Genotype x Environment Interaction and Stability Analysis in Maize Across the Southern Aravalli Ranges of Rajasthan

ABSTRACT

Crop production is the function of genotype, environment and their interaction (GEI) and evaluation of genotypes in multi environments helps to identify their adaptation and stability. The 45 hybrids along with their 18 parents and two check cultivars were evaluated in three environments *viz.*, E1 (*Kharif*-2019, Instructional Farm, RCA, Udaipur), E2 (*Kharif* -2019, Agriculture Research Sub-Station, Vallabhnagar, Udaipur) and E3 (*Rabi*-2019-2020, Instructional Farm, RCA, Udaipur) in randomized block design with three replications at each environment to assess the phenotypic stability of genotypes by using Eberhart and Russel (1968). The mean squares due to genotypes and environments were found significant for all the traits under study indicated inherent genetic differences among the genotypes. The G x E (linear) interaction was found significant for most of the traits under study The mean squares due to pooled deviation were found non-significant for all the traits indicated major portion of the genotype x environment interaction was formed by predictable portion. The majority of the hybrids depicted non-significant deviations from regression (S^2d_i) for grain yield per plant indicated their predictable response across the environments. A great majority of genotypes revealed non-significant non-linear estimates (S^2d_i) for different traits under the study indicated the prediction of stability was more or less accurate and reliable. The top three hybrids suitable for all environments ($b_i \approx 1$) were EI-2653 x EI-102, EI-2639 x EI-670 and EI-2505 x EI-102 with non-significant S^2d_i values. The hybrids EI-2176-3 x EI-03 ($b_i<1$) EI-2525-2 x EI-03 ($b_i>1$) and EI-2159 x EI-670 ($b_i>1$) out yielded the best check cultivar CC-1. Thus, these hybrids may be used in future breeding programmes of maize after further multi location yield testing.

Key Words: Stability Analysis, Genotype x Environments, Southern Aravalli Ranges, Rajasthan, Maize

1. Introduction:

Maize (*Zea mays* L.; 2n = 20) or corn which literarily means “that which sustains life” [1] is one of the versatile and multi utility grain crop. The crop has with its huge ears, packed with starch and oil [2]. it is a allogamous species, belongs to the monocot family Poaceae, Genus *Zea* and Species *mays*. It is third important food crop after rice and wheat in terms of area and production and staple food crop for 4.5 billion people of the world [3]. It is grown in 196.76 million-hectare area, with a total production of 1162.38 million metric tonnes, and average productivity of 5.91 metric tonnes per hectare around the world [4]. In India, it is grown in 9.20 million hectare area with a total production of 28.00 million metric tonnes, and average productivity of 3.04 metric tonnes per hectare [4]. Amid growing population around the world, the demand for maize is expected to double by 2050 and in Indian context the projected demand is expected to be 42 million tonnes by the year 2025 [5]. The climate change is projected to reduce maize production globally by 3-10 per cent by 2050 [6]. The single cross hybrids of maize play a crucial role in increased maize production [7] and food security. It is estimated that the maximum part of the increasing food demand in near future fulfilled from maize [8] and half of the increased world food demand in terms of cereals as a whole will be produced from maize [9]. Crop production is the function of genotype, environment and their interaction (GEI). Quantitative genetic traits, such as yield, are characterized by cumulative actions of many factors which include gene effects and effects due to the interaction of genotype and environment. A significant G x E interaction for a quantitative trait such as grain yield can seriously limit the efforts on selecting superior genotypes for improved cultivar development [10]. The differential responses of genotypes and cultivar performance across environments have a key role for assessment of performance stability of the breeding materials [11]. Thus, plant breeders develop cultivars adapted to a wide range of diversified environments or to specific environment to gain advantage of environment stimuli in terms of grain yield. The potential of genotypes should be assess at different environments (locations and years or both) before selecting desirable ones for release and commercial cultivation. Thus in view of the above facts and in order to select stable single cross hybrids, the present investigation was carried out to derive information on the G x E interaction and stability parameters.

2. Materials and Methods:

The 45 hybrids of maize were developed through line x tester mating design using 15 lines and 3 testers during *Rabi Season*-2017-2018. These 45 hybrids, 18 parents and two checks were evaluated in three environments *viz.*, E1 (*Kharif Season*-2019, Instructional Farm, Rajasthan College of Agriculture, Udaipur), E2 (*Kharif Season*-2019, Agriculture Research Sub-Station, Vallabhnagar, Udaipur) and E3 (*Rabi Season*-2019-2020, Instructional Farm, Rajasthan College of Agriculture, Udaipur) in randomized block design with three replications at each environment. The each treatment was sown in single row plot of 4.0 m length with geometry of 60 x 20 cm row to row and plant to plant spacing, respectively. The Udaipur district is located in the Aravalli Hill Ranges of Southern part of the Rajasthan with latitude 24°35'31.5" longitudes 73°44'18.2" with an altitude of 582.17 meters above mean sea level. The Vallabhnagar is located in Bhinder town of Udaipur district of Rajasthan State with latitude 24°40′23″ longitudes 74°00′09″ with an altitude of 495.00 m above mean sea level. The soil of both experimental field locations were clay loam, deep, well drained, alluvial in origin and have good moisture holding capacity. All the agronomic practices recommended by the Department of Agriculture, Government of Rajasthan for Zone IV-A (Sub-Humid Southern Plains of Rajasthan State) were used to raise a healthy crop. The data were recorded for 9 traits including phenological, grain yield and other component traits on five randomly plants selected from each plot in each replication. The phenotypic stability of genotypes for different characters was estimated according to model proposed by Eberhart and Russell (1966) [12]. The regression coefficient (b_i) of genotypes was tested using t-test for their significance, whereas significance of deviation from regression (S^2d_i) of genotypes was tested by F test.

