Estimation of Gene Effects for Grain Yield and its Related Traits Under Normal and Saline Sodic Soil in Barley (*Hordeum Vulgare* L.)

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Abstract Six generations (*P*₁, *P*₂, *F*₁, *F*₂, *BC*₁ and *BC*₂) of three barley crosses were used for computation of generation mean analysis under normal and saline sodic soil conditions for yield contributing traits. In general, magnitude of dominance effect (h) has a greater value than additive effect (d) in all the traits. It is obvious that non-fixable gene effects (h), (j) and (l) were higher than the fixable (d) (i) in all the crosses in all the characters, indicating greater role of non-additive effects in the inheritance of all the characters. Both additive (d) and dominance (h) gene effects were important for all the traits. It is obvious that non-fixable gene effects (h) (j) and (l) were higher than the fixable (d) (i) in all the crosses for all the characters, indicating greater role of non-additive effects in the inheritance of all the characters studied.

Keywords Barley; gene effects; generation mean analysis; quantitative trait; recurrent selection; scaling test

Introduction Barley (*Hordeum vulgare* L.) a member of Poaeeae family, it is an important *rabi* cereal crop of India, being grown in northern plains of country, representing the states of Rajasthan U.P., Haryana, M.P., Punjab, Bihar and Jharkhand in plains and Himachal Pradesh, Uttarakhand and Jammu & Kashmir in the hills. Barley occupies nearly 6.9 lakh ha area producing nearly 15.52 lakh tones grain, with a per hectare productivity of 22.45 q. Recently Rajasthan has taken up as number one barley producing state replacing U.P. and the change is mainly because of the shortage of rainfall and irrigation water experienced during past few years during the crop season. Since long it has been considered, as poor man's crop because of its low input requirement and better adaptability to harsh environments, like drought, salinity and alkalinity and marginal lands. Though major production is utilized as cattle feed and food, recent increase in industrial demand of barley as raw material resulted in its consideration as industrial crop. In addition to the use in feed and malt, barley is the main staple food crop in the tribal areas of the plains as well as hills. It is also utilized in preparation of the local beverages like sattu and chhang etc., which of course are common in the plains as well as in hills. In the modern time it is also preferred as medicinal food in urinary as well as cardiac problems. The changing climatic scenario in country for temperature, rainfall and crop duration has made it also a potential crop for near future, when we expect reduction in availability of all such resources. Understanding of the genetics underlying these traits is imperative for efficient management of available genetic variability and formulation of systematic breeding programmes. Few genetic studies have been conducted to understand the genetic control of grain yield and its component traits in barley. These studies have shown that both additive and non-additive genes control the grain yield in barley. The detection and estimation of epistasis would also enable the breeders to understand the genetic cause of heterosis with greater reliability. The presence or absence of epistasis can be detected by the analysis of generation means using the scaling test, which measures epistasis accurately whether it is complementary (additive × additive) or duplicate (additive × dominance) at the digenic level reported by Sharmila V. (2005). The present research was aimed to generate information on the nature of gene action in barley to decide selection
methods for the improvement of the barley. A lot of information on nature and relative magnitude of genetic components of variation (additive and dominance) have been generated by generation mean analysis, but literature on barley in respect of fixable and non fixable gene effect is meager. Therefore, the present study was planned to investigate genetics of days to ear emergence, days to maturity, no. of effective tillers/plant, and weight of grains/main spike (g), no. of grain/spike and 1000-grain weight (g) by using six-generations of the three crosses under normal and saline sodic soil conditions.

