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Non parametric measures to estimate GxE interaction of dual purpose barley genotypes for grain yield under multi-location trials

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Abstract: GxE interaction of seventeen dual purpose barley genotypes evaluated at ten major barley locations of the country by non parametric methods. Non parametric measures had been well established and expressed advantages over their counter parts i.e. parametric measures. Simple descriptive measures based on the ranks of genotypes i.e. Mean of ranks (MR) pointed towards RD2925 and BH1008 and standard deviation of ranks (SD) for KB1401 and UPB1054 whereas Coefficient of variation (CV) for JB322 and RD2925 as stable genotypes. Nonparametric measures based on original values (S_i^1, S_i^2, S_i^3, S_i^4, S_i^5, S_i^6, S_i^7) indicated the stable performance of NDB1650, JB322 and UPB1054 while UPB1053, RD2715, RD2927 and RD2035 were observed of unstable nature. CS_i^1, CS_i^2, CS_i^3, CS_i^4, CS_i^5, CS_i^6 and CS_i^7 measures based on the ranks of corrected grain yield identified JB322, RD2552, RD2925 and NDB1650 as stable genotypes. Spearman's rank correlation established highly significant positive correlation of yield with SD (0.67), S_i^1(0.65), S_i^2(0.59), S_i^5(0.68), S_i^7(0.67) whereas negative association observed for CMR (Mean of corrected ranks) (-0.62), CMed (Median of corrected ranks)(-0.60). $NP_i^{(2)}$ expressed negative correlation with CV(-0.32), S_i^6 (-0.30), CMR(-0.34) and CMed(-0.48). More over $NP_i^{(3)}$ maintained negative correlation with most of the measures though the magnitude was of low magnitude.

Keywords: GxE interaction, Non parametric methods, Rank correlation, Ward's clustering

INTRODUCTION

Barley has been cultivated as of dual purpose cereal as it provides nutrition to the animals via green fodder, at vegetative stage, and grains, from the regenerated plants and to human diet (Kharub *et al.,* 2013). Farm economics favour cultivation of dual purpose crop instead of only grain type. Presence of genotype x environment (G x E) interaction complicates the selection of genotypes for improved yield (Mohammadi *et al.,* 2016). Changes in cultivars' rank under multi environmental crop trials are of great concern. Most common approach had been the parametric relies heavily on distributional assumptions about genotypic, environmental and GxE interaction effects. Alternatively well known other approach is nonparametric / analytical without specific modeling assumptions. Nonparametric procedures are based on the ranks of genotypes in each environment and stable genotypes possess similar ranking across environments (Parmar *et al.*, 2012). Large number of nonparametric procedures had been seen in literature to interpret the GxE interaction in multi-environmental trials (MET). Huehn (1979), Huehn (1990), Thennarasu (1995) and Lima *et al* (2013), proposed several nonparametric indices of stability. Also, Sabaghnia *et al* (2012) and Rasoli *et al* (2015) had pro-posed procedures to test the GxE interaction apart from the conventional analysis of variance. Among these nonpara-metric procedures, Huehn and Leon (1995) measures had been used widely to assess the stable behavior of genotypes evaluated under Multi environmental trials (MET) (Hussein *et al,* 2000; Karimizadeh *et al.,* 2012; Khalili and Aboughadareh, 2016).

MATERIALS AND METHODS

Seventeen dual purpose barley genotypes were evaluated at 10 major barley growing locations across country during 2015-16 cropping season by randomized block designs with three replications. Parentage and location details had reflected in table 1 for ready reference. The recommended practices were followed to harvest the good crop. The grain yield of these genotypes were analysed further to calculate non parametric measures. Huehn and Leon (1995) proposed seven nonparametric methods for assessing GxE interaction and stability analysis. For a two-way dataset with k genotypes and n environments x_{ij} de-notes the phenotypic value of ith genotype in jth environ-ment where i=1,2, ...k, , j =, 1,2 ,..., n and r_{ij} as the rank of the $_i$th genotype in the $_j$th environment, and $\bar{r}_i$ as the mean rank across all environments for the $_i$th geno-type. The following measures were calculated as the ranks of genotypes in studied locations as:

$$S_i^{(1)} = \frac{2\sum_{j}^{n-1}\sum_{j=j+1}^{n}|r_{ij}-r_{ij'}|}{[n(n-1)]} \quad \text{i}$$

