Stability Analysis in Rice (*Oryza sativa* L.) Genotypes with High Grain Zinc

Vishal Pandey, S.K. Singh, Mounika Korada, D.K. Singh, A.R. Khaire, Sonali Habde, Prasanta Kumar Majhi

**ABSTRACT**

**Background:** Balanced nutrition is an essential part of human diet and rice being consumed by more than half of the world population, having rice cultivars biofortified for high zinc levels in polished rice would be very important to combat issues of malnutrition. Zinc being a highly variable trait and influenced by environmental and soil conditions, a multi-location stability analysis was conducted to identify cultivars stable for high grain zinc with consistency in yield performance.

**Methods:** Present experiment was conducted to study the stability of 22 high zinc rice genotypes in five different locations of Eastern Uttar Pradesh in RCBD with three replications in all the locations and 12 different traits were included in the study. Eberhart and Russell model was used for evaluating the stability of the genotypes.

**Result:** The results reported high significance for all the twelve characters studied. Mean sum of squares due to environment as well as linear component of environment were significant for all the characters suggesting presence of variation among the five environments tested. All the twenty-two genotypes showed significant differences for all the characters when tested against pooled error and pooled deviation. The genotype, IR15M1633 recorded highest mean grain zinc content but have negative association with yield. Therefore, considering for a high grain zinc genotype with consistent yield performance, the genotypes, DRR Dhan 48 and HURZ-3 showed good mean values for all the traits and was also stable for grain zinc, yield per hectare, 1000 grain weight, had shorter plant height and can be suggested for use as high yielding cultivars with high grain zinc and could be further used in breeding programmes successfully.

**Key words:** Eberhart and Russel, Rice, Stability, Zinc.
stable genotypes. A stable variety can be defined as the one having unit regression coefficient (b=1) and the least possible departure from the regression line (S²d=0) (Eberhart and Russel, 1966).

**MATERIALS AND METHODS**

**Experimental material**

The present investigation was carried out on twenty-two genotypes of rice. The list of genotypes used in the present investigation is provided in Table 1 along with their parentage and source of the material. The study was conducted at five different locations (Location 1 and 2: Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, UP. These two locations in BHU are always used for testing the performance of the genotypes. So, these two locations were selected. Location 3: Bhikaripur, Varanasi, UP, Location 4: Chittapur, Varanasi, UP and Location 5: Rampur, Mirzapur, UP) during Kharif 2018. Map attached below as Fig 1. Randomized block design with three replications was used for all the traits under investigation. A single plot consisted of three rows of 3 meter each, with 20cm spacing at all the five locations. Net plot size was 0.6 x 1 meters, i.e., 1.8m² for all the locations. Observations were recorded from five randomly selected competitive plants of each genotype in each replication for most of yield traits i.e., tillers per plant, plant height (cm), panicle length (cm), grain weight per panicle (g), grain yield per plant (g), 1000 grain weight (g), grain L/B ratio and grain Zn content (ppm) and related characters except days to first flowering, days to 50% flowering and days to maturity which were collected on plot basis. Grain yield per hectare (kg) was recorded on plot basis.

**Statistical analysis**

Eberhat and Russel (1966) model was utilized for stability analysis. In this model, three parameters were determined, viz. genotype's mean across environments, regression of genotype on environmental index and the function of the squared deviation from the regression. A genotype having regression coefficient as unit i.e., b=1 and non-significant deviation from Zero i.e., S²d=0, was considered as stable with uniform response.

**RESULTS AND DISCUSSION**

All the genotypes were recorded to be highly significant for all the twelve characters studied, viz., days to first flowering, days to 50% flowering, days to maturity, tillers per plant, plant height, panicle length, grain weight per panicle, grain

