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STABILITY ANALYSIS BY NONPARAMETRIC MEASURES OF WHEAT GENOTYPES EVALUATED UNDER NORTH EASTERN PLAINS ZONE OF INDIA

Ajay Verma*, G.P. Singh

ICAR-Indian Institute of Wheat & Barley Research, Post Bag # 158 Agrasain Marg, Karnal 132001 (Haryana), India

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KEYWORDS

BLUP

BLUE

 $S_i^{(s)}$ $CS_i^{(s)}$ $NP_i^{(s)}$

Coefficient of concordance

Biplot analysis

ABSTRACT

Nonparametric measures of stability had been compared based on ranks of genotypes as per BLUP and BLUE of wheat genotypes evaluated in North Eastern Plains Zone of the country. $S_i^{(s)}$ measures, as per the BLUP of yield for the first year, identified G5, G1, G7 as the stable genotypes whereas corrected yield measures $CS_i^{(s)}$ selected G4, G5, G7, G1. Values of measures $NP_i^{(s)}$ settled for G7, G5, G4 wheat genotypes. The significance of Kendall's coefficient of concordance resulted in an overall similarity of the ranking of genotypes as per nonparametric measures. Spearman coefficients had observed positive correlations by $S_i^{(s)}$, $CS_i^{(s)}$ & $NP_i^{(s)}$ with other measures. CV expressed close affinity with CCV, $NP_i^{(2)}$, $NP_i^{(3)}$, $NP_i^{(4)}$ & $S_i^{(6)}$, $CS_i^{(3)}$, $CS_i^{(6)}$ whereas SD, CSD, $NP_i^{(1)}$ associated with Z1, Z2, $S_i^{(1)}$, $S_i^{(2)}$, $S_i^{(3)}$, $S_i^{(4)}$, $S_i^{(5)}$, $S_i^{(7)}$, $CS_i^{(1)}$, $CS_i^{(4)}$, $CS_i^{(5)}$, $CS_i^{(7)}$ in Biplot graphical analysis. BLUE's of the yield shown G1, G2, G4, G5, G7 genotypes selected by $S_i^{(s)}$. Values of $CS_i^{(s)}$ identified G2, G4, G5, G6 genotypes, as opposed to G4, G5, G7 by $NP_i^{(s)}$. Positive correlation exhibited by $S_i^{(s)}$, $CS_i^{(s)}$ & $NP_i^{(s)}$ with other nonparametric measures. CV placed with $NP_i^{(2)}$, $NP_i^{(3)}$ & $NP_i^{(4)}$, $S_i^{(3)}$, $S_i^{(6)}$ measures in biplot analysis. Largest cluster expressed by Z1, Z2, SD, CSD, CCV, $S_i^{(1)}$, $S_i^{(2)}$, $S_i^{(4)}$, $S_i^{(5)}$, $S_i^{(7)}$, $CS_i^{(1)}$, $CS_i^{(2)}$, $CS_i^{(3)}$, $CS_i^{(4)}$, $CS_i^{(5)}$, $CS_i^{(6)}$, $CS_i^{(7)}$ measures. BLUP's of yield values for the second year (2017-18) revealed that $S_i^{(s)}$ selected G1, G12, G13 genotypes while $CS_i^{(s)}$ favoured G13, G1, G4 genotypes. Lower values of $NP_i^{(s)}$ identified G1, G4, G12, and G13 genotypes. Direct and positive relationships expressed by $S_i^{(s)}$, $CS_i^{(s)}$ & $NP_i^{(s)}$ measures. Maximum measures clustered together i.e. SD, CSD, CCV, $NP_i^{(1)}$, $S_i^{(1)}$, $S_i^{(2)}$, $S_i^{(4)}$, $S_i^{(5)}$, $S_i^{(7)}$, $CS_i^{(1)}$, $CS_i^{(2)}$, $CS_i^{(3)}$, $CS_i^{(4)}$, $CS_i^{(5)}$, $CS_i^{(6)}$, $CS_i^{(7)}$. Based on BLUE's values, $S_i^{(s)}$ measures pointed for G13, G1 G4 while G1, G13, G4 selected by $CS_i^{(s)}$ values. Lower values of $NP_i^{(s)}$ achieved by G1, G4, G11, G13 genotypes. $S_i^{(s)}$, $CS_i^{(s)}$ & $NP_i^{(s)}$ had achieved strong and weak relations with other measures. Measures Z1, Z2, SD, CSD, CCV, $NP_i^{(1)}$, $S_i^{(1)}$, $S_i^{(2)}$, $S_i^{(4)}$, $S_i^{(5)}$, $S_i^{(7)}$, $CS_i^{(1)}$, $CS_i^{(2)}$, $CS_i^{(3)}$, $CS_i^{(4)}$, $CS_i^{(5)}$, $CS_i^{(6)}$, $CS_i^{(7)}$ clubbed in bigger cluster. Nonparametric measures would be quite useful to researchers especially breeders to make the selection of genotypes in the presence of genotype X environment interactions.

* Corresponding author

E-mail: ajay.verma1@icar.gov.in (Ajay Verma)

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1 Introduction

High yield and stable genotypes have been identified by breeders for diverse environmental conditions to sustain a good harvest of the crop (Pour-Aboughadareh et al., 2019). Multi-environment trials (MET) have been established as inevitable to recommend promising genotypes for different locations of the country (Vaezi et al., 2018). Genotype x Environment (GxE) interaction effects decrease the association between genotypic and phenotypic values and also masks the selection of the desirable genotypes (Mohammadi et al., 2016). Stability analysis methods are categorized into two parametric and non-parametric groups (Huhn & Leon, 1995; Farshadfar et al., 2014; Golkar et al., 2020). The parametric approach is based on statistical assumptions about the distribution of genotype, environment, and GEI effects (Khalili & Pour-Aboughadareh, 2016). Moreover, nonparametric showed robust behavior without specific assumptions (Rasoli et al., 2015). Mostly breeding experiments utilized parametric methods for assessing the stability of genotypes. Recent studies showed the use of nonparametric approaches as the performance of genotypes had been judged by ranks. Additionally, these methods reduce the bias factor due to outliers and simple to use and interpret (Zali et al., 2011; Ahmadi et al., 2015; Khalili & Pour-Aboughadareh, 2016; Vaezi et al., 2018; Pour-Aboughadareh et al., 2019). A large number of nonparametric procedures has been compared in the literature to

interpret the stability and genotype x environment interactions analysis (Delić et al., 2009; Balalić et al., 2011; Karimizadeh et al., 2012; Mahtabi et al., 2013; Mortazavian & Azizinia, 2014; Ahmadi et al., 2015; Khalili & Pour-Aboughadareh, 2016; Vaezi et al., 2018; Pour-Aboughadareh et al., 2019).

With this in mind, the objectives of the present study were (1) to analyze stability based on BLUP and BLUE values of genotypes by nonparametric methods (2) to differentiate genotypes performance possessing high yield along with adaptations as per BLUP and BLUE across environments, (3) to find out the similarities or dissimilarities among the nonparametric measures.

2 Materials and Methods

Seven promising wheat genotypes were evaluated under field trials at sixteen major locations of the zone for 2016-17 whereas fifteen genotypes were tested at thirteen locations during 2017-18 cropping seasons of the country. Recommended agronomic practices had followed to have a good harvest of wheat genotypes. Parentage details and environmental conditions were reflected in tables 1 & 2 for ready reference. Huehn (1990 a & b) proposed seven nonparametric methods for assessing GxE interaction and stability analysis. X_{ij} denotes the yield of i th genotype in j th environment where $i=1,2, \dots, k$, $j = 1,2, \dots, n$ and rank of the i th genotype in the j th environment by r_{ij} , and $\bar{r}_i$ as the mean of i th

Table 1 Parentage details of wheat genotypes and environments (2016-17)

Code	Genotype	Parentage	Code	Locations	Latitude	Longitude	Altitude (m)
G1	DBW187	(NAC/TH.AC//3*PVN/3/MIRLO/BUC/4/2*PASTOR/5/KACHU/6/KACHU)	E1	Araul	26° 54' N	80° 01' E	139
G2	HD3219	(PBW343/HD2879)	E2	Banka	24° 88' N	86° 91' E	83
G3	HD2733	(ATTILA/3/TUI/CARC//CHEN/CHTO/4/ATTILA)	E3	Barabanki	26° 94' N	81° 37' E	119
G4	K0307	(K8321/UP2003)	E4	Bikramganj	25° 22' N	84° 26' E	92
G5	DBW39	(ATTILA/HUI)	E5	Burdwan	23° 13' N	87° 51' E	38
G6	K1006	(PBW343/HP1731)	E6	Coochbehar	26° 19' N	89° 27' E	48
G7	HD2967	(ALD/CUC//URES/HD2160M/HD2278)	E7	Chianki	26° 87' N	91° 48' E	216
			E8	Dumka	24° 16' N	87° 14' E	137
			E9	Faizabad	26° 77' N	82° 14' E	106
			E10	Ghazipur	25° 58' N	83° 59' E	72
			E11	Kanpur	26° 26' N	80° 19' E	133
			E12	Manikchak	25° 4' N	87° 54' E	33
			E13	Ranchi	23° 20' N	85° 18' E	644
			E14	Sabour	25° 23' N	87° 04' E	42
			E15	Shillongani	24° 38' N	77° 13' E	33
			E16	Varanasi	25° 19' N	82° 59' E	84

Table 2 Parentage details of wheat genotypes and environments (2017-18)

