Stability Analysis of Rice (*Oryza sativa* L.) Genotypes with High Grain Zinc in Five Different Locations of Eastern Uttar Pradesh

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Authors' contributions

This work was carried out in collaboration among all authors. Authors SKS, PPB and DKS designed the study and layout of the experiment. Author PPB performed statistical analysis and wrote the first draft of manuscript. Authors SKS, MK, SH and DKS managed the further analyses of the study and improved the manuscript. Authors AK and PPB managed the literature searches and recording of field data. All authors read and approved the final manuscript.

Original Research Article

ABSTRACT

Rice is a major energy source food crop and a staple food for more than half of the world's population. The knowledge of mean performance and stability of high grain Zinc rice genotypes from a multi-location trial is a way to assess the genotypes so as to achieve food and nutritional security. The present research was conducted to study the stability of 21 high grain Zinc rice genotypes for thirteen yield and yield attributing traits in RCBD with 3 replications in five different locations of Eastern Uttar Pradesh using the Eberhart and Russell stability model. Based on the environmental index, Bhikaripur village is identified as the most favourable environment. The inspection of stability and ANOVA revealed that there were significant linear G x E interactions for most of the characters studied expect plant height, spikelet fertility % and total effective tiller number which implied that there were significant variations among the genotypes. The environment +

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(genotype x environment) was significant for most of the traits except grain L/B ratio representing specific nature of environments and G x E interaction in morphological expression. Based on the stability parameters none of the genotypes could be identified as stable for any traits over the five environments but, IR 97443-11-2-1-1-1-1 –B and Local check (HUR3022) showed stability for high yield in all the environments. The genotype, IR 97443-11-2-1-1-1-1 –B having stability for grain yield per ha with higher mean and short duration, is also stable for grain yield per plant, grain weight per panicle and spikelet fertility % and could be used as high yielding cultivar and can be used as a parent in future breeding programs. The genotype, IR 95044:8-B-5-22-19-GBS is having the highest grain Zinc content. High grain zinc with higher yield was reported in BRRIdhan 64 and it is stable for grain zinc content and can be used for Zinc bio-fortification breeding programs to minimize malnutrition to ensure food and nutritional security.

1. INTRODUCTION

Rice (*Oryza sativa* L.*)* is a short day self-pollinated angiosperm under the genus *Oryza* of family Poaceae. It is the principal nourishment for 33% of the total population and involves very closely one-fifth of the aggregate land territory occupied under cereals [1]. Rice is produced in 114 countries across the globe with an estimated production of 753 mt and forecasting 758 mt with world rice acreage of 161.1 mha by FAO [2]. Among the rice growing countries in the world, India occupied the largest area under rice crop (about 45 million ha.) having the second position in production 112.76 million metric tons during 2017–2018 according to USDA data [3]. Zinc is an essential micronutrient for humans and plants. It is an activator of more than 300 enzymes in humans that plays an important role in growth and development including immune system, reproductive health, sensory functions, and neurobehavioral development. Millions of hectares of agricultural land are hampered due to deficiency of Zn which leads to under nutrition of Zn in about one-third of the world's population. Currently, Zn deficiencies in humans have emerged worldwide, and plant breeders certainly have a role in developing high grain zinc genotypes with higher yield through genetic zinc bio fortification. Zinc bio-fortification is the enrichment of bioavailable zinc content of food crops through genetic selection through using conventional and modern breeding methods to address nutritional security without affecting the growth and development of plant. A cultivar with smaller variance among environment is known as Static or biological concept of stability while a cultivar exhibit mean performance equal to its overall mean over environments is known as dynamic or agronomic stability. A cultivar exhibiting smaller residual mean squares (MS) from the regression model on the environmental index also become a part of the dynamic or agronomic stability concept according to Becker and Leon [4]. Steady performance in regard to productivity over a wide range of environmental conditions is the most suitable propertie for a genotype to be released as a variety or hybrid. As indicated by the dynamic idea, a steady genotype is one which gives predictable execution over environment with no deviation [4]. Yield is a polygenically controlled complex character and exceptionally impacted by genotype and environment interaction. Subsequently, building up a stable genotype with high return potential and great grain quality is of principal significance to the plant breeder through selection of genotypes that interface less with environment in which they are grown. Among the different methods, Eberhart and Russell (1966) and Additive Main Effect and Multiplicative association (AMMI) methods which depends on a multivariate system were utilized to evaluate the stability of various genotypes are most regularly utilized strategies. Testing of genotypes under various environments contrasting in unpredictable variation is an acknowledged approach for choosing stable genotypes and according to Eberhart and Russell [5] a stable variety is one with a regression coefficient of unity (b= 1) and minimum deviation from the regression line (S^2d = 0). With this background, the present study was conducted with 21 high zinc rice genotypes to identify a stable rice variety with high grain zinc content for eastern Uttar Pradesh using Eberhart and Russell model.