---

**Table 1: List of entries, their parentage and the source of the material.**

| Name of Genotype | Source | Parentage |
|------------------|--------|-----------|
| IR 95133:1-B-16-14-10-GBS-P1-2-2 | IRRI South Asia Hub, Hyderabad. | FEDEARROZ 50/SANHUANGZHAN NO 2/IR 45427-2B-2-2B-1-1/IR07F287/IRRI 123/IR 77298-14-1-2-10/NSIC RC 158/IR 4630-22-2-5-1-3/4/FEDEARROZ 50/IR07F287/IRRI 123/IR 45427-2B-2-2B-1-1//SANHUANGZHAN NO 2/NSIC RC 158/IR 77298-14-1-2-10/IR 4630-22-2-5-1-3/5/FED |
| IR 95133:1-B-16-14-10-GBS-P1-2-3 | IRRI South Asia Hub, Hyderabad. | -do- |
| IR 95133:1-B-16-14-10-GBS-P5-1-3 | IRRI South Asia Hub, Hyderabad. | -do- |
| IR 95133:1-B-16-14-10-GBS-P5-2-3 | IRRI South Asia Hub, Hyderabad. | -do- |
| IR 95133:1-B-16-14-10-GBS-P6-1-5 | IRRI South Asia Hub, Hyderabad. | -do- |
| IR15M1537 | IRRI South Asia Hub, Hyderabad. | IRRI 123*2/JORYEONGBYE |
| IR15M1546 | IRRI South Asia Hub, Hyderabad. | -do- |
| IR15M1689 | IRRI South Asia Hub, Hyderabad. | -do- |
| IR15M1633 | IRRI South Asia Hub, Hyderabad. | IR 69428-6-1-3-3/IRRI 123 |
| IR 99642-57-1-1-1-B | IRRI South Asia Hub, Hyderabad. | IR 91152-AC 438/BR 29/IR 69428-6-1-1-3-3/IR06A147/IR 75862-206-2-8-3-B-B/IR06A147 |
| HURZ-1 | IRRI South Asia Hub, Hyderabad. | RPBIO226/IR10M196 |
| HURZ-3 | IRRI South Asia Hub, Hyderabad. | RPBIO226/IR10M196 |
| BRRIdhan 64 | IRRI South Asia Hub, Hyderabad. | IR 75382-32-2-3/3-3/BR7166-4-5-3-2-5-5B1-92 |
| BRRIdhan 72 | IRRI South Asia Hub, Hyderabad. | BR 7166-4-5-3-BRRI DHAN 39 |
| DRR Dhan 45 | IRRI South Asia Hub, Hyderabad. | IR 73707-45-3-2-3/IR 77080-B-34-3 |
| DRR Dhan 48 | IRRI South Asia Hub, Hyderabad. | RPBio 226/1/CSR 27 |
| IR 64 | IRRI South Asia Hub, Hyderabad. | IR 5657-33-2-1/IR 2061-465-1-5-5 |
| MTU1010 | IRRI South Asia Hub, Hyderabad. | MTU-077/IR64 |
| Samba Mahsuri | IRRI South Asia Hub, Hyderabad. | GEB 24/T(N)-1/MAHSURI |
| Swarna | IRRI South Asia Hub, Hyderabad. | VASISTA/MAHSURI |
| HUR 105 (LC-1) | IRRI South Asia Hub, Hyderabad. | MUTANT OF MPR 7-2 |
| HUR 3022(LC-2) | IRRI South Asia Hub, Hyderabad. | IR36/HR137 |
yield per plant, 1000 grain weight, grain yield per ha, grain L/B ratio and grain Zn content, after partitioning of mean sum of squares into genotypes, environment + (genotypes x environment) and pooled error, which indicated the presence of genetic variability in the experimental material. Mean sum of squares due to environment as well as linear component of environment were significant for all the characters suggesting presence of variation among the environments tested. The linear component of genotype x environment interaction was found to be significant for days to first flowering, days to 50% flowering, days to maturity, tillers per plant, grain weight per panicle, grain yield per plant, 1000 grain weight and grain L/B ratio. This indicated the presence of significant differences among the genotypes for a linear response to environments and the interaction between genotype and environment was due to the linear function of environmental components. Therefore, stability parameters could be used reliably for predicting genotypes performance. Similar findings were also reported by Saidaiah et al. (2011) and Sreedhar et al. (2011) and Wasan et al. (2018). The pooled analysis of variance has been presented in Table 2. Mean performance and stability parameters of all the twelve traits studied were explained as under and represented in Tables 3, 4, 5 and 6.

Days to first flowering
The linear component of G x E interaction was significant, suggesting significant difference among the genotypes for a linear response to environments. Therefore, the behavior of genotypes over environments can be predicted more accurately. This showed conformity with the findings of Nandita Devi et al. (2006) and Bhakta and Das (2008).

The genotype DRR Dhan 45 was found most stable for days to flowering as it exhibited lower mean values (85.93 days) along with regression coefficients equal or closer to unity and the least deviation from regression coefficient.

Days to 50% flowering
Only the linear component of G x E interaction was significant suggesting significant difference among the genotypes for a linear response to environments. Therefore, the behavior of genotypes over environments can be predicted more accurately and it would be least susceptible to environmental fluctuations. This showed similarity with the findings of Nandita Devi et al. (2006) and Bhakta and Das (2008) and Koli et al. (2015).

The genotype IR 99642-57-1-1-1-B exhibited lower mean values (90.60 days) along with regression coefficient closer to unity and the least deviation from the regression coefficient, whereas HUR- 3022 was specifically adapted to poor environments with low mean, regression coefficient below unity and the least deviation from the regression coefficient.