3. Results and Discussion:

The ANOVA for all the nine traits under study (Table 1) affirmed significant mean squares due to genotypes indicating inherent genetic variability among the genotypes. The mean squares due to environments were found significant for all the nine traits indicating the differences among the environments and their role in character expression. The MSS due to [E+(G x E)] was found highly significant for all the traits which further confirms the distinct nature of environments and their interaction with genotypes. The highly significant mean squares due to environment linear component were observed for all the traits under study indicating considerable additive environmental variance for all the traits and further confirmation of existence of environmental differences under study. The MSS due to G x E linear component were also found significant for majority of the traits against pooled error indicated that the linear sensitivity of different genotypes was considerably variable under the study. On comparison of relative magnitude of linear (genotype x environment linear) and non-linear (pooled deviation) components, a greater role of linear component was found for the traits days to 50 per cent tasseling, days to 50 per cent silking, days to 75 per cent brown husk and grain yield per plant towards the genotype x environment interactions. While, almost equal contribution of both components was found for the traits plant height, ear length, ear girth, grain row per ear and test weight. The major part of the genotype x environment interaction was formed by predictable portion under the study as indicating by non-significance of MSS due to pooled deviation (non-linear portion). These results were found in general agreement with the findings of Ogunbodede *et al.* [13], Patel and Kathiria, [14], Bharathiveeramani *et al.* [15], Ahmad *et al.* [16], Synrem *et al.* [17] and Sowmya *et al.* [18] in maize.

A genotype having high mean performance, with b_i values around unity ($b_i \approx 1$) and deviation from regression (S^2d_i) close to zero is considered stable genotype across environments according to stability model of Eberhart and Russel [12]. The linear regression (b_i) of a genotype is the measure of response to the environment fluctuations, whereas deviation from regression (S^2d_i) is the measure of stability of the genotype. The significant magnitude of deviations from regression S^2d_i for a genotype indicates its unpredictable response or behavior towards different environments and their imprecise and unreliable prediction of stability. In the present investigation stability of genotypes were decided on the basis of their regression coefficient (b_i) and mean values in desirable direction, further genotypes having significant magnitude S^2d_i were not considered for their stability. The mean of genotypes in positive direction (mean>over all mean) were considered desirable for all the traits under the study except for the three phenological traits as well as for plant height (mean<over all mean). The mean (X), linear regression (b_i) and deviations from regression values (S^2d_i) of all the genotypes for different traits are presented in Table 2.1 to 2.2.

The 9 of the 18 parents recorded lower mean than over all mean with non-significant non-linear estimates for days to 50 per cent teaseling and among them three parents EI-2505, EI-2522 and EI-2639 were found stable ($b_i \approx 1$). Among the 45 hybrids, 17 hybrids depicted lower mean for this trait than over all mean with non-significant S^2d_i and among them, hybrids EI-2188 x EI-03, EI-2639 x EI-03, EI-2172 x EI-102, EI-2403 x EI-102, EI-2639 x EI-670, EI-2159 x EI-670, EI-2505 x EI-670, EI-2507 x EI-670 and EI-2525-2 x EI-102 were found stable ($b_i \approx 1$) towards all environments. The 8 parents and 12 hybrids divulged lower mean than grand mean with non-significant deviation from regression for days to 50 per cent silking and among them, single parent EI-2639 ($b_i \approx 1$) and hybrids EI-2188 x EI-03, EI-2639 x EI-03, EI-2525-2 x EI-102, EI-2159 x EI-670, EI-2188-1 x EI-670, EI-2505 x EI-670 and EI-2507 x EI-670 were found stable ($b_i \approx 1$) across the environments for this trait. For days to 75 per cent brown husk, 9 parents and 21 hybrids possessed below mean than over all mean with non-significant non-linear estimates and among them, single parent EI-2172 and hybrids EI-2188 x EI-03, EI-2642 x EI-03, EI-2159 x EI-670, EI-2507 x EI-670 and EI-2653 x EI-670 were found average sensitive ($b_i \approx 1$) towards different environments and adaptable to all environments conditions.

For all the above three phenological traits, hybrids EI-2188 x EI-03, EI-2159 x EI-670, and EI-2507 x EI-670 (mean<grand mean) were found stable ($b_i \approx 1$) with non-significant deviation from regression indicating their suitability for earliness under all environments. Similar findings of selection of stable genotypes for phenological traits were also reported by Djurovic *et al.* [19], Patel and Kathiria, [14], Bharathiveeramani *et al.*[15], Owusu *et al.* [20], Sowmya *et al.* [18], Raj *et al.* [21] and Arun kumar *et al.* [22] in maize.

The 15 parents and 10 hybrids depicted their lower mean than over all mean with non-significant deviations from regression for the trait plant height. The only parent EI-2188-1 ($b_i \approx 1$) and hybrids EI-2188 x EI-102 ($b_i \approx 1$) exhibited b_i values around unity with non-significant magnitude of S^2d_i indicating their average sensitivity towards changing environments and adaptable to all environments for the trait plant height. Raj *et al.* [21] and Arun kumar *et al.* [22] also reported stable hybrids lower plant stature in maize.

