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# Non Parametric Analysis in Multi Environmental Trials of Feed Barley Genotypes

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**A B S T R A C T**

GXE interaction of twenty seven feed barley genotypes tested at fifteen major barley locations interpreted by non-parametric measures. Genotype JB322 was high yielder followed by PL890 and HUB250 among feed barley genotypes. Descriptive statistics calculated from original yield values identified genotypes KB1436 and KB1434 were of stable performance. Nonparametric measures, free from distributional assumptions, Si1, Si2, Si3, Si4, Si5 Si6 and Si7 indicated JB322, UPB1054 and KB1434 as stable genotypes, however, unstable genotypes were RD2552G5 and DWRB156. CMR and CSD measures pointed towards HUB113, NDB1634 and UPB1054, JB322 as desirable genotypes respectively. CSi1 and CSi2 measures identified JB322 and UPB1054 along with UPB1054 and HUB 113 as of stable yield performance. Genotypes UPB1054, HUB113, BH1005 based on CSi3 and CSi6 were identified as the stable genotypes whereas KB1436 and RD2552 were unstable. First two NPs were very similar for unstable performance of RD2552 and last two NPs for similar performance of HUB250.

**Keywords**

Feed barley, Non-parametric measures, Spearman rank correlation, Ward's hierarchical clustering, Biplot analysis.

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## Introduction

Barley cereal crop has been cultivated for food, feed, forage and brewing purpose. Cereal is grown under varying agro climatic situations of the country. Interpretation of genotype x environment interactions facilitated by the use of statistical methods as interaction complicates the identification of superior genotypes (Berteroa *et al.*, 2004). The nonparametric measures, based on ranks only, proved to be a viable alternative to parametric measures (Dehghani, 2008). For many applications, including selection in breeding and testing programs, the rank orders of genotypes are the most essential information (Khalili and Aboughadareh, 2016). Quite large number of references justifies the use of nonparametric measures in the assessment of stable performance in crop improvement trials (Ebadi-Segherloo, 2008; Karimizadeh *et al.*, 2012). Nonparametric measures based rank of genotypes as per the yield values in different environments were developed by Huehn (1990a). The use of corrected values, instead of original means, for rank determination was proposed by Huehn (1990b). Nonparametric measures of phenotypic stability by Huehn have been used numerously (Dehghani, 2008; Ebadi-Segerloo *et al.*, 2008; Mahtabi *et al.*, 2013; Liu *et al.*, 2010; Sabaghnia *et al.*, 2006; Karimzadeh *et al.*, 2013). Recent papers have exploited nonparametric measures to analyze GxE interaction in agricultural trials (Mortazavian and Azizinia, 2014). Nonparametric stability statistics had been used by plant breeders worldwide due to the potential returns relative to other parameters (Farshadfar *et al.*, 2014).

## Materials and Methods

Research data of this study involved twenty seven feed barley genotypes evaluated at fifteen major barley growing locations across the country. Environmental conditions along with genotype pedigrees were given in table 1 for completeness. Xij denotes the phenotypic value of ith genotype in jth environ¬ment, where i= 1,2,,...k, j=1,2,..., n. Rank of the ith genotype in the jth environment denoted by rij and the average rank of the ith genotype across environments by. (Karimizadeh *et al.*, 2012) Si1 estimate considered all possible pair-wise rank differences, while Si2 was based on variances of ranks for each genotype across environments. The nonparametric stability statistic Si4 is similar to that of Yau and Hamblin (1994), which used relative yield not only to give equal weight to each environment, but also to provide a measure of yield stability. Non-parametric statistics of Si3 and Si6 combine yield and stability based on yield ranks of genotypes in each environment. Karimzadeh *et al.*, 2013 proposed the correction for yield of ith genotype in jth environment as (X*ij = Xij - .+) as X*ij, was the corrected phenotypic value;. was the mean of ith genotype in all environments and was the grand mean. The ranks obtained from these adjusted values X*ij, depend only on GxE interaction and error effects. The genotype with the highest adjusted yield was given a rank of 1 and vice versa for lowest adjusted yielder. Following nonparametric measures were calculated based on the ranks assigned by original and corrected values of yield to genotypes as:

$$S_i^{(1)} = 2\sum_{j}^{n-1}\sum_{j'=j+1}^{n}\left|r_{ij}-r_{ij'}\right| / [n(n-1)]$$

$$S_i^{(2)} = \sum_{j=1}^{n}(r_{ij}-\bar{r}_i)^2 / \sum_{j=1}^{n}\left|r_{ij}-\bar{r}_{i.}\right|$$

$$S_i^{(3)} = \frac{\sum_{j=1}^{n}(r_{ij}-\bar{r}_{i.})^2}{\bar{r}_{i.}}$$

$$S_i^{(7)} = \sum_{j=1}^{n}(r_{ij}-\bar{r}_i)^2/(n-1)$$

$$S_i^{(4)} = \sqrt{\frac{\sum_{j=1}^{n}(r_{ij}-\bar{r}_{i.})^2}{n}}$$

$$S_i^{(5)} = \frac{\sum_{j=1}^{n}\left|r_{ij}-\bar{r}_{i.}\right|}{n}$$

$$S_i^{(6)} = \frac{\sum_{j=1}^{n}\left|r_{ij}-\bar{r}_{i.}\right|}{\bar{r}_{i.}}$$

On parametric measures to measure stability defined by Thennarasu's (1995). In these measures r*ij was the rank of X*ij, and and Mdi were the mean and median ranks for original, where * and M*di were the same parameters computed from the corrected yield values.