Code	Genotype	Parentage	Code	Locations	Latitude	Longitude	Altitude (m)
G1	DBW233	(CHIBIA//PRLII/CM65531/3/SKAUZ/BAV92/4/MUNAL#1)	E1	Kalyani	22° 58' N	88° 26' E	16
G2	HD3249	(PBW343*2/KUKUNA//SRTU/3/PBW343*2/KHVAKI)	E2	Burdwan	23° 13' N	87° 51' E	38
G3	HD3254	(CL1705/HD2687)	E3	Manichak	25° 4' N	87° 54' E	33
G4	DBW221	(36IBWSN284/22ESWYT28)	E4	Pusa	25° 98' N	85° 67' E	56
G5	K1601	(K9107/DBW14)	E5	Purnea	25° 46' N	87° 28' E	43
G6	PBW769	(ATTILA/3*BCN/3/CROC 1/AE.SQUARROSA(224)//OPATA/4/C HIBIA//PRLII/CM65531/3/SKAUZ/BAV92/4/MUNAL#1)	E6	Sabour	25° 23' N	87° 04' E	42
G7	DBW187	(NAC/TH.AC//3*PVN/3/MIRLO/BUC/4/2*PASTOR/5/KACHU/6/ KACHU)	E7	Ranchi	23° 20' N	85° 18' E	644
G8	DBW223	(PBW550/CBW38)	E8	Dumka	24° 16' N	87° 14' E	137
G9	PBW762	(YR5/6*AVOCET//2*PBW550)	E9	Basti	26° 49' N	82° 45' E	85
G10	WH1218	(KA/NAC//TRCH/3/VORB)	E10	Varanasi	25° 19' N	82° 59' E	84
G11	K1006	(PBW343/HP1731)	E11	Gorakhpur	26° 45' N	83° 22' E	84
G12	HD2733	(ATTILA/3/TUI/CARC//CHEN/CHTO/4/ATTILA)	E12	Araul	26° 54' N	80° 01' E	139
G13	DBW39	(ATTILA/HUI)	E13	Kanpur	26° 26' N	80° 19' E	133
G14	HD2967	(ALD/CUC//URES/HD2160M/HD2278)					
G15	K0307	(K8321/UP2003)					

genotype. Sabaghnia et al. (2012) proposed the correction for the 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 *i*th genotype in all environments and $\bar{X}_.$ was the grand mean. Generally used seven statistics based on genotypes yield and corrected yield was expressed as follows:

$$S_i^{(1)} = \frac{2 \sum_{j=1}^{n-1} \sum_{j'+j+1}^n |r_{ij} - r_{ij'}|}{[n(n-1)]} \quad S_i^{(7)} = \frac{\sum_{j=1}^n (r_{ij} - \bar{r}_i)^2}{\sum_{j=1}^n |r_{ij} - \bar{r}_i|} \quad S_i^{(3)} = \frac{\sum_{j=1}^n (r_{ij} - \bar{r}_i)^2}{\bar{r}_i}$$

$$S_i^{(4)} = \sqrt{\frac{\sum_{j=1}^n (r_{ij} - \bar{r}_i)^2}{n}} \quad S_i^{(5)} = \frac{\sum_{j=1}^n |r_{ij} - \bar{r}_i|}{n} \quad S_i^{(6)} = \frac{\sum_{j=1}^n |r_{ij} - \bar{r}_i|}{\bar{r}_i}$$

$$S_i^{(2)} = \frac{\sum_{j=1}^n (r_{ij} - \bar{r}_i)^2}{(n-1)} \quad \bar{r}_i = \frac{1}{n} \sum_{j=1}^n r_{ij} \quad Z_i^{(v)} = \frac{[S_i^{(v)} - E\{S_i^{(v)}\}]^2}{\text{Var}\{S_i^{(v)}\}}, \quad = 1, 2$$

Nonparametric measures for stability analysis proposed by Thennarasu (1995) as $NP_i^{(1)}$, $NP_i^{(2)}$, $NP_i^{(3)}$ and $NP_i^{(4)}$ based on ranks of corrected means of genotypes. Ranks of genotypes as per corrected yield X_{ij}^* denoted by r_{ij}^* with average of ranks and median by $\bar{r}_i^*$ and M_{di}^* .

$$NP_i^{(1)} = \frac{1}{n} \sum_{j=1}^n |r_{ij}^* - M_{di}^*|$$

$$NP_i^{(3)} = \frac{\sqrt{\sum (r_{ij}^* - \bar{r}_i^*)^2 / n}}{\bar{r}_i^*}$$

$$NP_i^{(2)} = \frac{1}{n} \left(\frac{\sum_{j=1}^n |r_{ij}^* - M_{di}^*|}{M_{di}^*} \right) \quad NP_i^{(4)} = \frac{2}{n(n-1)} \left[\frac{\sum_{j=1}^{n-1} \sum_{j'=j+1}^n |r_{ij}^* - r_{ij'}^*|}{\bar{r}_i^*} \right]$$

Further, Nassar & Huehn (1987) proposed a test to judge the significance of $S_i^{(1)}$ and $S_i^{(2)}$ measures. The degree of had been assessed by correlation among genotypes ranking. Spearman's rank correlation values used to test the degree of similarity among measures (Piepho & Lotito, 1992) as: $\bar{r}_s = 1 - \frac{6 \sum_{i=1}^n d_i^2}{n(n^2-1)}$

where d_i denotes the difference between ranks for *i*th genotype and sum over the number of pairs.

3 Results and Discussion

3.1 First year 2016-17

3.1.1 Analytic analysis based on BLUP's

High yielder genotypes were G6, G5, G4, whereas Geometric Adaptability Index (GAI) selected G6, G5, G4 genotypes. Average of ranks (MR), standard deviation of ranks (SD), and coefficient of variation of ranks (CV) were calculated as per ranks based on

yield. MR identified for G7, G5, G4 while the consistent yield of G5, G1, G7 expressed by values of SD (Table 3). Genotypes G7, G5, G4 pointed out by values of CV. Sabaghnia et al. (2012) proposed two ranking methods according to mean and standard deviation of ranks while Mortazavian & Azizinia (2014) reported the advantages of these nonparametric procedures in stability studies. Median of ranks (Med) pointed towards G7, G5, G4 wheat genotypes. Measure S_i^1 selected G5, G7, G1 as opposed to G5, G1, G7 by S_i^2 values. G7, G5, G1 genotypes considered by S_i^3 & S_i^4 measures, next two S_i^5 & S_i^6 pointed towards G5, G7, G1 genotypes while S_i^7 favored G1, G7, G5 genotypes. Average ranks as per corrected yield values (CMR) selected G6, G5, G4, and corrected standard deviation (CSD) observed suitability of G1, G6, G9 genotypes. Coefficient of variation as per corrected yield (CCV) values found G5, G7, G1 while median values (CMed) G2, G1, G3 genotypes. Measures based on ranks as per corrected yield CS_i^1 , CS_i^2 , CS_i^3 , CS_i^4 & CS_i^5 pointed towards G5, G7, G1 while G5, G7, G4 by CS_i^6 and CS_i^7 identified G1, G7, G4 wheat genotypes (Table 4). The mentioned strategy determines the stability of

genotype over the environment if its rank is similar over other environments (biological concept). Many authors that have used the corrected Huehn's (1990b) nonparametric measures of stability and demonstrated the association of these measures with the biological concept of stability (Sabaghnia et al., 2012; Mahtabi et al 2013). Measures $NP_i^{(1)}$, $NP_i^{(2)}$, $NP_i^{(3)}$, $NP_i^{(4)}$, consider the ranks of genotypes as per yield and corrected yield simultaneously, found G7, G5, G4 as suitable wheat genotypes while Z1 & Z2 settled for G2, G4, G1 genotypes.

Kendall's coefficient of concordance, W was used as an additional tool to evaluate the degree of agreement among non-parametric measures and mean yield. Perfect agreement among rankings of the measures across the environments denoted as $W = 1$, while zero value indicated total disagreement (Vaezi et al., 2018). Calculated values of $W = 0.56$ and for its significance values of χ^2 statistic = 100.8 (Table 4). The calculated value was less than the table value of $\chi^2 (0.05, 290) = 124.3$ (135.8), which resulted in an overall similarity among nonparametric measures.

Table 3 Rank-based measures for wheat genotypes yield based on BLUP'S (2016-17)

Genotype	Yield	GAI	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
DBW187	46.81	46.07	3.61	1.75	0.486	3.50	2.05	3.08	14.48	1.70	1.50	7.48	1.94	3.72	1.78
HD3219	46.66	45.87	3.78	2.05	0.541	3.00	2.37	4.18	18.82	1.99	1.75	8.35	2.25	3.28	2.02
HD2733	46.91	46.03	3.78	2.49	0.658	3.50	2.86	6.18	27.82	2.42	2.22	10.59	2.63	3.72	2.42
K0307	47.10	46.67	4.00	1.91	0.477	4.50	2.20	3.65	15.50	1.86	1.56	7.00	2.21	4.22	1.93
DBW39	47.14	46.70	4.17	1.69	0.405	4.00	1.89	2.85	11.64	1.64	1.22	5.28	2.20	4.33	1.71
K1006	48.71	48.03	3.89	2.45	0.629	3.00	2.77	5.99	26.17	2.38	2.21	10.23	2.56	4.56	2.38
HD2967	46.38	45.74	4.72	1.78	0.376	5.00	2.01	3.15	11.35	1.73	1.45	5.53	2.05	4.17	1.72

Table 4 Rank-based measures for wheat genotypes corrected yield based on BLUP'S (2016-17)

Genotype														Z1	Z2
DBW187	0.477	3.50	2.06	3.15	14.40	1.73	1.50	7.25	1.99	0.429	0.122	0.478	0.570	0.742	0.929
HD3219	0.617	3.00	2.32	4.09	21.24	1.97	1.67	9.19	2.31	0.537	0.179	0.521	0.614	0.017	0.012
HD2733	0.650	3.50	2.79	5.86	26.76	2.35	2.17	10.48	2.55	0.619	0.177	0.623	0.739	3.679	4.483
K0307	0.456	4.50	2.25	3.71	14.95	1.87	1.67	7.11	2.10	0.370	0.082	0.468	0.562	0.020	0.107
DBW39	0.396	4.00	1.92	2.94	11.54	1.67	1.30	5.38	2.14	0.306	0.076	0.400	0.461	1.912	1.454
K1006	0.523	5.00	2.72	5.67	21.17	2.31	2.10	8.29	2.55	0.667	0.222	0.595	0.699	2.706	3.630
HD2967	0.414	4.00	2.01	2.97	12.12	1.67	1.41	6.08	1.99	0.278	0.056	0.355	0.425	1.124	1.374
E(S1)	2.29	Var(S1)	0.069											$\Sigma=10.20$	11.99
E(S2)	4.00	Var(S2)	0.77											$W=0.560$	$\chi^2 = 100.8$

MR = Mean of Rank; CMR = Corrected Mean of Rank; SD=Standard Deviation; CSD= Corrected Standard Deviation; CV= Coefficient of Variation; CCV= Corrected Coefficient of Variation; $S(i)$: Nassar & Huehn's (1987) non-parametric stability statistics; $NP(i)$: Thenararu's stability statistics; Z1 and Z2: the standard values of $S^{(1)}$ and $S^{(2)}$ respectively, for χ^2 test.

