Chapter-V

Discussion
Barley (*Hordeum Vulgare* L.) is an important cereal and hardy crop of ancient origin, grown worldwide for food, feed, and forage under varying agro-climatic conditions such as in rainfed areas, dry lands, saline, alkaline problematic soils and flood prone marginal and coastal areas. Barley has an advantage over wheat in terms of yield and quality of B glucon, soluble fiber protein, lysine and malt extract, and for its cooling and soothing effect under limited resources. Barley affords lower cost of cultivation and better price. In areas which have only a brief rainy season growers harvest mainly barley crop. Barley has advantages in aspects such as salt tolerance, frost tolerance, early period of development, drought tolerance etc. with great adaptive potential in many regions of the world.

In India, barley is grown in regions where the growing season is too short or the rainfall is inadequate for cultivation of other cereals. Most of the barley varieties have hulls and are useful for making beer or feeding cattle but the hulls must be removed before the grain can be eaten by humans. During last few decades due to progress in agriculture and easily availability of fine grains cereals like wheat and rice, it has been pushed to be utilized only as feed/industrial crop. Recent reports have shown a general declining trend in both production and acreage of barley. In order to stop this declining trend, high yielding varieties with stability and productivity are needed.

The success that a plant breeder can achieve depends on the correspondence between phenotypic and breeding value, if it is absent...
then selection is ineffective. The main aim of any crop breeding programme is to evolve a variety which has high yield potential across the environmental regions. Yield is the ultimate result of interaction of genetic and environmental factor and controlled by polygenes. According to Grafius (1964) and White House et al., (1958), there may not be gene for yield per se but for their components, the multiplicative interaction of which results in ultimate yield. It would be therefore desirable to have information on component characters and their relationship with vis a vis among components themselves. Large variability ensures better chance of obtaining new derived forms. Statistical analysis like range, mean, coefficient of variability, heritability and genetic advance provide information on variation at phenotypic level and simultaneously give an indication of the influence of environment that bring about the variation.

In the present investigation an attempt has been made to measure the variability for various characters, their heritability, genetic advance, character association, path coefficient and stability.

GENETIC VARIABILITY

Genetic variability may be discussed under following sub heads.

Analysis of variance

Pooled analysis of variance (Table-2) disclosed that mean square due to treatments were significant for all the traits except ear length. This indicated the presence of considerable genetic variability for these traits among the genotypes under study. Similar results were also reported in this crop by Yadav et al., (1991), Ram Kishor et al., (2000) and Pilania and Dhaka (2005).
Range of Variation

In present study, the estimates of genetic components of variance, heritability and genetic advance have provided useful information on the magnitude of phenotypic and genotypic coefficient of variation. Variability in the population especially in respect to the characters for which improvement is sought is a prerequisite for successful selection.

Phenotypic coefficient of variability (PCV) was higher than corresponding genotypic coefficient of variability (GCV) presented in Table-12 and 13. This is because of the fact that variability at phenotypic level includes genotypic and environmental variability. These findings are similar to Chauhan et al., (1988), Ram Kishor et al., (2000) and Pilania and Dhaka (2005).

On the basis of pooled analysis, phenotypic coefficient of variation for different characters ranged from 13.10 to 1.77 in all the environments whereas, genotypic coefficient of variation ranged from 12.64 to 1.07 in all the environments.

The high estimates of PCV and GCV values were observed for tiller number per plant, Number of spikelets per ear, number of seeds per spike, grain yield per plant, biological yield per plant, 1000-grain weight and harvest index, indicated the presence of ample genetic variability in the experimental material for these characters. High estimates of PCV and GCV for different characters in barley were also reported by Chauhan et al., (1988), Sharma and Maloo (1994) and Sajeda Begum et al., (1997), Ram Kishor et al., (2000), Pilania and Dhaka (2005) and Dhama (2007).
The lowest PCV and GCV values were observed for malt percentage, starch percentage and days to maturity indicating that these traits exhibited low variability, which suggest that more variability should be generated for these traits, through hybridization or mutation breeding.

The maximum GCV has also been reported in barley for grain yield per plant and number of grains per spike (El-Hennawy, 1997). These findings are similar to our results, indicating that considerable improvement in grain yield and number of grains per spike, could be ought about by adopting a suitable breeding programme. The lowest GCV were recorded for plant height, 1000-grain weight and grain yield per plant by (Yadav et al., 1993) and (El-Hennawy 1997). Whereas in present study, GCV was observed high for 1000-grain weight and grain yield per plant.

On the basis of these results it is concluded that the characters tiller number per plant, number of spikelets per ear, number of seeds per spike, grain yield per plant, biological yield per plant, 1000-grain weight and harvest index showed high variability. Therefore, greater emphasis should be given to these characters as selection based on these characters will be effective.