$$\mathrm{NP}_i^{(1)} = \frac{1}{m}\sum_{j=1}^{m}\left|r_{ij}^{*} - M_{di}^{*}\right|$$

$$\mathrm{NP}_i^{(2)} = \frac{1}{m}\left(\sum_{j=1}^{m}\frac{\left|r_{ij}^{*} - M_{di}^{*}\right|}{M_{di}}\right)$$

$$\mathrm{NP}_i^{(3)} = \frac{\sqrt{\sum(r_{ij}^{*} - \bar{r}_{i.}^{*})^2/m}}{\bar{r}_{i.}}$$

$$\mathrm{NP}_i^{(4)} = \frac{2}{m(m-1)}\left[\sum_{j=1}^{m-1}\sum_{j'=j+1}^{m}\frac{\left|r_{ij}^{*} - r_{ij'}^{*}\right|}{\bar{r}_{i.}}\right]$$

SAS-based computer program of Lu (1995) and SASGESTAB (Hussein *et al.*, 2000) employed to calculate nonparametric measures. Hierarchical clustering of genotypes based on yield along with non parametric measures by Ward's method (Ward, 1963) was performed to understand the relationships among the nonparametric methods. Spearman's rank correlation coefficient calculates the correlation among ranks as follows :

$$r_s = 1 - \frac{6\sum_{i=1}^{n} d_i^2}{n\,(n^2-1)}$$

$d_i$ = difference between two ranks of investigated trait;
n = number of correlated pairs.

## Results and Discussion

According to mean yield, genotype JB322 was the highest yielder followed by PL890 and HUB250, although remarkable differences were evident among the studied feed barley genotypes (Table 2).

The following three descriptive statistics; mean of ranks (MR), standard deviation of ranks (SD) and coefficient of variation of ranks (CV) were calculated for original ranks. According to these statistics, genotypes KB1436 and KB1434 were of stable performance, while genotypes JB322, JB325 and PL890 based on MR, genotypes DWRB156 and RD2552 based on SD and genotypes HUB250 and BH946 based on CV, were identified as of unstable nature. Simple descriptive statistics based on ranks discriminated among genotype performance (Karimzadeh *et al.*, 2012).

Seven nonparametric measures (Si1, Si2, Si3, Si4, Si5 Si6 and Si7) based on original yield values indicated genotypes JB322, UPB1054 and KB1434 were the most stable, however, most of studied measures pointed towards RD2552G5 and DWRB156 as the unstable genotypes, stable genotypes according to Huehn's nonparametric measures from uncorrected values demonstrated high mean yield. In other words, with maintenance of genotype effect in each cell of two-way data, mean yield confounds GEI and affects stability analysis (Farshadfar *et al.*, 2014). Simultaneous selection for both mean yield and stability is an important consideration as Kang and Pham (1991) studied several stability methods simultaneous for yield and stability. These methods provide a lot of flexibility for plant breeders for the simultaneous selection for both mean yield and stability (Mohammadi *et al.*, 2007).

According to table 3, genotype JB322 followed by UPB1054 were the most stable as well as RD2552 and DWRB156 were of unstable performance based on a corrected dataset that produced a mean of corrected ranks (CMR), standard deviation of corrected ranks (CSD), coefficient of variation of corrected ranks (CCV) and all Huehn's nonparametric measures (CSi1, CSi2, CSi3, CSi4, CSi5 CSi6 and CSi7). Also genotypes UPB1054 and HUB113 were identified as the most stable and KB1436 and RD2552 were unstable based on the above mentioned nonparametric measures of phenotypic stability (Karimizadeh *et al.*, 2012). In the mentioned strategy, the following concept of stability was applied; it determines the stability of genotype over environment if its rank is similar over other environments (biological concept). Many authors (Ebadi-Segerloo *et al.*, 2008; Zali *et al.*, 2011; Sabaghnia *et al.*, 2006) have used the nonparametric measures based on corrected values for stability and demonstrated that these statistics were associated with the biological concept of stability.

Nonparametric indices of Thennarasu's evaluated the genotypes performance differently *i.e.* NPi (1) pointed towards JB322 and UPB1054 as stable in comparison to others and RD2552 along BH946 unstable (Table 3) while, genotype PB891 showed lowest value NPi (2) followed by KB1434 and because of high value stabilities of BH946 and RD2552 were low, NPi (3) unlike NPi (2) identified BH1005 as the most stable followed by BH949. The unstable genotypes based on NPi (3) were JB322 and HUB250. Stability parameters NPi (4) like NPi (2) identified PB891 and KB1434 and BH946 but like NPi(3) pointed towards unstable performance of HUB250. The results of first two NPs were very similar for unstable performance of RD2552 and last two NPs towards HUB250 as unstable genotypes (Mohammadi *et al.*, 2007).

## Clustering of genotypes as per non parametric measures

Ward's method of hierarchical cluster analysis exploited to group genotypes according to yield and different nonparametric measures of phenotypic stability. The clustering considered squared Euclidean distance as dissimilarity measure among genotypes in Ward's method (Figure 2). In Ward's procedure, the dissimilarity between two clusters is shown by the "loss of information" from joining the two clusters with this loss of information measured by the increase in error sum of squares. The cluster analysis revealed four distinct clusters among twenty seven genotypes: cluster of high to moderate yielders consisted of genotypes JB890, PL890, BH902, and RD2922 as UPB1054 as the most favorable and next cluster of four genotypes consisted of unstable genotypes RD2552, DWRB156, BH946 and HUB250. Third cluster of six genotypes comprised of moderately yielder genotypes. Finally fourth cluster grouped highly unstable genotypes as per non parametric measures. It seems that according to corrected statistics, genotypes UPB1054, HUB113 and JB322 were the most stable, but when based on uncorrected statistics, genotypes UPB1054 and KB1434 were the most stable. Regarding mean yield regardless of stability, the most favorable genotypes were JB322 and PL890.