Z1 and Z2 values were calculated for each genotype, as per the ranks of adjusted yield, and then summed: Z_1 sum = 10.20 and Z_2 sum = 11.99 (Table 4). Both these statistics were distributed as χ^2 and were less than the critical value of χ^2 (0.05, 29) = 42.6. This indicated the non-significant differences among genotypes as per ranks of CS_i^1 and CS_i^2 measures (Kilic et al 2010). Moreover the no individual Z values more than the critical value of χ^2 (0.05, 1) = 3.84 as observed by Hameed et al., 2020.

3.1.2 Association analysis

Mean yield had expressed both positive and negative correlations with measures (Table 11). Highly significant positive correlation with GAI, MR, CMR measures and very weak relationships expressed with S_i^1 , S_i^2 , S_i^4 , S_i^5 , S_i^7 , CCV, CS_i^1 , CS_i^2 , CS_i^3 , CS_i^4 , CS_i^5 , CS_i^6 , CS_i^7 measures. GAI had a highly significant positive with MR & CMR only. Positive association of MR observed with CV, Med, CCV, CS_i^6 , $NP_i^{(3)}$ and $NP_i^{(4)}$ measures. SD & CV expressed highly significant positive correlations with measures. Med expressed only positive correlations with measures. Values of S_i^1 , S_i^2 , S_i^3 , S_i^4 , S_i^5 , S_i^6 , S_i^7 maintained direct relationships with exception of CMed. Measure CMR maintained highly significant negative with CMed and weak correlation with Z1 & Z2 values. CSD & CCV measures showed highly significant direct relationships with CS_i^1 , CS_i^2 , CS_i^3 , CS_i^4 , CS_i^5 , CS_i^6 , CS_i^7 , $NP_i^{(1)}$, $NP_i^{(2)}$, $NP_i^{(3)}$, $NP_i^{(4)}$. Weak and very weak relationships were observed for CMed measure. CS_i^1 , CS_i^2 , CS_i^3 , CS_i^4 , CS_i^5 , CS_i^6 , CS_i^7 had displayed highly significant to significant correlation with

other measures (Hameed et al., 2020). Similar behavior is managed by measures $NP_i^{(1)}$, $NP_i^{(2)}$, $NP_i^{(3)}$ and $NP_i^{(4)}$ as reported by Rasoli et al. (2015). Z1 & Z2, normalized forms of CS_i^1 & CS_i^2 measures, were related in negative manner.

3.1.3 Biplot graphical analysis

Biplot analysis of nonparametric measures had been carried out to explore any type of association among studied measures. Loadings of the first two principal components axes (PCA) of ranks of nonparametric measures were shown in figure 1 (Mohammadi et al., 2016). Two separate groups of Yield with GAI and MR with Med were displayed in the graphical analysis. Measure CV expressed close affinity with $NP_i^{(2)}$, $NP_i^{(3)}$ & $NP_i^{(4)}$, CCV, S_i^6 , CS_i^3 , CS_i^6 . Bigger cluster consisted of Z1, Z2, SD, CSD, $NP_i^{(1)}$, S_i^1 , S_i^2 , S_i^3 , S_i^4 , S_i^5 , S_i^7 , CS_i^1 , CS_i^4 , CS_i^5 , CS_i^7 measures.

3.1.4 Analytic analysis based on BLUE's

Maximum yield and GAI selected G6, G1, G4 genotypes while MR identified G5, G7, G4, and consistent performance of G4, G5, G2 judged by SD. Lower values of CV identified G4, G5, G7, and median settled for G5, G4, G7 genotypes (Table 5). S_i^1 favored G4, G5, G1 and S_i^2 for G4, G5, G1 whereas as per S_i^3 values G4, G5, G7 & S_i^4 found G4, G5, G1 as suitable genotypes and G4, G5, G2 by S_i^5 while as per S_i^6 values G5, G4, G7 were genotypes of choice. Lastly by S_i^7 , G4, G2, G1 would be of stable performance genotypes. CMR exhibited G6, G5, G7 as desirable ones and consistent yield would be of G4, G2, G5 by CSD values while

Figure 1 Biplot analysis of rank-based measures for wheat genotypes (2016-7) BLUP

Table 5 Rank-based measures for wheat genotypes yield based on BLUE'S (2016-17)

Genotype	Yield	GAI	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
DBW187	47.86	47.08	3.22	1.96	0.607	3.50	2.25	3.83	20.21	1.90	1.67	9.31	2.17	3.56	2.04
HD3219	46.60	45.75	3.78	1.96	0.518	3.00	2.26	3.83	17.24	1.90	1.64	7.82	2.20	3.72	1.87
HD2733	46.40	45.46	3.94	2.36	0.599	4.00	2.71	5.58	24.07	2.30	2.17	9.89	2.43	3.78	2.37
K0307	46.83	46.43	4.22	1.59	0.377	4.00	1.83	2.54	10.21	1.55	1.36	5.79	1.76	4.00	1.78
DBW39	46.29	45.73	4.78	1.83	0.384	5.00	2.00	3.36	11.95	1.78	1.41	5.30	2.25	4.39	1.88
K1006	49.20	48.53	3.56	2.09	0.589	3.50	2.44	4.38	20.94	2.03	1.78	9.00	2.33	4.56	2.15
HD2967	46.52	45.69	4.39	2.03	0.463	4.00	2.37	4.13	16.01	1.98	1.77	7.24	2.21	4.00	2.06

Table 6: Rank-based measures for wheat genotypes corrected yield based on BLUE'S (2016-17)

Genotype	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⁾	Z1	Z2
DBW187	0.573	4.00	2.37	4.14	19.81	1.98	1.72	8.69	2.28	0.476	0.136	0.614	0.734	0.093	0.027
HD3219	0.503	3.00	2.10	3.51	16.01	1.82	1.55	7.49	2.14	0.463	0.154	0.482	0.555	0.508	0.316
HD2733	0.626	3.50	2.73	5.59	25.18	2.30	2.11	10.06	2.50	0.528	0.132	0.583	0.693	2.872	3.298
K0307	0.446	4.00	2.08	3.18	13.50	1.73	1.44	6.50	2.08	0.361	0.090	0.410	0.492	0.619	0.879
DBW39	0.429	5.00	2.11	3.55	13.73	1.83	1.46	5.97	2.30	0.278	0.056	0.383	0.442	0.440	0.268
K1006	0.472	5.00	2.46	4.61	17.22	2.09	1.77	6.98	2.47	0.476	0.136	0.587	0.691	0.426	0.489
HD2967	0.514	3.50	2.38	4.24	18.00	2.00	1.78	8.00	2.25	0.444	0.111	0.456	0.542	0.126	0.072
χ^2 (0.05, 29)						42.6	W =	0.447	χ^2 =	80.5	χ^2 (0.05, 1) = 3.84			Σ =5.08	5.35

CCV pointed for G5, G4, G6, and CMed for G2, G3, G7 wheat genotypes (Table 6). Genotypes G4, G2, G5 mentioned by CS_i¹ and CS_i² found G4, G5, G2 as suitable genotypes; CS_i³ & CS_i⁴ settled for G4, G2, G5 genotypes while G4, G5, G2 selected by CS_i⁵ values & CS_i⁶ settled for G6, G5, G4. Lastly, CS_i⁷ pointed towards G5, G2, G7 as genotypes of choice. Values of NP_i^(s) identified G5, G4, G7 wheat genotypes for considered locations of the zone. Measure Z1 selected G1, G7, G6 while for Z2 genotypes G1, G7, G5 would be of choice.

Calculated values of Kendall's coefficient of concordance W = 0.45 and values of χ^2 statistics = 80.5 was less than the critical value. Values of Z₁ sum = 5.08 and Z₂ sum = 5.35 were less than the critical value of χ^2 (0.05, 29) = 42.6. This indicated the non-significant differences among genotypes as per the ranks of CS_i⁽¹⁾ and CS_i⁽²⁾ measures. However, individual Z values showed HD3043 & MACS6677 were significantly unstable (Table 6).

