

Nonparametric Measures of Stability Analysis Compared as Per BLUP & BLUE of Wheat Genotypes for Central Zone of Country

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ABSTRACT

Stability for wheat genotypes had been compared in Central Zone of the country as per the BLUP and BLUE of yield values. Measures based on ranks of BLUP for 2015-16 i.e. S_i^s identified G1, G5, G7, G6. Corrected yield measures CS_i^s pointed towards G1, G2, G5, G6. Values of $NP_i^{(s)}$ identified G1, G2, G7. Overall similarity among non-parametric measures tested by Kendall's coefficient of concordance. Positive correlations of S_i^s , CS_i^s & $NP_i^{(s)}$ observed with other measures. Biplot analysis exhibited cluster of CV with CCV , S_i^1 , S_i^2 , S_i^3 , S_i^4 , S_i^5 , S_i^6 , S_i^7 , S_i^8 , $NP_i^{(2)}$, $NP_i^{(3)}$ & $NP_i^{(4)}$. Based on BLUE's of genotypes, S_i^s found G1, G7, G4, G5 while CS_i^s identified G5, G4, G2 as opposed to G7, G1, G4 genotypes as by values $NP_i^{(s)}$. Positive and negative correlations exhibited by S_i^s , CS_i^s & $NP_i^{(s)}$ with the measures. Biplot analysis observed large cluster comprised of Yield with GAI, $NP_i^{(2)}$, $NP_i^{(3)}$, $NP_i^{(4)}$, S_i^1 , S_i^2 , S_i^3 , S_i^4 , S_i^5 , S_i^6 measures. Second year of study (2017-18) as per BLUP's seen, S_i^s settled for G8, G7, G2 genotypes. While $NP_i^{(s)}$ settled for G1, G2, G8, G5. Negative correlations of yield had been observed with MR, CV, Med, $NP_i^{(2)}$, $NP_i^{(3)}$, $NP_i^{(4)}$ while positive with GAI, CMR, CS_i^6 . Measure CV expressed affinity with $NP_i^{(2)}$, $NP_i^{(3)}$ & $NP_i^{(4)}$, SD, S_i^3 , S_i^6 , S_i^1 , S_i^2 , S_i^4 , S_i^5 , S_i^7 in Biplot analysis. Measures S_i^s as per BLUE's pointed towards G2, G5, G8, G7 whereas CS_i^s settled for G6, G8, G7. Wheat genotypes G8, G2, G7, G5 favoured by least values of $NP_i^{(s)}$. Positive correlation S_i^s , CS_i^s & $NP_i^{(s)}$ with others. Large cluster 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.

Highlights

- ① Stability of wheat genotypes had been compared as per the BLUP and BLUE of yield values for Central Zone of the country.
- ① Kendall's coefficient of concordance resulted an overall similarity among rank-based measures based on BLUP for first year. Positive correlations of rank-based measures based on BLUP viz. S_i^s , CS_i^s & $NP_i^{(s)}$ with other measures.
- ① While both type of correlations observed among measures as per BLUE of genotypes.
- ① First two PCA's based on BLUP's account for more of G×E sum of squares as compared to corresponding components by BLUE.

Keywords: BLUP, BLUE, $S_i^{(s)}$, $CS_i^{(s)}$, $NP_i^{(s)}$, Coefficient of concordance, Biplot analysis

Significant genotype-by-environment (G×E) interaction had been reported in large number of multi environmental studies (Pour *et al.* 2019). Cross over interaction masks the correlation between genotypic and phenotypic values of genotypes and hinders the selection of the promising genotypes (Mohammadi *et al.* 2016). Large number of statistical

approaches, based on univariate and multivariate models, have been observed in literature to estimate

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stable performance of genotypes (Vaezi *et al.* 2018). There are two major categories to interpret genotype-environment interaction by numerical analysis. The first group contains parametric methods. These are primarily used to assess genotype stability by relating observed genotypic responses to number of environmental conditions (Khalili *et al.* 2016). Statistical assumptions i.e. normal distribution and homogeneity of variance of the errors and their interaction effects have presumed under Parametric stability measures. Parametric measures would provide biased results under failure to satisfy these assumptions (Hühn and Leon 1995). The second group of analytical methods includes nonparametric methods. Non-parametric measures explain environments and phenotypes relative to both biotic and abiotic factors (Mortazavian *et al.* 2014). Ranks of the genotypes had been considered under Nonparametric measures to judge the suitability of genotypes (Nassar and Huhn 1987). These measures had been known as distribution free and no assumptions are required to satisfy (Rasoli *et al.* 2015). For many applications, including selection in breeding programs, the rank order of genotypes are the most essential data. There is ample justification for the use of nonparametric measures for the stability assessment of genotypes (Zali *et al.* 2011). Nonparametric procedures are based on the ranks of genotypes in each environment and stable genotypes possess similar ranking across environments (Farshadfar *et al.* 2014). Ranking classifies observations according to their values but not to their absolute differences. Different studies had used nonparametric measures of stability in the several literatures (Delić *et al.* 2009; Balalić *et al.* 2011; Karimizadeh *et al.* 2012; Mahtabi *et al.* 2013; Ahmadi *et al.* 2015; Rasoli *et al.* 2015; Khalili and Pour-Aboughadareh 2016).

The three defined objectives for current study was (1) analyse stability performance by nonparametric measures based on BLUP and BLUE of wheat genotypes yield (2) differentiate the performance pattern of wheat genotypes as per BLUP and BLUE values and (3) study the relationships, similarities and dissimilarities among non-parametric measures of stability.

MATERIALS AND METHODS

Seven promising wheat genotypes were evaluated

in research field trials at 14 centers of All India Coordinated Research Project on Wheat across zone during 2015-16 and a set of nine genotypes at twelve centers for 2017-18 cropping season. Randomized block designs had been laid out in field evaluation of genotypes with four replications. Recommended agronomical practices as per zone had followed in total to harvest the good wheat yield of 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 G×E interaction and stability analysis. For a two-way dataset with *k* genotypes and *n* environments X_{ij} denotes the phenotypic value of *i*th genotype in *j*th environment where *i* = 1, 2, ..., *k*, *j* = 1, 2, ..., *n* and r_{ij} as the rank of the *i*th genotype in the *j*th environment, and \bar{r}_i as the mean rank across all environments for the *i*th genotype. Sabaghnia *et al.* (2012) proposed the correction for yield of *i*th genotype in *j*th environment as $(X^*_{ij} = X_{ij} - \bar{x}_{i.} + \bar{x}_{.j})$ as X^*_{ij} was the corrected phenotypic value; $\bar{X}_{i.}$ was the mean of *i*th genotype in all environments and $\bar{X}_{.j}$ was the grand mean. Generally used seven statistics based on ranks of genotypes yield and corrected yield were expressed as follows:

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

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

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

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.

$$NP_i^{(1)} = \frac{1}{n} \sum_{j=1}^n |r^*_{ij} - M_{di}^*| \quad NP_i^{(3)} = \sqrt{\frac{\sum (r^*_{ij} - \bar{r}_i^*)^2 / n}{\bar{r}_i}}$$

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

Significance of $S_i^{(1)}$ and $S_i^{(2)}$ non parametric measures had been explored by Nassar and Huehn (1987). Z1 and Z2 values were calculated for each genotype,



Table 1: Parentage details of wheat genotypes along with environmental conditions (2015-16)

| Code | Genotype | Parentage | Code | Environments | Latitude | Longitude | Altitude (m) |
|------|----------|--|------|--------------|-----------|-----------|--------------|
| G 1 | HI8759 | (HI8663/HI8498) | E 1 | Amreli | 21° 36' N | 71° 13' E | 126 |
| G 2 | HI8774 | (HI8663/HI8498) | E 2 | Bhopal | 23° 15' N | 77° 24' E | 496 |
| G 3 | PDW344 | (GREEN/RXD-130) | E 3 | Banswara | 23° 32' N | 74° 26' E | 216 |
| G 4 | HI8498 | (RAJ6O7O/RAJ91 1) | E 4 | Indore | 22° 43' N | 75° 51' E | 550 |
| G 5 | HI8737 | (HI817 7 /HI81 58//H I8498) | E 5 | Junagarh | 21° 30' N | 70° 27' E | 90 |
| G 6 | MPO1215 | (GW1 1 1 3/GW1 1 1 4//HI8381) | E 6 | Jabalpur | 23° 10' N | 79° 55' E | 403 |
| G 7 | HD4728 | (A LTAR84/S T I N T//S I L V E R_4 5/ 3/SOM AT_3 . 1 /4 /GREEN_14//YAV_10/AUK) GIREEN_1 4 INAV_10/AUK) | E 7 | Kota | 25° 21' N | 75° 86' E | 271 |
| | | | E 8 | Powarkheda | 22° 70' N | 77° 73' E | 308 |
| | | | E 9 | Rewa | 24°53' N | 81°30' E | 304 |
| | | | E 10 | Sagar | 23° 50' N | 78° 44' E | 525 |
| | | | E 11 | SK Nagar | 21°18' N | 72°85' E | 11 |
| | | | E 12 | Sanosara | 21° 72' N | 71° 76' E | 89 |
| | | | E 13 | Udaipur | 24° 34' N | 73° 41' E | 585 |
| | | | E 14 | Vijapur | 23°33' N | 72°45' E | 129.4 |

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

| Code | Genotype | Parentage | Code | Environments | Latitude | Longitude | Altitude (m) |
|------|----------|---|------|--------------|-----------|-----------|--------------|
| G 1 | GW1339 | (DDW04/4/MEMO/YAV//AVK/3/RD214) | E 1 | Amreli | 21° 36' N | 71° 13' E | 126 |
| G 2 | AKAW4924 | (DL-9-65-2/AKW1071-1-2) | E 2 | Bhopal | 23° 15' N | 77° 24' E | 496 |
| G 3 | GW495 | (LOK54/RAJ4083) | E 3 | Bilaspur | 22° 4' N | 82° 9' E | 264 |
| G 4 | UAS465 | (STOT//ALTAR84/ALD*2/3/AUK/GUIL//GREEN) | E 4 | Banswara | 23° 32' N | 74° 26' E | 216 |
| G 5 | MPO1343 | (HG822/HI8498) | E 5 | Gwalior | 26° 13' N | 78° 10' E | 213 |
| G 6 | GW322 | (PBW173/GW196) | E 6 | Indore | 22° 43' N | 75° 51' E | 550 |
| G 7 | HI8713 | (HD4672/PDW233) | E 7 | Junagarh | 21° 30' N | 70° 27' E | 90 |
| G 8 | HI8737 | (HI8177/HI8158//HI8498) | E 8 | Jabalpur | 23° 10' N | 79° 55' E | 403 |
| G 9 | HI1544 | (HINDI62/BOBWHITE/CPAN2099) | E 9 | Powarkheda | 22° 70' N | 77° 73' E | 308 |
| | | | E 10 | SK Nagar | 21°18' N | 72°85' E | 11 |
| | | | E 11 | Udaipur | 24° 34' N | 73° 41' E | 585 |
| | | | E 12 | Vijapur | 23°33' N | 72°45' E | 129.4 |

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 :

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

where d_i denotes difference between ranks for i^{th} genotype and n is total number of pairs.