**Table.1** Parentage details of feed barley genotypes along with environmental conditions

| Code | Genotype | Parentage | Locations | Latitude | Longitude | Altitude (m) |
|---|---|---|---|---|---|---|
| IVTIRFB-1 | KB1436 | LAKHAN/JB137 | Durgapura | 26°51 'N | 75°47 ' E | 390 |
| IVTIRFB-2 | BH959 | BH393/BH331 | Hisar | 29°10 'N | 75°46 ' E | 215.2 |
| IVTIRFB-3 | RD2922 | RD2809/RD2743 | Ludhiana | 30°54 ' N | 75° 52' E | 247 |
| IVTIRFB-4 | HUB250 | RD2618/RD2660 | Tabiji | 26°35'N | 74°61' E | 456.1 |
| IVTIRFB-5 | BH1004 | 33rd IBON200/BH902 | Pant Nagar | 29 °02 ' N | 79°48' E | 237 |
| IVTIRFB-6 | UPB1054 | IBYT-LRA-M-12(Sr.No.27 of EIBGN 2013-14) | Karnal | 29 °43 ' N | 76°58 ' E | 252 |
| IVTIRFB-7 | PL890 | DWRUB52/DWRUB62 | Varanasi | 25°20 ' N | 83°03 ' E | 75.5 |
| IVTIRFB-8 | JB325 | RD2615/DL88 | Rewa | 24°31 ' N | 81°15 ' E | 365.7 |
| IVTIRFB-9 | BH1006 | 15th HBSN-4/BH902 | Faizabad | 26°47 'N | 82°12 ' E | 113 |
| IVTIRFB-10 | HUB113 | KARAN280/C138 | Kanpur | 26°29 ' N | 80°18 ' E | 125.9 |
| IVTIRFB-11 | KB1434 | GLORIA-BAR/COPAL//PM5/BEN/3/SEN/4/PETUNIA1/5/BBSC/CONGONA// BLLU/3/CIRU | Sabour | 25°24 ' N | 87°04 ' E | 41 |
| IVTIRFB-12 | RD2786 | RD2634/NDB1020//K425 | SK Nagar | 24°19 ' N | 72°19 ' E | 154.5 |
| IVTIRFB-13 | BH902 | BH495/RD2552 | Sagar | 23°83 ' N | 78°73 ' E | 523 |
| IVTIRFB-14 | JB322 | JB101/BH331 | Morena | 26°56 ' N | 78°80 ' E | 152 |
| IVTIRFB-15 | UPB1053 | IBYT-MRA-12(Sr.No.35 of EIBGN 2013-14) | Udaipur | 24°34 ' N | 70° 42 ' E | 582 |
| IVTIRFB-16 | PB891 | IBON 343/12th HSBN-176 | | | | |
| IVTIRFB-17 | BH1005 | BHMS24A/WG127 | | | | |
| IVTIRFB-18 | HUB249 | RD2618/RD2660 | | | | |
| IVTIRFB-19 | NDB1634 | IBON-HI-40 (2009-10 | | | | |
| IVTIRFB-20 | BH946 | BHMS22A/BH549//RD2552 | | | | |
| IVTIRFB-21 | RD2923 | RD2552/RD2786 | | | | |
| IVTIRFB-22 | KB1425 | K508/NDB1295 | | | | |
| IVTIRFB-23 | DWRB157 | ALANDA02/4/ARIZONA5908/ATHS//ASSE/3/F208.74/5/ALANDA/3/CI08887/CI05761//LIGNEE640-34 | | | | |
| IVTIRFB-24 | RD2921 | RD2508/RD2743 | | | | |
| IVTIRFB-25 | JB319 | LAKHAN/BH353 | | | | |
| IVTIRFB-26 | RD2552 | RD2035/DL472 | | | | |
| IVTIRFB-27 | DWRB156 | P.STO/3/LBIRAN/UNA80//LIGNEE640/4/BLLU/5/PETUNIA 1/6/M9846//CCXX14.ARZ3/PA | | | | |