3.1.5 Association analysis

Spearman's rank correlation analysis among all possible pairs of considered measures was tabulated. The yield had expressed

significant positive relation with GAI and negative correlations were seen with most measures (Table 12). Significant indirect relations of GAI were observed with MR, Med. Significant positive correlations were expressed by SD and CV measures, while weak negative with CMed, Z1, Z2. Med had a highly significant positive with NP_i⁽²⁾. Measures S_i¹, S_i², S_i³, S_i⁴, S_i⁵, S_i⁶, S_i⁷ maintained direct relationships with measures exception of CMed and Z1 only. CMR maintained significant positive to moderate positive with measures. Highly significant direct relationships shown by CSD & CCV with CS_i¹, CS_i², CS_i³, CS_i⁴, CS_i⁵, CS_i⁶, CS_i⁷, NP_i⁽¹⁾, NP_i⁽²⁾, NP_i⁽³⁾ & NP_i⁽⁴⁾ measures. Weak and highly significant positive relationships were observed for values of CMed measure. CS_i¹, CS_i², CS_i³, CS_i⁴, CS_i⁵, CS_i⁶, CS_i⁷ measures had displayed highly significant to significant direct correlations (Table 12). The same nature of relations was also expressed by NP_i⁽¹⁾, NP_i⁽²⁾, NP_i⁽³⁾ and NP_i⁽⁴⁾ measure. Z1 was negatively related to Z2.

3.1.6 Biplot graphical analysis

Loadings of the first two principal components axes (PCA) of ranks of nonparametric measures were shown in figure 2. Both

Table 7 Rank-based measures for wheat genotypes yield based on BLUP'S (2017-18)

Genotype	Yield	GAI	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
DBW233	44.02	43.28	8.69	3.33	0.383	8.00	3.92	11.06	15.27	3.20	2.75	4.11	3.72	7.62	3.15
HD3249	46.11	45.28	5.77	4.94	0.855	6.00	5.54	24.36	50.67	4.74	3.79	8.53	5.94	8.15	4.78
HD3254	44.12	43.58	8.77	3.98	0.454	10.00	4.56	15.86	21.70	3.83	3.21	4.75	4.56	8.23	4.15
DBW221	44.00	43.39	9.08	3.80	0.418	9.00	4.38	14.41	19.05	3.65	3.01	4.31	4.43	7.92	3.86
K1601	43.98	43.39	7.77	5.13	0.661	8.00	6.03	26.36	40.71	4.93	4.40	7.37	5.53	6.77	5.09
PBW769	44.17	43.59	8.85	4.76	0.538	8.00	5.49	22.64	30.71	4.57	4.12	6.05	5.07	8.00	5.26
DBW187	43.90	43.53	8.92	4.39	0.492	10.00	5.03	19.24	25.88	4.21	3.48	5.07	5.11	7.77	4.27
DBW223	45.41	44.84	7.85	5.40	0.688	11.00	6.21	29.14	44.57	5.19	4.93	8.18	5.45	8.77	5.13
PBW762	45.38	44.98	7.85	4.10	0.523	7.00	4.82	16.81	25.71	3.94	3.53	5.84	4.40	9.23	4.15
WH1218	42.86	42.42	8.54	5.13	0.600	6.00	5.90	26.27	36.92	4.92	4.73	7.21	5.12	6.00	5.39
K1006	44.40	43.75	8.92	4.11	0.461	10.00	4.77	16.91	22.74	3.95	3.34	4.86	4.68	8.69	4.59
HD2733	46.66	46.02	5.31	3.59	0.677	4.00	3.97	12.90	29.16	3.45	2.89	7.07	4.12	8.38	4.03
DBW39	44.98	44.34	7.62	2.99	0.392	7.00	3.26	8.92	14.06	2.87	2.14	3.66	3.85	8.62	2.87
HD2967	44.32	43.62	7.77	4.83	0.622	9.00	5.67	23.36	36.08	4.64	3.98	6.65	5.42	7.77	4.55
K0307	44.45	43.71	8.23	4.04	0.491	8.00	4.77	16.36	23.85	3.89	3.33	5.25	4.54	8.08	4.27

Figure 2 Biplot analysis of rank-based measures for wheat genotypes (2016-17) BLUE

significant PAC's accounting for 80.2% of the variance of the original variables. Two separate groups of Yield with GAI and MR with Med were displayed. Measure CV expressed close affinity with NP_i⁽²⁾, NP_i⁽³⁾, NP_i⁽⁴⁾, S_i³, S_i⁶ measures. Largest group consisted of Z1, Z2, SD, CSD, CCV, S_i¹, S_i², S_i⁴, S_i⁵, S_i⁷, CS_i¹, CS_i², CS_i³, CS_i⁴, CS_i⁵, CS_i⁶, CS_i⁷ measures.

3.2 Second year of study

3.2.1 Analytic measures based on BLUP's (2017-18)

The mean yield of genotypes showed G12 was the highest yielding with 46.7q/ha followed by G2 and G8, with remarkable differences among the studied genotypes (Table 7). GAI selected G12, G2, and

Table 7 Rank-based measures for wheat genotypes yield based on BLUP'S (2017-18)

Genotype	Yield	GAI	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
DBW233	44.02	43.28	8.69	3.33	0.383	8.00	3.92	11.06	15.27	3.20	2.75	4.11	3.72	7.62	3.15
HD3249	46.11	45.28	5.77	4.94	0.855	6.00	5.54	24.36	50.67	4.74	3.79	8.53	5.94	8.15	4.78
HD3254	44.12	43.58	8.77	3.98	0.454	10.00	4.56	15.86	21.70	3.83	3.21	4.75	4.56	8.23	4.15
DBW221	44.00	43.39	9.08	3.80	0.418	9.00	4.38	14.41	19.05	3.65	3.01	4.31	4.43	7.92	3.86
K1601	43.98	43.39	7.77	5.13	0.661	8.00	6.03	26.36	40.71	4.93	4.40	7.37	5.53	6.77	5.09
PBW769	44.17	43.59	8.85	4.76	0.538	8.00	5.49	22.64	30.71	4.57	4.12	6.05	5.07	8.00	5.26
DBW187	43.90	43.53	8.92	4.39	0.492	10.00	5.03	19.24	25.88	4.21	3.48	5.07	5.11	7.77	4.27
DBW223	45.41	44.84	7.85	5.40	0.688	11.00	6.21	29.14	44.57	5.19	4.93	8.18	5.45	8.77	5.13
PBW762	45.38	44.98	7.85	4.10	0.523	7.00	4.82	16.81	25.71	3.94	3.53	5.84	4.40	9.23	4.15
WH1218	42.86	42.42	8.54	5.13	0.600	6.00	5.90	26.27	36.92	4.92	4.73	7.21	5.12	6.00	5.39
K1006	44.40	43.75	8.92	4.11	0.461	10.00	4.77	16.91	22.74	3.95	3.34	4.86	4.68	8.69	4.59
HD2733	46.66	46.02	5.31	3.59	0.677	4.00	3.97	12.90	29.16	3.45	2.89	7.07	4.12	8.38	4.03
DBW39	44.98	44.34	7.62	2.99	0.392	7.00	3.26	8.92	14.06	2.87	2.14	3.66	3.85	8.62	2.87
HD2967	44.32	43.62	7.77	4.83	0.622	9.00	5.67	23.36	36.08	4.64	3.98	6.65	5.42	7.77	4.55
K0307	44.45	43.71	8.23	4.04	0.491	8.00	4.77	16.36	23.85	3.89	3.33	5.25	4.54	8.08	4.27

Table 8 Rank-based measures for wheat genotypes corrected yield based on BLUP'S (2017-18)

Genotype	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⁾	Z1	Z2
DBW233	0.414	7.00	3.54	9.92	15.64	3.03	2.45	4.18	3.74	2.31	0.288	0.348	0.407	4.10	2.98
HD3249	0.586	8.00	5.64	22.81	33.57	4.59	4.01	6.40	5.25	4.00	0.667	0.795	0.978	0.87	0.67
HD3254	0.504	10.00	4.82	17.19	25.07	3.98	3.60	5.68	4.41	3.46	0.346	0.454	0.550	0.05	0.08
DBW221	0.487	9.00	4.49	14.91	22.58	3.71	3.31	5.44	4.15	3.23	0.359	0.409	0.494	0.48	0.55
K1601	0.751	6.00	5.87	25.86	45.84	4.89	4.33	8.32	5.51	4.15	0.519	0.629	0.756	1.58	2.02
PBW769	0.657	6.00	5.97	27.67	41.50	5.05	4.62	7.50	5.53	4.31	0.538	0.571	0.675	1.96	3.16
DBW187	0.549	8.00	5.03	18.19	28.10	4.10	3.51	5.88	4.78	3.46	0.346	0.459	0.563	0.00	0.01
DBW223	0.585	11.00	5.95	26.36	36.07	4.93	4.56	6.75	5.34	4.38	0.399	0.629	0.758	1.86	2.31
PBW762	0.449	10.00	4.79	17.19	22.35	3.98	3.60	5.07	4.41	3.54	0.505	0.508	0.611	0.07	0.08
WH1218	0.898	4.00	6.10	29.00	58.00	5.17	4.62	10.00	5.80	4.31	0.718	0.606	0.715	2.50	4.17
K1006	0.528	10.00	5.36	21.06	29.08	4.41	3.76	5.63	5.17	3.62	0.362	0.494	0.601	0.29	0.22
HD2733	0.481	8.00	4.77	16.26	23.27	3.87	3.18	4.94	4.71	3.15	0.788	0.730	0.899	0.09	0.23
DBW39	0.334	8.00	3.31	8.26	11.50	2.76	2.20	3.32	3.46	2.15	0.308	0.363	0.434	5.52	4.23
HD2967	0.585	8.00	5.33	20.69	31.96	4.37	3.63	6.08	5.26	3.62	0.402	0.563	0.686	0.25	0.16
K0307	0.529	9.00	5.05	18.24	27.10	4.10	3.46	5.56	4.87	3.38	0.423	0.499	0.614	0.01	0.01
E(S1)	4.98	Var(S1)	0.506											Σ=19.62	20.89
E(S2)	18.67	Var(S2)	25.62	W =	0.514	χ ² =	215.7	χ ² (0.05, 29)	42.6	χ ² (0.05, 1)	= 3.84				