2. MATERIALS AND METHODS

The research was conducted to study the stability of high Zinc rice genotypes in five different locations (BHU Agriculture farm –I, BHU

Agriculture farm –II, Bhikaripur, Karsada and Rampur) of Eastern Uttar Pradesh for twenty-one rice genotypes during *Kharif* 2017. The list of entries used in the present study was given in Table 1. Net Plot size was 2.4 m × 2.4 m for each location under study. Inter and intra row spacing was 20 cm and 15 cm respectively in all the locations. In each plot, twelve rows were grown. All the cultivation practices were properly followed to grow a healthy crop. The experiment was conducted in a randomized complete block design (RCBD) with three replications and observations were documented on five randomly selected plants for 13 traits (days to first flowering, days to 50% flowering, days to maturity, number of effective tillers per plant, plant height (cm), panicle length (cm), spikelet fertility percent, grain weight per panicle (g) , 1000-grain weight (g), L/B ratio, grain zinc content(ppm) grain yield per plant (g) and Grain yield per ha (ton)).

Zinc content was assessed in the aliquot of seed extract by using Atomic Absorption Spectrophotometer (AAS) at 213.86 nm. According to the methodology of Eberhart and Russell's model (1966), three parameters namely (i) overall mean of each genotype over a range of environments, (ii) the regression of each genotype on the environmental index and (iii) a function of the squared deviation from the regression were estimated. Stability analysis was done by using Eberhart and Russell(1966) following model $Y_{ij} = \mu_1 + \beta_i I_j + \delta_{ij}$ where Y_{ij} the variety mean of the ith variety at the jth environment (i =1, 2… t and j=1, 2…s), μ_1 is the mean of the ith variety over all environments, β_i is the regression coefficient that measures the response of the ith variety to varying environments, I_j is the environmental index obtained as the mean of all varieties at the jth environment minus the grand mean, and δ_{ij} is the deviation from regression of the ith variety at the jth environment using Windostat Version 9.3 software at indostat services, Hyderabad. This model defines all the stability parameters to check the performance of a cultivar in series of different environments.

Table 1. List of genotypes (Collected from IRRI South Asia Hub, Hyderabad) used in the present study along with their grain zinc content

Entry No.	Entry Name	Grain Zinc Content(ppm)
1	IR 95044:8-B-5-22-19-GBS	20.6
2	IR 84847-RIL 195-1-1-1-1	21.8
3	IR 99704-24-2-1	14.67
4	IR 99647-109-1-1	23.7
5	IR 97443-11-2-1-1-1 –B	14.45
6	IR 97443-11-2-1-1-3 –B	23.47
7	IR 82475-110-2-2-1-2	24.73
8	IR 96248-16-3-3-2-B	27.18
9	R-RHZ-7	26.61
10	CGZR-1	24.43
11	BRRIdhan 62	23.33
12	BRRIdhan 64	24.97
13	BRRIdhan 72	20.7
14	DRR Dhan 45	18.13
15	DRR Dhan 48	19.2
16	DRR Dhan 49	17.63
17	IR 64	23.57
18	MTU1010	21.7
19	Sambamahsuri	24.47
20	Swarna	18.89
21	Local check (HUR3022)	16.9

3. RESULTS AND DISCUSSION

The interactions of Genotypes x Environment are of major importance to plant breeders in developing novel crop varieties, to a target environment. In the present study, five different locations were chosen to study the G*E interaction and these five environments recorded environment indices variedly for different traits in different environments. Traits like days to first flowering (3.33), days to 50% flowering (3.45) and days to maturity (4.49) were the highest in the fourth environment (Karsada) and the number of effective tillers per plant (0.524) and spikelet fertility percent (3.6) were the highest in the second environment (BHU agricultural farm II). Plant height (12.04), grains weight per panicle (0.56) and 1000-grain weight (1.71), grain yield per plant (4.9), and grain yield per hectare (1.656) were the highest in the third location (Bhikaripur). L/B ratio (0.07) was the highest in the first location (BHU agricultural farm I) and grain Zinc content (4.25) was the highest in the fifth location (Rampur). Fourth environment (Karsada) and fifth environment (Rampur) were not favourable as it had environmental indices lower to all environments for all most all characters except days to first flowering, days to 50 percent flowering, days to maturity and grain zinc content. Bhikaripur was considered the most favourable environment for all most all yield traits followed by BHU Agricultural farm II and BHU Agricultural farm I based on environmental indices values mentioned in Table 2.

The inspection of stability, pooled analysis of variance (Table 3) revealed that there was significant linear genotypes and environment interactions for most of the characters studied expect plant height, spikelet fertility % and total effective tiller number which implied that there was significant variation among the genotypes for linear response to different environments on which genotypes are more precisely predicted. The environment + (genotype x environment) was significant for all most all the traits except grain L/B ratio representing specific nature of environments and genotype x environment interactions in morphological expression. All the twenty-one genotypes exhibited significant variations for all the traits when tested against pooled deviation. Similar kind of results were reported by [6] and [7]. According to Eberhart and Russel model of stability analysis 1966, these points are considered for deciding stability of a genotype *i.e.* the genotypes with at least mean performance statistically greater than population mean (also within-population mean + S.E.) and S^2di low or non-significant and (1) 'bi' approaching to unity or not significantly deviating from unity are considered as general adaptability or average stability. (2) 'bi' significantly greater than unity is noted as below average stability (better adaptable to rich or favourable environment). (3) 'bi' significantly less than unity and having lower magnitude than unity are considered as above average stability (better adaptable to poor or unfavourable environment). Considering this, the analysis was made and the three stability parameters viz., mean, regression coefficient (bi) and mean square deviation from the regression line (S^2di) were estimated for all the thirteen traits and results obtained were explained below and presented each trait in the Tables 4, 5 & 6.

