the traits except, days to 50% flowering, days to maturity and plant height for which negative values (desirable ones) have been taken for consideration. In the present investigation, magnitude of heterosis over better parent for grain yield showed for crosses V morles × IBYT (LRA) 12 (144.25) over standard varieties (SV). Out of 15 $F_1$'s studied, twelve crosses expressed desirable heterosis over BP and one desirable heterosis over SV. Higher magnitude of heterotic response for seed yield in barley was also reported by Rugen *et al*. (2004), Saad *et al*. (2005).

**Combining ability**

ANOVA of combining ability showed the variances of GCA were significant for only plant height, spike length and 1000 grain weight. The variances of *SCA* were

**Table 2 :** General mean, heritability, genetic advance and genetic advance as per cent of mean for yield, its component related traits of barley.

| Traits | General mean | Heritability (Narrow Sense) | Genetic Advance | Genetic advance as % of mean |
|---|---|---|---|---|
| Days to 50% flowering | 84.38 | 45.01 | 5.88 | 6.96 |
| Days to maturity | 109.93 | 45.39 | 3.96 | 3.60 |
| Plant height (cm) | 100.76 | 69.89 | 13.43 | 13.33 |
| Number of effective tillers | 10.30 | 31.33 | 1.17 | 11.36 |
| Spike length (cm) | 7.63 | 54.36 | 1.07 | 14.02 |
| Awn length (cm) | 12.51 | 23.40 | 1.10 | 8.79 |
| Number of grains per spike | 55.46 | 30.96 | 9.62 | 17.35 |
| 1000 grain weight (g) | 39.96 | 59.79 | 4.21 | 10.53 |
| Harvest index | 44.92 | 20.88 | 2.06 | 4.58 |
| Grain yield per plant (g) | 20.18 | 30.93 | 4.08 | 16.20 |
| Biological yield (g) | 55.46 | 30.95 | 9.62 | 17.35 |

**Table 3 :** Estimates of genetic components of variance ($\sigma^2$A and $\sigma^2$D) and degree of dominance for yield, its component traits of barley.

| Components of variance | Days to 50% flowering | Days to maturity | Plant height (cm) | Number of effective tillers | Spike length (cm) | Awn length (cm) | Number of grains per spike | 1000 grain weight (g) | Harvest index | Grain yield per plant (g) | Biological yield |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **$\sigma^2$Male** | 6.00 | 2.00 | 22.84 | 0.65 | 0.07 | 0.82 | 7.07 | 4.92 * | 0.70 | 8.88 | 48.76 |
| **$\sigma^2$Female** | 14.13 | 7.55 | 42.97 | 0.28 | 0.55 * | 0.26 | 18.90 | 1.12 | 5.22 | 2.12 | 12.70 |
| **$\sigma^2$GCA** | 9.05 | 4.08 | 30.39** | 0.51 | 0.25* | 0.61 | 11.51 | 3.49 * | 2.39 | 6.34 | 35.24 |
| **$\sigma^2$SCA** | 21.79** | 9.50** | 25.46** | 2.22 | 0.40** | 3.93** | 78.25** | 4.46** | 17.83** | 28.17** | 156.72** |
| **$\sigma^2$GCA /$\sigma^2$SCA** | 0.42 | 0.43 | 1.19 | 0.23 | 0.63 | 0.16 | 0.15 | 0.78 | 0.13 | 0.23 | 0.22 |
| **$\sigma^2$A** | 18.11 | 8.16 | 60.79 | 1.02 | 0.50 | 1.22 | 23.02 | 6.99 | 4.79 | 12.69 | 70.48 |
| **$\sigma^2$D** | 21.79 | 9.50 | 25.46 | 2.22 | 0.39 | 3.93 | 78.25 | 4.46 | 17.83 | 28.17 | 156.72 |
| **Degree of dominance $\sqrt{(\sigma^2 D/\sigma^2 A)}$** | 1.097 | 1.08 | 0.73 | 1.47 | 0.89 | 1.79 | 1.84 | 0.79 | 1.93 | 1.49 | 1.49 |

significant for all the traits studied except for number of effective tillers. The ratio of *GCA/SCA* ranged from 0.13 in harvest index to 1.19 in plant height, indicating that non-additive effects played a more important role than additive effects for most of the traits. Previous findings of Soylu (2002), Sharma *et al*. (2003) also indicated the role of additive and non–additive gene effects in the expression of various traits in barley.