**Table.2** Descriptive statistics and non-parametric measures based on original values

| Code | Genotype | Yield (q/ha) | MR | SD | CV | Med | $S_i^1$ | $S_i^2$ | $S_i^3$ | $S_i^4$ | $S_i^5$ | $S_i^6$ | $S_i^7$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IVTIRFB-1 | KB1436 | 32.52 | 20.87 | 6.13 | 0.29 | 23.00 | 6.82 | 7.26 | 25.19 | 5.84 | 4.83 | 3.47 | 37.55 |
| IVTIRFB-2 | BH959 | 36.74 | 16.67 | 6.43 | 0.39 | 18.00 | 7.52 | 7.24 | 34.76 | 6.06 | 5.33 | 4.80 | 41.38 |
| IVTIRFB-3 | RD2922 | 39.68 | 11.00 | 6.60 | 0.60 | 10.00 | 7.64 | 7.63 | 55.45 | 6.29 | 5.33 | 7.27 | 43.57 |
| IVTIRFB-4 | HUB250 | 41.30 | 10.53 | 8.35 | 0.79 | 9.00 | 9.71 | 9.16 | 92.63 | 6.85 | 7.10 | 10.11 | 69.70 |
| IVTIRFB-5 | BH1004 | 35.55 | 16.87 | 7.14 | 0.42 | 19.00 | 8.29 | 8.07 | 42.32 | 6.83 | 5.89 | 5.24 | 50.98 |
| IVTIRFB-6 | UPB1054 | 39.91 | 11.53 | 5.30 | 0.46 | 13.00 | 6.17 | 5.93 | 34.14 | 4.84 | 4.43 | 5.76 | 28.12 |
| IVTIRFB-7 | PL890 | 41.45 | 10.07 | 6.80 | 0.68 | 7.00 | 7.41 | 8.38 | 64.26 | 5.93 | 5.15 | 7.67 | 46.21 |
| IVTIRFB-8 | JB325 | 40.76 | 9.87 | 6.28 | 0.64 | 10.00 | 7.33 | 7.44 | 55.92 | 6.06 | 4.94 | 7.51 | 39.41 |
| IVTIRFB-9 | BH1006 | 35.52 | 18.40 | 6.66 | 0.36 | 20.00 | 7.77 | 7.44 | 33.78 | 6.44 | 5.57 | 4.54 | 44.40 |
| IVTIRFB-10 | HUB113 | 39.51 | 11.60 | 6.56 | 0.57 | 11.00 | 7.54 | 7.75 | 51.86 | 6.30 | 5.17 | 6.69 | 42.97 |
| IVTIRFB-11 | KB1434 | 33.79 | 19.40 | 6.32 | 0.33 | 20.00 | 7.20 | 7.48 | 28.85 | 6.11 | 4.99 | 3.86 | 39.97 |
| IVTIRFB-12 | RD2786 | 40.52 | 11.93 | 7.89 | 0.66 | 13.00 | 9.22 | 8.96 | 72.98 | 7.26 | 6.48 | 8.15 | 62.21 |
| IVTIRFB-13 | BH902 | 40.99 | 10.13 | 6.59 | 0.65 | 8.00 | 7.45 | 7.35 | 59.97 | 6.01 | 5.51 | 8.16 | 43.41 |
| IVTIRFB-14 | JB322 | 41.85 | 8.87 | 4.79 | 0.54 | 9.00 | 5.66 | 5.53 | 36.29 | 4.60 | 3.88 | 6.56 | 22.98 |
| IVTIRFB-15 | UPB1053 | 38.97 | 13.00 | 7.73 | 0.59 | 13.00 | 8.99 | 9.50 | 64.31 | 6.90 | 5.87 | 6.77 | 59.71 |
| IVTIRFB-16 | PB891 | 33.77 | 19.60 | 8.19 | 0.42 | 24.00 | 9.07 | 9.10 | 47.94 | 7.74 | 6.88 | 5.27 | 67.11 |
| IVTIRFB-17 | BH1005 | 37.35 | 15.67 | 6.07 | 0.39 | 15.00 | 7.16 | 6.72 | 32.89 | 5.52 | 5.11 | 4.89 | 36.81 |
| IVTIRFB-18 | HUB249 | 34.93 | 18.00 | 7.65 | 0.43 | 18.00 | 8.91 | 8.72 | 45.56 | 7.23 | 6.27 | 5.22 | 58.57 |
| IVTIRFB-19 | NDB1634 | 37.52 | 14.27 | 7.56 | 0.53 | 13.00 | 8.95 | 8.15 | 56.14 | 6.76 | 6.55 | 6.89 | 57.21 |
| IVTIRFB-20 | BH946 | 41.24 | 11.80 | 8.82 | 0.75 | 9.00 | 10.25 | 9.35 | 92.24 | 8.39 | 7.76 | 9.86 | 77.74 |
| IVTIRFB-21 | RD2923 | 39.59 | 12.73 | 6.86 | 0.54 | 14.00 | 8.11 | 7.82 | 51.75 | 5.89 | 5.62 | 6.62 | 47.07 |
| IVTIRFB-22 | KB1425 | 36.77 | 15.73 | 7.52 | 0.48 | 18.00 | 8.67 | 8.30 | 50.27 | 6.60 | 6.36 | 6.06 | 56.50 |
| IVTIRFB-23 | DWRB157 | 39.57 | 13.93 | 8.17 | 0.59 | 15.00 | 9.56 | 8.89 | 67.10 | 7.89 | 7.01 | 7.55 | 66.78 |
| IVTIRFB-24 | RD2921 | 38.33 | 14.73 | 8.28 | 0.56 | 14.00 | 9.79 | 8.90 | 65.09 | 7.99 | 7.18 | 7.31 | 68.50 |
| IVTIRFB-25 | JB319 | 38.72 | 13.53 | 7.42 | 0.55 | 15.00 | 8.78 | 8.08 | 57.02 | 6.74 | 6.36 | 7.05 | 55.12 |
| IVTIRFB-26 | RD2552 | 39.01 | 13.27 | 9.71 | 0.73 | 11.00 | 11.33 | 10.12 | 99.42 | 9.34 | 8.68 | 9.82 | 94.21 |
| IVTIRFB-27 | DWRB156 | 40.54 | 13.00 | 9.51 | 0.73 | 14.00 | 11.18 | 10.38 | 97.38 | 9.06 | 8.13 | 9.38 | 90.43 |

