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

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## 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.

## INTRODUCTION

Rice (*Oryza sativa* L.) is an annual self-pollinated short-day plant of family *Poaceae* (Graminae) with chromosome number 2n=2x=24. Rice is the staple food of more than 2.7 billion people. Over 2 billion people in Asia alone derive 80% of their energy needs from rice (Juliano, 1985). Rice covers world's largest area (28%) covering 42.3 million hectares. Almost one fourth of the calories consumed by human beings globally is provided by rice (Subudhi *et al.*, 2006). Rice grain is rich in carbohydrates and contains a good amount of digestible protein but unfortunately, it is a poor source of micronutrients such as iron, zinc and vitamin A. Undernourishment is estimated to have reached around 82.1 crores people of the world (10.8 % of world's population) and in India, to about 19.59 crores people (about 14.8% of country's population).

Zinc deficiency may lead to health hazards including weak immunity, dwarfism, anorexia, skin lesions, diarrhea and hypogonadism. The biofortification of rice grain with high levels of Zn in polished rice could be a good, cost-effective and sustainable solution to cope up with the problems of undernourishment.

According to the dynamic concept of stability, a stable genotype is the one which has no departure from this expected response to environments (Becker and Leon, 1988). To exploit the benefits of genetic gain for Zn content in grain, yield and related traits, stable genotypes are needed. Multi-Environment Trials (MET) are included in breeding programs to evaluate potentially stable and adapted lines with the aim of producing high yielding and stable genotypes.

As yield is a polygenically controlled character, the presence or absence of Genotype × Environment (GE) interaction largely determines the average response of the varieties. G × E interaction, linked with high yield suggests the suitability of variety in varying environments. But this ideal condition is rare and the varieties with high stability generally show low yield capacity and *vice versa.* Evaluating genotypes under various contrasting environments with uncertain variation is a recognized approach for choosing

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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 ($S^2d=0$) (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*., 1.8$m^2$ 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.*, $S^2d_i=0$, 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 69428-6-1-1-3-3/2*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/IR06A 147//IR 75862-206-2-8-3-B-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/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 × 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 × 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 × 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 × 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).

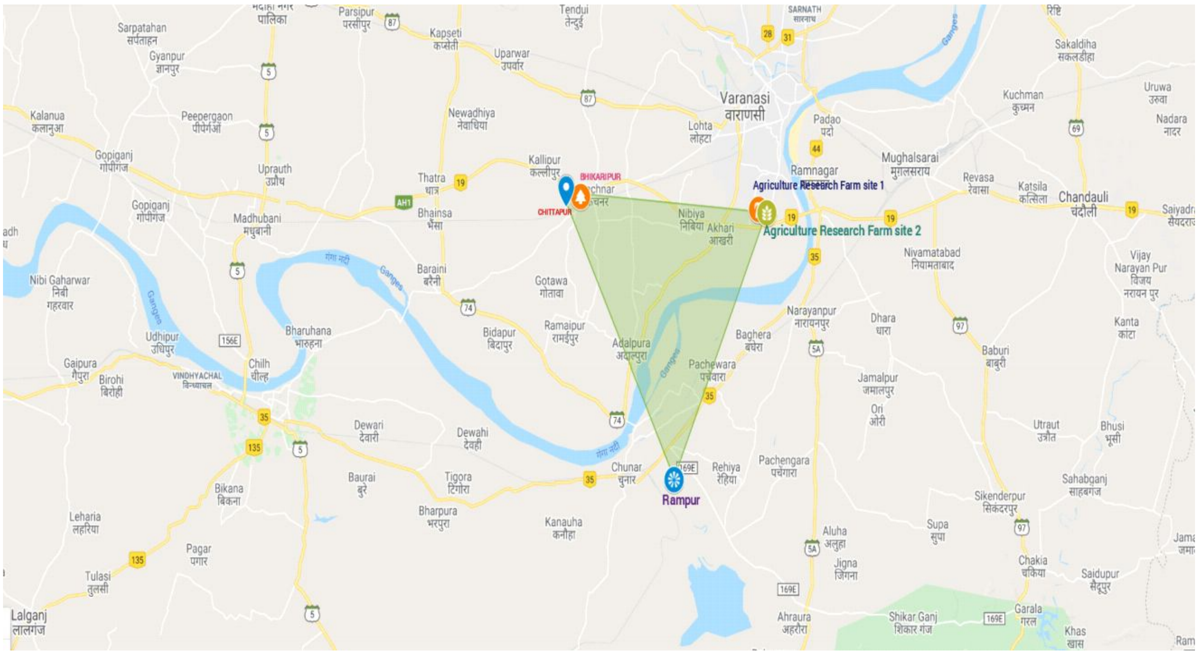


**Fig 1:** Map of 5 different Locations used for the study in Uttar Pradesh.

***Table 2:** Pooled analysis of variance for grain yield and yield attributing traits in rice (*Oryza sativa* L.) genotypes.

