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Genotype x Environment Relations and Stability Analysis in Different Land Races of Maize (*Zea mays* L.)

R.A. Gami[1*], J.M. Patel[2], S.M. Chaudhary[1] and G.K. Chaudhary[3]

[1]Maize Research Station, S.D. Agricultural University, Bhiloda-383 245 (Gujarat), India
[2]Wheat Research Station, S.D. Agricultural University, Vijapur (Gujarat), India
[3]Department of Agriculture Statistics, CPCA, S.D. Agricultural University, Sardarkrushinagar (Gujarat), India
**Corresponding author*

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A B S T R A C T

G X E interaction and stability analysis carried out in three consecutive years at Maize Research Station, S. D. Agricultural University, Bhiloda to evaluate 51 different land races of maize. The analysis of variance for stability showed that mean squares due to environments were statistically significant for all the traits except grain yield indicating that variability among environments was large enough for a proper estimation of 'b' values. The G x E interaction was significant for four traits *viz.*, plant height, ear height, cob weight and shelling percentage. The stability parameters for plant height showed that LR-09 was stable over the environments while, land races LR-24 and LR-51 were top among all land races for stability parameter for ear height. The land race LR-50 was ideally stable for Cob weight per plot as it exposed higher mean (2.08), near unit regression coefficient (b_i=1.17) and non-significant deviation of regression coefficient from zero (s^2d_i= -0.047). In case of shelling (%) land races LR-48 and LR-12 registered maximum shelling percentage and fulfill other parameter (b_i and S^2d_i values) of stability.

Introduction

Maize (*Zea mays* L.; 2n=20) is one of the most important economic cereal crops of the world. It was domesticated over the past 10,000 years from the grass teosinte in Central America (Doebley *et al.*, 2006) and has been subject to cultivation and selection ever since. It ranks one of the three important cereal crops in the world after wheat and rice for production and consumption. Maize is a monoecious plant, that is, the reproductive organs are partitioned into separate pistillate (ear), the female flower and staminate (tassel) inflorescence, the male flower on the same plant. It has a determinate growth habit and the shoot terminates into the inflorescences bearing staminate or pistillate flowers (Dhillon and Prasanna, 2001). Maize is the staple food of Asian people and is also utilized in starch, oil, food and feed industries. It is used as the major cereal in the local population in the form of local/stable foods for daily diet. Green cobs are either roasted or boiled and then consumed by people. It is also a good feed for poultry, piggery, swine, fish and other domestic animals. It supplies raw materials for manufacturing various industrial products. Maize grain contains about 70% starch, 9.9% protein, 4% oil and 2.7% crude fiber.

Stability of genotypes depends on maintaining certain morphological and physiological attributes steady and allowing others to vary, resulting in predictable G x E interaction for yield. Study of individual yield components can lead to simplification in genetic explanation of yield stability and hence are valuable to breeders in prediction and determination of the effects of the environments. Phenotype may be defined as a linear function of genotype (G), environment (E) and (G x E) interaction effect. Relative importance of main and interaction effects may vary from genotype to genotype and with environments. Thus, the study of G x E interaction serves as a guide and helps in identifying suitable genotypes for various environmental niches.

Materials and Methods

The experiment was conducted in three consecutive years in randomized block design at Maize Research Station, S. D. Agricultural University, Bhiloda during *kharif* 2014- 2016 to evaluate 51 different land races of maize. Each genotype was grown in two rows of 3m length with 60 x 20 (cm^2) spacing. The size of net plot was $3.6m^2$ and each plot >90 per cent plant population were maintained. The data were recorded from five randomly selected plants from each entry in each replication for plant height (cm), ear height (cm), 100 seed weight (g) and shelling (%) whereas days to 50 % tasseling, days to 50% silking days to 75 % dry husk were recorded on visual basis per plot while number of cobs and cob weight measured from plot basis. The grain yield (kg/ ha.) for each genotype was estimated by reducing grain moisture content to 15% with step wise formula. (a) grain yield at observed grain moisture content [☐ cob yield (kg/plot) at harvest x Multiple factor for ha x shelling proportion (%)], (b) grain dry matter content = 1- moisture per cent at harvest, (c) grain yield at 15% grain moisture content = [(grain yield at observed grain moisture content x grain dry matter content)/0.85], (d) grain yield at 15 % grain moisture content = [(grain yield at 15% grain moisture content)/100]. The mean of the data recorded over years were used for statistical analysis. The analysis of variance was calculated with the method suggested by Panse and Sukhatme, 1985. The statistical analysis for G x E interaction and stability parameters were carried out according to the Eberhart and Russell (1966).

