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STUDY ON DIFFERENT STABILITY PROCEDURES FOR YIELD OF RICE GENOTYPES (*Oryza sativa* L.)

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Abstract: Genotypic expression over environments is referred to as genotype by environment interaction (G x E) and is a main challenge faced by the plant breeders. Looking to the several methodologies applied for stability, it was thought to apply the different stability procedures (Eberhart and Russell (1966), Ecovanlence W_i^2, Shukla Stability variance σ_i^2, Hanson's genotypic stability D_i^2, Cultivar performance measure Pi and Hernandez*et al.* D_i) for assessment of the stability of different genotypes by using the same set of data on rice. Spearman rank correlation coefficients were worked out to assess the association between different stability measures. Twenty genotypes of late maturing group were tested at four locations of Gujarat statealong with one check GR-103 during *kharif*-2006. In the combined ANOVA, significance of genotype variance indicated the genetic diversity among genotypes yield. All the three components in Eberhart and Russell model, i.e. environment (Lin.), GxE (Lin.) and pooled deviations were found highly significant and accounted for 86.8, 7.9 and 5.2 per cent of total variance of environment and GEI.Genotypes NWGR-3006, IET-19140, IET-19123, IET-19147 and IET-19160 were found stable and adaptable to all the environments. Genotype IET-19146 was stable and well adaptable to favorable environment, whereas NWGR-3213, IET-19132 and GR-103 were found suitable for poor environment with lower yield. According to Ecovalence (W_i^2) and Shukla's stability variance (Sh-σ_i^2), the genotypes IET-19147 and NWGR-3006were the most stable with yield ranks of 3rd and 8th, respectively. Lower value of D_i^2 were observed for genotypes IET-19132 and GR-103 indicating stable but they were low yielding genotypes.On the basis of P_i values, IET-19147 was the most stable genotype followed by IET-19123 which ranked second highest in grain yield. The highest D_i values of genotypes IET-19140 and IET-19123 indicated them as stable genotypes. Near to perfect positive rank correlation coefficients were observed between rank of grain yield and stability parameters D_i (0.900). Positive and highly significant rank correlation coefficient (0.671) was observed between yield rank and rank of P_i (0.671), whereas negative significant rank correlation (-0.803) was observed between rank of D_i and D_i^2. Rank correlation coefficient of bi-Eber and S^2_{di} was observed highly significant with W_i^2 and Sh-σ^2. Perfect positive rank correlation coefficient between Ecovalence W_i^2 and Sh-σ^2 indicated that the two procedures were almost similar for ranking purpose. Positive and significant rank correlation coefficient of P_i was observed with D_i, W_i^2, Sh-σ^2.

INTRODUCTION

Genotypic expression over environments is referred to as genotype by environment interaction (G x E) and is a main challenge faced by the plant breeders. Significant G x E interaction indicates that all phenotypic responses of genotypes to varying agro-ecological

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conditions are not consistent. Some genotypes may perform well in some environments but not so well in others and thus the relative ranking of genotypes change from location-to-location and/or from year-to-year. The interplay in the effect of genetic and non-genetic on development is termed as 'genotype-environment interaction' (Comstock and Moll, 1963). GxE interactions hasgreater importance in plant breeding as they reduce the stability of genotypic values under diverse environments. The impact of the environment on phenology and growth varies depending on the crop species, crop variety and growth stages.

Looking to the several methodologies applied for stability, it was thought to examine all of them on the same set of data. Therefore, different stability procedures *viz.,* most commonly used method Eberhart and Russell (1966) and stability parametrs*viz.,* C.V.% (Francis and Kannenberg, 1978), Ecovanlence W_i^2 (Wricke, 1962), Shukla's Stability variance Sh-σ_i^2 (Shukla, 1972), Hanson's genotypic stability D_i^2 (1970), Cultivar performance measure P_i (Lin and Binns, 1988) and Hernandez *et al.* D_i (1993), were used to assess the stability of different genotypes by using the same set of data on rice.Spearman rank correlation coefficients were worked out to assess the efficiency of ranking the genotypes by different stability measures. The present investigation in rice (*Oryza sativa* L.) was therefore planned to compare different statistical methods for assessing the stability of different genotypes and to study the association between different stability statistics by using the Spearman rank correlation.

MATERIALS AND METHODS

Twenty one genotypes of late maturing group of rice were tested at Nawagam, Vyara, Dabhoi and Thasrahaving diverse soil type and rainfall pattern as well as weather parameters in *kharif* season.