1 Materials and Methods

The inheritance of genetic parameters were studies using six generations of three crosses of barley namely DL 88 × K 560, K 603 × Azad, RD 2552 × NDB 1020 by applying generation mean analysis. Six generations of these crosses viz., P1, P2, F1, F2, BC1 and BC2 were grown separately in Randomized Block Design with three replications in two environments, one sown in normal soil and other sown in saline sodic soil during the same season. Planting were done in row of 3 m long. Row to row distance was kept 25 cm apart. The parent (P1 and P2) and F1S were sown in 2 rows, while back cross generations and F2 generation were sown in 5 and 6 respectively 6 rows of 3 m length. The experiment was carried out during the 2011-12 at KVK Chhatarpur Farm, J.N.K.V Jabalpur Madhya Pradesh. Fifteen random plants in parent and F1 generation, 60 plants in F2 generation and 45 plants in back cross generations were used for recording observations for six traits in each replication. The analysis of variance for RBD was carried out following Panse and Sukhatme (1967). The scaling test was performed to test the estimates of six-parameter model using the digenic epistatic model of Hayman, 1958. The scaling tests ‘A’, ‘B’ ‘C’ and D was used to test the adequacy of the additive-dominance model.

2 Results and Discussion

Results of the scaling tests revealed that out of four scaling tests one or two scales were found significant in all the three crosses for most of the characters. Therefore, the six-parameter model to detect gene effects was applied in all the characters. The estimates of m, d, h, i, j and l of six parameter model for all the characters are presented in Table 1. Mean data and standard error of the six generations with five crosses for nine traits were calculated. The earliness in ear emergence and days to maturity along with dwarf stature have been considered as desirable traits in barley as it is mainly grown as a rainfed crop. Crosses found superior to their respective parents was RD 2552 × NDB 1020 for effective tillers/plant (10.57±0.39). The crosses of DL 88 × K 560, RD 2552 × NDB 1020, recorded maximum number of grains/main spike (64.43±0.39 and 92.03±0.46 respectively). The crosses RD 2552 × NDB 1020 registered maximum 1000 grain weight (40.20±0.36) while DL 88 × K 560 gave maximum grain yield/plant (26.97±0.33 g).

A simple additive-dominance model was inadequate as inferred from the significance of all traits. The additive, dominance and epistatic types of gene interaction in each cross for different traits were found different from each other (Table 1). Comparison of estimates of gene effect with respect to magnitude as well as significance revealed that additive (d) was of greater importance than to the dominance (h) gene effects for no. of effective tillers/plant, length of main spike and grain yield/plant in the RD 2552 × NDB 1020 cross. Thus, selection for no. of effective tillers/plant and 1000-grain weight will be effective in early segregating generations. Both additive (d) and dominance (h) effects were pronounced in crosses DL88 × K560 for weight of grains/spike, grain yield/plant and RD 2552 × NDB 1020 for no. of grains/spike.

The dominance (h) effect was more important than additive gene effects (d) in the inheritance of 1000-grain weight in the DL88 × K560 cross. The genetic effects for these characters suggested that selection for these characters will not be effective in segregating generations. Higher magnitude of dominance (h) component than the additive (d) component suggested that the parents involved in the crosses were in dispersion phase and dominance component was more important for these characters. Vimal and Vishwakarma (1999) also reported predominance of non-additive gene action for yield and yield components in barley.

Estimates of additive × additive (i), additive × dominance (j) and dominance × dominance (l) interactions indicated that the additive × additive (i)
Table 1: Scaling tests estimates of gene effects and type of epistasis for different characters in barley