Results and Discussion

The presence of G x E interactions reduces the correlation between phenotype and genotype, and makes it difficult to judge the genetic potential of a genotype. Stability of a cultivar refers to its consistency in performance across environments and is affected by the presence of G x E interactions. In presence of significant G x E interactions, stability parameters are estimated to determine the superiority of individual genotypes across the range of environments. Eberhart and Russell (1966) defined a stable genotype as one which produces high mean yield, depicts regression coefficients (b_i) around unity and non-significant deviations from regression (S^2d_i).

The linear response (b_i) should be simply regarded as a measure of response of a particular genotype, whereas the deviation from regression (S^2d_i) is regarded as a measure of stability. Becker *et al.,* (1982) regarded mean square for deviation from regression (S^2d_i) to be the most appropriate criterion for measuring phenotypic stability in an agronomic sense because this parameter measures the predictability of genotypic reaction to environments.

The Analysis of variance for individual environment revealed significant mean squares due to genotypes for days to 50% pollen shed, cob weight per plot, 100 seed weight and grain yield per hector in all tested years (Table 1). In pooled analysis of variance, the genotypic variance were significantly higher for plant height, ear height and grain yield, whereas environmental variances were significantly high for all the characters. The variances due to G x E interaction were observed significant for all the traits except ear height. This indicated very high influence of environments on the expression of yield and attributing traits in maize land races under study (Table 2). The analysis of variance for stability (Table 3) showed that mean squares due to environments were statistically significant for all the traits except grain yield indicating that variability among environments was large enough for a proper estimation of 'b' values. The G x E interaction was significant for four traits *viz.*, plant height, ear height, cob weight and shelling percentage. Such significant interaction encourage maize breeder to develop variety/hybrid under varied environment condition. Therefore, stability parameters of the land races worked out for these four characters (Table 5). Similar findings in maize were also reported by Nirla and Jha (2003), Soliman (2006), Dadheech and Joshi (2007) and Patel (2015) for yield and yield attributing traits.

The environment + (genotype x environment) interaction was also observed to be significant for all traits except number of cobs per plot and grain yield per ha. Indicating considerable interaction of genotype with environment and the distinct nature of environment and genotype x environment interaction in phenotypic expression. Further, partitioning of the environment + (genotype x environment) component into environment (linear) revealed the significance of environment (linear) component for all the traits except days to 75% dry husk and grain yield per ha, indicating that micro seasonal difference were presented under all the three year studies and forecast over year was possible. The higher magnitude of mean square for environment (linear) as compared to G x E (linear) indicated that linear response of environment accounted for major part of the total variance for all the traits and might be responsive for high adaptation of the genotype in relation to yield and other component trait. Further, the mean square due to genotype x environment (linear) were also significant for plant height, ear height, cobs, weight per plot and shelling (%), similar trend in maize for yield attributes also reported earlier Kaundal and Sharma (2006), Lata *et al.,* (2010) and Nadagoud *et al.,* (2012). While in case of mean square for pooled deviation (non-linear) were also observed to be significant for days to 75 % dry husk, number of cobs per plot, cobs weight per plot, 100 seed weight and grain yield. This is indicating that both linear and non-linear component may be contributing to the genotype x environment interaction observed for these traits. Dadheech and Joshi (2007), Jai Dev *et al.,* (2010) and Patel (2015) also reported similar findings in maize for yield and yield attributing traits.

An overall study of stability parameters revealed that not a single genotype was ideally stable for all the four characters. According to Eberhart and Russell (1966), a stable genotype would have approximately high mean with b_i=1 and S^2d_i=0. Whereas according to Johnson *et al.,* (1955), Paroda *et al.,* (1973) and Lin *et al.,* (1986) the squared deviation from regression as a measure of a stability while the regression was considered as measure of response, considering these parameter out of 51 land races studies, 15 top-ranked land races based on stability parameters identified (Table 4).

