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Association analysis among parametric and non parametric measures of G X E interactions for feed barley genotypes

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ABSTRACT

Gx E interaction of twenty eight feed barley genotypes, evaluated at fourteen locations under multi location trails of the country, was estimated by parametric and non parametric measures. Genotypes G15, G27, G25, G19, G3, G7, and G2 with b_i > 1 had the yield performance more than average yields and were adapted to the favorable environments. W^2_i and ó^2_i pointed towards genotypes G5, G12, G23, G20, G8 with lower values and of stable performance. GAI identified G25, G9, G11, G4, G26 while P_i marked G25, G11, G26, G23, G24 as desirable genotypes. Environmental variance selected G5, G12, G20, G8, and G3 as with minimum variation across environments. Significant tests of $S_i^{(1)}$ and $S_i^{(2)}$ observed significantly large values of G4, G7, G8, G14, G22, G25 relative to others. $S_i^{(1)}$ and $S_i^{(2)}$ marked G14, G4, G7, G22 and G25 as genotypes of stable performance. $S_i^{(3)}$ and $S_i^{(6)}$ found G14 followed by G22, G7 and G5 as stable ones. $NP_i^{(1)}$ recognized G8 followed by G4, G20, G22 and G5 were stable yield. Lower values of $NP_i^{(2)}$ and $NP_i^{(3)}$ exhibited by G14 besides G5, G22, and G7. More over $NP_i^{(4)}$ isolated G14, G22, G5, and G7 with the lower values. Kang's measure observed values of index for G23, G6, G12, G8 and G24. Average yield maintained positive significant correlation with GAI, P_i & Kang's while negative association with $S_i^{(6)}$, $NP_i^{(2)}$, $NP_i^{(3)}$, $NP_i^{(4)}$. Regression coefficient b_i was negatively correlated with P_i. GAI showed negative with $S_i^{(3)}$ and significant negative with $S_i^{(6)}$, $NP_i^{(2)}$, $NP_i^{(3)}$, $NP_i^{(4)}$.

Keywords: Adaptability, biplot analysis, G x E interaction, parametric non-parametric measures, ward's clustering

Cultivation of barley (*Hordeum vulgare* L.) had an important place at global level as total production stands at fourth place following wheat, rice and maize. The major growing area comes particularly in arid and semi-arid regions as crop has better ability to avoid drought stress than the other crops (Khalili *et al*. 2013). The wonder cereal is consumed as food and fodder for animals; moreover, it has been provided the raw material for the production of beer (Ahmadi *et al*. 2016).

Genotype by environment interaction (GxE) has important consequences in barley breeding. Under coordinated setup of Barley network programme large number of multi location trials carried out to identify / recommend better adapted genotypes. In the absence of significant interaction, means across environments are adequate indicators of genotypic performance (Jamshidmoghaddam and Pourdad, 2013.) More over this practice ignores genotypic difference over environments for significant interaction effects. Mostly used, parametric approaches are based on several assumptions: normality of the distribution, homogeneity of variances, and additive nature of effects. The validity of these measures may be questionable under violation of assumptions (Dehghani *et al*. 2016). Viable alternative would be nonparametric methods, simple and easy for analysis, free from strict assumptions (Ahmadi *et al*. 2015). Performance difference of parametric and nonparametric measures have been compared in the several publications (Vaezi *et al*. 2017; Sisay and Sharma, 2016).

The major objectives of the investigation were (1) analyze genotype x environment interaction of feed barley genotypes by parametric vis-a-vis nonparametric methods (2) to identify better adaptive barley genotypes with high yield and stable performance across environments (3) to study the relationships, similarities and dissimilarities among the parametric and non-parametric measures.

MATERIALS AND METHODS

Feed yield of promising twenty eight barley genotypes was considered to estimate GxE interaction by field trials conducted at fourteen locations of the country. Details of pedigree and location conditions were mentioned in table 1 for ready reference. Recommended agronomical practices were followed to harvest good crop by using randomized complete block design with four replications. Parametric and non parametric measures are described in next page for completeness.