Days to maturity
The linear component of G x E interaction was significant suggesting significant difference among the genotypes for linear response to environments. Therefore, the behavior of genotypes over environments can be predicted more accurately. Significant non-linear component of G x E interaction indicated the presence of genetic variability for this character in the material used. This showed conformity with the findings of Belhekar et al. (2004), Bhakta and Das (2008), Praveen et al. (2013) and Manjunatha et al. (2018).
Table 2: Pooled analysis of variance for grain yield and yield attributing traits in rice (*Oryza sativa* L.) genotypes.

| Trait                        | Rep. within Env. | Enviornment Ei - Ej | Var. × Enviornment Ei - Ej | Enviornment Ei - Ej | Var. × Enviornment Ei - Ej | Total          |
|------------------------------|------------------|---------------------|-----------------------------|---------------------|-----------------------------|----------------|
| Plant height (cm)            | 0.468            | 0.328               | 0.317                       | 0.317               | 0.317                       | 1.479          |
| Number of effective tillers per plant | 4.353            | 4.218               | 4.172                       | 4.172               | 4.172                       | 8.344          |
| Tillers per plant           | 2.207            | 2.064               | 2.012                       | 2.012               | 2.012                       | 4.067          |
| Plant height (cm)            | 0.878            | 0.759               | 0.718                       | 0.718               | 0.718                       | 1.479          |
| Grain weight per panicle (g) | 1.351            | 1.269               | 1.236                       | 1.236               | 1.236                       | 2.546          |

The genotype BRRI Dhan 64 found suitable for short duration with bi value closer to unity and non-significant deviation from regression.

**Number of effective tillers per plant**

The significant linear component of G × E interaction suggested significant differences among the genotypes for linear response to environments. Therefore, the behavior of genotypes over environments can be predicted more accurately and it would be least susceptible to environmental fluctuations. Similar results were reflected in the findings of Das and Choudhary (1996), Paray et al. (2006), Sreedhar et al. (2011), Saidaiah et al. (2011) and Vishnuvardhan et al. (2015).

The genotype IR 95133:1-B-16-14-10-GBS-P1-2-2 was most suitable for above-average number of tillers under better environmental conditions due to the presence of high mean value, bi value more than unity and non-significant deviation from regression, whereas, IR 95133:1-B-16-14-10-GBS-P6-1-5 was considered suitable for high number of tillers under poor environmental conditions.

**Plant height (cm)**

Mean sum of squares due to genotypes were significant, suggesting differential response of the genotypes to environments and independence of genetic systems in determining stability parameters. However, the genotype × environment (linear) was non-significant, which suggested that the performance of the genotype could probably be predicted across environments. The results showed a contradiction with the findings of Nandita Devi et al. (2006), Dalvi et al. (2007) and Manjunatha et al. (2018).

For tall plant height, BRRI Dhan 64 was considered stable and better adapted to favorable environments, with regression coefficient above unity and non-significant deviation from regression. Swarna and DRRDhan 48 were short heighted genotype as better suited to poor low yielding environments.

**Panicle length (cm)**

The mean sum of squares due to genotypes were significant, indicating the varied response of the genotypes to environments. The genotype × environment (linear) was non-significant, which suggested that the performance of the genotype could be predictable across environments. The results showed contradiction with the findings of Kulkami and Eswari (1994), Panwar et al. (2008) and Manjunatha et al. (2018).

Sambamahsuri and HUR-105 (LC-1) were most stable across environments for moderate panicle length with regression coefficient around unity and non-significant deviation from regression, whereas, MTU1010 and IR 99642-57-1-1-1-B were reported to be stable and suited for the favorable environment with longer panicle.

**Grain weight per panicle (g)**

The significant linear component of G × E interaction suggested...
Table 3: Mean performance and stability parameter of days to first flowering, days to 50% flowering and days to maturity of rice (*Oryza sativa* L.) genotypes.