**Table.3** Descriptive statistics and non-parametric measures based on corrected values

| Code | Genotype | CMR | CSD | CCV | CMed | CSi1 | CSi2 | CSi3 | CSi4 | CSi5 | CSi6 | CSi7 | $NP_i^{(1)}$ | $NP_i^{(2)}$ | $NP_i^{(3)}$ | $NP_i^{(4)}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IVTIRFB-1 | KB1436 | 13.33 | 8.99 | 0.67 | 11.00 | 10.53 | 13.93 | 148.70 | 10.53 | 9.49 | 10.68 | 141.61 | 7.667 | 0.333 | 0.551 | 0.505 |
| IVTIRFB-2 | BH959 | 14.07 | 7.19 | 0.51 | 13.00 | 8.44 | 8.44 | 58.60 | 7.33 | 6.51 | 6.94 | 58.88 | 6.267 | 0.348 | 0.445 | 0.506 |
| IVTIRFB-3 | RD2922 | 13.13 | 6.75 | 0.51 | 11.00 | 7.85 | 8.83 | 53.76 | 6.86 | 5.33 | 6.09 | 50.43 | 5.333 | 0.533 | 0.624 | 0.713 |
| IVTIRFB-4 | HUB250 | 14.60 | 8.87 | 0.61 | 13.00 | 10.44 | 11.03 | 92.44 | 8.48 | 8.16 | 8.38 | 96.40 | 7.333 | 0.815 | 0.901 | 0.991 |
| IVTIRFB-5 | BH1004 | 13.60 | 8.61 | 0.63 | 14.00 | 10.21 | 10.45 | 88.06 | 8.48 | 7.64 | 8.43 | 85.55 | 7.333 | 0.386 | 0.530 | 0.605 |
| IVTIRFB-6 | UPB1054 | 14.33 | 5.77 | 0.40 | 16.00 | 6.80 | 7.17 | 40.67 | 6.20 | 5.42 | 5.67 | 41.64 | 4.733 | 0.364 | 0.541 | 0.590 |
| IVTIRFB-7 | PL890 | 14.00 | 6.81 | 0.49 | 13.00 | 7.89 | 9.84 | 63.00 | 6.47 | 5.98 | 6.40 | 63.00 | 5.267 | 0.752 | 0.762 | 0.783 |
| IVTIRFB-8 | JB325 | 13.87 | 6.65 | 0.48 | 14.00 | 7.71 | 9.22 | 62.00 | 7.50 | 6.21 | 6.72 | 61.41 | 4.933 | 0.493 | 0.767 | 0.782 |
| IVTIRFB-9 | BH1006 | 14.80 | 8.64 | 0.58 | 17.00 | 9.96 | 10.83 | 83.70 | 9.05 | 7.63 | 7.73 | 88.49 | 7.533 | 0.377 | 0.494 | 0.541 |
| IVTIRFB-10 | HUB113 | 12.40 | 6.54 | 0.53 | 12.00 | 7.56 | 7.97 | 49.13 | 6.22 | 5.09 | 6.16 | 43.51 | 5.067 | 0.461 | 0.549 | 0.652 |
| IVTIRFB-11 | KB1434 | 13.40 | 7.94 | 0.59 | 14.00 | 9.28 | 12.85 | 106.24 | 9.55 | 7.39 | 8.27 | 101.69 | 6.467 | 0.323 | 0.502 | 0.478 |
| IVTIRFB-12 | RD2786 | 14.13 | 8.58 | 0.61 | 14.00 | 10.15 | 10.18 | 78.00 | 8.48 | 7.22 | 7.67 | 78.74 | 6.933 | 0.533 | 0.718 | 0.851 |
| IVTIRFB-13 | BH902 | 13.87 | 6.61 | 0.48 | 12.00 | 7.43 | 10.54 | 59.19 | 7.38 | 5.19 | 5.62 | 58.63 | 5.067 | 0.633 | 0.730 | 0.733 |
| IVTIRFB-14 | JB322 | 14.80 | 5.99 | 0.40 | 17.00 | 6.78 | 9.33 | 69.63 | 7.95 | 7.36 | 7.46 | 73.60 | 4.600 | 0.511 | 0.935 | 0.765 |
| IVTIRFB-15 | UPB1053 | 13.33 | 8.16 | 0.61 | 15.00 | 9.64 | 9.42 | 69.98 | 7.25 | 6.60 | 7.43 | 66.64 | 6.467 | 0.497 | 0.607 | 0.741 |
| IVTIRFB-16 | PB891 | 14.87 | 7.90 | 0.53 | 16.00 | 9.24 | 11.48 | 81.38 | 8.98 | 7.03 | 7.09 | 86.41 | 6.467 | 0.269 | 0.458 | 0.471 |
| IVTIRFB-17 | BH1005 | 13.53 | 6.53 | 0.48 | 15.00 | 7.62 | 8.12 | 49.21 | 6.07 | 5.47 | 6.06 | 47.57 | 5.333 | 0.356 | 0.425 | 0.486 |
| IVTIRFB-18 | HUB249 | 13.67 | 8.98 | 0.66 | 13.00 | 10.57 | 10.94 | 103.24 | 9.00 | 8.60 | 9.44 | 100.79 | 7.733 | 0.430 | 0.539 | 0.587 |
| IVTIRFB-19 | NDB1634 | 13.07 | 8.18 | 0.63 | 12.00 | 9.66 | 9.02 | 73.36 | 7.74 | 7.08 | 8.13 | 68.47 | 6.933 | 0.533 | 0.560 | 0.677 |
| IVTIRFB-20 | BH946 | 15.00 | 9.58 | 0.64 | 13.00 | 11.22 | 11.32 | 95.97 | 9.79 | 8.48 | 8.48 | 102.83 | 8.400 | 0.933 | 0.830 | 0.951 |
| IVTIRFB-21 | RD2923 | 14.33 | 7.02 | 0.49 | 15.00 | 8.25 | 8.24 | 50.77 | 6.27 | 5.88 | 6.16 | 51.98 | 5.733 | 0.410 | 0.547 | 0.648 |
| IVTIRFB-22 | KB1425 | 13.33 | 8.70 | 0.65 | 14.00 | 10.21 | 10.25 | 85.93 | 7.99 | 7.45 | 8.38 | 81.84 | 7.333 | 0.407 | 0.555 | 0.649 |
| IVTIRFB-23 | DWRB157 | 15.87 | 8.81 | 0.56 | 19.00 | 10.15 | 9.36 | 72.09 | 8.59 | 8.15 | 7.70 | 81.70 | 7.400 | 0.493 | 0.627 | 0.729 |
| IVTIRFB-24 | RD2921 | 13.73 | 8.72 | 0.64 | 14.00 | 10.34 | 9.58 | 78.64 | 8.48 | 7.52 | 8.21 | 77.14 | 7.467 | 0.533 | 0.576 | 0.702 |
| IVTIRFB-25 | JB319 | 14.00 | 7.76 | 0.55 | 14.00 | 9.20 | 8.76 | 60.38 | 7.00 | 6.43 | 6.89 | 60.38 | 6.400 | 0.427 | 0.555 | 0.680 |
| IVTIRFB-26 | RD2552 | 13.80 | 10.29 | 0.75 | 11.00 | 12.00 | 10.75 | 107.73 | 9.94 | 9.22 | 10.02 | 106.19 | 9.067 | 0.824 | 0.750 | 0.905 |
| IVTIRFB-27 | DWRB156 | 15.13 | 9.74 | 0.64 | 16.00 | 11.39 | 10.58 | 92.25 | 9.30 | 8.80 | 8.72 | 99.71 | 8.200 | 0.586 | 0.742 | 0.876 |

