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Research Article

Comparative performance of parametric and non-parametric measures for analyzing G x E interactions of grain yield for dual Purpose Barley genotypes

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Abstract
Present study aimed to compare parametric with non parametric measures for the adaptability bevaiour of fifteen dual purpose barley genotypes evaluated at ten locations under coordinated system of Barley network. Regression coefficients less than one attained by five genotypes while more than one by the six genotypes. Lower environmental variance exhibited by G14 followed by G03 and G15 whereas higher by G11 G10 and G5. Higher values of W^2_i by G11, G10, and G5 pointed out higher contribution to G x E interaction. Adaptable genotype would be G5, G7 and G8 as claimed by lower P_i values. GAI identified G20 genotype, followed by G7, G5, and G6, better in terms of yield and adaptability. $S_i^{(1)}$ and $S_i^{(2)}$ measures pointed G14 & G8 while $S_i^{(3)}$ and $S_i^{(6)}$ selected G14 followed by G4 and G10. $NP_i^{(1)}$, $NP_i^{(2)}$ and $NP_i^{(3)}$ considered G1 and G14 as stable genotypes whereas as per $NP_i^{(4)}$ G5 & G6 were of unstable types. Grain yield expressed significant negative relation with $S_i^{(6)}$, $NP_i^{(2)}$, $NP_i^{(3)}$, $NP_i^{(4)}$ while positive with Kang sum rank. b_i was negatively correlated with W_i^2 , S^2_{xi} , $CV_{i,}$ and $\sigma^2_{i.}$ Superiority index expressed significant negative association with $NP_i^{(2)}$, $NP_i^{(3)}$, $NP_i^{(4)}$ and direct positive relation with $S_i^{(2)}$, $NP_i^{(1)}$. Biplot analysis based on PCA1 versus PCA2 clustered measures in 3 major groups. Larger clubbed NPi $^{(1)}$, $S_i^{(1)}$, $S_i^{(2)}$, W_i^2, $\sigma^2_{i,}$ S^2_{xi} along with Kang whereas separate group comprised of yield, with GAI & P_i.

Keywords
Genotype x environment interaction, Parametric & nonparametric measures, Adaptability

Introduction

Plants differ in their ability to capture environmental inputs and convert into the final product (Annicchiarico, 2002). Primary objective of plant breeding is to recommend genotypes for such environments in turn improved phenotypes are obtained (Kılıç , 2012). Few genotypes do well across a wide range of conditions (widely adapted genotypes) and some genotypes perform relatively better than others under restricted conditions (specifically adapted genotypes). Specific adaptation of genotypes is closely related to the phenomenon of genotype-by-environment interaction. The promising genotypes evaluated through multi-environment trials (MET) in order to identify better adaptable genotypes (Dehghani et al 2016). Quite large methods have been proposed for estimating GxE and adaptability/ stability parameters in multi-environment trials. These methods use different concepts of parametric models, such as univariate (Finlay and Wilkinson 1963 ; Wricke 1962), multivariate (Zobel et al. 1988) and non-parametric (Huehn and Leon, 1995, Thennarasu 1995). Kang 1988; and Kang & Pham 1991 combined yield and stability into a single selection criterion. These approaches proved to be complemented and supplement each other to investigate and interpret GxE interaction (Elahe and Asghar 2015; Sisay and Sharma, 2016).

The existing methods classified based on the ability to explain GxE interaction sum of squares. Due to the diversity of measures for studying the G x E interaction, this study is aimed to compare different parametric as well non parametric methods to study the adaptability of dual purpose barley genotypes for grain yield.

Materials and Methods

Fifteen dual purpose barley genotypes were evaluated in field trials at ten major growing locations i.e. Hisar, Durgapura, Ludhiana, Varanasi, Kanpur, Faizabad, Rewa, Kota, Udaipur and Jabalpur in India during the cropping seasons of 2016-2017. Randomized complete block design followed with four replications and recommended agronomical practices were followed to harvest the good crop. The grain yield of genotypes was further analyzed to describe GxE interactions by parametric and non parametric measures. The parentage of genotypes as well as locations was reflected in Table Table1. for ready reference. More over the details of parametric and non parametric measures were reflected below:

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1.	Finally & Wilkinson regression coefficient	$b_i = 1 + \frac{\sum_i (X_{ij} - \bar{X}i. - \bar{X}.j + \bar{X}..)(\bar{X}.j - \bar{X}..)}{\sum_j (\bar{X}.j - \bar{X}..)^2}$ $b_i \neq 1$ showed better adapted to favourable or low yielding environments. bi = 1 for average adaptability
2.	Lin et al. Environmental variance	$S^2_{Xi} = \frac{\sum (X_{ij} - \bar{X}i.)^2}{(E-1)}$ Minimum variance associated with stable genotype.
3.	Shukla variance, σ^2_i	$\hat{\sigma}^2_i = \frac{1}{(G-1)(G-2)(E-2)} \left[G(G-1) \sum_j (X_{ij} - \bar{X}_{i.} - \bar{X}_{.j} + \bar{X})^2 - \sum_i \sum_j (X_{ij} - \bar{X}_{i.} - \bar{X}_{.j} + \bar{X})^2 \right]$ Lowest value indicate stability of genotype
4.	Lin and Binns , Superiority index	$P_i = \frac{\sum_{j=i}^{n} (X_{ij} - M_j)^2}{2E}$ Genotypes with highest Pi-value would be desirable
5.	Wricke's ecovalence, W^2_i	$W_i^2 = \sum (X_{ij} - \bar{X}i. - \bar{X}.j + \bar{X}..)^2$ Desirable genotypes show $W^2_i = 0$.
6.	Francis and Kannenberg, CV_i	$CV_i = (S_{Xi} / \bar{X}_i) \times 100$ Genotype with low CVs and high average yields were considered as the most desirable
7.	Mohammadi & Amri, GAI	$GAI = \sqrt[E]{\prod_{i=1}^{E} \bar{X}_i}$ Genotypes with high GAI will be desirable
8.	Nassar and Huehn, Non-parametric measures	$S_i^{(1)} = \frac{2 \sum_j^{m-1} \sum_{j=j+1}^{m} \lvert r_{ij} - r_{ij'} \rvert}{[m(m-1)]}$ $S_i^{(2)} = \frac{\sum_{j=1}^{m} (r_{ij} - \bar{r}_{i'})^2}{(m-1)}$ Significance tests of , $Si^{(1)}$ and $Si^{(2)}$ computed as $Z_{(1)}$ and $Z_{(2)}$ $S_i^{(3)} = \frac{\sum_{j=1}^{m} (r_{ij} - \bar{r}_i)^2}{\bar{r}_{i.}}$ $S_i^{(6)} = \frac{\sum_{j=1}^{m} \lvert r_{ij} - \bar{r}_i \rvert}{\bar{r}_{i.}}$
9.	Thennarasu's measures	$NP_i^{(1)} = \frac{1}{m} \sum_{j=1}^{m} \lvert r^*_{ij} - M^*_{di} \rvert$ $NP_i^{(2)} = \frac{1}{m} \left(\frac{\sum_{j=1}^{m} \lvert r^*_{ij} - M^*_{di} \rvert}{M_{di}} \right)$ $NP_i^{(3)} = \frac{\sqrt{\sum (r^*_{ij} - \bar{r}^*_{i.})^2 / m}}{\bar{r}_{i.}}$ $NP_i^{(4)} = \frac{2}{m(m-1)} \left[\sum_{j=1}^{m-1} \sum_{j=j+1}^{m} \frac{\lvert r^*_{ij} - r^*_{ij'} \rvert}{\bar{r}_{i.}} \right]$ r^*_{ij} was the rank of Y^*_{ij}, and $\bar{r}_i$ and M_{di} were the mean and median ranks for original, where $\bar{r}^*_i$ and M^*_{di} were the same parameters computed from the corrected yield values .
10.	Kang's rank sum	Consider simultaneous higher yield with lower Shukla's variance Lowest rank-sum denotes stable genotype.

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Spearman's rank correlation calculated for association analysis among ranks generated by considered measures (Piepho & Lotito, 1992) as follows : $\bar{r_s} = 1 - \frac{6\sum_{i=1}^{n} d_i^2}{n(n^2-1)}$;

where d_i denotes difference between two ranks for ith genotype and n is total number of pairs.