**Heritability**

The estimates of heritability in broad sense which determine the portion of the observed variance for which the differences in heritability is responsible, were obtained for several characters. Success in selection programme depends primarily on magnitude of heritable portion of total variation. Burton and De Vane (1953) suggested that genetic coefficient of variation, together with heritability estimates would give reliable indication
of the extent of improvement expected from selection and further explained that expected genetic advance under a particular system supplies a true practical information that is needed by breeder.

Broad sense heritability estimates of all the characters studied are given in Table-14. High heritability estimates were observed for number of tillers per plant, harvest index, grain yield per plant, 1000-grain weight, number of spikelets per ear, number of seeds per spike, biological yield per plant, malt percentage and starch percentage. It indicated that these traits are highly heritable and less affected by the environments. Therefore, selection should be based on these traits. Sajeda Bagum et al., (1997) reported that all the traits studied possessed high heritability values the highest being of grain yield per plant. Whereas, Kaepleer et al., (1991) reported the heritability of Alpha-amylase activity on an F2 plant basis ranged from 0.37 to 0.65, while on an F5 basis it ranged from 0.39 to 0.74.

High heritability has also been reported for number of tillers per plant and grain per spike (Yadav et al., 1991, El-Hennawy 1997), high heritability for 1000-grain weight (Yadav et al., 1993) and for grain yield per plant (Nadziak et al., 1994; Lu et al., 1995; Vimal and Vishwakarma 1998; Sinha et al., 1999, Kumar, 2003 and Dhama, 2007).

In this study, plant height, days to flowering and ear length exhibited moderate heritability, indicating that these traits are more influenced by the environments. Therefore, selection may not be so useful in improving these characters. In earlier studies, high heritability was observed for plant height (Nadziak et al., 1994; Kudla et al., 1995) and for ear length (Nadziak et al., 1994; Ram Kishor et al., 2000 and Pilania and Dhaka 2005). However, only one character namely days to maturity
showed low heritability in the present investigation which has also been reported by \( (\text{Leelu Babu 1998}) \).

**Genetic Advance**

Heritability and GCV are not sufficient to determine the amount of variation which is heritable from parents to their offsprings. Burton \( (\text{1953}) \) and Johnson \( \text{et al.,} \) \( (\text{1955}) \) found that the high heritability estimates alone is of little use in predicting the breeding value of any trait and therefore, this parameter can be better utilized in association with genetic advance and the heritability coupled with genetic advance gives an idea of the possible improvement through selection.

High heritability coupled with high genetic advance over mean (Table-15) was observed for tiller number per plant, biological yield per plant, harvest index, 1000-grain weight, grain yield per plant, number of seeds per spike and number of spikelets per ear indicated that additive genetic effects are of probable importance \( (\text{Panse 1957}) \) and improvement in this traits may be achieved through selection \( (\text{Jonson et al., 1955}) \). High genetic advance with high heritability for number effective tillers per plant, length of spike, number of spikelets per main spike and grain yield per plant was also observed by Aidum \( \text{et al.,} \) \( (\text{1990}) \) in barley and Pathak and Namu \( (\text{1985}) \) in wheat.

Similarly, high heritability coupled with high genetic advance was noted for number of tillers per plant, ear length, spikelets per ear and grain yield per plant by Virmas and Vishwakarma \( (\text{1998}) \) and for number of seeds per spike, 1000-grain weight and grain yield per plant by Leebu babu \( \text{et al.,} \) \( (\text{1998}) \); Ram Kishor \( \text{et al.,} \) \( (\text{2000}) \) and Pilania and Dhaka \( (\text{2005}) \). Sajeda
Begum et al., (1997) reported that the genetic advance was high for grain yield per plant, while Sinha et al., (1999) found high heritability with low genetic advance for grain yield per plant.

Plant height, ear length, days to flowering, malt percentage and starch percentage exhibited low genetic advance with moderate heritability estimates indicating the presence of direct selection for these traits in segregating populations will not contribute for the genetic improvement of grain yield in barley.

CORRELATION COEFFICIENTS

In the present investigation, correlation among 13 characters and direct and indirect contribution of 12 characters towards grain yield were estimated from the data recorded on 40 genotypes of barley in eight environments as well as in pooled analysis. The results are presented in table 16 to 24, and 25 to 33, respectively.

The grain yield of a crop is a complex character and is the ultimate product of actions and interactions of various component characters. Further, it is well known that no independent gene system is present for grain yield per se, but genes are available only for component characters (Grafius, 1969). Therefore, a successful breeding programme should depend not only on the information on association of various yield component characters with grain yield but also on the information of their inter association. Correlation of yield and some desirable characters with other characters should also be studied, because sometimes the selection on the basis of component characters of yield may not be effective due to low heritability. Therefore, it may become necessary to make selection on
the basis of characters other than the yield contributing characters. In view of this, the information on nature and magnitude of correlation between various characters is of utmost importance for initiating any successful breeding programme.