For the trait ear length, 3 parents and 25 hybrids divulged their mean values greater than over all mean with non-significant non-linear estimates. Out of the 25 above hybrids, the only hybrid EI-2188-1x EI-102 was found average stable ($b_i \approx 1$) and exhibited their adaptability towards all environments. The three superlative hybrids suitable for input rich environment ($b_i > 1$) were EI-2653 x EI-03, EI-2525-2 x EI-670 and EI-2507 x EI-670 with non-significant non-linear estimates. Similarly, The three top hybrids suitable for poor environment ($b_i < 1$) conditions were EI-2188 x EI-670, EI-2505 x EI-102 and EI-2507 x EI-102 with non-significant magnitude of S^2d_i.

Out of the 18 parents and 45 hybrids, 4 parents and 24 hybrids presented above mean values than over all mean for the trait ear girth with non-significant non-linear estimates. None of the parent and hybrid found suitable for all environment conditions for this trait. Among the above 24 hybrids (mean>over all mean), the three superlative hybrids found suitable for input rich environments ($b_i > 1$) with good management practices were EI-2188 x EI-670, EI-2507 x EI-03 and EI-2525-2 x EI-102, whereas EI-2188 x EI-03, EI-2403 x EI-670 and EI-2507 x EI-102 were the three top hybrids found suitable for harsh environment conditions ($b_i < 1$) with non-significant non-linear estimates for the trait ear girth.

The 4 parents and 24 hybrids revealed higher mean values than grand mean for the trait grain rows per ear with non-significant non-linear estimates. The three premier hybrids found suitable for input rich environments ($b_i > 1$) were EI-2642 x EI-670, EI-2639 x EI-102 and EI-2642 x EI-102, whereas EI-2639 x EI-670, EI-2188-1 x EI-102 and EI-2178 x EI-03 hybrids were found suitable for poor environment conditions ($b_i < 1$) with non-significant non-linear estimates (S^2d_i) for this trait.

For the trait 100-grain weight, the 24 of the 45 hybrids and 9 of the 18 parents depicted mean values higher than over all mean with non-significant non-linear estimates. The single hybrid EI-2525-2 x EI-670 was found stable ($b_i \approx 1$) across the environments with non-significant non-linear estimates. The three superlative hybrids found suitable for input rich environment ($b_i > 1$) were EI-2653 x EI-03, EI-2507 x EI-670 and EI-2159 x EI-670, whereas the top three hybrids found suitable for poor environments (($b_i < 1$) were EI-2639 x EI-03, EI-2642 x EI-102 and EI-2172 x EI-03 with non-significant non-linear estimates for this trait.

The 31 hybrids depicted their higher mean values than over all mean for the trait grain yield per plant with non-significant magnitude of deviations from regression values (S^2d_i). The top three stable ($b_i \approx 1$) hybrids were EI-2653 x EI-102, EI-2639 x EI-670 and EI-2505 x EI-102 with non-significant non-linear estimates. The three superlative hybrids found suitable for input rich environment ($b_i > 1$) were EI-2525-2 x EI-03, EI-2159 x EI-670 and EI-2522 x EI-03 with non-significant deviations from regression (S^2d_i). Similarly, three top hybrids found suitable for poor environments ($b_i < 1$) were EI-2176-3 x EI-03, EI-2505 x EI-670 and EI-2653 x EI-03 with non-significant non-linear estimates for the trait grain yield per plant. Similar findings of selection of genotypes for yield and component traits were also reported by Karadavat and Akili, [23], Ahmad *et al.* [16], Synrem *et al.* [17] and Arunkumar *et al.* [22] in maize.

4. Conclusion:

The stability parameters of genotypes (18 parents, 45 hybrids and 2 checks) for different traits divulged that none of the hybrid or parent was found stable for all the traits under study. According to their regression coefficient (b_i), a total of 5 hybrids for all environments ($b_i \approx 1$), 12 hybrids for input rich environments ($b_i > 1$) and 14 hybrids for poor environment ($b_i < 1$) were found suitable for the trait grain yield per plant. The magnitude of deviation from regression (S^2d_i) of genotypes for grain yield per plant revealed that a great majority of genotypes (41 hybrids, 17 parents 2 checks) depicted non-significant S^2d_i, indicated bulk of genotypes responded in predictable manner. The varied magnitude of regression coefficient (b_i) and deviation from regression (S^2d_i) of genotypes was found under the study for different traits possibly due to presence of different set of alleles for stability in them. The genotypes selected in the present study for different environments were diverse and random. A great majority of genotypes revealed non-significant non-linear estimates (S^2d_i) for different traits under the study indicated the prediction of stability was more or less accurate and reliable. Thus from the stability analysis, the top three hybrids suitable for all environments ($b_i \approx 1$) were EI-2653 x EI-102, EI-2639 x EI-670 and EI-2505 x EI-102. The top three hybrids EI-2525-2 x EI-03, EI-2159 x EI-670 and EI-2522 x EI-03 for input rich environments ($b_i > 1$), whereas hybrid EI-2176-3 x EI-03, EI-2505 x EI-670 and EI-2653 x EI-03 for poor environments ($b_i < 1$) found suitable under the study for grain yield per plant. Among them, hybrids EI-2525-2 x EI-03 ($b_i > 1$), EI-2159 x EI-670 ($b_i > 1$) and EI-2176-3 x EI-03 ($b_i < 1$) out yielded the best check CC-1 under the study for grain yield per plant. Thus, these hybrids may be used in future breeding programmes of maize after further evaluation at both spatial and temporal levels with increased number of environments to validate the stability.

Competing Interests:

Authors have declared that no competing interests exist.

