Original Research Article

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Non parametric Measures of Stability Compared as per BLUP and BLUE of Wheat Genotypes Evaluated in North Western Plains Zone of the Country

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ABSTRACT

Non parametric measures as per the BLUP values of original yield for first year, S_i^s measures identified G11, G10, G4 as stable genotypes. Corrected yield measures CS_i^s selected G11, G12, G8 for stable performance. Values of $NP_i^{(s)}$ identified G4, G10, G11 as desirable genotypes. Association analysis among measures observed positive correlations of S_i^s , with others and of negative with CMR, Z1 and Z2. Positive relationships exhibited by CS_i^s measures. Negative relationships of $NP_i^{(s)}$ expressed with Z1 and Z2 only. Biplot analysis showed CMed & CMR expressed close affinity with SD, $NP_i^{(3)}$, $NP_i^{(4)}$ & S_i^s whereas CCV, CSD, $NP_i^{(1)}$ associated with CS_i^s along with Z1. Based on BLUE's of genotypes yield, measures S_i^s found G4, G8, G12 as suitable genotypes. CS_i^s identified G4, G8, G11, G12, as opposed to G4, G5, G8, G11 by measures $NP_i^{(s)}$ measures. Positive correlations exhibited by S_i^s except of negative with CMR, Z1 and Z2. Measures CS_i^s expressed highly significant indirect relationship with Z2 only. Negative relationships of $NP_i^{(s)}$ had observed with Z2 only. CV expressed affinity with CMR, S_i^3 , S_i^6 , $NP_i^{(2)}$, $NP_i^{(3)}$ & $NP_i^{(4)}$ whereas SD grouped with S_i^1 , S_i^2 , S_i^4 , S_i^5 , S_i^7 measures. BLUP's of genotypes for second year of study seen, measures S_i^s settled for G1, G9, G13, G15 genotypes. While $NP_i^{(1)}$ identified G9, G11, G14 and G15 genotypes of stable performance. Measures CMR and Z2 showed negative correlations with S_i^s , and CS_i^s , behaved in direct manner along with indirect to Z2. Negative relationships of $NP_i^{(s)}$ exhibited with Z1 and Z2. CV along with CMR expressed affinity with, SD, CMed, $NP_i^{(2)}$, $NP_i^{(3)}$, $NP_i^{(4)}$, S_i^3 , S_i^5 , S_i^6 . Large cluster comprises of CCV, CSD, $NP_i^{(1)}$, S_i^1 , S_i^2 , S_i^4 , CS_i^1 , CS_i^2 , CS_i^3 , CS_i^4 , CS_i^5 , CS_i^6 , CS_i^7 and Z1 measures. S_i^s non parametric while considering BLUE's values of genotypes pointed towards G5, G9, G14 whereas G6, G9 by CS_i^s values. Wheat genotypes G5, G9, G14, G15 settled by least values of $NP_i^{(s)}$. Indirect relations with Z2 only exhibited by S_i^s measures. CS_i^s maintained positive relationships. $NP_i^{(s)}$ had positive relationships with others and negative relationships with Z2 only. Largest cluster consists of SD, CSD, CCV, $NP_i^{(1)}$, S_i^1 , 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.

Keywords

BLUP, BLUE, $S_i^{(s)}$,
 $CS_i^{(s)}$, $NP_i^{(s)}$,
Coefficient of
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Introduction

Mostly genotypes possessed high yield with broad stability were recommended for diverse environmental conditions of the country to sustain the production levels of cereal crops (Pour *et al.*, 2019). High yield stability proved the genotype's ability to perform consistently, whether at high or low-yield levels, across a wide range of environments (Vaezi *et al.*, 2018). With weather vagaries the significant genotype-by-environment (GxE) interaction affected the genotypes performance (Rasoli *et al.*, 2015). Modeling GxE interaction in multi-environment trials (MET) helps to determine phenotypic stability of genotypes as two concepts of interaction i.e., crossover, and non-crossover, have been cited in literature (Ahmadi *et al.*, 2015). Change in the rankings of the genotypes in different environments proved the presence of crossover interaction. More over the similar rankings in various environments had been analysed by simple process with absence of crossover interaction (Zali *et al.*, 2011). Some genotypes have similar performance regardless of the productivity level of the environment, and others have their performance directly related to the productivity potential of the environment, highlighted the importance of stability analysis (Mahtabi *et al.*, 2013). Genotype x environment interactions complicate the identification of superior genotypes (Mortazavian and Azizinia, 2014) but their interpretation can be facilitated by the use of several statistical modeling methods. Two major approaches for the stability analysis of genotypes had been mentioned (Khalili *et al.*, 2016; Mohammadi *et al.*, 2016). First, most commonly used, approach known as parametric which presumed certain assumptions about distributions of genotypic, environmental, and their linear interaction effects. Other approach called non-parametric which had no compulsions of any assumptions. Non-

parametric procedures proposed based on the ranks of genotypes in each environment, and the genotypes with similar ranking across environments were classified as stable (Farshadfar *et al.*, 2014). Non-parametric methods had certain advantages over counterpart parametric stability methods. Reduced the bias due to outliers, if any and easy to use along with simple to interpret, and little effect on the results had been observed with additions or deletions of few genotypes (Vaezi *et al.*, 2018). Ranking of genotypes had classified genotypes according to values but not to their absolute differences. However, nonparametric procedures are used less often than parametric procedures despite certain advantages (Mohammadi *et al.*, 2016). Quite large number of nonparametric procedures has been developed to interpret stability in GxE interaction studies to determine whether or not genotypes evaluated in MET were possessing stable yield performance (Delić *et al.*, 2009; Kilic *et al.*, 2010; Balalić *et al.*, 2011; Karimizadeh *et al.*, 2012; Mortazavian and Azizinia 2014; Pour *et al.*, 2019).

The present study was carried out with the objectives (1) analyze stability analysis genotypes by nonparametric measures using BLUP and BLUE values (2) to differentiate the yield and stable pattern of genotypes vis-à-vis BLUP and BLUE and (3) study the relationships, similarities and dissimilarities among non-parametric measures of stability.

Materials and Methods

Twelve promising wheat genotypes were evaluated in research field trials at 28 centers of All India Coordinated Research Project on Wheat across mega zone of the country during 2016-17 and fifteen at twenty-five centers during 2017-18 cropping season. Field trials were laid out in Randomized block designs with four replications. Recommended practices of packages had followed in total to

harvest the good yield. 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. For a two-way dataset with k genotypes and n environments X_{ij} denotes the phenotypic value of ith genotype in jth environment where $i=1,2, \dots, k, j=1,2, \dots, n$ and r_{ij} as the rank of the ith genotype in the jth environment, and $\bar{r}_i$ as the mean rank across all environments for the ith genotype. Sabaghnia *et al.*, (2012) proposed the correction for yield of ith genotype in jth 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. Generally used seven statistics based on ranks of genotypes yield and corrected yield were expressed as follows:

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

$$NP_i^{(2)} = \frac{1}{n} \left(\frac{\sum_{j=1}^n |r_{ij}^* - M_{di}^*|}{M_{di}^*} \right)$$

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

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

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

Non parametric 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. In the 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.

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

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

Significance of $Si^{(1)}$ and $Si^{(2)}$ non parametric measures had been explored by Nassar and Huehn (1987). Z_1 and Z_2 values were calculated for each genotype, based on the ranks of adjusted data and then sum of i.e. Z_1 sum and Z_2 sum are distributed as χ^2 . Degree of similarity among measures had assessed by estimating correlation coefficients while considering genotypes ranking. Spearman's rank correlation values among pairs (Piepho and Lotito, 1992) estimated as follows:

$$\bar{r}_s = 1 - \frac{6 \sum_{i=1}^n d_i^2}{n(n^2-1)} \text{ where } d_i \text{ denotes difference between ranks for } i\text{th genotype and } n \text{ is total number of pairs.}$$

Results and Discussion

First year of study 2016-17

Analytic analysis as per BLUP's

Average yield of wheat genotypes observed G1 was the highest yielding with 57.4q/ha followed by G7 and G6, although differences were evident among the genotypes (Table 3). Measure GAI selected G1, G12, G7 as genotypes with higher adaptable index values. The following three descriptive statistics; mean of ranks (MR), standard deviation of ranks (SD) and coefficient of variation of ranks (CV) were calculated as per original

values of genotypes yield. MR pointed towards G5, G4, G3 and SD for G11, G8, G10 whereas CV for G11, G4, G10 as genotypes of stable performance, while G5, G3 based on MR; G1, G5 based on SD and G6, G1 based on CV, would be genotypes of unstable behavior. These descriptive statistics based on ranks can be used for genotype comparative evaluation. Two ranking methods according to mean and standard deviation of ranks proposed by Sabaghnia *et al.*, (2012) and advantages of non-parametric procedures in phenotypic stability studies had reported by Rasoli *et al.*, (2015). Median selected G6, G7, G9 wheat genotypes. Seven nonparametric measures based on original yield of genotypes ($S_i^1, S_i^2, S_i^3, S_i^4, S_i^5, S_i^6, S_i^7$) indicated G11, G10, G4 as the stable genotypes, however G1, G6, would achieve unstable yield. According to corrected yield values (table 4), G1, G8 & G10 were of choice by mean of corrected ranks (CMR), G12, G11 & G8 by standard deviation of corrected ranks (CSD) and G8, G10 & G4 were of stable nature as per coefficient of variation of corrected ranks (CCV). Measures based on corrected yield ($CS_i^1, CS_i^2, CS_i^3, CS_i^4, CS_i^5, CS_i^6, CS_i^7$) identified G11, G12, G8 as stable genotypes and G5, G1 would be of unstable type. The mentioned strategy determines the stability of genotype over environment if its rank is similar over other environments (biological concept). Many authors that have used the corrected Huehn's (1979, 1990b) nonparametric measures of phenotypic stability and demonstrated that these statistics were associated with the biological concept of stability (Karimizadeh *et al.*, 2012; Sabaghnia *et al.*, 2012; Ahmadi *et al.*, 2015). Results of Thennarasu's (1995) non-parametric measures, which considered the ranks of adjusted yield means, were shown in Table 4. As per values of first measure $NP_i^{(1)}$, G11, G10 and G12 genotypes were considered as of stable type in comparison to the other genotypes. The genotypes G11, G4 and G10

had the lower value of $NP_i^{(2)}$, $NP_i^{(3)}$ considered G4, G11 followed by G10, whereas $NP_i^{(4)}$ identified G4, G11 and G10. The most unstable genotypes based on $NP_i^{(s)}$ were G6 followed by G1 and G5. Measures Z1 and Z2 were the standardized values CS_i^1 & CS_i^2 had pointed for G9, G2, G7 genotypes.