Every aspect of the phenotype of a plant is the result of a large number of factors. There are evidences to suggest that selection for yield is not so easy. Selection for one character invariably affects a number of other characters also. Thus, one realizes that it is the whole integrated genotype that is being selected rather than the particular part that is responsible for the characters we are selecting for.

In present study, the magnitude of genotypic correlation coefficient is higher than corresponding phenotypic correlation. The same results were also observed by Singh, (1987); Ram Kishor et al., (2000) Kumar, 2003 and Dhama, 2007.

In present investigation, grain yield per plant was found consistently associated positively and significantly with biological yield and harvest index in all the environments as well as in pooled analysis. These results are in conformity with, Theoulakis et al., (1994) and El- Hennawy (1997). Grain yield per plant was correlated significantly with number of spikelets per ear in all the environments except environment-IV, and with tiller number per plant in five environments. The same pattern was observed by Yadav (1993), Irfan-ul Haq (1997), Singh et al., (1998). Subash et al., (1998). Khodzhakulu (1980), Ram Kishor et al. (2000), Bhattacharya, (2005) and Dhama, (2007). This emphasizes that the characters biological yield per plant, harvest index, number of spikelets per ear and tiller number per plant are more important attributes in determining
grain yield in barley. Their importance in yield improvement is further substantiated with the fact that they had significant positive association with other component characters. Some more characters like, ear length, number of seeds per spike and 1000-grain weight were observed to have positive significant correlation with grain yield showing their relative importance. Similar results were observed by El-Henawy (1997), Irfan-ul-Hag (1997), Singh et al., (1998) and Ram Kishor et al., (2000). A negative but significant correlation was also observed between plant height and grain yield per plant in three environments as well as pooled analysis while, Hadjichristodoulou A (1991), Ram Kishor et al. (2000), Dhama, (2007) and Singh and Khare (2008) reported that the plant height had positive and significant correlation with grain yield.

The character biological yield per plant was found consistently correlated negatively and significantly with harvest index across the environments, while it had positive significant correlation with number of spikelets per ear in five environments. For instance, biological yield with number of spikelets per ear, grain yield, number of seeds per spike in majority of the environments, number of spikelets per ear with number of seeds per spike in seven environments, number of seeds per spike with grain yield and biological yield. Number of tillers per plant with grain yield per plant and biological yield per plant in five and three environments, respectively showed positive and significant correlation.

In contrast, number of spikelets per ear was also associated negatively with malt percentage. Harvest index showed negative significant correlation with number of seeds per spike in five environments as well as in pooled analysis. Some other characters, plant height had negative
correlation with grain yield per plant in three environments while days to maturity consistently associated negatively with plant height in all environments.

Keeping the above results and discussion in view, selection for better genotypes in barley over a range of given environments, The characters biological yield per plant, tiller number per plant, harvest index and number of spikelets per ear have high correlation with grain yield and are thus the main contributors for improving grain yield. Therefore, the simultaneous selection for these traits aimed at yield improvement in barley.

PATH COEFFICIENT

Correlation coefficient analysis provides only the direction and degree of association between various characters but, do not clearly bring out the characters on which breeder should concentrate to improve the productivity or yield potential of a crop. Therefore, path coefficients analysis was also carried out in the same material. This estimates the direct effects and indirect effects via alternate characters towards grain yield. The correlation coefficients of grain yield with various component characters were further analyzed following path coefficients analysis.

The estimates of direct and indirect effects of various characters on grain yield are presented in Table-25 to 33. It would be interesting to note the characters recommended earlier on the basis of correlation studies, showed consistent high direct effects and indirect effects through each other towards dependable variable. The characters biological yield per plant and harvest index exhibited high direct contribution towards grain yield.
The other important yield contributing characters namely number of spikelets per ear and number of seeds per spike had positive and significant correlation with grain yield per plant in majority of environments as well as in pooled analysis.

But these characters did not exhibit considerable direct influence on grain yield; instead, they contributed towards grain yield via biological yield. Whereas, Singh, 1987; García, et al., 1991; Ganeshvada, et al., 1992; Mandai and Dana, 1993; Naik, et al., 1998; Verma, et al., 1998; Fathi and Rezacimoghholdam, 2000; Kumar, 2003 and Kumar and Khare, 2008 reported that the number of seeds per spike had greatest effect on grain yield. It is pertinent to mention that character tiller number per plant had positive and significant correlation with grain yield but it had negative direct effects on grain yield. However, it contributes towards grain yield via biological yield per plant. While Kumar, et al., 1986; Jadav and Jadon, 1987; Singh, 1987; Sarker, et al., 1988; Singh, 1990; Garcia, et al., 1991; Yadav, 1993; Kudla, 1995; Maled, and Hanchinal, 1997; Naik, et al., 1998; Verma, et al., 1998; Fathi and Rezaeimoghddam 2000; Dhama, 2007 and Singh and Khare, 2008 observed the character tiller number per plant had positive and direct effect on grain yield per plant.