G9 as desirable genotypes. MR pointed towards G4, G7, G11 and SD settled for G13, G1, G12, whereas CV for G1, G13, G4 as stable genotypes, while G12, G2 based on MR, G8, G5 based on SD and G2, G8 based on CV, were most unstable wheat genotypes for studied locations of this zone. G13, G1, G12 were the stable genotypes as per values of S_i¹, S_i², S_i³, S_i⁴, S_i⁵, S_i⁶, and S_i⁷, however

G8, G5 would be genotypes of unstable yield. CMR selected G9, G8 & G11; CSD observed suitability of G13, G1 & G4 and G13, G1 & G9 were the stable genotypes by CCV. Genotypes G8, G9, G11 favoured by CMed criterion. CS_i¹, CS_i², CS_i³, CS_i⁴, CS_i⁵, CS_i⁶, and CS_i⁷ values pointed for G13, G1, G4 as stable genotypes, and G10, G6 would be undesirable ones (Table 8). NP_i⁽¹⁾ selected G13,

G1, G12; while measures $NP_1^{(2)}$, $NP_1^{(3)}$, $NP_1^{(4)}$ pointed towards G1, G13, G4 as desirable wheat genotypes at the same time reflected G2 & G12 would not be able to express stable yield performance for the locations of this zone. Values of Z1 found G7, G15, G3 whereas G15, G7, G3 would be genotypes of choice as per Z2.

Values of $W = 0.51$ and χ^2 statistic = 215.7 showed an overall dissimilarity among ranking of genotypes as per considered non parametric measures (Table 8). Values of Z_1 sum = 19.6 and Z_2 sum = 20.9 were less than the critical value of χ^2 (0.05, 29) = 42.6. This indicated the non-significant differences among ranks as per $CS_1^{(1)}$ and $CS_1^{(2)}$ measures. Genotypes DBW233, WH1218, DBW39 expressed values more than the critical value of χ^2 (0.05, 1) = 3.84 to show the unstable performance.

3.2.2 Association analysis

Significant positive Spearman's rank correlation of Yield observed with GAI, CMR while negative with MR, CV, $NP_1^{(3)}$, and $NP_1^{(4)}$ measures (Table 13). GAI showed mostly negative correlations with measures. MR expressed weak, moderate and significant positive relationships. SD and CV had maintained highly significant positive and weak negative correlations. More degree of positive as compared to negative correlation expressed by Med. Measures S_1^1 , S_2^2 , S_3^3 , S_4^4 , S_5^5 , S_6^6 , S_7^7 maintained direct relationships as evident with positive values. CMR, CSD, CCV & CMed had developed only direct relationships with one or two exceptions.

Highly significant, significant, and moderate positive correlations had seen for CS_1^1 , CS_2^2 , CS_3^3 , CS_4^4 , CS_5^5 , CS_6^6 , CS_7^7 measures. Highly significant and significant direct relationships were achieved by $NP_1^{(1)}$, $NP_1^{(2)}$, $NP_1^{(3)}$, and $NP_1^{(4)}$. A weak negative correlation was observed between Z1 and Z2 values.

3.2.3 Biplot graphical analysis

The first two principal components axes (PCA) contributed more than 80% of the variance of the original variables. Biplot analysis of nonparametric measures had displayed five clusters in figure 3. Three separate clusters each of two measures were observed as Yield with GAI, MR with Med, and CMR with CMed. $NP_1^{(2)}$, $NP_1^{(3)}$, $NP_1^{(4)}$, S_1^6 & S_1^3 expressed close affinity with CV measure. Largest cluster comprised of SD, CSD, CCV, $NP_1^{(1)}$, S_1^1 , S_2^2 , S_4^4 , S_5^5 , S_7^7 , CS_1^1 , CS_2^2 , CS_3^3 , CS_4^4 , CS_5^5 , CS_6^6 , CS_7^7 measures.

3.2.4 Analytic measures based on BLUE's (2017-18)

Genotype G12 was the highest yielding (48.9q/ha) followed by G2 and G9 (Table 9). GAI values pointed for G12, G3, and G9 genotypes. MR identified G11, G4, G15 and G13, G1, G4 selected as per SD whereas CV found G4, G13, G1 as stable genotypes. Genotypes G10, G5 as per MR, G1, G10 based on SD and G2, G5 by values of CV, would be of unstable yield. S_1^1 , S_2^2 , S_3^3 , S_4^4 , S_5^5 , S_6^6 , and S_7^7 observed maximum yield achievable by G13, G1, G4 genotypes, however G5, G10 would show inconsistency yield.

Figure 3 Biplot analysis of rank-based measures for wheat genotypes (2017-18) BLUP

Table 9 Rank-based measures for wheat genotypes yield based on BLUE'S (2017-18)

Genotype	Yield	GAI	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
DBW233	45.65	44.89	8.54	3.31	0.387	8.00	3.82	10.94	15.37	3.18	2.51	3.82	4.02	7.69	3.33
HD3249	48.31	47.84	5.62	4.52	0.805	5.00	5.10	20.42	43.64	4.34	3.43	7.95	5.49	7.77	4.62
HD3254	46.15	45.54	8.08	3.86	0.478	9.00	4.54	14.91	22.15	3.71	3.15	5.07	4.37	8.08	3.88
DBW221	45.62	45.23	9.31	3.47	0.373	9.00	3.95	12.06	15.55	3.34	2.64	3.69	4.22	8.15	3.85
K1601	45.49	45.17	7.54	5.24	0.695	6.00	6.08	27.44	43.67	5.03	4.58	7.90	5.53	6.85	5.21
PBW769	46.31	45.83	8.15	5.11	0.627	8.00	5.92	26.14	38.47	4.91	4.34	6.92	5.56	7.62	5.08
DBW187	46.19	45.72	8.15	3.91	0.480	8.00	4.59	15.31	22.53	3.76	3.09	4.92	4.57	7.92	4.07
DBW223	47.54	46.83	8.08	4.89	0.605	11.00	5.62	23.91	35.52	4.70	4.38	7.05	5.04	9.00	5.21
PBW762	47.58	47.20	7.54	4.58	0.607	6.00	5.38	20.94	33.33	4.40	4.12	7.10	4.69	8.77	4.40
WH1218	44.87	44.23	8.15	5.15	0.631	6.00	6.05	26.47	38.96	4.94	4.47	7.13	5.46	6.77	5.33
K1006	45.74	45.24	9.69	4.11	0.424	11.00	4.67	16.90	20.92	3.95	3.15	4.22	4.95	8.69	4.31
HD2733	48.88	48.38	6.08	4.11	0.677	5.00	4.74	16.91	33.39	3.95	3.33	7.11	4.69	8.31	4.33
DBW39	46.72	46.19	8.15	3.11	0.381	7.00	3.54	9.64	14.19	2.98	2.37	3.77	3.76	8.38	3.45
HD2967	46.28	45.55	7.92	4.39	0.554	9.00	5.18	19.24	29.15	4.21	3.62	5.94	4.91	7.77	4.69
K0307	45.91	45.19	8.85	4.88	0.552	10.00	5.77	23.81	32.30	4.69	4.04	5.93	5.45	8.23	4.40

Table 10 Rank-based measures for wheat genotypes corrected yield based on BLUE'S (2017-18)

Genotype	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⁾	Z1	Z2
DBW233	0.43	7.00	3.79	11.06	17.26	3.20	2.54	4.30	4.01	2.38	0.298	0.374	0.444	2.77	2.26
HD3249	0.59	8.00	5.46	21.36	32.99	4.44	3.79	6.34	5.21	3.77	0.754	0.791	0.973	0.46	0.28
HD3254	0.48	9.00	4.56	15.08	22.40	3.73	3.30	5.31	4.22	3.23	0.359	0.462	0.565	0.34	0.50
DBW221	0.47	9.00	4.44	14.81	21.79	3.70	3.22	5.13	4.25	3.15	0.350	0.397	0.477	0.58	0.58
K1601	0.76	5.00	6.00	27.14	47.57	5.01	4.45	8.45	5.63	4.31	0.718	0.664	0.796	2.07	2.80
PBW769	0.67	6.00	5.74	25.76	40.59	4.88	4.30	7.33	5.53	4.08	0.510	0.598	0.704	1.16	1.96
DBW187	0.51	8.00	4.72	16.58	25.11	3.91	3.31	5.44	4.62	3.31	0.413	0.480	0.579	0.13	0.17
DBW223	0.58	11.00	6.00	27.17	36.22	5.01	4.62	6.67	5.43	4.31	0.392	0.620	0.743	2.07	2.82
PBW762	0.50	9.00	5.08	19.36	26.49	4.23	3.94	5.84	4.53	3.92	0.654	0.561	0.673	0.02	0.02
WH1218	0.79	5.00	6.21	28.36	50.27	5.12	4.64	8.91	5.64	4.38	0.731	0.627	0.761	2.98	3.67
K1006	0.50	10.00	4.85	18.56	25.63	4.14	3.30	4.94	5.19	3.00	0.273	0.427	0.500	0.03	0.00
HD2733	0.52	9.00	5.13	18.73	27.06	4.16	3.51	5.50	4.92	3.46	0.692	0.684	0.844	0.04	0.00
DBW39	0.41	8.00	4.05	11.92	17.06	3.32	2.72	4.22	4.04	2.69	0.385	0.407	0.497	1.70	1.77
HD2967	0.60	8.00	5.56	22.03	34.02	4.51	3.79	6.34	5.37	3.77	0.419	0.569	0.702	0.68	0.44
K0307	0.53	8.00	5.18	19.36	28.22	4.23	3.48	5.50	5.14	3.46	0.346	0.478	0.586	0.08	0.02
				χ^2 (0.05, 29)	42.6	W =	0.581					$\chi^2 =$ 244.1	χ^2 (0.05, 1) = 3.84	$\Sigma = 15.11$	17.30

Genotypes G8, G9 & G11 settled by CMR values, CSD found G1, G13 & G4 as genotypes of consistent yield and G13, G1 & G4 were of stable performance as per CCV. Genotypes G8, G11, G12 favored by CMed values. CS_i¹, CS_i², CS_i³, CS_i⁴, CS_i⁵, CS_i⁶, CS_i⁷ measures identified G1, G13, G4 as stable genotypes

(table 10). NP_i⁽¹⁾ selected G1, G13, G11; while measure NP_i⁽²⁾ settled for G13, G1, G15, and last two NP_i⁽³⁾, NP_i⁽⁴⁾ pointed towards G1, G4, G13 as desirable wheat genotypes. Z1 observed suitability of G9, G11, G12 whereas G13, G12, G9 would be genotypes of choice as per Z2.