SAS-based computer program SASGESTAB (Hussein *et al.* 2000) employed to calculate nonparametric measures. For hierarchical clustering the Euclidean distance was used as a dissimilarity measure required in Ward's (Ward 1963) clustering method. SAS software version 9.3 and JMP version 9 (2016) software's utilized to calculate the statistics.

Results and Discussion

Highly significant effects of genotypes, environments and interaction were observed among grain yield of the dual purpose barley genotypes by analysis of variance. As per average yield, eight genotypes showed yield more than average yield across 10 environments as G7, G5, G6 and G8 had the higher yield realization while G11 & G10 were the lowest yielders (Tables 2 & 3). Five genotypes showed values of regression coefficients (b_i) less than one i.e. G7, G1, G10, G4 and G15 expressed well adaptation to the favorable environments; whereas the six genotypes G9, G13 ,G12 ,G6 ,G2 ,G11 with b_i more than one were better adapted to the environments.

Environmental variance (S^2_{xi}) pointed out towards G14 followed by G03 and G15 with lower variation across the environments at the same time isolated G11 followed by G10 and G5 for higher variation (Tables 2 & 3).

Lower values of W^2_i observed for genotypes G14, G03, and G08 and therefore these genotypes were considered more stable. More over higher values observed for genotypes G11, G10, G5 as these genotypes with higher contribution to G x E interaction were recognized as unstable ones. CV_i indicated genotypes G14, G03 and G15 were of stable performance, although they had low performance, and genotypes G7, G5 and G6 with higher yield performance were considered as unstable. Higher values of SRT pointed out the unstable performance of G9, G10 and G12 with lower yield (Table 3). Adaptable genotype would be the one with the lower P_i value, accordingly G5, G7 and G8 had the moderately yield performance and the lowest P_i-values (Table 2). Geometric adaptability index (GAI) identified G20 genotype, followed by G7, G5, and G6, better in terms of yield and adaptability, whereas genotypes G10, G11, and G9 were the undesirable ones. Shukla's measure identified G16, G17, G20, G5, G7 and G8 with the lower values for stable lines (Tables 2 & 3).

Non parametric measures

Significance tests of $S_i^{(1)}$ and $S_i^{(2)}$ were conducted based on the total of Z_1 and Z_2 values as Z^1 sum = 28.76 and Z^2 sum = 29.86 (Table 2). These test statistics followed χ^2 distribution and calculated values were less than the critical value of χ^2 (0.01, 15) = 30.6. This indicated the non-significant differences in rank stability among the genotypes. Among the individual Z values, it was found that none of the genotypes was significantly unstable, except genotypes G8 and G24 with $Z_i^{(1)}$ and $Z_i^{(2)}$ greater than the critical value of χ^2 (0.05, 1) = 3.84.

$S_i^{(1)}$ and $S_i^{(2)}$ measures considered ranks of the genotypes across environments and assign equal weight to environments (Table 5). Genotypes with fewer changes in rank are considered to be more stable (Becker and Leon 1988). Based on these measures, genotype G14 & G8 had the smallest changes in rank and thus, is regarded as the abatable genotypes. According to the two other nonparametric statistics $S_i^{(3)}$ and $S_i^{(6)}$ selected stable genotype G14 followed by G4, and G10, while of lower stability would be G6, G5 and G9.

Non-parametric measures proposed by Thennarasu (1995) considered the ranks of adjusted yield means were given in Table 2. $NP_i^{(1)}$, $NP_i^{(2)}$ and $NP_i^{(3)}$ considered G1 and G14 were of stable performance as compared to others. Unstable genotype pointed out by $NP_i^{(4)}$ was G5 followed by G6. All measures identified G9 as unstable genotype with of lower yield.