It is apparent from the direct effect and high positive correlation with grain yield that biological yield and harvest index have true relationship with grain yield. Therefore, direct selection for high biological yield and high harvest index will result in improvement of grain yield. Because, all other component characters had indirect effect on grain yield via these two characters, correlated response in component characters will automatically be obtained.
It is interesting to mention that important yield contributing trait 1000-grain weight had positive and significant correlation with grain yield in only two environments and also have positive direct effects on grain yield in same environments. However, pooled analysis of correlation and path coefficient revealed that it does not have any influence on grain yield directly or indirectly on the contrary, Singh, 1987; Gansheva, et al., 1992; Mandai and Dana, 1993; Kudla, 1995; Verma, et al., 1998; Bhattacharya, 2005 and Singh and Khare, 2008 reported that 1000-grain weight had positive direct effects on grain yield. Therefore, it may be suggested that 1000-grain weight is not a stable selection criteria for yield improvement in barley, because other yield contributing characters like days to maturity, biological yield, grains per ear, tiller number per plant and number of spikelets contributes indirectly yield.

In spite of agronomic characters, quality traits like malt and starch percentage has important role to stabilize the barley as a raw product for different industrial purposes. In the present investigation malt percentage has positive and significant correlation with harvest index in pooled analysis whereas it has negative and significant correlation with number of spikelets per ear, in three environments. It also has negligible direct and indirect effects on most of the characters concerned. Therefore, it may be concluded that selection for harvest index can also improve the malt percentage along with grain yield in barley. However, character starch percentage did not show correlation, direct and indirect effects in the direction of yield improvement. Therefore, it necessitates formulating specific breeding procedures for starch percentage improvement without affecting the yield.
It may also be important to mention that the phenomenal increase in barley yield potential during the past few decades is attributed to increased level of harvest index. The general consequence of this progression has been that the modern varieties are high yielding with shorter height but have little or no increase in overall biological yield over their forebearers and further efforts to increase yield potential have not been successful. In barley, although the physiological limit for harvest index has been to 50 per cent, the further improvement of present level of harvest index has not been feasible. Therefore, the future improvement in grain yield of barley can be attained by increasing the biological yield, tiller number per plant and number of seeds per spike while maintaining the optimum not higher level of harvest index.

PHENOTYPIC STABILITY

It is realized that there is the importance of G x E interaction in predicting the performance of genotypes for their subsequent use in breeding programmes. The success of breeding programme depends upon the extent of genetic viability in the breeding material. The variable performance of genotypes under different environments makes it difficult for breeders to exploit the variability for different characters. Stability in performance is one of the most desirable properties of a genotype for selecting a parent for any breeding programme used to develop varieties best suited for wider cultivation. For this purpose the multi-location trials over a number of years are conducted. Some time the uni-location trials can also serve the purpose provided different environments are created by planting experimented trials at different date of sowing and providing various spacing, different doses of fertilizer and irrigation levels etc., (Luthra et al.,
Whereas, Nissila et al., (1992) concluded that the variation between years was highly significant and there was no interaction between genotypes and years.

Earlier Spargue (1966) discussed the importance of G x E interactions in estimating the variance components and described them as factors limiting the efficiency of selection programme. Although breeders have realized the importance of G x E interaction since the beginning of crop cultivation, yet efficient techniques were not available to quantify such interactions.

The regression analysis used by Eberhart and Russell (1966) and Perkins and Jinks (1968) is efficient in providing both the pooled estimates of G x E interactions for individual genotypes. Estimates of G x E interactions for each genotype could be further partitioned into linear components represented by regression coefficient (b=1) and non linear components represented by deviation from regression $S^2_{di}$. Karssena (1997) concluded that the mean yield was significantly correlated with coefficient of determination ($r^2_i$). The linear regression (bi) statistic showed significant positive correlation with $r^2_i$ genotypic variance ($S^2_i$) and coefficient variability (cvi). The covariance stability index ($W^2_i$) and stability variance were perfectly correlated ($r=1.00$). The phenotypic performance of a genotype can be predicted if the G x E interaction is accounted for by linear components, such prediction can not be made if the non linear component is predominating. Keeping in view these points, the present study was undertaken to work out the phenotypic stability of 40 genotypes of barley (Hordeum vulgare L.) grown under eight environment over two different locations and the results thus, obtained are discussed here under.
Following the Eberhart and Russell (1966) model, forty barley genotypes involved in the present study were observed to differ in their sensitivity, mean performance and stability for different characters when analyzed. Availability of different levels of mean performance and stability for a particular genotype indicated that both the attributes are governed by different sets of genes. Therefore, sensitivity is specific characteristics of a genotype. Moreover, the nature and magnitude of sensitivity exhibited by different genotypes remained inconsistent for different characters. The genotypes were observed having different levels of mean performance and stability for various characters suggesting that the mean performance of genotypes were independent to their stability (Table-35). It may be assumed from these observations that there are different sets of genes governing both the attributes (mean performance and stability) for each character. Thus, it may be possible to incorporate both sets of genes in to the genotype to derive desirable cultivars with high mean and stable performance.