| Entry no. | Name of Genotype | Days to first flowering | Days to 50% Flowering | Days to maturity |
|-----------|------------------|-------------------------|-----------------------|-----------------|
|           |                  | Mean | $\beta_i$ | $S^2_{Di}$ | Mean | $\beta_i$ | $S^2_{Di}$ | Mean | $\beta_i$ | $S^2_{Di}$ |
| 1         | IR 95133:1-B-16-14-10-GBS-P1-2-2 | 89.2 | 0.41 | 7.91*** | 93.333 | 2.23 | 4.74*** | 126.2 | 0.81 | 9.63*** |
| 2         | IR 95133:1-B-16-14-10-GBS-P1-2-3 | 87.4 | 0.42 | 8.61*** | 91.467 | 1.87 | 2.76*** | 127.467 | 1.28 | 6.05*** |
| 3         | IR 95133:1-B-16-14-10-GBS-P5-1-3 | 84.2 | -0.15 | 1.83*** | 88.333 | 0.52 | 1.68*** | 118.267 | 0.91 | 2.68*** |
| 4         | IR 95133:1-B-16-14-10-GBS-P5-2-3 | 87.733 | 1.22 | 0.81* | 92.267 | 2.54 | 5.99*** | 124.6 | 1.49 | 6.91*** |
| 5         | IR 95133:1-B-16-14-10-GBS-P6-1-5 | 84.467 | 0.53 | 0.09 | 89.467 | 0.41 | 0.67* | 120.533 | 0.72 | -0.04 |
| 6         | IR15M1537 | 83.267 | 0.2 | 0.89* | 87.667 | 0.21 | 1.9*** | 117.533 | 0.98 | 3.06** |
| 7         | IR15M1546 | 78.4 | -0.47 | 6.31*** | 81.667 | 1.13 | 1.67*** | 112.867 | 1.07 | 10.06*** |
| 8         | IR15M1689 | 79.133 | -0.46 | 2.71*** | 83.267 | 0.29 | 4.25*** | 120.467 | 1.73 | 3.53*** |
| 9         | IR15M1633 | 81.533 | -0.06 | 0.13 | 85.333 | 0.4 | -0.17 | 117.533 | 1.2 | 3.72*** |
| 10        | IR 99642-57-1-1-1-B | 85.733 | 0.8 | 1.28** | 90.6 | 1.32 | -0.03 | 124.267 | 1.45 | 1.43* |
| 11        | HURZ-1 | 89.733 | 1.58 | 2.35*** | 96.133 | 1.41 | 1.39** | 128.867 | 0.76 | 1.29* |
| 12        | HURZ-3 | 85.867 | 0.88 | 3.91*** | 91.467 | 1.05 | 6.18*** | 126.533 | 1.02 | 8.67*** |
| 13        | BRRI Dhan 64 | 87.667 | 1.01 | 1.98*** | 93.067 | 0.08 | 1.68*** | 122.733 | 0.76 | -0.3 |
| 14        | BRRI Dhan 72 | 96.333 | 2.53 | 11.17*** | 103.4 | 0.89 | 5.99*** | 132.4 | 0.8 | 7.8*** |
| 15        | DRR Dhan 45 | 85.933 | 0.85 | 0.35 | 90.6 | 1.79 | -0.03 | 124.333 | 1.72 | 0.03 |
| 16        | DRR Dhan 48 | 89.067 | 1.36 | 1.44** | 95 | 1.7 | 2.00*** | 127.867 | 1.28 | 1.17* |
| 17        | IR 64 | 83.067 | 0.39 | 3.9*** | 87.133 | 1.59 | 2.37*** | 117.733 | 0.8 | 4.24*** |
| 18        | MTU1010 | 81.8 | 0.07 | 0.93* | 86.467 | 0.62 | 0.68* | 118.4 | 1.21 | 1.16* |
| 19        | Sambamahasuri | 104.333 | 3.98 | 19.36*** | 113.6 | 0.57 | 1.27** | 146.667 | 0.47 | 2.66** |
| 20        | Swarna | 103.8 | 3.87 | 19.43*** | 113.267 | 0.21 | 0.08 | 147.867 | 0.32 | 0.52 |
| 21        | HUR 105 (LOCAL CHECK1) | 96.267 | 2.49 | 11.53*** | 103.067 | 0.51 | 1.79*** | 132.733 | 0.64 | -0.4 |
| 22        | HUR 3022 (LOCAL CHECK2) | 84.667 | 0.55 | 0.03 | 89.4 | 0.68 | -0.11 | 120.733 | 0.58 | -0.01 |

* G.M. 87.709 93 125.379
  CV 1.028 1.806 2.224
  CD (5%) 2.859 1.207 2.004

* Significant at 10% level of significance; ** Significant at 5% level of significance; *** Significant at 1% level of significance.
Table 4: Mean performance and stability parameter of tillers per plant, plant height (cm) and panicle length (cm) of rice (*Oryza sativa* L.) genotypes.

| Entry no. | Name of Genotype | Tillers per Plant | Plant Height (cm) | Panicle Length (cm) |
|-----------|------------------|-------------------|-------------------|---------------------|
| 1         | IR 9533:1-B-16-14-10-GBS-P1-2-1 | 7.956 | 111.838 | 28.919 |
| 2         | IR 9533:1-B-16-14-10-GBS-P1-2-3 | 8.239 | 106.42 | 3.95 |
| 3         | IR 9533:1-B-16-14-10-GBS-P5-1-3 | 7.973 | 0.79 | 3.86 |
| 4         | IR 9533:1-B-16-14-10-GBS-P5-1-5 | 8.222 | 1.26 | 4.46 |
| 5         | IR15M1537         | 8.933 | 0.52 | 0.18 |
| 6         | IR15M1546         | 9.978 | 0.26 | 1.47 |
| 7         | IR15M1689         | 9.065 | 0.51 | 1.35 |
| 8         | BRRI Dhan 64      | 7.022 | 1.21 | 0.98 |
| 9         | Sambamahsuri      | 8.578 | 0.24 | 0.12 |
| 10        | MTU1010           | 8.252 | 2.46 | 2.08 |
| 11        | HUR 105 (LOCAL CHECK1) | 5.971 | 1.03 | 0.33 |
| 12        | HUR 3022 (LOCAL CHECK2) | 10.311 | 1.69 | 3.36 |