Association analysis

Grain yield was significantly and negatively correlated with measures of $S_i^{(6)}$ and $NP_i^{(2)}$, $NP_i^{(3)}$, $NP_i^{(4)}$ while positive with Kang rank sum (Table 4). Similar trends were seen for GAI as expressed positive correlation with P_i, Kang rank sum and negative with $NP_i^{(2)}$, $NP_i^{(3)}$, $NP_i^{(4)}$. The coefficient of regression (bi) was negatively correlated with W_i^2, S^2_{xi}, CV_i, σ^2_i. Superiority index expressed significant negative association with $NP_i^{(2)}$, $NP_i^{(3)}$, $NP_i^{(4)}$ and direct positive relation with $S_i^{(2)}$, $NP_i^{(1)}$. CV_i maintained positive correlation with σ^2_i and Kang rank sum. Superiority index (P_i) showed significant negative association with $NP_i^{(2)}$, $NP_i^{(3)}$, $NP_i^{(4)}$ while inverse relation $S_i^{(6)}$ and direct with Kang, $S_i^{(6)}$ and CV_i. Environmental variance (S^2_{xi}) maintained a positive correlation with all other measures. $S_i^{(1)}$ showed direct correlation with other $S_i^{(s)}$ similar trend observed among $NP_i^{(s)}$. Kang rank sum measure depicted significant positive association with most of the measures.

Biplot analysis based on PCA1 and PCA2

Principle component analysis (PCA) was performed to study the relationships between the rankings of genotypes proposed from parametric and non-parametric measures (Khalili and Aboughadareh, 2016). First two PCAs jointly explained 73.3 % (41.1 and 32.2 % respectively) of the total variations. The relationships among different measures were graphically displayed (Fig. 1). Studied measures clustered in major 3 groups by Biplot analysis. Larger group I included the $NP_i^{(1)}$, $S_i^{(1)}$, $S_i^{(2)}$, W_i^2, σ^2_i, S^2_{xi} along with Kang rank sum while separate group joined yield, GAI with P_i measures. Nonparametric $NP_i^{(2)}$, $NP_i^{(3)}$, $NP_i^{(4)}$ with $S_i^{(1)}$ separated in group III whereas remaining measures b_i, $S_i^{(3)}$ were scattered separately.

Hierarchical clustering of genotypes

The multivariate analysis provides additional information on the actual response of genotypes to environments. Dendrogram generated by the analysis separated the genotypes into three clusters (Figure 2). The first cluster (I) comprised the lower yielding and relatively unstable lines G10, G11, and G9. The second cluster (II) included the highest and stable lines G6, G7, G8, and G5. Finally, G3, G15 and G4 with moderate yields and good level of adaptability were placed into the third cluster (III).

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References

Annicchiarico, P. 2002. G x E interactions. Challenges and opportunities for plant breeding and cultivar recommendations. FAO Plant Production and Protection Rome: 115 – 174

Becker HC, Leon J. 1988. Stability analysis in plant breeding. *Plant Breed*. **101**:1–23.

Dehghani, M.R., Majidi, M.M., Mirlohi, A., Saeidi G. 2016. Integrating parametric and non-parametric measures to investigate genotype × environment interactions in tall fescue. *Euphytica*. **208**:583–596.

Elahe, N., Asghar E . 2015. Comparison of Parametric and Non-parametric Methods for Analysing Genotype× Environment Interactions in Sunflower (Helianthus annuus L.) Inbred Lines *Jordan Journal of Agricultural Sciences,* **11(4):**959-978.

Finlay, K.W., Wilkinson G.N. 1963. Adaptation in a plant breeding programme. Aust J Agric Res. **14**:742–754.

Francis, T.R., Kannenberg L.W. 1978. Yield stability studied in short-season maize. I. A descriptive method for grouping genotypes. Can J Plant Sci **58**:1029–1034

Hasan K .2012. Assessment of Parametric and Non-Parametric Methods For Selecting Stable And Adapted Spring Bread Wheat Genotypes In Multi – Environments *Journal of Animal & Plant Sciences*, **22(2)**: 390-398

Huehn, M., Leon, J. 1995. Nonparametric analysis of cultivar performance trials : experimental results and comparison of different procedures based on ranks. *Agronomy Journal*, **87** : 627-632.

Hussein, M.A., Bjornstad, A. and Aastveit, A.H. (2000). SASG x ESTAB: A SAS program for computing genotype x environment stability statistics. Agron. J., **92**: 454-459.

Kang, M.S. 1988. A rank–sum method for selecting high yielding, stable corn genotypes. *Cereal Research Communications*, **19**: 361-364.

Kang, M.S., Pham, H.N. 1991. Simultaneous selection for high yielding and stable crop genotypes. *Agronomy Journal*, **83** :161-165.

