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Genotype x Environment Interaction and Stability Analysis for Yield And Quantitative Traits in Maize (*Zea Mays* L.) Under Different Dates of Sowing

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ABSTRACT

Maize (Zea mays L.) cultivars vary in their performance and response to variable environmental conditions. Climate change is the most talked and concerned phenomena of this century, where agricultural scientists are looking for answers to maintain the ever increasing demand for food and sustainability. Hence,an experiment was conducted during kharif 2013 to evaluate 45 maize single cross hybrids and 10 parents including 3checks to study the stability parameters and G x E interaction for grain yield and yield component traits under three different environments created by the different dates of sowing at Allahabad. Among the treatments studied, early and timely sown seeds recorded the highest and positive environment index for the traits Chlorophyll content, Leaf area/ plant, ***Kernel rows/Cob, Number of kernels/ row and Grain yield/ plant. Analysis of variance and stability analysis were computed by Eberhart and Russell model. Variances due to genotypes, environments and G x E interaction were significant for grain yield and its related traits.Significant variance due to environments (linear) for all the traits studied indicated considerable differences among the environments and their pre-dominant effects on the traits. Grain yield and its related traits were taken into account while evaluating genotypes for stability performance over the environments. Stability analysis for grain yield indicated that six hybrids viz., CML 41 x Early yellow, CML 41 x CML 359, DMR-QPM-28 x CM 129, DMR-QPM-28 x LM-13, CM- 124 x CM 129, LM-13 x CM 129 recorded mean value higher than population mean, positive phenotypic index (P_i>1), regression coefficient near to unity (βi≈1) and non-significant deviation from regression (s^2di) there by indicating its stability performance over the environments. The hybrid POP 31 Q_2 x POP 445 had negative phenotypic index (P_i<1), regression coefficient near to unity (βi≈1) and non-significant deviation from regression (s^2di) there by indicating its stability over all environments and suitability for early maturity. Some hybrids showed relatively good performance in one environment whereas some in other, indicating the possibility to develop environment specific hybrids.*

Key words:Maize (Zea mays L.), G x E interaction, environment, stability, regression, grain yield, climate change, Eberhart and Russell model

I.INTRODUCTION

Maize or Indian corn (*Zea mays* L.) is the third important cereal crop of the world after wheat and rice in terms of growing area, production and grain yield [1]**.**Among the maize growing countries, USA stands first followed by China and Brazil accounting for 35% of the total maize produced in the world. India is the sixth largest producer of maize in the world, and contributed about 2 per cent to the global maize production of 855.72 million tonnes (Mt) in 2012-13[2]. In the state of Uttar Pradesh the area and production during 2015-2016 was 0.67 m ha and 1255 mt, respectively with productivity of 1848 kg/ha, which is less compared to the center with the area and production of 8.69 mha and 21.80 mt, and productivity of 2509 kg/ha [3].

Maize has a wider range of uses than any other cereals as animal feed, human food and for hundreds of industrial purposes [4].Maize produced is used as stock feed, eg. 40% in tropical areas and up to 85 % in developed countries [5],[6].The growing demand for maize is mainly attributed to its multipurpose use and its importance in today's world agricultural scenario.