* Significant at 10% level of significance; ** Significant at 5% level of significance; *** Significant at 1% level of significance.
### Table 5: Mean performance and stability parameter of grain wt. per panicle, grain yield per plant and 1000 grain wt. of rice (*Oryza sativa* L.) genotypes.

| Entry no. | Name of Genotype                        | Grain wt. per Panicle | Grain yield per Plant | 1000 grain Wt. |
|-----------|-----------------------------------------|-----------------------|-----------------------|----------------|
|           |                                         | Mean | $\beta_i$ | $S^2_{Di}$ | Mean | $\beta_i$ | $S^2_{Di}$ | Mean | $\beta_i$ | $S^2_{Di}$ |
| 1         | IR 95133:1-B-16-14-10-GBS-P1-2-2        | 3.431 | 0.89    | 0.02    | 27.889 | 0.65    | 26.03***   | 24.857 | 1.39    | 0.18    |
| 2         | IR 95133:1-B-16-14-10-GBS-P1-2-3        | 3.386 | 0.77    | -0.02   | 24.32  | 0.08    | 29.09***   | 24.185 | 1.92    | 1.8***  |
| 3         | IR 95133:1-B-16-14-10-GBS-P5-1-3        | 3.254 | -0.86   | 0.32*** | 30.5   | 1.43    | 29.04***   | 22.673 | 0.29    | -0.08   |
| 4         | IR 95133:1-B-16-14-10-GBS-P5-2-3        | 3.689 | 1.92    | 0.05    | 27.138 | 2.09    | 31.84***   | 25.146 | 0.72    | -0.06   |
| 5         | IR 95133:1-B-16-14-10-GBS-P6-1-5        | 3.323 | 0.54    | -0.04   | 27.956 | 0.64    | 70.27***   | 23.722 | 2.43    | -0.12   |
| 6         | IR15M1537                               | 3.115 | -0.38   | 0.06    | 28.4   | 1.01    | 79.11***   | 24.474 | 0.42    | 0.1     |
| 7         | IR15M1546                               | 3.015 | -0.17   | 1.16*** | 26.833 | -0.26   | 28.47***   | 22.536 | 1.34    | 2.45*** |
| 8         | IR15M1689                               | 3.049 | 0.53    | 0.03    | 26.111 | 1.46    | 37.94***   | 23.529 | -0.07   | 4.02*** |
| 9         | IR15M1633                               | 3.413 | 1.22    | 1.9***  | 25.256 | -0.2    | 337.84***  | 27.223 | 1.18    | 2.76*** |
| 10        | IR 99642-57-1-1-1 -B                    | 4.6   | 1.24    | 0.52*** | 27.656 | -0.52   | 57.39***   | 18.932 | 1       | -0.24   |
| 11        | HURZ-1                                  | 3.96  | 1.98    | -0.02   | 27.2   | 1.7     | 20.19***   | 22.986 | 1.63    | -0.23   |
| 12        | HURZ-3                                  | 4.085 | 3.63    | 0.42*** | 26     | 1.91    | 32.78***   | 23.369 | 0.33    | 0.62*   |
| 13        | BRRI Dhan 64                            | 4.979 | 2.06    | 0       | 31.111 | 0.4     | 66.28***   | 23.555 | 0.63    | 0.84*   |
| 14        | BRRI Dhan 72                            | 5.308 | 3.19    | 0.09*   | 39.322 | 3.16    | 80.44***   | 26.609 | 2.17    | 0.66*   |
| 15        | DRR Dhan 45                             | 4.389 | 2.57    | 0.4***  | 37.329 | 2.72    | 39.43***   | 24.358 | 0.09    | 1.27**  |
| 16        | DRR Dhan 48                             | 4.674 | 1.54    | 0.17**  | 42.578 | 0.41    | 11.99**    | 24.001 | 1.06    | -0.21   |
| 17        | IR 64                                   | 3.165 | 0.64    | 0.02    | 20.671 | 0.43    | 0.99       | 25.27   | 1.12    | 1.39**  |
| 18        | MTU1010                                 | 3.899 | -0.06   | 0       | 30.733 | 2.75    | 54.03***   | 25.219 | 0.86    | -0.05   |
| 19        | Sambamahsuri                            | 3.179 | -0.07   | 0.03    | 27.444 | -0.14   | -1.56      | 21.927  | 0.71    | -0.27   |
| 20        | Swarna                                  | 3.965 | -0.28   | -0.03   | 24.704 | 0       | -2.36      | 22.993  | 0.63    | -0.24   |
| 21        | HUR 105 (LOCAL CHECK1)                  | 3.238 | 1.09    | 0.25*** | 34.1   | 2.22    | 77.76***   | 22.31   | 1.28    | -0.09   |
| 22        | HUR 3022 (LOCAL CHECK2)                 | 3.109 | -0.01   | 0.17**  | 26.622 | 0.04    | -2.4       | 21.043  | 0.86    | 0.42    |

| G.M.      | 3.719                                   | 29.065 | 23.678 |
| CV        | 16.646                                  | 25.362 | 5.399  |
| CD(5%)    | 0.445                                   | 5.301  | 6.919  |