3.1 Days to First Flowering

Among all the genotypes, Swarna flowered very lately (114.8 days) while CGZR-1 came to flowering very early (80.26 days). Eleven genotypes were earlier in flowering when compared to the general mean (93.74 days) of the days to first flowering (Table 4). The significance of the non-linear component appeared to be due to the presence of genetic variability among the material tested. Similar results were also reported in the earlier findings of [8],[9],[10] and [11]. The genotypes IR 97443-11-2-1-1-1-3 –B and IR 95044:8-B-5-22-19-GBS were considered as stable for early flowering as it possessed low mean performance, closer to unity regression coefficient and non-significant deviation from regression. The genotype IR 97443-11-2-1-1-1 –B was found suitable for early flowering under favourable environment as it possessed low mean performances, bi values greater than unity and non-significant deviation from regression, whereas the genotype CGZR-1 were considered as suitable for early flowering under poor environmental conditions based on low mean, low bi value and non-significant deviation from regression, they could be regarded as specifically adopted to poor environments.

3.2 Days to 50% Flowering & Days to Maturity

Among all the genotypes, CGZR-1 comes to 50 percent flowering and maturity very early (85.0 &111.8 days) whereas Swarna recoded late 50% flowering and maturity (119 days & 148.33 days).Ten genotypes were earlier in flowering

when compared to the general mean (98.18 days) of the days to 50 percent flowering and eleven genotypes were earlier in maturity when compared to mean (126.8 days) maturity of the genotypes for this trait (Table 4). Days to 50 percent flowering maturity indicate the appropriate duration of the variety and is an important criterion in rice breeding programs to develop rice varieties with different maturity groups to fit into different farming situations under diverse agro-climatic zones. For evolving early types in rice, these genotypes can be used as donor parents in hybridization programs.

The non-linear genotype environment interactions were found to be significant for both characters and hence it could be possible to predict the performance of genotypes and selection would be reliable. Similar results were also reported in the earlier findings of [12], [10] and [11] (Table 3). The genotypes IR 95044:8-B-5-22-19-GBS and IR 97443-11-2-1-1-3 –B were considered as stable for both early 50% flowering and short duration as it possessed low mean performance, closer to unity regression coefficient and non-significant deviation from regression (Table 4). The genotype MTU1010 was found suitable for early flowering under a favourable environment, whereas no one was considered as suitable for early flowering under poor environmental conditions. The genotype R-RHZ-7, BRRIdhan 72 and Local check (HUR3022) were found suitable for long-duration under poor environmental conditions as they possessed high mean performance, bi value less than unity and non-significant deviation from regression. The genotype IR 97443-11-2-1-1-1 –B was considered as suitable for a short duration under favourable environmental condition, whereas no one was found to be suitable for short duration under poor environmental condition.

3.3 Total Effective Tiller Number

The highest number of tillers per plant was recorded in BRRIdhan 62 (9.73) whereas BRRIdhan 64 has recorded the lowest (6.07). Eleven genotypes had higher total effective tiller number when compared to the general mean (7.87) of total effective tiller number. The pooled deviation was significant against a pooled error which indicated that the genotypes differed in their regression on the environmental index and also the importance of non-linear components. The genotype ´ environment (linear) was not significant for this trait (Table 3), which indicated

the possibility to predict the performance of a genotype across the environments. The obtained result showed contradiction to the result reported by [13] and [14] for this trait in rice. DRR Dhan-48 was considered stable for a higher number of tillers over all the five environments. Similar findings were reported by [15].

The genotypes IR 99647-109-1-1, R-RHZ-7, DRR Dhan-49, MTU1010, Sambamahsuri and Local check (HUR3022) were found suitable with higher tillers per plant for the high yielding environment, whereas the genotypes BRRIdhan -72 was found suitable with less number of tillers for low yielding environment (Table 4). The genotypes DRR Dhan-45 and IR 99704-24-2-1 were found stable for less number of tillers over all the five environments as they possessed low mean, regression coefficient around unity with non-significant deviation from regression.

3.4 Plant Height (cm)

The lowest mean performance for plant height was recorded by IR 64 (98.43 cm) whereas the highest mean performance was showed by BRRIdhan 64 (128.08 cm). Twelve genotypes were shorter in height on par to the general mean (106.7 cm) height. The pooled deviation was significant against a pooled error which showed that the genotypes differed in their regression on the environmental index and also the importance of non-linear components. Both linear and non-linear components of stability were insignificant, indicating fewer differences between environments (Table 3) and their considerable influence on this trait as reported earlier by [16],[17] and [18]. As far as the mean value for plant height is considered, the lowest mean value is desirable. A similar consideration was also made by [19] and [20]. Stability parameters identified DRR Dhan 48 and IR 84847-RIL 195-1-1-1-1 with low mean value, non-significant deviation from regression and regression coefficient around unity as the most stable for short plant height of the plant over the five environments whereas the hybrids BRRIdhan 72 found stable for tall plant height over the five environments (Table 4). The genotypes CGZR-1 and BRRIdhan 62 were considered as suitable for short plant height under the poor environment with predictable performance, while IR 99647-109-1-1, IR 97443-11-2-1-1-1 –B and IR 97443-11-2-1-1-3 -B found to be suitable for tall plant height under poor environment.