RESULTS AND DISCUSSION

First year of study 2015-16

Analytic analysis as per BLUP's

Mean wheat yield observed, G5 as the highest yielding with 58q/ha followed by G2 and G4, though remarkable yield differences were observed among the genotypes (Table 3). Measure GAI selected G5, G2, G6 as genotypes with higher adaptable index values. The following three descriptive statistics; mean of ranks (MR), standard deviation of ranks

Table 3: Nonparametric measures as per yield of genotypes (BLUP)

| 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 |
|----------|-------|-------|------|------|------|------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|------|------|
| HI8759 | 45.64 | 44.86 | 5.14 | 1.23 | 0.24 | 6.00 | 1.23 | 1.52 | 3.83 | 1.19 | 0.98 | 2.67 | 1.44 | 4.14 | 1.70 |
| HI8774 | 50.38 | 49.15 | 4.00 | 1.75 | 0.44 | 4.50 | 2.01 | 3.08 | 10.00 | 1.69 | 1.43 | 5.00 | 2.00 | 4.79 | 1.97 |
| PDW344 | 49.11 | 48.45 | 3.43 | 2.10 | 0.61 | 3.00 | 2.44 | 4.42 | 16.75 | 2.03 | 1.86 | 7.58 | 2.21 | 3.43 | 2.38 |
| HI8498 | 49.51 | 48.62 | 3.36 | 1.82 | 0.54 | 3.00 | 1.99 | 3.32 | 12.87 | 1.76 | 1.32 | 5.49 | 2.34 | 3.57 | 1.91 |
| HI8737 | 51.84 | 50.87 | 2.36 | 1.50 | 0.64 | 2.00 | 1.58 | 2.25 | 12.39 | 1.44 | 1.08 | 6.42 | 1.93 | 4.43 | 1.65 |
| MPO1215 | 49.38 | 48.70 | 3.50 | 1.34 | 0.38 | 4.00 | 1.49 | 1.81 | 6.71 | 1.30 | 1.07 | 4.29 | 1.57 | 3.57 | 1.74 |
| HD4728 | 39.55 | 38.28 | 6.21 | 1.76 | 0.28 | 7.00 | 1.40 | 3.10 | 6.49 | 1.70 | 1.23 | 2.78 | 2.33 | 4.07 | 2.59 |

Table 4: Nonparametric measures as per corrected yield of genotypes (BLUP)

| 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 |
|----------|-------|------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|-------------|-------------|
| HI8759 | 0.41 | 3.50 | 1.92 | 2.90 | 9.10 | 1.64 | 1.47 | 4.97 | 1.83 | 1.43 | 0.28 | 1.19 | 0.37 | 1.38 | 1.17 |
| HI8774 | 0.41 | 5.00 | 2.25 | 3.87 | 10.52 | 1.90 | 1.56 | 4.57 | 2.30 | 1.50 | 0.38 | 1.77 | 0.56 | 0.01 | 0.02 |
| PDW344 | 0.69 | 3.00 | 2.74 | 5.65 | 21.42 | 2.29 | 2.06 | 8.42 | 2.54 | 2.00 | 0.58 | 2.50 | 0.80 | 2.13 | 2.63 |
| HI8498 | 0.53 | 3.50 | 2.25 | 3.65 | 13.28 | 1.84 | 1.57 | 6.16 | 2.16 | 1.57 | 0.47 | 2.05 | 0.67 | 0.01 | 0.12 |
| HI8737 | 0.37 | 4.00 | 1.91 | 2.73 | 8.00 | 1.59 | 1.35 | 4.26 | 1.88 | 1.29 | 0.55 | 2.53 | 0.81 | 1.47 | 1.57 |
| MPO1215 | 0.49 | 4.00 | 2.03 | 3.03 | 11.04 | 1.68 | 1.49 | 5.84 | 1.89 | 1.43 | 0.41 | 1.79 | 0.58 | 0.67 | 0.91 |
| HD4728 | 0.64 | 4.00 | 2.95 | 6.69 | 21.35 | 2.49 | 2.36 | 8.11 | 2.63 | 2.36 | 0.38 | 1.50 | 0.47 | 4.57 | 6.99 |
| | E(S1) | 2.29 | Var (S1) | 0.095 | | | | W = | 0.4015 | $\chi^2 = 72.27$ | $\chi^2 (0.05, 1) = 3.84$ | $\Sigma = 10.25$ | 13.40 | | |
| | E(S2) | 4.00 | Var (S2) | 1.033 | | | | | | | | | | | |

(SD) and coefficient of variation of ranks (CV) were calculated for original ranks (Khalili *et al.* 2016). MR pointed towards G7, G1, G2 and SD for G1, G6, G5 whereas CV for G1, G7, G6 as genotypes of stable performance, while G5, G4 based on MR, G3, G4 based on SD and G5, G3 as per CV, would be unstable genotypes. These descriptive statistics based on ranks can be used for genotype comparative evaluation. Values of Median selected G7, G1, G2 genotypes.

Seven nonparametric measures based on original grain yield of genotypes (S_i¹, S_i², S_i³, S_i⁴, S_i⁵, S_i⁶ and S_i⁷) indicated that (G1, G7, G6), (G1, G6, G5), (G1, G7, G6), (G1, G6, G5), (G1, G6, G5), (G1, G7, G6), (G1, G6, G5) as sets of genotypes respectively. According to corrected yield (table 8), G2, G5 & G1 by mean of corrected ranks (CMR), G5, G1 & G6 by standard deviation of corrected ranks (CSD) and G5, G1 & G2 were the stable as per coefficient of variation of corrected ranks (CCV). Nonparametric measures of stability based on corrected yield values (CS_i¹, CS_i², CS_i³, CS_i⁴, CS_i⁵, CS_i⁶, CS_i⁷) identified stable genotypes (G5, G1, G6), (G5, G1, G6), (G5, G1, G2), (G5, G1, G6), (G5, G2, G1), (G5, G2, G1), (G1, G5, G6) and G7, G3 were of unstable nature (Sabaghnia *et al.* 2012). NP_i⁽¹⁾ considered genotypes G5, G1, G6 of stable yield. G1, G2 and G7 had expressed the lower values of NP_i⁽²⁾

whereas as per NP_i⁽³⁾ & NP_i⁽⁴⁾ values genotypes G1, G7, G2 would be of stable performance. Z1 and Z2 pointed for G2, G4, G6 as of suitable performance.

Calculated value of Kendall’s coefficient of concordance (W=0.40) and for the significance of W value the magnitude of $\chi^2 = 72.3$ statistics was less than table of $\chi^2 (0.01, 290) = 135.8$, which resulted an overall similarity among non-parametric measures (Vaezi *et al.* 2018). For ensuring significance of CS_i¹ and CS_i² measures, Z1 and Z2 values were calculated based on the ranks of adjusted data and then summed: Z₁ sum = 10.3 and Z₂ sum = 13.4 (Table 4). Both these statistics are distributed as χ^2 and were less than the critical value of $\chi^2 (0.05, 29) = 42.6$. This indicated the non-significant differences among genotypes as per ranks of CS_i¹ and CS_i² measures. HD4728 was significantly unstable as compared to others due to Z values more than the critical value of $\chi^2 (0.05, 1) = 3.84$.

Association analysis

Spearman’s rank correlation analysis as per BLUP’s of genotypes yield had been reflected in table 11. Yield had positive correlation with GAI, CMR, CSD, CCV, Z1, Z2 CS_i¹, CS_i², CS_i³, CS_i⁴, CS_i⁵, CS_i⁶, NP_i⁽¹⁾ and negative correlation with MR, CV, Med,



$S_i^1, S_i^3, S_i^6, NP_i^{(2)}, NP_i^{(3)}, NP_i^{(4)}$. GAI mentioned negative correlations with MR, CV, Med, S_i^1, S_i^3, S_i^6 . Value of MR expressed mostly significant positive correlations with CV, Med, $S_i^3, S_i^6, NP_i^{(2)}, NP_i^{(3)}, NP_i^{(4)}$. Significant positive correlation maintained by SD with $S_i^1, S_i^2, S_i^3, S_i^4, S_i^5, S_i^7, CSD, CCV, CS_i^1, CS_i^2, CS_i^3, CS_i^4, CS_i^5, CS_i^6, CS_i^7, NP_i^{(1)}$ values. Similar behaviour portrayed by CV values. Median had expressed significant values for positive correlations. $S_i^1, S_i^2, S_i^3, S_i^4, S_i^5, S_i^6, S_i^7$ exhibited direct relations of significant nature among themselves and with other measures. Measures CMR, CSD, CCV and CMed expressed positive correlations with most of the measures besides few weak negative correlations with $NP_i^{(2)}, NP_i^{(3)}, NP_i^{(4)}$. Similar behaviour expressed by $CS_i^1, CS_i^2, CS_i^3, CS_i^4, CS_i^5, CS_i^6, CS_i^7$ and expressed only significant positive relationships. $NP_i^{(1)}, NP_i^{(2)}, NP_i^{(3)}, NP_i^{(4)}$ had also expressed only significant direct relationships. Z1 is related to Z2 in weak inverse manner.

Graphical analysis based on biplot

The loadings of measures based on first two significant principal components were reflected in table 12 (Mohammadi *et al.* 2016). Both significant PAC's accounting for 85.9% of the variance of the original variables (Fig. 1). Grouping of Yield with GAI, MR grouped with Med in addition to affinity of CMR towards CMed. Cluster comprises of Z1 & Z2 with $NP_i^{(1)}, CSD, CS_i^1, CS_i^2, CS_i^3, CS_i^4, CS_i^5, CS_i^6$ and CS_i^7 was observed. CV expressed affinity with CCV, $S_i^1, S_i^2, S_i^4, S_i^5, S_i^7, S_i^3, S_i^6, NP_i^{(2)}, NP_i^{(3)}$ & $NP_i^{(4)}$ as separate cluster.

FIRST YEAR OF STUDY 2015-16

Analytic analysis as per BLUE's

Average yield of genotypes showed G5 as of highest yield with 58 q/ha followed by G2 and G6, genotypes (Table 7). Measure GAI selected G5, G6,

Table 5: Nonparametric measures as per yield of genotypes (BLUE)

| 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 |
|----------|-------|-------|------|------|------|------|---------|---------|---------|---------|---------|---------|---------|------|------|
| HI8759 | 50.31 | 49.85 | 4.71 | 1.64 | 0.35 | 5.50 | 1.76 | 2.68 | 7.39 | 1.58 | 1.37 | 4.06 | 1.82 | 4.07 | 2.06 |
| HI8774 | 55.17 | 54.19 | 3.79 | 1.97 | 0.52 | 4.50 | 2.27 | 3.87 | 13.30 | 1.90 | 1.67 | 6.19 | 2.15 | 4.43 | 1.83 |
| PDW344 | 54.18 | 53.59 | 3.79 | 1.85 | 0.49 | 3.50 | 2.14 | 3.41 | 11.72 | 1.78 | 1.50 | 5.55 | 2.11 | 3.50 | 2.41 |
| HI8498 | 54.56 | 53.79 | 3.50 | 1.61 | 0.46 | 4.00 | 1.81 | 2.58 | 9.57 | 1.55 | 1.29 | 5.14 | 1.86 | 3.93 | 1.69 |
| HI8737 | 57.11 | 56.37 | 2.57 | 1.65 | 0.64 | 2.00 | 1.76 | 2.73 | 13.78 | 1.59 | 1.22 | 6.67 | 2.07 | 4.29 | 1.64 |
| MPO1215 | 55.06 | 54.66 | 3.21 | 1.85 | 0.57 | 3.50 | 2.14 | 3.41 | 13.80 | 1.78 | 1.64 | 7.16 | 1.93 | 3.79 | 2.19 |
| HD4728 | 43.27 | 42.30 | 6.43 | 1.16 | 0.18 | 7.00 | 0.99 | 1.34 | 2.71 | 1.12 | 0.90 | 1.96 | 1.39 | 4.00 | 2.42 |