Khalili, M., Pour-Aboughadareh A. 2016. Parametric and non-parametric measures for evaluating yield stability and adaptability in barley doubled haploid lines. *J Agr Sci Tech*. **18:**789–803.

Kılıç H. 2012.Assessment of parametric and non-parametric methods for selecting stable and adapted spring bread wheat genotypes in multi – environments. *Journal of Animal & Plant Sciences*, **22(2):**390-398.

Lin, C.S., Binns M.R., Lefkovitch L.P.1986. Stability analysis: where do we stand? *Crop Sci* **26**:894–900

Lin, C. S. and M. R. Binns 1988. A method of analyzing cultivar × location × year experiments: A new stability parameter. *Theor. Appl. Genet.,* **76**: 425–430.

Mohammadi. R., Amri, A. 2008. Comparison of parametric and non-parametric methods for selecting stable and adapted durum wheat genotypes in variable environments. *Euphytica* **159**:419–432.

Nassar R, Huehn M. 1987. Studies on estimation of phenotypic stability: tests of significance for nonparametric measures of phenotypic stability. *Biometrics*. **43**:45–53.

Piepho, H.P., Lotito, S. 1992. Rank correlation among parametric and nonparametric measures of phenotypic stability. *Euphytica* **64**: 221–225.

Shukla, G.K. 1972. Some statistical aspects of partitioning genotype environmental components of variability. *Heredity,* **29:**237–245.

Sisay, A. and Sharma M.K. 2016. Parametric and Non-Parametric Methods to Describe Genotype by Environment Interaction and Grain Yield Stability of Bread Wheat *Statistics and Applications* .**14(1&2)** : 9-29

Thennarasu, K. 1995. On certain non-parametric procedures for studying genotype-environment interactions and yield stability. Unpublished Ph.D. Thesis. P.G. School, IARI, New Delhi.

Ward, JH. 1963. Hierarchical grouping to optimize an objective function. J Am Stat Assoc. **58**:236–244.

Wricke, G. 1962. On a method of understanding the biological diversity in field research. Z. Pflanzenzucht, **47**: 92–96.

Zobel, R.W., Wright M.J., Gauch H.G. 1988. Statistical analysis of a yield trial. *Agron J*. **80**:388–393.

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Table 1. Parentage details and environmental conditions

Code	Genotype	Parentage	Code	Environments	Latitude	Longitude	Altitude (m)
G 1	RD2953	RD2552/RD2786	E 1	Hisar	29°10'N	75° 46'E	215.2
G 2	JB348	DL88/BG105	E 2	Durgapura	26° 51'N	75° 47' E	390
G 3	AZAD	K12/K19	E 3	Ludhiana	30° 54' N	75° 52' E	247
G 4	RD2951	RD2552/RD2743	E 4	Varanasi	25° 20' N	83° 03' E	75.5
G 5	UBP1066	IBYT-HI-11 (2013-14)	E 5	Kanpur	26° 29'N	80°18'E	125.9
G 6	RD2552	RD2035/DL472	E 6	Faizabad	26° 47' N	82° 12' E	113
G 7	UPB1064	1st GSBSN-80 (2013-14)	E 7	Rewa	24° 31' N	81° 15' E	365.7
G 8	NDB1660	1st GSBSN-19 (2013-14)	E 8	Kota	25° 21' N	75° 86' E	259.7
G 9	KB1530	EIBGN-68 (2014-15)	E 9	Udaipur	24° 34' N	70° 42'E	582
G 10	RD2715	RD387/BH602//RD2035	E 10	Jabalpur	23° 90' N	79° 58' E	394
G 11	RD2954	RD2808/ RD2743					
G 12	RD2035	RD103/PL101					
G 13	UPB1065	IBYT-HI-16 (2012-13)					
G 14	KB1527	PL 816/K 551					
G 15	RD2952	RD2552/RD2743					

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Table 2. Parametric and non parametric measures of GxE interactions