The estimates of general combining ability effects for eight diverse parents (five lines and three testers) for eleven characters of barley are presented in table 5. Positive and significant *GCA* effects were considered desirable for panicle length, number of grains per panicle, 1000 grain weight, harvest index and grain yield per plant. On the other hand some of the traits such as days to 50% flowering, days to maturity and plant height, negative values of general combining ability effects are considered as desirable. A wide range of variation was observed for $\sigma^2$ GCA for most of the characters studied (table 4).

Among the genotypes, HUBL 09-17, IBYT 04-177, IBYT 04-09 and Moroc 09-75 showed significant negative GCA effects for days to 50% flowering and days to maturity (considering negative effects as desirable), therefore these genotypes can be utilised for developing early varieties. Negative *GCA* effects are desirable for plant also since it contributes for lodging resistance, IBYT-04-10, IBYT O4-177, IBYT-04-09 and V morles had shown significant negative effects for plant hieght. The negative GCA of plant height and was in consensus with reports of LI Hong-tao *et al*. (2015) and they could be used as parents in improving the structure of the plant height. HUBL 09-17, IBYT (LYR) 12 and V morles had

**Table 4 :** Estimates of standard heterosis for yield and its component traits in barley.

| Crosses \ Traits | Days to 50% flowering | | Days to maturity | | Plant height (cm) | | Number of effective tillers | | Spike length (cm) | | Awn length (cm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SH | BPH | SH | BPH | SH | BPH | SH | BPH | SH | BPH | SH | BPH |
| V morles × IBYT 04-10 | 6.37** | 0.00 | 1.47* | 0.00 | 1.18 | 1.18 | -3.75 | -3.75 | 16.59** | 16.17** | 32.30** | -17.34** |
| V morles ×IBYT 09-17 | 8.86** | -3.37 ** | 9.97** | -0.87 | -9.68** | -9.68** | 58.18** | 47.15** | 16.39** | 3.65 | 54.95** | -9.11** |
| V morles × IBYT 04-177 | 1.59 | -4.12 ** | -2.65** | -4.35** | 2.96** | 2.96* | 29.00** | 29.00** | -14.50** | -14.50** | -3.28 | -18.19** |
| V morles × IBYT (LRA) 12 | 6.94** | -1.87 | 9.09** | -2.61** | 3.28** | 3.28** | 92.37** | 61.14** | 26.78** | 7.48** | 18.32** | -8.32* |
| V morles × IBYT04-09 | 7.11** | -4.12 ** | 2.81** | -4.64** | -0.84 | -0.84 | 67.95** | 24.87** | 51.96** | 4.86 | 21.03** | 7.47* |
| Morac 09-75 × IBYT 04-10 | 13.15** | 9.23 | 3.24** | 3.24** | 2.24** | -3.36** | -0.17 | -2.36 | 34.18** | 34.18** | 79.62** | 48.83** |
| Morac 09-75 × IBYT 09-17 | -9.70** | -17.69 ** | 0.96 | -3.09** | 1.03 | 1.03 | 23.24** | -3.14 | 16.59** | 15.54** | 24.94** | -2.81 |
| Morac 09-75 × IBYT 04-177 | -6.75** | -9.62 ** | -6.49** | -6.49** | 0.77 | 0.77 | -0.39 | -0.39 | 0.76 | 0.76 | 0.98 | 0.98 |
| Morac 09-75 × IBYT (LRA) 12 | 6.53** | 0.38 | 9.74** | 4.32** | 7.17** | 7.17** | 65.31** | 16.99** | 28.59** | 21.30** | 8.00* | 8.00* |
| Morac 09-75 × IBYT 04-09 | 0.42 | -7.69 ** | -0.31 | -1.54* | 9.38** | 9.38** | 58.16** | -0.65 | 51.63** | 16.44** | -13.55** | -13.55** |
| HUB 113 × IBYT 04-10 | 6.37** | 6.37 | 0.59 | 0.59 | 14.82** | -4.00** | 26.31** | 26.31** | 22.38** | 17.90** | 13.81** | 13.81** |
| HUB 113 × IBYT 09-17 | 7.59** | 5.81 | 6.75** | 4.08** | 10.65** | 9.14** | 46.69** | 23.41** | 23.62** | 6.45* | 47.77** | 47.77** |
| HUB 113 × IBYT 04-177 | 5.95** | 5.95 | -0.29 | -0.29 | 11.91** | 2.16 | 4.26 | 4.26 | -14.88** | -14.88** | -12.21** | -12.21** |
| HUB 113 × IBYT (LRA) 12 | 3.27** | 3.27 | 4.22** | 0.63 | 3.63** | 3.63** | 31.31** | -0.53 | 15.41** | -5.40 | 4.40 | 4.40 |
| HUB 113 × IBYT 04-09 | 6.69** | 5.81 | 1.56* | 1.56* | 5.05** | -4.30** | 64.15** | 10.37** | 82.51** | 21.78** | -7.40* | -7.40* |