To judge the degree of agreement among non-parametric measures, Kendall's coefficient of concordance, W was used. Numerical values equal to 1 indicates a perfect agreement among rankings of the measures across the environments and near to 0 suggests total disagreement among ranks (Vaezi *et al.*, 2018). Calculated values of W and significance of numerical value judged by χ^2 statistic were given in Table 4. Since calculated value is less than table of χ^2 (0.05, 290) = 124.3 (135.8), resulted an overall similarity among non parametric measures. Significance of CS_i^1 and CS_i^2 were tested as per Nassar and Huehn (1987). For each genotype, Z1 and Z2 values were calculated based on the ranks of adjusted data and then summed: $Z_1 \text{ sum} = 30.37$ and $Z_2 \text{ sum} = 41.63$ (Table 4). Both these statistics are 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. More over the individual Z values showed BRW3773 & HD2967 were significantly unstable relative to others, with their individual Z values more than the critical value of χ^2 (0.05, 1) = 3.84.

Association analysis

Spearman's rank correlation analysis among possible pairs of non parametric measures (Table 11) observed highly significant ($p < 0.01$) positive correlation of yield with GAI, Med and negative correlation with MR, CV, $S_i^6, NP_i^{(2)}, NP_i^{(3)}, NP_i^{(4)}$ along with indirect relationships with SD, $S_i^1, S_i^2, S_i^3, S_i^4, S_i^5, S_i^7$,

$CS_i^1, CS_i^2, CS_i^3, CS_i^4, CS_i^5, CS_i^6$ and CS_i^7 . GAI measure showed negative correlations with MR, CV, S_i^6 , $NP_i^{(2)}$, $NP_i^{(3)}$, $NP_i^{(4)}$ and positive with median. Mean rank (MR) expressed positive correlation with CV, S_i^3 , S_i^6 , $NP_i^{(2)}$, $NP_i^{(3)}$, $NP_i^{(4)}$ and negative with Med. Measure SD maintained highly significant and significant direct relations with almost all the measures exception of Z2. Significant positive correlation showed by CV with nearly all measures while of negative with Median. All negative correlations were seen of Median. Measures of set of S_i^1 , S_i^2 , S_i^3 , S_i^4 , S_i^5 , S_i^6 , S_i^7 exhibited positive correlations with other measures as well as among themselves except of negative with CMR, Z1 and Z2 values. CMR measure maintained negative relationships with most of the measures. CSD, CMR & CMed had positive relationships with all measures and negative with Z2 only. 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 behaved in similar manner as all expressed positive relationships with others and themselves while indirect with measure Z2. The rank of a genotype in a specific environment cannot be judged as per the phenotypic values, because the stability has to be measured independently of the genotypic effect. Therefore, the rank of the i th genotype in the j th environment is estimated based on the corrected phenotypic values (Sabaghnia *et al.*, 2012). Thennarasu (1995) proposed four non-parametric stability measures on the basis of adjusted ranks of genotypes within each test environment. These measures $NP_i^{(1)}$, $NP_i^{(2)}$, $NP_i^{(3)}$, $NP_i^{(4)}$ had expressed negative relationships with Z1 and Z2 otherwise had positive relationships. Z1 is related to Z2 in inverse manner.

Biplot graphical analysis

Biplot analysis of rank-based measures had been carried out to explore if any type of association among measures. Loadings of the

first two principal components axes (PCA) of non-parametric measures were shown in table 12 (Mohammadi *et al.*, 2016). Both significant PAC's accounting for 87.7% of the variations of the original variables. The PCA1 versus PCA2 were used to generate four clusters in the biplot graphical analysis as illustrated in figure 1. Grouping of Yield with GAI as well as of MR and Med were clubbed together in graphical analysis which is otherwise also obvious. Measure CMed & CMR expressed close affinity with SD, $NP_i^{(3)}$, $NP_i^{(4)}$ & S_i^1 , S_i^2 , S_i^3 , S_i^4 , S_i^5 , S_i^6 , S_i^7 whereas CCV, CSD, $NP_i^{(1)}$ associated with CS_i^1 , CS_i^2 , CS_i^3 , CS_i^4 , CS_i^5 , CS_i^6 , CS_i^7 along with Z1.

Analytic analysis as per BLUE's

Average yield of wheat genotypes identified G1, G7, G12, whereas GAI selected G1, G12, G9 as genotypes of choice, large values of Median observed for G5, G4, G2 while consistent yield of G8, G12, G4 expressed by least values of standard deviation (Table 5). G4, G5, G3 as genotypes of least variations as pointed by values of coefficient of variation; S_i^1 measure selected G8, G12, G4 opposed to S_i^2 for G8, G4, G3. Same set of genotypes G4, G8, G12 considered by S_i^3 & S_i^4 , while S_i^5 favoured G12, G8, G4 whereas S_i^6 measure identified G4, G5, G3 & S_i^7 pointed towards G8, G12, G4 wheat genotypes. Average median of ranks as per corrected yield values selected G7, G10, G4 and corrected standard deviation observed suitability of G12, G8, G4 genotypes. Coefficient of variation as per corrected yield values exhibited G8, G12, G4 while median values for G5, G6, G9 and G12, G8, G11 by CS_i^1 , G12, G8, G9 by CS_i^2 , CS_i^3 for G8, G12, G4 & as per CS_i^4 values G12, G8, G4 while G12, G8, G11 by CS_i^5 & G8, G12, G4 by CS_i^6 values and lastly CS_i^7 pointed towards G12, G8, G4 (table 6). No parametric measures $NP_i^{(1)}$ for (G12, G8, G11); $NP_i^{(2)}$, $NP_i^{(3)}$, $NP_i^{(4)}$ considered ranks of genotypes by original and corrected values

also selected G4, G5, G8 wheat genotypes and G1 along with G6 would be of unsuitable type as per value of $NP_i^{(1)}$, $NP_i^{(2)}$, $NP_i^{(3)}$, $NP_i^{(4)}$ whereas values of measures Z1 observed G9, G3, G4 and genotypes G3, G9, G11 as per Z2 values.

Calculated value of $\chi^2 = 97.6$ is less than table of χ^2 (0.05, 290) = 124.3 (135.8), resulted an overall similarity among non parametric measures. Values of both measures : Z_1 sum = 17.89 and Z_2 sum = 16.8 (Table 6) 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. More over the individual Z values showed HP1963, &WH1202 were significantly unstable relative to others, with their individual Z values more than the critical value of χ^2 (0.05, 1) = 3.84.

Association analysis

As per values of rank correlation among non-parametric measures, highly significant ($p < 0.01$) positive correlation of yield observed with GAI, Med and negative correlation with MR, CV, S_i^3 , S_i^6 , $NP_i^{(2)}$, $NP_i^{(3)}$, $NP_i^{(4)}$ (Table 13). Measure GAI showed negative correlations with most of the measures and positive with Med only. Mean rank (MR) expressed positive correlation with CV, S_i^3 , S_i^6 , $NP_i^{(2)}$, $NP_i^{(3)}$, $NP_i^{(4)}$ and negative with Med. Measure SD maintained highly significant and significant direct relations with almost all the measures exception of S_i^3 & S_i^6 i.e. perfect positive correlation. CV showed significant positive correlation with S_i^3 , S_i^6 , $NP_i^{(2)}$, $NP_i^{(3)}$, $NP_i^{(4)}$ and negative with Median. All negative correlations of significance and others were seen of Median. Set of S_i^1 , S_i^2 , S_i^3 , S_i^4 , S_i^5 , S_i^6 , S_i^7 behaved in similar manner and exhibited positive correlation with other measures as well as among themselves except of negative with CMR, Z1 and Z2 values. CMR measure maintained weak negative relationships with

all the measures. CSD, CMR & CMed had expressed positive correlations with measures and only significant negative with Z2 values. Seven non parametric measures based on corrected yield values of genotypes i.e. CS_i^1 , CS_i^2 , CS_i^3 , CS_i^4 , CS_i^5 , CS_i^6 and CS_i^7 expressed positive relationships with others and themselves while highly significant indirect with Z2 values. Measures $NP_i^{(1)}$, $NP_i^{(2)}$, $NP_i^{(3)}$, $NP_i^{(4)}$ had expressed negative relationships with Z2 otherwise maintained positive relationships. An inverse relationship has evident between Z1 & Z2 values.

Biplot graphical analysis

Biplot analysis based on first two principal components had expressed five clusters of 30 non parametric measures. Loadings of the first two principal components axes (PCA) of ranks of non-parametric measures were shown in table 14. Both significant PAC's accounting for 85.3% of the variance of the original variables (Figure 2). Grouping of Yield with GAI along with Z1 & Z2 whereas MR with Med are observed in graphical analysis. CV expressed affinity with CMR, S_i^3 , S_i^6 , $NP_i^{(2)}$, $NP_i^{(3)}$ & $NP_i^{(4)}$ whereas SD grouped with S_i^1 , S_i^2 , S_i^4 , S_i^5 , S_i^7 measures. Separate cluster of $NP_i^{(1)}$, CSD, CCV, CS_i^1 , CS_i^2 , CS_i^3 , CS_i^4 , CS_i^5 , CS_i^6 and CS_i^7 .

Second year of study 2017-18

Analytic analysis as per BLUP's

Mean wheat yield of genotypes observed, G4 as the highest yielding with 58q/ha followed by G2 and G7, though remarkable yield differences were observed among the genotypes (Table 7). Measure GAI selected G4, G2, G7 as genotypes with higher adaptable index values. MR pointed towards G5, G14, G11 and SD for G9, G14, G15 whereas CV for G5, G14, G15 as genotypes of stable performance, while G5, G15 based on

MR & GAI, G7, G4 based on SD and CV, would be unstable genotypes. These descriptive statistics based on ranks can be used for genotype comparative evaluation. Values of Median selected G4, G2, G7 genotypes.

Seven nonparametric measures based on original grain yield of genotypes ($S_i^1, S_i^2, S_i^3, S_i^4, S_i^5, S_i^6$ and S_i^7) indicated that (G9, G15, G14), (G9, G8, G6), (G9, G13, G15), (G9, G13, G1), (G9, G13, G1), (G9, G15, G13), (G9, G13, G1) as sets of genotypes respectively. According to corrected yield (table 8), G1, G8 & G10 by mean of corrected ranks (CMR), G12, G11 & G8 by standard deviation of corrected ranks (CSD) and G8, G10 & G4 were the stable as per coefficient of variation of corrected ranks (CCV). Nonparametric measures of stability based on corrected yield values ($CS_i^1, CS_i^2, CS_i^3, CS_i^4, CS_i^5, CS_i^6, CS_i^7$) identified stable genotypes (G14, G13, G9), (G14, G11, G9), (G14, G8, G1), (G14, G13, G8), (G8, G13, G14), (G14, G8, G1), (G14, G13, G8) and G7, G10 were of unstable type as per these nonparametric measures. First measure $NP_i^{(1)}$ considered genotypes G9, G14 and G13 were of stable yield. Genotypes G14, G11 and G15 had expressed the lower values of $NP_i^{(2)}, NP_i^{(3)}$ & $NP_i^{(4)}$, whereas Z1 and Z2 pointed for G15, G11, G6 as suitable as well as G7 & G10 would be of unsuitable performance.

Value of the χ^2 statistics was less than table value of χ^2 (0.01, 290) = 135.8, which resulted an overall similarity among non-parametric measures. Values of both measures Z_1 sum = 17.29 and Z_2 sum = 18.66 (Table 8) 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. The individual Z values showed DBW 233 was significantly unstable as compared to studied

genotypes as Z values more than the critical value of χ^2 (0.05, 1) = 3.84.