The experimentswere laid outin randomized complete block design (RCBD) with two replications for all trials under study. Net Plot size was 4.2m x 2.2m for each location under study. Inter and intra raw spacing was 20cm and 15cm, respectively in each location. Normal cultural practices and plant protection measures were followed in each trial.

The yield data on multi-location trials (MLT) were analysed on individual and pooled basis as per RBD. The same data were also used to estimate different stability parameters (1) Eberhartand Russell model, (mean performance of genotype, regression coefficient, (b_i) and deviation from regression (S^2_{di} (2) Ecovalence (W_i^2), Wricke (1962) defined it as the measure of stability. It is the contribution of each genotype to the GEI sum of square across environment. (3) Shukla's stability variance (Sh-σ_i^2) (1972) based on the residual ($GE_{ij}+e_{ij}$)

matrix in a two-way classification. (4) Hanson's (1970) genotypic stability (D_i^2) based on regression analysis and uses the minimum slope from Eberhart and Russell's analysis. Genotypes are identified as desirable if they have low D_i^2 values. (5) Lin and Binns (1988a) gave superiority measure P_i (Cultivar performance measure) as 'cultivar general superiority' and defined it as 'the distance mean square between the cultivar's response and the maximum response over locations'. Genotypes are identified as desirable if they have low Pi value. (6) Hernandez *et al.* (1993) defined this index as "the area under the linear regression function divided by the difference between the two extreme environmental indices" Genotypes are identified as desirable if they have high D_i values. Spearman rank correlation were work out to study the association between different stability parameters.

RESULT AND DISCUSSION

Yield data of 21 rice genotypes collected from the Main Rice Research Station, Nawgam, Anand Agricultural University, Anand were subjected to analysis of variance for individual location as well as pooled over locations. The Analysis of Variance (ANOVA) presented in Table 1 indicated that the variance for genotypes was found significant in all the locations except E3 (Dabhoi) location. This suggests the presence of genetic variability among the genotypes under study in most of the locations (Anandan*et al.*(2009), Ozberk, (2005), Sharma *et al*. (1998) and Shinde*et al*. (2002)). The coefficient of variation (C.V. %) ranged from 3.97 (E4, Thasra) to 18.09 (E3, Dabhoi). Looking to environmental index, the environment E1 was high yielding, whereas the environment E2, E3 and E4 were found low yielding environment.

Result of analysis of variance over locations presented in Table 2 gave the overall picture of the relative magnitude of the genotypes (G), locations (E) and genotype-environment interaction (GEI) variance. The combined ANOVA revealed that genotype, environment and genotype-environment interaction were highly significant and contributed 7.8, 80.1 and 12.1 per cent of trial variation (Gauch and Zobel, 1997; Kaya *et al*., 2006 and Pourdad and Mohmmadi, 2008). Significant genotypes indicated genetic diversity among genotypes yield. The mean yield of genotypes over environment ranged from 3.288 kg plot^{-1}(G3) to 5.426 kg plot^{-1} (G10) (Table 4) (Shinde*et al*., 2004).

Eberhart and Russell model

Result of analysis of variance as per Eberhart and Russell (1966) are presented in Table 3, which indicated that the sum of squares for genotype x environment interaction (GEI) was found significant which accounted for 12.1% variance of trial variance (Table 2).

In stability analysis, environment and GEI component were further partitioned into environment (linear), G x E (linear) and pooled deviations from regression.

ANOVA (Table 3) indicated that the sources of variation for Environment + (G x E) was found highly significant. All the three components i.e. environment (Lin.), G x E (Lin.) and pooled deviations were found highly significant and accounted for 86.8, 7.9 and 5.2 per cent of total environment and GEI (Majmudar and Borthakur, 1991;Maurya and Singh, 1977; Shinde *et al*., 2004; Laghari *et al*., 2003 and Hugo-Ferney *et al*., 2006).

The stability parameters for all the genotypes are given in Table 4. Rank of b_i valuesare given on the basis of b_i-1. In present study the regression coefficient (b_i) values ranged from 0.071 (IET-19132) to 1.63 (IET-19143). All the values of bi were found significant when tested for β_i=0 except for G15 and found non-significant for βi=1 except for genotypes NWGR-3213 (G6), IET-19132 (G15), IET-19143 (G17), IET-19146 (G20) and GR 103 (G21). Out of twenty one genotypes thirteen had non-significant S^2_{di} which indicated their stability over environments.