| Scale               | DL 88 × K 560 | K 603 × Azad | RD 2552 × NDB 1020 |
|---------------------|---------------|---------------|---------------------|
|                     | Normal soil (N) | Saline sodic soil ($) | Normal soil (N) | Saline sodic soil ($) | Normal soil (N) | Saline sodic soil ($) |
| I                   | 2             | 3             | 4             | 5             | 6             | 7             |
| Days to ear emergence |               |               |               |               |               |               |
| A                   | 7.34**        | 21.00**±1.70  | 26.00**       | 8.33**        | 6.34**        | 8.33**        |
|                     | ±1.56         | ±0.94         | ±1.63         | ±1.24         | ±2.31         |               |
| B                   | −3.34**       | 15.33**       | 14.00**       | 7.00**        | −6.34*        | −7.67**        |
|                     | ±1.05         | ±1.70         | ±1.88         | ±2.00         | ±1.63         | ±1.15         |
| C                   | −2.66         | 26.33**       | 1.34          | 8.67          | −2.67         | 12.00         |
|                     | ±6.30         | ±2.87         | ±6.20         | ±3.80         | ±2.30         | ±4.14         |
| D                   | −3.34         | −5.00**       | −19.34**      | −3.33         | −1.34         | 6.33**         |
|                     | 3.12          | +1.50         | +3.19         | +2.08         | +1.00         | ±2.00         |
| Type of epistasis   |               |               |               |               |               |               |
| DL 88 × K 560       | Normal soil   | Normal soil   | Normal soil   | Normal soil   | Normal soil   |
|                     | (N)           | ($)           | (N)           | ($)           | (N)           |
| m                   | 83.00**       | 87.00**       | 78.00**       | 77.33**       | 77.33**       | 77.67**       |
|                     | ±1.52         | ±0.57         | ±1.52         | ±0.89         | ±0.33         | ±0.88         |
| (d)                 | 2.66**        | −3.67**       | 0.00          | −1.33         | 2.66**        | 1.00          |
| (h)                 | 5.33          | 11.17**       | 37.99**       | 9.67*         | 7.34**        | 12.67**       |
| (i)                 | 6.66          | 10.00**       | 38.67**       | 6.67          | 2.67          | 12.67         |
| (j)                 | ±6.25         | ±2.98         | ±6.39         | ±4.16         | ±2.00         | ±4.00         |
| (l)                 | 5.33          | 2.83*         | 6.00**        | 0.67          | 6.34**        | 8.00**        |
|                     | ±1.38         | +1.02         | ±1.27         | ±0.81         | ±1.30         |               |
| Type of epistasis   | −              | D             | D             | D             | −             | D             |
| Scale               | Days to maturity |               |               |               |               |               |
| A                   | 8.34**        | 5.00*         | 7.00**        | 7.33          | 22.00**       | 7.67**        |
|                     | ±2.26         | ±0.49         | ±1.24         | ±4.00         | ±3.05         | ±2.45         |
| B                   | 6.00          | 8.00          | 4.67**        | 6.67**        | 17.67**       | 6.00**        |
|                     | ±2.62         | ±1.37         | ±1.20         | ±2.00         | ±3.46         | ±0.82         |
| C                   | 7.67*         | 3.00          | 4.34*         | ±2.00         | 53.67**       | −3.00         |
|                     | ±3.16         | ±4.20         | ±2.42         | ±4.94         | ±5.65         | ±1.56         |
| Type of epistasis   | −              | D             | D             | D             | −              | D             |
| Scale               |               |               |               |               |               |               |
| m                   | 137.33**      | 146.00**      | 137.67**      | 143.33**      | 146.00**      | 144.33**      |
| (d)                 | ±0.33         | ±1.00         | ±0.33         | ±0.33         | ±1.00         | ±0.33         |
| (h)                 | −1.33         | −3.00*        | 0.34          | 0.00          | −1.67         | 0.33          |
| (i)                 | 9.83**        | 12.83**       | 8.17**        | 13.67**       | −13.83**      | 19.17**       |
| Type of epistasis   | −              | D             | D             | D             | −              | D             |
| Scale | No. of effective tillers/plant | Gene effect 6 -parameters | Type of epistasis |
|-------|-------------------------------|---------------------------|------------------|
|       |                               |                           |                  |
|       | A                             |                           |                  |
|       | 1.6**                         | -3.03**                   | -0.36**          |
|       | ±0.68                         | ±0.57                     | ±0.47**          |
|       | ±1.11                         | ±0.79                     | ±0.70**          |
|       | 1.47**                        | 5.75**                    | -1.17**          |
|       | ±0.28                         | ±0.62                     | ±0.52**          |
|       | ±1.05                         | ±0.47                     | ±0.58**          |
|       | 1.43**                        | 13.63**                   | 1.87             |
|       | ±0.33                         | ±1.04                     | ±1.82            |
|       | ±1.09                         | ±0.47                     | ±1.26**          |
|       | ±1.00**                       | 5.47**                    | 1.70             |
|       | ±0.33                         | ±0.55                     | ±0.91            |
|       | ±0.71                         | ±0.74                     | ±5.88            |
|       |                               |                           |                  |
|       | B                             |                           |                  |
|       | ±0.33                         | ±0.21                     | ±0.43            |
|       | ±0.09                         | ±0.32                     | ±0.24            |
|       | 0.53                          | -3.47**                   | 1.23**           |
|       | ±2.77**                       | 6.67**                    | 2.80**           |
|       | ±0.31                         | ±0.35                     | ±0.27            |
|       | ±0.28                         | ±0.36                     | ±0.34            |
|       | 4.58                          | 10.72**                   | -2.53            |
|       | ±0.68                         | ±1.13                     | ±1.86            |
|       | ±0.69                         | ±1.52                     | ±1.25            |
|       | 2.00                          | -10.93**                  | -3.39            |
|       | ±0.66                         | ±0.66                     | ±1.48            |
|       | ±1.81                         | ±1.48                     | ±1.18            |
|       | 0.25                          | -4.38**                   | 0.40             |
|       | ±0.37                         | ±0.36                     | ±0.30            |
|       | ±0.30                         | ±0.41                     | ±0.36            |
|       | 5.43                          | 8.23**                    | 4.93*            |
|       | ±0.13                         | ±1.75                     | ±2.12            |
|       | ±1.27                         | ±2.06                     | ±1.86            |
|       | D                             | D                         | D                |