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Table 1 Analysis of variance for stability analysis (Eberhart and Russel Model, 1966) in maize for different traits under the study

S. No	Source of variations	d.f.	Mean sums of squares								
			Days to 50 per cent tasseling	Days to 50 per cent silking	Days to 75 per cent brown husk	Plant Height (cm)	Ear length (cm)	Ear girth (cm)	Grain rows per ear	100-grain weight (g)	Grain yield per plant (g)
1	Genotypes	64	18.48**	16.7**	16.36**	840.02**	4.02**	2.88**	3.55**	15.97**	667.5**
2	Environment	2	71191.38**	76663.15**	83262.74**	2837.36**	65.3**	33.39**	31.26**	118.53**	3191.44**
3	Env. + (G x E)	130	1098.36**	1182.5**	1284.94**	89.89**	1.38**	0.99**	0.91**	2.54**	77.76**
4	Env. (linear)	1	142382.76**	153326.3**	166525.47**	5674.72**	130.6**	66.78**	62.53**	237.06**	6382.88**
5	G x E (linear)	64	5.15**	4.78**	7.33**	46.91	0.45	0.41	0.4	0.99**	44.3**
6	Pooled deviations	65	1.16	1.43	0.74	46.28	0.31	0.55862	0.47	0.47	13.7
7	Pooled error	390	1.03	0.78	0.84	15.09	0.34	0.223	0.37	1.39	8.69

* and ** represent level of significance at 5 and 1%, respectively

Table 2.1 The three parameters of stability model of Eberhart and Russel (1966) for different traits in maize

S. No	Genotypes	Days to 50 per cent tasseling			Days to 50 per cent silking			Days to 75 per cent brown husk			Plant Height (cm)			Ear length (cm)		
		Mean	**b_i**	**S^2d_i**	**Mean**	**b_i**	**S^2d_i**	**Mean**	**b_i**	**S^2d_i**	**Mean**	**b_i**	**S^2d_i**	**Mean**	**b_i**	**S^2d_i**
1	EI-2159 X EI-03	78.22	0.92**#	-1.03	81.11	0.95**#	-0.57	109.33	0.96**#	-0.51	139.19	1.16**	-14.26	12.06	1.10	1.08*
2	EI-2172 X EI-03	79.44	0.94**#	-0.82	81.33	0.98**#	-0.67	108.11	0.87**#	-0.32	132.67	1.63*	23.83	12.73	0.93**	-0.33
3	EI-2176-3 X EI-03	79.78	0.97**≠	-0.63	82.22	0.99**	-0.2	111.22	1.05**	-0.74	176.60	0.98*	-2.14	13.64	1.26**	0.03
4	EI-2178 X EI-03	76.78	1.02**	3.89*	79.22	0.98**	8.38**	109.11	1.00**	2.9*	155.72	1.25	92.05**	13.51	0.13	2.0**
5	EI-2188 X EI-03	72.78	1.02**	-0.68	76.22	1.01**	-0.72	105.89	0.99**	-0.78	140.08	0.07	31.17	14.67	0.83**	-0.31
6	EI-2188-1 X EI-03	78.22	1.05**	-0.99	80.67	1.02**	-0.88	106.78	1.09**	-0.13	154.82	-0.02#	-10.24	12.98	0.81**	-0.32
7	EI-2403 X EI-03	77.67	1.05**	-1.11	79.67	1.04**	-0.22	111.00	1.00**	-0.34	164.37	0.21	28.16	14.31	1.11**	-0.15
8	EI-2448 X EI-03	74.33	1.06**	-0.82	76.89	1.09**	0.42	107.33	1.06**	-0.66	149.96	1.55*	22.66	13.43	0.24≠	-0.12
9	EI-2505 X EI-03	77.78	1.04**	-0.89	79.67	1.04**	-0.71	105.89	1.08**	0.09	176.62	-0.19	18.74	11.82	0.08#	-0.27
10	EI-2507 X EI-03	80.89	0.90**#	0.33	83.22	0.93**#	0.33	109.78	1.05**	2.55*	151.92	1.20	68.3*	15.25	1.74**	-0.31