| | DF | Days to first flowering | Days to 50% Flowering | Days to maturity | Tillers per Plant | Plant Height (cm) | Panicle Length (cm) | Grain wt. per Panicle | Grain Yield per Plant | 1000 grain Wt. | Grain Yield per Ha | Grain L/B Ratio | Grain Zn content |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rep within Env. | 10 | 0.468 | 0.229 | 0.847 | 1.479 | 4.393 | 0.759 | 0.058 | 4.523 | 0.805 | 39340.44 | 0.006 | 3.636 |
| Varieties | 21 | 240.056*** | 359.528*** | 376.026*** | 3.888*** | 446.463*** | 16.858*** | 2.302*** | 133.547*** | 16.400*** | 4541888*** | 1.47*** | 4.69 |
| Env. + (Var.×Env.) | 88 | 25.863*** | 3.499*** | 53.126*** | 1.287* | 22.095 | 2.909 | 0.538** | 68.022* | 3.735*** | 1117499 | 0.044** | 9.216** |
| Environments | 4 | 197.026*** | 25.813*** | 1014.659*** | 6.755*** | 138.426** | 13.464*** | 4.632*** | 353.379*** | 60.696*** | 4640694** | 0.393*** | 106.13*** |
| Var.×Env. | 84 | 17.713*** | 2.436 | 7.339* | 1.026 | 16.556 | 2.406 | 0.343 | 54.434 | 1.023 | 949727.9 | 0.027 | 4.601 |
| Environments (Lin.) | 1 | 788.105*** | 103.253*** | 4058.635*** | 27.019*** | 553.702*** | 53.856*** | 18.527*** | 1413.516*** | 242.783*** | 18562780*** | 1.574*** | 424.522*** |
| Var.×Env. (Lin.) | 21 | 54.584*** | 3.547* | 15.816*** | 1.734** | 11.794 | 2.366 | 0.538* | 81.876* | 1.466* | 191475.1 | 0.040* | 4.067 |
| Pooled Deviation | 66 | 5.176*** | 1.972*** | 4.308*** | 0.755 | 17.318*** | 2.309*** | 0.266*** | 43.227*** | 0.835*** | 1147821*** | 0.022*** | 4.561* |
| Pooled Error | 210 | 0.306 | 0.341 | 0.694 | 0.555 | 4.515 | 0.527 | 0.042 | 3.619 | 0.354 | 43520.27 | 0.005 | 2.934 |
| Total | 109 | 67.13 | 72.097 | 115.336 | 1.778 | 103.854 | 5.596 | 0.878 | 80.646 | 6.157 | 1777244 | 0.318 | 8.344 |
| S.E.D Genotype Gi - Gj | | 1.439 | 0.993 | 1.275 | 0.886 | 2.632 | 0.961 | 0.341 | 4.642 | 0.649 | 677.590 | 0.103 | 1.351 |
| Enviornment Ei - Ej | | 0.686 | 0.473 | 0.608 | 0.423 | 1.255 | 0.458 | 0.163 | 2.213 | 0.309 | 323.028 | 0.049 | 0.644 |
| CD5% Genotype Gi - Gj | | 2.873 | 1.982 | 2.545 | 1.769 | 5.254 | 1.919 | 0.681 | 9.268 | 1.295 | 1352.853 | 0.207 | 2.697 |
| Enviornment Ei - Ej | | 1.369 | 0.945 | 1.213 | 0.844 | 2.505 | 0.915 | 0.325 | 4.418 | 0.618 | 644.947 | 0.099 | 1.286 |

* Significant at 10% level of significance; ** Significant at 5% level of significance; *** Significant at 1% level of significance