Table 6: Nonparametric measures as per corrected yield of genotypes (BLUE)

| 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 | |
|----------|------|------|----------|----------|----------|----------|----------|----------|----------|--------------|------------------|--------------|--|------|------|--|
| HI8759 | 0.50 | 4.00 | 2.38 | 4.23 | 13.49 | 1.98 | 1.66 | 5.72 | 2.36 | 1.64 | 0.35 | 1.57 | 0.51 | 0.10 | 0.05 | |
| HI8774 | 0.41 | 5.00 | 2.13 | 3.34 | 9.81 | 1.76 | 1.51 | 4.77 | 2.05 | 1.43 | 0.38 | 1.74 | 0.56 | 0.25 | 0.42 | |
| PDW344 | 0.69 | 3.00 | 2.74 | 5.81 | 21.57 | 2.32 | 2.07 | 8.29 | 2.60 | 1.93 | 0.51 | 2.30 | 0.72 | 2.13 | 3.16 | |
| HI8498 | 0.43 | 4.00 | 1.97 | 2.84 | 9.40 | 1.62 | 1.37 | 4.87 | 1.93 | 1.36 | 0.39 | 1.74 | 0.56 | 1.07 | 1.30 | |
| HI8737 | 0.38 | 4.00 | 1.91 | 2.68 | 8.13 | 1.58 | 1.33 | 4.33 | 1.88 | 1.29 | 0.50 | 2.30 | 0.74 | 1.47 | 1.68 | |
| MPO1215 | 0.58 | 4.50 | 2.54 | 4.80 | 16.47 | 2.11 | 1.96 | 7.25 | 2.27 | 1.93 | 0.60 | 2.46 | 0.79 | 0.67 | 0.61 | |
| HD4728 | 0.60 | 4.00 | 2.81 | 5.85 | 19.00 | 2.33 | 2.00 | 7.00 | 2.71 | 2.00 | 0.31 | 1.36 | 0.44 | 2.93 | 3.30 | |
| | | | | | | | | | | W = 0.2360 | $\chi^2 = 42.48$ | | $\chi^2 (0.05, 1) = 3.84 \quad \Sigma = 18.87 \quad 23.93$ | | | |

Table 7: Nonparametric measures as per yield of genotypes (BLUP)

| 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 |
|----------|-------|-------|------|------|------|------|---------|---------|---------|---------|---------|---------|---------|------|------|
| GW1339 | 50.86 | 50.22 | 4.50 | 2.11 | 0.47 | 4.00 | 2.39 | 4.45 | 10.89 | 2.02 | 1.58 | 4.22 | 2.58 | 4.08 | 2.23 |
| AKAW4924 | 49.34 | 48.12 | 6.50 | 1.83 | 0.28 | 6.50 | 2.12 | 3.36 | 5.69 | 1.76 | 1.50 | 2.77 | 2.06 | 4.92 | 2.47 |
| GW495 | 52.34 | 51.69 | 3.92 | 3.29 | 0.84 | 2.00 | 3.68 | 10.81 | 30.36 | 3.15 | 2.90 | 8.89 | 3.41 | 5.17 | 3.01 |
| UAS465 | 50.35 | 49.06 | 5.50 | 3.00 | 0.55 | 5.50 | 3.52 | 9.00 | 18.00 | 2.87 | 2.50 | 5.45 | 3.30 | 5.08 | 3.26 |
| MPO1343 | 50.16 | 49.18 | 5.75 | 2.34 | 0.41 | 6.50 | 2.68 | 5.48 | 10.48 | 2.24 | 1.96 | 4.09 | 2.56 | 5.42 | 2.35 |
| GW322 | 52.24 | 51.38 | 3.33 | 2.42 | 0.73 | 2.50 | 2.73 | 5.88 | 19.40 | 2.32 | 1.94 | 7.00 | 2.77 | 5.17 | 2.33 |
| HI8713 | 51.84 | 50.99 | 4.08 | 1.73 | 0.42 | 4.00 | 1.95 | 2.99 | 8.06 | 1.66 | 1.29 | 3.80 | 2.12 | 5.58 | 2.31 |
| HI8737 | 49.59 | 48.79 | 5.75 | 1.48 | 0.26 | 5.50 | 1.71 | 2.20 | 4.22 | 1.42 | 1.25 | 2.61 | 1.62 | 4.67 | 2.10 |
| HI1544 | 49.40 | 48.40 | 5.67 | 3.37 | 0.59 | 6.50 | 3.88 | 11.33 | 22.00 | 3.22 | 2.89 | 6.12 | 3.60 | 4.92 | 3.50 |



G2 based on higher adaptable index values. MR pointed towards G7, G1, G2 and SD for G7, G4, G1 whereas CV for G7, G1, G4 as genotypes of stable performance, while G5, G6 based on MR, G7, G4 based on SD and G5, G6 as large values of CV, would be unstable genotypes. Median selected G7, G1, G2 wheat genotypes for considered locations of this zone.

$S_i^1, S_i^2, S_i^3, S_i^4, S_i^5, S_i^6$ and S_i^7 indicated that (G7, G1, G5), (G7, G4, G1), (G7, G1, G4), (G7, G4, G1), (G7, G5, G4), (G7, G1, G4), (G7, G1, G4) as sets of desirable genotypes as per respective measure. G2, G5 & G1 by CMR values, G5, G4 & G2 by CSD and G5, G2 & G4 were the stable as per CCV. Median favoured G2, G6, G1 genotypes. $CS_i^1, CS_i^2, CS_i^3, CS_i^4, CS_i^5, CS_i^6, CS_i^7$ identified stable genotypes (G5, G4, G2) and G7, G3 were of unstable type as per these nonparametric measures. $NP_i^{(1)}$ considered G5, G4 and G2 as desirable genotypes. Genotypes G7, G1 and G2 had expressed the lower values of $NP_i^{(2)}$, while as per lower values of $NP_i^{(3)}$ & $NP_i^{(4)}$, G7, G1, G4 and lastly by Z1 and Z2 values selected G1, G2, G6 as suitable as well as G7 & G3 would be of unsuitable performance.

Calculated value of W (0.23) and for its significance $\chi^2 = 42.5$ statistics was less than table of χ^2 (0.01, 290) = 135.8, which resulted an overall similarity among non-parametric measures. Values of Z_1 sum = 18.9 and Z_2 sum = 23.9 (Table 4) 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.

Association analysis

Yield has expressed highly significant positive correlation with GAI, CSD, CCV, $CS_i^1, CS_i^2, CS_i^3, CS_i^4, CS_i^5, CS_i^6, CS_i^7, NP_i^{(2)}$ along with negative correlation with other measures (table 18). GAI showed positive with CSD, CCV, $CS_i^1, CS_i^2, CS_i^3, CS_i^4, CS_i^5, CS_i^6, CS_i^7, NP_i^{(2)}$. Values of MR expressed positive correlation with CV, Med, $S_i^3, S_i^6, NP_i^{(2)}, NP_i^{(3)}, NP_i^{(4)}$. SD maintained only highly significant and significant positive correlations with almost all the measures. CV measure also showed significant positive correlation and negative correlation of moderate to weak nature. Same type of relations was depicted by Median. $S_i^1, S_i^2, S_i^3, S_i^4, S_i^5, S_i^6, S_i^7$ exhibited indirect relations only with $CS_i^7, Z1, Z2,$

Table 8: Nonparametric measures as per corrected yield of genotypes (BLUP)

| 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 |
|----------|------|----------|----------|------------|----------|----------|-------------------|----------|----------|---------------------------|--------------|--------------|------------------------|-------------|-------------|
| GW1339 | 0.55 | 4.00 | 2.53 | 4.99 | 13.45 | 2.14 | 1.60 | 4.69 | 2.87 | 1.58 | 0.35 | 1.65 | 0.56 | 0.95 | 0.80 |
| AKAW4924 | 0.50 | 4.50 | 2.92 | 6.08 | 13.61 | 2.36 | 2.08 | 5.08 | 2.68 | 2.08 | 0.32 | 1.26 | 0.45 | 0.01 | 0.10 |
| GW495 | 0.58 | 5.00 | 3.55 | 9.06 | 19.29 | 2.88 | 2.67 | 6.19 | 3.11 | 2.67 | 0.68 | 2.55 | 0.91 | 1.72 | 1.63 |
| UAS465 | 0.64 | 5.00 | 3.77 | 10.63 | 23.00 | 3.12 | 2.61 | 6.16 | 3.73 | 2.58 | 0.47 | 1.97 | 0.69 | 3.33 | 4.45 |
| MPO1343 | 0.43 | 6.00 | 2.74 | 5.54 | 11.25 | 2.25 | 2.08 | 4.62 | 2.44 | 2.08 | 0.36 | 1.36 | 0.48 | 0.25 | 0.36 |
| GW322 | 0.45 | 6.00 | 2.73 | 5.42 | 11.55 | 2.23 | 1.97 | 4.58 | 2.52 | 1.83 | 0.55 | 2.32 | 0.82 | 0.28 | 0.44 |
| HI8713 | 0.41 | 5.50 | 2.68 | 5.36 | 10.55 | 2.22 | 1.92 | 4.12 | 2.56 | 1.92 | 0.47 | 1.88 | 0.66 | 0.40 | 0.49 |
| HI8737 | 0.45 | 5.00 | 2.42 | 4.42 | 10.43 | 2.01 | 1.83 | 4.71 | 2.21 | 1.83 | 0.32 | 1.21 | 0.42 | 1.47 | 1.43 |
| HI1544 | 0.71 | 5.50 | 4.05 | 12.27 | 27.44 | 3.35 | 3.10 | 7.56 | 3.63 | 3.08 | 0.54 | 2.05 | 0.71 | 5.95 | 8.89 |
| E(S1) | 2.96 | Var(S1) | 0.197 | W = 0.4619 | | | $\chi^2 = 110.85$ | | | χ^2 (0.05, 1) = 3.84 | | | $\Sigma = 14.36$ 18.57 | | |
| E(S2) | 6.67 | Var (S2) | 3.525 | | | | | | | | | | | | |

Table 9: Nonparametric measures as per yield of genotypes (BLUE)

| 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 |
|----------|-------|-------|------|------|------|------|---------|---------|---------|---------|---------|---------|---------|------|------|
| GW1339 | 50.53 | 49.87 | 5.00 | 2.63 | 0.53 | 5.00 | 3.09 | 6.91 | 15.20 | 2.52 | 2.33 | 5.60 | 2.71 | 4.75 | 2.80 |
| AKAW4924 | 49.13 | 47.85 | 6.42 | 1.78 | 0.28 | 6.00 | 2.11 | 3.17 | 5.44 | 1.71 | 1.49 | 2.78 | 1.96 | 4.42 | 2.68 |
| GW495 | 52.57 | 51.90 | 3.92 | 3.15 | 0.80 | 3.00 | 3.56 | 9.90 | 27.81 | 3.01 | 2.74 | 8.38 | 3.32 | 5.00 | 3.05 |
| UAS465 | 50.66 | 49.31 | 4.67 | 3.03 | 0.65 | 3.50 | 3.48 | 9.15 | 21.57 | 2.90 | 2.61 | 6.71 | 3.21 | 4.83 | 2.98 |
| MPO1343 | 50.08 | 48.96 | 5.42 | 2.35 | 0.43 | 5.00 | 2.71 | 5.54 | 11.25 | 2.25 | 1.82 | 4.03 | 2.79 | 5.17 | 2.52 |
| GW322 | 52.57 | 51.69 | 3.50 | 2.24 | 0.64 | 3.00 | 2.55 | 5.00 | 15.71 | 2.14 | 1.75 | 6.00 | 2.62 | 5.25 | 2.30 |
| HI8713 | 52.26 | 51.35 | 3.83 | 2.04 | 0.53 | 3.50 | 2.36 | 4.15 | 11.91 | 1.95 | 1.67 | 5.22 | 2.28 | 5.58 | 2.15 |
| HI8737 | 48.91 | 48.09 | 5.92 | 1.98 | 0.33 | 6.50 | 2.29 | 3.90 | 7.25 | 1.89 | 1.60 | 3.24 | 2.24 | 5.00 | 2.22 |
| HI1544 | 49.41 | 48.43 | 6.08 | 2.68 | 0.44 | 7.00 | 3.08 | 7.17 | 12.97 | 2.56 | 2.24 | 4.41 | 2.94 | 5.00 | 3.19 |