Association analysis

Spearman's rank correlation values among non-parametric measures had reflected in table 15 as based on BLUP's of genotypes yield across environments. Yield had highly significant positive correlation with GAI, Med and negative correlation with MR, SD, CV, $S_i^3, S_i^6, NP_i^{(2)}, NP_i^{(3)}, NP_i^{(4)}$ along with weak direct relationships with CMR, Z2 & negative with other measures SD, $S_i^2, S_i^4, S_i^5, S_i^7, CSD, CCV, CS_i^1, CS_i^2, CS_i^3, CS_i^4, CS_i^5, CS_i^6$ and CS_i^7 . Measure GAI mentioned negative correlations with MR, SD, CV, $S_i^3, S_i^6, NP_i^{(2)}, NP_i^{(3)}, NP_i^{(4)}$ and positive with median. Mean rank (MR) expressed positive correlations with all measures though degree of correlations vary except negative with Median. SD also expressed positive correlation with measures with Median and Z2 as exceptions. Similarly, CV exhibited same type of behavior. Median expressed only negative correlations with variable degree of association. Measures CMR and Z2 showed negative correlations with $S_i^1, S_i^2, S_i^3, S_i^4, S_i^5, S_i^7$ otherwise only direct relationships were noticed. CMR showed only significant negative correlation with CMed. Measures CSD, CMR & CMed had significant positive relationships with all measures and negative with Z2 only. Set of $CS_i^1, CS_i^2, CS_i^3, CS_i^4, CS_i^5, CS_i^6$ and CS_i^7 behaved in similar manner as all expressed positive relationships with others and themselves while indirect with Z2. Non-parametric measures considered adjusted ranks of genotypes within each test environment. These measures $NP_i^{(1)}, NP_i^{(2)}, NP_i^{(3)}, NP_i^{(4)}$ had expressed negative relationships with Z1 and Z2 otherwise had positive relationships. Z1 is related to Z2 in weakly but inverse manner.

Table.1 Parentage details of genotypes and environmental conditions (2016-17)

Code	Genotype	Parentage	Code	Environments	Latitude	Longitude	Altitude (m)
G1	DBW189	(KACHU#1/4/CROC_1/AE.SQUARROSA(205)//BORL95/3/2*MILAN/5/KACHU)	E1	Alwar	27° 7'N	76° 1'E	271
G2	DBW196	(ROLF07*2/KACHU#1)	E2	Bareilly	28° 22'N	79° 24'E	172.9
G3	PBW750	(TOB/ERA//TOB/CNO67/3/PLO/4/VEE#5/5/KAUZ/6/FRET2/7/PASTOR//MILAN/KAUZ/3/BAV92)	E3	Bawal	28° 10'N	76° 50'E	266
G4	WH1202	(D67.2/PARANA66.270//AE.SQ.(320)/3/CUNNINGHAM)	E4	Bathinda	30° 09' N	74° 55 'E	211
G5	HD3226	(GRACKLE/HD2894)	E5	Bikaner	28°02'N	73° 30'E	230
G6	UP2942	(CS/TH.SC//3*PVN/3/MIRLO/BUC/4/URES/JUN//KAUZ/5/HUITES/6/YANAC/7/CS/ TH.SC//3*PVN/3/MIRLO/BUC/4/MILAN/5/TILHI)	E6	Bulandshahr	28° 24 'N	77° 50 'E	204
G7	HP1963	(FRET2/TUKURU//FRET2/3/MUNIA/CHTO//AMSEL/4/FRET2/TUKURU//FRET 2)	E7	Delhi	28° 38'N	77° 13 'E	222
G8	BRW3773	(FRANCOLIN#1//WBLL1*2/BRAMBLING/3/WBLL1*2)	E8	Dhakrani	30.44 'N	77.74 'E	452
G9	HD2967	(ALD/CUC//URES/HD2160M/HD2278)	E9	Dhaulakuan	30°16 'N	74°56 'E	236
G10	WH1105	(MILAN/S87230//BABAX)	E10	Durgapura	26°51'N	75° 47'E	390
G11	DBW88	(KAUZ//ALTAR84/AOS/3/MILAN/KAUZ/4/HUITES)	E11	Faridkot	30° 40 'N	74° 04 'E	200
G12	HD 3086	(DBW14/HD2733//HUW468)	E12	Gurdaspur	32° 2 'N	75° 24 'E	265
			E13	Hanumangarh	29° 62'N	74° 28'E	177
			E14	Hisar	29° 19'N	75° 43 'E	215
			E15	Jammu	32° 43'N	74° 51 'E	351
			E16	Jodhpur	26°26'N	73° 00'E	235
			E17	Karnal	29° 43' N	70° 58'E	245
			E18	Kashipur	29° 21'N	78° 96'E	218
			E19	Kapurthala	31° 22'N	75° 22 'E	229
			E20	Ludhiana	30° 54'N	75° 51 'E	252
			E21	Modipuram	29°43 'N	77°42'E	237
			E22	Nagina	29° 28' N	78° 32'E	245
			E23	Pantnagar	29°05'N	79°29 'E	236.54
			E24	Rauni	30° 90'N	75° 85'E	262
			E25	Rohtak	28° 53' N	76° 35'E	222.5
			E26	Rampur-KVK	28°48 'N	79°10 'E	1021
			E27	Sriganganagar	29° 66'N	75° 53'E	175.6
			E28	Shikopur	29°10 'N	77°27 'E	217

Table.2 Parentage details of wheat genotypes along with environmental conditions (2017-18)

Code	Genotype	Parentage	Code	Environments	Latitude	Longitude	Altitude (m)
G1	UP2981	(CHYAK/PAURAQ)	E1	Delhi	28°4'N	77°13'E	228
G2	DBW221	(36IBWSN284/22ESWYT28)	E2	Faridkot	30°40'N	74°04'E	200
G3	DBW222	(KACHU/SAUAL/8/ATTILA*2/PBW65/6/PVN//CAR422/ANA/5/BOW/CROW//BUC/PVN/3/YR/4/TRAP#1/7/ATTILA/2*PASTOR)	E3	Gurdaspur	30°02'N	75°24'E	265
G4	BRW3792	(PF74354/LD/ALD/4/2*BR12*2/3/JUP//PAR214)	E4	Bathinda	30°09'N	74°55'E	211
G5	PBW763	(PBW621/3/YR10/6*AVOCET//4*PBW343/4/2*PBW621/5/PBW621/3/YR15/6*AVOCET//4*PBW343/4/2*PBW621)	E5	Kapurthala	31°22'N	75°22'E	229
G6	PBW766	(NAC/TH.AC//3*PVN/3/MIRLO/BUC/4/2*PASTOR/5/KACHU/6/KACHU)	E6	Ludhiana	30°54'N	75°48'E	247
G7	DBW233	(CHIBIA//PRLII/CM65531/3/KAUZ/BAV92/4/MUNAL#1)	E7	Rauni	30°90'N	75°85'E	262
G8	HD3226	(GRACKLE/HD2894)	E8	Hisar	29°10'N	75°46'E	229
G9	PBW801	(PBW621/3/Yr10/6*Avocet//4*PBW 343/4/ 2*PBW 621/5/PBW 621/3/Yr 15/6*Avocet// 4*PBW 343/4/2*PBW 621)	E9	Bawal	28°10'N	76°50'E	266
G10	PBW800	(HD 2967/4/BW 9250*3// Yr10/6*Avocet/3/ BW 9250*3//Yr15/6*Avocet/5/2*HD 2967)	E10	Karnal	29°43'N	70°58'E	245
G11	DPW621-50	(KAUZ//ALTAR84/AOS/3/MILAN/KAUZ/4/HUITES)	E11	Rohtak	28°53'N	76°35'E	222.5
G12	HD3086	(DBW14/HD2733//HUW468)	E12	Jammu	32°40'N	74°54'E	356
G13	HD 2967	(ALD/CUC//URES/HD2160M/HD2278)	E13	Pantnagar	29°02'N	79°48'E	243.8
G14	DBW 88	(KAUZ//ALTAR84/AOS/3/MILAN/KAUZ/4/HUITES)	E14	Kashipur	29°21'N	78°96'E	218
G15	WH 1105	(MILAN/S87230//BABAX)	E15	Bulandshahr	28°40'N	77°84'E	195
			E16	Bareilly	28°22'N	79°24'E	172.9
			E17	Nagina	29°28'N	78°32'E	245
			E18	Sriganganagar	29°66'N	75°53'E	175.6
			E19	Tabiji	26°35'N	74°61'E	508
			E20	Kotputli	27°42'N	76°12'E	362
			E21	Hanumangarh	29°62'N	74°28'E	177
			E22	Jodhpur	26°26'N	73°00'E	235
			E23	Alwar	27°7'N	76°1'E	271
			E24	Bikaner	28°02'N	73°30'E	230
			E25	Durgapura	26°51'N	75°47'E	390

Table.3 Non parametric measures of genotypes based on original values of yield 2016-17 (BLUP)

blup16-17	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
BRW3773	57.43	56.82	5.57	3.99	0.717	5	4.56	15.96	77.33	3.92	3.41	17.13	4.51	7.25	4.29
DBW189	55.25	54.57	7.50	3.20	0.427	8.5	3.62	10.26	36.93	3.15	2.71	10.13	3.64	6.68	3.46
DBW196	54.78	54.06	7.50	3.01	0.402	8	3.47	9.07	32.67	2.96	2.54	9.47	3.45	6.07	3.28
DBW88	55.04	54.52	8.21	2.99	0.363	9	3.33	8.92	29.30	2.93	2.54	8.66	3.38	6.86	3.14
HD2967	51.86	51.07	9.32	3.66	0.393	11.5	3.78	13.41	38.85	3.60	3.09	9.27	4.19	6.21	4.65
HD3086	57.16	56.33	4.71	3.56	0.755	4	4.03	12.66	72.48	3.49	3.03	18.00	4.03	6.46	3.67
HD3226	57.23	56.39	4.96	3.17	0.638	4	3.57	10.04	54.58	3.11	2.74	15.47	3.53	6.68	3.53
HP1963	56.85	56.23	5.71	2.71	0.474	6	3.07	7.32	34.60	2.66	2.09	10.25	3.38	6.96	2.97
PBW750	56.98	56.24	5.00	3.19	0.637	4	3.57	10.15	54.80	3.13	2.57	14.40	3.81	6.29	3.41
UP2942	55.80	55.09	7.39	2.71	0.367	8	3.01	7.36	26.87	2.66	2.01	7.60	3.53	6.93	3.03
WH1105	55.14	54.41	7.29	2.54	0.348	8	2.84	6.43	23.84	2.49	1.96	7.53	3.17	5.54	2.97
WH1202	56.99	56.39	4.82	3.06	0.634	4.5	3.46	9.34	52.29	3.00	2.46	14.31	3.65	6.07	2.94

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 and Huehn's (1987) non-parametric stability statistics; NP(i): Thennarasu's (1995) non-parametric stability statistics; Z1 and Z2: the standard values of S(1) and S(2) respectively, for χ^2 test.