Table 11 Spearman's rank correlation coefficient values among nonparametric measures as per BLUP's (2016-17)

	GAI	MR	SD	CV	Med	S ₁ ¹	S ₁ ²	S ₁ ³	S ₁ ⁴	S ₁ ⁵	S ₁ ⁶	S ₁ ⁷	CMR	CSD	CCV	CMed	CS ₁ ¹	CS ₁ ²	CS ₁ ³	CS ₁ ⁴	CS ₁ ⁵	CS ₁ ⁶	CS ₁ ⁷	NP ₁ ⁽¹⁾	NP ₁ ⁽²⁾	NP ₁ ⁽³⁾	NP ₁ ⁽⁴⁾	ZI	Z2	
Yield	0.964	0.89	-0.107	-0.286	-0.143	-0.179	-0.107	-0.357	-0.107	-0.179	-0.107	-0.393	0.804	-0.179	0.071	-0.571	-0.179	0.000	-0.179	0.000	-0.179	0.071	-0.429	-0.393	-0.321	-0.286	-0.286	-0.286	-0.464	-0.464
GAI	1.000	0.81	0.071	-0.179	-0.143	-0.036	0.071	-0.214	0.071	-0.036	0.000	-0.179	0.804	-0.036	0.179	-0.571	-0.036	-0.036	0.143	-0.036	-0.036	0.179	-0.214	-0.321	-0.286	-0.179	-0.179	-0.321	-0.321	-0.321
MR	1.000	0.304	0.696	0.696	0.518	0.304	0.554	0.304	0.518	0.661	0.161	0.536	0.518	0.696	0.696	-0.411	0.518	0.554	0.518	0.518	0.696	0.125	0.661	0.661	0.696	0.696	0.696	-0.054	-0.054	-0.054
SD	1.000	0.821	0.536	0.964	1.000	0.893	1.000	0.893	1.000	0.964	0.893	0.893	0.196	0.964	0.857	-0.036	0.964	0.929	0.964	0.964	0.964	0.857	0.786	0.786	0.714	0.821	0.821	0.821	0.321	0.321
CV	1.000	0.786	0.929	0.821	0.964	0.821	0.964	0.821	0.929	0.964	0.821	0.929	0.786	0.232	0.929	-0.214	0.929	0.929	0.893	0.929	0.929	0.929	0.750	0.964	0.893	1.000	1.000	0.357	0.357	
Med	1.000	0.643	0.536	0.714	0.536	0.643	0.714	0.536	0.643	0.643	0.643	0.643	0.304	0.643	0.714	-0.143	0.643	0.643	0.643	0.643	0.643	0.714	0.607	0.857	0.929	0.786	0.786	0.143	0.143	
S ₁ ¹	1.000	0.964	0.964	0.964	1.000	0.964	1.000	0.964	1.000	0.964	1.000	0.964	0.857	0.232	1.000	0.929	-0.107	1.000	1.000	1.000	1.000	0.929	0.750	0.893	0.821	0.929	0.929	0.286	0.286	
S ₁ ²	1.000	0.893	1.000	0.964	0.893	1.000	0.964	0.893	1.000	0.964	0.893	0.893	0.196	0.964	0.857	-0.036	0.964	0.929	0.964	0.964	0.964	0.857	0.786	0.786	0.714	0.821	0.821	0.821	0.321	0.321
S ₁ ³	1.000	0.893	0.964	0.929	0.893	0.161	0.964	0.893	-0.107	0.964	0.964	0.929	0.964	0.929	0.964	0.964	0.929	0.964	0.964	0.964	0.964	0.857	0.786	0.786	0.714	0.821	0.929	0.857	0.964	0.321
S ₁ ⁴	1.000	0.964	0.893	0.196	0.964	0.857	-0.036	0.964	0.964	0.929	0.964	0.929	0.964	0.929	0.964	0.964	0.929	0.964	0.964	0.964	0.964	0.857	0.786	0.786	0.714	0.821	0.821	0.821	0.321	0.321
S ₁ ⁵	1.000	0.964	0.857	0.232	1.000	0.929	-0.107	1.000	1.000	0.964	1.000	1.000	0.964	0.929	0.964	0.964	0.929	0.964	0.964	0.964	0.964	0.964	0.964	0.679	0.929	0.857	0.964	0.964	0.321	0.321
S ₁ ⁶	1.000	0.750	0.304	0.964	0.964	-0.214	0.964	0.964	0.964	0.929	0.964	0.964	0.929	0.964	0.964	-0.214	0.964	0.964	0.929	0.964	0.964	0.964	0.964	0.679	0.929	0.857	0.964	0.964	0.321	0.321
S ₁ ⁷	1.000	0.018	0.857	0.714	0.036	0.857	0.857	0.857	0.857	0.857	0.857	0.857	0.018	0.857	0.714	0.036	0.857	0.857	0.821	0.857	0.857	0.714	0.964	0.750	0.679	0.786	0.786	0.429	0.429	
CMR	1.000	0.232	0.518	-0.768	0.232	0.232	0.446	0.232	0.232	0.232	0.232	0.446	0.232	0.518	-0.018	0.089	0.161	0.232	0.232	0.232	0.232	0.518	-0.018	0.089	0.161	0.232	0.232	-0.411	-0.411	
CSD	1.000	0.929	-0.107	1.000	1.000	0.964	1.000	0.964	1.000	0.964	1.000	0.964	0.857	0.232	1.000	0.929	-0.107	1.000	1.000	1.000	1.000	0.929	0.750	0.893	0.821	0.929	0.929	0.286	0.286	
CCV	1.000	-0.429	0.929	0.929	0.964	0.929	0.964	0.929	0.964	0.929	0.964	0.929	0.964	0.929	0.964	0.929	0.964	0.929	0.964	0.929	0.964	0.929	1.000	0.643	0.857	0.821	0.929	0.929	0.143	0.143
CMed	1.000	-0.107	-0.107	-0.321	-0.107	-0.321	-0.107	-0.321	-0.107	-0.321	-0.107	-0.321	-0.107	-0.321	-0.107	-0.321	-0.107	-0.321	-0.107	-0.321	-0.107	-0.321	-0.429	0.000	-0.071	-0.143	-0.214	-0.214	0.393	0.393
CS ₁ ¹	1.000	0.964	1.000	0.964	1.000	0.964	1.000	0.964	1.000	0.964	1.000	0.964	0.857	0.232	1.000	0.929	-0.107	1.000	1.000	1.000	1.000	0.929	0.750	0.893	0.821	0.929	0.929	0.286	0.286	
CS ₁ ²	1.000	0.964	1.000	0.964	1.000	0.964	1.000	0.964	1.000	0.964	1.000	0.964	0.857	0.232	1.000	0.929	-0.107	1.000	1.000	1.000	1.000	0.929	0.750	0.893	0.821	0.929	0.929	0.286	0.286	
CS ₁ ³	1.000	0.964	1.000	0.964	1.000	0.964	1.000	0.964	1.000	0.964	1.000	0.964	0.857	0.232	1.000	0.929	-0.107	1.000	1.000	1.000	1.000	0.929	0.750	0.893	0.821	0.929	0.929	0.286	0.286	
CS ₁ ⁴	1.000	0.964	1.000	0.964	1.000	0.964	1.000	0.964	1.000	0.964	1.000	0.964	0.857	0.232	1.000	0.929	-0.107	1.000	1.000	1.000	1.000	0.929	0.750	0.893	0.821	0.929	0.929	0.286	0.286	
CS ₁ ⁵	1.000	0.929	0.750	0.893	0.821	0.929	0.750	0.893	0.821	0.929	0.750	0.893	0.821	0.929	0.750	0.893	0.821	0.929	0.750	0.893	0.821	0.929	0.750	0.893	0.821	0.929	0.929	0.286	0.286	
CS ₁ ⁶	1.000	0.643	0.536	0.714	0.536	0.643	0.714	0.536	0.643	0.643	0.643	0.643	0.304	0.643	0.714	-0.143	0.643	0.643	0.643	0.643	0.643	0.714	0.607	0.857	0.929	0.786	0.786	0.143	0.143	
CS ₁ ⁷	1.000	0.714	0.643	0.536	0.714	0.643	0.536	0.714	0.643	0.643	0.643	0.643	0.304	0.643	0.714	-0.143	0.643	0.643	0.643	0.643	0.643	0.714	0.607	0.857	0.929	0.786	0.786	0.143	0.143	
NP ₁ ⁽¹⁾	1.000	0.964	1.000	0.964	1.000	0.964	1.000	0.964	1.000	0.964	1.000	0.964	0.857	0.232	1.000	0.929	-0.107	1.000	1.000	1.000	1.000	0.929	0.750	0.893	0.821	0.929	0.929	0.286	0.286	
NP ₁ ⁽²⁾	1.000	0.964	1.000	0.964	1.000	0.964	1.000	0.964	1.000	0.964	1.000	0.964	0.857	0.232	1.000	0.929	-0.107	1.000	1.000	1.000	1.000	0.929	0.750	0.893	0.821	0.929	0.929	0.286	0.286	
NP ₁ ⁽³⁾	1.000	0.964	1.000	0.964	1.000	0.964	1.000	0.964	1.000	0.964	1.000	0.964	0.857	0.232	1.000	0.929	-0.107	1.000	1.000	1.000	1.000	0.929	0.750	0.893	0.821	0.929	0.929	0.286	0.286	
NP ₁ ⁽⁴⁾	1.000	0.964	1.000	0.964	1.000	0.964	1.000	0.964	1.000	0.964	1.000	0.964	0.857	0.232	1.000	0.929	-0.107	1.000	1.000	1.000	1.000	0.929	0.750	0.893	0.821	0.929	0.929	0.286	0.286	
ZI	1.000	-0.607	-0.607	-0.607	-0.607	-0.607	-0.607	-0.607	-0.607	-0.607	-0.607	-0.607	-0.607	-0.607	-0.607	-0.607	-0.607	-0.607	-0.607	-0.607	-0.607	-0.607	-0.607	-0.607	-0.607	-0.607	-0.607	-0.607	-0.607	-0.607