Table 10: Nonparametric measures as per corrected yield of genotypes (BLUE)

| 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 |
|----------|------|---------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|------|------|
| GW1339 | 0.59 | 4.50 | 3.32 | 7.84 | 18.16 | 2.68 | 2.42 | 6.11 | 2.97 | 2.42 | 0.48 | 1.86 | 0.66 | 0.64 | 0.39 |
| AKAW4924 | 0.61 | 4.00 | 3.17 | 7.17 | 17.87 | 2.56 | 2.15 | 5.85 | 3.05 | 2.08 | 0.32 | 1.38 | 0.49 | 0.21 | 0.07 |
| GW495 | 0.61 | 5.50 | 3.55 | 9.27 | 20.40 | 2.92 | 2.67 | 6.40 | 3.19 | 2.67 | 0.68 | 2.58 | 0.91 | 1.72 | 1.93 |
| UAS465 | 0.62 | 4.00 | 3.45 | 8.88 | 20.21 | 2.85 | 2.47 | 6.14 | 3.29 | 2.33 | 0.50 | 2.12 | 0.74 | 1.23 | 1.39 |
| MPO1343 | 0.49 | 5.00 | 2.97 | 6.33 | 13.48 | 2.41 | 2.03 | 4.71 | 2.86 | 2.00 | 0.37 | 1.54 | 0.55 | 0.00 | 0.03 |
| GW322 | 0.44 | 5.50 | 2.68 | 5.30 | 11.10 | 2.20 | 1.92 | 4.38 | 2.53 | 1.92 | 0.55 | 2.18 | 0.77 | 0.40 | 0.53 |
| HI8713 | 0.39 | 5.50 | 2.56 | 4.63 | 9.12 | 2.06 | 1.75 | 3.76 | 2.42 | 1.75 | 0.46 | 1.86 | 0.67 | 0.82 | 1.18 |
| HI8737 | 0.44 | 5.00 | 2.58 | 4.91 | 10.80 | 2.12 | 1.67 | 4.00 | 2.70 | 1.67 | 0.28 | 1.24 | 0.44 | 0.76 | 0.88 |
| HI1544 | 0.64 | 6.50 | 3.64 | 10.18 | 22.40 | 3.06 | 2.83 | 6.80 | 3.29 | 2.67 | 0.44 | 1.74 | 0.60 | 2.30 | 3.51 |
| E(S1) | 2.96 | Var(S1) | 0.197 | | | | W = 0.4215 | $\chi^2 = 101.17$ | | $\chi^2 (0.05, 1) = 3.84$ | | $\Sigma = 8.08$ | | 9.90 | |
| E(S2) | 6.67 | Var(S2) | 3.525 | | | | | | | | | | | | |

NP_i⁽¹⁾. Negative correlations of weak nature by CMR, CSD, CCV, CMed with NP_i⁽²⁾, NP_i⁽³⁾, NP_i⁽⁴⁾ only. CS_i¹, CS_i², CS_i³, CS_i⁴, CS_i⁵, CS_i⁶, CS_i⁷ also expressed only weak indirect relations with NP_i⁽²⁾, NP_i⁽³⁾, NP_i⁽⁴⁾ measures. Significant positive relationships of NP_i⁽¹⁾, NP_i⁽²⁾, NP_i⁽³⁾, NP_i⁽⁴⁾ obtained with few negative values of lower magnitude.

Graphical analysis based on biplot

Table 16 mentioned the values of loadings of measures as per the first two principal components axes (PCA) as 84.8% variations of measures accounted by these two in Fig. 3. Smaller clusters of only two measures i.e. MR with Med and CMR with CMed were observed in biplotgraphical analysis. Yield with GAI, NP_i⁽²⁾, NP_i⁽³⁾, NP_i⁽⁴⁾, S_i¹, S_i², S_i⁴, S_i⁵, S_i⁶ clustered in a group. Z1, Z2 expressed affinity with, SD, CCV, CSD, NP_i⁽¹⁾, CS_i¹, CS_i², CS_i³, CS_i⁴, CS_i⁵, CS_i⁶, CS_i⁷ in large cluster.

SECOND YEAR OF STUDY 2017-18

Analytic analysis as per BLUP's

High yield achieved by G3 followed by G6, G7 wheat genotypes, whereas GAI selected G3, G6, G7 genotypes, large values of mean ranks selected G2, G5, G8 more over the consistent yield of G8, G7, G2 expressed by least values of standard deviation (Table 9). Values of coefficient of variation anticipated G8, G5, G2 would be genotypes of least variations; Median observed suitability of G2, G5, G9 wheat genotypes for studied locations of central zone. S_i¹ and S_i² measures selected G8, G7, G2 as opposed to G8, G2, G7 by S_i³ measure. Next two measures S_i⁴ & S_i⁵ settled for G8, G7, G2 and remaining two measures S_i⁶ and S_i⁷ favoured G8, G2, G7 wheat genotypes.

Average mean of ranks as per corrected yield values selected G7, G5, G6 and corrected standard deviation observed suitability of G8, G1, G7 genotypes. Coefficient of variation as per corrected yield values exhibited G7, G5, G8 while median values for G5, G6, G7 and G8, G1, G7 by CS_i¹ & CS_i², CS_i³ pointed for G8, G7, G5 & as per CS_i⁴ wheat genotypes G8 G1 G7, G1 G8 G7 by criterion of CS_i⁵ & CS_i⁶ settled for G7 G6 G5 and lastly by values of CS_i⁷ genotypes G8, G5, G6 (table 10). NP_i⁽¹⁾ selected (G1, G6, G8); NP_i⁽²⁾ identified (G8, G2, G1), NP_i⁽³⁾ & NP_i⁽⁴⁾ settled for (G8, G2, G5), whereas G4 along with G6 would be of unsuitable type. Z1 and Z2 favoured G2, G5, G6 wheat genotypes.

Concordance coefficient W=0.46 and for its significance $\chi^2 = 110.8$ statistic was less than table of $\chi^2 (0.05, 290) = 124.3 (135.8)$, which resulted an overall similarity among non-parametric measures. Values of Z₁ sum = 14.4 and Z₂ sum = 18.6 (Table 10) were less than the critical value of $\chi^2 (0.05, 29) = 42.6$. This indicated the non-significant differences among genotypes as per ranks of CS_i¹ and CS_i² measures. Unstable performance of HI1544 & UAS 465 judged by larger values as compared to the critical value of $\chi^2 (0.05, 1) = 3.84$.

Association analysis

Spearman's rank correlation analysis observed highly significant negative correlations of yield with MR, CV, Med, NP_i⁽²⁾, NP_i⁽³⁾, NP_i⁽⁴⁾ and positive with GAI, CMR, CS_i⁶ (Table 15). GAI showed mostly significant negative correlations and positive values with CMR, CSD, CCV, CS_i⁶. Significant direct relations maintained by MR along with few negative values of low magnitude. SD & CV maintained highly significant direct relations with almost

Table 11: Spearman's rank correlation coefficient values among nonparametric measures (2015-16) BLUP

| Yield | 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 |
|--------------------------------|-------|--------|-------|--------|--------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|--------|--------|--------|--------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|--------|--------|
| | 0.964 | -0.750 | 0.036 | -0.714 | -0.661 | -0.500 | 0.036 | -0.500 | 0.036 | -0.179 | -0.571 | 0.036 | 0.482 | 0.500 | 0.536 | 0.286 | 0.446 | 0.500 | 0.536 | 0.500 | 0.536 | 0.679 | 0.321 | 0.661 | -0.321 | -0.643 | -0.643 | 0.589 | 0.571 |
| GAI | 1.000 | -0.679 | 0.179 | -0.643 | -0.625 | -0.429 | 0.179 | -0.393 | 0.179 | -0.071 | -0.500 | 0.214 | 0.482 | 0.536 | 0.571 | 0.393 | 0.518 | 0.536 | 0.571 | 0.536 | 0.607 | 0.714 | 0.357 | 0.732 | -0.286 | -0.607 | -0.607 | 0.554 | 0.536 |
| MR | | 1.000 | 0.250 | 0.893 | 0.982 | 0.536 | 0.250 | 0.786 | 0.250 | 0.214 | 0.821 | 0.143 | 0.196 | -0.464 | -0.179 | 0.143 | -0.411 | -0.464 | -0.179 | -0.464 | -0.357 | -0.214 | -0.286 | -0.375 | 0.786 | 0.929 | 0.929 | -0.125 | -0.179 |
| SD | | | 1.000 | 0.500 | 0.232 | 0.714 | 1.000 | 0.750 | 1.000 | 0.893 | 0.643 | 0.893 | 0.554 | 0.714 | 0.786 | 0.357 | 0.768 | 0.714 | 0.786 | 0.714 | 0.786 | 0.679 | 0.786 | 0.732 | 0.607 | 0.429 | 0.429 | 0.304 | 0.214 |
| CV | | | | 1.000 | 0.911 | 0.750 | 0.500 | 0.893 | 0.500 | 0.536 | 0.964 | 0.321 | 0.161 | -0.143 | 0.000 | 0.071 | -0.125 | -0.143 | 0.000 | -0.143 | -0.107 | -0.107 | 0.071 | -0.161 | 0.857 | 0.964 | 0.964 | 0.089 | 0.000 |
| Med | | | | | 1.000 | 0.554 | 0.232 | 0.768 | 0.232 | 0.839 | 0.089 | 0.214 | -0.411 | -0.161 | 0.161 | -0.393 | -0.411 | -0.161 | -0.411 | -0.339 | -0.196 | -0.232 | -0.357 | 0.804 | 0.946 | 0.946 | 0.000 | -0.054 | |
| S ₁ ¹ | | | | | | 1.000 | 0.714 | 0.893 | 0.714 | 0.893 | 0.857 | 0.464 | 0.268 | 0.321 | 0.357 | 0.179 | 0.339 | 0.321 | 0.357 | 0.321 | 0.286 | 0.179 | 0.429 | 0.232 | 0.607 | 0.643 | 0.643 | -0.089 | -0.250 |
| S ₁ ² | | | | | | | 1.000 | 0.750 | 1.000 | 0.893 | 0.643 | 0.893 | 0.554 | 0.714 | 0.786 | 0.357 | 0.768 | 0.714 | 0.786 | 0.714 | 0.786 | 0.679 | 0.786 | 0.732 | 0.607 | 0.429 | 0.429 | 0.304 | 0.214 |
| S ₁ ³ | | | | | | | | 1.000 | 0.750 | 0.964 | 0.536 | 0.446 | 0.143 | 0.357 | 0.357 | 0.196 | 0.143 | 0.357 | 0.143 | 0.214 | 0.250 | 0.286 | 0.161 | 0.857 | 0.857 | 0.857 | 0.018 | -0.071 | |
| S ₁ ⁴ | | | | | | | | | 1.000 | 0.893 | 0.643 | 0.893 | 0.554 | 0.714 | 0.786 | 0.357 | 0.768 | 0.714 | 0.786 | 0.714 | 0.786 | 0.679 | 0.786 | 0.732 | 0.607 | 0.429 | 0.429 | 0.304 | 0.214 |
| S ₁ ⁵ | | | | | | | | | | 1.000 | 0.679 | 0.714 | 0.304 | 0.679 | 0.607 | 0.179 | 0.696 | 0.679 | 0.607 | 0.679 | 0.643 | 0.429 | 0.750 | 0.589 | 0.464 | 0.393 | 0.393 | 0.125 | -0.036 |
| S ₁ ⁶ | | | | | | | | | | | 1.000 | 0.393 | 0.339 | 0.036 | 0.214 | 0.250 | 0.054 | 0.036 | 0.214 | 0.036 | 0.071 | 0.107 | 0.214 | 0.018 | 0.893 | 0.929 | 0.929 | 0.125 | 0.036 |
| S ₁ ⁷ | | | | | | | | | | | | 1.000 | 0.375 | 0.679 | 0.679 | 0.107 | 0.768 | 0.679 | 0.679 | 0.679 | 0.786 | 0.571 | 0.750 | 0.732 | 0.393 | 0.250 | 0.250 | 0.196 | 0.107 |
| CMR | | | | | | | | | | | | | 1.000 | 0.411 | 0.804 | 0.696 | 0.429 | 0.411 | 0.804 | 0.411 | 0.554 | 0.875 | 0.375 | 0.571 | 0.589 | 0.304 | 0.304 | 0.393 | 0.411 |
| CSD | | | | | | | | | | | | | | 1.000 | 0.857 | 0.036 | 0.982 | 1.000 | 0.857 | 1.000 | 0.964 | 0.750 | 0.964 | 0.946 | 0.036 | -0.214 | -0.214 | 0.411 | 0.286 |
| CCV | | | | | | | | | | | | | | | 1.000 | 0.393 | 0.875 | 0.857 | 1.000 | 0.857 | 0.929 | 0.964 | 0.821 | 0.911 | 0.357 | 0.036 | 0.036 | 0.411 | 0.357 |
| CMed | | | | | | | | | | | | | | | | 1.000 | 0.054 | 0.036 | 0.393 | 0.036 | 0.179 | 0.536 | -0.071 | 0.268 | 0.321 | 0.107 | 0.107 | 0.161 | 0.179 |
| CS ₁ ¹ | | | | | | | | | | | | | | | | | 1.000 | 0.982 | 0.875 | 0.982 | 0.982 | 0.768 | 0.946 | 0.964 | 0.054 | -0.196 | -0.196 | 0.321 | 0.196 |
| CS ₁ ² | | | | | | | | | | | | | | | | | | 1.000 | 0.857 | 1.000 | 0.964 | 0.750 | 0.964 | 0.946 | 0.036 | -0.214 | -0.214 | 0.411 | 0.286 |
| CS ₁ ³ | | | | | | | | | | | | | | | | | | | 1.000 | 0.857 | 0.929 | 0.964 | 0.821 | 0.911 | 0.357 | 0.036 | 0.036 | 0.411 | 0.357 |
| CS ₁ ⁴ | | | | | | | | | | | | | | | | | | | | 1.000 | 0.964 | 0.750 | 0.964 | 0.946 | 0.036 | -0.214 | -0.214 | 0.411 | 0.286 |
| CS ₁ ⁵ | | | | | | | | | | | | | | | | | | | | | 1.000 | 0.857 | 0.929 | 0.982 | 0.1143 | -0.143 | -0.143 | 0.411 | 0.321 |
| CS ₁ ⁶ | | | | | | | | | | | | | | | | | | | | | | 1.000 | 0.679 | 0.875 | 0.321 | -0.036 | -0.036 | 0.482 | 0.464 |
| CS ₁ ⁷ | | | | | | | | | | | | | | | | | | | | | | | 1.000 | 0.875 | 0.214 | 0.000 | 0.000 | 0.446 | 0.321 |
| NP ₁ ⁽¹⁾ | | | | | | | | | | | | | | | | | | | | | | | | 1.000 | 0.089 | -0.196 | -0.196 | 0.464 | 0.375 |
| NP ₁ ⁽²⁾ | | | | | | | | | | | | | | | | | | | | | | | | | 1.000 | 0.929 | 0.929 | 0.339 | 0.321 |
| NP ₁ ⁽³⁾ | | | | | | | | | | | | | | | | | | | | | | | | | | 1.000 | 1.000 | 0.125 | 0.071 |
| NP ₁ ⁽⁴⁾ | | | | | | | | | | | | | | | | | | | | | | | | | | | 1.000 | 0.125 | 0.071 |
| Z1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1.000 | -0.214 |