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

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

$$S_i^{(4)} = \sqrt{\frac{\sum_{j=1}^{n}(r_{ij}-\bar{r}_i)^2}{n}} \quad \text{iv}$$

$$S_i^{(5)} = \frac{\sum_{j=1}^{n}|r_{ij}-\bar{r}_i|}{n} \quad \text{v}$$

$$S_i^{(6)} = \frac{\sum_{j=1}^{m}|r_{ij}-\bar{r}_i|}{\bar{r}_{i.}} \quad \text{vi}$$

$$S_i^{(7)} = \frac{\sum_{j=1}^{n}(r_{ij}-\bar{r}_{i'})^2}{(n-1)} \quad \text{vii}$$

Karimizadeh *et al*. (2012) proposed the correction for yield of $_i$th genotype in $_j$th environment as ($x^*_{ij} = x_{ij} - \bar{x}_{i.} + \bar{x}_{..}$) as x^*_{ij}, was the corrected phenotypic value; $\bar{x}_{i.}$ was the mean of ith genotype in all environments and $\bar{x}_{..}$ was the grand mean. Thennarasu (1995) proposed stability measures as $NP_i^{(1)}$, $NP_i^{(2)}$, $NP_i^{(3)}$ and $NP_i^{(4)}$ based on ranks of adjusted means of genotypes. In the above formulas, r^*_{ij} was the rank of x^*_{ij}, and $\bar{r}_i$ and M_{di} were the mean and median ranks for original (unadjusted) grain yield, where $\bar{r}_i^*$ and M^*_{di} were the same parameters computed from the corrected (adjusted) data.

$$NP_i^{(1)} = \frac{1}{m}\sum_{j=1}^{m}|r^*_{ij} - M^*_{di}| \quad \text{viii}$$

$$NP_i^{(2)} = \frac{1}{m}\left(\frac{\sum_{j=1}^{m}|r^*_{ij}-M^*_{di}|}{M_{di}}\right) \quad \text{ix}$$

$$NP_i^{(3)} = \frac{\sqrt{\sum(r^*_{ij}-\bar{r}^*_{i})^2/m}}{\bar{r}_{i.}} \quad \text{x}$$

$$NP_i^{(4)} = \frac{2}{m(m-1)}\left[\sum_{j=1}^{m-1}\sum_{(j'=j+1)}^{m}\frac{|r^*_{ij}-r^*_{ij'}|}{\bar{r}_{i.}}\right] \quad \text{xi}$$

SAS-based computer programs of Lu (1995) and SASGESTAB (Hussein *et al,* 2000) exploited to calculate the nonparametric measures based on the ranks of genotypes as per original and corrected grain yield. Spearman's rank correlation coefficient calculated among each possible pairs as follows :

$$\bar{r}_s = 1 - \frac{6\sum_{i=1}^{n}d_i^2}{n(n^2-1)} \quad \text{xii}$$

d_i = difference between two ranks of investigated trait and n was number of correlated pairs

RESULTS AND DISCUSSION

As per average grain yield of dual purpose barley genotypes, RD2552 was the highest yielding with 32.9q/ha followed by NDB1650 and RD2035, although remarkable differences were evident among the studied 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. MR pointed towards RD2925, BH1008 and SD for KB1401, UPB1054 whereas CV for JB322 and RD2925 as stable genotypes, while AZAD and NDB1650 based on MR, UPB1053 and RD2715 based on SD and AZAD and RD2035 based on CV, were most unstable. Simple descriptive statistics based on the ranks of genotypes can be used to study comparative evaluation of genotypes. Liu *et al* (2010) proposed two ranking methods according to mean and standard deviation of ranks and Ashgar *et al* (2008) reported advantages of these non - parametric procedures in phenotypic stability studies. Many authors used the nonparametric measures of phenotypic stability based on the ranks of genotypes as per corrected yield trait and demonstrated these measures associated with the biological concept of stability (Sabaghnia *et al*, 2006; Ebadi *et al*, 2008).