Commercially desirable genotypes should be stable with high and moderate level of mean performance and medium mean value. In the present study, the pooled analysis of variance for different characters is presented in (Table-34). The mean square due to varieties was found significant for all the characters except ear length, indicating the presence of sufficient variability for these characters. Costa et al., (2001) and Pilania (2004) observed significant differences among barley cultivars and experimental lines for grain yield, plant height and heading date. Sial et al., (2000) also reported the combined analysis of variance over all environments revealed highly significant differences for genotypes, environments and G x E interaction. Whereas, Oliveira et al.,
(1994) concluded that the environment had a significant effect on four granules traits.

It is clear from results that the linear component of G x E interaction played an important role in all the thirteen characters under study. Genotype x location interaction from analysis of variance was reported significant for grain yield by the May et al., (1993). Same findings were also found by the Fekadu Fufa et al., (1995); Das, et al., (1996); Salem, et al., (1998); Forshadfar, (1999); Pilania, (2004) and Verma (2008) the genotype x environment interaction was higher than those of spikes per plant and seed weight. Upreti (1999) reported the presence of G x E interaction for all the traits except tillers per meter. The linear component G x E interactions was significant for days to heading, days to maturity, spike length, grains per spike and 1000-grain weight. However, Oliveira (1994) observed that G x E interaction was not significant. The non-linear components of G x E interaction were observed significant only for nine characters. Upreti (1999) also reported that the non-linear component was significant for most of the characters except days to maturity, spike length and spikelets per spike the variance due to deviation (non-linear) were significant for days to flowering, days to maturity, plant height, ear length, number of spikelets per ear, number of seeds per spike, harvest index, malt and starch percentage reflecting considerable genetic diversity in the material.

1. Days to flowering

The mean performance of the 40 genotypes of barley for days to flowering ranged from 88.34 (K-633) to 100.03 (K-141) with the population mean 94.53. Considering the response of genotypes to environmental changes,
the genotypes Jagrati, PL-781, K-169, K-252, K-370, K-551, Lakhan, K-1155, K-633 and Amber showed early flowering with b=1 and non significant S^2_{di}.

2. **Days to maturity**

The mean performance of different genotypes for days to maturity ranged from 117.28 (K-633) to 129.12 (K-783) with population mean 124.33. Considering low mean, b=1 and S^2_{di}=0, only nine genotypes namely RD-2684, Jagrati, PL-781, K-370, K-341, K-603, K-792, K-784 and Amber were showing early maturity, with regression coefficient close to unity and deviation from regression zero.

3. **Plant height (cm)**

The genotype K-784 showed minimum plant height and stable having b<1 and non significant S^2_{di} while genotype Jagrati showed maximum plant height and non significant S^2_{di} but their “bi” value was greater than unity therefore this variety perform better in good fertility levels.

4. **Number of tillers per plant**

Considering high mean value (>9.37), bi=1 and S^2_{di}=0 four out of forty varieties namely, K-169, K-804, K-633 and K-794 were identified as desirable and stable for number of tillers per plant over eight environments. The genotypes K-784, RD-2684, Jagrati, BH-851, K-729, K-784, K-1149, K-551, K-790, Lakhan and K-791 had near medium mean values for number of tillers per plant and bi=1 but it had S^2_{di}= significant these genotypes were not therefore suitable for cultivation in the environments studied because unpredictable components of G x E interaction.
considering in the performance of these genotypes. However, genotypes K-252, K-603 and K-783 were observed as high tiller producing genotypes and stable but its corresponding “bi” values were significantly greater than unity indicating that these genotypes perform better in favourable conditions and these varieties could be recommended for cultivation under better management practices.

5. **Ear length (cm)**

The mean values of different genotypes for ear length ranged from 8.24 (Jyoti) to 9.57 (Manjula) with population mean 8.82. The genotype Manjula was found maximum ear length producer from other genotypes and some more genotypes namely, K-804, K-789. K-784, K-409, K-551, Lakhan and K-789 were also maximum ear length producer genotypes and these genotypes had b=1 and $S^2_{di}=0$. Therefore these genotypes could be recommended for general cultivation.