Rank of the ith genotype in the jth environment denoted by r_{ij} and $\bar{r}_{\tau}$ the average rank of the ith geno-type across environments. Significance tests of $Si^{(1)}$ and $Si^{(2)}$ computed as $Z_{(1)}$ and $Z_{(2)}$. In these measures r^*_{ij} was the rank of Y^*_{ij}, and 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. SAS-based computer program SASGESTAB (Hussein *et al*. 2000) employed to calcu-late nonparametric measures. Spearman's rank correlation (Piepho and Lotito, 1992) was calculated to measure the relationship among the statistical measures using SAS software version 9.3 and principal component analysis (PCA) were performed by JMP version 9 (2016) software in order to comprehend the relationships among the statistics. For hierarchical classification Ward's (1963) method was exploited as Euclidean distance was used as a similarity measure.

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Parametric measures		
Finlay and Wilkinson (1963) linear regression coefficient bi	$b_i = 1 + \frac{\sum_i (X_{ij} - X_{i.} - X_{.j} + X_{..})(X_{.j} - X_{..})}{\sum_j (X_{.j} - X_{..})^2}$	bi > 1 are better adapted to favourable environmental condi-tions. bi < 1, perform better in low yielding environments. bi = 1, for average adaptability to environments.
Lin *et al*. (1986) Environmental variance	$S^2_{Xi} = \frac{\sum (X_{ij} - X_{i.})^2}{(E-1)}$	Genotype with minimum variance considered to be more stable
Shukla's variance (1972)	$\hat{\sigma}_i^2 = \frac{1}{(G-1)(G-2)(E-2)}\left[G(G-1)\sum_j (X_{ij} - X_{i.} - X_{.j} + \bar{X}_{..})^2 - \sum_i \sum_j (X_{ij} - \bar{X}_{i.} - \bar{X}_{.j} + \bar{X}_{..})^2\right]$	Large value associated with instability of genotype
Lin and Binns (1988) Superiority index (P_i)	$P_i = \frac{\sum_{j=1}^{n} (X_{ij} - M_j)^2}{2E}$	Genotypes with the largest yield difference in comparison to the reference genotype would have the highest Pi-value
Wricke's ecovalence (1962) W^2_i	$W_i^2 = \sum (X_{ij} - X_{i.} - X_{.j} + X_{..})^2$	Greatest stability associated with $W^2_i = 0$.
Francis and Kannenberg (1978) Coefficient of variation (CV_i)		Low CVs and high average yields were considered as the most desirable one
Mohammadi & Amri (2008) Geometric adaptability index (GAI)	$\sqrt[E]{\prod_{i=1}^{E} X_i}$	Genotypes with high GAI will be desirable
Non-parametric measures		
Nassar and Huehn (1987)	$S_i^{(1)} = \frac{2\sum_{j}^{m-1}\sum_{j'=j+1}^{m} \lvert r_{ij} - r_{ij'} \rvert}{[m(m-1)]}$ $S_i^{(2)} = \frac{\sum_{j=1}^{m} (r_{ij} - \bar{r}_{i.})^2}{(m-1)}$ $S_i^{(3)} = \frac{\sum_{j=1}^{m} (r_{ij} - \bar{r}_{i.})^2}{\bar{r}_{i.}}$ $S_i^{(6)} = \frac{\sum_{j=1}^{m} \lvert r_{ij} - \bar{r}_{i.} \rvert}{\bar{r}_{i.}}$ $NP_i^{(1)} = \frac{1}{m}\sum_{j=1}^{m} \lvert r^*_{ij} - M^*_{di}$	$S_i^{(1)}$ mean of the absolute rank differences of a genotype over the n environments, $S_i^{(2)}$ variance among the ranks over the n environments $S_i^{(3)}$ sum of the absolute deviations for each genotype relative to the mean of ranks and $S_i^{(6)}$ sum of squares of rank for each genotype relative to the mean of ranks r^*_{ij} was the rank of Y^*_{ij}, and $\bar{r}_{i.}$ and M_{di} were the mean and median ranks for original, where * and M^*_{di} were the same parameters computed from the corrected yield values.
Thennarasu's (1995)	$NP_i^{(2)} = \frac{1}{m}\left(\frac{\sum_{j=1}^{m} \lvert r^*_{ij} - M^*_{di} \rvert}{M_{di}}\right)$ $NP_i^{(3)} = \frac{\sqrt{\sum (r^*_{ij} - \bar{r}^*_{i.})^2 / m}}{\bar{r}_{i.}}$ $NP_i^{(4)} = \frac{2}{m(m-1)}\left[\sum_{j=1}^{m-1}\sum_{j'=j+1}^{m} \frac{\lvert r^*_{ij} - r^*_{ij'} \rvert}{\bar{r}_{i.}}\right]$	
Kang's rank sum (1988)	Combines yield and Shukla's stability variance into one statistic.	Highest yielder assigned rank of 1, lowest variance got rank of 1. Ranks for yield and variance are summed as genotype with lowest rank would be desir-able