Being a C4 plant, it is physiologically more efficient and being a photo insensitive crop, maize has wider adaptation over a range of environmental conditions [7]**.** Since maize is a highly cross pollinated crop it offers great scope for exploitation of heterosis by development of hybrids. But the performances of these hybrids are not the same at all the places. Hence the plant breeder has to select hybrids which perform consistently across all the environments. Hence, the study on the genotype x environment interaction for grain yield and quantitative traits in maize hybrids is of paramount importance assessing their stability grown under different environments.Phenotype (P) is the product of the genotype (G) of the individual, the environment (E) that the phenotype is exposed to and the interaction that occurs between the genotype of the individual and the environment (G x E). Genotype x environment interactions is of major importance to the scientist in developing improved varieties. When varieties are compared over a series of environments, the relative ranking usually differs. For plant breeders, large genotype by environment (G x E) interaction impede progress from selection and have important implications for testing and cultivar release programme. In fact, G x E interactions is a function of the genotype as they are of the environment and so are partly heritable [8]. Statistically, G x E interactions are detected as a significantly different pattern of response among the genotypes across environments and biologically, this will occur when the contributions (or level of expression) of the genes regulating the trait differ among environments [9]. Therefore, an ideal approach in plant breeding is to develop cultivars that have fairly uniform performance (low G x E) over a range of environments with the ability to utilize the resources in high yielding environment. When the performance of cultivars is compared across environments, several cultivar attributes are considered, of which grain yield is one of the most important [10**].**Wide adaption to the particular environment and consistent performance of recommended genotypes is one of the main objectives in breeding programme. A genotype is considered to be stable if it possesses an un-changed or least changed performance regardless of any variation in the environmental conditions. Such stability analysis in maize has been reported by many authors like [11], [12], [13].

Hence the assessment of stability or desirability among genotypes assumes importance. Of the various models available for assessment of stability[14].The model proposed by Eberhart and Russell is widely employed by plant breeders. Hence, an experiment was undertaken to identify high yielding and stable maize hybrids, in a range of environment for its cultivation in Allahabad region.

II.MATERIALS AND METHODS

During Kharif 2013, forty five single cross maize hybrids developed from crossing 10 x 10 half diallel mating design,(P1,)and two hybrid checks and one composite (K-25, GA-85 and Navjyot) were evaluated at three different dates of sowing *viz.*, Environment 1 (E_1); 1st July (Early sown), Environment 2 (E_2); 15th July (Timely sown) and Environment 3 (E_3); 31st July (Late sown) in the field experimentation center of the Department of Genetics and Plant Breeding, Sam Higginbottom University of Agriculture, Technology and Sciences, Allahabad. The trialswere conducted in Randomized Block Design (RBD) with three replications. For raising a healthy crop, therecommended package of practices were followed and fertilizer application i.e., N:P:K@120:60:60kg/ha was applied.Data were recorded on 10 randomly selected plants for the traits;Days to 50 % tasselling, Days to 50 % silking, Days to 50% brown husk, Plant height, Cob length, Cob girth, Kernel rows per cob, Number of Kernels per row, Grain yield per plant, Biological yield per plant, Harvest index, Chlorophyll content, Leaf relative water content, Flag leaf area per plant, Leaf area per plant, Leaf area index, Leaf area ratio, Specific leaf weight and Specific leaf area. The soil analysis revealed Sandy loam type withsoil pH (7.6-7.8) which is slightly alkaline.The stability of yield performance for each genotype was calculated by regressing the mean yields of individual genotypes on environmental index and calculating the deviations from regression as suggested [14], the behavior of the cultivars was assessed by the model $Y_{ij} = m + \beta_i I_j + \delta_{ij} + \varepsilon_{ij}$, where Y_{ij}= observation of the i-th (i = 1, 2, ..., g) cultivar in the j-th (j = 1, 2, ...n) environment, m = general mean, β_i = regression coefficient, I_j= environmental index obtained by the difference among the mean of each environment and the general mean ($\Sigma\ I_j = 0$), δ_{ij}= the regression deviation of the i-th cultivar in the j-th environment and ε_{ij}= effect of the mean experimental error.

III. RESULTS AND DISCUSSION

The experimental results on the basis of overall performance over three environments with respect to grain yield (g/plant), revealed 37 entries, could statistically out yield the hybrid check K-25 and GA-85, while 43 hybrids recorded highermean values over the composite checkNavjyot (Table 1). The mean grain yield of the hybrids across the environments ranged from 38.46 g/plant (CML 41x POP 31 Q_2) to 109.55 g/plant(HKI-193-2 x CM 129). The top five ranked hybrids based on over all mean performance were HKI-193-2 x CM 129 (109.55 g), CM- 124 x LM-13 (108.60 g), DMR-QPM-28 x CM- 124 (102.75 g), HKI-193-2 x POP 445 (99.73 g) and CML 41 x POP 445 (96.95 g) respectively.The above top five entries also exhibited variable percent increase, 48.00 to 68.00 %over the check K-25, 67.00 to 89.00 % over GA-85and 119.00 to 148.00 %over the Composite check Navjyot.This indicated that the percentage of the genotypes varied from one environment to the other environment confirming the presence of G x Einteraction and for high yield potential a more specific breeding approach is necessary for specific environment.