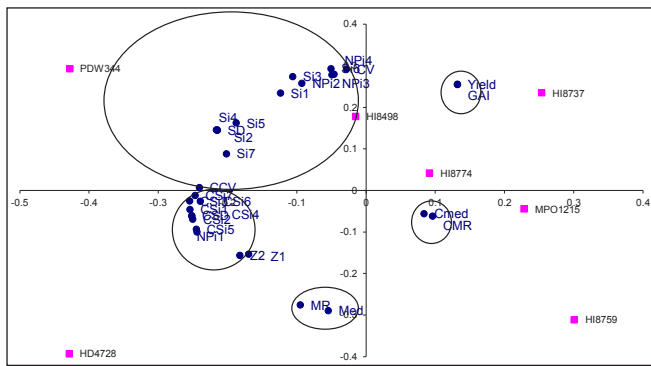


Fig. 1: Biplot analysis of nonparametric measures based on BLUP's of genotypes (2015-16)

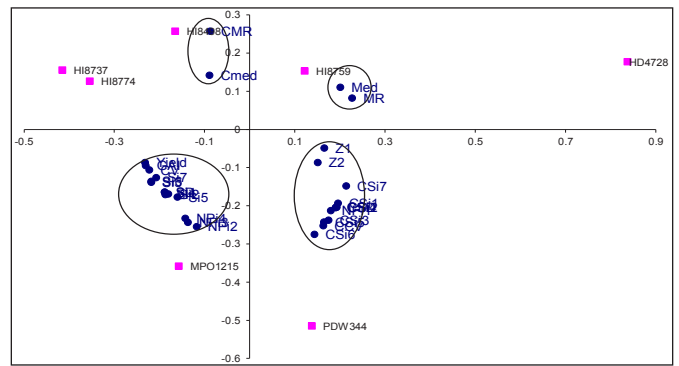


Fig. 2: Biplot analysis of nonparametric measures based on BLUE's of genotypes (2015-16)

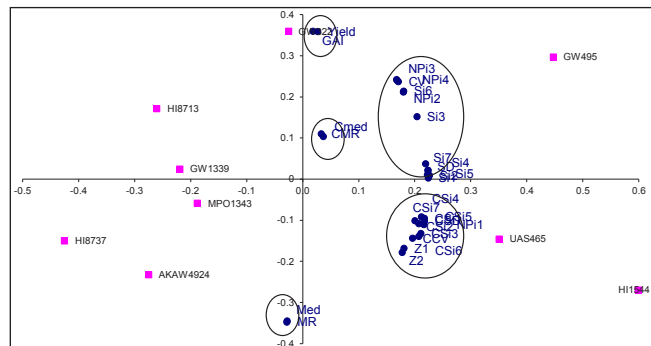


Fig. 3: Biplot analysis of nonparametric measures based on BLUP's of genotypes (2017-18)

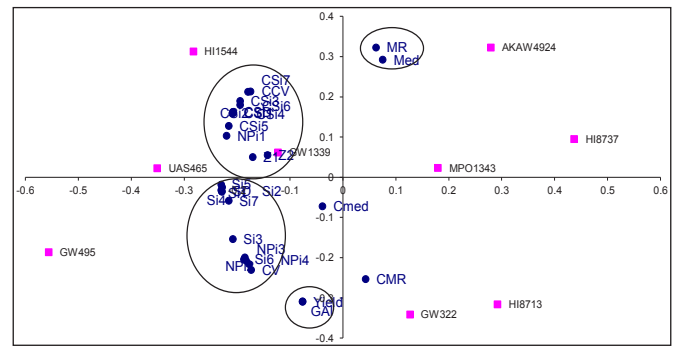


Fig. 4: Biplot analysis of nonparametric measures based on BLUE's of genotypes (2017-18)

all the measures. Median reflected both types of correlations. $S_1^1, S_1^2, S_1^3, S_1^4, S_1^5, S_1^6, S_1^7$ exhibited highly significant to significant positive correlations with exception of CMR & CMed. Negative relationships maintained CMR with most of the measures. CSD had maintained only significant and perfect positive relationships with CS_1^1, CS_1^2, CS_1^4 . Only direct relationships showed by CCV. While indirect relations of CMed had observed. $CS_1^1, CS_1^2, CS_1^3, CS_1^4, CS_1^5, CS_1^6, CS_1^7$ behaved in similar manner and exhibited only direct relations with other and themselves. Values of $NP_i^{(1)}, NP_i^{(2)}, NP_i^{(3)}, NP_i^{(4)}$ had expressed positive correlations. Z1 is related to Z2 in inverse manner.

Table 12: Loadings of rank-based measure (2015-16)
BLUP

| Measure | Component PC1 | Component PC2 |
|---------|---------------|---------------|
| Yield | 0.1316 | 0.2552 |
| GAI | 0.1315 | 0.2553 |
| MR | -0.0953 | -0.2753 |
| SD | -0.2150 | 0.1450 |
| CV | -0.0285 | 0.2921 |
| Med | -0.0550 | -0.2895 |

| | | |
|--------------|---------|---------|
| S_1^1 | -0.1238 | 0.2345 |
| S_1^2 | -0.2163 | 0.1461 |
| S_1^3 | -0.1061 | 0.2738 |
| S_1^4 | -0.2150 | 0.1450 |
| S_1^5 | -0.1878 | 0.1624 |
| S_1^6 | -0.0509 | 0.2926 |
| S_1^7 | -0.2019 | 0.0885 |
| CMR | 0.0954 | -0.0615 |
| CSD | -0.2521 | -0.0609 |
| CCV | -0.2411 | 0.0067 |
| CMed | 0.0835 | -0.0558 |
| CS_1^1 | -0.2547 | -0.0460 |
| CS_1^2 | -0.2506 | -0.0692 |
| CS_1^3 | -0.2549 | -0.0250 |
| CS_1^4 | -0.2521 | -0.0609 |
| CS_1^5 | -0.2456 | -0.0935 |
| CS_1^6 | -0.2396 | -0.0263 |
| CS_1^7 | -0.2471 | -0.0119 |
| $NP_i^{(1)}$ | -0.2444 | -0.0998 |
| $NP_i^{(2)}$ | -0.0930 | 0.2580 |
| $NP_i^{(3)}$ | -0.0498 | 0.2781 |
| $NP_i^{(4)}$ | -0.0464 | 0.2799 |
| Z1 | -0.1700 | -0.1536 |
| Z2 | -0.1827 | -0.1560 |
| % variance | 49.50 | 36.38 |

