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Parametric Stability Analysis of Cold Tolerant Rice Genotypes for Grain Yield

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ABSTRACT

Assessment of genotype × environment interaction is an important and challenging issue for the evaluation of promising genotypes with high adaptability and stability in large multi-environment trials. Both the effect of genotype × environment interaction and the selection of genotypes play a crucial role in improving the yield and stability of performance of the genotypes in a more precise and refined manner. To investigate GEI and identify the best-performing stable genotypes, a study comprising of 38 cold-tolerant rice genotypes was conducted in four seasons to determine their grain yield stability and adaptability, by employing various stability models that explained the adaptability of genotypes differently, irrespective of the yield performance. From the current study, among all the rice genotypes, CHENAB and VIVEK DHAN-85 were stable for two or more stability parameters, while VIVEK DHAN-82 had a greater general mean and was characterized as adaptable to favorable environments. On the other hand, HIMALAYA-2216, K-429, and CHINA-1039 were found to be unstable from all the stability models. Genotypes HPR-2513, CHINA-1007, and SHALIMAR-1 were found to be having wider adaptability which could serve as potential parents for future selection programs in different environmental conditions.

Keywords- *Rice, Parametric Stability analysis, Genotype x Environment interaction, Shukla's Stability Variance, Wricke's ecovalence, Superiority Index, Coefficient of Variation*

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INTRODUCTION

Rice (*Oryza sativa* L.) is a major source of staple food around the globe playing a vital role in food security and sovereignty. Since rice is originated in tropical and subtropical regions, it is more sensitive to cold stress than other cereals. Cold stress is a fundamental determinant of rice growth, production, and distribution over the world. Rice production is significantly impeded by its vulnerability to cold stress at both the seedling and reproductive stages, resulting in spikelet sterility. Thus, breeding for cold-tolerant varieties is an encouraging path to counteract the detrimental effects of low-temperature stress on rice. High yield performance of rice varieties is one of the most significant aims of plant breeders, alongside abiotic stress resistance, which explains their preference for a dynamic concept of stability [1]. However, grain yield is a polygenic trait, controlled by numerous genes and is highly under environmental influence [2]. Thus, consistent and stable performance across different environments is a necessary pre-requisite which is termed as yield stability. Research on yield stability, genotype × environment interaction (GEI), is necessary to evaluate the stability of rice grain yield and to develop varieties that respond consistently across years and diverse agroecological conditions is of prime importance to plant breeders. Enhanced perception of the extent of GEI and performance stability in crops is a call tool to get essential information on the pattern of adaptation in breeding lines and to work out the recommendation domains for released varieties [3].

The concept of stability has been described in a variety of ways utilizing a many biometrical statistics, including univariate and multivariate stability measures [4]. The regression approach, which is based on regressing the mean value of each cultivar on the environmental index or marginal means of habitats, is the most extensively utilized. Another method to measure stability is by using G x E interaction effects for each genotype, squared and summed across all environments [5]. The variance component of each genotype across environments as another relevant measure of phenotypic stability [6]. Utilization of the distance mean square between the cultivar's response and the maximum response averaged over all locations as superiority measure of genotypic performance [7]. Similarly, coefficient of variation (CV) as a stability measure [8]. However, the method which uses a linear regression coefficient and variance of regression deviations to assess cultivar responsiveness to environmental changes, is one of the most extensively used stability models [9]. Thus, the present investigation was taken up to compare different stability statistical methods for assessing the adaptation level and GE interactions of cold-tolerant rice genotypes over four environments.