Table 1: Parentage details and environmental conditions

Code	Genotype	Parentage	Environments	Latitude	Longitude	Altitude (m)
G 1	BH1019	IBON-HI-119 (2014-15)	Durgapura	26º51’N	75º47’ E	390
G 2	BH902	BH495/RD2552	Hisar	29º10’N	75º 46’E	215.2
G 3	BH946	BHMS22A/BH549//RD2552	Ludhiana	30º54’ N	75º52’ E	247
G 4	BH959	BH393/BH331	Pant nagar	29 º02 ‘ N	79 f 48’ E	237
G 5	DWRB167	P.STO/3/P.STO/3/LBIRAN/UNA80// LIGNEE640/4/BLLU/5/PETUNIA.1/6/ LEGACY	Varanasi	25º 20’ N	83º 03’ E	75.5
G 6	DWRB169	MSEL/GOB	Rewa	24º 31 ‘ N	81º 15 ‘ E	365.7
G 7	HUB113	KARAN280/C138	Faizabad	26º47 ‘ N	82º12 ‘ E	113
G 8	HUB252	JB 18/31st IBON-4-01	Kanpur	26º29 ‘ N	80º18 ‘ E	125.9
G 9	JB346	22nd IBYT-2/ DL88	Ranchi	23 º 34 ‘ N	85 º 31 ‘ E	634
G 10	JB347	EIBGN07-18 / RD2503	Sabour	25 f 24 ‘ N	87 f 04 ‘ E	41
G 11	KARAN16	AZAM (DWARF)1/EB7576	Pusa	28 º 64 ‘ N	77 º 16 ‘ E	54
G 12	KB1501	BH 910/K 878	Udaipur	24º 34 ‘ N	70º42 ‘ E	582
G 13	KB1528	PL 816/K 551	Gwalior	26 º 22 ‘ N	78 º 18 ‘ E	212
G 14	KB1531	EIGBN-67 (2014-15	Morena	26 f 56 ‘ N	78 f 80 ‘ E	152
G 15	NDB1653	1 st GSBSN-32 (2013-14)				
G 16	NDB943	K 1178/Karan 748				
G 17	PL891	IBON 343/12th HSBN-176				
G 18	PL892	RD2683/RD2552				
G 19	PL894	BL29/BH657				
G 20	PL898	PL751/BH 902				
G 21	RD2552	RD2035/DL472				
G 22	RD2786	RD2634/NDB1020//K425				
G 23	RD2947	RD2552/RD2786				
G 24	RD2948	RD2660/RD2811				
G 25	RD2949	RD2552/RD2786				
G 26	RD2950	RD2636/RD2521//RD 2503				
G 27	UPB1064	1 st GSBSN-80 (2013-14)				
G 28	UPB1066	IBYT-HI-11 (2013-14)				

RESULTS AND DISCUSSION

Analysis of variance showed the highly significant effects of genotypes, environments and G x E interaction. Genotypes G25, G11, G9 and G24 had the higher yield while G14, G17, G7, and G19 observed as with lowest yields across 14 environments (Table 2). Genotypes G15, G27, G25, G19, G3, G7, and G2 with $b_i > 1$ had the yield performance more than average yields and were adapted to the favorable environments; while G3,G16, G14, G20, G28 with $b_i < 1$ and the lower yields were poorly adapted to the environments and might have specific adaptation to harsh poor conditions. Wricke’s ecovalance (W^2_i) and Shukla’s variance ($ó^2_i$) pointed towards genotypes G5, G12, G23, G20, G8 with lower values and of stable performance.GAI identified G25, G9, G11, G4, G26 while P_i marked G25, G11, G26, G23, G24 as desirable genotypes. Environmental variance selected G5, G12, G20, G8, G3 as with minimum variation across environments.