Table 13: Spearman's rank correlation coefficient values among nonparametric measures (2015-16) 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⁾ | ZI | ZZ | |
|--------------------------------|-------|--------|--------|--------|--------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|--------|--------|--------|--------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|-------|--------|--------|
| GAI | 1.000 | -0.839 | -0.661 | -0.929 | -0.661 | -0.500 | -0.661 | -0.857 | -0.661 | -0.357 | -0.857 | -0.714 | 0.393 | 0.750 | 0.750 | 0.357 | 0.750 | 0.750 | 0.679 | 0.750 | 0.607 | 0.607 | 0.857 | 0.661 | -0.536 | -0.750 | -0.750 | 0.250 | 0.250 | |
| MR | 1.000 | 1.000 | 0.214 | 0.839 | 0.893 | 0.232 | 0.214 | 0.804 | 0.214 | 0.054 | 0.804 | 0.339 | 0.018 | -0.696 | -0.554 | -0.089 | -0.696 | -0.696 | -0.625 | -0.696 | -0.375 | -0.375 | -0.839 | -0.679 | 0.732 | 0.804 | 0.804 | 0.804 | -0.089 | |
| SD | 1.000 | 1.000 | 1.000 | 0.661 | 0.429 | 0.911 | 1.000 | 0.732 | 1.000 | 0.875 | 0.732 | 0.875 | -0.054 | -0.125 | -0.054 | -0.107 | -0.536 | -0.536 | -0.429 | -0.536 | 0.054 | 0.054 | -0.232 | -0.107 | 0.589 | 0.696 | 0.696 | 0.696 | -0.411 | -0.411 |
| CV | 1.000 | 1.000 | 1.000 | 1.000 | 0.875 | 0.536 | 0.661 | 0.393 | 0.964 | 0.714 | -0.143 | -0.536 | -0.500 | -0.107 | -0.536 | -0.500 | -0.107 | -0.536 | -0.429 | -0.321 | -0.679 | -0.518 | 0.750 | 0.929 | 0.929 | 0.929 | 0.929 | 0.929 | -0.143 | -0.143 |
| Med | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.375 | 0.429 | 0.804 | 0.429 | 0.161 | 0.804 | 0.589 | 0.196 | -0.446 | -0.268 | 0.304 | -0.446 | -0.304 | -0.446 | -0.304 | -0.125 | -0.554 | -0.464 | 0.839 | 0.875 | 0.875 | 0.875 | 0.875 | 0.161 | 0.161 |
| S _i ¹ | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.911 | 0.929 | 0.643 | 0.821 | 0.143 | -0.107 | -0.036 | -0.107 | -0.107 | 0.071 | -0.107 | 0.071 | 0.143 | -0.214 | -0.089 | 0.607 | 0.607 | 0.607 | 0.607 | 0.607 | 0.607 | 0.607 | -0.393 | -0.393 |
| S _i ² | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.875 | 0.732 | 0.875 | 0.732 | 0.875 | -0.054 | -0.125 | -0.054 | -0.125 | 0.054 | -0.125 | 0.054 | 0.054 | -0.232 | -0.107 | 0.589 | 0.696 | 0.696 | 0.696 | 0.696 | 0.696 | 0.696 | -0.411 | -0.411 |
| S _i ³ | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.732 | 0.536 | 1.000 | 0.679 | 0.000 | -0.393 | -0.357 | -0.143 | -0.393 | -0.393 | -0.286 | -0.393 | -0.286 | -0.143 | -0.571 | -0.339 | 0.821 | 0.964 | 0.964 | 0.964 | 0.964 | 0.964 | -0.214 | -0.214 |
| S _i ⁴ | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.875 | 0.732 | 0.875 | 0.732 | 0.875 | -0.054 | -0.125 | -0.054 | -0.125 | 0.054 | -0.125 | 0.054 | 0.054 | -0.232 | -0.107 | 0.589 | 0.696 | 0.696 | 0.696 | 0.696 | 0.696 | 0.696 | -0.411 | -0.411 |
| S _i ⁵ | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.536 | 0.679 | 0.036 | 0.000 | 0.000 | 0.000 | 0.000 | 0.143 | 0.000 | 0.143 | 0.179 | -0.071 | 0.018 | 0.429 | 0.464 | 0.464 | 0.464 | 0.464 | 0.464 | 0.464 | 0.464 | 0.464 | -0.607 | -0.607 |
| S _i ⁶ | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.679 | 0.000 | -0.393 | -0.357 | -0.143 | -0.393 | -0.393 | -0.286 | -0.143 | -0.393 | -0.286 | -0.143 | -0.393 | -0.286 | -0.143 | -0.393 | 0.821 | 0.964 | 0.964 | 0.964 | 0.964 | 0.964 | -0.214 | -0.214 |
| S _i ⁷ | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | -0.143 | -0.321 | -0.286 | 0.107 | -0.321 | -0.143 | -0.321 | -0.143 | -0.321 | -0.143 | -0.179 | -0.393 | -0.375 | 0.536 | 0.643 | 0.643 | 0.643 | 0.643 | 0.643 | 0.643 | 0.643 | 0.643 | -0.143 | -0.143 |
| CMR | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.536 | 0.786 | 0.607 | 0.536 | 0.536 | 0.643 | 0.536 | 0.643 | 0.536 | 0.643 | 0.857 | 0.429 | 0.554 | 0.536 | 0.214 | 0.214 | 0.214 | 0.214 | 0.214 | 0.214 | 0.214 | 0.214 | 0.214 | 0.214 |
| CSD | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.929 | 0.357 | 1.000 | 1.000 | 0.964 | 1.000 | 0.964 | 1.000 | 0.964 | 0.857 | 0.964 | 0.857 | 0.964 | 0.982 | -0.143 | -0.286 | -0.286 | 0.393 | 0.393 | 0.393 | 0.393 | 0.393 | 0.393 | 0.393 |
| CCV | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.571 | 0.929 | 0.964 | 0.929 | 0.964 | 0.929 | 0.964 | 0.964 | 0.893 | 0.911 | 0.071 | -0.179 | -0.179 | 0.429 | 0.429 | 0.429 | 0.429 | 0.429 | 0.429 | 0.429 | 0.429 | 0.429 | 0.429 | 0.429 |
| CMed | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.357 | 0.357 | 0.500 | 0.357 | 0.500 | 0.357 | 0.500 | 0.357 | 0.393 | 0.232 | 0.286 | 0.071 | 0.071 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 |
| CS _i ¹ | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| CS _i ² | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| CS _i ³ | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| CS _i ⁴ | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| CS _i ⁵ | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| CS _i ⁶ | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| CS _i ⁷ | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| NP _i ⁽¹⁾ | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| NP _i ⁽²⁾ | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| NP _i ⁽³⁾ | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| NP _i ⁽⁴⁾ | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| ZI | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |



Graphical analysis based on biplot

Five clusters among 30 rank-based measures had been expressed Biplot analysis and the loadings of measures were shown in table 16. Both significant PAC's accounting for 88.2% of the variance of the original variables (Fig. 3). Grouping of Yield with GAI, MR with Med and CMR with CMed were observed in graphical analysis. CV expressed affinity with $NP_i^{(2)}$, $NP_i^{(3)}$ & $NP_i^{(4)}$, SD, S_i^3 , S_i^6 , S_i^1 , S_i^2 , S_i^4 , S_i^5 , S_i^7 as grouped in cluster. Another large cluster comprised of Z1, Z2, CCV, CSD, Z1, Z2, $NP_i^{(1)}$, CS_i^1 , CS_i^2 , CS_i^3 , CS_i^4 , CS_i^5 , CS_i^6 and CS_i^7 measures.

Table 14: Loadings of rank-based measure (2015-16) BLUE

| Measure | Component PC1 | Component PC2 |
|--------------|---------------|---------------|
| Yield | -0.2322 | -0.0864 |
| GAI | -0.2307 | -0.0944 |
| MR | 0.2263 | 0.0825 |
| SD | -0.1891 | -0.1642 |
| CV | -0.2231 | -0.1055 |
| Med | 0.2000 | 0.1107 |
| S_i^1 | -0.1874 | -0.1704 |
| S_i^2 | -0.1810 | -0.1687 |
| S_i^3 | -0.2191 | -0.1378 |
| S_i^4 | -0.1891 | -0.1642 |
| S_i^5 | -0.1611 | -0.1768 |
| S_i^6 | -0.2189 | -0.1358 |
| S_i^7 | -0.2076 | -0.1255 |
| CMR | -0.0884 | 0.2577 |
| CSD | 0.1900 | -0.2045 |
| CCV | 0.1622 | -0.2522 |
| CMed | -0.0898 | 0.1423 |
| CS_i^1 | 0.1948 | -0.1928 |
| CS_i^2 | 0.1924 | -0.2033 |
| CS_i^3 | 0.1741 | -0.2377 |
| CS_i^4 | 0.1900 | -0.2045 |
| CS_i^5 | 0.1639 | -0.2426 |
| CS_i^6 | 0.1430 | -0.2744 |
| CS_i^7 | 0.2131 | -0.1479 |
| $NP_i^{(1)}$ | 0.1791 | -0.2124 |
| $NP_i^{(2)}$ | -0.1178 | -0.2542 |
| $NP_i^{(3)}$ | -0.1375 | -0.2429 |
| $NP_i^{(4)}$ | -0.1432 | -0.2323 |
| Z1 | 0.1649 | -0.0487 |
| Z2 | 0.1498 | -0.0866 |
| % variance | 56.08 | 28.66 |

SECOND YEAR OF STUDY 2017-18

Analytic analysis as per BLUE's

Higher average yield had expressed by G3, G6, G7

wheat genotypes, whereas G3, G6, G7 for possessed higher adaptability index values, mean of ranks selected G2, G9, G8 more over the consistent yield of G2, G8, G5 expressed by least values of standard deviation (Table 9). CV identified as G2, G8, G5 genotypes; Median found G9 G8 G2 as suitable genotypes as per considered locations of the zone. S_i^1 & S_i^2 measures selected G2, G8, G7 opposed to G2, G8, G5 by S_i^3 values. Genotypes G2, G8, G7 considered by S_i^4 as well as by S_i^5 , genotypes G2, G8, G5 favoured by S_i^6 whereas S_i^7 settled for G2, G8, G7 genotypes.

CMR selected G7, G6, G5 and CSD observed suitability of G7, G8, G6 genotypes. CCV exhibited genotypes G7, G6, G8 while median values for G9, G7, G6 and genotypes G7, G8, G6 by CS_i^1 , CS_i^2 , CS_i^3 , CS_i^4 measures whereas as per least values of CS_i^5 genotypes were G8, G7, G6 & for CS_i^6 values G7, G8, G6 while G7, G6, G8 by CS_i^7 (table 10). $NP_i^{(1)}$ favoured (G8, G7, G6); while (G8, G2, G5) by $NP_i^{(2)}$, $NP_i^{(3)}$ & $NP_i^{(4)}$. Measure Z1 settled for G5, G2, G6 and while genotypes G5, G2, G1 by Z2 values.

$W=0.42$ and $\chi^2 = 101.2$ statistic was less than table of χ^2 (0.05, 290) = 124.3 (135.8), which resulted an overall similarity among non-parametric measures. Values of Z_1 sum = 8.08 and Z_2 sum = 9.9 (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.