**Fig.1** Principal component analysis (PC1 vs PC2) plot of ranks based on measures

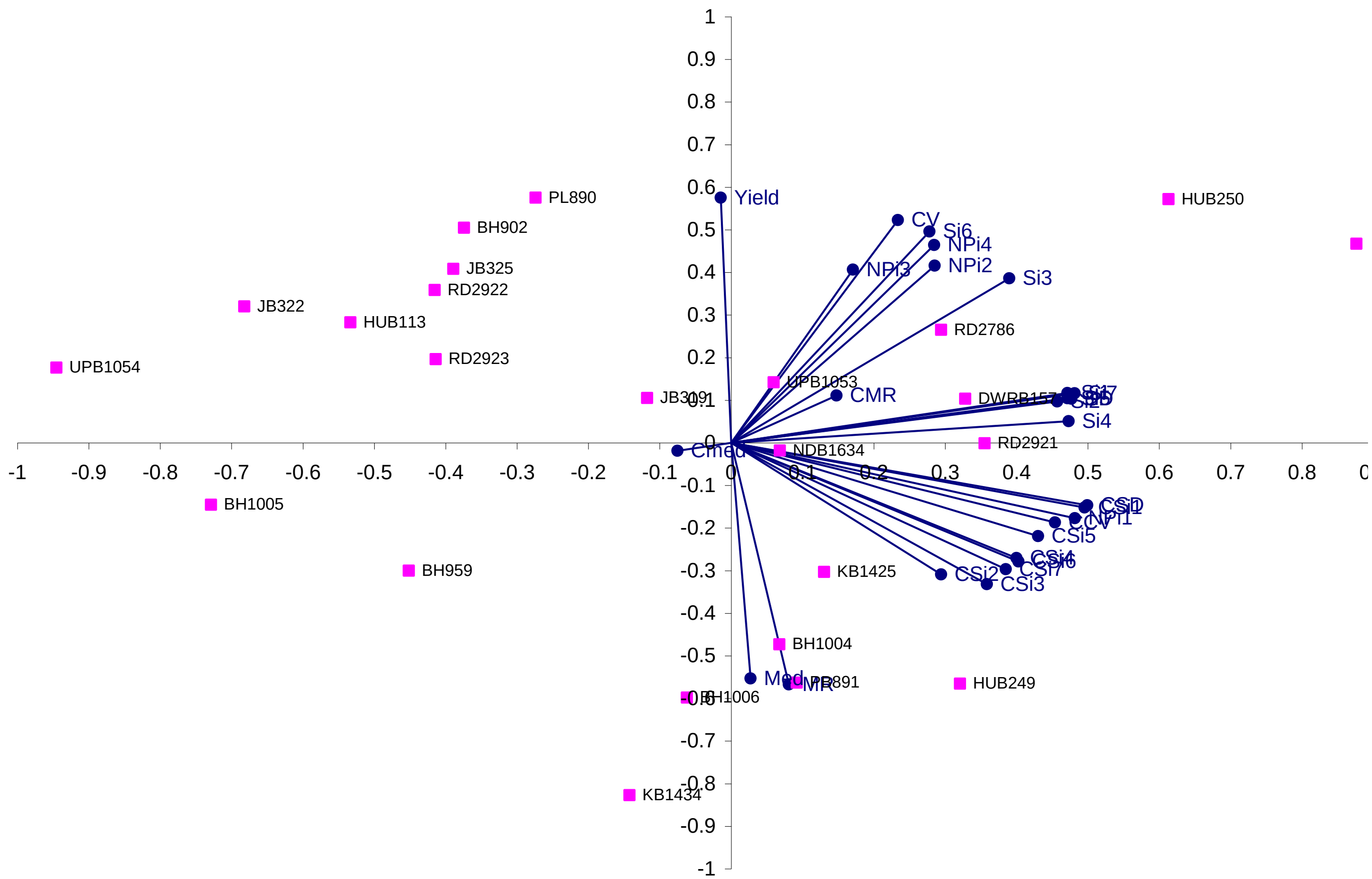



**Table.4** Loadings of rank derived from measures for PC1 and PC2

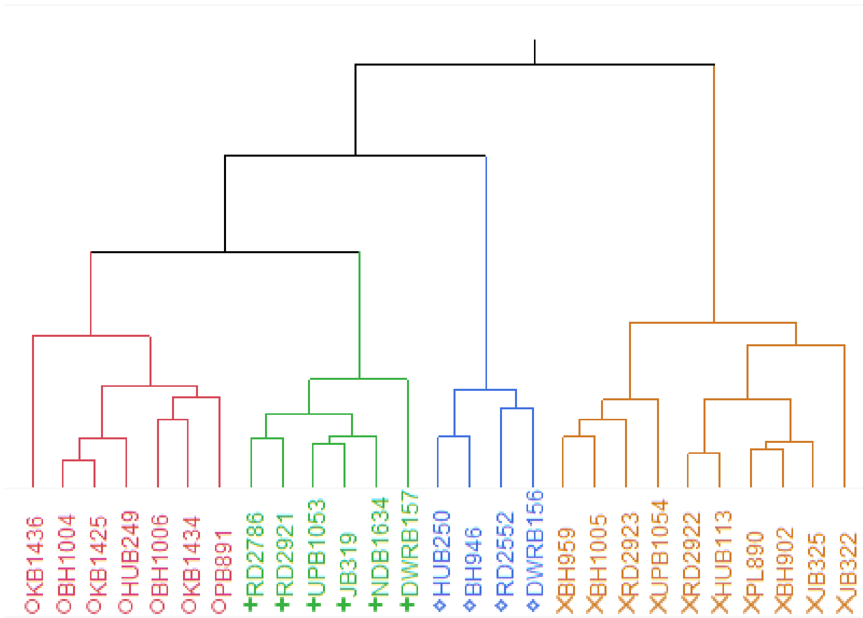
| | PC1 | PC2 |
|---|---|---|
| Yield | -0.008 | 0.340 |
| MR | 0.042 | -0.335 |
| SD | 0.250 | 0.061 |
| CV | 0.122 | 0.309 |
| Med | 0.014 | -0.327 |
| Si1 | 0.247 | 0.069 |
| Si2 | 0.239 | 0.057 |
| Si3 | 0.204 | 0.228 |
| Si4 | 0.248 | 0.030 |
| Si5 | 0.247 | 0.062 |
| Si6 | 0.146 | 0.293 |
| Si7 | 0.252 | 0.069 |
| CMR | 0.077 | 0.066 |
| CSD | 0.261 | -0.087 |
| CCV | 0.238 | -0.111 |
| Cmed | -0.039 | -0.011 |
| CSi1 | 0.259 | -0.090 |
| CSi2 | 0.154 | -0.183 |
| CSi3 | 0.188 | -0.196 |
| CSi4 | 0.209 | -0.160 |
| CSi5 | 0.225 | -0.129 |
| CSi6 | 0.211 | -0.165 |
| CSi7 | 0.201 | -0.176 |
| NPi1 | 0.252 | -0.105 |
| NPi2 | 0.149 | 0.246 |
| NPi3 | 0.089 | 0.241 |
| NPi4 | 0.149 | 0.275 |
| % Variance | 49.36 | 31.23 |