Non-parametric measures for grain yield and ranks of genotypes as per these measures are given in tables 3 and 4. Significant tests of $S_i^{(1)}$ and $S_i^{(2)}$ were conducted as suggested by Nassar and Huehn (1987). For genotypes, Z_1 and Z_2 values were calculated and totaled over to obtain Z-values (Z_1 = 81.29 and Z_2 = 58.37). These values were more than the significant value of $÷^2$ (0.01, 28) = 48.3. This result showed the significant difference in rank stability among the 28 genotypes grown in 14 environments. Six out of twenty eight genotypes showed significantly large values as compared to $÷^2$ (0.05, 1) = 3.84 this proved the stable behavior of G4, G7, G8, G14, G22, G25 relative to others. $S_i^{(1)}$ and $S_i^{(2)}$ measures marked G14, G4, G7, G22 and G25 genotypes with lower rank, hence regarded as the stable ones. Other two $S_i^{(3)}$ and $S_i^{(6)}$ found line G14 followed by G22, G7 and G5 were stable, while G11, G9, and G2 would be with lower stability.

Thennarasu’s (1995) non-parametric measures calculated from the ranks of adjusted yield are given in Table 3 and genotypes with the lower values will be promising ones and ranked in table 4. $NP_i^{(1)}$ recognized G8 followed by G4, G20, G22 and G5 were stable as compared to other at the same times G19, G24 and G15 with the higher values. According to $NP_i^{(2)}$ and $NP_i^{(3)}$,

Table 2: Parametric measures of GxE interactions

Code	Genotype	Yield	GAI	b_i	P_i	S^2_{xi}	CV_i	W_i^2	σ^2_i
G 1	PL894	36.02	32.76	1.09	205.66	105.99	28.58	1375	104
G 2	HUB113	37.82	35.75	1.15	156.25	69.90	22.11	882	66
G 3	BH1019	36.92	35.95	0.76	133.92	32.71	15.49	422	30
G 4	UPB1064	40.28	39.08	1.00	89.10	51.95	17.90	470	34
G 5	KB1528	35.06	33.76	1.07	146.06	15.81	11.34	178	12
G 6	BH902	39.91	39.00	0.98	93.17	41.74	16.19	375	27
G 7	NDB943	30.10	28.52	1.16	287.71	118.62	36.19	977	73
G 8	HUB252	38.17	37.12	0.96	113.42	31.44	14.69	367	26
G 9	RD2948	40.98	39.45	1.00	87.14	101.28	24.56	1029	77
G 10	JB346	36.30	35.09	0.90	146.04	37.67	16.91	489	36
G 11	DWRB167	41.58	39.40	1.11	67.87	96.06	23.57	881	66
G 12	NDB1653	37.54	36.04	1.06	103.09	23.21	12.83	285	20
G 13	RD2786	32.05	27.61	1.09	242.64	99.52	31.13	1023	77
G 14	KARAN16	25.49	23.87	0.82	356.72	164.42	50.31	455	33
G 15	RD2947	33.69	28.01	1.48	215.80	120.40	32.57	1458	110
G 16	KB1501	35.54	34.71	0.68	151.75	40.48	17.90	514	38
G 17	PL891	28.79	26.83	0.89	292.65	123.54	38.61	785	58
G 18	RD2552	40.42	38.64	1.14	115.20	68.62	20.49	671	50
G 19	RD2949	30.59	25.94	1.21	267.34	125.04	36.55	1145	86
G 20	BH959	36.18	35.38	0.75	148.14	27.02	14.37	350	25
G 21	RD2950	34.48	33.31	0.85	157.03	34.91	17.14	399	29
G 22	DWRB169	33.94	32.03	0.99	186.86	44.85	19.73	495	36
G 23	JB347	40.19	38.97	0.97	81.35	39.98	15.73	324	23
G 24	KB1531	40.83	38.78	1.08	83.70	106.62	25.29	1118	84
G 25	BH946	42.66	40.95	1.22	47.53	84.29	21.52	555	41
G 26	PL892	40.46	39.06	0.95	73.14	72.16	21.00	713	53
G 27	UPB1066	35.24	32.92	1.33	165.41	46.72	19.39	587	43
G 28	PL898	39.38	38.44	0.83	90.94	41.39	16.34	418	30

G14 followed by G5, G22, and G7 had the lower values for stable behaviour. The unstable performance of G11 followed by G24 and G18 based on these measures. $NP_i^{(4)}$ isolated G14, G22, G5, and G7 with the lower whereas G24, G25, G11, and G19 had the higher values for unstable nature. Kang's rank-sum (1988) stability measure indicated that G23, G6, G12, G8 and G24 with the lower value for index, G15, G19, G7, and G13 with higher values were unstable. Consequently, the results of non-parametric statistics were very similar to each other and those identified G14, G22 and G5 had high yield and lower ranks for stable performance.