11	EI-2522 X EI-03	72.11	0.93**	1.74	75.33	0.91**≠	2.54*	103.56	0.96**	1.47	157.48	1.24	130.78**	14.03	1.44**	-0.22
12	EI-2525-2 X EI-03	78.00	1.03**	-0.68	80.67	1.03**	0.18	110.67	1.03**	-0.83	170.34	1.09*	2.69	15.12	0.69**#	-0.34
13	EI-2639 X EI-03	73.78	1.01**	-1.06	76.22	1.00**	-0.74	105.00	1.06**	-0.79	142.49	0.83	106.75**	14.71	1.71**	0.09
14	EI-2642 X EI-03	74.00	0.97**	-0.25	76.78	0.97**	1.36	102.22	1.00**	1.18	167.43	2.65**	-0.38	13.04	0.63**#	-0.3
15	EI-2653 X EI-03	80.33	0.94**#	-0.93	82.11	0.92**≠	1.76	111.67	0.95**#	-0.95	149.40	0.97	125.07**	16.00	1.27	0.51
16	EI-2159 X EI-102	79.33	1.00**	7.48**	81.56	0.99**	2.7*	106.00	0.97**	0.48	140.49	2.02*	42.86	13.41	1.12**	-0.33
17	EI-2172 X EI-102	74.22	1.01**	1.24	77.44	0.98**	3.88*	107.00	0.94**	3.13*	151.34	1.64	85.22*	13.65	1.02**	-0.30
18	EI-2176-3 X EI-102	79.78	1.02**	-0.79	83.00	1.03**	0.18	109.89	0.95**#	-0.43	175.39	0.21≠	-1.74	13.75	0.84**#	-0.34
19	EI-2178 X EI-102	76.44	1.05**	1.89	79.56	1.05**	0.36	107.67	1.07**	-0.66	171.69	1.73	51.04*	12.02	0.96**	-0.33
20	EI-2188 X EI-102	77.78	0.97**	1.55	80.89	0.96**≠	-0.15	108.55	0.99**	-0.71	156.18	-0.98#	26.31	13.73	0.70	0.15
21	EI-2188-1 X EI-102	78.67	0.99**	-0.94	81.55	0.95**#	-0.34	107.00	0.96**	3.04*	172.65	1.00	106.98**	13.98	1.00**	-0.29
22	EI-2403 X EI-102	73.67	1.00**	2.22	76.00	1.00**	2.75*	104.89	0.96**#	-0.36	165.76	-0.36	69.26*	15.43	2.18**	-0.23
23	EI-2448 X EI-102	81.00	0.95**#	-0.85	83.22	0.99**#	-0.73	110.78	1.02**	-0.69	158.99	0.21	-0.41	12.37	0.4**#	-0.33
24	EI-2505 X EI-102	77.78	1.00**	-0.74	80.22	1.00**	-0.45	111.89	0.99**≠	-0.77	169.64	1.08**	-14.54	15.18	0.96	0.19
25	EI-2507 X EI-102	73.78	0.96**	3.77*	76.44	0.95**	4.25*	106.56	0.96**	0.51	173.87	1.73**	-14.4	15.18	0.62**#	-0.34
26	EI-2522 X EI-102	78.55	1.07**	0.41	81.56	1.06**	4.48**	110.89	1.09**	-0.83	151.99	1.46**	-4.91	12.3	1.18**	0.03
27	EI-2525-2 X EI-102	75.67	0.99**#	-1.02	79.22	0.98**	-0.43	104.56	1.03**	-0.89	159.26	1.5**	0.10	15.46	1.67**	0.12
28	EI-2639 X EI-102	78.45	0.88**#	-0.89	80.56	0.92**#	-0.67	110.89	0.94**#	-0.07	142.22	0.88*	-2.35	12.37	0.73	0.10
29	EI-2642 X EI-102	77.33	0.9**#	-0.87	79.55	0.89**#	-0.13	108.78	0.91**#	-0.75	175.91	0.54	46.64*	15.29	2.35**	0.06
30	EI-2653 X EI-102	78.78	1.04**	-0.88	81.11	1.04**	-0.77	109.33	1.03**	-0.86	147.36	0.20	56.13*	14.08	1.14	0.43
31	EI-2159 X EI-670	75.22	0.99**	-0.87	78.22	0.99**	0.6	105.55	1.01**	-0.30	156.67	1.80	268.05**	14.07	0.61	0.11
32	EI-2172 X EI-670	75.00	1.03**	9.25**	78.22	1.04**	7.39**	106.66	1.08**	-0.93	164.50	1.49	129.1**	12.95	0.46	1.16*
33	EI-2176-3 X EI-670	75.00	0.94**#	-0.93	78.11	0.96**	0.36	105.00	0.94**#	-0.91	177.40	1.39**	-2.29	14.16	1.26**	-0.16