Genotypes NWGR-3006 (G7), IET-19140 (G10), IET-19123 (G12), IET-19147 (G13) and IET-19160 (G14) had higher mean yield, unit regression coefficient (b_i=1) and non-significant $S^2_{di.}$ Thus they were stable, high yielding genotypes which can be adapted to all the environments. Genotype G20 had higher mean than overall mean, b_i significantly greater than 1, non-significant S^2_{di}. Therefore, G20 was stable and well adaptable to favorable environment, whereas G6, G15 and G21 were found suitable for poor environment with lower yield. Genotypes G4 (NWGR-3132) G5 (NWGR-3199), G8 (NWGR-2018), G9 (NWGR-2032) G18 (IET19189) and G19 (IET-1917) were found unstable due to their significant S^2_{di} values (Seboksa *et al*., 2001; Akcura *et al*., 2005 and Arshad *et al*., 2003; Laghari *et al*., 2003).

These results are also presented through Figure 1. It is apparent from the graph that the point for G3 and G10 deviated from the zone of interception of the two vertical ($\overline{X} \pm \sigma$) and the horizontal (bi ± σ) lines. Genotypes G1, G2, G5, G7, G9, G13, G14, G16 and G19 fall into the interception of the two vertical and the horizontal lines indicated that these genotypes have average adaptability (Akcura *et al*.,2005 and Ahmed *et al*., 2009).

Wricke'secovalence (W_i^2)

The ecovalence term was used for the relative contribution of genotype ‘i’ to the overall genotype-environment interaction (Wricke, 1962) and considered the GEI mean square as the criteria for stability. The minimum W_i^2 indicates the stable genotypes. The ecovalence values

(W_i^2) were worked out for rice genotypes over four locations and are presented in Table 5. The results indicated that the genotypes G13, G7, G16, G2 and G6 had the lowest ecovalence values and therefore, would be considered to be the most stable. The ranks of these genotypes for yield were 3, 8, 13, 18 and 11, respectively. Ecovalence values for G16, G2, and G6 were lower but they had lower mean yield than overall mean yield. Genotype G15 produced higher ecovalence values and lower mean yield, whereas G17 produced higher ecovalence and higher mean yield and considered as most unstable genotypes (Carvalho*et al.*, 1983; Chandrasiri *et al.*,2002; Brancourt-Hulmel and Leconite, 2003 and Mekbib, 2003).

Shukla's stability variance (Sh-σ_i^2)

Shukla (1972) proposed partitioning of GEI sum of square into variance components (σ_i^2) corresponding to each of the genotypes. On the basis of these variance components, a genotype is stable if its stability variance (σ_i^2) is equal to environmental variance (σ_o^2), which mean that Sh-σ_i^2 = 0. A relatively large value of σ_i^2 indicate higher instability of genotype 'i', whereas stable genotypes are those having minimum stability variance (σ_i^2). This approach is considered of practical importance because it identifies environmental factors that contribute to the heterogeneity in the GEI.

Results for stability variance and overall means are summarized in Table 5 for grain yield of rice with their ranking order. Results indicated that the most stable genotypes were IET-19147 (G13), NWGR-3006 (G7) and IET-19114 (G16) and their respective rank for grain yield were 3, 8 and 13. Genotype G16 ranked 13th position for yield indicating lower yield. The genotypes G15, G17 and G8 had poor stability according to this procedure. Among these genotypes, G15 gave lower grain yield than overall mean yield. Results obtained for W_i^2 and Sh-σ_i^2 stability methods were at par for measuring stability and the same was also reported by Albert (2004), Purchase (1997), Bhargave *et al.* (2005), and Mekbib (2003).

Hanson's genotypic stability D_i^2

Hanson (1970) gave the concepts of relative genotypic stability as the measures of homeostasis which measures the proximity between two genotypes. D_i^2 were worked out for all the genotypes and are presented in Table 5. Lower value of D_i^2 were observed for genotypes G15, G21 and G3 and it can be concluded that these genotypes were stable and ranked 12th, 20th and 21st for grain yield, respectively. All the three genotypes had lower grain yield than overall mean. Genotype G17, G20 and G10 had higher D_i^2 values and they were considered as unstable genotypes. G10 ranked first for mean yield and remaining two occupied 5th and 9th rank for grain yield of rice (Bhargava*et al.*,2007 and Dehghani*et al.*, 2008).