Table 2. Environmental indices for grain yield and yield contributing characters in rice (*Oryza sativa* L.) genotypes at five different locations of Eastern Uttar Pradesh

SL. No	Character		BHU Agricultural Farm I (L- 1)	BHU Agricultural Farm II (L -2)	Bhikaripur (L -3)	Karsada (L- 4)	Rampur (L-5)
					Location		
1	Days to first flowering	Ij	-7.857	2.175	-0.603	3.333	2.952
2	Days to 50 % flowering	Ij	-7.848	2.105	-0.578	3.454	2.867
3	Days to maturity	Ij	-9.016	2.556	-0.968	4.492	2.937
4	Total effective tiller number	Ij	0.127	0.524	0.460	-0.635	-0.476
5	Plant height (cm)	Ij	4.619	5.862	12.043	-16.222	-6.302
6	Panicle length (cm)	Ij	1.408	0.096	1.206	-2.626	-0.086
7	Spikelet fertility percentage	Ij	1.165	3.606	-0.609	-2.394	-1.767
8	Grain weight per panicle(g)	Ij	0.121	0.354	0.563	-0.511	-0.527
9	1000-grain weight (g)	Ij	1.089	1.608	1.718	-2.605	-1.810
10	L / B Ratio	Ij	0.070	0.014	-0.033	-0.057	0.006
11	Grain Zinc content(ppm)	Ij	1.894	0.156	1.593	-7.892	4.250
12	Grain yield per plant (g)	Ij	1.010	3.326	4.908	-4.612	-4.632
13	Grain yield per ha (ton)	Ij	0.346	1.122	1.656	-1.556	-1.563

Table 3. Pooled analysis of variance for grain yield and yield attributing traits in Rice (*Oryza sativa* L.) genotypes

	Rep within Env.	Varieties	Env. + (Var.* Env.)	Environments	Var.* Env.	Environments (Lin.)	Var.* Env. (Lin.)	Pooled Deviation	Pooled Error	Total
df	10	20	84	4	80	1	20	63	200	104
Days to 1st Flowering Date	0.839	476.064***	25.767***	454.939***	4.308*	1819.756***	9.412***	2.482***	0.546	112.362
Days to 50% Flowering	0.542	466.443***	25.305***	454.107***	3.865**	1816.429***	8.727***	2.137***	0.385	110.139
Days to Maturity	0.631	535.861***	36.258***	617.169***	7.212*	2468.677***	15.012***	4.393***	0.468	132.335
Total effective tiller number	0.297	4.153***	0.856*	5.944***	0.602	23.778***	0.779	0.517**	0.308	1.490
Plant Height (cm)	21.767	255.871***	150.012***	2643.846***	25.320	10575.384***	35.497	20.884***	9.902	170.370
Panicle Length (cm)	0.655	11.667***	4.164***	54.342***	1.655	217.367***	2.690*	1.248**	0.696	5.607
Spikelet Fertility %	11.815	51.829***	22.219*	123.803***	17.139	495.213***	23.919	14.171***	7.221	27.913
Grain Weight Per Panicle (g)	0.018	0.604***	0.325***	5.228***	0.080**	20.910***	0.178***	0.045***	0.016	0.379
Weight of 1000 Seed (gm)	0.521	35.801***	6.278***	88.138***	2.185*	352.552***	4.609***	1.311***	0.376	11.955
Grain L/B Ratio	0.004	0.360***	0.070	0.050	0.071	0.200	0.120**	0.052***	0.006	0.126
Grain Zinc Content (ppm)	0.495	47.760***	26.211***	454.119***	4.816*	1816.477***	10.107***	2.907***	1.329	30.355
Grain Yield/Plant (g)	0.482	12.097***	22.231***	414.148***	2.635	1656.592***	4.723**	1.847***	0.719	20.282
Grain Yield (ton/ha)	54.803	1378.36***	2532.417***	47176.364***	300.220	188705.456***	538.112**	210.402***	81.907	2310.483*

Table 4. Mean performance and stability parameter of (1St DF), (50% DF), (DM), (TETN) and (PHT) of rice genotypes