MATERIALS AND METHODS

Field experiments were conducted at ARI, Rajendranagar, Hyderabad (17°19 N latitude and 79.23° E longitude) at an altitude of 542.6 m above mean sea level during four seasons, namely, *Kharif* -2018 (E1), -mid-*Kharif* -2018 (E2), late *Kharif* -2018 (E3) and *Rabi*-2018-19 (E4). During all the seasons, the experiment was conducted in a randomized complete block design (RBD) with two replications. The experimental material comprised of 38 cold-tolerant genotypes (Table 1) along with three checks (Tellahamsa, Rajendra, and MTU 1010). Healthy Nursery was raised using the uniform package of practices. Thirty-day old seedlings were transplanted with a single seedling per hill and with a planting density of 44 hills per m^{-2}. Each entry was planted in four to five rows with an inter and intra row spacing of 15 × 15 cm inter and a row length of 4.5 m. For assessment of stability of genotypes, the yield data was subjected to statistical analysis using GENSTAT statistical package (12th *edition*) [10] and the following stability models were used.

1. Wricke's ecovalence [5]

$$W_i = [\bar{Y}_{ij} - \bar{Y}_{i.} - \bar{Y}_{.j} - \bar{Y}_{..}]^2$$

2. Coefficient of variation (CV) [8]

$$CV_i = \left(\frac{\sqrt{S_i^2}}{\bar{X}_i}\right) X\ 100$$

3. Superiority Index (Pi) [7]

$$Pi = \sum_{j=1}^{n} (x_{ij} - M_j)/2E$$

4. Shukla's stability variance [6]

$$\sigma_i^2 = \frac{1}{(G-1)(G-2)(E-1)}[G(G-1)\sum_j(Y_{ij} - \bar{Y}_{i.} - \bar{Y}_{.j} + \bar{Y}_{..}))^2 - \sum_i\sum_j(Y_{ij} - \bar{Y}_{i.} - \bar{Y}_{.j} + \bar{Y}_{..}))^2$$

5. Ebherhart and Russell model [9]

$$Y_{ij} = m + b_i I_j + \delta_{ij}$$

(i= 1,2,.....,t and j= 1,2,......,s)

RESULTS AND DISCUSSION

Various stability models were considered in order to estimate G×E interaction to discover the contribution of GEI to the variation and also to identify superior cultivars with high performance under different environments [11,12] (Table 2). Wricke ecovalence statistic is a stability parameter that describes the relative contribution of a cultivar to the total GEI by utilizing the GEI mean squares as the criteria for the stability assessment [5]. Genotypes with the lowest Wi^2 values have lesser fluctuations across environmental conditions and thus are regarded as stable. The ecovalence values (Wi^2) for 38 rice genotypes over four environments were worked out as presented in Table 2, which ranged from 1.30 for the genotype CHINA-1007 to 188.24 for HIMALAYA-2216. Since genotypes with the smallest ecovalence (Wi2) values are considered stable, CHINA-1007 was highly stable, followed by VL DHAN-208 (2.37). Though ecovalence values for the genotypes were lower, they had a lower mean yield than the overall mean yield indicating that stability for this parameter is negatively correlated with grain yield [13].

Stability index is obtained by merging mean grain yield, and coefficient of variation together with environmental variance [8]. Genotypes with low environmental variance (S2i) and coefficient of variation (CVi) are considered to be more stable and consistent. Accordingly, VL DHAN-206, HPR-2373, VL DHAN-86, and CHINA-1007 genotypes had smaller environmental variance (S2i) and coefficient of variation (CVi) than those of the rest for grain yield indicating their high stability (Table 2, Fig. 1). Promising cultivar would be the one having lowest superiority value, which pertained among the most responsive cultivar in a given set of environmental conditions. This stability parameter regarded HIMALAYA-2216 as the most promising genotype ranked first with lower Pi values followed by the genotypes RAJENDRA and SKAU 341, which ranked second and third respectively (Table 3). This parameter was found to be highly correlated with yield, since, genotypes with higher yield were also found to be highly stable, according to this parameter.