Nonparametric measures based on the ranks of geno-

Table 1. Parentage details of dual purpose genotypes along with environmental conditions.

Code	Genotype	Parentage	Code	Locations	Latitude	Longitude	Altitude (m)
IVTIRTSDP-2	RD2715	RD387/BH602//RD2035	E1	Durgapura	26°51 'N	75 °47 ' E	390
IVTIRTSDP-3	UPB1054	IBYT-LRA-M-12	E2	Bikaner	28° 02' N	73° 31' E	225.3
IVTIRTSDP-4	KB1420	EIBGN(13)-7	E3	Ludhiana	30°54' N	75°52' E	247
IVTIRTSDP-5	BH1008	EIBGN-9/BH902(2009)	E4	Hisar	29°10'N	75 °46 ' E	215.2
IVTIRTSDP-6	RD2927	RD2624/RD2696	E5	Varanasi	25 °20 ' N	83° 03 ' E	75.5
IVTIRTSDP-7	RD2035	RD103/PL101	E6	Kanpur	26°29 ' N	80°18 ' E	125.9
IVTIRTSDP-8	BH1010	BHMS22A/WG81	E7	Faizabad	26°47'N	82°12 'E	113
IVTIRTSDP-9	JB325	RD2615/DL88	E8	Rewa	24 °31 ' N	81°15 ' E	365.7
IVTIRTSDP-10	RD2925	RD2606/RD2719//RD2660	E9	Kota	25° 21' N	75° 86' E	259.7
IVTIRTSDP-11	AZAD	K12/K19	E10	Udaipur	24°34 ' N	70 °42 ' E	582
IVTIRTSDP-12	RD2552	RD2035/DL472	E11	Jabalpur	23°90' N	79 ° 58' E	394
IVTIRTSDP-13	KB1401	IBYT-HI (13)-14					
IVTIRTSDP-14	UPB1053	IBYT-MRA-12					
IVTIRTSDP-15	JB319	LAKHAN/BH353					
IVTIRTSDP-16	RD2928	RD2552/BH902					
IVTIRTSDP-17	JB322	JB101/BH331					
IVTIRTSDP-18	NDB1650	38th IBON-9030 (2006-07)/NB3					

Table 2. Descriptive statistics and non parametric stability statistics based on original values for grain yield of dual purpose barley genotypes.

Original	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
IVTIRTSDP-2	RD2715	23.64	11.18	5.40	0.48	13.00	5.58	5.90	26.08	5.15	4.50	4.42	29.16
IVTIRTSDP-3	UPB1054	30.32	6.91	3.48	0.50	6.00	3.20	4.18	17.50	3.32	2.63	4.18	12.09
IVTIRTSDP-4	KB1420	28.05	10.09	4.83	0.48	10.00	4.89	5.96	23.08	4.60	3.55	3.87	23.29
IVTIRTSDP-5	BH1008	24.57	11.27	5.10	0.45	12.00	5.00	5.82	23.08	4.86	4.07	3.97	26.02
IVTIRTSDP-6	RD2927	26.59	8.82	5.29	0.60	9.00	5.33	5.57	31.71	5.04	4.56	5.69	27.96
IVTIRTSDP-7	RD2035	32.76	6.55	5.16	0.79	6.00	5.25	5.99	40.75	4.92	4.05	6.81	26.67
IVTIRTSDP-8	BH1010	28.06	10.55	4.08	0.39	9.00	4.11	4.11	15.81	3.89	3.69	3.85	16.67
IVTIRTSDP-9	JB325	27.37	9.09	3.91	0.43	10.00	4.15	4.65	16.82	3.73	2.99	3.62	15.29
IVTIRTSDP-10	RD2925	23.34	12.64	4.54	0.36	14.00	4.31	5.68	16.35	4.33	3.31	2.88	20.65
IVTIRTSDP-11	AZAD	31.96	5.64	4.72	0.84	3.00	4.76	5.10	39.48	4.50	3.97	7.74	22.25
IVTIRTSDP-12	RD2552	32.88	5.82	4.00	0.69	5.00	3.76	5.42	27.44	3.81	2.68	5.06	15.96
IVTIRTSDP-13	KB1401	29.06	9.73	4.47	0.46	9.00	4.82	5.17	20.58	4.27	3.52	3.98	20.02
IVTIRTSDP-14	UPB1053	29.43	8.36	6.04	0.72	6.00	6.40	6.39	43.59	5.76	5.19	6.82	36.45
IVTIRTSDP-15	JB319	27.29	9.18	4.49	0.49	11.00	4.78	4.82	21.96	4.28	3.80	4.55	20.16
IVTIRTSDP-16	RD2928	24.55	10.36	5.14	0.50	11.00	5.35	5.99	25.53	4.90	4.02	4.26	26.45
IVTIRTSDP-17	JB322	26.14	10.64	3.53	0.33	11.00	3.73	4.39	11.71	3.36	2.58	2.67	12.45
IVTIRTSDP-18	NDB1650	32.64	5.45	2.70	0.49	6.00	2.76	3.08	13.33	2.57	2.15	4.34	7.27