Genotypes No	Days to 1st flowering (1St DF)			Days to 50% flowering (50% DF)			Days to Maturity (DM)			Total effective tiller number (TETN)			Plant height (cm) (PHT)		
	Mean	ßi	S²Di	Mean	ßi	S²Di	Mean	ßi	S²Di	Mean	ßi	S²Di	Mean	ßi	S²Di
1	84.9333	1.046	0.3744	89	1.032	0.3333	116.5	1.027	-0.2694	8.2667	1.766	0.5441*	102	0.912	33.115**
2	90.1333	1.375*	0.546	94.8	1.349**	-0.3315	122.8	1.267 **	-0.3418	7.9333	0.098	0.681*	103.2	0.953	-2.324
3	90.4667	1.057	3.7476***	95.4	1.001	4.3648***	123.5	0.982	4.6946***	7.6667	1.098	0.348	108.9	1.195	27.5984*
4	86.0667	1.144	4.5769***	90.8	1.165	3.9565***	118.5	1.118	2.5494***	8	2.164	-0.0746	111	0.845	-5.1757
5	89.5333	1.197	0.1519	93.6	1.234	0.8606*	121.5	1.155	0.4414	6.8667	-0.098	0.6958*	108.4	0.726	4.3466
6	86.8667	1.09	-0.0311	91.4	1.025	-0.1617	119.3	0.977	-0.1827	6.4667	1.21	-0.0756	108.9	0.932	-3.5866
7	92.4	1.572	5.167***	97.3333	1.525	5.2603***	126	1.526	3.9926***	7.1333	1.467	0.035	105.9	1.173	17.5536*
8	87.2	1.343*	0.0216	91.5333	1.335*	-0.0823	119.2	1.252**	-0.36	8.1333	0.818	-0.0714	109.2	0.771	43.2021**
9	99.2	0.823	1.4071*	103.6667	0.855	2.0131***	132.5	0.842	4.0646***	9.4667	1.528	0.3367	103	1.273	7.2415
10	80.2667	0.991	0.8606	85	0.93	1.2549**	111.8	0.867	1.8323**	7.2667	1.341	0.0058	100.4	0.916	2.784
11	81.6	1.007	6.1522***	86.2	0.976	3.3471***	113.3	0.935	6.9539***	9.7333	0.654	0.8194*	101.8	0.89	6.5511
12	93.0667	1.313*	-0.1045	97.6667	1.358*	0.3304	126.5	1.385*	0.9549*	6.0667	-1.379	0.7823*	128.1	1.617*	-1.1045
13	104.6	0.587	5.3108***	109	0.634	4.9038***	138.6	0.544	5.6774***	6.8	*-0.308	-0.2253	114.9	1.133	24.5152*
14	94.6	1.087	1.2572*	98.7333	1.057	1.2467**	127.8	1.055	1.3137*	7.4667	1.023	-0.1402	118.8	1.278	0.6058
15	100.267	0.619	1.4956*	104.6667	0.628*	0.3115	134.3	0.658*	0.4476	8	1.112	0.4845	99.4	1.065	3.0895
16	101.333	1.024	0.0188	105.5333	1.06	-0.2369	135	1.049	0.596	8.5333	1.547	0.3891	99.7	1.122	14.4102
17	85.2	1.229	2.8459***	89.8667	1.23	1.8968***	119.7	1.593	25.098***	7.8	1.612	-0.0592	98.4	0.684*	-7.6179
18	87.7333	1.093	-0.1682	91.7333	1.105	0.0571	121.7	1.441	15.7414***	8.3333	1.308	0.157	107.7	0.801	-4.9998
19	112.8	0.311**	-0.0548	117	0.327**	0.0114	146.5	0.322**	0.4002	8.5333	1.822	-0.0355	103	0.491	28.4635*
20	114.8	0.311**	-0.4883	119	0.331**	-0.2098	148.3	0.308**	-0.202	8.2	0.855	-0.021	102.3	1.397	3.4424
21	105.6	0.779	7.2892***	109.8667	0.842	7.5045***	139.8	0.697	8.8427***	8.6667	1.36	-0.191	106.1	0.826	26.6484*
	93.746			98.181			126.8			7.873			106.7		

3.5 Panicle Length (cm)

The longest panicle was recorded in IR 82475-110-2-2-1-2 (30.3 cm) whereas the shortest panicle was recorded in Local check (23.41 cm). Seven genotypes had higher panicle length when compared to the general mean (26.01 cm). Only the linear components of genotype x environment interaction were significant, indicating that the whole interaction was linear in nature and prediction over the environments was possible (Table 3). Similar kinds of results were also observed by [21] and [11] for panicle length in rice. The BRRIdhan 72, IR 99704-24-2-1 and Swarna found to be stable for long panicle as per the definition of stability as possessed high mean value, regression coefficient around unity along with IR 95044:8-B-5-22-19-GBS and DRR Dhan 45 for short panicle (Table 5). The IR 97443-11-2-1-1-1 –B and IR 97443-11-2-1-1-3 -B were identified to be suitable for long panicle under high yielding environment as they were with high mean, high bi values and non-significant S^2di values.