The G × E interaction effect is partitioned by [14] stability statistic into two components with α (vertical axis) measuring the linear response to the effects of the environment and λ (horizontal axis) computing the deviation from the linear response as indicated by error variance. The region between α axis and λ = 1 in the Alpha-Lambda space (Fig. 3), inside the curve with values of α not significantly different from 0 and λ values non-significant different from 1, includes average stable cultivars which are SKAU-339, VL DHAN-206, VL DHAN-208. Those with α < 0 and λ= 1, i.e., VIVEK DHAN-82 represent above-average stable cultivars. However, cultivar K-429 contained within the area above α = 0 and λ =1, i.e., (α > 0, λ= 1) would be considered as below- average performance. GEI sum of squares is fractioned into variance components (σi^2) and a relatively large value of σi^2 indicates higher instability of genotype, whereas stable genotypes are those with minimum stability variance (σi^2) [6]. Results of the current study revealed that the most stable genotypes were VL DHAN-86, CHINA-1039 and MTU 1010. For this statistic, the stable genotypes had lower mean yield similar to Wricke's ecovalence model. Perkins and Jinks used a statistical approach to determine non-linear sensitivity to environmental changes, taking into account the GEI component of each cultivar as a linear function of the additive environmental component. In this model, a cultivar with βi and σ^2i values close to zero is regarded as consistent. Accordingly, genotypes HPR-1068, SUKARADHAN-1, and K-429 emerged as stable compared with others.

Eberhart and Russell (1966) introduced a modified joint regression analysis approach that is extensively utilized and regarded as the most appropriate for interpreting crop stability statistics [9]. High mean yield is thought to be possessed by stable and adaptive cultivars with a regression coefficient close to unity and a deviation from regression value close to zero. As a result, cultivars with low variance in regression deviation have highly predictable responses, whereas cultivars with large variance in regression deviation have less predictable responses [15]. The results indicated the existence of wide differences among the genotypes with Regression coefficient (bi) values of genotypes ranging from 0.1083 to 2.5117 (Table 2, Fig. 3). Nineteen genotypes were with bi-values greater than unity (>1.0), indicating better adaptability of these genotypes to environments with the favorable growing condition. As a result, such genotypes would have a lower than- average response when grown in bad conditions, but may have a maximum response when grown in ideal environments. The remaining genotypes had bi-values less than unity (< 1.0), indicating specific adaptation to low-yielding environments as suggested by [16]. The deviation from regression (S^2di) value among the genotypes ranged from 0.1447 to 62.0697. Of the total 38 genotypes, 8 genotypes had deviation from regression (S^2di) value equal to zero indicating the stable performance of these genotypes over environments. Overall, when the combination of parameters with high mean yield, regression coefficient and deviation mean square was examined, VIVEK DHAN-82, CHENAB and VIVEK DHAN-85 of all the genotypes were identified as suitable for general adaptation beneficial for cultivation over all the environments. Interestingly, the most stable genotypes were found to be the same under both the Eberhart and Russell model and Wricke's criteria of selection.

In summary, the genotype CHINA-1007 emerged as stable according to Wricke's ecovalence, Coefficient of variationv and Eberhart and Russell model, while VIVEK DHAN-82 was promising as per Eberhart and Russell, Coefficient of variation measure and VL DHAN-208 as supported by Tai stability analysis (Fig. 2) and Wricke's ecovalence. Thus, it was evident that of all the genotypes, CHINA- 1007 and VIVEK DHAN-82 emerged as stable genotypes according to most of the models. VIVEK DHAN-82, CHENAB, and VIVEK DHAN-85 were stable for two or more stability parameters with superior mean yield performance.

CONCLUSION

The current study revealed the presence of significant differences in grain yield among genotypes and environments implying differential responses of genotypes to diverse environmental conditions. The use of various stability statistics was beneficial in identifying adaptable cold-tolerant genotypes across a varied range of environments. Among the promising genotypes that were identified with superior mean yield performance, VIVEK DHAN-82, CHENAB, and VIVEK DHAN-85 were stable for two or more stability parameters. Genotypes HPR-2513, CHINA-1007, and SHALIMAR-1 had wider adaptability to the environmental conditions, while HIMALAYA-2216, CHINA-1039, and K-429 were found to be least stable despite their high yield indicating that stable genotypes are always not high yielders. The study also revealed a clear opportunity to breed cold-tolerant genotypes with high yield, wide adaptation, and high-yield stability by exploring the genotype by environment interactions.