S. No	**Genotypes**	**Days to 50 per cent tasseling**			**Days to 50 per cent silking**			**Days to 75 per cent brown husk**			**Plant Height (cm)**			**Ear length (cm)**		
		Mean	**b_i**	**S^2d_i**	**Mean**	**b_i**	**S^2d_i**	**Mean**	**b_i**	**S^2d_i**	**Mean**	**b_i**	**S^2d_i**	**Mean**	**b_i**	**S^2d_i**
34	EI-2178 X EI-670	79.33	1.03**	4.14*	82.00	1.02**	10.1**	104.67	1.07**	-0.66	168.03	0.06≠	2.64	13.76	1.60**	-0.04
35	EI-2188 X EI-670	80.33	1.01**	-1.05	83.11	0.98**	0.40	105.11	0.97**	1.45	138.24	0.37	9.72	15.56	0.97**	-0.28
36	EI-2188-1 X EI-670	72.22	0.97**	-0.41	75.33	0.98**	1.06	103.11	0.97**#	-0.66	154.19	0.21	320.17**	14.04	0.19	0.14
37	EI-2403 X EI-670	78.00	0.93**#	-1.11	80.11	0.93**#	-0.56	108.45	0.97**	-0.30	156.91	1.63*	24.91	15.1	1.9**	-0.32
38	EI-2448 X EI-670	75.00	0.93**#	0.24	78.22	0.94**≠	1.03	107.78	0.92**#	-0.57	166.07	0.69	17.14	14.25	1.08*	0.12
39	EI-2505 X EI-670	75.33	0.98**	-0.33	78.00	0.99**	-0.38	107.89	1**	1.19	173.43	0.85*	-1.87	13.94	0.77**	-0.27
40	EI-2507 X EI-670	73.22	1.01**	-0.95	76.34	0.99**	1.85	106.33	1**	-0.26	164.31	1.7**	-11.93	15.68	1.47**	-0.29
41	EI-2522 X EI-670	79.11	1**	-0.27	81.22	1**	-0.22	107.22	1.05**	-0.74	156.80	-0.79#	14.85	13.85	0.72**#	-0.33
42	EI-2525-2 X EI-670	78.22	0.98**	-0.31	80.56	0.97**#	-0.72	109.44	1.08**	-0.68	179.80	1.29**	-10.83	15.87	1.59*	0.6
43	EI-2639 X EI-670	76.67	1.01**	-0.86	80.78	1.02**	-0.78	108.56	1.04**	-0.5	152.45	1.13**	0.32	15.18	1.6*	0.85
44	EI-2642 X EI-670	77.78	1.02**	0.02	80.44	1.02**	0.17	106.22	1.05**	-0.74	176.69	1.56**	-7.32	14.8	1.09**	-0.18
45	EI-2653 X EI-670	73.67	1.05**	-0.67	76.22	1.03**	1.15	106.11	1**	-0.74	146.99	0.32	50.58*	14.47	1.28**	0.02
46	EI-2159	80.00	0.99**	-0.69	82.44	1.01**	-0.64	109.11	0.92**#	-0.78	121.27	1.93**	26.21	12.7	0.89**	-0.27
47	EI-2172	75.22	1.04**	-1.01	77.89	1.06**	-0.46	104.33	1**	-0.43	126.68	1.53**	-5.5	12.07	0.37	-0.02
48	EI-2176-3	76.11	1.05**	-0.99	79.45	1.04**	0.13	106.44	1.05**	1.89	144.46	1.04**	-14.96	13.04	0.34**#	-0.33
49	EI-2178	78.00	0.99**	-0.77	80.67	0.99**	0.61	108.00	0.94**≠	0.82	138.69	0.47**#	-14.4	11.86	0.68	1.68*
50	EI-2188	75.67	1.08**	-0.75	78.22	1.05**	-0.09	107.22	1.04**	-0.37	122.16	1.66**	9.2	13.58	1.19**	-0.34
51	EI-2188-1	79.11	0.97**≠	-0.68	81.67	0.99**#	-0.77	106.44	0.89**#	-0.8	130.19	0.98**	-14.2	12.24	0.95**	-0.08
52	EI-2403	73.11	1.04**	-0.62	76.11	1.04**	0.14	105.00	1.06**	-0.79	131.12	1.77**	13.77	14.46	1.09**	-0.3
53	EI-2448	78.22	0.92**#	0.35	81.67	0.93**#	0.04	108.56	0.93**#	-0.83	139.71	1.68**	2.62	13.4	0.37**#	-0.34
54	EI-2505	71.22	1.01**	0.04	73.67	1.03**	-0.68	104.89	0.93**#	-0.83	149.53	0.05#	-13.27	12.83	1.74**	-0.34
55	EI-2507	77.11	1.1**	4.43*	79.67	1.08**	0.37	108.89	1.04**	-0.82	148.49	1.24	86.28**	14.51	1.09**	-0.26
56	EI-2522	73.89	1.02**	-1.09	76.55	1.03**	-0.72	104.67	0.97**	1.68	116.51	1.52**	-0.67	11.77	1	0.75
57	EI-2525-2	78.00	1**	-0.87	80.78	1.02**	-0.78	107.78	1**	-0.96	139.83	1.38**	-8.29	13.99	0.72**#	-0.34
58	EI-2639	75.33	1.01**	-0.88	77.67	1.02**	0.13	106.56	1.07**	0.26	114.98	1.67**	15.59	12.83	0.96**#	-0.34
59	EI-2642	79.11	1.07**	4.23*	81.78	1.05**	0.72	110.67	0.99**	1.05	144.58	1.47	93.55**	13.71	1.08**	-0.34
60	EI-2653	72.45	0.95**#	-0.97	74.78	0.94**#	-0.55	104.11	0.96**#	-0.4	130.46	1.92**	18.67	13.04	0.44≠	-0.2
61	EI-03	78.55	1.04**	-0.78	81.33	1.03**	-0.73	109.11	1.01**	-0.77	147.34	0.4*#	-12.16	12.93	1.02**	-0.25
62	EI-102	75.11	1.07**	-1.13	78.11	1.09**	-0.48	103.11	1.08**	-0.67	143.76	1.05*	2.19	12.79	0.98**	-0.23
63	EI-670	78.56	1.05**	-1.03	80.78	1.05**	-0.37	109.56	1.01**	0.59	155.95	0.4≠	-10.27	14.11	0.64**#	-0.33
64	CC-1	77.00	1.03**	-0.97	80.22	1**	-0.22	108.00	1.01**	-0.94	176.02	1.64**	-5.6	16.03	0.97**	-0.34
65	CC-2	79.11	1.01**	-1.08	81.55	0.99**	-0.05	109.00	1**	-0.42	178.37	0.01#	-14.12	15.14	1.08**	-0.28
Grand Mean		76.77			79.46			107.46			153.45			13.85		