* Significant at 10% level of significance; ** Significant at 5% level of significance; *** Significant at 1% level of significance.
Table 6: Mean performance and stability parameter of grain yield per ha, grain l/b ratio and grain Zn content of rice (*Oryza sativa* L.) genotypes.

| Entry no. | Name of Genotype                  | Grain yield per Ha | Grain L/B Ratio | Grain Zn content |
|-----------|-----------------------------------|--------------------|-----------------|-----------------|
|           |                                   | Mean              | **i**           | S²Di            | Mean | **i** | S²Di |
| 1         | IR 95133:1-B-16-14-10-GBS-P1-2-2  | 4893.333          | 1.32            | 1200431***      | 4.459 | 0.77 | 0     |
| 2         | IR 95133:1-B-16-14-10-GBS-P1-2-3 | 4687.778          | 0.82            | 19246           | 4.381 | -0.08 | 0.01* |
| 3         | IR 95133:1-B-16-14-10-GBS-P5-1-3 | 5336.667          | 1.31            | 1700301***      | 4.075 | -1.71 | 0.01* |
| 4         | IR 95133:1-B-16-14-10-GBS-P5-2-3 | 4691.481          | 0.91            | 192750**        | 4.323 | -1.27 | 0.03***|
| 5         | IR 95133:1-B-16-14-10-GBS-P6-1-5 | 5856.89           | 1.45            | 955649***       | 4.148 | -1.18 | 0     |
| 6         | IR15M1537                         | 4068.889          | 1.05            | 130050**        | 3.502 | -0.2  | 0.14***|
| 7         | IR15M1546                         | 4098.889          | 0.06            | 1156902***      | 3.299 | 3.55  | 0.02***|
| 8         | IR15M1689                         | 5068.889          | 0.41            | 2289679***      | 3.413 | 1.74  | 0.01** |
| 9         | IR15M1633                         | 4068.518          | 0.25            | 700761***       | 3.63  | -1.13 | 0     |
| 10        | IR 99642-57-1-1-1 -B              | 6228.89           | 1.44            | 546483***       | 3.557 | 4.3   | 0.05***|
| 11        | HURZ-1                            | 5745.556          | 0.99            | 1012980***      | 3.384 | 0.86  | 0.02** |
| 12        | HURZ-3                            | 5681.853          | 0.43            | 1072132***      | 3.295 | -0.2  | 0     |
| 13        | BRRI Dhan 64                      | 6068.518          | 1.45            | 642751***       | 2.481 | 3.79  | 0.12***|
| 14        | BRRI Dhan 72                      | 7431.853          | 1.11            | 2922053***      | 2.826 | 0.93  | 0     |
| 15        | DRR Dhan 45                       | 5589.259          | 0.76            | 1504048***      | 3.275 | 3.46  | 0.06***|
| 16        | DRR Dhan 48                       | 7368.89           | 1.62            | 23896           | 3.149 | 0.66  | 0     |
| 17        | IR 64                             | 4610              | 0.47            | 210927***       | 3.305 | 2.84  | 0.01** |
| 18        | MTU1010                           | 5331.111          | 1.49            | 961390***       | 3.204 | -0.02 | 0     |
| 19        | Sambamahsuri                      | 5252.963          | 0.74            | 2644268***      | 2.865 | 0.71  | 0     |
| 20        | Swarna                            | 6232.963          | 1.28            | 1974098***      | 2.627 | 0.63  | 0     |
| 21        | HUR 105 (LOCAL CHECK1)            | 6500.371          | 0.84            | 1481950***      | 3.45  | 0.87  | 0     |
| 22        | HUR 3022 (LOCAL CHECK2)           | 6126.667          | 1.81            | 955687***       | 3.46  | 2.65  | 0     |

| G.M.      |                                  | 5497.374          | 3.459           | 23.556          |
| CV        |                                  | 17.327            | 5.259           | 13.578          |
| CD (5%)   |                                  | 684.521           | -              |

* Significant at 10% level of significance; ** Significant at 5% level of significance; *** Significant at 1% level of significance.
significant difference among the genotypes for linear response to environments. Therefore, it would be least susceptible to environmental fluctuations and the behavior of genotypes over environments can be predicted more accurately. Significant genotypes mean sum of squares were observed due to the differential effect of environments on genotypes. The results showed conformity with the findings of Saidaiah et al. (2011) and Sreedhar et al. (2011) for panicle weight.