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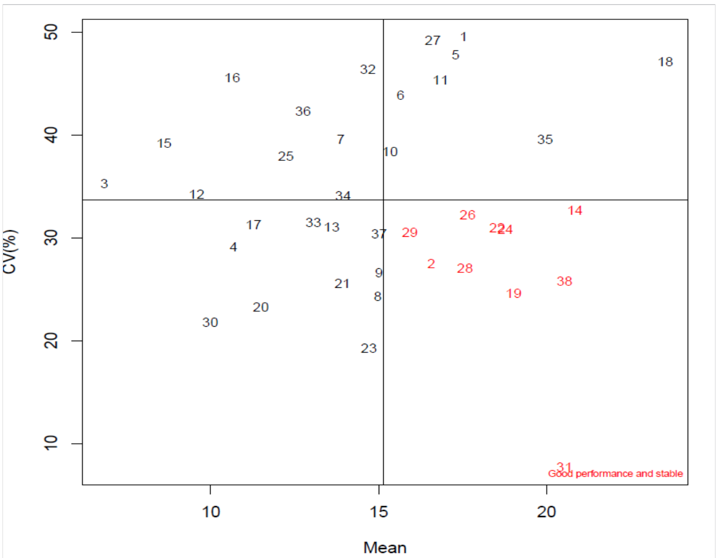

Figure 1. Distribution of the 38 rice genotypes on the basis of coefficient of variation

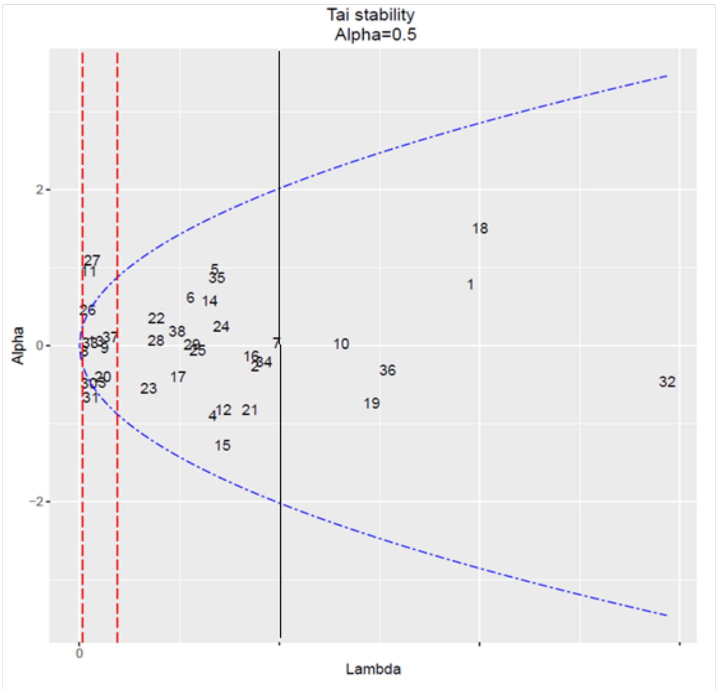

Figure 2. Allotment of the 38 genotypes of rice on Alpha-Lambda space showing different stability regions according to (Tai, 1971) method