Association among stability parameters and clustering lines

Spearman's rank correlation values were depicted in table 5. Mean yield was significantly and positively correlated with GAI, P_i & Kang's rank-sum while negatively associated with $S_i^{(6)}$, $NP_i^{(2)}$, $NP_i^{(3)}$, $NP_i^{(4)}$. b_i was negatively correlated with P_i. GAI showed negative with $S_i^{(3)}$ and significant negative with $S_i^{(6)}$, $NP_i^{(2)}$, $NP_i^{(3)}$, $NP_i^{(4)}$. Worth to mention in the present study, the positive correlation of S^2_{xi} with all the considered parametric as well as non parametric measures. Similar observations recorded for CV_i i.e. direct relation with other measures. W_i^2 and σ^2_i maintained the positive and same values of correlation. Nassar and Huehn's measures maintained positive relation among themselves. Thennarsu's measures had a significant positive correlation with each other.

Dendrogram obtained from hierarchical cluster analysis by Ward's method based on ranks of yields and measures was performed. Genotypes were classified into four clusters (Figure 1). First cluster (I) included the high

Table 3: Non - parametric measures of GxE interactions

Code	Genotype	$S_i^{(1)}$	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 RS
G1	PL894	10.15	0.4346	73.45	0.2326	71.87	7.33	7.79	0.5561	0.6799	0.8346	40
G2	HUB113	10.81	1.3957	85.80	1.4608	89.75	8.53	8.07	0.6494	0.7643	0.9187	39
G3	BH1019	7.58	1.8968	41.67	1.9229	39.09	5.32	5.93	0.4560	0.5126	0.6257	17
G4	UPB1064	5.52	9.0805	23.54	6.0173	30.60	4.80	4.71	0.4714	0.6046	0.7165	12
G5	KB1528	7.15	2.9469	38.03	2.5630	27.80	3.82	5.00	0.2778	0.3347	0.4053	20
G6	BH902	7.21	2.7994	40.57	2.1063	50.58	6.71	5.71	0.5479	0.6826	0.8177	18
G7	NDB943	6.03	6.7827	28.25	4.7354	17.79	2.73	6.86	0.3117	0.3862	0.4578	54
G8	HUB252	6.37	5.4502	30.13	4.2653	32.26	4.99	4.64	0.3869	0.4857	0.5710	17
G9	RD2948	9.56	0.0358	70.29	0.0877	92.70	9.48	6.29	0.6984	0.8267	1.0033	29
G10	JB346	9.19	0.0114	60.37	0.0822	51.35	6.02	7.71	0.5047	0.5588	0.6873	30
G11	DWRB167	10.05	0.3375	83.72	1.1798	111.2	10.64	8.50	1.0625	0.9474	1.1510	28
G12	NDB1653	7.26	2.6557	37.57	2.6506	33.03	4.94	5.36	0.3623	0.4302	0.5269	14
G13	RD2786	8.59	0.3324	55.36	0.3381	37.60	4.60	8.57	0.4478	0.4783	0.5832	44
G14	KARAN16	4.11	17.035	17.96	7.7357	9.50	1.53	6.43	0.2571	0.3010	0.3721	39
G15	RD2947	11.36	2.6133	96.73	3.4263	76.54	7.62	9.21	0.4388	0.6266	0.7645	44
G16	KB1501	9.25	0.0030	62.68	0.0228	53.31	6.37	6.57	0.3866	0.5172	0.6355	23
G17	PL891	7.08	3.1598	53.19	0.5033	30.83	3.04	8.00	0.3333	0.3911	0.4704	44
G18	RD2552	8.85	0.1417	58.53	0.1560	76.64	9.57	8.57	0.8633	0.8996	1.0780	25
G19	RD2949	10.12	0.4009	77.17	0.4914	53.81	5.31	9.50	0.5096	0.5648	0.6796	42
G20	BH959	8.10	0.9374	47.26	1.1195	41.55	5.61	6.36	0.4300	0.4881	0.5968	25
G21	RD2950	8.40	0.5376	51.05	0.6969	38.72	4.77	6.00	0.3333	0.4262	0.5128	34
G22	DWRB169	5.58	8.7686	23.52	6.0236	17.12	2.99	4.79	0.2815	0.3344	0.3957	30
G23	JB347	7.56	1.9450	44.75	1.4538	57.35	7.35	6.14	0.6825	0.7244	0.8862	17
G24	KB1531	9.87	0.1875	72.84	0.1990	88.37	9.52	9.36	0.8733	0.9102	1.0923	28
G25	BH946	6.08	6.6026	30.03	4.2907	50.14	7.06	6.36	0.8165	1.0060	1.2124	25
G26	PL892	7.31	2.5434	38.23	2.5259	45.47	6.51	5.64	0.5130	0.6383	0.7552	22
G27	UPB1066	8.26	0.7017	53.60	0.4690	41.69	4.74	6.21	0.3271	0.4577	0.5542	40
G28	PL898	7.75	1.5543	43.65	1.6130	49.35	6.78	5.86	0.4881	0.6295	0.7606	12
Sum = 81.29			58.37				$\chi^2(0.05,1)$	3.84	χ^2 (0.01,1)	6.63		
	$E(s^1)$ =	9.3214	$E(s^2)$ =	65.25	$V(s^1)$=	1.5944	$V(s^2)$=	289.15	χ^2 (0.05,28) =	41.3	χ^2(0.01,28) =	48.3