The genotypes IR 95133:1-B-16-14-10-GBS-P1-2-3 and IR 95133:1-B-16-14-10-GBS-P1-2-2 were considered stable with average grain weight per panicle, for poor yielding environment, having values of regression coefficients lesser than unity and non-significant deviation from regression coefficient, whereas, the genotypes IR 99642-57-1-1-1-B and DRR Dhan 48 were considered stable for high grain weight per panicle in favorable environment.

Grain yield per plant (g)

Only the linear component of G × E interaction was recorded significant, which suggested significant difference among the genotypes for linear response to environments. Hence, it would be least susceptible to environmental changes and the behavior of genotypes over environments can be predicted more accurately. Significant genotypes mean sum of squares were observed due to the varied effect of environments on genotypes. Similar findings were reported by Reddy et al. (1998), Bhakta and Das (2008) and Saidaiah et al. (2011).

The genotype IR-64 and HUR-3022 (LC-2) were regarded as stable with lower grain yield per plant and good for poor yielding environments exhibiting regression coefficients lesser than unity with non-significant deviation from regression coefficient.

1000-grain weight (g)

The significant linear component of G × E interaction suggested significant difference among the genotypes for linear response to environments. Therefore, the behavior of genotypes over environments can be predicted more accurately and it would be least susceptible to environmental fluctuations. The results showed conformity with the findings of Panwar et al. (2008) and Sreedhar et al. (2011) who reported significant G × E interaction and genotypes mean sum of squares for 1000-grain weight.

The genotype DRR Dhan 48 was considered most stable with above average 1000-grain weight across environments with regression coefficient closer to unity and non-significant deviation from regression coefficient. The genotype IR 95133:1-B-16-14-10-GBS-P1-2-2 was found stable for high 1000-grain weight in favorable environment, whereas HUR-105 (LC-1) was considered stable for lower 1000-grain weight in favorable environment.

Grain yield per ha (kg)

Significant values of pooled deviation against pooled error were observed, suggesting difference in their regression on the environmental index. The genotype x environment interactions were significant, however, genotype x environment (linear) was not significant, indicating the predictable nature of trait over the five environments. The results showed disagreement with the findings of Murphy et al. (2007).

The genotype DRR Dhan 48 was reported stable and high yielding in favorable environments as it possessed high mean values, regression coefficients greater than unity with non-significant deviation from regression coefficient.

L/B ratio

The significant linear component of G × E interaction suggested significant difference among the genotypes for linear response to environments. Therefore, it would be least susceptible to environmental fluctuations and the behavior of genotypes over environments can be predicted more accurately significant genotypes mean sum of squares were observed due to the differential effect of environments on genotypes.

The genotype IR 95133:1-B-16-14-10-GBS-P1-2-2 was recognized as most stable for high mean L/B ratio in poor yielding environments. BRRI Dhan 72 was reported to be stable for less L/B ratio across all environments owing to its low mean value, regression coefficients near unity with non-significant deviation from regression coefficient.

Grain zinc content (ppm)

Significant values of pooled deviation against pooled error were reported for this trait, indicating difference in their regression on the environmental index and also suggested the importance of non-linear components. However, linear and non-linear components of G × E interaction were not significant, which showed disagreement with the finding of Velu et al. (2012) and Prasanna et al. (2011).

The genotypes DRR Dhan 48 and IR 95133:1-B-16-14-10-GBS-P5-1-3 exhibited higher mean values, regression coefficients closer to unity with non-significant deviation from regression coefficient and were considered most stable for high grain zinc under all five environments. On the contrary, Swarna and BRRI Dhan 72 were considered as stable for low grain zinc under less favorable environments owing to their low mean values, regression coefficients less than unity with non-significant deviation from regression coefficient.

CONCLUSION

Based on overall performance of the genotypes across five different locations tested in Eastern Uttar Pradesh, the genotype, IR15M1633 recorded highest mean grain Zinc content but have negative association with yield. So, considering all aspects, the genotypes, DRR Dhan 48 and HURZ-3 showed good mean values for most of the traits studied and was also stable for grain zinc, yield per hectare, 1000- grain weight, had shorter plant height and hence can
be suggested for use as a stable high zinc rice genotypes with consistent yield performance. Further, these genotypes can be used in planning for future breeding programmes.

ACKNOWLEDGEMENT
The authors are highly thankful for the support given by the project Harvest Plus to develop high zinc rice for Eastern India, funded by IFPRI (USA) and CIAT (Columbia), for conducting the experiment and by the IRRI- South Asia Hub at ICRISAT, Hyderabad for their valuable support in zinc analysis as well as for providing the rice genotypes.