GY	Yield	GAI	W_i^2	σ^2_i	S^2_{xi}	CV_i	b_i	P_i	$S_i^{(1)}$	Z_1	$S_i^{(2)}$	Z_2	$S_i^{(3)}$	$S_i^{(6)}$	$NP_i^{(1)}$	$NP_i^{(2)}$	$NP_i^{(3)}$	$NP_i^{(4)}$	Kang
G 1	29.49	26.77	604.52	74.29	72.54	28.88	0.93	193.90	6.02	1.53	25.17	1.37	26.65	5.06	0.70	0.0778	0.2003	0.1542	24
G 2	32.06	30.70	227.28	25.93	25.41	15.72	1.09	119.90	4.87	0.02	16.77	0.12	18.63	3.85	3.40	0.4250	0.5090	0.6310	15
G 3	34.32	33.64	98.12	9.37	18.61	12.57	0.99	63.52	3.47	3.20	10.40	2.21	15.10	3.61	2.20	0.4000	0.4633	0.5233	8
G 4	29.33	27.89	258.93	29.99	34.94	20.15	0.95	128.29	3.33	3.79	7.96	3.71	7.31	2.24	3.30	0.3474	0.4506	0.4739	20
G 5	38.06	36.80	635.10	78.21	115.78	28.27	0.95	26.29	4.36	0.54	13.60	0.83	22.67	5.70	4.00	0.8889	0.8607	1.0617	16
G 6	36.83	36.30	217.82	24.72	53.64	19.88	1.05	60.50	4.47	0.37	15.12	0.41	28.96	7.32	3.70	1.2333	0.9102	1.0544	8
G 7	38.18	37.55	436.64	52.77	95.35	25.58	0.82	37.35	3.36	3.69	7.79	3.83	14.91	4.89	3.00	0.6667	0.9371	1.0213	11
G 8	36.54	35.85	174.25	19.13	45.51	18.47	0.98	45.32	3.20	**4.43**	7.29	**4.19**	13.67	4.58	3.20	0.7111	0.7974	0.9722	7
G 9	28.13	26.08	500.01	60.89	69.61	29.66	1.14	176.51	5.98	1.40	27.79	2.69	26.89	4.71	4.70	0.4273	0.5618	0.6571	24
G 10	22.28	18.06	762.64	94.57	183.02	60.72	0.93	327.06	3.93	1.53	12.77	1.13	9.50	2.38	5.00	0.3704	0.4330	0.5326	30
G 11	23.76	20.66	534.80	65.35	129.13	47.82	1.02	295.11	4.02	1.28	15.21	0.39	12.33	2.58	4.00	0.3200	0.4049	0.5005	26
G 12	34.37	33.39	221.73	25.22	32.66	16.63	1.07	91.66	4.56	0.25	15.17	0.40	21.00	5.38	3.80	0.5429	0.7576	0.8000	11
G 13	29.60	28.47	362.97	43.33	45.14	22.69	1.10	132.17	5.20	0.07	22.49	0.47	19.09	3.74	3.50	0.2692	0.4187	0.5178	19
G 14	30.24	29.59	44.79	2.53	7.30	8.94	0.99	119.14	3.02	**5.36**	6.89	**4.49**	6.20	1.80	1.60	0.1600	0.2236	0.2622	10
G 15	32.08	31.12	177.40	19.53	19.89	13.90	0.98	89.07	3.67	2.41	9.79	2.55	11.44	3.17	2.30	0.3286	0.3961	0.4820	11
E(s1)	4.98		V(s 1)	0.7136					Sum	29.86		28.76			χ^2 (0.05,1)	3.84	χ^2 (0.01,1)	6.63	
E(s 2)	18.67		V(s 2)	30.92											χ^2 (0.05,15)	25.0	χ^2 (0.01,15)	30.6	

$S_i^{(1)}$ average absolute rank dispersion of a genotype over environments, $S_i^{(2)}$ variance among the ranks over environments, Z_1 and Z_2 the standard values of $S_i^{(1)}$ and $S_i^{(2)}$ respectively, for χ^2 test, $S_i^{(3)}$ and $S_i^{(6)}$ the sum of absolute deviations and sum of squares of ranks for each genotype relative to the mean of ranks respectively, NP nonparametric stability parameters

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Table 3. Ranking of genotypes by parametric vis-à-vis non parametric measures