3.6 Spikelet Fertility Percent

The highest spikelet fertility percent was recorded in DRR Dhan 48 (81.67%) whereas the lowest spikelet fertility percent was recorded in DRR Dhan 49 (71.68%). Twelve genotypes had higher spikelets fertility percent on par when compared to the general mean (80.27%) of this character. The pooled deviation was significant against a pooled error which implied that the genotypes varied in their regression on the environmental index and also the importance of non-linear components. The significance of non-linear and linear components appeared to be due to the presence of genetic variability among the material tested (Table 3). Similar results were also described in the earlier findings of [12]. For this trait the genotypes IR 97443-11-2-1-1-1 –B and IR 84847-RIL 195-1-1-1-1 was found stable with high spikelets fertility percent as per the requirement with high mean value, regression coefficient around unity (Table 5). The genotypes BRRIdhan 62 with high spikelets fertility percent were found responsible to improved environments along with genotypes BRRIdhan 72 and IR64 with low spikelet fertility percent.

3.7 Grain Weight per Panicle (g)

The IR 97443-11-2-1-1-3 -B recorded the highest grain weight per panicle (2.18 g)

whereas BRRIdhan 62 registered the lowest grain weight per panicle (1.02 g). Out of twenty-one genotypes, four genotypes showed above the general mean (1.507 g). The environments were contrasting and caused differential responses on genotypes for producing grain weight per panicle. Highly significant mean squares were observed for linear as well as non-linear components (Table 3). A similar result was obtained by [22] for grain weight per panicle in rice. IR 97443-11-2-1-1-1 –B genotype could be identified as stable for higher grain yield over five environments for this trait but the genotypes BRRIdhan 72 and BRRIdhan 64 had high grain weight found suitable for improved environmental condition along with genotype IR 96248-16-3-3-2-B with low grain weight as recorded low mean, regression coefficient greater than unity with non-significant deviation from regression (Table 5).

3.8 1000-Grain Weight (g)

The genotype BRRIdhan 72 recorded a maximum 1000-grain weight (21.769 g) whereas R-RHZ-7 recorded a minimum 1000-grain weight (13.82 g). Seven genotypes exceeded the general mean grain weight (22.62 g). Genotype mean squares were found to be significant indicating that the genotypes differed significantly in their response to environments and independent nature of genetic systems in controlling stability parameters (Table.3). Similar significant mean squares for 1000 grain weight in rice was also reported by [23],[19], [11] and [14]. The genotypes IR 99704-24-2-1, IR 82475-110-2-2-1-2 could be identified as stable high 1000-grain weight overall five environments for this trait (Table.5). The IR 99704-24-2-1 and BRRIdhan-64 with high 1000 grain weight were found responsible for improved environmental conditions along with the genotype DRR Dhan- 49 and Swarna for low 1000 grain weight.

3.9 L/B Ratio

L/B ratio of rice grain estimates the slenderness, which is a major factor to determine the head rice recovery and quality point of view. The highest LB ratio was registered in genotypes Swarna (4.454) whereas the lowest LB ratio was found in BRRIdhan-64 (3.205). Ten genotypes had a higher LB ratio when compared to the general mean (3.99). The stability analysis of variance (Table 3) for the L/B ratio revealed that significant

differences among genotypes and environment for this trait due to only a linear portion of interactions suggested the least susceptible to environmental fluctuations. The genotypes CGZR-1 and IR 95044:8-B-5-22-19-GBS were recorded with low mean value, regression coefficients around unity along with minimum deviation to regression and those genotypes are stable in nature (Table 6). The genotypes MTU1010 was recorded with high mean value, regression coefficient greater than unity with non-significant deviation from regression and it was below the stability could be adapted only in a favourable environment.

3.10 Grain Zinc Content (ppm)

The highest grain Zinc content value was recorded in genotype IR 95044:8-B-5-22-19-GBS (26.64 ppm) while lowest in genotype Swarna (16.64 ppm). Ten genotypes exceeded the general mean (22.158 ppm). Both linear and non-linear components of stability were significant, indicating differences between environments and their considerable influence on this trait (Table 3). Earlier similar kind of results stated by [24],[25] and [26]. The genotype BRRIdhan 64 was regarded as stable genotype for more grain zinc content overall five environments considering stability requirements of high mean performance, regression coefficient around unity, least deviation from regression along with the IR 95044:8-B-5-22-19-GBS and BRRIdhan 64 found to be suitable for more grain zinc content over high yielding environment (Table 6). The genotypes IR 97443-11-2-1-1-1-3 –B, BRRIdhan 72 and DRR Dhan 48 recorded low grain zinc yield, regression coefficient less than unity as it indicated that low stability and suitable for poor environmental conditions. The high grain zinc with higher yield was reported in BRRIdhan 64 and it is stable for grain zinc content whereas unstable for grain yield per ha (kg).

3.11 Grain Yield per Plant (g)

The BRRIdhan 72 recorded the highest grain yield (14.57 g) whereas IR 64 registered the lowest grain yield per plant (8.97 g). Eleven genotypes exceeded the general mean (11.618 g) for this trait. Genotype mean squares were found to be significant indicating that the genotypes differed significantly in their response to environments and independent nature of genetic systems in controlling stability parameters. Highly significant mean squares were observed for linear (Table 3). Similar kinds of reports were also reported by [13],[22],[16],[10],[11],[27] and [28] for genotype x environment interaction for grain yield per plant in rice. Based on high mean values, unit bi and non-significant S^2di values, the genotypes IR 97443-11-2-1-1-1-3 –B and Local check (HUR 3022) identified as stable for higher grain yield over three environments for this trait (Table 6). The genotypes R-RHZ-7 and BRRIdhan 62 with low mean, regression coefficient around unity with non-significant deviation from regression showed stability over all the five environments with low grain yield. The genotypes IR64, BRRIdhan 62, CGZR-1 and DRR Dhan 48 showed low grain yield was found not responsible to improved environmental conditions based on low mean, low bi values and non-significant S^2di values along with the IR 97443-11-2-1-1-1-3 –B and Local check for high grain yield per plant were considered as suitable under improved environment.