The combined analysis of variance for stability (Table 2) revealed significant genetic variability forall the traits studied, except for days to 50 % brown husk, which revealed the presence of variability among hybrids and environments.Significant mean squares for genotypes x environment (G x E) interactions were observed for all the traits studied. The presence of significant G x E interaction showed the inconsistency of performance of maize hybrids across the environment. Further, partitioning of G x E interaction into G x E linear and non-linear portions exhibited that both were important and revealed that all the traits accounted for G x E interaction.

Significant variance due to environments (linear) for all the traits studied indicated considerable differences among the environments and their pre-dominant effects on the traits. This could be due to the variations in the genotypes, weather, rainfall, different dates of sowing and soil conditions over different environments. The results were well supported by the earlier findings of researcher [15].

Significant pooled deviations for all the traits suggested that the deviation from linear regression also contributed substantially towards the differences in stability of hybrids thereby indicating difficulty in predicting the performance of hybrids over environments for these traits. Similar results in maize have been reported[16], [17].

Stability analysis for grain yield indicated that six hybrids*viz.*, CML 41 x Early yellow, CML 41 x CML 359, DMR-QPM-28 x CM 129, DMR-QPM-28 x LM-13, CM- 124 x CM 129, LM-13 x CM 129 had positive phenotypic index (P_i>1), regression coefficient near to unity (βi≈1) and non-significant deviation from regression (s^2di) there by indicating its stability over all environments, therefore these hybrids were considered suitable and stable in performance in different environments for high grain yield per plant (Table 3).Theparental line P_5 (CM-129) showed non-significant (s^2di) and regression coefficient higher than unity (βi>1), with mean values higher than the population mean, thereby indicating that this parent is stable under favorable environments with high yield potential. The results were well supported by the findingsof earlier workers[18], [19], [20], [21].

Stability results for days to 50% tasseling and days to 50 % silking showed that out of 45 hybrids, 33 hybrids showed non-significant deviation from regression (s^2di) hence their behavior was predictable, while 12 hybrids showed significant deviation from regression (s^2di) there by their behavior was unstable. The hybrid HKI-193-2 x Early yellow however, showed negative phenotypic index (P_i<1), regression coefficient near to unity (βi≈1) and non-significant deviation from regression (s^2di) there by indicating its stability over all environments and suitability for early tasseling and for early silking. Parental line P_5 (CM 129) showed non-significant deviation from regression (s^2di) and regression coefficient less than unity (βi<1), with mean values lesser than the population mean, thereby indicating its adaptability under un-favorable environments and suitable for early tasseling. Parental line P_4 (CML 359) showed non-significant s^2di and regression coefficient greater than unity (βi>1), with mean values lesser than the population mean, thereby indicating their adaptability under favorable environments and suitability for early tasseling and silking. Similar results were observed by earlier scientists [22], [23], [24].

Stability outcomes for days to 50 % brown husk revealed that out of the 45 hybrids, 42 hybrids showed non-significant deviation from regression (s^2di) hence their behavior was predictable, while 3 hybrids showed significant deviation from regression (s^2di) there by their behavior was unstable. The hybrid POP 31 Q_2 x POP 445 had negative phenotypic index (P_i<1), regression coefficient near to unity (βi≈1) and non-significant deviation from regression (s^2di) there by indicating its stability over all environments and suitability for early maturity.Parental line (P_1) Early yellow and (P_2) POP 445 showed non-significant (s^2di) and regression coefficient near to unity (βi≈1), with mean values lesser than the population mean, thereby indicating its adaptability under favorable environments and suitability for early maturity (Table 3).The results were supported by the earlier findings [25],[26], [27].