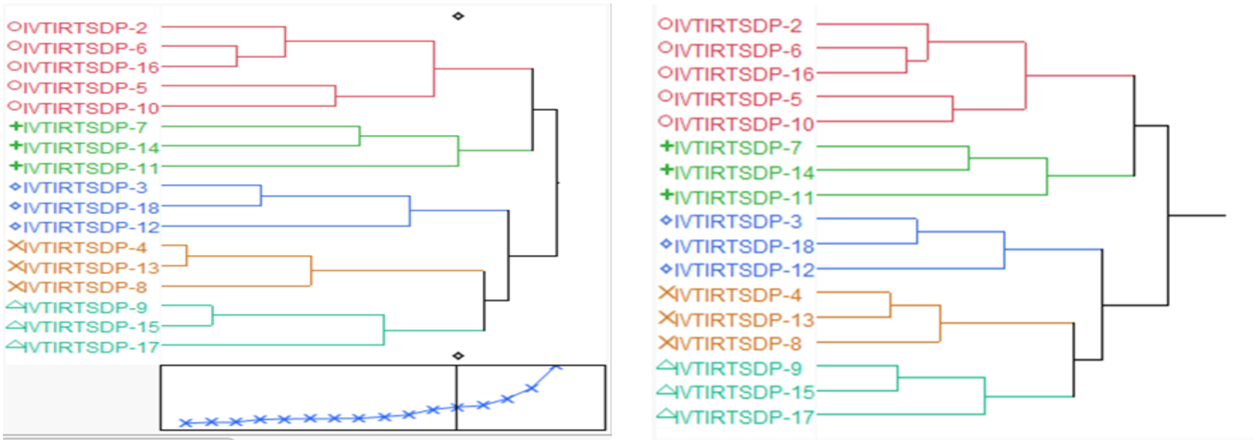

Fig. 1. *Hierarchical cluster analysis of dual purpose barley genotypes based on non parametric measures by Ward's method.*

types as per grain yield (S_i^1 ,S_i^2 ,S_i^3 ,S_i^4 ,S_i^5 ,S_i^6 and S_i^7) indicated that NDB1650, JB322 and UPB1054 were the stable genotypes, however UPB1053, RD2715, RD2927and RD2035 were unstable genotypes. Genotypes BH1010 and KB1401 pointed by the mean of ranks based on corrected grain yield (CMR), RD2552 and JB322 by standard deviation of ranks based on corrected yield (CSD) and coefficient of variation (CCV) observed stable performance of RD2552 and NDB1650 (Rasoli *et al* 2015). Good potential of the measures S_i^3 and S_i^6 for the selection of stable high yielder genotypes. Furthermore, nonparametric

Table 3. Descriptive statistics and non parametric stability statistics based on corrected values for grain yield of dual purpose barley genotypes.