	Yield	**GAI**	**W_i^2**	**σ^2_i**	**S^2_{xi}**	**CV_i**	**b_i**	**P_i**	**$S_i^{(1)}$**	**$S_i^{(2)}$**	**$S_i^{(3)}$**	**$S_i^{(6)}$**	**$NP_i^{(1)}$**	**$NP_i^{(2)}$**	**$NP_i^{(3)}$**	**$NP_i^{(4)}$**	**Kang**	**SRT**
G 1	11	12	13	13	11	12	2	13	15	14	13	12	1	1	1	1	13	174
G 2	8	8	7	7	4	4	13	9	12	12	9	8	8	9	9	9	8	146
G 3	6	5	2	2	2	2	8	5	5	6	8	6	3	8	8	7	3	106
G 4	12	11	8	8	6	8	4	10	3	4	2	2	7	6	7	3	11	137
G 5	2	2	14	14	13	11	5	1	9	8	12	14	13	14	13	15	9	180
G 6	3	3	5	5	9	7	11	4	10	9	15	15	10	15	14	14	3	160
G 7	1	1	10	10	12	10	1	2	4	3	7	11	5	12	15	13	7	149
G 8	4	4	3	3	8	6	6	3	2	2	6	9	6	13	12	12	1	128
G 9	13	13	11	11	10	13	15	12	14	15	14	10	14	10	10	10	13	**226**
G 10	15	15	15	15	15	15	3	15	7	7	3	3	15	7	6	8	15	**195**
G 11	14	14	12	12	14	14	10	14	8	11	5	4	13	4	4	5	14	180
G 12	5	6	6	6	5	5	12	7	11	10	11	13	11	11	11	11	7	154
G 13	10	10	9	9	7	9	14	11	13	13	10	7	9	3	5	6	10	162
G 14	9	9	1	1	1	1	9	8	1	1	1	1	2	2	2	2	4	85
G 15	7	7	4	4	3	3	7	6	6	5	4	5	4	5	3	4	7	104

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Table 4. Linear association analysis among measures

	Yield	**GAI**	**b i**	**$W_i^{\ 2}$**	**P i**	**$S^{\ 2}_{\ xi}$**	**CV_i**	**$\sigma^2_{\ i}$**	**$S_i^{\ (1)}$**	**$S_i^{\ (2)}$**	**$S_i^{\ (3)}$**	**$S_i^{\ (6)}$**	**$NP_i^{\ (1)}$**	**$NP_i^{\ (2)}$**	**$NP_i^{\ (3)}$**	**$NP_i^{\ (4)}$**
GAI	0.9929															
b i	0.1429	0.1500														
$W_i^{\ 2}$	0.3750	0.4071	-0.2750													
P i	0.9607	0.9786	0.1750	0.4393												
$S^{\ 2}_{\ xi}$	0.1786	0.2071	-0.3536	0.8679	0.2321											
CV_i	0.4429	0.4679	-0.2214	0.9250	0.4857	0.9393										
$\sigma^2_{\ i}$	0.3750	0.4071	-0.2750	1.0000	0.4393	0.8679	0.9250									
$S_i^{\ (1)}$	0.2214	0.2857	0.4464	0.4929	0.3929	0.2643	0.4036	0.4929								
$S_i^{\ (2)}$	0.3786	0.4286	0.5143	0.5107	0.5214	0.2893	0.4643	0.5107	0.9679							
$S_i^{\ (3)}$	-0.3000	-0.2500	0.3607	0.2393	-0.1571	0.2250	0.2214	0.2393	0.7857	0.7036						
$S_i^{\ (6)}$	-0.6214	-0.5607	0.0750	0.1893	-0.4714	0.2857	0.1500	0.1893	0.5286	0.3857	0.8821					
$NP_i^{\ (1)}$	0.2482	0.2554	0.3232	0.5661	0.2482	0.5875	0.6125	0.5661	0.3304	0.3982	0.2232	0.1482				
$NP_i^{\ (2)}$	-0.6821	-0.6893	0.0357	-0.0429	-0.6857	0.2071	-0.0036	-0.0429	-0.0571	-0.1357	0.4250	0.6500	0.3768			
$NP_i^{\ (3)}$	-0.6929	-0.7036	0.0214	-0.0036	-0.6750	0.2250	0.0357	-0.0036	-0.0536	-0.1250	0.4214	0.6429	0.3339	0.9607		
$NP_i^{\ (4)}$	-0.6607	-0.6536	0.0964	0.1000	-0.6250	0.3321	0.1214	0.1000	0.0679	-0.0143	0.4893	0.6929	0.4804	0.9536	0.9429	
Kang	0.7554	0.7768	-0.0554	0.8554	0.7875	0.6089	0.8018	0.8554	0.4946	0.5768	0.0268	-0.1625	0.4893	-0.3911	-0.3554	-0.2911