Association analysis

Majority of highly significant negative correlations of yield had evident from table. At the same time yield expressed positive values observed with GAI, CMR, CCV, CMed and CS_i^7 (Table 17). GAI showed negative correlations with most of the measures. MR expressed significant positive correlation with CV, Med, S_i^3 , S_i^6 , $NP_i^{(2)}$, $NP_i^{(3)}$, $NP_i^{(4)}$. SD and CV depicted same type of correlations with measures. Median had maintained highly significant and significant direct relations with the measures. S_i^1 , S_i^2 , S_i^3 , S_i^4 , S_i^5 , S_i^6 , S_i^7 exhibited significant positive correlation with other measures. CMR measure maintained both type of relationships. CSD, CCV had expressed positive correlations with measures & CMed maintained only negative values of correlation. CS_i^1 , CS_i^2 , CS_i^3 , CS_i^4 , CS_i^5 , CS_i^6 and CS_i^7 expressed only significant positive relationships with others and themselves. $NP_i^{(1)}$, $NP_i^{(2)}$, $NP_i^{(3)}$, $NP_i^{(4)}$ had expressed only direct

Table: 15 Spearman's rank correlation coefficient values among nonparametric measures (2017-18) BLUP

| | 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 | |
|-------------------|-------|--------|--------|--------|--------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|--------|--------|--------|--------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-------------------|-------------------|-------------------|-------------------|--------|--------|-------|
| GAI | 1.000 | -0.992 | -0.200 | -0.650 | -0.753 | -0.200 | -0.200 | -0.500 | -0.200 | -0.250 | -0.600 | -0.333 | 0.467 | 0.167 | 0.117 | 0.192 | 0.167 | 0.167 | 0.117 | 0.167 | 0.100 | 0.333 | -0.050 | 0.250 | -0.633 | -0.667 | -0.667 | -0.083 | -0.083 | |
| MR | 1.000 | -0.942 | -0.167 | -0.600 | -0.725 | -0.167 | -0.167 | -0.467 | -0.167 | -0.233 | -0.567 | -0.283 | 0.517 | 0.217 | 0.217 | 0.258 | 0.217 | 0.217 | 0.200 | 0.217 | 0.117 | 0.400 | 0.067 | 0.267 | -0.600 | -0.617 | -0.617 | 0.017 | 0.017 | |
| SD | 1.000 | 0.325 | 0.325 | 0.325 | 0.325 | 0.325 | 0.625 | 0.625 | 0.325 | 0.275 | 0.708 | 0.492 | -0.425 | -0.058 | 0.058 | -0.317 | -0.058 | -0.058 | 0.058 | -0.058 | -0.058 | -0.275 | 0.208 | -0.175 | 0.742 | 0.808 | 0.808 | 0.192 | 0.192 | |
| CV | 1.000 | 0.833 | 0.833 | 0.833 | 0.833 | 0.833 | 0.967 | 0.967 | 0.833 | 0.783 | 0.983 | 0.900 | -0.167 | 0.833 | 0.767 | -0.308 | 0.833 | 0.833 | 0.833 | 0.833 | 0.617 | 0.700 | 0.817 | 0.700 | 0.817 | 0.800 | 0.800 | 0.550 | 0.550 | |
| Med | 1.000 | 0.508 | 0.833 | 0.833 | 0.833 | 0.833 | 0.967 | 0.967 | 0.833 | 0.783 | 0.983 | 0.900 | -0.283 | 0.517 | 0.567 | -0.292 | 0.517 | 0.517 | 0.600 | 0.517 | 0.300 | 0.583 | 0.367 | 0.950 | 0.983 | 0.983 | 0.983 | 0.467 | 0.467 | |
| S ¹ | 1.000 | -0.058 | -0.058 | 0.308 | -0.058 | -0.042 | 0.425 | 0.108 | -0.358 | -0.458 | -0.192 | -0.150 | -0.458 | -0.458 | -0.292 | -0.458 | -0.408 | -0.408 | -0.408 | -0.408 | -0.408 | -0.408 | -0.108 | -0.492 | 0.425 | 0.508 | 0.508 | 0.008 | 0.008 | |
| S ² | 0.933 | 1.000 | 0.967 | 0.883 | 0.967 | 0.883 | 0.967 | -0.167 | 0.833 | 0.767 | -0.308 | 0.833 | 0.833 | 0.833 | 0.833 | 0.833 | 0.833 | 0.833 | 0.833 | 0.833 | 0.617 | 0.700 | 0.817 | 0.700 | 0.817 | 0.800 | 0.800 | 0.550 | 0.550 | |
| S ³ | 1.000 | 0.933 | 0.900 | 0.983 | 0.967 | 0.883 | 0.967 | -0.217 | 0.633 | 0.667 | -0.292 | 0.633 | 0.633 | 0.700 | 0.633 | 0.650 | 0.450 | 0.633 | 0.650 | 0.917 | 0.933 | 0.933 | 0.933 | 0.933 | 0.933 | 0.933 | 0.933 | 0.533 | 0.533 | |
| S ⁴ | 1.000 | 0.967 | 0.883 | 0.967 | 0.883 | 0.967 | -0.167 | 0.833 | 0.767 | -0.308 | 0.833 | 0.833 | 0.833 | 0.833 | 0.833 | 0.833 | 0.617 | 0.700 | 0.817 | 0.700 | 0.817 | 0.700 | 0.817 | 0.700 | 0.817 | 0.800 | 0.800 | 0.550 | 0.550 | |
| S ⁵ | 1.000 | 0.850 | 0.917 | -0.233 | 0.817 | 0.700 | -0.275 | 0.817 | 0.817 | 0.783 | 0.817 | 0.850 | 0.617 | 0.667 | 0.733 | 0.783 | 0.783 | 0.783 | 0.783 | 0.783 | 0.617 | 0.667 | 0.733 | 0.783 | 0.783 | 0.750 | 0.750 | 0.500 | 0.500 | |
| S ⁶ | 1.000 | 0.917 | -0.267 | 0.550 | 0.583 | -0.325 | 0.550 | 0.617 | 0.550 | 0.567 | 0.333 | 0.550 | 0.400 | 0.933 | 0.950 | 0.950 | 0.400 | 0.933 | 0.950 | 0.950 | 0.400 | 0.933 | 0.550 | 0.400 | 0.933 | 0.950 | 0.950 | 0.433 | 0.433 | |
| S ⁷ | 1.000 | -0.133 | 0.733 | 0.767 | -0.258 | 0.733 | 0.800 | 0.733 | 0.717 | 0.550 | 0.750 | 0.583 | 0.850 | 0.867 | 0.867 | 0.867 | 0.867 | 0.867 | 0.867 | 0.867 | 0.867 | 0.867 | 0.867 | 0.867 | 0.867 | 0.867 | 0.867 | 0.650 | 0.650 | |
| CMR | 1.000 | -0.217 | 0.417 | 0.708 | -0.217 | -0.217 | 0.150 | -0.217 | -0.333 | 0.383 | 0.133 | -0.267 | -0.533 | -0.417 | -0.417 | 0.267 | 0.267 | 0.267 | 0.267 | 0.267 | 0.267 | 0.267 | 0.267 | 0.267 | 0.267 | 0.267 | 0.267 | 0.267 | 0.267 | |
| CSD | 1.000 | 0.717 | -0.192 | 1.000 | 0.883 | 1.000 | 0.883 | 1.000 | 0.950 | 0.717 | 0.750 | 0.917 | 0.583 | 0.533 | 0.533 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | |
| CCV | 1.000 | 0.292 | 0.717 | 0.717 | 0.933 | 0.717 | 0.600 | 0.867 | 0.867 | 0.550 | 0.417 | 0.483 | 0.483 | 0.700 | 0.700 | 0.700 | 0.700 | 0.700 | 0.700 | 0.700 | 0.700 | 0.700 | 0.700 | 0.700 | 0.700 | 0.700 | 0.700 | 0.700 | 0.700 | |
| CMed | 1.000 | -0.192 | -0.192 | 0.175 | -0.192 | -0.375 | 0.275 | 0.292 | -0.258 | -0.525 | -0.392 | -0.392 | -0.392 | -0.008 | -0.008 | -0.008 | -0.008 | -0.008 | -0.008 | -0.008 | -0.008 | -0.008 | -0.008 | -0.008 | -0.008 | -0.008 | -0.008 | -0.008 | -0.008 | |
| CS ¹ | 1.000 | 1.000 | 0.883 | 1.000 | 0.950 | 0.717 | 0.750 | 0.917 | 0.583 | 0.533 | 0.533 | 0.533 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | |
| CS ² | 1.000 | 0.883 | 1.000 | 0.950 | 0.717 | 0.750 | 0.917 | 0.583 | 0.533 | 0.533 | 0.533 | 0.533 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 |
| CS ³ | 1.000 | 0.883 | 1.000 | 0.950 | 0.717 | 0.750 | 0.917 | 0.583 | 0.533 | 0.533 | 0.533 | 0.533 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 |
| CS ⁴ | 1.000 | 0.883 | 1.000 | 0.950 | 0.717 | 0.750 | 0.917 | 0.583 | 0.533 | 0.533 | 0.533 | 0.533 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 |
| CS ⁵ | 1.000 | 0.883 | 1.000 | 0.950 | 0.717 | 0.750 | 0.917 | 0.583 | 0.533 | 0.533 | 0.533 | 0.533 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 |
| CS ⁶ | 1.000 | 0.883 | 1.000 | 0.950 | 0.717 | 0.750 | 0.917 | 0.583 | 0.533 | 0.533 | 0.533 | 0.533 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 |
| CS ⁷ | 1.000 | 0.883 | 1.000 | 0.950 | 0.717 | 0.750 | 0.917 | 0.583 | 0.533 | 0.533 | 0.533 | 0.533 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 |
| NP ⁽¹⁾ | 1.000 | 0.500 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 | 0.417 |
| NP ⁽²⁾ | 1.000 | 0.983 | 0.983 | 0.400 | 0.400 | 0.400 | 0.400 | 0.400 | 0.400 | 0.400 | 0.400 | 0.400 | 0.400 | 0.400 | 0.400 | 0.400 | 0.400 | 0.400 | 0.400 | 0.400 | 0.400 | 0.400 | 0.400 | 0.400 | 0.400 | 0.400 | 0.400 | 0.400 | 0.400 | 0.400 |
| NP ⁽³⁾ | 1.000 | 1.000 | 1.000 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 |
| NP ⁽⁴⁾ | 1.000 | 1.000 | 1.000 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 | 0.450 |
| Z1 | 1.000 | -0.590 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |



relationships. More over Z1 was related Z2 values by an inverse relationship.

Table 16: Loadings of rank-based measure (2017-18) BLUP

| Measure | Component PC1 | Component PC2 |
|--------------------------------|---------------|---------------|
| Yield | 0.0266 | 0.3596 |
| GAI | 0.0179 | 0.3601 |
| MR | -0.0285 | -0.3472 |
| SD | 0.2233 | 0.0219 |
| CV | 0.1705 | 0.2377 |
| Med | -0.0282 | -0.3441 |
| S _i ¹ | 0.2237 | 0.0035 |
| S _i ² | 0.2259 | 0.0100 |
| S _i ³ | 0.2036 | 0.1525 |
| S _i ⁴ | 0.2233 | 0.0219 |
| S _i ⁵ | 0.2221 | 0.0109 |
| S _i ⁶ | 0.1802 | 0.2147 |
| S _i ⁷ | 0.2194 | 0.0379 |
| CMR | 0.0327 | 0.1105 |
| CSD | 0.2171 | -0.1007 |
| CCV | 0.1958 | -0.1435 |
| CMed | 0.0366 | 0.1042 |
| CS _i ¹ | 0.2170 | -0.0945 |
| CS _i ² | 0.2160 | -0.1098 |
| CS _i ³ | 0.2108 | -0.1317 |
| CS _i ⁴ | 0.2171 | -0.1007 |
| CS _i ⁵ | 0.2115 | -0.0916 |
| CS _i ⁶ | 0.2068 | -0.1391 |
| CS _i ⁷ | 0.2002 | -0.1009 |
| NP _i ⁽¹⁾ | 0.2068 | -0.1078 |
| NP _i ⁽²⁾ | 0.1794 | 0.2126 |
| NP _i ⁽³⁾ | 0.1682 | 0.2408 |
| NP _i ⁽⁴⁾ | 0.1674 | 0.2431 |
| Z1 | 0.1804 | -0.1675 |
| Z2 | 0.1773 | -0.1776 |
| % variance | 63.64 | 24.60 |

Table 18: Loadings of rank-based measure (2017-18) BLUE

| Measure | Component PC1 | Component PC2 |
|-----------------------------|---------------|---------------|
| Yield | -0.0767 | -0.3088 |
| GAI | -0.0763 | -0.3077 |
| MR | 0.0621 | 0.3231 |
| SD | -0.2290 | -0.0348 |
| CV | -0.1739 | -0.2297 |
| Med | 0.0749 | 0.2930 |
| S _i ¹ | -0.2287 | -0.0239 |
| S _i ² | -0.2305 | -0.0318 |
| S _i ³ | -0.2084 | -0.1527 |
| S _i ⁴ | -0.2290 | -0.0348 |
| S _i ⁵ | -0.2304 | -0.0176 |
| S _i ⁶ | -0.1874 | -0.2038 |
| S _i ⁷ | -0.2163 | -0.0575 |

| | | |
|--------------------------------|---------|---------|
| CMR | 0.0423 | -0.2524 |
| CSD | -0.2084 | 0.1627 |
| CCV | -0.1747 | 0.2142 |
| CMed | -0.0391 | -0.0712 |
| CS _i ¹ | -0.2073 | 0.1611 |
| CS _i ² | -0.2096 | 0.1594 |
| CS _i ³ | -0.1947 | 0.1901 |
| CS _i ⁴ | -0.2084 | 0.1627 |
| CS _i ⁵ | -0.2159 | 0.1282 |
| CS _i ⁶ | -0.1943 | 0.1805 |
| CS _i ⁷ | -0.1797 | 0.2128 |
| NP _i ⁽¹⁾ | -0.2201 | 0.1038 |
| NP _i ⁽²⁾ | -0.1855 | -0.1984 |
| NP _i ⁽³⁾ | -0.1834 | -0.2070 |
| NP _i ⁽⁴⁾ | -0.1781 | -0.2151 |
| Z1 | -0.1707 | 0.0508 |
| Z2 | -0.1425 | 0.0561 |
| % variance | 58.08 | 29.15 |

Graphical analysis based on biplot

Values of the loadings for measures as per first two significant principal components axes (PCA) were shown in table 18. Both significant PAC's accounting for 78.4% of the variations in the variables (Fig. 4). 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_i³, S_i⁵, S_i⁶. Large cluster comprises of CCV, CSD, NP_i⁽¹⁾, S_i¹, S_i², S_i⁴, CS_i¹, CS_i², CS_i³, CS_i⁴, CS_i⁵, CS_i⁶, CS_i⁷ and Z1 measures.