6. **Number of spikelets per ear**

Using the stability criteria, high mean, b=1 and $S^2_{di}=0$, out of 40 genotypes, four genotypes BEU-73, K-784, K-141 and K-794 were identified as desirable and stable for number of spikelets per ear over the eight environments. This could be recommended for commercial cultivation.

7. **Number of seeds per spike**

Mean performance of forty genotypes for this traits ranged from 49.63 (Vijaya) to 68.23 (K-141) with grand mean 57.15. Out of forty, six genotypes namely, RD-2684, K-729, RD-2035, K-115, Amber and K-141
were screened as desirable and stable for this trait. Therefore, these varieties are suitable for general cultivation under normal fertility levels.

8. **Grain yield per plant (g)**

Out of 40 varieties, thirty one genotypes showed stability for grain yield because these varieties had non significant deviation ($S^2_{di}=0$) however, Hadjichristodolou (1974) reported that grain yield is a less stable trait in comparison to 1000-grain weight. Seven genotypes out of thirty one were stable for grain yield with high mean performance having unit regression and non significant deviation from regression over eight environments. These varieties are K-273, K-169, K-252, K-792, K-784, RD-2035 and K-794 which can be recommended for commercial cultivation in the environments tested in the present study. Fekadu Fufa (1995) and Thakur et al., (1999) also reported the genotypes PG-3510 (I), PG-3515 (I) and PG-319 (I) and DL-78 and DL-226 were stable for high yields and are suitable for commercial cultivation. Mishra et al., (2000) also observed the genotypes DL-788-2 and GW 190 had higher adaptability and stability and may be recommended for normal and later sowing condition. All the seven stable genotypes for grain yield per plant with high mean performance showed stability for different characters which are mentioned in Table 36. The variety K-273 showed stability and high mean performance, unit regression with biological yield per plant and harvest index. K-169 exhibited stability for days to flowering, number of tillers per plant, 1000-grain weight, biological yield per plant, harvest index and starch percentage. K-252 showed stability for days to flowering, the genotype K-792 showed stability for days to maturity, 1000-grain weight, biological yield per plant, harvest index and malt percentage and genotype K-784 showed stability for days to
<table>
<thead>
<tr>
<th>S. No.</th>
<th>Genotypes</th>
<th>Grain yield/plant (g)</th>
<th>Category</th>
<th>Stable characters</th>
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<tbody>
<tr>
<td>1</td>
<td>K-273</td>
<td>11.63</td>
<td>H</td>
<td>Biological yield per plant</td>
</tr>
<tr>
<td>2</td>
<td>K-169</td>
<td>12.10</td>
<td>H</td>
<td>Days to flowering, number of tillers per plant, 1000-grain weight, biological yield per plant, harvest index and starch percentage</td>
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<td>K-252</td>
<td>11.84</td>
<td>H</td>
<td>Days to flowering</td>
</tr>
<tr>
<td>4</td>
<td>K-792</td>
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<td>H</td>
<td>Days to maturity, 1000-grain weight, biological yield per plant, harvest index and malt percentage</td>
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<td>5</td>
<td>K-784</td>
<td>11.68</td>
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<td>Days to maturity, ear length, number of spikelets per ear and 1000-grain weight</td>
</tr>
<tr>
<td>6</td>
<td>RD-2035</td>
<td>11.56</td>
<td>H</td>
<td>Number of seeds per spike</td>
</tr>
<tr>
<td>7</td>
<td>K-794</td>
<td>11.95</td>
<td>H</td>
<td>Number of tillers per plant, number of spikelets per ear, biological yield per plant, malt percentage and starch percentage</td>
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<td>8</td>
<td>Jagrati</td>
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<td>Days to flowering, days to maturity, ear length, 1000-grain weight and harvest index</td>
</tr>
<tr>
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<td>K-603</td>
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<td>Days to maturity, 1000-grain weight and starch percentage</td>
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<tr>
<td>10</td>
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<td>Plant height, 1000-grain weight and biological yield</td>
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<td>Days to flowering, plant height, ear length, number of seeds per spike, 1000-grain weight, biological yield and starch percentage</td>
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<tr>
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</tbody>
</table>

Population mean 11.34
maturity, ear length, number of spikelets per ear and 1000-grain weight indicating these varieties showing their consistent performance across the environments and it can be concluded that the varieties recommended for wider cultivation over the environments. Genotypes x environment interactions measured through regression analysis were significant for grain yield, heading date and plant height. Most barley genotypes tested (90%) had regression slope for grain yield that did not differ from 100 (Costa et al., 2001, Pilania, 2004 and Verma, 2008).