Table 4: Ranking of genotypes by parametric vis-à-vis non parametric measures

Code	Genotype	Yield	GAI	b_i	P_i	S^2_{xi}	CV_i	W_i^2	σ^2_i	$S_i^{(1)}$	$S_i^{(2)}$	$S_i^{(3)}$	$S_i^{(6)}$	$NP_i^{(1)}$	$NP_i^{(2)}$	$NP_i^{(3)}$	$NP_i^{(4)}$	Kang	SRT
G1	PL894	17	21	20	22	22	22	27	27	26	24	22	21	20	21	20	21	23	**376**
G2	HUB113	12	14	23	18	16	18	21	21	27	27	26	24	22	22	23	23	19	356
G3	BH1019	14	13	3	13	5	5	9	9	13	11	11	13	9	14	12	12	13	179
G4	UPB1064	7	4	15	7	14	12	11	11	2	3	5	9	2	15	16	16	7	156
G5	KB1528	20	18	17	15	1	1	1	1	8	8	4	5	4	2	3	3	9	120
G6	BH902	9	6	12	9	11	7	6	6	9	10	17	18	7	20	21	20	3	191
G7	NDB943	26	23	24	26	24	25	22	22	4	4	3	2	18	4	4	4	26	261
G8	HUB252	11	11	10	11	4	4	5	5	6	6	7	11	1	10	10	9	5	126
G9	RD2948	3	2	15	6	21	20	24	24	22	22	27	25	13	24	24	24	15	311
G10	JB346	15	16	8	14	7	9	12	13	20	20	18	15	19	17	14	15	15	247
G11	DWRB167	2	3	21	2	19	19	20	21	24	26	28	28	23	28	27	27	10	328
G12	NDB1653	13	12	16	10	2	2	2	2	10	7	8	10	5	8	7	7	3	124
G13	RD2786	24	25	20	24	20	23	23	24	18	18	9	6	25	13	9	10	25	316
G14	KARAN16	28	28	4	28	28	28	10	10	1	1	1	1	16	1	1	1	22	209
G15	RD2947	23	24	28	23	25	24	28	28	28	28	23	23	26	12	17	19	28	407
G16	KB1501	18	17	1	17	9	12	14	14	21	21	19	16	17	9	13	13	18	249
G17	PL891	27	26	7	27	26	27	19	19	7	16	6	4	21	7	5	5	24	273
G18	RD2552	6	9	22	12	15	15	17	17	19	19	24	27	25	26	25	25	13	316
G19	RD2949	25	27	25	25	27	26	26	26	25	25	20	12	28	18	15	14	28	392
G20	BH959	16	15	2	16	3	3	4	4	15	14	12	14	15	11	11	11	8	174
G21	RD2950	21	19	6	19	6	10	7	7	17	15	10	8	10	7	6	6	16	190
G22	DWRB169	22	22	13	21	12	14	13	13	3	2	2	3	3	3	2	2	21	171
G23	JB347	8	7	11	4	8	6	3	3	12	13	21	22	11	23	22	22	1	197
G24	KB1531	4	8	18	5	23	21	25	25	23	23	25	26	27	27	26	26	17	349
G25	BH946	1	1	26	1	18	17	15	15	5	5	16	20	15	25	28	28	5	241
G26	PL892	5	5	9	3	17	16	18	18	11	9	14	17	6	19	19	17	13	216
G27	UPB1066	19	20	27	20	13	13	16	16	16	17	13	7	12	5	8	8	21	251
G28	PL898	10	10	5	8	10	8	8	9	14	12	15	19	8	16	18	18	7	195