Corrected	Genotype	CMR	CSD	CCV	CMed	CS_i^1	CS_i^2	CS_i^3	CS_i^4	CS_i^5	CS_i^6	CS_i^7	$NP_i^{(1)}$	$NP_i^{(2)}$	$NP_i^{(3)}$	$NP_i^{(4)}$
IVTIRTSDP-2	RD2715	7.55	6.31	0.84	6.00	6.44	6.59	52.84	6.02	5.50	8.02	39.87	2.050	0.158	0.538	0.576
IVTIRTSDP-3	UPB1054	9.73	4.27	0.44	11.00	3.91	4.64	18.73	4.07	3.57	4.04	18.22	7.430	1.238	0.589	0.566
IVTIRTSDP-4	KB1420	10.09	5.24	0.52	11.00	5.11	5.88	27.24	5.00	4.25	4.63	27.49	6.752	0.675	0.495	0.506
IVTIRTSDP-5	BH1008	8.55	5.05	0.59	8.00	5.22	5.99	29.81	4.81	3.87	4.98	25.47	4.214	0.351	0.427	0.463
IVTIRTSDP-6	RD2927	7.73	5.82	0.75	5.00	5.58	5.96	43.76	5.54	5.16	7.34	33.82	1.577	0.175	0.629	0.633
IVTIRTSDP-7	RD2035	9.45	5.99	0.63	8.00	6.40	6.24	37.94	5.71	5.22	6.08	35.87	2.859	0.477	0.872	0.978
IVTIRTSDP-8	BH1010	10.36	4.86	0.47	10.00	4.98	5.10	22.82	4.64	4.21	4.47	23.65	5.785	0.643	0.440	0.472
IVTIRTSDP-9	JB325	7.82	4.26	0.55	8.00	4.53	5.02	23.23	4.06	3.29	4.63	18.16	4.711	0.471	0.447	0.498
IVTIRTSDP-10	RD2925	7.64	5.32	0.70	6.00	5.22	5.55	37.00	5.07	4.63	6.67	28.25	1.865	0.133	0.401	0.413
IVTIRTSDP-11	AZAD	9.09	4.95	0.54	10.00	5.36	5.71	26.94	4.72	3.90	4.72	24.49	6.099	2.033	0.837	0.952
IVTIRTSDP-12	RD2552	9.45	3.62	0.38	9.00	3.84	4.16	13.83	3.45	2.86	3.33	13.07	6.141	1.228	0.593	0.659
IVTIRTSDP-13	KB1401	10.64	5.10	0.48	13.00	5.20	5.53	24.50	4.87	4.28	4.43	26.05	8.720	0.969	0.500	0.535
IVTIRTSDP-14	UPB1053	9.36	6.17	0.66	8.00	6.76	6.30	40.64	5.88	5.49	6.45	38.05	2.578	0.430	0.703	0.809
IVTIRTSDP-15	JB319	8.64	4.15	0.48	9.00	4.36	4.75	19.98	3.96	3.31	4.21	17.25	5.695	0.518	0.431	0.475
IVTIRTSDP-16	RD2928	8.18	5.69	0.70	6.00	5.75	5.76	39.56	5.42	5.11	6.87	32.36	1.736	0.158	0.523	0.554
IVTIRTSDP-17	JB322	9.00	3.74	0.42	7.00	4.07	4.12	15.56	3.57	3.09	3.78	14.00	3.909	0.355	0.335	0.383
IVTIRTSDP-18	NDB1650	9.73	3.98	0.41	10.00	4.11	5.40	16.26	3.79	2.66	3.01	15.82	7.339	1.223	0.695	0.753

statistics were reviewed by Mohammadi *et al* (2014) for statistical properties. Mohammadi *et al* (2016) pointed out that the S_i^1 and S_i^2 nonparametric measures of stability, were similar in concept to GxE interaction and defined stability in terms of homeostasis.

Nonparametric measures based on the ranks of genotypes as per corrected yield (CS_i^1 ,CS_i^2 ,CS_i^3 ,CS_i^4 ,CS_i^5 ,CS_i^6 and CS_i^7) identified stable genotypes as JB322, RD2552, RD2925 and NDB1650.