|       | D                             | D                         | D                |
|       | D                             | C                         | D                |
|       | Type of epistasis             |                           |                  |
|       | Scale                         | Weight of grains/main spike (g) |                  |
|       | A                             |                           |                  |
|       | -0.17                         | 0.67**                    | -0.67**          |
|       | ±0.35                         | ±0.14                     | ±0.16            |
|       | ±0.13                         | ±0.19                     | ±0.22            |
|       | ±0.19                         | ±0.16                     | ±0.22            |
|       | ±0.09                         | ±0.22                     | ±0.22            |
|       | ±0.57                         | ±0.00                     | -0.63*           |
|       | ±0.40                         | ±0.34                     | ±0.27            |
|       | D                             | D                         | D                |
|       | D                             | D                         | D                |
|       | D                             | C                         | D                |
|       | D                             |                           |                  |
|       | m                             |                           |                  |
|       | 2.80                          | 2.03**                    | 0.22**           |
|       | ±0.06                         | ±0.07                     | ±0.06            |
|       | ±0.08                         | ±0.08                     | ±0.03            |
|       | 0.57                          | 0.13*                     | -0.50**          |
|       | ±0.15                         | ±0.09                     | ±0.09            |
|       | 1.92                          | 0.73*                     | 1.75**           |
|       | ±0.41                         | ±0.32                     | ±0.33            |
|       | 1.13                          | 0.93**                    | 0.87*            |
|       | ±0.37                         | ±0.30                     | ±0.32            |
|       | ±0.17                         | ±0.08                     | ±0.12            |
|       | Type of epistasis             |                           |                  |
|       | Scale                         | No. of grain/spike         |                  |
|       | A                             |                           |                  |
|       | 3.87                          | -2.20                     | 0.47             |
|       | ±2.65                         | ±1.58                     | ±2.08            |
|       | ±1.93                         | ±2.28                     | ±2.13            |
|       | 20.87**                       | -22.37**                  | 24.57**          |
|       | ±1.20                         | ±0.81                     | ±3.14            |
|       | ±2.24                         | ±4.12                     | ±5.62            |
|       | C                             | -27.33**                  | 1.79             |
|       | ±4.77**                       | 40.76**                   | 37.07**          |
|       | ±5.88                         | ±12.00**                  | ±24.80**         |
|       | D                             | -26.03**                  | -11.10**         |
|       | ±3.42                         | ±1.89                     | ±5.43            |
|       | 3.07**                        | 12.07**                   | 12.07            |
|       | 3.47**                        | 6.93**                    | 6.93**           |
|       | 5.17**                        | 2.18**                    | 2.18**           |
|       | 5.25**                        | ±0.20                     | ±0.24            |
|       | 1.30**                        | 1.63**                    | 1.63**           |
|       | 0.03                          | 0.03                      | 0.03             |
|       | 0.12                          | 0.45                      | 0.45             |
|       | -1.67**                       | 2.77**                    |
|       | 5.33**                        | 0.05                      |
|       | 0.67**                        | 0.13                      |
|       | 0.13                          | 0.19                      |
|       | 6.67**                        | 0.34                      |
|       | 0.53**                        | 0.19                      |
|       | 0.03                          | 0.03                      |
|       | 0.12                          | 0.45                      |
|       | 2.77**                        | 0.05                      |
|       | 0.67**                        | 0.13                      |
|       | 0.13                          | 0.03                      |
|       | 0.03                          | 0.03                      |
|       | 0.12                          | 0.45                      | 0.45             |
|       | -1.67**                       | 2.77**                    |
|       | 5.33**                        | 0.05                      |
|       | 0.67**                        | 0.13                      |
|       | 0.13                          | 0.03                      |
|       | 0.03                          | 0.03                      |
|       | 0.12                          | 0.45                      |
|       | 2.77**                        | 0.05                      |
|       | 0.67**                        | 0.13                      |
|       | 0.13                          | 0.03                      |
|       | 0.03                          | 0.03                      |
|       | 0.12                          | 0.45                      | 0.45             |
|       | -1.67**                       | 2.77**                    |
|       | 5.33**                        | 0.05                      |
|       | 0.67**                        | 0.13                      |
|       | 0.13                          | 0.03                      |
|       | 0.03                          | 0.03                      |
|       | 0.12                          | 0.45                      |
|       | 2.77**                        | 0.05                      |
|       | 0.67**                        | 0.13                      |
|       | 0.13                          | 0.03                      |
|       | 0.03                          | 0.03                      |
|       | 0.12                          | 0.45                      | 0.45             |
was more important in the inheritance of all the characters. Additive × additive (i) epistatic effect was more important and higher than the dominance × dominance (l) epistatic effect in the inheritance of no. of effective tillers/plant in DL88 × K560, grain yield/plant in RD 2552 × NDB1020. However, dominance × dominance (l) epistatic effect was also more important and higher than the additive × additive (i), dominance × dominance (l) epistatic gene interaction was significant and greater in magnitude than all the gene effects (d, h, i and j) in the inheritance no of effective tillers/plant, days to maturity and 1000-grain weight in DL 88 × K560. The weight of grains/main spike and1000-grain weight was significantly higher in RD 2552 × NDB 1020. These findings are in agreement with those reported earlier Prakash V. et al. (2005) . Thus, these characters were mainly under the control of dominance × dominance (l) type of epistasis. Therefore, selection for these characters would be fruitful, if delayed till dominance and epistatic effects are reduced to minimum