Table 5: Association analysis among measures

	Yield	GAI	b_i	P_i	S^2_{xi}	CV_i	W_i^2	σ^2_ι	$S_i^{(1)}$	$S_i^{(2)}$	$S_i^{(3)}$	$S_i^{(6)}$	$NP_i^{(1)}$	$NP_i^{(2)}$	$NP_i^{(3)}$	$NP_i^{(4)}$
GAI	0.959															
b_i	-0.348	-0.194														
P_i	0.924	0.891	-0.397													
S^2_{xi}	0.068	0.132	0.114	0.197												
CV_i	0.262	0.325	0.009	0.381	0.973											
W_i^2	-0.039	0.020	0.005	0.119	0.905	0.873										
σ^2_ι	-0.039	0.020	0.005	0.119	0.905	0.873	1.000									
$S_i^{(1)}$	-0.092	0.035	-0.128	-0.003	0.239	0.241	0.475	0.475								
$S_i^{(2)}$	-0.047	0.072	-0.198	0.054	0.326	0.341	0.534	0.534	0.967							
$S_i^{(3)}$	-0.510	-0.415	-0.018	-0.364	0.307	0.203	0.513	0.513	0.834	0.825						
$S_i^{(6)}$	-0.705	-0.628	0.055	-0.533	0.167	0.032	0.367	0.367	0.659	0.629	0.933					
$NP_i^{(1)}$	0.332	0.415	-0.129	0.382	0.631	0.685	0.682	0.682	0.639	0.707	0.441	0.224				
$NP_i^{(2)}$	-0.738	-0.696	0.081	-0.566	0.258	0.100	0.434	0.434	0.528	0.512	0.856	0.911	0.245			
$NP_i^{(3)}$	-0.763	-0.710	0.163	-0.564	0.322	0.157	0.500	0.500	0.497	0.483	0.842	0.914	0.209	0.966		
$NP_i^{(4)}$	-0.775	-0.723	0.143	-0.582	0.299	0.134	0.476	0.476	0.503	0.489	0.851	0.923	0.201	0.974	0.996	
Kang	0.667	0.693	-0.239	0.725	0.694	0.810	0.696	0.696	0.322	0.406	0.047	-0.203	0.742	-0.184	-0.161	-0.186

Critical values of correlation at 5% & 1% level of significance are 0.3894 & 0.5002 respectively

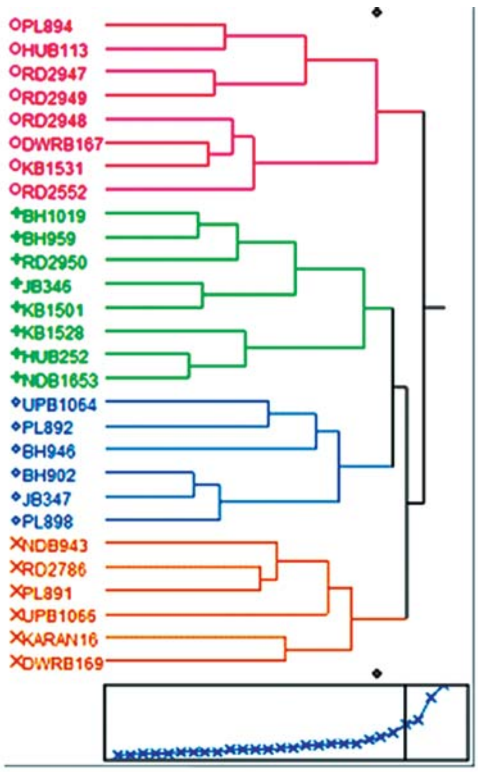

Fig. 1 : Hierarchical classification of barley genotypes based on yield along with other measures