The cluster analysis by Ward's (1963) method, considered yield and nonparametric measures, revealed two distinct clusters among seventeen genotypes: cluster A consisted of genotypes RD2715, RD2927, RD2928, BH1008, RD2925, RD2035, UPB1053 and AZAD and cluster B consisted of UPB1054, NDB1650, RD2552, KB1420, KB1401, JB319, JB322 genotypes as the favorable as mentioned by Mortazavian and Azizinia 2014. Corrected statistics identified genotypes JB322, NDB1650 and RD2552 were the stable ones, while based on uncorrected statistics, genotypes NDB1650 JB322 and UPB1054 were the preferable. Regarding mean yield regardless of stability, the most favorable genotype would be NDB1650.

Relationship among nonparametric statistics: According to Spearman's rank correlation analysis among all possible pairs there was a highly significant ($p< 0.01$) positive rank correlation of mean yield with SD (0.67), S_i^1(0.65), S_i^2(0.59), S_i^5(0.68), S_i^7(0.67) and negative correlation observed for CMR(-0.62), CMed(-0.60). More over no significant correlation with stability measures $NP_i^{(1)}$, $NP_i^{(2)}$, $NP_i^{(3)}$ and $NP_i^{(4)}$. Mean rank (MR) expressed positive correlation with $NP_i^{(1)}$ (0.67), $NP_i^{(2)}$(0.52) and negative with CV(-0.75), Si^3(-0.60), Si^6(-0.72), CMR(-0.73) and CMed(-0.67). SD maintained ($p<0.01$) significant positive with S_i^1 (0.97), S_i^2(0.97), S_i^3(0.85), S_i^5(0.97), S_i^7(0.76), CSD (0.68), CCV(0.74) as well as with CS_i^1(0.65), CS_i^2 (0.69), CS_i^3(0.69), CS_i^4(0.70), CS_i^5(0.62), CS_i^6(0.67) and CS_i^7(0.68) as observed by Scapim *et al* 2010. Also S_i^1 had a highly significant positive rank correlation with S_i^2 (0.93), S_i^3(0.84), S_i^4 (0.97), S_i^5(0.98), S_i^6(0.75), S_i^7 (0.97) as well as with CS_i^1(0.60), CS_i^2(0.64),CS_i^3 (0.66),CS_i^4(0.65), CS_i^5(0.58), CS_i^6(0.65) and CS_i^7 (0.64). Subsequently positive correlations seen among Si^s (0.69 to 0.99) and with CS_i^s(0.70 to 0.99). However, $NP_i^{(1)}$ showed negative association with CV, S_i^3, CMR and CMed. While $NP_i^{(2)}$ expressed negative rank correlation with CV, S_i^6, CMR and CMed. $NP_i^{(3)}$ maintained negative correlation with most of the measures though the magnitude was of low magnitude. Similar behavior observed for $NP_i^{(3)}$ with other nonparametric measures. Seven nonparametric measures based on corrected datasets (CS_i^1, CS_i^2, CS_i^3 ,CS_i^4 ,CS_i^5 ,CS_i^6 ,CS_i^7) were correlated with each

Table 4. Correlation values of yield with non parametric stability statistics for grain yield of dual purpose barley genotypes.