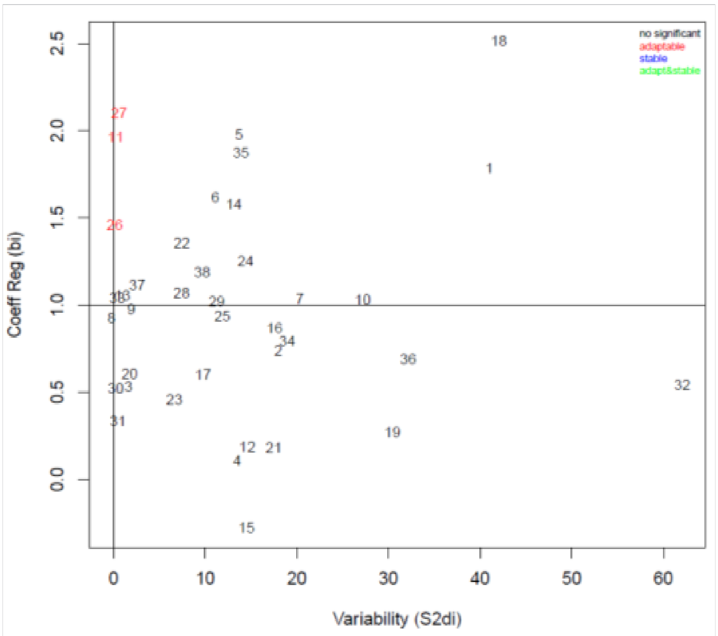

Figure 3. Distribution of stable genotypes of rice as per Eberhart and Russell model

Table 1. List and codes of 38 genotypes of rice evaluated in the study

SKUAST, Khudwani, Kashmir		
1	CHINA-1039	G1
2	SKAU-382	G2
3	K-116	G3
4	K-475	G4
5	CHINA-988	G5
6	JHELUM	G6
7	SKAU-5	G7
8	CHINA-1007	G8
9	SHALIMAR-1	G9
10	SKAU-389	G10
11	CHENAB	G11
12	K-332	G12
13	SKAU-339	G13
14	SKAU-341	G14
15	K-429	G15
KVV, Malan, Himachal Pradesh		
16	HIMALAYA-1	G16
17	HIMALAYA-741	G17
18	HIMALAYA-2216	G18
19	RP-2421	G19
20	HPR-2143	G20

21	HPR-1068	G21
22	SUKARADHAN-1	G22
23	HPR-2373	G23
24	HPR-2336	G24
25	HPR-2513	G25
VPKS, Almora, Uttarakhand		
26	VIVEK DHAN-85	G26
27	VIVEK DHAN-82	G27
28	VIVEK DHAN-62	G28
29	VIVEK DHAN-65	G29
30	VL DHAN-86	G30
31	VL DHAN-206	G31
32	VL DHAN-207	G32
33	VL DHAN-208	G33
34	VL DHAN-209	G34
35	VL DHAN-221	G35
APRRI, Maruteru, Andhra Pradesh		
36	MTU 1010	G36
IRR, Rajendranagar, Hyderabad, Telangana		
37	TELLAHAMSA	G37
38	RAJENDRA	G38