The environmental indices of the 58 genotypes for days to 50 % tasselling ranged from -1.67 in (E_1) to 1.77 in (E_3) while for days to 50 % silking it ranged from -1.64 in (E_1) to 1.76 in (E_3) indicating significant variations across the environments. While for days to 50 % brown husk environmental indices ranged from -3.45 in (E_3) to 3.77 in (E_1)owing to the different dates of sowing. The environmental indices for grain yield ranged from -7.08 (E_3) to 4.03 (E_1) indicating significant variations across the environments (Table 4). Among the treatments studied, early sown i.e. environment (E_1) and timely sown i.e. environment (E_2) seeds recorded the highest and positive environment index for the traits Chlorophyll content, Leaf area/ plant**,** Kernel rows/Cob, Number of kernels/ row and Grain yield/ plant.Highest and positive environmental index was recorded in irrigated condition [28].Hence, these traits appeared to be the most favorable for timely sown in maize.

Table 1. Overall performance of maize hybrids for grain yield (g/plant) under different Environments (E_1, E_2 and E_3) during *kharif* 2013

S.N.	**Hybrid**	**Grain yield (g/plant)**				**Rank**	**% increase over Checks**		
		Environments			**Over all mean**		**K-25**	**GA-85**	**Navjyot**
		E_1	**E_2**	**E_3**					
1	HKI-193-2 x Early yellow	79.45	72.33	62.64	71.47	20	9.63	23.74	62.02
2	HKI-193-2 x POP 445	115.07	103.33	80.78	99.73	4	52.97	72.66	126.07
3	HKI-193-2 x POP 31 Q_2	72.18	66.26	56.76	65.07	29	-0.19	12.65	47.50
4	HKI-193-2 x CML 359	78.48	71.18	62.24	70.63	24	8.34	22.29	60.12
5	HKI-193-2 x CM 129	133.06	114.11	81.47	109.55	1	68.03	89.66	148.33
6	HKI-193-2 x LM-13	94.15	82.64	72.46	83.08	13	27.44	43.84	88.34
7	HKI-193-2 x CM- 124	59.85	50.87	41.22	50.65	44	-22.31	-12.32	14.81
8	HKI-193-2 x DMRQPM-28	107.77	94.89	78.92	93.86	6	43.97	62.50	112.77
9	HKI-193-2 x CML 41	79.86	71.68	60.67	70.74	22	8.50	22.47	60.35
10	CML 41 x Early yellow	85.08	73.94	61.83	73.62	18	12.92	27.45	66.88
11	CML 41 x POP 445	109.47	100.74	80.63	96.95	5	48.71	67.84	119.77
12	CML 41x POP 31 Q_2	49.34	36.87	29.18	38.46	48	-41.00	-33.41	-12.81
13	CML 41x CML 359	88.04	77.22	65.60	76.95	16	18.04	33.23	74.44