Breeders' main aim as emphasized earlier, is to have genotypes which are high yielding as well as stable for yield. The seven genotypes earlier recommended were high yielding as well as stable for yield. Noaman et al., (1992) also identified five barley genotypes which exhibited both high yield and high stability. The genotypes K-678, BH-851, K-341, K-791, K-675 and K-804 were high yielding and stable but their corresponding “bi” values were significantly lower than unity. It shows that these genotypes would perform better in poor environment conditions hence these can be utilized as donor parent to breed a suitable line for poor environments. Mishra et al. (2000) reported that the genotype DL-803-3 and Raj-1555 showed stability and sustainability under poor environmental conditions and may be recommended for cultivation under late sowing conditions. Similarly, genotypes Lakhan, Vijaya, Jyoti, K-551, K-790, Lakhan, K-804 and K-141 were observed to be high yielding and stable but its corresponding “bi” values was greater than unity. It shows that these varieties would perform better in favourable conditions and hence could be recommended for cultivation under better management practices. Verma and Ram (1990) also identified the variety hulled BHO 113 and HBO 316 for high yield but suitability for better environment.
The genotypes RD-2684, Manjula, PL-781 and K-318 had low grain yield over the grand mean and significant S^2 di hence were unstable. These genotypes were not therefore, suitable for cultivation in environment studied, because unpredictable components of G x E interaction considerably shared in the performance of these genotypes. Noaman et al. (1992) also reported that environment has influenced some genotypes. While some other genotypes were relatively consistent in ranking at different environment.

9. **1000-grain weight (g)**

Out of forty varieties only ten varieties exhibiting high mean (>27.64), bi=1 and S^2 di=0 were screened as desirable and stable for eight environments under study. Hadjichristodolou (1974) also reported that 1000-grain weight is most stable trait other than remaining yield contributing traits. However, he also concluded that six rowed varieties were less stable than two rowed varieties. While three genotypes namely, RD-2035, K-794 and K-141 had high mean performance and stable but its corresponding "bi" values was lower than the unity, therefore, these varieties perform better under poor environmental conditions and these could be used as donor parent to breed a suitable line for poor environment.

10. **Biological yield per plant (g)**

Eleven genotypes were observed as desirable and stable with high mean (>26.80), bi=1 and S^2 di=0 for biological yield per plant across the environments while genotypes K-252, BH-851, K-341, RD-2035 and Amber had high mean performance and stable with S^2 di=0 but its corresponding "bi" values were significantly greater than unity. Therefore, these varieties
perform better in favourable environments. However, genotypes RD-2684 and K-804 had greater mean performance with bi=1 but its S²di= significant hence were unstable. These genotypes were not suitable for cultivation under environment studied, because G × E interaction plays major role for the performance of these genotypes.

11. Harvest index (%)

On the basis of mean performance, responsiveness and deviation from regression of individual genotypes the genotypes Vijaya, Jagrata, K-169 and K-792 were identified as stable for harvest index over eight environments and these genotypes performed better in normal environments.

12. Malt percentage

Considering high mean (>80.02), regression coefficient close to unity (bi=1) and deviation from regression zero the seven promising varieties namely, RD-2684, Manjula, K-678, BH-851, K-792, K-790 and K-794 were screened as desirable and stable for malt percentage over eight environments. These varieties could be recommended for commercial cultivation for malt percentage in the environments tested in the present study.

These seven stable genotypes for malt percentage with high mean performance (>80.02) had stability with different characters maintained against each genotype in Table 37. The genotypes K-273, Vijaya, K-252, K-1149, Lakhan, K-804, RD-2035, K-1155 and K-791 had medium malt percentage than population but significant S²di hence were unstable therefore, these genotypes were not suitable for cultivation in the environments under study, as unpredictable components of G × E interactions considerably shared in the performance in these genotypes.
Table-37: Genotypes stable for malt percentage with high and medium mean performance showing stability for other characters in barley.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Genotypes</th>
<th>Malt percentage (%)</th>
<th>Category</th>
<th>Stable characters</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>RD-2684</td>
<td>82.41</td>
<td>H</td>
<td>Days to flowering, days to maturity and number of seeds per spike</td>
</tr>
<tr>
<td>2</td>
<td>K-678</td>
<td>81.70</td>
<td>H</td>
<td>Plant height and ear length</td>
</tr>
<tr>
<td>3</td>
<td>BH-851</td>
<td>81.05</td>
<td>H</td>
<td>Plant height</td>
</tr>
<tr>
<td>4</td>
<td>K-792</td>
<td>81.69</td>
<td>H</td>
<td>Days to maturity, plant height, grain yield, 1000-grain weight and biological yield per plant</td>
</tr>
<tr>
<td>5</td>
<td>K-790</td>
<td>81.13</td>
<td>H</td>
<td>Plant height, ear length, number of seeds per spike, grain yield per plant and 1000-grain weight</td>
</tr>
<tr>
<td>6</td>
<td>K-794</td>
<td>81.71</td>
<td>H</td>
<td>plant height, ear length, number of tillers per plant, number of spikelets per ear, grain yield per plant, biological yield per plant and starch percentage</td>
</tr>
<tr>
<td>7</td>
<td>K-169</td>
<td>79.42</td>
<td>M</td>
<td>Plant height, ear length, number of tillers per plant, ear length, number of spikelets per ear, number of seeds per spike, grain yield per plant, 1000-grain weight, biological yield per plant, harvest index and starch percentage</td>
</tr>
<tr>
<td>8</td>
<td>K-341</td>
<td>80.21</td>
<td>M</td>
<td>Days to maturity, plant height, number of tillers per plant, ear length and 1000-grain weight</td>
</tr>
<tr>
<td>9</td>
<td>K-551</td>
<td>81.56</td>
<td>M</td>
<td>Days to flowering, plant height, ear length, number of seeds per spike, 100-grain weight and harvest index</td>
</tr>
<tr>
<td>10</td>
<td>K-789</td>
<td>80.54</td>
<td>M</td>
<td>Plant height, number of tillers per plant, ear length and 1000-grain weight</td>
</tr>
<tr>
<td>11</td>
<td>Amber</td>
<td>77.72</td>
<td>M</td>
<td>Days to flowering, days to maturity, number of tillers per plant, ear length, number of sees per spike, 1000-grain weight and starch</td>
</tr>
<tr>
<td></td>
<td>Population mean</td>
<td>80.92</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
On the basis of mean performance, responsiveness and deviation from regression of individual genotypes, the genotypes Jagrati, PL-781, K-370, K-729, BEU-73, and K-675 were observed to be high yielding and stable, but its corresponding 'bi' values were significantly greater than unity. It shows that these genotypes would perform better in favourable conditions and hence could be recommended for cultivation under better management practices.