*Contd…*

| Crosses \ Traits | Number of grains per spike | | 1000 grain weight (g) | | Harvest Index | | Grain yield per plant (g) | | Biological yield | |
|---|---|---|---|---|---|---|---|---|---|---|
| | SH | BPH | SH | BPH | SH | BPH | SH | BPH | SH | BPH |
| V morles × IBYT 04-10 | 3.56* | -9.13** | 9.21** | -22.52** | 3.67 | -10.80** | 104.20** | 8.01** | 97.0** | 66.25** |
| V morles × IBYT 09-17 | 13.97** | -11.22** | 7.11** | -10.71** | 1.29 | -1.43 | 44.19** | 44.19** | 42.31** | 42.31** |
| V morles × IBYT 04-177 | 58.66** | 58.66** | -18.15** | -19.36** | -7.74** | -7.74** | 34.96** | 34.96** | 100.50** | 41.67** |
| V morles× IBYT-(LRA) 12 | -2.07 | -2.07 | 3.56** | -9.13** | 15.59** | 3.75 | 144.25** | 58.39** | 112.04** | 53.43** |
| V morles × IBYT 04-09 | -16.82** | -16.82** | 13.97** | 11.22** | 19.32** | 7.24** | -0.94 | -0.94 | -16.97** | -16.97** |
| Morac 09-75 × IBYT 04-10 | 15.38** | 15.38** | 58.66** | 58.66** | 34.10** | 22.97** | 42.12** | 25.17** | 6.06* | 1.80 |
| Morac 09-75 × IBYT 09-17 | 4.46** | 4.46 | -2.07 | -2.07 | 1.02 | 1.02 | 10.10** | 10.10** | 8.00** | 8.00** |
| Morac 09-75 × IBYT 04-177 | 45.49** | 45.20** | -16.82** | -16.82** | 3.16 | 3.16 | 52.36** | 35.06** | 47.68** | 18.68** |
| Morac 09-75 × IBYT (LRA) 12 | 21.45** | 21.45** | 15.38** | 15.38** | -1.66 | -5.93** | 121.24** | 74.33** | 125.36** | 85.47** |
| Morac 09-75 × IBYT 04-09 | -13.58** | 13.58** | 4.46** | 4.46** | 9.82** | 5.18* | -15.72** | -15.72** | -23.28** | - 23.28** |
| HUB 113 × IBYT 04-10 | -11.82** | -11.82** | 45.49** | 45.20** | 18.96** | 6.03** | 103.45** | 29.22** | 69.09** | 56.02** |
| HUB 113 × IBYT 09-17 | 13.37** | 13.37** | 21.45** | 21.45** | -10.32** | -10.32** | 38.14** | 25.16** | 54.03** | 54.03** |
| HUB 113 × IBYT 04-177 | -13.58** | 13.58** | -13.58** | -13.58** | -5.20** | -5.20** | 64.52** | 5.17* | 73.55** | 34.07** |
| HUB 113 × IBYT (LRA) 12 | -11.82** | -11.82** | -11.82** | -11.82** | 0.05 | -6.98** | 36.13** | -22.64** | 36.10** | 7.67**** |
| HUB 113 × IBYT 04-09 | 13.37** | 13.37** | 13.37** | 13.37** | 23.88** | 15.33** | 29.62** | 29.62** | 0.99 | 0.99 |