* and ** represent significance at 5 and 1%, respectively

≠ and # represent significance at 5 and 1%, respectively when tested against unity

Table 2.2 The three parameters of stability model of Eberhart and Russel (1966) for different traits in maize

S. No	Genotypes	Ear girth (cm)			Grain rows per ear			100-grain weight (g)			Grain yield per plant (g)		
		Mean	**b_i**	**S^2d_i**	**Mean**	**b_i**	**S^2d_i**	**Mean**	**b_i**	**S^2d_i**	**Mean**	**b_i**	**S^2d_i**
1	EI-2159 X EI-03	12.19	1.06	0.45	12.69	0.37**#	-0.35	28.79	1.61**	-0.58	83.07	1.16**	-4.55
2	EI-2172 X EI-03	12.52	0.62*	-0.16	13.24	-0.28	0.37	31.14	0.73**#	-1.36	70.22	1.07**	-8.65
3	EI-2176-3 X EI-03	13.77	0.81	0.34	13.58	0.54	0	29.52	0.85**	-1.32	106.00	0.86	72.08
4	EI-2178 X EI-03	12.49	1	1.06*	14.18	0.66	0.04	23.57	0.84	2.66	64.89	1.42**	-8.58
5	EI-2188 X EI-03	14.05	0.62**≠	-0.20	12.97	1.43**	-0.36	25.20	1.19**	-1.35	83.30	1.06**	-0.53
6	EI-2188-1 X EI-03	11.91	0.31	1.32**	14.39	1.22*	-0.02	28.95	0.71	-0.58	64.50	1.28**	-4.26
7	EI-2403 X EI-03	13.34	0.52	0.05	14.74	1.39**	-0.11	29.53	1.15**	-1.33	75.32	1.6**	-5.64
8	EI-2448 X EI-03	12.63	-0.3#	0.02	12.44	-0.77#	-0.37	29.70	1.11**	-1.37	73.19	0.81**#	-8.37
9	EI-2505 X EI-03	11.04	1.66**	-0.04	14.67	2.14**	-0.24	30.57	0.93**	-1.13	81.04	0.67**#	-8.69
10	EI-2507 X EI-03	14.29	1.41*	0.13	13.77	0.28	-0.06	25.89	0.48*#	-1.25	79.62	0.67	12.81
11	EI-2522 X EI-03	12.85	2.15**	0.08	13.77	1.19**	-0.31	25.68	0.76**#	-1.36	89.21	1.03**	-8.48
12	EI-2525-2 X EI-03	13.74	0.69	0.11	13.39	1.36**	-0.32	26.56	1.23**	-1.27	109.22	1.51**	5.93
13	EI-2639 X EI-03	13.60	2.3*	0.59	13.91	0.54	-0.09	31.55	0.33#	-1.28	86.09	0.56**#	-6.79
14	EI-2642 X EI-03	13.16	-0.2#	-0.07	14.37	1.73**	-0.36	23.79	1.25**	-1.24	73.36	1.45**	-3.44
15	EI-2653 X EI-03	14.58	0.73	1.14*	15.02	0.69	2.89**	30.55	1.15**	-1.31	88.73	-0.46#	-7.83
16	EI-2159 X EI-102	13.30	3.03**	0.04	13.36	-0.32#	-0.27	26.45	0.96**#	-1.39	86.64	0.78**≠	-7.58
17	EI-2172 X EI-102	13.21	1.39*	0.08	12.27	0.36	0.81	29.58	1.05**	-1.37	52.23	0.56**#	-6.04
18	EI-2176-3 X EI-102	13.15	-0.2#	-0.22	12.90	1.16*	-0.18	27.65	1.32**	-1.21	82.83	1.72**	-5.81
19	EI-2178 X EI-102	11.08	1.13	0.16	13.22	0.88	0.01	31.29	0.44	-0.06	89.15	3.40	286.33
20	EI-2188 X EI-102	13.43	1.28**	0.02	15.04	1.78*	0.06	27.27	0.97	0.35	78.06	0.54**#	-6.02
21	EI-2188-1 X EI-102	13.34	-0.26	0.84*	15.10	0.63	-0.13	29.64	-0.55#	-1.29	76.89	0.77**≠	-7.42
22	EI-2403 X EI-102	13.66	1.72**	0.08	12.88	0.22≠	-0.25	30.29	0.55	-0.54	78.78	0.98**	-8.64
23	EI-2448 X EI-102	12.67	0.22#	-0.18	13.73	0.7	1.02	31.59	0.57**≠	-1.29	80.06	1.02**	-8.64
24	EI-2505 X EI-102	14.19	1.26*	0.08	13.83	1.39**	-0.31	27.06	0.9**	-1.34	81.90	0.99**	-8.07
25	EI-2507 X EI-102	13.97	0.26	0.21	13.27	1.22**	-0.26	27.72	0.72	1.64	61.63	0.82**	-6.92
26	EI-2522 X EI-102	11.70	1.53	0.66*	11.80	0.52	1.26*	29.24	0.34	-0.21	73.53	0.98**	-3.53
27	EI-2525-2 X EI-102	14.28	1.38*	0.08	14.86	1.6**	-0.34	23.75	1.73**	-0.26	77.46	0.96**	-7.32
28	EI-2639 X EI-102	11.44	1.07**	-0.09	15.79	1.21	0.41	25.94	0.18#	-1.33	85.37	1.8**	-7.87
29	EI-2642 X EI-102	14.21	1.74	3.50**	15.65	1.12**	-0.34	25.34	0.21#	-1.25	67.83	1.06	29.6*
30	EI-2653 X EI-102	14.15	1.45**	-0.22	14.51	2.51**	-0.26	28.66	1.22**	-1.38	92.73	0.98**	-4.44
31	EI-2159 X EI-670	13.46	0.61**≠	-0.20	13.18	0.42	-0.04	30.18	2.05**	-1.37	101.78	1.59**	-4.23
32	EI-2172 X EI-670	12.15	1.27**	-0.22	14.10	1.93*	0.37	26.77	1.79**	-1.29	79.41	0.79	7.43
33	EI-2176-3 X EI-670	13.32	0.84**	-0.21	12.46	0.31	0.18	28.38	0.71	-0.01	94.33	3.28**	121.92**
34	EI-2178 X EI-670	12.86	1.78**	-0.19	12.77	1.85**	-0.34	28.53	1.05**	-1.31	69.77	1.01**	-8.69
35	EI-2188 X EI-670	14.49	1.07	0.58	12.59	1**	-0.34	22.93	0.71**	-1.27	85.20	1.16**	-8.47
36	EI-2188-1 X EI-670	13.65	0.91**	-0.21	13.47	1.12	-0.06	24.86	0.38	1.66	71.60	1.22**	-4.22