Critical values of Spearman's correlation coefficients are 0.648 & 0.794 at 5 & 1 % levels of significance

Table 12 Spearman's rank correlation coefficient values among nonparametric measures as per BLUE's (2016-17)

Table 12: Spearman's Rank Correlation Coefficient values among non-parametric measures as per B2012-3 (2010-17)																													
	GAI	MR	SD	CV	Med	S ₁ ¹	S ₁ ²	S ₁ ³	S ₁ ⁴	S ₁ ⁵	S ₁ ⁶	S ₁ ⁷	CMR	CSD	CCV	CMed	CS ₁ ¹	CS ₁ ²	CS ₁ ³	CS ₁ ⁴	CS ₁ ⁵	CS ₁ ⁶	CS ₁ ⁷	NP ₁ ⁽¹⁾	NP ₁ ⁽²⁾	NP ₁ ⁽³⁾	NP ₁ ⁽⁴⁾	ZI	Z2
Yield	0.893	-0.786	-0.071	-0.321	-0.714	0.000	-0.054	-0.214	-0.054	-0.071	-0.321	0.357	-0.054	0.036	-0.036	-0.268	0.036	0.036	0.000	0.036	0.071	-0.036	0.179	-0.482	-0.696	-0.643	-0.464	0.393	0.071
GAI	1.000	-0.643	0.214	-0.143	-0.643	0.286	0.232	0.000	0.232	0.214	-0.036	0.393	0.089	0.250	0.321	-0.554	0.250	0.286	0.250	0.393	0.321	0.179	-0.196	-0.518	-0.429	-0.214	0.429	0.179	
MR	1.000	0.357	0.786	0.750	0.286	0.411	0.643	0.411	0.357	0.750	-0.107	0.482	0.214	0.464	-0.125	0.214	0.214	0.429	0.214	0.214	0.464	0.143	0.768	0.875	0.929	0.857	-0.286	-0.071	
SD	1.000	0.714	0.036	0.964	0.982	0.893	0.982	0.893	0.982	1.000	0.786	0.750	0.018	0.964	0.714	-0.196	0.964	0.964	0.857	0.964	0.964	0.714	0.750	0.804	0.375	0.643	0.679	-0.071	0.179
CV	1.000	0.429	0.607	0.732	0.893	0.732	0.714	0.929	0.321	0.554	0.643	0.786	-0.196	0.643	0.643	0.857	0.643	0.643	0.857	0.643	0.786	0.571	0.911	0.696	0.929	0.964	-0.286	-0.143	
Med	1.000	0.107	0.161	0.321	0.893	0.357	-0.286	0.411	-0.179	0.143	-0.554	-0.179	0.036	-0.179	-0.071	0.143	-0.250	0.339	0.875	0.571	0.464	-0.321	-0.250						
S ₁ ¹	1.000	0.982	0.857	0.982	0.964	0.714	0.786	-0.018	0.893	0.643	-0.339	0.893	0.893	0.643	-0.339	0.893	0.893	0.750	0.893	0.929	0.643	0.679	0.732	0.411	0.536	0.571	0.071	0.286	
S ₁ ²	1.000	0.911	1.000	0.982	0.804	0.732	0.107	0.911	0.732	-0.286	0.911	0.911	0.839	0.911	0.946	0.732	0.696	0.821	0.500	0.661	0.696	-0.018	0.196						
S ₁ ³	1.000	0.911	0.893	0.929	0.643	0.268	0.821	0.714	-0.196	0.821	0.821	0.821	0.821	0.821	0.821	0.786	0.714	0.750	0.946	0.625	0.821	0.857	0.000	0.214					
S ₁ ⁴	1.000	0.982	0.804	0.732	0.107	0.911	0.732	-0.286	0.911	0.911	0.839	0.911	0.946	0.732	0.696	0.821	0.500	0.661	0.696	-0.018	0.196								
S ₁ ⁵	1.000	0.786	0.750	0.018	0.964	0.714	-0.196	0.964	0.964	0.857	0.964	0.964	0.857	0.964	0.964	0.714	0.750	0.804	0.375	0.643	0.679	-0.071	0.179						
S ₁ ⁶	1.000	0.357	0.518	0.679	0.857	0.857	-0.339	0.679	0.679	0.679	0.857	0.857	0.679	0.714	0.857	0.536	0.982	0.661	0.893	0.964	0.000	0.179							
S ₁ ⁷	1.000	-0.375	0.821	0.214	0.089	0.821	0.821	0.464	0.821	0.464	0.821	0.679	0.214	0.893	0.375	-0.054	0.143	0.179	0.214	0.357									
CMR	1.000	-0.125	0.661	-0.750	-0.125	-0.125	0.446	-0.125	0.089	0.661	-0.196	0.357	0.464	0.446	0.589	-0.054	-0.268												
CSD	1.000	0.607	0.018	1.000	1.000	0.821	0.821	1.000	0.929	0.607	0.857	0.696	0.161	0.536	0.571	-0.107	0.143												
CCV	1.000	-0.625	0.607	0.607	0.607	0.929	0.607	0.786	1.000	0.321	0.768	0.446	0.679	0.821	-0.071	-0.036													
CMed	1.000	0.018	0.018	0.018	-0.339	0.018	-0.339	0.018	-0.339	-0.625	0.304	-0.286	-0.500	-0.125	-0.268	-0.339	-0.125												
CS ₁ ¹	1.000	1.000	1.000	1.000	0.821	1.000	0.929	0.607	0.857	0.696	0.161	0.536	0.571	-0.107	0.143														
CS ₁ ²	1.000	0.821	1.000	0.929	0.607	0.857	0.696	0.161	0.536	0.571	-0.107	0.143																	
CS ₁ ³	1.000	0.821	1.000	0.929	0.607	0.857	0.696	0.161	0.536	0.571	-0.107	0.143																	
CS ₁ ⁴	1.000	0.821	1.000	0.929	0.607	0.857	0.696	0.161	0.536	0.571	-0.107	0.143																	
CS ₁ ⁵	1.000	0.321	0.768	0.446	0.679	0.821	-0.071	-0.036																					
CS ₁ ⁶	1.000	0.321	0.768	0.446	0.679	0.821	-0.071	-0.036																					
CS ₁ ⁷	1.000	0.554	0.018	0.393	0.429	0.036	0.214																						
NP ₁ ⁽¹⁾	1.000	0.679	0.911	0.946	-0.089	0.161																							
NP ₁ ⁽²⁾	1.000	0.804	0.732	-0.304	-0.161																								
NP ₁ ⁽³⁾	1.000	0.964	-0.357	-0.107																									
NP ₁ ⁽⁴⁾	1.000	-0.214	-0.036																										
ZI	1.000	-0.268																											

Table 13 Spearman's rank correlation coefficient among nonparametric measures BLUP (2017-18)