14	CML 41x CM 129	80.13	71.65	60.37	70.72	23	8.47	22.43	60.31
15	CML 41x LM-13	93.06	83.98	72.76	83.27	11	27.72	44.16	88.76
16	CML 41x CM- 124	91.48	77.65	80.54	83.22	12	27.66	44.08	88.66
17	CML 41x DMR-QPM-28	79.33	67.81	63.78	70.31	25	7.84	21.72	59.38
18	DMR-QPM-28 x Early yellow	68.28	60.96	51.90	60.38	37	-7.38	4.54	36.87
19	DMR-QPM-28 x POP 445	97.85	80.63	69.86	82.78	14	26.98	43.32	87.65
20	DMR-QPM-28 x POP 31 Q_2	56.06	42.44	32.65	43.72	47	-32.94	-24.31	-0.90
21	DMR-QPM-28 x CML 359	69.32	59.54	48.80	59.22	38	-9.16	2.53	34.25
22	DMR-QPM-28 x CM 129	95.25	84.18	72.67	84.03	10	28.90	45.49	90.49
23	DMR-QPM-28 x LM-13	103.07	92.70	78.85	91.54	8	40.41	58.48	107.51
24	DMR-QPM-28 x CM-124	123.73	102.90	81.62	102.75	3	57.61	77.89	132.92
25	CM- 124 x Early yellow	73.15	62.80	51.62	62.52	34	-4.10	8.25	41.73
26	CM- 124 x POP 445	64.67	53.34	42.55	53.52	41	-17.91	-7.34	21.32
27	CM- 124 x POP 31 Q_2	92.03	81.68	70.84	81.52	15	25.04	41.13	84.79
28	CM- 124 x CML 359	63.08	53.66	42.67	53.14	42	-18.49	-8.00	20.45
29	CM- 124 x CM 129	85.21	72.79	62.43	73.48	19	12.71	27.21	66.56
30	CM- 124 x LM-13	132.42	112.19	81.18	108.60	2	66.58	88.01	146.18
31	LM-13 x Early yellow	73.06	63.36	53.11	63.18	30	-3.09	9.38	43.21
32	LM-13 x POP 445	110.08	92.71	77.43	93.41	7	43.28	61.72	111.74
33	LM-13 x POP 31 Q_2	82.45	66.59	52.94	67.33	26	3.27	16.56	52.62
34	LM-13 x CML 359	72.03	61.86	50.69	61.53	35	-5.62	6.52	39.47
35	LM-13 x CM 129	86.82	75.70	63.91	75.48	17	15.77	30.67	71.10

36	CM 129 x Early yellow	61.83	51.85	40.83	51.50	43	-21.00	-10.83	16.75
37	CM 129 x POP 445	76.01	65.07	54.72	65.27	27	0.11	13.00	47.95
38	CM 129 x POP 31 Q_2	74.86	62.87	50.44	62.72	33	-3.79	8.59	42.19
39	CM 129 x CML 359	104.15	91.75	75.70	90.53	9	38.87	56.74	105.23
40	CML 359 x Early yellow	62.48	56.72	46.09	55.10	40	-15.49	-4.61	24.90
41	CML 359 x POP 445	75.59	64.33	52.44	64.12	31	-1.65	11.01	45.35
42	CML 359 x POP 31 Q_2	74.45	63.59	51.05	63.03	32	-3.32	9.12	42.88
43	POP 31 Q_2 x Early yellow	59.25	49.35	37.93	48.84	45	-25.08	-15.44	10.72
44	POP 31 Q_2 x POP 445	82.08	71.58	60.74	71.47	21	9.62	23.73	62.01
45	POP 445 x Early yellow	71.06	62.57	50.50	61.38	36	-5.85	6.26	39.13
46	K-25(Check 1)	76.06	65.61	53.91	65.19	28	0.00	12.87	47.79
47	GA-85(Check 2)	67.45	57.04	48.79	57.76	39	-11.40	0.00	30.94
48	Navjyot (Check 3)	56.33	42.67	33.34	44.11	46	-32.33	-23.63	0.00
Grand Mean		83.04	71.71	59.46	71.40	-			
Range		49.34-133.06	36.87-114.11	29.18-81.62	38.46-109.55	-			
C.V. (%)		7.83	2.50	1.50	7.60	-			
S.E.		3.68	1.40	0.85	4.35	-			
C.D. (5%)		10.32	2.79	1.38	8.57	-			

Table 2.Combined analysis of variance for stability for different characters in maize (*Zea mays* L.) over three environments