**Table 5 :** Estimates of general combining ability effects for yield and its component in barley.

| Parents \ Traits | Days to 50% flowering | Days to maturity | Plant height (cm) | Number of effective tillers | Spike length (cm) | Awn length (cm) | Number of grains per spike | 1000 grain weight (g) | Harvest index | Grain yield per plant(g) | Biological yield |
|---|---|---|---|---|---|---|---|---|---|---|---|
| IBYT 04-10 | 5.77** | 4.69** | - 8.78** | -0.42** | 1.13** | 0.49** | 6.41** | 0.61* | 1.36** | 0.10 | -0.39 |
| HUBL 09-17 | -4.33** | -0.87* | 2.42** | 0.29** | -0.20* | -0.27 | 1.01** | -1.48** | -2.13** | 0.64** | 4.52** |
| IBYT 04-177 | -0.89* | -1.20** | -1.01* | 0.17 | -0.89** | -0.75** | -5.22** | 1.26** | 0.33 | -2.16** | -4.97** |
| IBYT (LRA) 12 | 1.11** | -0.09 | 9.24** | 0.62** | -0.28** | 0.002 | 0.33 | -0.73* | -2.49** | -0.46 | 2.14** |
| IBYT 04-09 | -1.67** | -2.53** | -1.87** | -0.67** | 0.24** | 0.52** | -2.50** | 0.34 | 2.94** | 1.84** | -1.29** |
| Std. error | 0.26 | 0.25 | 0.38 | 0.07 | 0.07 | 0.12 | 0.26 | 0.22 | 0.26 | 0.18 | 0.33 |
| **Testers** | | | | | | | | | | | |
| V-MORLES | 1.49** | 1.49** | -4.79** | 0.87** | -0.29** | 0.84** | -3.07** | 2.41** | -0.24 | 2.68** | 6.40** |
| MORAC 09-75 | -2.84** | -1.38** | 0.002 | -0.73** | 0.23** | 0.13 | 1.80** | -0.43 | 0.97** | -3.22** | -7.46** |
| HUB113 | 1.36** | -0.11 | 4.79** | -0.15* | 0.06 | -0.97** | 1.27** | -1.98** | -0.73** | 0.54 | 1.06** |
| Std. error | 0.33 | 0.32 | 0.49 | 0.09 | 0.09 | 0.16 | 0.33 | 0.29 | 0.34 | 0.23 | 0.43 |