Critical values of correlation at 5% & 1% level of significance are 0.5549 & 0.6978 respectively

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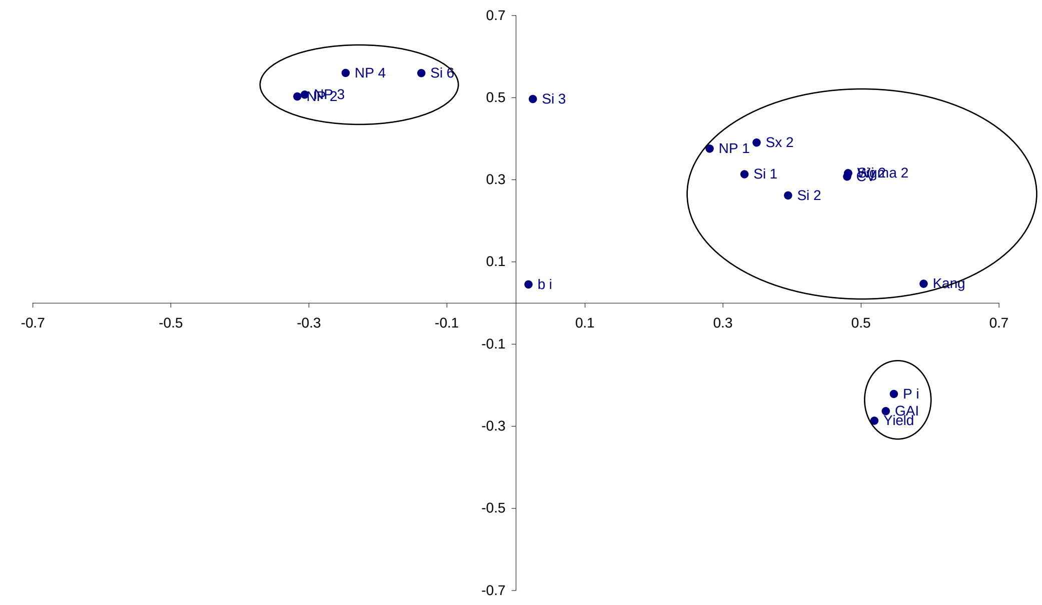

Fig. 1. Graphical display of measures by Biplot analysis

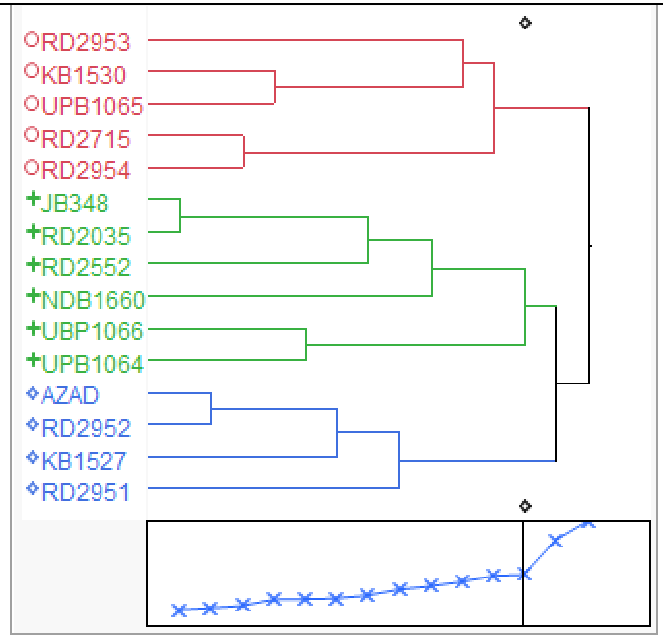

Fig. 2. Dendogram of barley genotypes based on yield along with other measures