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), Parray *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 Kulkarni 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 | ßi | S²Di | Mean | ßi | S²Di | Mean | ßi | S²Di |
| 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*** | 119.267 | 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 | Sambamahsuri | 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) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | ßi | $S^2Di$ | Mean | ßi | $S^2Di$ | Mean | ßi | $S^2Di$ |
| 1 | IR 95133:1-B-16-14-10-GBS-P1-2-2 | 7.956 | 1.18 | 0.19 | 111.838 | 1.56 | 7.1 | 28.919 | 1.32 | 1.11* |
| 2 | IR 95133:1-B-16-14-10-GBS-P1-2-3 | 8.289 | 1.28 | 2.55*** | 112.633 | 1.59 | 8.43* | 29.825 | 1.14 | 2.15** |
| 3 | IR 95133:1-B-16-14-10-GBS-P5-1-3 | 9.422 | 0.79 | 3.86*** | 106.42 | 1.35 | 1.58 | 27.435 | 1.17 | 2.53*** |
| 4 | IR 95133:1-B-16-14-10-GBS-P5-2-3 | 8.422 | 1.07 | 0.62* | 111.923 | 1.18 | 15.52** | 27.442 | 0.45 | 6.58*** |
| 5 | IR 95133:1-B-16-14-10-GBS-P6-1-5 | 9.4 | 0.52 | 0.18 | 105.48 | 2.16 | 3.95 | 27.096 | 1.62 | 0.79 |
| 6 | IR15M1537 | 9.933 | 2.74 | 1.65*** | 106.778 | 0.21 | 12.25* | 25.704 | 0.91 | -0.23 |
| 7 | IR15M1546 | 8.267 | 1.36 | 1.57*** | 100.598 | 0.69 | 24.55*** | 26.084 | -1.63 | 0.96* |
| 8 | IR15M1689 | 8.978 | 0.26 | 1.47*** | 101.361 | -0.56 | 17.51** | 25.756 | 1.63 | 3.6*** |
| 9 | IR15M1633 | 8.067 | 0.51 | 1.35** | 107.923 | 1.17 | 8.75* | 24.931 | 1.97 | 1.8** |
| 10 | IR 99642-57-1-1-1 -B | 6.578 | 0.72 | 0.83* | 129.726 | 1.1 | 2.96 | 28.262 | 1.35 | 1.77** |
| 11 | HURZ-1 | 8.044 | 2.46 | 0.59* | 102.147 | 0.8 | 17.48** | 25.669 | 0.05 | 0.02 |
| 12 | HURZ-3 | 7.022 | 1.21 | 0.96** | 100.135 | 1.27 | 13.42** | 26.26 | -1.13 | 0.3 |
| 13 | BRRI Dhan 64 | 7.555 | 1.18 | 5.82*** | 124.146 | 1.81 | -2.77 | 25.764 | 0.02 | 0.32 |
| 14 | BRRI Dhan 72 | 6.978 | -0.65 | 2.45*** | 118.016 | -0.07 | 12.49* | 31.193 | 2.11 | 1.72** |
| 15 | DRR Dhan 45 | 8.556 | 2.28 | 2.04*** | 120.737 | 1.62 | 33.86*** | 25.787 | 1.79 | 10.49*** |
| 16 | DRR Dhan 48 | 9.133 | 0.92 | 2.28*** | 104.698 | 0.41 | -0.7 | 26.798 | 1.83 | 1.7** |
| 17 | IR 64 | 8.178 | 0.24 | 0.12 | 95.605 | 1.87 | 26.06*** | 24.756 | 1.96 | 2.12** |
| 18 | MTU1010 | 8.556 | 1.85 | 2.08*** | 108.727 | 1.25 | 9.92* | 27.024 | 1.84 | -0.18 |
| 19 | Sambamahsuri | 10.711 | -0.33 | 1.73*** | 96.414 | 0.25 | 49.85*** | 23.111 | 0.85 | -0.03 |
| 20 | Swarna | 8.822 | 0.32 | 0.14 | 95.953 | 0.33 | -1.08 | 24.813 | 1.39 | -0.37 |
| 21 | HUR 105 (LOCAL CHECK1) | 10.311 | 1.69 | 3.36*** | 118.491 | 0.91 | 21.5*** | 24.789 | 0.93 | 0.62 |
| 22 | HUR 3022 (LOCAL CHECK2) | 9.045 | 0.39 | 0.77* | 99.694 | 1.08 | -0.74 | 27.193 | 0.42 | 1.19* |
| | **G.M.** | **8.556** | | | **108.157** | | | **26.573** | | |
| | CV | **17.837** | | | **4.516** | | | **6.723** | | |
| | CD(5%) | **1.097** | | | **3.511** | | | **1.284** | | |