Table.4 Non parametric measures of genotypes based on corrected values of yield (BLUP)

blup16-17	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
BRW3773	0.592	8.5	4.90	18.42	68.59	4.21	3.88	12.76	4.58	3.82	0.764	0.756	0.880	6.78	9.72
DBW189	0.519	7	4.01	12.00	48.53	3.40	3.01	12.04	3.85	2.96	0.349	0.454	0.534	0.01	0.00
DBW196	0.540	6.5	3.80	10.74	47.74	3.22	2.79	12.00	3.72	2.79	0.348	0.429	0.507	0.22	0.32
DBW88	0.457	7	3.65	9.83	38.71	3.08	2.65	10.61	3.57	2.64	0.294	0.375	0.444	0.84	1.00
HD2967	0.748	6.5	5.22	21.58	93.77	4.56	4.36	18.77	4.78	4.36	0.379	0.489	0.560	12.25	21.49
HD3086	0.567	6	4.28	13.44	56.15	3.60	3.07	14.32	4.22	3.04	0.759	0.764	0.907	0.73	0.54
HD3226	0.528	7.5	4.07	12.45	50.33	3.46	3.20	11.95	3.75	3.18	0.795	0.698	0.820	0.08	0.07
HP1963	0.427	7.5	3.45	8.85	34.31	2.92	2.47	9.22	3.46	2.46	0.411	0.511	0.603	2.16	2.16
PBW750	0.542	5.5	3.95	11.62	49.91	3.35	2.90	14.75	3.87	2.86	0.714	0.669	0.789	0.00	0.02
UP2942	0.437	7	3.48	9.18	35.77	2.98	2.37	9.49	3.73	2.36	0.295	0.402	0.471	1.89	1.72
WH1105	0.537	5.5	3.37	8.85	43.17	2.92	2.32	11.82	3.68	2.32	0.290	0.401	0.463	2.81	2.16
WH1202	0.485	6	3.40	8.66	38.52	2.89	2.37	11.07	3.52	2.36	0.524	0.599	0.705	2.60	2.44
		E(S ¹)	3.97	V(S ¹)	0.1276	W =	0.338	$\chi^2 =$	111.594					$\Sigma = 30.37$	41.63
		E(S ²)	11.92	V(S ²)	4.35			$\chi^2(0.05,290) =$	124.3					$\chi^2 0.05,1 =$	3.84

Table.5 Non parametric measures of genotypes based on original values of yield 2016-17 (BLUE)

blue16-17	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
BRW3773	57.29	56.63	5.86	3.97	0.678	5	4.54	15.76	72.63	3.90	3.48	16.63	4.37	6.68	3.98
DBW189	55.41	54.71	7.14	3.56	0.498	8	4.08	12.65	47.80	3.49	3.06	12.00	3.98	6.64	3.76
DBW196	54.91	54.15	6.86	3.15	0.459	6.5	3.67	9.90	39.00	3.09	2.71	11.08	3.52	6.00	3.46
DBW88	54.88	54.33	7.86	2.99	0.381	9	3.37	8.94	30.73	2.94	2.47	8.80	3.49	6.75	3.36
HD2967	51.69	50.87	9.00	3.47	0.386	10.5	3.74	12.07	36.22	3.41	2.86	8.89	4.08	6.14	3.88
HD3086	57.05	56.13	5.39	3.35	0.621	5	3.90	11.21	56.13	3.29	2.88	14.94	3.76	6.57	3.75
HD3226	57.22	56.30	5.68	3.41	0.601	6.5	3.94	11.63	55.31	3.35	3.01	14.84	3.73	6.96	3.65
HP1963	56.94	56.29	5.75	2.85	0.496	5.5	3.26	8.12	38.13	2.80	2.32	11.30	3.37	6.57	2.79
PBW750	57.07	56.33	5.54	3.40	0.615	5.5	3.93	11.59	56.54	3.34	2.82	14.27	3.96	6.54	3.48
UP2942	55.82	55.11	6.79	3.36	0.495	7	3.89	11.29	44.91	3.30	2.76	11.39	3.94	6.75	3.56
WH1105	55.12	54.28	6.75	3.26	0.483	8	3.75	10.64	42.56	3.20	2.70	11.19	3.80	6.11	3.38
WH1202	57.10	56.50	5.14	2.92	0.567	5	3.26	8.50	44.61	2.86	2.24	12.22	3.65	6.29	2.76

Table.6 Non parametric measures of genotypes based on corrected values of yield (BLUE)

blue16-17	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
BRW3773	0.596	6	4.61	15.86	64.10	3.91	3.51	16.39	4.35	3.46	0.693	0.668	0.787	3.20	3.57
DBW189	0.567	7	4.36	14.16	57.57	3.70	3.22	12.88	4.24	3.14	0.393	0.517	0.610	1.18	1.16
DBW196	0.577	6	4.03	12.00	54.00	3.40	2.86	13.33	4.05	2.86	0.440	0.496	0.588	0.03	0.00
DBW88	0.498	7	3.91	11.31	45.22	3.30	2.79	11.14	3.91	2.75	0.306	0.420	0.497	0.03	0.09
HD2967	0.631	5.5	4.50	15.02	66.00	3.81	3.44	17.51	4.21	3.43	0.327	0.423	0.500	2.21	2.21
HD3086	0.570	6	4.37	14.03	57.65	3.68	3.29	15.33	4.12	3.29	0.657	0.682	0.809	1.21	1.03
HD3226	0.524	8	4.21	13.29	51.54	3.58	3.26	11.39	3.94	3.11	0.478	0.631	0.741	0.44	0.44
HP1963	0.425	6.5	3.23	7.81	32.09	2.74	2.29	9.85	3.29	2.29	0.416	0.477	0.562	4.29	3.88
PBW750	0.532	6	4.03	12.11	50.03	3.42	3.00	14.01	3.89	2.96	0.539	0.617	0.728	0.03	0.01
UP2942	0.527	7	4.13	12.64	50.56	3.49	3.00	12.00	4.06	2.96	0.423	0.514	0.609	0.19	0.12
WH1105	0.554	6	3.90	11.43	50.54	3.32	2.77	12.90	3.99	2.75	0.344	0.492	0.578	0.04	0.05
WH1202	0.439	6	3.17	7.62	32.73	2.71	2.26	10.52	3.26	2.21	0.443	0.527	0.616	5.05	4.25
		E(S ¹)	3.97	V(S ¹)	0.1276	W =	0.296	$\chi^2 =$	97.600					$\Sigma = 17.89$	16.80
		E(S ²)	11.92	V(S ²)	4.35			$\chi^2(0.05, 290)$	=124.3					$\chi^2(0.05, 1)$	=3.84

Table.7 Non parametric measures of genotypes based on original values of yield 2017-18 (BLUP)

blup 17-18	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
UP 2981	55.30	54.60	8.36	4.39	0.5247	8	5.08	19.24	55.23	4.30	3.57	10.69	5.17	8.60	4.05
DBW 221	56.72	56.17	6.24	4.55	0.7289	4	5.11	25.37	97.58	4.94	4.53	18.15	5.38	8.32	4.56
DBW 222	54.53	53.82	9.00	4.77	0.5300	9	5.55	23.18	61.80	4.72	4.03	11.18	5.53	8.24	4.52
BRW 3792	58.00	57.19	5.04	5.06	1.0044	3	5.25	37.11	176.69	5.97	5.71	28.31	6.24	7.84	4.76
PBW 763	52.14	51.49	11.68	4.36	0.3730	12	4.81	30.46	62.59	5.41	5.01	10.73	5.83	8.08	4.88
PBW 766	56.09	55.26	6.80	4.41	0.6480	6	5.06	21.95	77.48	4.59	4.18	15.37	5.04	8.00	4.38
DBW 233	56.34	55.37	6.80	5.09	0.7487	5	5.83	28.45	100.42	5.23	4.77	17.54	5.73	8.08	5.12
HD 3226	55.94	55.25	7.04	4.51	0.6411	6	5.16	22.19	75.64	4.62	4.26	15.13	5.00	8.52	3.97
PBW 801	54.33	53.67	8.64	3.57	0.4131	8	4.14	12.82	35.62	3.51	2.97	8.61	4.14	7.60	3.86
PBW 800	55.25	54.66	7.44	4.80	0.6447	8	5.53	23.89	77.06	4.79	4.12	13.85	5.56	7.92	4.97
DPW 621-50	53.27	52.69	10.48	4.37	0.4169	11	5.03	23.78	54.45	4.78	4.19	10.00	5.45	7.80	4.13
HD 3086	53.55	53.08	9.68	4.52	0.4665	10	5.27	22.21	55.06	4.62	3.88	10.01	5.50	7.56	4.61
HD 2967	54.03	53.31	9.16	4.22	0.4607	9	4.90	18.47	48.40	4.21	3.49	9.52	5.08	7.44	3.79
DBW 88	53.23	52.71	10.72	4.08	0.3804	12	4.44	22.43	50.21	4.64	4.24	9.89	5.08	8.32	3.78
WH 1105	53.14	52.58	10.44	4.08	0.3911	11	4.73	21.18	48.69	4.51	3.94	9.43	5.16	7.68	4.23

Table.8 Non parametric measures of genotypes based on corrected values of yield (BLUP)

	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
UP 2981	0.4711	8.0	4.69	16.42	45.81	3.97	3.34	10.45	4.71	3.32	0.4150	0.4749	0.5614	0.3529	0.416
DBW 221	0.5483	8.0	5.28	20.89	60.26	4.48	4.10	12.83	4.89	4.08	1.0200	0.7177	0.8462	0.3984	0.407
DBW 222	0.5487	8.0	5.25	20.58	59.93	4.44	3.78	11.83	5.22	3.76	0.4178	0.4938	0.5830	0.3154	0.299
BRW 3792	0.6069	7.0	5.52	23.24	71.15	4.72	3.99	14.26	5.59	3.80	1.2667	0.9372	1.0952	1.2823	1.721
PBW 763	0.6041	8.0	5.70	24.11	71.61	4.81	4.23	13.23	5.47	4.16	0.3467	0.4119	0.4880	2.2750	2.435
PBW 766	0.5472	8.0	5.11	19.54	58.63	4.33	3.86	12.08	4.86	3.84	0.6400	0.6370	0.7510	0.0725	0.063
DBW 233	0.6340	8.0	5.93	26.53	78.79	5.05	4.58	14.33	5.55	4.56	0.9120	0.7421	0.8716	3.9272	5.077
HD 3226	0.4659	9.0	4.62	15.77	44.41	3.89	3.22	8.93	4.71	3.20	0.5333	0.5526	0.6563	0.5583	0.691
PBW 801	0.5082	7.0	4.43	15.96	50.39	3.91	3.29	11.74	4.66	3.00	0.3750	0.4530	0.5131	1.2929	0.603
PBW 800	0.6281	10.0	5.75	25.23	76.44	4.92	4.33	10.82	5.60	4.24	0.5300	0.6614	0.7724	2.5785	3.536
DPW 621-50	0.5299	7.0	4.81	17.75	54.62	4.13	3.68	13.14	4.63	3.52	0.3200	0.3939	0.4593	0.1179	0.069
HD 3086	0.6099	7.0	5.37	22.38	71.06	4.64	3.95	14.11	5.44	3.84	0.3840	0.4789	0.5544	0.6596	1.136
HD 2967	0.5090	7.0	4.39	15.74	50.78	3.89	3.24	11.57	4.66	3.08	0.3422	0.4244	0.4796	1.4898	0.703
DBW 88	0.4547	10.0	4.31	14.39	41.51	3.72	3.24	8.10	4.26	3.04	0.2533	0.3467	0.4017	1.9644	1.503
WH 1105	0.5508	7.0	4.96	18.78	58.67	4.25	3.75	13.40	4.80	3.64	0.3309	0.4067	0.4751	0.0014	0.001
		E(S ¹)	4.98	V(S ¹)	0.2293			W=	0.3091	$\chi^2 = 129.82$				$\Sigma = 17.29$	18.66
		E(S ²)	18.67	V(S ²)	12.1624				$\chi^2(0.05,290)$	=124.3				$\chi^2(0.05,1)=$	3.84