Table.1 Analysis of variance for individual environments

Sources of variation	d.f.	Days to 50% Pollenshed	Days to 50% Silking	Days to 75% Dryhusk	Plant Height(cm.)	Ear Height(cm.)	Number of Cobs per Plot	Cob wt. per Plot (Kg)	100-seed weight	Shelling (%)	Grain yield (kg/ha)
ENVIRONMENT – I											
Replication	1	3.92	6.13	0.09	333.37	29.01	6.63	0.022	1.14	25.10	17323.88
Genotype	50	5.99*	5.65	4.60	521.24*	342.89	10.95	0.262**	18.21*	14.57	898715.50*
Error	50	3.22	3.59	5.79	272.34	219.59	7.74	0.122	10.45	12.72	525577.28
SEm±		1.27	1.34	1.70	11.67	10.48	1.97	0.25	2.29	2.52	512.63
ENVIRONMENT – II											
Replication	1	0.48	0.09	5.65	434.41	194.36	10.04	0.257	0.19	60.57	461785.75
Genotype	50	3.87**	4.06	6.40**	272.69	276.62**	5.33	0.159**	15.33**	186.88**	1725060.46**
Error	50	1.46	4.19	2.89	367.44	125.05	3.94	0.071	5.93	106.56	643524.12
SEm±		0.85	1.45	1.20	17.85	7.91	1.40	0.19	1.72	7.30	567.24
ENVIRONMENT – III											
Replication	1	0.35	1.41	20.75	118.20	8.77	4.75	0.155	0.41	9.24	329872.21
Genotype	50	8.05**	10.25	18.26*	455.28**	309.57**	10.12*	0.56**	14.69**	39.29**	2792128.73**
Error	50	3.03	5.23	9.27	146.38	66.09	5.47	0.130	4.69	12.32	663670.65
SEm±		1.23	1.62	2.15	8.56	5.75	1.65	0.26	1.53	2.48	576.05

*, ** Significant at P = 5 and 1 per cent levels, respectively.

Table.2 Pooled analysis of variance over environments for different characters in maize

Sources of variation	d.f.	Days to 50% Pollenshed	Days to 50% Silking	Days to 75% Dryhusk	Plant Height(cm.)	Ear Height(cm.)	Number of Cobs per Plot	Cob wt. per Plot (Kg)	100-seed weight	Shelling (%)	Grain yield (kg/ha)
Genotype	50	6.69	6.76	9.68	718.51**	590.08**	6.42	0.368	18.75	96.95	2369360.0**
Environment	2	872.52**	740.02**	1472.57**	31150.39**	13123.34**	292.17**	1.37**	1189.20**	1013.25**	2580829.0**
G x E	100	5.61**	6.60**	9.83**	265.35	169.50	9.99**	0.306**	14.74**	71.89**	1523272.**
Pooled error	150	2.57	4.34	5.98	352.05	136.91	5.72	0.108	7.02	43.87	610924.0

*, ** Significant at 5 and 1 per cent levels, respectively when tested against pooled error.

Table.3 Analysis of variance (mean squares) for stability for various traits in maize

Sources of variation	d.f.	Days to 50% Pollenshed	Days to 50% Silking	Days to 75% Dryhusk	Plant Height (cm.)	Ear Height (cm.)	Number of Cobs per Plot	Cob wt. per Plot (Kg)	100-seed weight	Shelling (%)	Grain yield (kg/ha)
Genotypes	50	3.34	3.38	4.84	359.26**	295.04**	3.21	0.184**	9.37	48.47**	1184682
Environments	2	436.26**	370.01**	736.28**	15575.27**	6551.63**	146.09**	0.686**	594.59**	506.58**	1290455
G x E	100	2.81	3.30	4.91	132.67**	84.75**	5.00	0.15*	7.37	35.95**	761635.3
E + (G x E)	102	11.30**	10.49**	19.26**	435.47**	211.75**	7.76	0.16*	18.89**	45.18**	772004.3
Environment(Linear)	1	872.5**	740.02**	1472.55	31150.54**	13123.27**	292.17**	1.37**	1189.14**	1013.16**	2580910
Genotype x Environment (Linear)	50	3.12	3.79	2.90	216.17**	136.14**	2.89	0.21**	7.82	57.21**	626183.4
Pooled deviation	51	2.44	2.76	6.79**	48.21	32.70	6.96**	0.09**	6.78**	14.40	8794497.3**
Pooled error	150	1.29	2.17	2.99	176.04	68.45	2.86	0.054	3.51	21.94	305462.6
Total	152	8.69	8.15	14.51	410.40	239.15	6.26	0.17	15.76	46.26	907753.5

*, ** Significant at 5 and 1 per cent levels, respectively when tested against pooled deviation

Table.4 Stable land races based on mean, regression coefficient (b_i) and deviation from regression ($S^2 d_i$) yield component in maize