Cultivar performance measure (P_i)

Lin and Binns (1988) proposed Cultivar performance (Pi) as the mean squares of distance between genotypes i and 'i' where 'i' is the genotype with maximum response over all locations. The smaller the value of P_i, the smaller the distance to the genotype with maximum yield, the better the genotype. P_i values were measured on overall locations mean, it represents superiority in the sense of general adaptability (wide adaptation). Table 5 presents the cultivar performance measure (P_i) for grain yield of rice. On the basis of P_i values, G13 was the most stable genotype followed by G12, G8 and G14 of which G12 ranked second highest in grain yield. The most unstable genotypes according to this analysis were G3, G21 and G17 of which G3 and G21 were low yielder and G17 was high yielder as compared to overall mean (Aremu *et al.*, 2007b; Lin and Binns, 1988a; Dashiell *et al.*,1994 and Purchase, 1997).

Desirability index (D_i)

Hernandez *et al.* (1993) proposed a desirability index that would combine both yield and regression coefficient. They defined this index as "the area under the linear regression function divided by the difference between the two extreme environmental indices". Genotypes with high D_i values are desirable. If the difference between the minimum and the maximum environmental indices is zero the trial is symmetric otherwise asymmetric. D_i depends largely on mean yields in symmetric trials whereas for the later the slopes have a large impact on D_i. D_i values given in Table 5 indicated that genotypes G10, G12, G17 and G18 had the highest D_i values and were stable but genotypes G3, G21 and G15 were unstable. The rank of genotypes for D_i value and mean yield were partially superimposing each other (Dehghani *et al.*, 2008; Bilgin and Korkut, 2000 and Mohebodini *et al.*,2006).

Spearman rank correlation and stability parameters comparison

Spearman's rank correlation coefficient was used to compare the ranks and relationships among stability parameters (Table 6). Correlation results revealed that for six stability procedures and overall means, some were positively and others negatively correlated. About perfect positive correlation coefficients were observed between grain yield rank and rank of stability parameters D_i (0.900). This indicated that these parameters are in close agreement with yield rank. Positive and highly significant rank correlation coefficient was observed between yield rank and P_i (0.671), whereas negative significant rank correlation was observed with D_i^2 (-0.500). Mohebodini *et al.* (2006) observed significant rank correlation coefficient between mean yield and P_i and D_i (desirability index).Rank correlation coefficient of bi-Eber and S^2_{di} was observed highly significant with W_i^2 and Sh-σ^2. In case of Ecovalence W_i^2, perfect positive rank correlation coefficient was observed with Sh-σ^2. This indicated that the two procedures were equivalent for ranking purpose. Positive and significant rank correlation coefficient of Pi was observed with D_i, W_i^2, Sh-σ^2 whereas negative significant rank correlation was observed between D_i and D_i^2 (-0.803).

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Table 1: Analysis of variance for individual location.

Source	df	Mean squares			
		Nawagam (E1)	Vyara (E2)	Dabhoi (E3)	Thasra (E4)
Replication	1	0.0437	0.0003	0.4484	0.0748
Genotype	20	2.3901**	1.1002**	0.8317	0.4176**
Error	20	0.2169	0.0537	0.4724	0.0219
C.V. (%)	-	6.72	7.68	18.09	3.97
Overall mean (kg plot^{-1})	-	6.922	3.017	3.799	3.725
Yield range (kg plot^{-1})	-	4.400-8.662	1.500-4.300	2.260-4.900	3.070-4.857
Environmental Index	-	2.556	-1.349	-0.567	-0.640

** Significant at 1 per cent level of probability

Table 2: Analysis of variance for Pooled over locations.

Sources of variation	Df	SS	SS (%)	MS
Repl/Environments	4	0.57	--	0.142
Environments	3	381.64	80.1	127.213**
Genotypes	20	36.97	7.8	1.849**
G x E	60	57.83	12.1	0.964**
Pooled error	80	15.30		0.191
Total	167			

** Significant at 1 per cent level of probability

Table 3: Analysis of variance for Stability model (Eberhart and Russell model, 1966).

Sources of Variation	df	SS	MS	%
Genotypes	20	18.4843	0.9242*	--
Env.+ (G x E)	63	219.7287	3.4878**	100.0
Environment(Lin.)	1	190.8186	190.8186**	86.8
G x E (Lin.)	20	17.4015	0.8701**	7.9(60.2)
Pooled Deviation	42	11.5086	0.2740**	5.2(6.0)
Pooled Error	80	7.6496	0.0956	--
Total	167	--	--	--

* and ** significant at 5 and 1 per cent level of probability, respectively

Table 4: Stability parameters of different rice genotypes (Eberhart and Russell model, 1966).