* 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 | ßi | $S^2Di$ | Mean | ßi | $S^2Di$ | Mean | ßi | $S^2Di$ |
| 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 | 3.565 | -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** | | | **29.085** | | | **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 | ßi | $S^2Di$ | Mean | ßi | $S^2Di$ | Mean | ßi | $S^2Di$ |
| 1 | IR 95133:1-B-16-14-10-GBS-P1-2-2 | 4893.333 | 1.32 | 1200431*** | 4.459 | 0.77 | 0 | 23.793 | 1.06 | -2.45 |
| 2 | IR 95133:1-B-16-14-10-GBS-P1-2-3 | 4687.778 | 0.82 | 19246 | 4.381 | -0.08 | 0.01* | 22.807 | 0.45 | -0.3 |
| 3 | IR 95133:1-B-16-14-10-GBS-P5-1-3 | 5336.667 | 1.31 | 1700301*** | 4.075 | -1.71 | 0.01* | 24.66 | 1.11 | -2.62 |
| 4 | IR 95133:1-B-16-14-10-GBS-P5-2-3 | 4691.481 | 0.91 | 192750** | 4.323 | -1.27 | 0.03*** | 23.797 | 0.94 | 2.05 |
| 5 | IR 95133:1-B-16-14-10-GBS-P6-1-5 | 5858.89 | 1.45 | 955649*** | 4.148 | -1.18 | 0 | 23.5 | 1.26 | -1.21 |
| 6 | IR15M1537 | 4068.889 | 1.05 | 130050** | 3.502 | -0.2 | 0.14*** | 23.24 | 0.95 | 3.99 |
| 7 | IR15M1546 | 4098.889 | 0.06 | 1156902*** | 3.299 | 3.55 | 0.02*** | 22.563 | 1.2 | -2.35 |
| 8 | IR15M1689 | 5068.889 | 0.41 | 2289679*** | 3.413 | 1.74 | 0.01** | 25.86 | 1.42 | 7.26* |
| 9 | IR15M1633 | 4068.518 | 0.25 | 700761*** | 3.63 | -1.13 | 0 | 25.163 | 1.67 | 5.61* |
| 10 | IR 99642-57-1-1-1 -B | 6228.89 | 1.44 | 546483*** | 3.557 | 4.3 | 0.05*** | 23.643 | 1.83 | -2.78 |
| 11 | HURZ-1 | 5745.556 | 0.99 | 1012980*** | 3.384 | 0.86 | 0.02** | 22.94 | 1.68 | 17.76*** |
| 12 | HURZ-3 | 5681.853 | 0.43 | 1072132*** | 3.295 | -0.2 | 0 | 23.867 | 1.17 | 3.02 |
| 13 | BRRI Dhan 64 | 6068.518 | 1.45 | 642751*** | 2.481 | 3.79 | 0.12*** | 22.2 | 1.09 | 1.01 |
| 14 | BRRI Dhan 72 | 7431.853 | 1.11 | 2922053*** | 2.826 | 0.93 | 0 | 21.637 | 0.78 | 1.31 |
| 15 | DRR Dhan 45 | 5589.259 | 0.76 | 1504048*** | 3.275 | 3.46 | 0.06*** | 24.217 | 1.22 | -2.74 |
| 16 | DRR Dhan 48 | 7368.89 | 1.62 | 23896 | 3.149 | 0.66 | 0 | 24.473 | 1.03 | -2.06 |
| 17 | IR 64 | 4610 | 0.47 | 210927*** | 3.305 | 2.84 | 0.01** | 23.243 | 0.54 | 0.82 |
| 18 | MTU1010 | 5331.111 | 1.49 | 961390*** | 3.204 | -0.02 | 0 | 23.387 | 0.36 | -2.02 |
| 19 | Sambamahsuri | 5252.963 | 0.74 | 2644628*** | 2.865 | 0.71 | 0 | 23.603 | 0.54 | 4.55 |
| 20 | Swarna | 6232.963 | 1.28 | 1974098*** | 2.627 | 0.63 | 0 | 22.617 | 0.4 | -1.06 |
| 21 | HUR 105 (LOCAL CHECK1) | 6500.371 | 0.84 | 1481950*** | 3.45 | 0.87 | 0.01 | 24.02 | 1.21 | -1.09 |
| 22 | HUR 3022 (LOCAL CHECK2) | 6126.667 | 1.81 | 955687*** | 3.46 | 2.65 | 0 | 22.997 | 0.09 | 8.4 |
| | **G.M.** | **5497.374** | | | **3.459** | | | **23.556** | | |
| | CV | **17.327** | | | **5.259** | | | **13.578** | | |
| | CD(5%) | **684.521** | | | **0.131** | | | **-** | | |

* 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 favourable 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 x 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.

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