Table 1: Dependence of rank correlation coefficients on parameters α and β (Eq. 14, 15)																													
	GAI	MR	SD	CV	Med	S ₁ ¹	S ₁ ²	S ₁ ³	S ₁ ⁴	S ₁ ⁵	S ₁ ⁶	S ₁ ⁷	CMR	CSD	CCV	CMed	CS ₁ ¹	CS ₁ ²	CS ₁ ³	CS ₁ ⁴	CS ₁ ⁵	CS ₁ ⁶	CS ₁ ⁷	NP ₁ ⁽¹⁾	NP ₁ ⁽²⁾	NP ₁ ⁽³⁾	NP ₁ ⁽⁴⁾	Z1	Z2
Yield	0.957	-0.627	0.136	-0.364	-0.354	0.145	0.136	-0.136	0.136	0.146	-0.254	0.125	0.795	0.132	0.329	0.502	0.154	0.154	0.254	0.154	0.146	0.354	0.171	0.098	-0.227	-0.361	-0.393	0.082	0.071
GAI	1.000	-0.598	0.046	-0.436	-0.325	0.059	0.046	-0.207	0.046	0.068	-0.304	0.021	0.823	0.064	0.250	0.534	0.089	0.089	0.179	0.089	0.075	0.271	0.107	0.023	-0.280	-0.421	-0.439	0.221	0.179
MR	1.000	1.000	0.059	0.545	0.648	0.079	0.059	0.384	0.059	0.023	0.484	0.095	-0.168	-0.030	-0.013	0.068	-0.045	-0.045	-0.009	-0.045	-0.120	-0.080	0.041	-0.093	0.443	0.555	0.570	0.173	0.209
SD	1.000	0.746	-0.200	0.991	1.000	0.991	1.000	0.893	1.000	0.971	0.821	0.936	0.216	0.914	0.889	0.145	0.907	0.907	0.914	0.907	0.882	0.921	0.889	0.934	0.495	0.689	0.693	0.064	0.096
CV	1.000	0.250	0.741	0.746	0.954	0.746	0.711	0.975	0.725	-0.027	0.664	0.646	0.059	0.650	0.650	0.650	0.650	0.650	0.650	0.650	0.621	0.700	0.648	0.788	0.968	0.975	-0.057	0.043	
Med	1.000	-0.195	-0.200	0.132	-0.200	-0.157	0.246	-0.232	0.038	-0.100	-0.086	0.409	-0.132	-0.132	-0.125	-0.132	-0.171	-0.193	-0.068	-0.245	0.584	0.375	0.332	0.239	0.332	0.239	0.325		
S ₁ ¹	1.000	0.991	0.884	0.991	0.980	0.816	0.909	0.229	0.898	0.877	0.139	0.888	0.888	0.888	0.891	0.888	0.863	0.905	0.880	0.918	0.500	0.677	0.684	0.027	0.055				
S ₁ ²	1.000	0.893	1.000	0.971	0.821	0.936	0.216	0.914	0.889	0.145	0.907	0.907	0.914	0.907	0.882	0.921	0.889	0.934	0.495	0.689	0.693	0.064	0.096						
S ₁ ³	1.000	0.893	0.857	0.979	0.861	0.159	0.814	0.818	0.195	0.804	0.804	0.832	0.804	0.750	0.804	0.832	0.798	0.730	0.914	0.918	0.029	0.107							
S ₁ ⁴	1.000	0.971	0.821	0.936	0.216	0.914	0.889	0.145	0.907	0.907	0.914	0.893	0.914	0.907	0.882	0.921	0.889	0.934	0.495	0.689	0.693	0.064	0.096						
S ₁ ⁵	1.000	0.793	0.846	0.191	0.929	0.864	0.177	0.914	0.914	0.914	0.893	0.914	0.921	0.911	0.896	0.959	0.534	0.664	0.657	0.096	0.139								
S ₁ ⁶	1.000	0.771	0.077	0.761	0.736	0.148	0.746	0.746	0.746	0.746	0.764	0.764	0.689	0.714	0.779	0.730	0.805	0.964	0.968	0.014	0.096								
S ₁ ⁷	1.000	0.252	0.818	0.889	0.102	0.829	0.829	0.879	0.829	0.782	0.896	0.818	0.830	0.427	0.657	0.671	-0.018	0.011											
CMR	1.000	0.213	0.491	0.793	0.230	0.230	0.377	0.230	0.377	0.230	0.130	0.413	0.327	0.089	0.096	-0.005	-0.016	0.223	0.213										
CSD	1.000	0.918	0.263	0.996	0.996	0.996	0.961	0.996	0.954	0.925	0.971	0.955	0.613	0.682	0.675	0.136	0.182												
CCV	1.000	0.423	0.929	0.929	0.975	0.929	0.857	0.971	0.950	0.852	0.584	0.650	0.646	0.079	0.132														
CMed	1.000	0.263	0.263	0.359	0.263	0.180	0.341	0.359	0.104	0.289	0.148	0.095	0.509	0.548															
CS ₁ ¹	1.000	1.000	0.971	1.000	0.954	0.939	0.975	0.952	0.591	0.668	0.664	0.132	0.179																
CS ₁ ²	0.971	1.000	0.954	0.939	0.975	0.952	0.591	0.668	0.664	0.132	0.179																		
CS ₁ ³	1.000	0.971	0.907	0.971	0.982	0.909	0.591	0.689	0.686	0.132	0.189																		
CS ₁ ⁴	1.000	0.954	0.939	0.975	0.952	0.591	0.668	0.664	0.132	0.179																			
CS ₁ ⁵	1.000	0.918	0.904	0.984	0.545	0.607	0.579	0.146	0.196																				
CS ₁ ⁶	1.000	0.932	0.916	0.505	0.607	0.596	0.107	0.164																					
CS ₁ ⁷	1.000	0.905	0.652	0.718	0.125	0.182																							
NP ₁ ⁽¹⁾	1.000	0.504	0.627	0.613	0.123	0.166																							
NP ₁ ⁽²⁾	1.000	0.891	0.859	-0.038	0.088																								
NP ₁ ⁽³⁾	1.000	0.989	-0.011	0.096																									
NP ₁ ⁽⁴⁾	1.000	-0.036	0.061																										
Z1	1.000	-0.105

Calculated $W = 0.58$ and values of χ^2 statistic = 244.1 observed overall similarity among the ranking of genotypes. Values of Z_1 sum = 15.1 and Z_2 sum = 17.3 were less than the critical value of $\chi^2 (0.05, 29) = 42.6$. The stable yield performance of genotypes reflected by lower Z values of genotypes as compared to the critical value.

A significant positive correlation of yield had been observed with GAI & CMR and negative correlations of moderate to the weak degree with others (Table 14). GAI expressed only positive relations of moderate nature. Moderate to weak direct relationships maintained by MR values. SD expressed significant direct relations with CV, S_i^1 , S_i^2 , S_i^3 , S_i^4 , S_i^5 , S_i^6 , S_i^7 , CSD, CCV, CS_i^1 , CS_i^2 , CS_i^3 , CS_i^4 , CS_i^5 , CS_i^6 , CS_i^7 , $NP_i^{(1)}$, $NP_i^{(3)}$, $NP_i^{(4)}$ measures. Significant positive correlations of CV were observed with measures while weak with CMR, CMed, Z1, Z2 values. Med had achieved moderate to weak positive correlations. S_i^1 , S_i^2 , S_i^3 , S_i^4 , S_i^5 , S_i^6 , S_i^7 maintained direct relationships of moderate to a higher degree with measures. CMR maintained moderate to weak direct relations with measures. CSD & CCV expressed highly significant and significant positive values with measures, while CMed maintained a weak positive correlation. Measures CS_i^1 , CS_i^2 ,

3.2.6 Biplot graphical analysis

The loadings of the first two principal components axes (PCA) of nonparametric measures were shown in figure 4. More than 82% of the variance of the variables accounted for two significant PAC's. Biplot analysis of nonparametric measures had displayed five clusters. Three clusters each of two measures were observed as Yield with GAI, MR with Med, and CMR with CMed. Measures $NP_i^{(2)}, NP_i^{(3)}, NP_i^{(4)}, S_i^6$ & S_i^3 clubbed with CV. Large cluster comprised of Z1, Z2, SD, CSD, CCV, $NP_i^{(1)}, S_i^1, S_i^2, S_i^4, S_i^5, S_i^7, CS_i^1, CS_i^2, CS_i^3, CS_i^4, CS_i^5, CS_i^6, CS_i^7$ measures.

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Table 14 Spearman's rank correlation coefficient among nonparametric measures BLUE (2017-18)

	GAI	MR	SD	CV	Med	S ¹	S ²	S ³	S ⁴	S ⁵	S ⁶	S ⁷	CMR	CSD	CCV	CMed	CS ¹	CS ²	CS ³	CS ⁴	CS ⁵	CS ⁶	CS ⁷	NP ⁽¹⁾	NP ⁽²⁾	NP ⁽³⁾	NP ⁽⁴⁾	Z1	Z2
Yield	0.9714	-0.6214	0.0607	-0.3107	-0.2982	0.1000	0.0607	-0.1429	0.0607	0.0625	-0.2750	0.0214	0.5232	-0.0339	0.0571	0.4304	-0.0196	-0.0143	0.0464	-0.0143	-0.0768	-0.0143	0.1214	-0.1089	-0.3071	-0.3750	-0.3679	0.4018	0.4464
GAI	1.0000	-0.6107	0.0679	-0.3036	-0.3089	0.1179	0.0679	-0.1571	0.0679	0.0696	-0.2643	0.0214	0.5446	-0.0304	0.0643	0.4875	-0.0196	-0.0107	0.0536	-0.0107	-0.0911	-0.0214	0.0929	-0.1196	-0.3464	-0.3929	-0.3750	0.4339	0.4500
MR	1.0000	1.0000	0.2929	0.7214	0.6018	0.2571	0.2929	0.5714	0.2929	0.3518	0.7429	0.2393	0.0018	0.3518	0.3571	-0.1089	0.3411	0.3393	0.3393	0.3393	0.4339	0.4500	0.2000	0.4482	0.7250	0.7321	0.7250	-0.1339	-0.1607
SD	1.0000	1.0000	1.0000	0.7893	0.1554	0.9929	1.0000	0.9036	1.0000	0.9804	0.7964	0.9036	0.3089	0.9518	0.9071	0.3482	0.9411	0.9464	0.9536	0.9464	0.9339	0.9250	0.8929	0.9339	0.5964	0.7357	0.7357	0.1875	0.2750
CV	1.0000	1.0000	1.0000	1.0000	0.5982	0.7571	0.7893	0.9536	0.7893	0.7625	0.9821	0.7821	0.3304	0.7768	0.8214	0.2768	0.7839	0.7714	0.8107	0.7714	0.8018	0.8321	0.7143	0.8125	0.8786	0.9643	0.9679	0.0375	0.0321
Med	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
S ¹	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
S ²	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
S ³	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
S ⁴	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
S ⁵	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
S ⁶	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
S ⁷	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
CMR	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
CSD	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
CCV	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
CMed	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
CS ¹	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
CS ²	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
CS ³	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
CS ⁴	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
CS ⁵	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
CS ⁶	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
CS ⁷	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
NP ⁽¹⁾	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
NP ⁽²⁾	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
NP ⁽³⁾	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
NP ⁽⁴⁾	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Z1	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Z2	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Conflict of Interest

No conflict of interest among authors for this study.

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