| Gene effects, 6 parameters | 83.13** | 50.27** | 72.57** | 100.67** | 80.73** | 63.67** |
|---------------------------|---------|---------|---------|---------|---------|---------|
| (m)                       | ±0.29   | ±0.49   | ±0.49   | ±1.06   | ±0.75   | ±0.67   |
| (d)                       | 1.89    | 8.57    | 13.00** | 20.73** | 1.40    | 5.46**  |
| (h)                       | ±1.32   | ±0.92   | ±0.91   | ±1.81   | ±1.21   | ±1.29   |
| (i)                       | 68.86   | 27.15   | -24.75**| 40.53** | 59.62** | 15.08** |
| (j)                       | ±2.97   | ±2.75   | ±2.82   | ±5.44   | ±3.99   | ±4.44   |
| (l)                       | 52.07   | 22.20** | 15.73** | -23.99**| 49.59** | 14.67** |
| Type of epistasis         |         |         |         |         |         |         |
| D                         |         |         |         |         |         |         |
| C                         |         |         |         |         |         |         |
| Scale                     | 1000−grain weight (g) |         |         |         |         |         |
| A                         | -8.93** | -13.67**| 19.47** | -0.67   | -6.17** | 7.67**  |
| (m)                       | ±1.33   | ±1.58   | ±1.17   | ±1.31   | ±1.32   | ±1.12   |
| (d)                       | 2.60**  | -23.80**| 21.13** | -4.30** | 13.97** | 4.73**  |
| (h)                       | ±1.06   | ±1.95   | ±1.28   | ±1.21   | ±0.52   | ±1.04   |
| (i)                       | 19.07** | -30.87**| -20.13**| -12.63* | -26.40**| -2.47** |
| (j)                       | ±2.44   | ±1.97   | ±2.44   | ±5.49   | ±2.08   | ±0.74   |
| (l)                       | 12.70** | 3.30**  | -30.36**| -3.83   | -17.10**| 30.50** |
| Type of epistasis         |         |         |         |         |         |         |
| D                         | ±0.92   | ±0.73   | ±1.41   | ±2.76   | ±1.19   | ±0.21   |
| D                         |         |         |         |         |         |         |