REFERENCES
Becker, H.C. and Leon, J. (1988). Stability analysis in plant breeding. Plant Breeding. 101(1): 1-23.
Belhekar, P.S., Jadhav, R.Y., Bhor, T.J. and Kamble, S.K. (2004). Genotype x environment interaction for yield and yield components in early rice genotypes. Journal of Maharashtra Agricultural Universities. 29(1): 16-19.
Bhakta, N. and Das, S.R. (2008). Phenotypic stability for grain yield in rice. Oryza. 45(1): 115-119.
Dalvi, V.V., Patel, P.S., Vashi, P.S. and Khirsagar, R.M. (2007). Genotype x environment interaction for yield and its components in rice hybrids. Journal of Maharashtra Agricultural Universities. 32(1): 25-28.
Das, P.K. and Deb Choudhary, P.K. (1996). Phenotypic stability for grain yield and its components in rainy season rice (Oryza sativa). India Journal of Genetics. 56(2): 214-218.
Eberhart, S.A. and Russel, W.A. (1966). Stability Parameters for Comparing Varieties. Crop Science. 6(1): 36-40.
Juliano, B.O. (1985). Criteria and Tests for Rice Grain Qualities. In: Rice Chemistry and Technology, 2nd Edition, American Association of Cereal Chemists, 443-524.
Koli, N.R., Bagri, R.K., Kumhar, B.L., Prakash, C., Mahawar, R.K. and Punia, S.S. (2015). Assessment of stability performance in scented rice genotypes under transplanted condition of south-eastern plain zone of Rajasthan. Electronic Journal of Plant Breeding. 6(4): 992-995.
Kulkarni, N. and Eswari, K.B. (1994). Genotype x environment interaction of varieties to age of seedling in rice (Oryza sativa L.). Oryza. 31: 88-88.
Manjunatha B., Malleshappa, C. and Niranjana, K.B. (2018). Stability Analysis for Yield and Yield Attributing Traits in Rice (Oryza sativa L.). International Journal of Current Microbiology and Applied Sciences. 7(6): 1629-1638.
Murphy, K.M., Campbell, K.G., Lyon, S.R. and Jones, S.S. (2007). Evidence of varietal adaptation to organic farming systems. Field Crops Research. 102(3): 172-177.
NanditaDevi, H.; Singh, N.B.; Singh, M.R.K. and Sharma, P.R. (2006). Stability analysis of selected rice genotypes at varying spacing and sowing dates under rainfed lowland condition in Manipur valley. Oryza. 43(1): 20-24.
Panwar, L.L., Joshi, V.N. and Ali, M. (2008). Genotype x environment interaction in scented rice. Oryza-An International Journal on Rice. 45(2): 103-109.
Paray, G.A., Shikari, A.B., Ganai, M.A. and Sofi, S.A. (2006). Stability in elite local rice (Oryza sativa L.) genotypes under high altitude environment of Kashmir Valley. Journal of Rice Research. 1(2): 131-138.
Praveen, S.P., Pandey, A. and Kumar, R. (2013). Stability study in aromatic rice (Oryza sativa L.). Crop Research. 45(1to3): 59-65.
Prasanna, B.M., Mazumdar, S., Chakrabarti, M., Hossain, F., Manjaiha, K.M., Agrawal, P.K. and Gupta, H.S. (2011). Genetic variability and genotype x environment interactions for kernel iron and zinc concentrations in maize (Zea mays) genotypes. Indian Journal of Agricultural Sciences. 81(8): 704-711.
Reddy, J.N., Pani, D. and Roy, J.K. (1998). Genotype x environment interaction for grain yield of low-rain rice cultivars. Indian Journal of Genetics. 58(2): 209-213.
Saiadiah, P., Kumar, S.S. and Ramesha, M.S. (2011). Stability analysis of rice (Oryza sativa) hybrids and their parents. Indian Journal of Agricultural Sciences. 81(2): 111-115.
Sreedhar, S., Dayakar, R.T. and Ramesha, M.S. (2011). Genotype x Environment Interaction and Stability for Yield and its Components in Hybrid Rice Cultivars (Oryza sativa L.). International Journal of Plant Breeding and Genetics. 5: 194-208.
Subudhi, P.K., Sasaki, T. and Khush, G.S. (2006). Rice. In: KoleC (ed.) Genome Mapping and Molecular Breeding in Plants, Cereals and Millets. Springer-Verlag Berlin Heidelberg. 1: 1-78.
Vishnuvardhan, R.B., Payasi, K.D. and Anwar, Y. (2015). Stability analysis for yield and its components in promising rice hybrids. The Ecoscan. 9(1&2): 311-321.
Velu, G., Singh, R.P., Huerta-Espino, J., Peña, R.J., Arun, B., Mahendru-Singh, A. and Alvarado, G. (2012). Performance of biofortified spring wheat genotypes in target environments for grain zinc and iron concentrations. Field Crops Research. 137: 261-267.
Wasan, J., Tidaraj, M., Sompong, C., Bhalang, S., Jirawat, S. (2018). Evaluation of stability and yield potential of upland rice genotypes in North and Northeast Thailand. Journal of Integrative Agriculture. 17(1): 28-36.