Table 2. Comparison of different stability parameters for each genotype

S. No.	Genotype	CV(%)	bi	S2di	Wi2	pi	Sh-σi 2	PJ
1	CHINA-1039	49.58	1.78	41.04	111.21	0.56	0.41	0.03
2	SKAU-382	27.47	0.74	18.01	40.48	0.65	14.58	0.07
3	K-116	35.25	0.53	1.67	14.74	2.17	1.47	-0.47
4	K-475	29.13	0.11	13.53	64.24	1.65	13.81	-0.06
5	CHINA-988	47.72	1.98	13.72	71.78	0.55	24.25	0.25
6	JHELUM	43.83	1.62	11.14	40.84	0.85	47.09	0.05
7	SKAU-5	39.52	1.03	20.36	42.24	0.93	7.32	0.02
8	CHINA-1007	24.31	0.93	0.20	1.30	0.83	9.47	0.03
9	SHALIMAR-1	26.61	0.97	1.94	5.38	0.82	29.98	-0.13
10	SKAU-389	38.33	1.03	27.22	55.94	0.76	22.99	0.11
11	CHENAB	45.31	1.96	0.25	43.49	0.65	21.95	0.96
12	K-332	34.21	0.19	14.61	60.50	1.77	22.18	-0.26
13	SKAU-339	31.02	1.05	0.99	3.58	1.02	11.23	-0.81
14	SKAU-341	32.68	1.58	13.15	42.65	0.35	7.41	0.58
15	K-429	39.16	-0.28	14.53	103.93	2.02	38.70	0.98
16	HIMALAYA-1	45.57	0.87	17.59	37.42	1.59	12.74	0.35
17	HIMALAYA-741	31.26	0.60	9.77	28.13	1.41	14.87	-1.28
18	HIMALAYA-2216	47.11	2.51	42.06	188.25	0.17	7.46	-0.54
19	RP-2421	24.58	0.27	30.45	86.42	0.52	24.83	-0.07
20	HPR-2143	23.27	0.61	1.77	12.00	1.32	20.86	0.46
21	HPR-1068	25.55	0.18	17.50	66.57	1.13	4.76	1.51
22	SUKARADHAN-1	30.95	1.35	7.47	22.02	0.46	8.03	1.10
23	HPR-2373	19.29	0.46	6.66	28.03	0.98	14.43	-0.48
24	HPR-2336	30.83	1.25	14.42	33.13	0.51	5.40	-0.73
25	HPR-2513	37.93	0.94	11.89	25.43	1.30	65.81	-0.03
26	VIVEK DHAN-85	32.25	1.46	0.14	11.18	0.55	3.91	-0.31
27	VIVEK DHAN-82	49.21	2.10	0.63	56.97	0.70	2.12	0.78
28	VIVEK DHAN-62	27.03	1.07	7.45	16.57	0.61	8.52	-0.82
29	VIVEK DHAN-65	30.49	1.02	11.27	24.03	0.80	3.79	0.87
30	V L DHAN-86	21.78	0.52	0.27	12.32	1.59	0.03	-0.21
31	V L DHAN-206	7.70	0.34	0.49	22.28	0.37	13.94	0.04
32	V L DHAN-207	46.33	0.54	62.07	135.07	1.20	19.25	0.19
33	V L DHAN-208	31.50	1.04	0.42	2.37	1.07	9.43	0.62
34	V L DHAN-209	34.04	0.79	18.97	41.35	1.01	36.14	-0.39
35	V L DHAN-	39.55	1.87	13.94	63.60	0.37	14.12	-0.46
36	MTU 1010	42.30	0.69	32.18	70.13	1.19	0.83	-0.66
37	TELLAHAMSA	30.38	1.11	2.59	7.23	0.82	3.50	-0.89
38	RAJENDRA	25.78	1.19	9.70	22.43	0.24	19.62	-0.40

Table 3. Ranking of genotypes based on yield response and stability parameters

S. No.	Genotype	Yield	CV (%)	S2di	Wi2	pi	Sh-σi 2	PJ
1	CHINA-1039	11	38	36	36	11	2	17
2	SKAU-382	15	11	30	20	14	24	14
3	K-116	38	24	9	9	38	4	30
4	K-475	33	12	22	30	35	20	21
5	CHINA-988	12	36	23	33	10	32	11
6	JHELUM	17	31	18	21	21	37	15
7	SKAU-5	26	28	32	23	22	11	19
8	CHINA-1007	21	5	1	1	20	17	18
9	SHALIMAR-1	20	9	11	4	19	34	23
10	SKAU-389	18	26	33	26	16	31	13