**Table.5** Speraman's rank correlation of yield with non-parametric measures calculated from original and corrected values

| | Yield | MR | SD | CV | Med | $S_i^1$ | $S_i^2$ | $S_i^3$ | $S_i^4$ | $S_i^5$ | $S_i^6$ | $S_i^7$ | CMR | CSD | CCV | CMed | CSi1 | CSi2 | CSi3 | CSi4 | CSi5 | CSi6 | CSi7 | $NP_i^{(1)}$ | $NP_i^{(2)}$ | $NP_i^{(3)}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MR | -0.950 | | | | | | | | | | | | | | | | | | | | | | | | | |
| SD | 0.070 | 0.105 | | | | | | | | | | | | | | | | | | | | | | | | |
| CV | 0.817 | -0.729 | 0.553 | | | | | | | | | | | | | | | | | | | | | | | |
| Med | -0.889 | 0.931 | -0.027 | -0.775 | | | | | | | | | | | | | | | | | | | | | | |
| $S_i^1$ | 0.051 | 0.113 | 0.984 | 0.535 | -0.003 | | | | | | | | | | | | | | | | | | | | | |
| $S_i^2$ | 0.115 | 0.042 | 0.957 | 0.599 | -0.078 | 0.922 | | | | | | | | | | | | | | | | | | | | |
| $S_i^3$ | 0.587 | -0.464 | 0.786 | 0.921 | -0.552 | 0.781 | 0.793 | | | | | | | | | | | | | | | | | | | |
| $S_i^4$ | -0.072 | 0.226 | 0.933 | 0.438 | 0.102 | 0.951 | 0.894 | 0.690 | | | | | | | | | | | | | | | | | | |
| $S_i^5$ | 0.015 | 0.163 | 0.967 | 0.481 | 0.038 | 0.978 | 0.866 | 0.739 | 0.915 | | | | | | | | | | | | | | | | | |
| $S_i^6$ | 0.773 | -0.671 | 0.603 | 0.975 | -0.737 | 0.590 | 0.605 | 0.946 | 0.484 | 0.567 | | | | | | | | | | | | | | | | |
| $S_i^7$ | 0.070 | 0.105 | 1.000 | 0.553 | -0.027 | 0.984 | 0.957 | 0.786 | 0.933 | 0.967 | 0.603 | | | | | | | | | | | | | | | |
| CMR | 0.392 | -0.172 | 0.281 | 0.283 | -0.045 | 0.260 | 0.200 | 0.267 | 0.200 | 0.276 | 0.305 | 0.281 | | | | | | | | | | | | | | |
| CSD | -0.239 | 0.433 | 0.756 | 0.193 | 0.278 | 0.741 | 0.701 | 0.422 | 0.760 | 0.734 | 0.237 | 0.756 | 0.155 | | | | | | | | | | | | | |
| CCV | -0.353 | 0.496 | 0.672 | 0.097 | 0.319 | 0.665 | 0.653 | 0.331 | 0.710 | 0.654 | 0.128 | 0.672 | -0.172 | 0.916 | | | | | | | | | | | | |
| CMed | 0.002 | 0.111 | -0.017 | -0.182 | 0.358 | -0.005 | -0.009 | -0.141 | 0.013 | -0.015 | -0.187 | -0.017 | 0.572 | -0.126 | -0.246 | | | | | | | | | | | |
| cSi1 | -0.270 | 0.447 | 0.757 | 0.171 | 0.295 | 0.742 | 0.710 | 0.402 | 0.765 | 0.736 | 0.211 | 0.757 | 0.097 | 0.988 | 0.939 | -0.131 | | | | | | | | | | |
| cSi2 | -0.248 | 0.392 | 0.416 | 0.013 | 0.232 | 0.328 | 0.418 | 0.096 | 0.425 | 0.337 | 0.034 | 0.416 | 0.179 | 0.687 | 0.609 | -0.111 | 0.659 | | | | | | | | | |
| cSi3 | -0.319 | 0.474 | 0.514 | 0.000 | 0.310 | 0.458 | 0.506 | 0.153 | 0.553 | 0.460 | 0.030 | 0.514 | 0.070 | 0.860 | 0.824 | -0.118 | 0.855 | 0.898 | | | | | | | | |
| cSi4 | -0.299 | 0.455 | 0.495 | -0.003 | 0.325 | 0.469 | 0.440 | 0.157 | 0.587 | 0.470 | 0.047 | 0.495 | 0.244 | 0.832 | 0.730 | -0.035 | 0.800 | 0.870 | 0.934 | | | | | | | |
| cSi5 | -0.237 | 0.436 | 0.543 | 0.033 | 0.324 | 0.522 | 0.491 | 0.207 | 0.581 | 0.521 | 0.066 | 0.543 | 0.251 | 0.910 | 0.805 | 0.028 | 0.896 | 0.722 | 0.912 | 0.897 | | | | | | |
| cSi6 | -0.308 | 0.469 | 0.535 | 0.004 | 0.329 | 0.514 | 0.509 | 0.182 | 0.585 | 0.511 | 0.026 | 0.535 | 0.038 | 0.904 | 0.894 | -0.107 | 0.910 | 0.716 | 0.938 | 0.869 | 0.959 | | | | | |
| cSi7 | -0.287 | 0.464 | 0.515 | 0.009 | 0.318 | 0.462 | 0.501 | 0.153 | 0.555 | 0.460 | 0.034 | 0.515 | 0.202 | 0.857 | 0.772 | -0.045 | 0.838 | 0.901 | 0.985 | 0.960 | 0.929 | 0.922 | | | | |
| $NP_i^{(1)}$ | -0.357 | 0.552 | 0.729 | 0.074 | 0.388 | 0.724 | 0.655 | 0.322 | 0.758 | 0.729 | 0.125 | 0.729 | 0.117 | 0.975 | 0.917 | -0.077 | 0.972 | 0.671 | 0.838 | 0.819 | 0.882 | 0.878 | 0.835 | | | |
| $NP_i^{(2)}$ | 0.733 | -0.692 | 0.518 | 0.900 | -0.831 | 0.503 | 0.518 | 0.855 | 0.405 | 0.469 | 0.906 | 0.518 | 0.106 | 0.247 | 0.203 | -0.357 | 0.224 | 0.044 | 0.083 | 0.060 | 0.110 | 0.105 | 0.063 | 0.154 | | |
| $NP_i^{(3)}$ | 0.824 | -0.745 | 0.323 | 0.853 | -0.781 | 0.290 | 0.374 | 0.730 | 0.221 | 0.247 | 0.837 | 0.323 | 0.263 | 0.178 | 0.086 | -0.163 | 0.132 | 0.126 | 0.143 | 0.133 | 0.181 | 0.143 | 0.153 | 0.023 | 0.849 | |
| $NP_i^{(4)}$ | 0.827 | -0.730 | 0.488 | 0.949 | -0.776 | 0.477 | 0.531 | 0.869 | 0.389 | 0.419 | 0.924 | 0.488 | 0.286 | 0.247 | 0.153 | -0.145 | 0.223 | 0.052 | 0.103 | 0.089 | 0.170 | 0.136 | 0.109 | 0.115 | 0.915 | 0.936 |