13. Starch percentage

In most of the breeding programmes, it is usually desired to identify promising genotypes for better, medium and poor environments. This can be done by using Eberhart and Russell (1966) model. Considering stability criteria, the varieties PL-781, K-1155, K-633, and K-794 were identified promising for starch percentage under eight environments tested in present study. These four varieties showed stability with some other characters as mentioned against each genotype in Table-38. While, the genotypes RD-2648, K-729, BEU-73, K-792, K-784, K-1149, and K-804 had high starch percentage and were stable ($S^2_{di}=0$) but the 'bi' values were found significantly lower than the unity. It shows that these genotypes would perform better in poor environments hence these can be utilized as donor parent to breed a suitable lines for poor environments.
**Table-38** : Genotypes stable for starch percentage with high and medium mean performance showing stability for other characters in barley.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Genotypes</th>
<th>Starch percentage Population mean</th>
<th>Category</th>
<th>Stable characters</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PL-781</td>
<td>59.21</td>
<td>H</td>
<td>Days to flowering, plant height, days to maturity, 1000-grain weight and biological yield per plant</td>
</tr>
<tr>
<td>2</td>
<td>K-1155</td>
<td>60.31</td>
<td>H</td>
<td>Days to flowering, number of seeds per spike and biological yield per plant</td>
</tr>
<tr>
<td>3</td>
<td>K-633</td>
<td>58.90</td>
<td>H</td>
<td>Days to flowering, plant height and number of tillers per plant</td>
</tr>
<tr>
<td>4</td>
<td>K-794</td>
<td>59.37</td>
<td>H</td>
<td>Plant height, number of tillers per plant, number of spikelets per ear, grain yield per plant, biological yield per plant and malt percentage</td>
</tr>
<tr>
<td>5</td>
<td>K-169</td>
<td>58.51</td>
<td>M</td>
<td>Days to flowering, number of tillers per plant, ear length, number of spikelets per ear, number of seeds per spike, grain yield per plant, 1000-grain weight, biological yield per plant and harvest index</td>
</tr>
<tr>
<td>6</td>
<td>Lakhan</td>
<td>58.50</td>
<td>M</td>
<td>Days to flowering, plant height, ear length and 1000-grain weight</td>
</tr>
<tr>
<td>7</td>
<td>K-791</td>
<td>57.58</td>
<td>M</td>
<td>Plant height, 1000-grain weight and biological yield per plant</td>
</tr>
<tr>
<td>8</td>
<td>K-318</td>
<td>58.07</td>
<td>M</td>
<td>Plant height, number of tillers per plant and 1000-grain weight</td>
</tr>
<tr>
<td>9</td>
<td>Amber</td>
<td>57.62</td>
<td>M</td>
<td>Days to flowering, days to maturity, number of tillers per plant, ear length, number of seeds per plant, 1000-grain weight and malt percentage</td>
</tr>
<tr>
<td>10</td>
<td>K-141</td>
<td>58.31</td>
<td>M</td>
<td>Plant height, number of spikelets per ear, number of seeds per spike and biological yield per plant</td>
</tr>
</tbody>
</table>

Population mean 58.69