Table.9 Non parametric measures of genotypes based on original values of yield 2017-18 (BLUE)

blue 17-18	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
UP 2981	55.18	54.42	8.00	4.20	0.5254	8	4.91	4.93	53.00	4.12	3.44	10.75	17.67	8.32	4.38
DBW 221	56.85	56.28	5.84	4.20	0.7192	3	4.73	4.53	72.49	4.12	3.74	16.01	17.64	7.92	4.62
DBW 222	54.49	53.71	8.44	4.65	0.5505	8	5.39	5.11	61.39	4.55	4.06	12.02	21.59	7.92	4.70
BRW 3792	58.13	57.20	5.08	4.78	0.9405	3	4.99	5.76	107.84	4.68	3.80	18.71	22.83	7.84	4.76
PBW 763	52.07	51.36	10.52	3.90	0.3703	11	4.47	4.53	34.62	3.82	3.22	7.64	15.18	8.32	4.60
PBW 766	56.19	55.32	6.36	3.85	0.6054	6	4.43	4.47	55.94	3.77	3.18	12.50	14.82	8.00	4.11
DBW 233	56.31	55.28	6.88	4.65	0.6757	5	5.34	5.05	75.38	4.55	4.11	14.92	21.61	8.08	4.82
HD 3226	56.08	55.42	6.84	4.03	0.5889	6	4.69	4.55	56.92	3.95	3.42	12.50	16.22	8.00	4.36
PBW 801	54.36	53.69	8.04	3.45	0.4286	7	3.93	4.12	35.44	3.38	2.77	8.61	11.87	7.76	4.11
PBW 800	55.22	54.61	7.16	4.52	0.6307	8	5.25	5.11	68.35	4.42	3.83	13.39	20.39	7.80	4.84
DPW 621-50	53.30	52.68	9.48	3.91	0.4121	10	4.51	4.49	38.63	3.83	3.26	8.60	15.26	7.88	4.38
HD 3086	53.58	53.11	9.04	3.93	0.4349	8	4.52	4.69	41.04	3.85	3.16	8.75	15.46	7.72	4.37
HD 2967	53.90	53.10	8.72	4.13	0.4734	9	4.81	4.88	46.91	4.04	3.35	9.61	17.04	7.80	4.01
DBW 88	53.22	52.68	9.80	3.51	0.3584	11	3.93	4.20	30.20	3.44	2.82	7.18	12.33	8.52	3.53
WH 1105	52.99	52.36	9.48	3.95	0.4165	9	4.53	4.49	39.48	3.87	3.34	8.80	15.59	8.12	4.27

Table.10 Non parametric measures of genotypes based on corrected values of yield (BLUE)

	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
UP 2981	0.5270	9	5.12	19.23	55.46	4.30	3.75	10.41	4.93	3.72	0.4650	0.5370	0.6400	0.0882	0.026
DBW 221	0.5831	7	5.33	21.33	64.63	4.52	4.16	14.85	4.93	4.12	1.3733	0.7748	0.9132	0.5514	0.582
DBW 222	0.5933	7	5.46	22.08	66.90	4.60	4.08	14.56	5.20	4.04	0.5050	0.5455	0.6469	1.0142	0.956
BRW 3792	0.6069	8	5.51	22.64	69.31	4.66	3.78	11.81	5.75	3.76	1.2533	0.9177	1.0853	1.2510	1.298
PBW 763	0.5527	8	5.34	21.14	60.99	4.51	3.72	11.62	5.46	3.68	0.3345	0.4283	0.5076	0.5723	0.504
PBW 766	0.5141	8	4.81	16.92	50.75	4.03	3.60	11.25	4.51	3.60	0.6000	0.6336	0.7568	0.1179	0.252
DBW 233	0.5967	8	5.55	23.24	69.04	4.72	4.33	13.53	5.15	4.32	0.8640	0.6866	0.8072	1.4448	1.722
HD 3226	0.5449	8	5.08	19.00	57.00	4.27	3.60	11.25	5.07	3.60	0.6000	0.6244	0.7427	0.0456	0.009
PBW 801	0.5291	7	4.73	16.86	52.13	4.02	3.31	11.83	4.89	3.16	0.4514	0.5003	0.5879	0.2750	0.269
PBW 800	0.6204	10	5.57	23.42	72.05	4.74	4.30	10.76	5.22	4.12	0.5150	0.6622	0.7784	1.5470	1.855
DPW 621-50	0.5560	6	5.10	19.19	58.46	4.29	3.88	16.15	4.75	3.80	0.3800	0.4528	0.5380	0.0652	0.023
HD 3086	0.5665	7	5.07	19.13	59.46	4.29	3.63	12.96	5.06	3.60	0.4500	0.4740	0.5612	0.0398	0.017
HD 2967	0.5142	8	4.63	16.08	49.49	3.93	3.20	10.00	4.83	3.16	0.3511	0.4506	0.5306	0.5377	0.549
DBW 88	0.4137	9	4.04	12.43	35.00	3.45	2.90	8.04	4.12	2.80	0.2545	0.3524	0.4122	3.8357	3.201
WH 1105	0.5253	7	4.98	18.19	53.77	4.18	3.73	13.34	4.68	3.68	0.4089	0.4408	0.5253	0.0000	0.018
			E(S ¹)	4.98	V(S ¹)	0.2293		W=	0.3287	$\chi^2 = 138.06$				$\sum = 11.39$	11.28
			E(S ²)	18.67	V(S ²)	12.1624				$\chi^2(0.05,290)$	=124.3			$\chi^2(0.05,1)=$	3.84

Table.11 Spearman's rank correlation analysis among non parametric measures (2016-17) BLUP

	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	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⁾	ZI	ZZ
Yield	0.9720	-0.9126	-0.3217	-0.8392	0.8811	-0.3636	-0.3706	-0.7203	-0.3217	-0.3077	-0.8182	-0.3217	0.4196	-0.1469	-0.0559	-0.2343	-0.1818	-0.1538	-0.1748	-0.1014	-0.1853	-0.0350	-0.1014	-0.1853	-0.8182	-0.8112	-0.8112	0.1189	0.1538
GAI	1.0000	-0.8846	-0.3077	-0.8042	0.8531	-0.3217	-0.3916	-0.7063	-0.3077	-0.2657	-0.7902	-0.3077	0.4196	-0.0490	0.0280	-0.2343	-0.1049	-0.0559	-0.0769	0.0035	-0.1224	0.0350	0.0035	-0.1224	-0.7832	-0.7622	-0.7622	0.0769	0.0559
MR		1.0000	0.1154	0.7587	-0.8776	0.1573	0.2203	0.6049	0.1154	0.0594	0.7378	0.1154	-0.0035	-0.1014	0.0385	-0.2098	-0.0664	-0.0315	0.0385	-0.0769	-0.0070	0.0105	-0.0769	-0.0070	0.7028	0.7587	0.7587	-0.1713	-0.0105
SD			1.0000	0.6294	-0.1399	0.9720	0.9161	0.8252	1.0000	0.9441	0.6364	1.0000	-0.1049	0.8671	0.7483	0.0874	0.9021	0.8601	0.8671	0.8566	0.8986	0.8322	0.8566	0.8986	0.6434	0.6643	0.6643	-0.0070	-0.8601
CV				1.0000	-0.7343	0.6993	0.5944	0.9301	0.6294	0.6084	0.9930	0.6294	-0.2448	0.4615	0.3566	0.1364	0.5105	0.3986	0.4615	0.4510	0.5629	0.4056	0.4510	0.5629	0.9510	0.9720	0.9720	-0.2517	-0.3986
Med					1.0000	-0.1888	-0.1958	-0.6014	-0.1399	-0.1119	-0.7203	-0.1399	0.1538	0.0280	-0.0420	0.1643	-0.0070	0.0070	-0.0629	0.0734	-0.0175	-0.0490	0.0734	-0.0175	-0.6993	-0.7133	-0.7133	0.3287	0.1049
S_i¹						1.0000	0.8252	0.8392	0.9720	0.9650	0.7133	0.9720	-0.1469	0.8951	0.7343	0.1643	0.9231	0.8182	0.8741	0.8846	0.9266	0.7972	0.8846	0.9266	0.6923	0.7133	0.7133	-0.0699	-0.8182
S_i²							1.0000	0.7902	0.9161	0.7762	0.5734	0.9161	-0.0839	0.6993	0.6783	-0.0385	0.7483	0.8112	0.7133	0.6888	0.7238	0.7413	0.6888	0.7238	0.6014	0.6573	0.6573	0.1329	-0.8112
S_i³								1.0000	0.8252	0.7902	0.9371	0.8252	-0.1678	0.6294	0.5734	0.0594	0.6783	0.6014	0.6713	0.6189	0.7238	0.6294	0.6189	0.7238	0.9301	0.9441	0.9441	-0.1189	-0.6014
S_i⁴									1.0000	0.9441	0.6364	1.0000	-0.1049	0.8671	0.7483	0.0874	0.9021	0.8601	0.8671	0.8566	0.8986	0.8322	0.8566	0.8986	0.6434	0.6643	0.6643	-0.0070	-0.8601
S_i⁵										1.0000	0.6364	0.9441	-0.2168	0.9371	0.7133	0.2483	0.9580	0.8182	0.8951	0.9266	0.9685	0.7622	0.9266	0.9685	0.6573	0.6364	0.6364	-0.0210	-0.8182
S_i⁶											1.0000	0.6364	-0.2378	0.4685	0.3636	0.1364	0.5175	0.3776	0.4755	0.4580	0.5769	0.4126	0.4580	0.5769	0.9441	0.9580	0.9580	-0.2587	-0.3776
S_i⁷												1.0000	-0.1049	0.8671	0.7483	0.0874	0.9021	0.8601	0.8671	0.8566	0.8986	0.8322	0.8566	0.8986	0.6434	0.6643	0.6643	-0.0070	-0.8601
CMR													1.0000	-0.2028	0.3427	-0.8217	-0.2168	-0.0350	0.1119	-0.1364	-0.1853	0.3077	-0.1364	-0.1853	-0.2517	-0.1678	-0.1678	0.0490	0.0769
CSD														1.0000	0.7483	0.2413	0.9930	0.9091	0.9161	0.9965	0.9685	0.7902	0.9965	0.9685	0.5175	0.5105	0.5105	-0.0490	-0.9091
CCV															1.0000	-0.3182	0.7273	0.8322	0.9161	0.7797	0.7028	0.9231	0.7797	0.7028	0.3776	0.4615	0.4615	0.1608	-0.8322
Cmed																1.0000	0.2552	-0.0245	-0.0524	0.2378	0.3287	-0.3392	0.2378	0.3287	0.2133	0.0664	0.0664	0.0664	0.0245
CS_i¹																	1.0000	0.8951	0.9021	0.9825	0.9825	0.7832	0.9825	0.9825	0.5664	0.5524	0.5524	-0.0559	-0.8951
CS_i²																		1.0000	0.9091	0.9196	0.8357	0.8811	0.9196	0.8357	0.4336	0.4825	0.4825	0.0000	-1.0000
CS_i³																			1.0000	0.9336	0.8916	0.9091	0.9336	0.8916	0.5245	0.5455	0.5455	0.0280	-0.9091
CS_i⁴																				1.0000	0.9580	0.8077	1.0000	0.9580	0.5070	0.5070	0.5070	0.0035	-0.8636
CS_i⁵																					1.0000	0.7587	0.9580	1.0000	0.6469	0.6049	0.6049	-0.0175	-0.7797
CS_i⁶																						1.0000	0.8077	0.7587	0.4126	0.4825	0.4825	-0.1049	-0.8811
CS_i⁷																							1.0000	0.9580	0.5070	0.5070	0.5070	0.0035	-0.8636
NP_i⁽¹⁾																								1.0000	0.6469	0.6049	0.6049	-0.0175	-0.7797
NP_i⁽²⁾																									1.0000	0.9650	0.9650	-0.1538	-0.4336
NP_i⁽³⁾																										1.0000	1.0000	-0.0979	-0.4825
NP_i⁽⁴⁾																											1.0000	-0.0979	-0.4825
ZI																												1.0000	-0.5350