	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	C MR	C SD	C CV	C Med	CS_i^1	CS_i^2	CS_i^3	CS_i^4	CS_i^5	CS_i^6	CS_i^7	$NP_i^{(1)}$	$NP_i^{(2)}$	$NP_i^{(3)}$
MR	0.275																									
SD	0.674	-0.174																								
CV	0.254	-0.749	0.702																							
Med	0.266	0.942	-0.200	-0.686																						
S_i^1	0.652	-0.169	0.973	0.695	-0.170																					
S_i^2	0.588	-0.145	0.971	0.643	-0.156	0.934																				
S_i^3	0.426	-0.605	0.848	0.955	-0.567	0.838	0.797																			
S_i^4	0.674	-0.174	1.000	0.702	-0.200	0.973	0.971	0.848																		
S_i^5	0.675	-0.146	0.972	0.696	-0.172	0.977	0.915	0.832	0.972																	
S_i^6	0.326	-0.716	0.760	0.989	-0.668	0.750	0.696	0.978	0.760	0.756																
S_i^7	0.674	-0.174	1.000	0.702	-0.200	0.973	0.971	0.848	1.000	0.972	0.760															
C MR	-0.616	-0.734	-0.278	0.400	-0.652	-0.229	-0.327	0.156	-0.278	-0.248	0.308	-0.278														
C SD	0.895	0.042	0.684	0.455	0.099	0.640	0.600	0.564	0.684	0.680	0.517	0.684	-0.337													
C CV	0.949	0.262	0.735	0.278	0.259	0.711	0.701	0.453	0.735	0.737	0.348	0.735	-0.656	0.850												
C Med	-0.602	-0.665	-0.180	0.417	-0.600	-0.126	-0.183	0.205	-0.180	-0.115	0.352	-0.180	0.887	-0.317	-0.565											
CS_i^1	0.890	0.032	0.652	0.450	0.097	0.603	0.574	0.544	0.652	0.653	0.500	0.652	-0.357	0.983	0.863	-0.347										
CS_i^2	0.705	0.063	0.688	0.419	0.123	0.638	0.688	0.533	0.688	0.676	0.494	0.688	-0.319	0.879	0.778	-0.169	0.854									
CS_i^3	0.971	0.213	0.694	0.320	0.237	0.657	0.627	0.480	0.694	0.695	0.392	0.694	-0.548	0.944	0.949	-0.506	0.946	0.808								
CS_i^4	0.901	0.028	0.697	0.466	0.081	0.648	0.614	0.577	0.697	0.691	0.528	0.697	-0.350	0.999	0.857	-0.328	0.984	0.870	0.950							
CS_i^5	0.900	0.051	0.623	0.420	0.124	0.578	0.537	0.525	0.623	0.619	0.473	0.623	-0.352	0.978	0.846	-0.357	0.980	0.805	0.949	0.979						
CS_i^6	1.000	0.275	0.674	0.254	0.266	0.652	0.588	0.426	0.674	0.675	0.326	0.674	-0.616	0.895	0.949	-0.602	0.890	0.705	0.971	0.901	0.900					
CS_i^7	0.895	0.042	0.684	0.455	0.099	0.640	0.600	0.564	0.684	0.680	0.517	0.684	-0.337	1.000	0.850	-0.317	0.983	0.879	0.944	0.999	0.978	0.895				
$NP_i^{(1)}$	0.282	0.672	0.054	-0.428	0.646	0.076	0.020	-0.279	0.054	0.026	-0.400	0.054	-0.580	0.100	0.154	-0.688	0.027	0.004	0.159	0.089	0.049	0.282	0.100			
$NP_i^{(2)}$	0.195	0.518	0.026	-0.316	0.542	0.045	-0.013	-0.210	0.026	-0.012	-0.300	0.026	-0.343	0.055	0.023	-0.483	-0.021	-0.074	0.107	0.051	0.009	0.195	0.055	0.891		
$NP_i^{(3)}$	-0.010	-0.221	-0.042	0.112	-0.129	-0.061	-0.074	0.056	-0.042	-0.138	0.059	-0.042	0.141	-0.061	-0.181	-0.060	-0.049	-0.298	-0.044	-0.045	0.002	-0.010	-0.061	0.061	0.406	
$NP_i^{(4)}$	-0.017	-0.245	-0.025	0.131	-0.158	-0.037	-0.059	0.071	-0.025	-0.124	0.076	-0.025	0.170	-0.074	-0.181	-0.048	-0.061	-0.308	-0.054	-0.058	-0.012	-0.017	-0.074	0.059	0.398	0.993

Critical values of Spearman correlation at 5% and 1% level of significance (df 15) are 0.521 and 0.604 respectively.

other. The most prominent relation was no positive or negative association of $NP_i^{(s)}$ with CS_i^s. The effect of correction and removing the genotype effect is clear on the negative association between mean yield and CMR. Mean rank (MR) had a significant negative rank correlation with CV and S_i^3 while it had a significant negative rank correlation with CMR, CMed and had low rank correlation with the other CS_i^s nonparametric statistics.

Conclusion

Non parametric measures based on the ranks of genotypes in studied environments showed advantages over their counter parts i..e. parametric measures. Non parametric measures based on the ranks as per the original and corrected grain yield values explained the static and dynamic concept of stability. The strong relationship among measures suggested the possible use of non parametric measures instead of parametric values to point out the stable as well as unstable performance of genotypes.

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