Sr. No.	Genotype	Mean Yield (kg plot^{-1})	Rank	bi-Eber	Rank	S^2di	Rank
G1	NWGR-3026	4.165	17	1.085*	5	0.210+	14
G2	NWGR-3113	4.017	18	0.906*	8	0.067	7
G3	NWGR-3215	3.288	21	0.754*	16	0.170	12
G4	NWGR-3132	4.534	7	1.182*	11	0.249+	15
G5	NWGR-3199	4.265	16	0.912*	6	0.386+	17
G6	NWGR-3213	4.334	11	0.809*@	12	-0.059	4
G7	NWGR-3006	4.470	8	1.083*	4	-0.046	3
G8	NWGR-2018	4.410	10	0.732*	17	0.480+	20

G9	NWGR-2032	3.910	19	0.976*	1	0.427+	19
G10	IET-19140	5.426	1	1.231*	15	0.039	2
G11	IET-19148	4.278	15	1.216*	14	0.137	10
G12	IET-19123	5.351	2	1.131*	9	0.109	9
G13	IET-19147	4.634	3	0.909*	7	-0.060	5
G14	IET-19160	4.579	4	1.081*	3	0.164	11
G15	IET-19132	4.327	12	0.071@	21	0.191	13
G16	IET-19114	4.322	13	1.028*	2	-0.003	1
G17	IET-19143	4.574	5	1.636*@	20	0.638+	21
G18	IET-19189	4.565	6	1.197*	13	0.376+	16
G19	IET-19117	4.292	14	1.136*	10	0.421+	18
G20	IET-19146	4.424	9	1.297*@	18	-0.064	6
G21	GR-103	3.515	20	0.631*@	19	-0.093	8
	Overall mean	4.366					

*significant for β = 0 and @ significant for β = 1 at 5 per cent level of probability
+ significant at 5 per cent level of probability
bi-Eber = Regression coefficient (Eberhart and Russell, 1966)

Table 5: Different measures of stability for twenty one rice genotypes over environments.

Sr. No.	Genotypes	Mean Yield (kg plot^{-1})	Rank	W^2_i	Rank	Sh-σ_i^2	Rank	D_i^2	Rank	P_i	Rank	D_i	Rank
G1	NWGR-3026	4.165	17	0.676	8	0.224	8	8.453	13	3.013	13	4.820	15
G2	NWGR-3113	4.017	18	0.406	4	0.124	4	5.163	7	3.079	16	4.564	17
G3	NWGR-3215	3.288	21	1.081	15	0.373	15	3.274	3	5.026	21	3.743	21
G4	NWGR-3132	4.534	7	0.990	12	0.340	12	10.405	16	2.778	10	5.247	5
G5	NWGR-3199	4.265	16	1.033	13	0.355	13	5.902	8	2.668	9	4.816	16
G6	NWGR-3213	4.334	11	0.406	5	0.124	5	3.526	4	2.452	5	4.822	14
G7	NWGR-3006	4.470	8	0.163	2	0.035	2	7.916	11	2.535	7	5.124	9
G8	NWGR-2018	4.410	10	1.806	19	0.640	19	3.619	5	2.432	3	4.852	13
G9	NWGR-2032	3.910	19	1.052	14	0.362	14	6.991	9	3.456	18	4.499	18
G10	IET-19140	5.426	1	0.754	9	0.253	9	10.998	19	2.504	6	6.169	1
G11	IET-19148	4.278	15	0.889	11	0.302	11	10.881	17	3.055	14	5.012	10
G12	IET-19123	5.351	2	0.566	6	0.183	6	9.125	14	2.152	2	6.034	2
G13	IET-19147	4.634	3	0.148	1	0.029	1	4.951	6	2.066	1	5.182	8
G14	IET-19160	4.579	4	0.579	7	0.188	7	8.295	12	2.443	4	5.232	6
G15	IET-19132	4.327	12	8.424	21	3.078	21	-0.928	1	3.246	17	4.369	19
G16	IET-19114	4.322	13	0.192	3	0.046	3	7.013	10	2.665	8	4.943	12
G17	IET-19143	4.574	5	5.142	20	1.869	20	22.228	21	4.180	19	5.562	3
G18	IET-19189	4.565	6	1.295	18	0.452	18	10.963	18	2.816	11	5.287	4
G19	IET-19117	4.292	14	1.202	16	0.418	16	9.845	15	2.922	12	4.978	11
G20	IET-19146	4.424	9	0.866	10	0.294	10	12.229	20	3.074	15	5.207	7
G21	GR-103	3.515	20	1.239	17	0.431	17	1.362	2	4.563	20	3.896	20