11	CHENAB	13	32	3	25	13	29	4
12	K-332	36	23	27	28	36	30	25
13	SKAU-339	27	17	8	3	25	18	35
14	SKAU-341	2	21	21	24	3	12	8
15	K-429	37	27	26	35	37	36	3
16	HIMALAYA-1	34	33	29	19	34	19	10
17	HIMALAYA-741	32	18	17	17	32	25	38
18	HIMALAYA-2216	1	35	37	38	1	13	32
19	RP-2421	6	6	34	34	8	33	22
20	HPR-2143	31	4	10	7	31	28	9
21	HPR-1068	25	7	28	31	27	9	1
22	SUKARADHAN-1	8	16	15	11	6	14	2
23	HPR-2373	22	2	13	16	23	23	31
24	HPR-2336	7	15	25	18	7	10	34
25	HPR-2513	30	25	20	15	30	38	20
26	VIVEK DHAN-85	9	20	2	6	9	8	26
27	VIVEK DHAN-82	14	37	7	27	15	5	6
28	VIVEK DHAN-62	10	10	14	10	12	15	36
29	VIVEK DHAN-65	16	14	19	14	17	7	5
30	V L DHAN-86	35	3	4	8	33	1	24
31	V L DHAN-206	4	1	6	12	5	21	16
32	V L DHAN-207	23	34	38	37	29	26	12
33	V L DHAN-208	28	19	5	2	26	16	7
34	V L DHAN-209	24	22	31	22	24	35	27
35	V L DHAN-	5	29	24	29	4	22	29
36	MTU 1010	29	30	35	32	28	3	33
37	TELLAHAMSA	19	13	12	5	18	6	37
38	RAJENDRA	3	8	16	13	2	27	28

REFERENCES

1. Becker HC, Leon J (1988) Stability analysis in plant breeding. Plant breeding 101(1):1-23.
2. Jennings PR, Coffman WR, Kauffman HE (1979) Rice improvement, 186 p. International Rice Research Institute (IRRI), Los Baños, Laguna, Philippines.
3. Yan W (2011) GGE biplot vs. AMMI graphs for genotype-by-environment data analysis. Journal of the Indian Society of Agricultural Statistics 65(2):181-93.
4. Crossa J (1990) Statistical analyses of multilocation trials. Advances in agronomy 44:55-85.
5. Wricke G (1962) on a method of understanding the biological diversity in field research. Z. Pflanzenzucht 47(1):92-6.
6. Shukla GK (1972) Some statistical aspects of partitioning genotype environmental components of variability. Heredity 29(2):237-45.
7. Lin CS, Binns MR (1988) A superiority measure of cultivar performance for cultivar × location data. Canadian journal of plant science 68(1):193-8.
8. Francis TR, Kannenberg LW (1978) Yield stability studies in short-season maize. I. A descriptive method for grouping genotypes. Canadian Journal of plant science 58(4):1029-34.
9. Eberhart ST, Russell WA (1966) Stability parameters for comparing varieties 1. Crop science 6(1):36-40.
10. Payne R, Murray D, Harding S, Baird D, Soutou D. GenStat for Windows 12th Edition Introduction(2009): VSN International, 5 The Waterhouse. Waterhouse Street, Hemel Hempstead, Hertfordshire HP1 1ES, UK.
11. Bernardo R (2002) Breeding for quantitative traits in plants. Woodbury: Stemma press.
12. Génard M, Lescourret F, Bevacqua D, Boivin T (2017). Genotype-by-environment interactions emerge from simple assemblages of mathematical functions in ecological models. Frontiers in Ecology and Evolution 5:13.
13. Parmar DJ, Motaka GN, Patel JS, Patel SG (2016). Study on different stability procedures for yield of rice genotypes (*Oryza sativa* L.). International Journal of Science Environment and Technology 5(3):1503-14.
14. Tai GC (1971). Genotypic stability analysis and its application to potato regional trials. Crop science 11(2):184-90.
15. Scapim CA, Pacheco CA, do Amaral Júnior AT, Vieira RA, Pinto RJ, Conrado TV (2010) Correlations between the stability and adaptability statistics of popcorn cultivars. Euphytica 174(2):209-18.
16. Das S, Misra RC, Patnaik MC, Das SR (2010) GxE interaction, adaptability and yield stability of mid-early rice genotypes. Indian journal of agricultural research 44(2):104-11.