Continued Table 1

| Gene effect 6-parameters | 37.47** | 30.50** | 26.13** | 32.76** | 28.77** | 30.50** |
|--------------------------|---------|---------|---------|---------|---------|---------|
| (m)                      | ±0.41   | ±0.06   | ±0.58   | ±1.33   | ±0.49   | ±2.21   |
| (d)                      | -1.83   | 5.23**  | -0.17   | 0.89    | -5.29** | -2.80** |
| (h)                      | ±0.41   | ±0.72   | ±0.80   | ±0.70   | ±0.67   | ±0.61   |
| (i)                      | -22.07**| -10.43  | 58.99** | 11.15   | 43.86** | 4.33**  |
| (j)                      | ±2.04   | ±1.75   | ±2.84   | ±5.56   | ±2.39   | ±1.59   |
| (l)                      | -25.40**| -6.60** | 60.73** | 7.67    | 34.20   | 4.93**  |
| Type of epistasis        |         |         |         |         |         |         |
| D                         | ±1.83   | ±1.45   | ±2.81   | ±5.52   | ±2.37   | ±1.48   |
| D                         | ±5.76** | 5.07**  | -0.83   | 1.83    | -10.07**| 6.19**  |
| D                         | ±0.68   | ±0.74   | ±0.85   | ±0.83   | ±0.67   | ±0.72   |
| D                         | ±2.94   | ±3.48   | ±4.03   | ±6.17   | ±3.37   | ±2.86   |

Note: *, ** = 0.05 and 0.01 respectively; D = Duplicate; C = Complementary
The dominance (h) and dominance × dominance (l) effects were in the opposite direction indicating predominantly dispersed alleles at the interacting loci and suggesting that duplicate – type epistasis (D^θ) reported by Jinks J. L. (1958) occurred in most cases. In cross, DL88 × K560 for days to maturity and grain yield/plant, cross RD2552 × NDB 1020 for length of main spike were observed with complementary epistasis (C^α). This suggested the possibility of considerable amount of heterosis in these two crosses for days to maturity, grain yield/plant and 1000-grain weight. On the basis of present study, it could be concluded that grain yield/plant and the component characters like days to ear emergence, no. of effective tillers/plant, days to maturity, weight of grains/main spike, no. of grains/spike, 1000-grain weight were mainly under the control of non-additive gene action viz., dominance (h) gene action and dominance × dominance (l) gene interaction which indicated their poor amenability to simple selection procedure, under such a situation, maximum gain could be achieved by maintaining considerable heterozygosity through inter-mating of selected plant in early segregating generation or by following some form of recurrent selection reported by Parlevliet J.E. and Van O.A (1988). This will increase the possibility of various recombinants, which may result in accumulation of favorable genes in the ultimate homozygous line with higher grain yield. Therefore, few cycles of recurrent selection followed by pedigree breeding will be effective in the improvement of 1000-grain/plant in barley.

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