Critical values of Spearman correlation at 5% and 1% level of significance (df 25) are 0.398 and 0.510 respectively

**Fig.2** Hierarchical cluistering of feed barley genotypes as per non parametric measures




**Relationship among nonparametric statistics**

Spearman's rank correlations among rank of genotypes as per various non-parametric measures were then calculated (Table 5). According to results of rank correlations there was a highly significant ($p<0.01$) positive rank correlation between mean yield with Si3,Si6 NPi(2) NPi(3), NPi(4) and highly significant negative association with MR and CV (Mohammadi *et al.*, 2007). Yield expressed low correlation of inverse relation with CSi1, CSi2, CSi3, CSi4, CSi5, CSi6 and CSi7. MR had significant negative rank correlation with CV, Si6 NPi (2) NPi(3) NPi(4) whereas significant positive with CSi1,CSi2,CSi3,CSi4,CSi5,CSi6 and CSi7 (Mahtabi *et al.*, 2013). SD had a highly significant positive with most of the measures either based on original or corrected values. Si1 showed highly significant positive rank correlation with Si2,Si3,Si4 Si5,Si6,Si7 CSi1,CSi5 CSi6, NPi(1) and significant Positive CSi3, CSi6, NPi (2) and NPi(4) (Mohammadi and Ahmed, 2008). Significant positive association among Sis, Si3 showed significant correlation with NPi(s).

Si4 and. Si3 maintained same type of relationship with other measures. Similar behavior expressed by Si7 to show positive relationship. CSD showed significant positive correlation with CSis, and with very low positive interaction with NPi(s). CSi1 had positive significant relationship and very low with NPi(s). More over CSis were positively associated among themselves. NPi(2) expressed significant positive rank correlation with NPi(3) and NPi(4) (Mortazavian and Azizinia, 2014).

**Biplot analysis of non-parametric measures**

Principal component (PC) analysis based on the rank correlation matrix generated by non para-metric measures was performed understand relationships if any among these measures. Table 4 shows the loading of the first two PCA of ranks of non-parametric measures as two first PCs (PC1 and PC2) explained 80.6% (49.36 and 31.23 % by PC1 and PC2, respectively) of the total variance. Better visualization of relationships among the different measures and yield (Y) displayed graphically by biplot (Dehghani *et al.*, 2009). In this plot, the PC1 axis mainly distinguished mean yield besides the measures of CV, MR and (6) is from the other measures.

Thus, the first principal component separated the measures into two groups according to the two stability concepts (biological and agronomic concept of stability). The second PC separated the nonparametric measures of phenotypic stability into two groups according to the yield and stability (Fig. 1). The original data-based nonparametric measures showed close correlation with CV, Si3 Si6 and no relation with CMR, Si4, Si7 as vectors corresponding to these measures expressed right angle with vector of yield (Mortazavian and Azizinia, 2014). Genotypes HUB250, RD2786, DWRB156, UPB1053 and DWRB157 clustered with measures based on original yield values. Corrected data-based nonparametric measures were closely related among themselves and clustered together.

Yield showed nearly straight line angle with vectors of MR and Median. These measures favored HUB249, KB1425, BH1004 and PL891.

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