**Table 6 :** Estimates of specific combining ability effects for yield and its component related traits in barley.

| Parents \ Traits | Days to 50% flowering | Days to maturity | Plant height (cm) | Number of effective tillers | Spike length (cm) | Awn length (cm) | Number of grains per spike | 1000 grain weight (g) | Harvest index | Grain yield per plant (g) | Biological yield |
|---|---|---|---|---|---|---|---|---|---|---|---|
| V morles × IBYT 04-10 | -3.38** | -1.82** | 0.46 | -1.99** | -0.29* | -1.76** | -12.49** | 0.84 | -5.79** | 0.54 | 8.99** |
| V morles × HUBL 09-17 | 3.73** | 2.73** | -5.99** | 0.37* | 0.13 | 0.27 | 1.96** | -3.18** | 2.01** | 0.25 | -2.71** |
| V morles × IBYT 04-177 | -0.38 | -0.93 | 2.62** | 0.96** | -0.10 | -0.64* | 1.58** | 1.56** | -1.89** | 0.06 | 2.25** |
| V morles × IBYT(LRA)12 | -0.38 | -0.04 | 3.28** | 1.24** | 0.49** | 0.12 | 3.87** | 0.93 | 4.75** | 3.33** | 0.55 |
| V morles × IBYT 04-09 | 0.40 | 0.07 | -0.37 | -0.58* | -0.23 | 2.01 | 5.08** | -0.15 | 0.92 | -4.19** | -9.09** |
| Morac 09-75 × IBYT04-10 | 6.62** | 3.04** | -3.39** | -0.03 | 0.49** | 3.46** | 9.57** | -0.84 | 5.04** | -3.11** | -12.49** |
| Morac 09-75 × HUBL09-17 | -6.60** | -3.73** | 0.37 | -0.83** | -0.38** | -1.71 | -8.77** | 2.19** | 0.68 | -1.33** | -5.67** |
| Morac 09-75 × IBYT04-177 | -3.04** | -2.40** | -4.29** | -0.43** | 0.58** | 0.62** | -2.28** | -2.18** | 2.08** | 0.90 | -1.08** |
| Morac 09-75 × IBYT(LRA)12 | 3.62** | 3.49** | 2.64** | 0.89** | 0.08 | -0.39 | 6.96** | 1.71** | -3.58** | 6.07** | 18.86** |
| Morac 09-75 × IBYT 04-09 | -0.60 | -0.40 | 4.67** | 0.39* | -0.77** | -1.97** | -5.47** | -0.88 | -4.22** | -2.53** | 0.39 |
| HUB 113 × IBYT04-10 | -3.24** | -1.22 | 2.93** | 2.02** | -0.20 | -1.71** | 2.93** | -0.005 | 0.75 | 2.57** | 3.495 |
| HUB 113 × HUBL09-17 | 2.87** | 1.00 | 5.62** | 0.46** | 0.26 | 1.44** | 6.81** | 1.00 | -2.69** | 1.07** | 8.39** |
| HUB 113 × IBYT 04-177 | 3.42** | 3.33** | 1.67 | -0.54** | -0.48** | 0.02 | 0.70 | 0.62 | -0.19 | -0.96* | -1.17** |
| HUB 113 × IBYT (LRA)12 | -3.24** | -3.44** | -5.93** | -2.14** | -0.57** | 0.28 | -10.83** | -2.65** | -1.17 | -9.39** | -19.41** |
| HUB 113 × IBYT 04-09 | 0.20 | 0.33 | -4.29** | 0.19 | 0.99** | -0.03 | 0.39 | 1.025* | 3.29** | 6.72** | 8.71** |

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

| S.no. | Traits | | | |
|---|---|---|---|---|
| | | Line (%) | Tester (%) | Line x Tester (%) |
| 1 | Days to 50 % flowering | 14.86 | 41.82 | 43.31 |
| 2 | Days to maturity | 10.81 | 48.07 | 41.13 |
| 3 | Plant height(cm) | 24.00 | 54.13 | 21.87 |
| 4 | Number of effective tillers | 23.55 | 12.18 | 64.27 |
| 5 | Spike length (cm) | 6.53 | 62.43 | 31.04 |
| 6 | Awn length(cm) | 19.03 | 7.91 | 73.06 |
| 7 | Number of grains per spike | 7.69 | 24.58 | 67.74 |
| 8 | 1000 grain weight (g) | 48.85 | 14.19 | 36.97 |
| 9 | Harvest index | 3.55 | 29.50 | 66.95 |
| 10 | Grain yield per plant (g) | 26.06 | 7.64 | 66.30 |
| 11 | Biological yield | 25.70 | 8.13 | 66.17 |

exhibited positive significant *GCA* effects for both number of effective tillers and bilogical yield making them desirable combiners for those traits. Positive significant *GCA* effects were recorded for spike length, awn length and harvest index by IBYT 04-10 and IBYT 04-09. HUBL 09-17, IBYT 04-09 and V morles showed desirable positive effects for grain yield per plant. The available literature also indicates significant and positive *GCA* effects for seed yield and yield components in barley (Sayed *et al*., 2008).