Characters	**Environment (E) (df = 2)**	**Genotypes(G) (df = 57)**	**G×E interaction (df = 114)**	**E+(G×E) (df = 116)**	**E (linear) (df = 1)**	**G×E (linear) (df = 57)**	**Pooled deviation (df = 58)**	**Pooled error (df = 342)**
Days to 50 % tasselling	513.43**	20.05**	3.30**	4.03**	342.28**	1.36*	0.82**	0.86
Days to 50 % silking	507.14**	22.36**	3.47**	4.05**	338.10**	1.46*	0.84**	0.83
Days to 50% brown husk	2280.25**	44.63	12.36**	17.15**	1520.17**	5.35**	2.84*	4.65
Plant height	292354.69**	3422.95**	571.36**	1867.37**	194903.23**	38.99	336.02**	58.43
Cob length	817.99**	23.83**	3.06**	5.70**	545.34**	1.23	0.80**	0.85
Cob girth	326.42**	11.91**	1.56**	2.39**	217.61**	0.49	0.54**	0.58
Kernel rows per cob	894.78**	8.92**	2.01**	5.80**	596.52**	0.72	0.61	1.26
Number of Kernels per row	4198.59**	111.33**	15.11**	29.08**	2799.06**	6.23*	3.78**	3.75
Grain yield per plant	23580.38**	2435.54**	43.46**	39.41**	4383.76**	0.35	2.89	28.49
Biological yield per plant	62938.20**	6547.60**	1495.40**	449.03**	17971.23**	382.00*	212.80	332.20
Harvest index	1549.71	247.29**	61.23**	86.89**	280.68**	8.43	10.73	16.63
Chlorophyll content	5741.70*	87.30*	29.01*	42.50**	3827.93**	19.30**	0.04	0.76
Leaf relative water content	2334.00*	389.00*	1.81*	72.84**	1556.14**	97.76**	22.77**	0.00
Flag leaf area per plant	82050.00*	5417.00*	899.00*	766.06**	54701.74**	445.78**	150.88**	0.00
Leaf area per plant	36289841.00*	2607414.00*	188470.00*	270302.22**	24193216.00**	86070.50**	38893.46**	21248.00
Leaf area index	25.20	1.81*	0.13*	0.19**	16.77**	0.06**	0.03**	0.01
Leaf area ratio	11474.16*	357.53*	72.85*	89.80**	7648.92**	37.82**	10.56	42.00
Specific leaf weight	11.85	3.17*	0.33*	0.18**	7.89**	0.21**	0.01	0.10
Specific leaf area	7467.30	2224.70*	316.60*	146.64**	4978.14**	196.62**	14.21	118.20

*Significant at 5% level of significance; **Significant at 1%level of significance.