Sr. No.	**Plant Height (cm.)**				**Ear Height (cm.)**				**Cob wt. per Plot (Kg)**				**Shelling (%)**			
	Genotype	**Mean**	**b_i**	**$S^2 d_i$**	**Genotype**	**Mean**	**b_i**	**$S^2 d_i$**	**Genotype**	**Mean**	**b_i**	**$S^2 d_i$**	**Genotype**	**Mean**	**b_i**	**$S^2 d_i$**
1.	LR-47	206.2	0.98	-80.17	LR-24	85.7	1.01	-56.89	LR-01	1.52	1.04	-0.002	LR-48	82.0	0.94	-20.77
2.	LR-09	192.9	1.03	-66.73	LR-51	97.1	0.98	-60.00	LR-11	1.67	1.08	-0.047	LR-12	78.1	0.89	-20.68
3.	LR-46	197.9	1.03	-175.38	LR-30	101.7	1.04	-44.65	LR-50	2.08	1.17	-0.047	LR-20	80.3	1.16	-18.20
4.	LR-12	202.8	1.04	-150.08	LR-45	121.1	0.94	-38.65	LR-38	1.58	0.81	-0.038	LR-49	64.9	1.24	218.9
5	LR-45	207.4	0.96	-34.90	LR-26	98.9	0.90	-64.44	LR-12	1.87	1.22	-0.013	LR-07	77.7	1.29	-16.11
6	LR-41	205.4	1.04	-137.60	LR-11	95.4	0.87	45.59	LR-10	1.58	0.77	-0.049	LR-51	82.7	0.65	-9.61
7	LR-34	200.7	0.94	-162.20	LR-50	117.4	1.13	-58.68	LR-32	1.80	0.61	0.113	LR-27	75.8	0.59	-19.93
8	LR-21	192.4	0.93	-122.6	LR-09	106.1	0.83	56.57	LR-51	1.96	0.57	0.137	LR-39	75.1	1.45	-18.89
9	LR-11	179.9	0.92	-132.9	LR-01	81.5	1.19	0.74	LR-48	1.65	0.46	0.059	LR-25	77.2	0.51	3.06
10	LR-03	178.5	0.91	-119.5	LR-03	92.8	0.77	37.30	LR-07	1.54	0.37	0.204*	LR-08	78.4	0.47	-21.27
11	LR-28	207.1	0.89	-175.4	LR-32	110.3	1.24	-58.70	LR-03	1.79	0.30	-0.050	LR-06	76.0	0.43	-10.29
12	LR-32	205.3	1.13	-171.1	LR-48	96.9	0.75	-67.20	LR-09	1.74	1.81	0.005	LR-45	75.7	0.43	-16.98
13	LR-48	196.9	1.14	-80.2	LR-39	120.6	1.25	-17.69	LR-23	1.65	1.82	0.024	LR-37	75.7	0.36	-6.02
14	LR-15	198.2	1.16	-158.3	LR-22	95.8	1.27	-50.9	LR-34	2.00	0.06	-0.053	LR-19	70.5	1.71	3.14
15	LR-05	220	1.20	-167.3	LR-34	110.3	0.71	-42.9	LR-40	1.93	1.95	-0.022	LR-46	77.9	1.86	-21.71
	Mean (µ)	**193.80**			**Mean (µ)**	**103.70**			**Mean (µ)**	**1.85**			**Mean (µ)**	**76.91**		
	S.Em.±	**4.90**			**S.Em.±**	**4.00**			**S.Em.±**	**0.21**			**S.Em.±**	**2.68**		

The stability parameters for plant height showed that LR-09 was stable over the environments as it register minimum plant height, unit regression coefficient (b_i=1.03) and non-significant deviation from regression. In case of ear height land race LR-24 and LR-51 stood top among all genotype for stability parameter as it registered minimum height (cm), 85.7 and 97.1 respectively, unit regression coefficient and non-significant deviation from regression. The land race LR-50 was ideally stable for Cob weight per plot as it exposed higher mean (2.08), near unit regression coefficient (b_i=1.17) and non-significant deviation of regression coefficient from zero (s^2d_i= -0.047). In case of Shelling (%) two land races were found top ranked among stable genotype, viz., LR-48 and LR-12 as they registered maximum shelling percentage and fulfill other parameter (b_i and S^2d_i values) of stability. Earlier Kaundal and Sharma (2006), Javed *et al.*, (2006), Jai Dev *et al.*, (2010) and Nadagoud *et al.*, (2012) have also identified stable maize genotype based on phenotypic stability analysis across the environment.

The result of present investigation revealed that since no single land races genotype found stable for all the traits. However LR-09 for plant height, LR-24 for ear height, while LR-50, was ideal stable for Cob weight per plot. These land races may further tested at multi-location for confirmation of present findings.

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