Table 6: Spearman's rank correlation between ranks of mean yield and stability parameters

	Mean Yield	bi-Eber	S^2_{di}	W_i^2	Sh-σ_i^2	D_i^2	P_i	D_i
Mean Yield	1.000							
bi-Eber	-0.047	1.000						
S^2_{di}	0.190	0.162	1.000					
W_i^2	0.222	0.651**	0.758**	1.000				
Sh-σ_i^2	0.222	0.651**	0.758**	1.000**	1.000			
D_i^2	-0.500*	0.010	0.099	-0.005	-0.005	1.000		
P_i	0.671**	0.387	0.312	0.542**	0.542**	-0.056	1.000	
D_i	0.900**	-0.003	0.109	0.196	0.196	-0.803**	0.514*	1.000

* and ** significant at 5 and 1 per cent level of probability, respectively

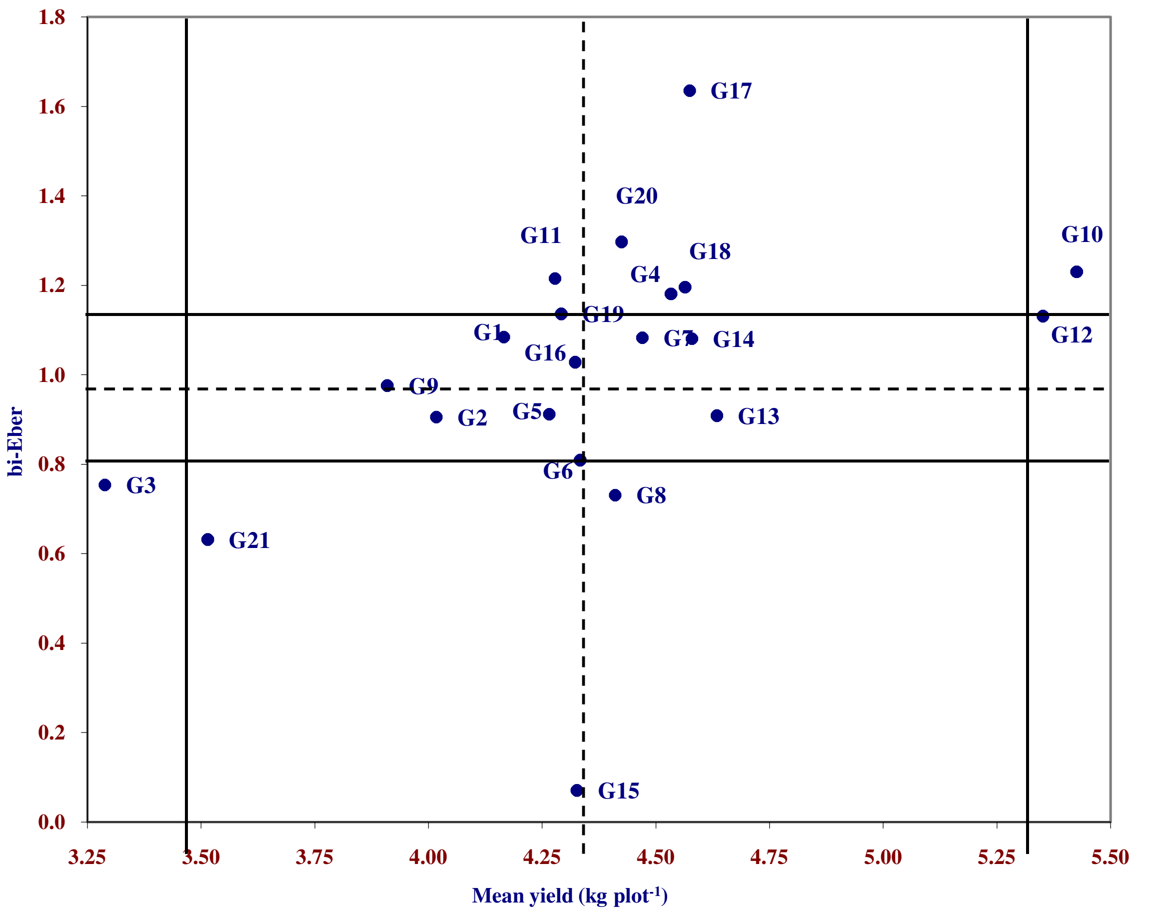

Figure 1: Average yield and linear regression coefficients of rice genotypes