Table 3.Stability parameters for maize hybrids over three environments

S.N.	Parents/crosses	Days to 50 % tasselling			Days to 50 % silking			Days to 50 % brown husk			Grain yield/plant (g)		
		$\bar{g}_i$ (Pi)	Bi	s^2di	$\bar{g}_i$ (Pi)	Bi	s^2di	$\bar{g}_i$ (Pi)	Bi	s^2di	$\bar{g}_i$ (Pi)	βi	s^2di
1.	HKI-193-2 x Early yellow	49.22 (-0.83)	0.99	0.62	51.22(-0.84)	1.00	0.58	85.22(-2.15)	0.55*	-1.89	71.47(1.61)	0.72	-8.87
2.	HKI-193-2 x POP 445	49.33(-0.72)	1.57	0.08	50.89(-1.17)	1.59	0.42	85.78(-1.59)	1.44	-1.74	99.73(29.87)	1.48	5.66
3.	HKI-193-2 x POP 31 Q_2	51.22(1.17)	0.57	0.07	53.22(1.16)	0.57	0.09	85.33(-2.04)	1.49	-0.80	65.07(-4.79)	0.66	-7.99
4.	HKI-193-2 x CML 359	50.78(0.73)	0.70	0.44	52.78(0.72)	0.71	0.41	85.94(-1.43)	0.82	-1.19	70.63(0.77)	0.70	-9.32
5.	HKI-193-2 x CM 129	51.78(1.73)	1.67	0.25	53.78(1.72)	1.68	0.19	89.78(2.41)	1.44	-1.74	109.55(36.69)	2.22	13.60
6.	HKI-193-2 x LM-13	52(1.95)	1.16	-0.29	54(1.94)	1.17	-0.28	90.22(2.85)	0.87	-1.66	83.08(13.22)	0.93	-8.74
7.	HKI-193-2 x CM- 124	52.11(2.06)	0.95	1.15*	54.11(2.05)	0.95	1.21*	87(-0.37)	1.19	3.84	50.65(-19.21)	0.80	-9.50
8.	HKI-193-2 x DMR-QPM-28	50(-0.05)	1.18	0.14	51.67(-0.39)	1.19	0.10	86.44(-0.93)	1.06	4.78	93.86(24.00)	1.24	-8.82
9.	HKI-193-2 x CML 41	50.33(0.28)	1.06	-0.02	52.33(0.27)	1.06	0.01	86.28(-1.09)	1.24	-0.73	70.74(0.88)	0.83	-8.75
10.	CML 41 x Early yellow	47.56(-2.49)	0.20	-0.25	49.67(-2.39)	0.11	-0.16	85.33(-2.04)	0.75	3.61	73.62(3.76)	1.00	-9.49
11.	CML 41 x POP 445	48.89(-1.16)	0.50	0.07	50.89(-1.17)	0.50	0.06	86(-1.37)	0.76	-0.11	96.95(27.09)	1.24	8.21
12.	CML 41x POP 31 Q_2	51(0.95)	0.56	0.48	53.33(1.27)	0.56	0.50	89.33(1.96)	0.75	3.61	38.46(-31.40)	0.86	-4.41
13.	CML 41x CML 359	49.11(-0.94)	1.14	1.21*	51(-1.06)	1.24	1.68*	86.28(-1.09)	0.81*	-1.89	76.95(7.09)	0.96	-9.50

14.	CML 41x CM 129	49.78(-0.27)	1.23	2.42*	51.78(-0.28)	1.23	2.52**	85.89(-1.48)	1.43	6.99*	70.72(0.86)	0.85	-8.79
15.	CML 41x LM-13	50.67(0.62)	1.18	0.14	52.67(0.61)	1.19	0.10	89.33(1.96)	0.91	-0.50	83.27(13.41)	0.87	-9.18
16.	CML 41x CM- 124	50.11(0.06)	1.25	0.39	52.11(0.05)	1.25	0.44	86.94(-0.43)	1.10	-1.37	83.22(13.36)	0.46	39.36
17.	CML 41x DMR-QPM-28	49.89(-0.16)	0.87	-0.25	51.89(-0.17)	0.87	-0.24	85.44(-1.93)	0.90	0.12	70.31(0.45)	0.66	1.34
18.	DMRQPM-28 x Earlyyellow	48.56(-1.49)	0.78	-0.28	50.22(-1.84)	0.79	-0.29	86(-1.37)	0.77	-1.38	60.38(-9.48)	0.70	-9.28
19.	DMR-QPM-28 x POP 445	50.11(0.06)	0.49*	-0.31	52.11(0.05)	0.49*	-0.31	88.33(0.96)	1.13	0.92	82.78(12.92)	1.20	-0.15
20.	DMR-QPM-28 x POP 31 Q_2	51.11(1.06)	1.16	-0.14	53.22(1.16)	1.26	-0.21	88.89(1.52)	0.79	-1.75	43.72(-26.14)	1.00	-5.82
21.	DMR-QPM-28 x CML 359	50.78(0.73)	0.38	-0.21	52.78(0.72)	0.38	-0.20	89.22(1.85)	0.44	0.48	59.22(-10.64)	0.88	-9.49
22.	DMR-QPM-28 x CM 129	51.44(1.39)	1.14	1.21*	53.44(1.38)	1.14	1.28*	90(2.63)	0.52	-0.85	84.03(14.17)	0.97	-9.47
23.	DMR-QPM-28 x LM-13	51.89(1.84)	1.05	0.86	54.33(2.27)	1.15	0.67	90.78(3.41)	0.38	-1.73	91.54(21.68)	1.04	-8.39
24.	DMR-QPM-28 x CM- 124	49.78(-0.27)	1.07*	-0.31	51.89(-0.17)	1.18	-0.30	89.33(1.96)	1.33	5.65*	102.75(32.89)	1.81	-9.29
25.	CM- 124 x Early yellow	47.89(-2.16)	0.87	-0.25	49.56(-2.50)	0.87	-0.24	84.11(-3.26)	1.27	0.66	62.52(-7.34)	0.92	-9.50
26.	CM- 124 x POP 445	49(-1.05)	1.16	-0.29	51(-1.06)	1.17	-0.28	85.67(-1.70)	1.48	5.07	53.52(-16.34)	0.95	-9.19
27.	CM- 124 x POP 31 Q_2	49.22(-0.83)	1.52	2.10**	50.89(-1.17)	1.52	2.22**	85.89(-1.48)	0.88	-1.78	81.52(11.66)	0.91	-9.48
28.	CM- 124 x CML 359	50.89(0.84)	0.87	-0.25	52.89(0.83)	0.87	-0.24	90.33(2.96)	0.18*	-1.88	53.14(-16.72)	0.88	-9.39
29.	CM- 124 x CM 129	50.56(0.51)	0.50	0.07	52.56(0.50)	0.50	0.06	88.56(1.19)	0.77	-0.30	73.48(3.62)	0.98	-8.09