Critical values of Spearman's correlation coefficients 0.591 & 0.780 at 5 & 1 % level of significance

Table 12: Loadings of non parametric measures

Measure	Component PC1	Component PC2
Yield	0.0196	-0.3296
GAI	0.0240	-0.3274
MR	0.0185	0.3240
SD	-0.2323	-0.0307
CV	-0.1320	-0.2735
Med	0.0198	0.3276
S _i ¹	-0.2178	-0.0895
S _i ²	-0.2330	-0.0280
S _i ³	-0.1766	-0.2224
S _i ⁴	-0.2323	-0.0307
S _i ⁵	-0.2257	-0.0300
S _i ⁶	-0.1452	-0.2604
S _i ⁷	-0.2257	-0.0295
CMR	-0.0557	-0.0959
CSD	-0.2273	0.0978
CCV	-0.1930	0.1516
Cmed	-0.0697	-0.0404
CS _i ¹	-0.2299	0.0839
CS _i ²	-0.2244	0.1101
CS _i ³	-0.2119	0.1437
CS _i ⁴	-0.2273	0.0978
CS _i ⁵	-0.2233	0.0991
CS _i ⁶	-0.1814	0.1243
CS _i ⁷	-0.2220	0.0955
NP _i ⁽¹⁾	-0.2217	0.1057
NP _i ⁽²⁾	-0.1442	-0.2499
NP _i ⁽³⁾	-0.1565	-0.2445
NP _i ⁽⁴⁾	-0.1520	-0.2506
Z1	-0.1468	0.1881
Z2	0.2221	-0.0926
% variance	58.276	29.461

Table.13 Spearman's rank correlation values among non parametric measures (2016-17) BLUE

	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	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
Yield	0.9510	-0.8112	-0.1958	-0.9091	0.8252	-0.4406	-0.1259	-0.7972	-0.1958	-0.2937	-0.9161	-0.1958	0.3357	-0.1049	0.2238	-0.1469	-0.0699	0.1329	0.0839	-0.1049	-0.1748	0.0909	-0.1049	-0.0909	-0.8531	-0.8322	-0.8322	-0.3566	-0.1329
GAI	1.0000	-0.7762	-0.0839	-0.8392	0.8182	-0.3007	-0.0699	-0.6923	-0.0839	-0.1399	-0.8182	-0.0839	0.3636	0.0280	0.3566	-0.1399	0.0629	0.2587	0.2517	0.0280	-0.0490	0.1958	0.0280	0.0280	-0.7552	-0.6993	-0.6993	-0.3846	-0.2587
MR		1.0000	-0.2378	0.7622	-0.6923	0.0559	-0.1888	0.5804	-0.2378	-0.1049	0.7343	-0.2378	-0.0420	-0.2657	-0.3776	0.1259	-0.2797	-0.4615	-0.3357	-0.2657	-0.1608	-0.1888	-0.2657	-0.1958	0.7483	0.7063	0.7063	0.2797	0.4615
SD			1.0000	0.3706	0.2168	0.8881	0.8951	0.5734	1.0000	0.9301	0.4196	1.0000	-0.2727	0.9301	0.6643	0.0070	0.8531	0.7762	0.7832	0.9301	0.8741	0.6643	0.9301	0.9021	0.2587	0.4196	0.4196	-0.0210	-0.7762
CV				1.0000	-0.6434	0.6154	0.3287	0.9231	0.3706	0.5105	0.9860	0.3706	-0.2797	0.3427	0.0559	0.1538	0.3007	0.1189	0.1678	0.3427	0.3986	0.2028	0.3427	0.3776	0.9021	0.9371	0.9371	0.3077	-0.1189
Med					1.0000	-0.0070	0.1818	-0.4755	0.2168	0.0629	-0.6084	0.2168	0.0769	0.1678	0.2238	0.2098	0.1399	0.2727	0.2098	0.1678	0.0839	0.1119	0.1678	0.1608	-0.7063	-0.5804	-0.5804	-0.2587	-0.1049
S _i ¹						1.0000	0.7413	0.8182	0.8881	0.9231	0.6643	0.8881	-0.3986	0.7972	0.4895	0.2517	0.7203	0.6503	0.6154	0.7972	0.7622	0.5245	0.7972	0.7902	0.4965	0.6783	0.6783	-0.1469	-0.6503
S _i ²							1.0000	0.5245	0.8951	0.7343	0.3497	0.8951	-0.0140	0.8182	0.6923	-0.2028	0.7133	0.7273	0.6993	0.8182	0.7273	0.7413	0.8182	0.7972	0.2028	0.3357	0.3357	0.0559	-0.7273
S _i ³								1.0000	0.5734	0.6643	0.9371	0.5734	-0.2937	0.4965	0.2308	0.2168	0.4336	0.3007	0.3147	0.4965	0.5175	0.3636	0.4965	0.5245	0.8601	0.9371	0.9371	0.0210	-0.3007
S _i ⁴									1.0000	0.9301	0.4196	1.0000	-0.2727	0.9301	0.6643	0.0070	0.8531	0.7762	0.7832	0.9301	0.8741	0.6643	0.9301	0.9021	0.2587	0.4196	0.4196	-0.0210	-0.7762
S _i ⁵										1.0000	0.5594	0.9301	-0.3636	0.9441	0.6503	0.1049	0.9091	0.7972	0.8182	0.9441	0.9231	0.6364	0.9441	0.9301	0.4196	0.5804	0.5804	0.0000	-0.7972
S _i ⁶											1.0000	0.4196	-0.3566	0.3916	0.0699	0.2098	0.3566	0.1748	0.2238	0.3916	0.4406	0.1958	0.3916	0.4196	0.9021	0.9650	0.9650	0.3007	-0.1748
S _i ⁷												1.0000	-0.2727	0.9301	0.6643	0.0070	0.8531	0.7762	0.7832	0.9301	0.8741	0.6643	0.9301	0.9021	0.2587	0.4196	0.4196	-0.0210	-0.7762
CMR													1.0000	-0.2448	0.3427	-0.6084	-0.2727	-0.1189	0.0210	-0.2448	-0.2867	0.3147	-0.2448	-0.2378	-0.1538	-0.2587	-0.2587	-0.0909	0.0629
CSD														1.0000	0.7832	-0.0909	0.9790	0.8951	0.9231	1.0000	0.9650	0.7622	1.0000	0.9860	0.2797	0.4126	0.4126	0.0839	-0.8951
CCV															1.0000	-0.3916	0.7902	0.8392	0.9161	0.7832	0.7413	0.9371	0.7832	0.7832	0.1469	0.1818	0.1818	-0.0979	-0.8392
Cmed																1.0000	-0.0909	-0.0699	-0.2308	-0.0909	-0.1119	-0.4476	-0.0909	-0.0629	0.0909	0.1958	0.1958	-0.1538	0.1958
CS _i ¹																	1.0000	0.8951	0.9441	0.9790	0.9720	0.7552	0.9790	0.9790	0.2937	0.3986	0.3986	0.0909	-0.8951
CS _i ²																		1.0000	0.9161	0.8951	0.7902	0.7133	0.8951	0.8601	0.0839	0.2238	0.2238	0.0629	-1.0000
CS _i ³																			1.0000	0.9231	0.8881	0.8322	0.9231	0.9091	0.2028	0.3147	0.3147	0.0699	-0.9161
CS _i ⁴																				1.0000	0.9650	0.7622	1.0000	0.9860	0.2797	0.4126	0.4126	0.0839	-0.8951
CS _i ⁵																					1.0000	0.7762	0.9650	0.9860	0.3776	0.4685	0.4685	0.0490	-0.7902
CS _i ⁶																						1.0000	0.7622	0.8042	0.2797	0.2867	0.2867	-0.1469	-0.7133
CS _i ⁷																							1.0000	0.9860	0.2797	0.4126	0.4126	0.0839	-0.8951
NP _i ⁽¹⁾																								1.0000	0.3357	0.4476	0.4476	0.0490	-0.8182
NP _i ⁽²⁾																									1.0000	0.9231	0.9231	0.1469	-0.0839
NP _i ⁽³⁾																										1.0000	0.1608	-0.2238	
NP _i ⁽⁴⁾																											1.0000	0.1608	-0.2238
Z1																												1.0000	-0.1503

Figure 2: Biplot analysis of non parametric measures based on BLUE (2016-17)

Table.15 Spearman's rank correlation values among non parametric measures (2017-18) BLUP