3.12 Grain Yield per Ha (ton)

The maximum grain yield per ha was recorded by BRRIdhan 72 (4.91 tons) while IR 64 showed minimum grain yield per ha (3.027 tons). Stability analysis of variance (Table 3) indicated that linear components of the genotype-environment, contributed to the total genotype-environment interaction. Only linear components of stability were significant, this results not lined with the result reported earlier by [21],[17] and [18] indicating differences between environments and their considerable influence on this trait. The genotypes IR 97443-11-2-1-1-1-1 –B and Local check (HUR3022) were regarded as stable genotype for more grain yield per ha over all five environments considering stability requirements of high mean performance, regression coefficient around unity, least deviation from regression along with RHZ-7 for less grain yield per hectare (Table 6). The genotypes IR 97443-11-2-1-1-1-3 –B, BRRIdhan-72, DRR Dhan-45 and MTU1010 were found to be suitable for more grain yield per hectare in high yielding environment based on high mean values, high bi values and non-significant S^2di values.

Table 5. Mean performance and stability parameter of (PL), (SFP), (GWPPL) and Weight of 1000 seeds of Rice Genotypes

Genotypes No	Panicle length(cm) (PL)			Spikelet fertility percentage (SFP)			Grain weight per panicle(g) (GWPPL)			Weight of 1000 seeds (g)		
	Mean	ßi	S²Di	Mean	ßi	S²Di	Mean	ßi	S²Di	Mean	ßi	S²Di
1	24.2173	0.963	-0.6183	77.84	2.329	17.3734*	1.22	0.513	0.0705*8	17.7613	1.127	1.5266**
2	25.8793	1.081	1.394*	78.78	0.937	-7.0087	1.3853	0.954	0.0612**	19.7987	1.398	-0.0562
3	26.4273	0.908	1.0264	77.67	0.003	18.3254*	1.6074	0.607	0.0288*	21.066	1.004	-0.0712
4	25.7333	0.188	0.388	75.00	1.677	14.9151*	1.1961	0.934	0.0349*	20.0893	2.094	4.5562***
5	26.8433	1.358	0.526	80.11	0.992	1.6504	2.054	1.25	0.014	15.66	0.594	0.3337
6	27.6027	1.355	1.0336	74.22	-0.156	-1.2829	2.182	1.312	0.0474**	15.626	0.855	0.6298
7	30.3041	1.443*	-0.5729	79.24	0.597	10.3657	1.6473	0.738	0.0886***	21.3267	0.965	0.1384
8	25.604	-0.02536	-0.3831	77.59	2.144	-2.3265	1.3507	1.284	-0.0015	19.5933	1.767	1.4369*
9	25.948	1.257	-0.155	79.36	1.225	38.6183***	1.0661	0.804	0.008	13.826	0.484	0.1346
10	25.6161	2.113*	0.3974	75.752	0.477	-3.3361	1.3833	0.598	0.0582**	20.4447	1.143	0.9386*
11	25.1139	0.92	-0.2001	77.78	1.816	-4.5639	1.0239	0.867	0.0009	18.372	1.371	0.8271*
12	25.8813	1.525	0.31	72.00	*-1.658	4.3651	2.0327	2.06**	0.0111	20.638	1.144	0.226
13	28.8681	1.125	0.3862	72.44	1.374	-4.3167	2.1793	1.72*	0.0026	21.7693	1.46	2.7328***
14	24.6621	1.048	3.5219***	71.72	-0.123	-0.4813	1.5907	1.214	0.0151	20.57	1.049	1.8008***
15	24.204	0.697	2.3456***	81.67	0.293	-3.2731	1.338	0.495	0.0158	14.438	*-0.323	2.4599***
16	25.7313	1.519**	-0.6593	71.60	0.902	10.9267	1.5406	0.686	0.0718**	15.394	1.093	-0.0183
17	25.9887	1.135	-0.6641	72.65	1.996	-4.3502	1.138	0.61	0.0036	19.7073	0.888	-0.2495
18	25.644	0.696	-0.1448	78.06	0.76	-5.0572	1.4955	1.188	0.04418*	19.9527	1.051	0.6773*
19	26.284	0.333	1.83*	80.34	1.33	17.0774*	1.244	0.69	0.0403*	13.946	0.092**	-0.0554
20	26.3027	1.068	-0.2375	77.48	2.735	23.4987**	1.4899	1.566*	-0.0059	15.0467	1.037	0.9499*
21	23.4113	0.279	2.101**	72.43	1.352	20.233*	1.4759	0.91	-0.0117	18.3947	0.709	0.5718
	26.0127			76.37			1.5067			18.2581		