CONCLUSION

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 nonparametric measures. More affinity among measures had reflected by a smaller number of clusters in biplot analysis based on BLUP's. Association of S_i^s, CS_i^s, NP_i^(s) with other measures is independent of ranks as per BLUP or BLUE of genotypes. Positive and direct relationships exhibited by these measures with other nonparametric measures.

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Table 17: Spearman's rank correlation coefficient values among nonparametric measures (2017-18) BLUE

| | GAI | MR | SD | CV | Med | S ₁ ¹ | S ₂ ² | S ₃ ³ | S ₄ ⁴ | S ₅ ⁵ | S ₆ ⁶ | S ₇ ⁷ | CMR | CSD | CCV | CMed | CS ₁ ¹ | CS ₂ ² | CS ₃ ³ | CS ₄ ⁴ | CS ₅ ⁵ | CS ₆ ⁶ | CS ₇ ⁷ | NP ₁ ⁽¹⁾ | NP ₂ ⁽²⁾ | NP ₃ ⁽³⁾ | NP ₄ ⁽⁴⁾ | NP ₅ ⁽⁵⁾ | NP ₆ ⁽⁶⁾ | NP ₇ ⁽⁷⁾ | Z1 | Z2 | | |
|--------------------------------|-------|--------|--------|--------|--------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|--------|--------|--------|--------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|--------|--------|--------|--------|
| GAI | 0.967 | -0.900 | -0.533 | -0.917 | -0.775 | -0.567 | -0.533 | -0.817 | -0.533 | -0.567 | -0.883 | -0.517 | 0.375 | -0.083 | -0.133 | 0.375 | -0.083 | -0.083 | -0.083 | -0.183 | -0.083 | 0.133 | -0.292 | -0.933 | -0.967 | -0.967 | -0.967 | -0.967 | -0.967 | -0.967 | -0.967 | -0.250 | -0.300 | |
| MR | | 1.000 | -0.917 | -0.883 | -0.725 | -0.567 | -0.517 | -0.800 | -0.517 | -0.567 | -0.867 | -0.483 | 0.442 | -0.017 | -0.233 | 0.442 | -0.017 | -0.017 | -0.017 | -0.100 | -0.017 | 0.233 | -0.242 | -0.900 | -0.917 | -0.917 | -0.917 | -0.917 | -0.917 | -0.917 | -0.917 | -0.250 | -0.283 | |
| SD | | | 1.000 | 0.283 | 0.892 | 0.333 | 0.283 | 0.667 | 0.283 | 0.333 | 0.767 | 0.267 | -0.558 | -0.283 | -0.467 | -0.442 | -0.283 | -0.283 | -0.283 | -0.200 | -0.283 | -0.467 | -0.242 | 0.783 | 0.833 | 0.833 | 0.833 | 0.833 | 0.833 | 0.833 | 0.833 | 0.117 | 0.183 | |
| CV | | | | 1.000 | 0.825 | 0.750 | 0.733 | 0.950 | 0.733 | 0.750 | 0.983 | 0.700 | -0.275 | 0.283 | 0.117 | -0.375 | 0.283 | 0.283 | 0.283 | 0.350 | 0.283 | 0.117 | 0.308 | 0.950 | 0.967 | 0.967 | 0.967 | 0.967 | 0.967 | 0.967 | 0.967 | 0.517 | 0.550 | |
| Med | | | | | 1.000 | 0.425 | 0.375 | 0.708 | 0.375 | 0.425 | 0.792 | 0.375 | -0.200 | -0.025 | -0.175 | -0.133 | -0.025 | -0.025 | 0.042 | -0.025 | -0.175 | 0.000 | 0.842 | 0.875 | 0.875 | 0.875 | 0.875 | 0.875 | 0.875 | 0.875 | 0.875 | 0.875 | 0.092 | 0.158 |
| S ₁ ¹ | | | | | | 1.000 | 0.983 | 0.867 | 0.983 | 1.000 | 0.817 | 0.950 | 0.075 | 0.717 | 0.567 | -0.142 | 0.717 | 0.717 | 0.717 | 0.733 | 0.717 | 0.567 | 0.725 | 0.733 | 0.667 | 0.667 | 0.667 | 0.667 | 0.667 | 0.667 | 0.667 | 0.533 | 0.483 | |
| S ₂ ² | | | | | | | 1.000 | 0.850 | 1.000 | 0.983 | 0.783 | 0.983 | 0.008 | 0.767 | 0.633 | -0.242 | 0.767 | 0.767 | 0.767 | 0.783 | 0.767 | 0.633 | 0.758 | 0.700 | 0.650 | 0.650 | 0.650 | 0.650 | 0.650 | 0.650 | 0.617 | 0.583 | | |
| S ₃ ³ | | | | | | | | 1.000 | 0.850 | 0.867 | 0.983 | 0.800 | -0.108 | 0.500 | 0.317 | -0.308 | 0.500 | 0.500 | 0.533 | 0.500 | 0.317 | 0.508 | 0.950 | 0.917 | 0.917 | 0.917 | 0.917 | 0.917 | 0.917 | 0.917 | 0.533 | 0.550 | | |
| S ₄ ⁴ | | | | | | | | | 1.000 | 0.983 | 0.783 | 0.983 | 0.008 | 0.767 | 0.633 | -0.242 | 0.767 | 0.767 | 0.767 | 0.783 | 0.767 | 0.633 | 0.758 | 0.700 | 0.650 | 0.650 | 0.650 | 0.650 | 0.650 | 0.617 | 0.583 | | | |
| S ₅ ⁵ | | | | | | | | | | 1.000 | 0.817 | 0.950 | 0.075 | 0.717 | 0.567 | -0.142 | 0.717 | 0.717 | 0.717 | 0.733 | 0.717 | 0.567 | 0.725 | 0.733 | 0.667 | 0.667 | 0.667 | 0.667 | 0.667 | 0.667 | 0.533 | 0.483 | | |
| S ₆ ⁶ | | | | | | | | | | | 1.000 | 0.733 | -0.158 | 0.367 | 0.183 | -0.292 | 0.367 | 0.367 | 0.367 | 0.417 | 0.367 | 0.183 | 0.392 | 0.967 | 0.950 | 0.950 | 0.950 | 0.950 | 0.950 | 0.950 | 0.950 | 0.483 | 0.500 | |
| S ₇ ⁷ | | | | | | | | | | | | 1.000 | -0.075 | 0.733 | 0.617 | -0.275 | 0.733 | 0.733 | 0.733 | 0.750 | 0.733 | 0.617 | 0.708 | 0.650 | 0.617 | 0.617 | 0.617 | 0.617 | 0.617 | 0.567 | 0.550 | | | |
| CMR | | | | | | | | | | | | | 1.000 | 0.442 | 0.542 | 0.817 | 0.442 | 0.442 | 0.442 | 0.392 | 0.442 | 0.542 | 0.333 | -0.158 | -0.275 | -0.275 | -0.275 | -0.142 | -0.242 | | | | | |
| CSD | | | | | | | | | | | | | | 1.000 | 0.950 | -0.025 | 1.000 | 1.000 | 1.000 | 1.000 | 0.983 | 1.000 | 0.950 | 0.958 | 0.350 | 0.267 | 0.267 | 0.267 | 0.533 | 0.483 | | | | |
| CCV | | | | | | | | | | | | | | | 1.000 | 0.142 | 0.950 | 0.950 | 0.950 | 0.917 | 0.950 | 1.000 | 0.842 | 0.133 | 0.067 | 0.067 | 0.067 | 0.517 | 0.467 | | | | | |
| CMed | | | | | | | | | | | | | | | | 1.000 | -0.025 | -0.025 | -0.025 | -0.075 | -0.025 | 0.142 | -0.200 | -0.342 | -0.425 | -0.425 | -0.492 | -0.575 | | | | | | |
| CS ₁ ¹ | | | | | | | | | | | | | | | | | 1.000 | 1.000 | 1.000 | 0.983 | 1.000 | 0.950 | 0.958 | 0.350 | 0.267 | 0.267 | 0.267 | 0.533 | 0.483 | | | | | |
| CS ₂ ² | | | | | | | | | | | | | | | | | | 1.000 | 1.000 | 0.983 | 1.000 | 0.950 | 0.958 | 0.350 | 0.267 | 0.267 | 0.267 | 0.533 | 0.483 | | | | | |
| CS ₃ ³ | | | | | | | | | | | | | | | | | | | 1.000 | 1.000 | 0.983 | 1.000 | 0.950 | 0.958 | 0.350 | 0.267 | 0.267 | 0.267 | 0.533 | 0.483 | | | | |
| CS ₄ ⁴ | | | | | | | | | | | | | | | | | | | | 1.000 | 0.983 | 1.000 | 0.950 | 0.958 | 0.350 | 0.267 | 0.267 | 0.267 | 0.533 | 0.483 | | | | |
| CS ₅ ⁵ | | | | | | | | | | | | | | | | | | | | | 1.000 | 0.983 | 0.917 | 0.975 | 0.417 | 0.350 | 0.350 | 0.550 | 0.500 | | | | | |
| CS ₆ ⁶ | | | | | | | | | | | | | | | | | | | | | | 1.000 | 0.950 | 0.958 | 0.350 | 0.267 | 0.267 | 0.267 | 0.533 | 0.483 | | | | |
| CS ₇ ⁷ | | | | | | | | | | | | | | | | | | | | | | | 1.000 | 0.842 | 0.133 | 0.067 | 0.067 | 0.517 | 0.467 | | | | | |
| NP ₁ ⁽¹⁾ | | | | | | | | | | | | | | | | | | | | | | | | 1.000 | 0.408 | 0.325 | 0.325 | 0.492 | 0.425 | | | | | |
| NP ₂ ⁽²⁾ | | | | | | | | | | | | | | | | | | | | | | | | | 1.000 | 0.983 | 0.983 | 0.367 | 0.400 | | | | | |
| NP ₃ ⁽³⁾ | | | | | | | | | | | | | | | | | | | | | | | | | | 1.000 | 1.000 | 0.400 | 0.450 | | | | | |
| NP ₄ ⁽⁴⁾ | | | | | | | | | | | | | | | | | | | | | | | | | | | 1.000 | 0.400 | 0.450 | | | | | |
| Z1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1.000 | -0.625 |



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