S. No	**Genotypes**	**Ear girth (cm)**			**Grain rows per ear**			**100-grain weight (g)**			**Grain yield per plant (g)**		
		Mean	**b_i**	**S^2d_i**	**Mean**	**b_i**	**S^2d_i**	**Mean**	**b_i**	**S^2d_i**	**Mean**	**b_i**	**S^2d_i**
37	EI-2403 X EI-670	13.99	0.96	0.14	13.24	0.39	0.06	27.97	1.24**	-1.31	84.99	2.7**	-4.38
38	EI-2448 X EI-670	13.54	0.54	0.21	15.23	1.48**	-0.14	24.57	0.51*≠	-1.23	75.52	0.92**	-8.04
39	EI-2505 X EI-670	13.43	0.26	0.19	13.93	1.37	0.94	27.80	1.1**	-1.04	95.68	-0.18#	10.17
40	EI-2507 X EI-670	14.73	0.88	1.36**	15.71	1.07**	-0.34	30.51	1.31**	-0.84	76.33	0.85**	-6.99
41	EI-2522 X EI-670	12.36	0.88	0.76*	14.43	1.68**	-0.22	29.01	1.55**	-1.38	78.58	0.68**#	-8.11
42	EI-2525-2 X EI-670	13.93	1.25	4.81**	13.49	1.09*	-0.14	28.61	0.98**	-1.38	86.65	1.43**	-6.54
43	EI-2639 X EI-670	14.70	0.92	2.68**	15.55	0.64**	-0.32	27.68	0.93**	-1.29	92.18	-0.98#	-5.77
44	EI-2642 X EI-670	14.13	2.08**	-0.18	15.84	1.17*	-0.13	27.95	1.44**	-1.17	79.45	1.33**	-8.66
45	EI-2653 X EI-670	14.22	1.1	1.05*	15.08	1.45**	-0.36	28.20	1.43**	-1.14	92.09	0.17	65.63**
46	EI-2159	12.01	0.34	0.22	12.78	1.61	0.34	28.02	1.93**	-0.99	59.52	1.19**	-7.23
47	EI-2172	11.33	0.81	0.10	13.53	1.53**	-0.3	26.52	2.32**	-0.84	49.60	1.07**	-8.55
48	EI-2176-3	12.16	1	0.04	11.93	1.49	2.33**	24.49	1.72**	-1.32	72.03	1.44**	-7.53
49	EI-2178	10.92	1.66	0.66*	12.77	1.84**	0	27.93	1.01**	-1.03	49.40	1**	-8.52
50	EI-2188	12.46	0.93**	-0.17	11.75	1.55	1.46*	29.27	0.39	-0.79	54.80	1.28**	-6.64
51	EI-2188-1	11.79	0.68	0.73*	12.65	1.41	2.27**	26.00	0.49	-1.16	67.36	1.11**	-6.6
52	EI-2403	13.52	1.1**	-0.12	11.36	1.76**	0.04	25.73	1.17**	-1.35	43.64	0.25#	-1.86
53	EI-2448	12.86	0.19≠	-0.09	13.44	1.56**	-0.19	24.31	1.15	-0.04	54.11	1.01**	-8.68
54	EI-2505	12.32	1.16	0.16	13.81	1.03	0.84	28.8	-0.37#	-1.01	61.59	0.59**≠	-5.08
55	EI-2507	13.52	1.56**	-0.21	13.17	0.42	-0.08	27.50	1.45**	-1.39	54.08	0.55	32*
56	EI-2522	11.54	1.83	0.83*	12.70	0.23#	-0.34	25.55	1.41**	-1.3	48.46	0.82	17.24
57	EI-2525-2	13.12	0.54	-0.11	12.61	0.21	1.29*	23.54	1.57**	-1.35	56.34	0.72**#	-7.96
58	EI-2639	12.12	1.08**	-0.21	14.71	2.06**	-0.3	28.26	0.91**	-1.38	66.92	1.07**	-8.21
59	EI-2642	12.91	1.75**	-0.18	12.47	0.36	-0.22	29.70	0.93**	-1.31	52.41	0.13≠	8.62
60	EI-2653	12.76	0.42	0.6	13.68	0.72**#	-0.36	28.51	0.82	0.09	57.90	0.76**#	-8.52
61	EI-03	12.66	0.44	-0.05	12.91	0.49**#	-0.36	31.23	0.56	-1.39	60.13	0.57**#	-7.02
62	EI-102	11.98	0.94**	-0.2	13.73	0.49**#	-0.35	23.52	0.97	0.08	72.84	0.7**	-5.13
63	EI-670	13.51	0.83**#	-0.22	11.96	0.26≠	-0.29	27.11	1.38**	-1.36	67.18	0.54*≠	-4.51
64	CC-1	14.14	0.99**	-0.22	14.57	0.59	-0.1	30.89	1.09**	-1.23	94.95	1.15**	-6.61
65	CC-2	13.78	1.04**	-0.14	13.99	0.94**	-0.37	29.83	1.35**	-1.33	92.12	1.07**	2.99
Grand Mean		13.08			13.65			27.74			75.26		

* and ** represent significance at 5 and 1%, respectively

≠ and # represent significance at 5 and 1%, respectively when tested against unity