Fifteen crosses had a preferred *SCA* for at least four traits (table 6). Several crosses showed preferred *SCA* for days to 50% flowering, plant height, number of effective tillers, number of grains per spike, harvest index, grain yield per plant and biological yield. IBYT(LRA)12 and IBYT 04-10 had shown preferred negative *SCA* for days to 50% flowering and days to maturity in more crosses. IBYT(LRA)12 had also shown preferred *SCA* for number of effective tillers, grain yield per plant and bilogical yield. These results were in accordance with Potla *et al*. (2013). Two crosses, Moroc 09-95 × IBYT 04-177 exhibited negative desirable SCA for all three traits *viz*., days to 50% flowering, days to maturity and plant height. The cross Moroc 09-95 × IBYT(LRA)12 had highest *SCA* for biological yield along with preferred *SCA* for number of effective tillers, number of grains per spike, 1000 grain weight and grain yield per plant. The results are in agreement with the findings of Bornere *et al*. (2014).

Proportional contribution of lines, testers and line × testers for different characters are presented in table 7.

Proportional contributions of line were observed maximum for 1000 grain weight (48.85) followed by grain yield per plant (26.06), biological yield (25.70), plant height (24), number of effective tillers (23.55), awn length (19.03), days to 50% flowering (14.86), days to maturity (10.81), spike length (6.53) and harvest index (3.55).

The proportional contribution of testers to total variance was observed maximum for spike length (62.43), followed by plant height (54.13), days to maturity (48.07), days to 50 % flowering (41.82), harvest index (29.50), number of grains per spike (24.58), 1000 grain weight (14.19), number of effective tillers (12.18), biological yield (8.13) and grain yield per plant (7.64).

The proportional contribution of lines × testers to total variance was observed maximum for awn length (73.06) followed by number of grains per spike (67.74), harvest index (66.95), grain yield per plant (66.30), biological yield (66.17), number of effective tillers (64.27), days to 50 % flowering (43.13), days to maturity (41.13), 1000 grain weight (36.97), spike length (31.04) and plant height (21.87).

## Conclusion

The analysis of variance for combining ability revealed that the variance due to lines×testers effect were showed highly significant and some showed significant for all the nine characters like days to maturity, productive tillers/plant, grains/spike and 1000-grain weight showed highly significant and remaining showed significant. Combining ability analysis elucidated higher magnitude of $\sigma^2$s (estimated variance due to *SCA*) than $\sigma^2$g (estimated variance due to *GCA*) indicating preponderance of non-additive gene action for all the characters. The relative contribution of lines × testers' component was higher than the lines and testers for all the characters and again confirming predominant role of non-additive gene effects in the inheritance of all the characters studied. Based on desirable *GCA* effects, HUBL 09-17 and IBYT04-09 among lines and V-morles among testers were identified as superior donors for grain yield. V morles × IBYT (LRA) 12, Moroc-9-75 × IBYT-04-09, HUB-113 × IBYT-04-10 and HUB 113 × IBYT 04-09 exhibited positive *sca* effects for grain yield per plant, indicating the preponderance of non-additive gene action. Crosses common for Positive heterobeltiosis and exhibiting positive standard heterosis for grain yield per plant were *viz*. V morles × IBYT 04-10, V morles × IBYT 09-17, V morles × IBYT 04-177, V morles × IBYT(LRA) 12, Moroc 9-75 × IBYT 4-10, Moroc-9-75 × HUBL 9-17, Moroc-9-75 × IBYT-04-177, Moroc 9-75 × IBYT (LRA) 12, HUB 113 × IBYT 04-10, HUB 113 × IBYT 09-17, HUB 113 × IBYT 04-177 and HUB 113 × IBYT 04-09. Based on the *per se* performance and *GCA* performance IBYT 04-09 and HUBL 09-17 are promising cross for grain yield. Based on the *per se* performance and *SCA* performance HUB 113 × IBYT 4-10 and Moroc 9-75 × IBYT (LRA) 12 are promising crosses for grain yield.

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