Table 6. Mean performance and stability parameter of (L/B Ratio), (grain zinc content), (GYPP), and (GYPH) of rice genotypes

Genotypes No	L/B Ratio			Grain Zinc content (ppm)			Grain yield per plant (g) (GYPP)			Grain yield per ha (ton) (GYPH)		
	Mean	ßi	S²Di	Mean	ßi	S²Di	Mean	ßi	S²Di	Mean	ßi	S²Di
1	3.8313	-0.299	0.0035	26.64	1.499	1.6414	10.1854	0.737	2.216**	3.43	0.738	252.48**
2	3.7313	9.357	0.1012***	25.7	1.165	6.0651***	10.788	0.739	1.2904*	3.64	0.739	147.69*
3	4.1538	0.558	0.0008	24.1133	0.838	6.0245***	12.292	0.695	2.2328**	4.14	0.695	254.19**
4	4.4265	-0.766	0.0111*	25.9667	1.344	3.1331*	9.9187	1.109	2.0898**	3.34	1.109	238.20**
5	4.1461	-2.08	0.0325***	17.3867	1.086	1.8264	13.8	1.002	0.0881	4.65	1.002	10.18
6	3.8886	-1.741	0.0295***	19.0627	0.584	0.6111	14.2327	1.204	0.2875	4.80	1.204	32.90
7	3.9603	2.389	0.0581***	25.7933	1.579*	0.248	11.8613	0.874	1.9653*	4.00	0.874	223.76*
8	4.3333	2.511	0.0315***	24.8667	1.162	2.8448*	11.1101	1.313*	-0.3698	3.74	1.313*	-419.77
9	4.0758	1.659	0.0648***	23.8733	1.003	3.8701**	10.1967	1.01	-0.0082	3.44	1.01	-0.91
10	3.9449	-0.039	0.0775***	25.06	0.92	2.7651*	10.0673	0.702	1.0302	3.39	0.702	116.92
11	4.0821	-2.089	0.1788***	23.0467	0.954	0.3714	9.7855	0.961	-0.372	3.30	0.961	-42.39
12	3.205	-2.238	0.1087***	23.9733	1.131	-0.0189	11.6487	1.109	5.9622***	3.93	1.109	678.89***
13	3.8531	-1.709	0.0243**	17.04	0.706	0.4992	14.5748	1.204	0.5649	4.91	1.204	64.49
14	4.0938	3.354	0.0915***	21.8933	1.098	-1.0573	11.8981	1.178	0.2114	4.01	1.177	23.98
15	3.8583	*-4.537	0.0191**	20.62	0.744	1.8675	10.7653	0.648	0.3807	3.63	0.648	43.53
16	4.1559	4.037	0.0469***	19.74	1.098	0.9505	13.1761	0.997	1.1951*	4.44	0.997	136.31
17	3.8474	9.296*	0.032***	21.8887	1.191	0.0712	8.9714	0.754	0.4457	3.02	0.754	50.56
18	3.893	2.137	0.0034	20.7533	1.129	1.629	12.5053	1.27	0.6281	4.22	1.27	71.61
19	3.9301	*-2.283	0.0034	20.3507	0.109**	-0.3299	10.8673	0.853	4.4151***	3.66	0.852	503.06***
20	4.454	1.397	0.0232**	16.6467	0.461*	-0.461	12.4427	1.586*	0.1339	4.19	1.586*	15.58
21	4.1339	2.085	0.0273**	20.9067	1.198	1.4157	12.8807	1.055	-0.4701	4.34	1.055	-536.33
	3.9999			22.1582			11.6175			3.92		

4. CONCLUSION

Based on the environmental index, Bhikaripur village is identified as the most favourable environment for most of the characters under study followed by BHU Agriculture farm II, BHU Agriculture farm I, Karsada and Rampur. Rampur location can be used for screening of stable genotypes. The inspection of stability, analysis of variance revealed that there was significant linear genotypes and environment interactions for most of the characters expect *viz.,* plant height, Spikelet Fertility % and total effective tiller number which implied that there were significant variations among the genotypes for linear response to different environments on which genotypes are more precisely predicted. The environment + (genotype x environment) was significant for all most all the traits except grain L/B ratio representing specific nature of environments and genotype x environment interactions in morphological expression. All the twenty-one genotypes exhibited significant variations for all the traits when tested against pooled deviation. Based on the stability parameters none of the genotypes could be identified as stable for all the traits over five environments but, the IR 97443-11-2-1-1-1-1 –B and Local check (HUR3022) showed stability for high yield in all the environments. IR 97443-11-2-1-1-1-1 –B having stability for Grain yield per ha (kg) with higher mean and short duration also stable for Grain yield per plant (g), Grain weight per panicle (g) and Spikelet Fertility % could be used as high yielding cultivars and also used as parent for future breeding programs. IR 95044:8-B-5-22-19-GBS having the highest grain Zinc content. The high grain zinc with higher yield was reported in BRRIdhan 64 and it is stable for grain zinc content, can be used for the Zinc bio-fortification to ensure both food and nutritional security using different breeding approaches to minimize malnutrition.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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