	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	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⁾	ZI	Z2
Yield	0.9929	-0.9482	-0.7107	-0.9500	0.9696	-0.5929	-0.1107	-0.7571	-0.2464	-0.3179	-0.8071	-0.2464	0.3036	-0.3036	-0.1500	-0.0946	-0.3036	-0.3857	-0.2071	-0.2893	-0.2482	-0.0929	-0.2893	-0.3054	-0.9286	-0.9071	-0.9071	-0.0071	0.3857
GAI	1.0000	-0.9482	-0.7179	-0.9500	0.9625	-0.5964	-0.1107	-0.7679	-0.2679	-0.3357	-0.8143	-0.2679	0.3036	-0.3179	-0.1714	-0.1375	-0.3179	-0.4143	-0.2286	-0.3036	-0.2696	-0.0643	-0.3036	-0.3232	-0.9321	-0.9214	-0.9179	-0.0714	0.4143
MR		1.0000	0.6768	0.9339	-0.9964	0.5482	0.0875	0.7304	0.2089	0.2804	0.7696	0.2089	-0.2304	0.3304	0.2089	0.1857	0.3304	0.4304	0.2518	0.3196	0.3143	0.1304	0.3196	0.3071	0.9339	0.9196	0.9161	0.0054	-0.3982
SD			1.0000	0.8643	-0.7018	0.9536	0.6536	0.8500	0.6429	0.4714	0.8500	0.6429	-0.2500	0.7607	0.6536	0.2732	0.7607	0.7857	0.6750	0.7321	0.6661	0.3857	0.7321	0.7089	0.8143	0.8679	0.8607	0.1607	-0.7857
CV				1.0000	-0.9625	0.7643	0.2964	0.8286	0.3786	0.3643	0.8607	0.3786	-0.2357	0.4929	0.3821	0.2125	0.4929	0.5571	0.4107	0.4714	0.4518	0.2429	0.4714	0.4839	0.9321	0.9500	0.9357	0.0143	-0.5571
Med					1.0000	-0.5661	-0.1161	-0.7589	-0.2518	-0.3411	-0.8018	-0.2518	0.1554	-0.3554	-0.2339	0.0357	-0.3554	-0.4339	-0.2839	-0.3446	-0.2929	-0.2232	-0.3446	-0.3393	-0.9696	-0.9518	-0.9446	-0.0518	0.3875
S _i ¹						1.0000	0.5750	0.6893	0.4821	0.2750	0.7000	0.4821	-0.2286	0.6679	0.5964	0.2768	0.6679	0.7036	0.5821	0.6357	0.5446	0.2821	0.6357	0.6196	0.6893	0.7607	0.7429	0.1357	-0.7036
S _i ²							1.0000	0.5429	0.8286	0.5179	0.4750	0.8286	-0.0179	0.8357	0.7964	0.0875	0.8357	0.7929	0.8393	0.8321	0.7946	0.6143	0.8321	0.7125	0.3036	0.3679	0.3893	0.3321	-0.7929
S _i ³								1.0000	0.7286	0.7500	0.9857	0.7286	-0.4679	0.7214	0.5000	0.4054	0.7214	0.7214	0.5929	0.6893	0.6768	0.3464	0.6893	0.7304	0.8750	0.8500	0.8786	0.1464	-0.7214
S _i ⁴									1.0000	0.8679	0.6821	1.0000	-0.2857	0.7536	0.6036	0.2839	0.7536	0.6500	0.7107	0.7357	0.7411	0.4929	0.7357	0.6911	0.4143	0.4286	0.4571	0.3536	-0.6500
S _i ⁵										1.0000	0.7214	0.8679	-0.4714	0.5071	0.3000	0.3446	0.5071	0.4107	0.4214	0.4714	0.4875	0.3571	0.4714	0.4946	0.4357	0.3821	0.4214	0.2500	-0.4107
S _i ⁶											1.0000	0.6821	-0.4964	0.6357	0.4071	0.3982	0.6357	0.6536	0.5071	0.6000	0.5875	0.2786	0.6000	0.6518	0.9000	0.8643	0.8857	0.0929	-0.6536
S _i ⁷												1.0000	-0.2857	0.7536	0.6036	0.2839	0.7536	0.6500	0.7107	0.7357	0.7411	0.4929	0.7357	0.6911	0.4143	0.4286	0.4571	0.3536	-0.6500
CMR													1.0000	-0.0286	0.2929	-0.6268	-0.0286	-0.0214	0.1714	0.0107	0.0089	0.3821	0.0107	-0.1125	-0.3286	-0.2107	-0.2893	-0.0179	-0.0214
CSD														1.0000	0.9286	0.1911	1.0000	0.9393	0.9643	0.9964	0.9589	0.6714	0.9964	0.9482	0.5643	0.6214	0.6393	0.2857	-0.9393
CCV															1.0000	-0.0089	0.9286	0.8893	0.9714	0.9357	0.8954	0.7607	0.9357	0.8554	0.3964	0.5036	0.4893	0.2786	-0.8893
Cmed																1.0000	0.1911	0.2054	0.0768	0.1661	0.2357	-0.3304	0.1661	0.2929	0.2589	0.2339	0.2768	0.2982	-0.0732
CS _i ¹																	1.0000	0.9393	0.9643	0.9964	0.9589	0.6714	0.9964	0.9482	0.5643	0.6214	0.6393	0.2857	-0.9393
CS _i ²																		1.0000	0.9107	0.9321	0.8768	0.5429	0.9321	0.8625	0.6464	0.7107	0.7214	0.3179	-1.0000
CS _i ³																			1.0000	0.9714	0.9554	0.7250	0.9714	0.9054	0.4607	0.5464	0.5464	0.3500	-0.9107
CS _i ⁴																				1.0000	0.9696	0.6857	1.0000	0.9375	0.5464	0.6071	0.6250	0.2964	-0.9321
CS _i ⁵																					1.0000	0.6589	0.9696	0.9500	0.5125	0.5696	0.5875	0.3375	-0.8375
CS _i ⁶																						1.0000	0.6857	0.5875	0.2679	0.2964	0.2821	-0.0357	-0.5429
CS _i ⁷																							1.0000	0.9375	0.5464	0.6071	0.6250	0.2964	-0.9321
NP _i ⁽¹⁾																								1.0000	0.5375	0.5804	0.5946	0.2125	-0.8804
NP _i ⁽²⁾																									1.0000	0.9786	0.9857	0.0607	-0.6464
NP _i ⁽³⁾																										1.0000	0.9929	0.1643	-0.7107
NP _i ⁽⁴⁾																											1.0000	0.1607	-0.7214
ZI																												1.0000	-0.0982

Critical values of Spearman's correlation coefficients 0.525 & 0.689 at 5 & 1 % level of significance

Figure 3: Biplot analysis of non parametric measures based on BLUP (2017-18)

Table 16: Loadings of non parametric measure (2017-18)

Measure	Component PC1	Component PC2
Yield	-0.1503	0.3079
GAI	-0.1479	0.3116
MR	0.1487	-0.2946
SD	-0.2093	0.0262
CV	-0.1949	0.2328
Med	0.1515	-0.2872
S _i ¹	-0.1759	-0.0236
S _i ²	-0.1955	-0.0190
S _i ³	-0.2018	0.1713
S _i ⁴	-0.1939	-0.0286
S _i ⁵	-0.1851	0.0155
S _i ⁶	-0.1944	0.2117
S _i ⁷	-0.1896	-0.0998
CMR	-0.0127	0.1681
CSD	-0.2131	-0.1615
CCV	-0.1928	-0.2140
Cmed	-0.0015	0.0494
CS _i ¹	-0.2121	-0.1669
CS _i ²	-0.2102	-0.1800
CS _i ³	-0.1995	-0.2056
CS _i ⁴	-0.2104	-0.1799
CS _i ⁵	-0.2005	-0.1801
CS _i ⁶	-0.1389	-0.1646
CS _i ⁷	-0.2040	-0.1602
NP _i ⁽¹⁾	-0.1996	-0.1635
NP _i ⁽²⁾	-0.1967	0.2025
NP _i ⁽³⁾	-0.2081	0.1842
NP _i ⁽⁴⁾	-0.2095	0.1840
ZI	-0.0935	-0.1184
Z2	0.2039	0.1599
% variance	58.87	19.56

Table.17 Spearman's rank correlation values among non parametric measures (2017-18) BLUE

	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	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
Yield	0.9821	-0.8125	-0.6036	-0.9571	0.9036	-0.5214	-0.4393	-0.8964	-0.6036	-0.5964	-0.9286	-0.6036	-0.1929	-0.4821	-0.4643	-0.2464	-0.4571	-0.3357	-0.4500	-0.4821	-0.4304	-0.0982	-0.4821	-0.4250	-0.9732	-0.9643	-0.9643	-0.2607	0.3357
GAI	1.0000	-0.7961	-0.5500	-0.9321	0.8964	-0.4643	-0.4071	-0.8643	-0.5500	-0.5357	-0.9000	-0.5500	-0.2107	-0.4429	-0.4464	-0.2250	-0.4214	-0.3429	-0.4321	-0.4429	-0.3732	-0.0839	-0.4429	-0.3714	-0.9768	-0.9500	-0.9500	-0.1679	0.3429
MR		1.0000	0.5125	0.9375	-0.9839	0.4304	0.3482	0.8482	0.5125	0.4982	0.9125	0.5125	0.1946	0.3839	0.3732	0.2054	0.3625	0.2839	0.3625	0.3839	0.3500	0.0536	0.3839	0.3911	0.9464	0.9411	0.9411	0.1339	-0.3161
SD			1.0000	0.7357	-0.4464	0.9679	0.9107	0.8571	1.0000	0.9500	0.7607	1.0000	0.0750	0.7714	0.6964	0.1929	0.7571	0.6393	0.7214	0.7714	0.7196	0.1696	0.7714	0.7179	0.5804	0.6571	0.6571	0.3143	-0.6393
CV				1.0000	-0.8821	0.6714	0.5857	0.9714	0.7357	0.7214	0.9893	0.7357	0.2321	0.6107	0.5857	0.2214	0.5821	0.4571	0.5893	0.6107	0.5732	0.1589	0.6107	0.6071	0.9411	0.9679	0.9679	0.2571	-0.4571
Med					1.0000	-0.3571	-0.2429	-0.7964	-0.4464	-0.4286	-0.8536	-0.4464	-0.2893	-0.3714	-0.4250	0.0036	-0.3429	-0.2821	-0.3893	-0.3714	-0.3482	-0.3054	-0.3714	-0.3321	-0.9804	-0.9179	-0.9179	-0.0786	0.2464
S_i¹						1.0000	0.9071	0.8036	0.9679	0.9536	0.6929	0.9679	0.1179	0.7464	0.6750	0.1536	0.7357	0.6214	0.6893	0.7464	0.7161	0.1768	0.7464	0.7143	0.5089	0.5893	0.5893	0.2821	-0.6214
S_i²							1.0000	0.7107	0.9107	0.8214	0.5786	0.9107	0.1786	0.7464	0.7036	0.2679	0.7464	0.7821	0.7250	0.7464	0.5804	0.0161	0.7464	0.5786	0.3839	0.5071	0.5071	0.3286	-0.7821
S_i³								1.0000	0.8571	0.8464	0.9750	0.8571	0.1857	0.7036	0.6679	0.1821	0.6786	0.5250	0.6786	0.7036	0.6768	0.2304	0.7036	0.7000	0.8946	0.9286	0.9286	0.2750	-0.5250
S_i⁴									1.0000	0.9500	0.7607	1.0000	0.0750	0.7714	0.6964	0.1929	0.7571	0.6393	0.7214	0.7714	0.7196	0.1696	0.7714	0.7179	0.5804	0.6571	0.6571	0.3143	-0.6393
S_i⁵										1.0000	0.7571	0.9500	-0.0500	0.8036	0.6857	0.1786	0.8036	0.5964	0.7286	0.8036	0.8018	0.2339	0.8036	0.8107	0.6018	0.6607	0.6607	0.3679	-0.5964
S_i⁶											1.0000	0.7607	0.1571	0.6107	0.5571	0.2214	0.5857	0.4250	0.5786	0.6107	0.5982	0.1696	0.6107	0.6321	0.9304	0.9429	0.9429	0.2321	-0.4250
S_i⁷												1.0000	0.0750	0.7714	0.6964	0.1929	0.7571	0.6393	0.7214	0.7714	0.7196	0.1696	0.7714	0.7179	0.5804	0.6571	0.6571	0.3143	-0.6393
CMR													1.0000	0.0607	0.3929	-0.3964	0.0071	0.1643	0.2179	0.0607	0.0339	0.2268	0.0607	0.0321	0.1375	0.2607	0.2607	-0.1357	-0.1786
CSD														1.0000	0.9143	0.0643	0.9929	0.8000	0.9679	1.0000	0.9196	0.3946	1.0000	0.9143	0.5518	0.6500	0.6500	0.3893	-0.8000
CCV															1.0000	-0.1107	0.8929	0.8036	0.9750	0.9143	0.8196	0.4911	0.9143	0.8071	0.5304	0.6464	0.6464	0.3464	-0.8036
Cmed																1.0000	0.1071	0.2143	-0.0214	0.0643	-0.1232	-0.7554	0.0643	-0.0536	0.0768	0.1214	0.1214	0.4536	-0.2357
CS_i¹																	1.0000	0.8286	0.9571	0.9929	0.8946	0.3554	0.9929	0.8929	0.5268	0.6214	0.6214	0.3964	-0.8286
CS_i²																		1.0000	0.8429	0.8000	0.5304	0.1232	0.8000	0.5429	0.3696	0.4643	0.4643	0.3429	-1.0000
CS_i³																			1.0000	0.9679	0.8589	0.4518	0.9679	0.8536	0.5375	0.6357	0.6357	0.3607	-0.8429
CS_i⁴																				1.0000	0.9196	0.3946	1.0000	0.9143	0.5518	0.6500	0.6500	0.3893	-0.8000
CS_i⁵																					1.0000	0.5893	0.9196	0.9911	0.5571	0.6232	0.6232	0.2554	-0.5054
CS_i⁶																						1.0000	0.3946	0.5911	0.3036	0.2696	0.2696	-0.2304	-0.1054
CS_i⁷																							1.0000	0.9143	0.5518	0.6500	0.6500	0.3893	-0.8000
NP_i⁽¹⁾																								1.0000	0.5911	0.6464	0.6464	0.2607	-0.4786
NP_i⁽²⁾																									1.0000	0.9696	0.9696	0.1018	-0.3946
NP_i⁽³⁾																										1.0000	1.0000	0.2464	-0.4643
NP_i⁽⁴⁾																											1.0000	0.2464	-0.4643
Z1																												1.0000	-0.2982

