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Research Article

Genotype x Environment interaction and stability analysis in maize around Southern Aravalli Hilly Ranges of Rajasthan

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Abstract
Crop production is the function of genotype, environment and their interaction (GEI) and evaluation of genotypes in multi environments helps in identifying their adaptation and stability. Forty five maize hybrids along with their 18 parents and two checks 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. The mean squares due to genotypes and environments were found significant for all the traits under study which indicated inherent genetic differences among the genotypes. The mean squares due to G x E (linear) interaction were found significant for most of the traits under study indicating differences among genotypes for linear response to varying environments. The MSS due to pooled deviation were found non-significant for all the traits which indicated major portion of the genotype x environment interaction was formed by predictable component. The majority of the hybrids depicted non-significant deviations from regression (S^2d_i) for grain yield per plant. It indicated their predictable response across the environments. A great majority of genotypes revealed non-significant non-linear estimates (S^2d_i) for different traits which suggested that 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, EI-2525-2 x EI-03 and EI-2159 x EI-670 out yielded the best check cultivar CC-1 for grain yield per plant. Thus, these combinations may be exploited commercially after further multi location yield testing.

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

INTRODUCTION

Maize (*Zea mays* L.; 2n = 20) or corn which literarily means "that which sustains life" (Akinyele and Adigun, 2006) is one of the most important food crops in the world with its huge ears, packed with starch and oil. It is a versatile and multi utility grain crop and model genetic plant (Hake and Ross-Ibarra, 2015). It is a allogamous species, belonging to the monocot family Poaceae, Genus *Zea* and Species *mays*. The average productivity of maize in India is 3.04 metric tonnes/hectare with a production of 28.00 million metric tonnes in comparison to the world average productivity of 5.91 metric tonnes/hectare (USDA, 2020). Dass *et al.* (1987) predicted a demand of 42 million tonnes of maize in India by the year of 2025. Yan *et al.* (2011) highlights the prominence of maize and estimated that the increased world food demand in terms of cereals as a whole will be met from maize in near future. Crop production is the function of genotype, environment and their interaction (GEI). Quantitative 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 (Kang and Gorman, 1989). The differential responses of genotypes and cultivar performance across environments have a key role for assessment of performance stability of the breeding materials (Moldovan *et al.,* 2000). 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.

MATERIALS AND METHODS

Forty five 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 in each environment. 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. 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, while Vallabhnagar is located in latitude 24°40′23″, longitude 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 nature and have good moisture holding capacity. All the recommended agronomic practices were followed to raise a healthy crop. Data were recorded for nine traits including phenological, grain yield and other component traits on five random plants 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). 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.

RESULTS AND DISCUSSION

The analysis of variance (ANOVA) for all the nine traits under study (**Table 1**) affirmed significance of 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 indicating 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 G x E 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 G x E interaction was formed by predictable portion under the study as indicated 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.* (2001), Patel and Kathiria (2016), Bharathiveeramani *et al.* (2017), Ahmed *et al.* (2017), Synrem *et al.* (2017) and Sowmya *et al.* (2018) in maize.

A genotype having high mean performance, with b_i values around unity (b_i≈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 (1966). 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 and 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.**

Nine of the 18 parents were observed to record lower mean than over all mean with non-significant non-linear

Table 1. Analysis of variance for stability analysis (Eberhart and Russel Model, 1966) in maize.

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

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≈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≈1) towards all environments. A total of eight parents and 12 hybrids expressed lower mean than grand mean with non-significant deviation from regression for days to 50 per cent silking and among them, the parent EI-2639 (b_i≈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≈1) across the environments for this trait. For days to 75 per cent brown husk, nine parents and 21 hybrids possessed mean values lesser than the over all mean with non-significant non-linear estimates. Among them, the 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 to have average sensitivity (b_i≈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≈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.* (2014), Patel and Kathiria (2016), Bharathiveeramani *et al.* (2017), Owusu *et al.* (2018), Sowmya *et al.* (2018), Raj *et al.* (2019) and Arun kumar *et al.* (2020) in maize.

Fifteen parents and 10 hybrids expressed lower mean than over all mean with non-significant deviations from regression for the trait plant height. Parent EI-2188-1 (b_i≈1) and hybrids EI-2188 x EI-102 (b_i≈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.

For the trait ear length, three parents and 25 hybrids showed mean values greater than over all mean with non-significant non-linear estimates. Out of the 25 hybrids, cross EI-2188-1x EI-102 was found to have average stability (b_i≈1) and exhibited good 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 parents and hybrids were found suitable for all environment conditions for this trait. Among the above 24 hybrids (mean>over all mean), the three good 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.

A total of four 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

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*

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

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Table 2.1. Continued..

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
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
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 level of significance at 5 and 1%, respectively, ≠ and # represent level of 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

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

Table 2.2. Continued..

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
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
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

($b_i>1$) 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 hybrid EI-2525-2 x EI-670 was found stable ($b_i\approx1$) 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.
Thirty one hybrids depicted 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 ($b_i\approx1$) 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 Lata *et al.* (2010), Karadavut and Akili (2012), Bharathiveeramani *et al.* (2017), Ahmed *et al.* (2017), Synrem *et al.* (2017), Raj *et al.* (2019) and Arunkumar *et al.* (2020) in maize.

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 five hybrids for all environments ($b_i\approx1$), 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, indicating that bulk of genotypes responded in predictable manner. 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 ($b_i\approx1$) were EI-2653 x EI-102, EI-2639 x EI-670 and EI-2505 x EI-102. The top three hybrids for input rich environments ($b_i>1$) were EI-2525-2 x EI-03, EI-2159 x EI-670 and EI-2522 x EI-03, whereas hybrid EI-2176-3 x EI-03, EI-2505 x EI-670 and EI-2653 x EI-03 identified suitable for poor environments ($b_i<1$) with respect to 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. Thus, these hybrids may be exploited commercially after further evaluation at both spatial and temporal levels with increased number of environments to validate the stability.

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