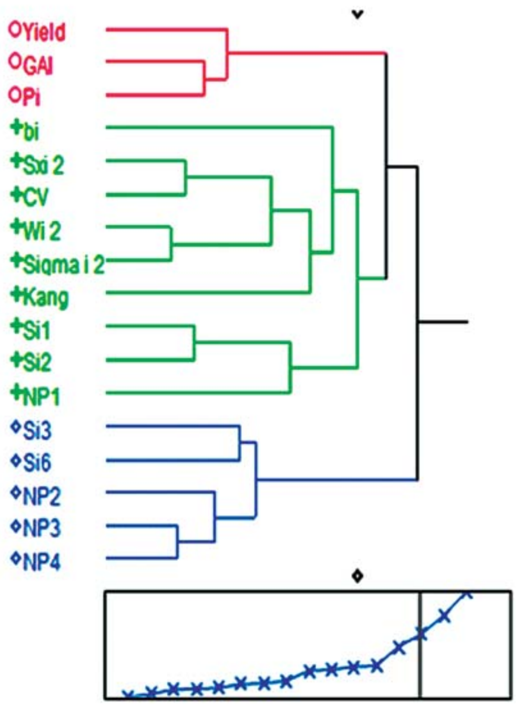

Fig. 2 : Clustering of parametric and non parametric measures by Ward's method

yielders and unstable G14, G11, G23, G24, G25 and G1, however, of these, G11 had the higher yield. However, cluster II included moderately yielder genotypes G3, G20, G21, G10, G16 and G5. The third cluster (III) comprised the high yielder as well as more than average yielder G4, G26, G25, G6, and G28. Finally, G22, G14, G27 and G17, and G13 with acceptable yields were placed into the fourth cluster (IV). Last cluster comprised of lowest yielder genotypes.

Hierarchical cluster analysis of considered measures was carried out to find out any relationship among measures fig. 2. The measures were clustered in three major groups. Parametric measures of Yield with GAI and Pi placed in separate group. Non parametric measures of $S_i^{(3)}$, $S_i^{(6)}$, $NP_i^{(2)}$, $NP_i^{(3)}$, $NP_i^{(4)}$ consisted in third group. More over larger group comprised of remaining measures i.e. b_i, S^2_{xi}, CV_i, W_i^2, σ^2_i, Kang, $S_i^{(1)}$, $S_i^{(2)}$, $NP_i^{(1)}$.

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REFERENCES

Ahmadi J., Vaezi B. and Pour-Aboughadareh A. 2016. Analysis of variability, heritability, and interrelationships among grain yield and related characters in barley advanced lines. *Genetika*. 48:73-85.

Ahmadi J., Vaezi B., Shaabani A., Khademi K., Fabriki-Ourang S., and Pour-Aboughadareh A. 2015. Non-parametric measures for yield stability in grass pea (Lathyrus sativus L.) advanced lines in semi warm regions. *J Agr Sci Tech.* **17:** 1825-38

Dehghani M.R., Majidi M.M., Mirlohi A., and Saeidi G. 2016. Integrating parametric and non-parametric measures to investigate genotype × environment interactions in tall fescue. *Euphytica*. **208 :** 583-96.

Finlay K.W., and Wilkinson G.N. 1963. Adaptation in a plant breeding programme. *Aust J Agric Res.* **14 :** 742-54.

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 :** 1029-34

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:** 454-59.

Jamshidmoghaddam M. and Pourdad, S.S. 2013. Genotype × environment interactions and simultaneous selection for high oil yield and stability in rainfed warm areas rapeseed (*Brassica napus L.*) from Iran. *Euphytica*. **180 :** 321-35.

Kang, M.S. 1988. A rank-sum method for selecting high-yielding, stable corn genotypes. *Cereal Res Commun*. **16 :** 113-15.

Khalili, M. and 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 :** 789-03.

Lin, C.S. and Binns, M.R. 1988. A method for analyzing cultivar x location x year experiments: a new stability parameter. *Theor Appl Genet* **76 :** 425-30

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

Mohammadi, R. and Amri A. 2008. A. Comparison of parametric and non-parametric methods for selecting stable and adapted durum wheat genotypes in variable environments. *Euphytica*, **159** : 419-32.

Nassar R. and 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. and Lotito, S. 1992. Rank correlation among parametric and nonparametric measures of phenotypic stability. *Euphytica* **64 :** 221-25.

Shukla, GK. 1972. Some statistical aspects of partitioning genotype-environmental components of variability. *Heredity*. **29 :** 237-45.

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 *Stat. 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

Vaezi B., Pour-Aboughadareh A., Mehraban A., Hossein-Pour T., Mohammadi R., Armion M. and Dorri M.2017. The use of parametric and non-parametric measures for selecting stable and adapted barley lines. *Archives Agron. Soil Sci.*, DOI: 10.1080/03650340.2017.1369529

Ward, J.H. 1963. Hierarchical grouping to optimize an objective function. *J Amer. Stat Assoc*. **58 :** 236-44.

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