Measure	Component PC1	Component PC2
Yield	-0.1711	0.2969
GAI	-0.1679	0.3019
MR	0.1685	-0.2917
SD	-0.2071	-0.0426
CV	-0.2004	0.2207
Med	0.1708	-0.2445
S ₁ ¹	-0.1884	-0.1177
S ₁ ²	-0.2070	-0.0347
S ₁ ³	-0.2092	0.1711
S ₁ ⁴	-0.2071	-0.0426
S ₁ ⁵	-0.2032	-0.0744
S ₁ ⁶	-0.2061	0.1985
S ₁ ⁷	-0.1847	0.0076
CMR	0.0944	0.0421
CSD	-0.2058	-0.1875
CCV	-0.2053	-0.1690
Cmed	-0.0151	0.1569
CS ₁ ¹	-0.2044	-0.1933
CS ₁ ²	-0.2067	-0.1804
CS ₁ ³	-0.2092	-0.1705
CS ₁ ⁴	-0.2058	-0.1875
CS ₁ ⁵	-0.1866	-0.1835
CS ₁ ⁶	-0.0938	-0.2387
CS ₁ ⁷	-0.1750	-0.1372
NP ₁ ⁽¹⁾	-0.1906	-0.1731
NP ₁ ⁽²⁾	-0.1756	0.2028
NP ₁ ⁽³⁾	-0.2019	0.2029
NP ₁ ⁽⁴⁾	-0.2018	0.2021
ZI	0.0333	0.1649
Z2	0.1754	0.1418
% variance	63.61	15.07

Biplot graphical analysis

Loadings of the first two principal components axes (PCA) of ranks of non-parametric measures were shown in table 16. Both significant PAC's accounting for 78.4% of the variations in the variables. The PCA1 versus PCA2 were used to generate the clustering pattern of measures by biplot as illustrated in Fig. 3. Biplot analysis expressed both types of large and small clusters of measures. Smaller clusters of only two measures i.e. Yield with GAI and MR with Med are observed in graphical analysis. CV along with CMR expressed affinity with, SD CMed, $NP_i^{(2)}$, $NP_i^{(3)}$, $NP_i^{(4)}$, S_i^3 , S_i^5 , S_i^6 . Large cluster comprises of CCV, CSD, $NP_i^{(1)}$, S_i^1 , S_i^2 , S_i^4 , CS_i^1 , CS_i^2 , CS_i^3 , CS_i^4 , CS_i^5 , CS_i^6 , CS_i^7 and Z1 measures.

Analytic analysis as per BLUE's

Higher average yield had expressed by G4, G2, G7 wheat genotypes, whereas GAI selected G4, G2, G8 as genotypes of choice, large values of mean ranks selected G5, G14, G15 more over the consistent yield of G9, G14, G6 expressed by least values of standard deviation (Table 9). G14, G5, G11 would be genotypes of least variations as pointed by values of coefficient of variation; S_i^1 measure selected G14, G9, G6 opposed to G9, G14, G6 by S_i^2 & S_i^3 measures. Same set of genotypes G6, G9, G14 considered by S_i^4 along with S_i^5 , G14, G5, G11 genotypes favoured S_i^6 whereas S_i^7 pointed towards G9, G14, G6 wheat genotypes.

Average mean of ranks as per corrected yield values selected G14, G5, G1 and corrected standard deviation observed suitability of G14, G13, G9 genotypes. Coefficient of variation as per corrected yield values exhibited G14, G6, G13 while median values for G11, G3, G9 and G14, G13, G9 by CS_i^1 , G14, G6, G15 by CS_i^2 , CS_i^3 pointed for G14, G6, G13 & as per CS_i^4 , CS_i^5 & CS_i^7 values

G14, G13, G9 while G14, G13, G1 by CS_i^6 (table 10). No parametric measures while considering ranks of genotypes by original and corrected yield values $NP_i^{(1)}$, (G14, G9, G13); $NP_i^{(2)}$ (G14, G5, G13), $NP_i^{(3)}$ & $NP_i^{(4)}$ (G14, G5, G15), also selected G4, G5, G8 wheat genotypes and G2 along with G7 would be of unsuitable type as per value of $NP_i^{(1)}$, $NP_i^{(2)}$, $NP_i^{(3)}$, $NP_i^{(4)}$ whereas values of measures Z1 observed G15, G12, G8 and G8, G12, G15 by Z2 values.

Value of the χ^2 statistic was less than table of χ^2 (0.05, 290) = 124.3 (135.8), which resulted an overall similarity among non-parametric measures. Value of Z_1 sum = 11.39 and Z_2 sum = 11.28 (Table 10) 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. Unstable performance of DBW 88 judged by larger values as compared to the critical value of χ^2 (0.05, 1) = 3.84.

Association analysis

Yield has expressed highly significant positive correlation with GAI, Med and negative correlation with MR, CV, S_i^3 , S_i^6 , $NP_i^{(2)}$, $NP_i^{(3)}$, $NP_i^{(4)}$ measures as Spearman's rank correlation values among non-parametric measures had put in table 17. GAI measure showed negative correlations with MR, CV, S_i^3 , S_i^6 , $NP_i^{(2)}$, $NP_i^{(3)}$, $NP_i^{(4)}$ and positive with median. Mean rank of original values (MR) expressed positive correlation with CV, S_i^3 , S_i^6 , $NP_i^{(2)}$, $NP_i^{(3)}$, $NP_i^{(4)}$ and negative with Med. Measure SD maintained highly significant and significant positive correlations with almost all the measures exception of Z2. Measure CV also showed significant positive correlation with nearly all measures with negative of Median. More over Median managed negative correlations considered measures. All measures S_i^1 , S_i^2 , S_i^3 , S_i^4 , S_i^5 , S_i^6 , S_i^7 exhibited indirect relations with Z2 otherwise only positive correlation

values were seen with other measures. Mean of ranks based on corrected yield values (CMR) maintained weak relationships of both kinds with most of the measures. CSD, CMR & CMed had significant positive relationships with all measures whereas negative observed with Z2. Measures based on ranks of corrected yield values ($CS_i^1, CS_i^2, CS_i^3, CS_i^4, CS_i^5, CS_i^6, CS_i^7$) able to maintain positive relationships with non parametric measures with highly significant negative values of correlation with Z2 values. Four non-parametric measures based of adjusted ranks of genotypes within each test environment $NP_i^{(1)}, NP_i^{(2)}, NP_i^{(3)}, NP_i^{(4)}$ had positive relationships with others as well as themselves while expressed negative relationships with Z2. Lastly Z1 is related to Z2 in inverse manner.

Biplot graphical analysis

Table 18 showed the loadings of the first two PCA of non parametric measures, as contributed about for 78.7% of the variations of measures. The PCA1 versus PCA2 were used to generate possible clusters in the biplot analysis as illustrated in Figure 4. Two small clusters of Med with MR and other of Yield with GAI also observed for this data set of genotypes evaluated with major locations of this zone of the country. CMR joined hands with Z1 and Z2 to form a cluster of three measures. CV with CMed and $NP_i^{(2)}, NP_i^{(3)}, NP_i^{(4)}$ as well S_i^2, S_i^3, S_i^6 comprised in cluster. Largest cluster consists of SD, CSD, CCV, $NP_i^{(1)}, S_i^1, S_i^4, S_i^5, S_i^7, CS_i^1, CS_i^2, CS_i^3, CS_i^4, CS_i^5, CS_i^6, CS_i^7$ measures.

BLUP's of wheat genotypes provide more valid estimates of yield in multi environment trials and more variations accounted by first two significant principal components of non-parametric measures. More affinity among measures had reflected by a smaller number of clusters in biplot analysis based on

BLUP's. Association of $S_i^1, CS_i^1, NP_i^{(1)}$ with other measures is independent of ranks as per BLUP or BLUE of genotypes. Positive and direct relationships exhibited by these measures with other non-parametric measures.

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Conflict of Interest

No conflict of interest among authors for this study.

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