30.	CM- 124 x LM-13	49.89(-0.16)	0.29	-0.28	51.89(-0.17)	0.29	-0.28	89.89(2.52)	0.14*	-1.85	108.60(38.74)	2.21	3.64
31.	LM-13 x Early yellow	48.22(-1.83)	0.39	-0.26	50.22(-1.84)	0.40	-0.26	85(-2.37)	0.92	-1.76	63.18(-6.68)	0.86	-9.49
32.	LM-13 x POP 445	47.89(-2.16)	0.38	0.04	49.89(-2.17)	0.38	0.05	84.61(-2.37)	0.94	24.63**	93.41(23.55)	1.40	-7.68
33.	LM-13 x POP 31 Q_2	49.11(-0.94)	1.65*	-0.31	51.11(-0.95)	1.66*	-0.30	86.11(-1.26)	1.31	-1.17	66.22(-3.64)	1.12	-9.49
34.	LM-13 x CML 359	51.33(1.28)	0.88	-0.22	53.33(1.27)	0.89	-0.23	90.11(2.74)	0.43	-1.27	61.53(-8.33)	0.92	-9.49
35.	LM-13 x CM 129	51.89(1.84)	1.52	2.10*	54(1.94)	1.43	1.76*	89.33(1.96)	1.14	-1.14	75.48(5.62)	0.98	-9.49
36.	CM 129 x Early yellow	47.44(-2.61)	0.79	-0.11	49.44(-2.62)	0.79	-0.13	84(-3.37)	0.64	-1.82	51.50(-18.36)	0.90	-9.49
37.	CM 129 x POP 445	49.22(-0.83)	0.89	0.01	51.22(-0.84)	0.89	-0.01	86.56(-0.81)	1.17	1.46	65.27(-4.59)	0.91	-9.18
38.	CM 129 x POP 31 Q_2	48.67(-1.83)	1.58	1.76**	50.67(-1.39)	1.60	1.65*	85.22(-2.15)	1.54	-1.10	62.72(-7.14)	1.05	-9.46
39.	CM 129 x CML 359	49.67(-0.38)	1.67	0.73	51.67(-0.39)	1.69	0.65	87.33(-0.04)	1.10	4.01	90.53(20.67)	1.22	-8.38
40.	CML 359 x Early yellow	48.22(-1.83)	0.39	-0.26	50.22(-1.84)	0.40	-0.26	85.33(-2.04)	0.75	-1.62	55.10(-14.76)	0.71	-6.47
41.	CML 359 x POP 445	46.33(-3.72)	0.39*	-0.31	48.22(-3.84)	0.40	-0.26	84(-3.37)	0.37*	-1.87	64.12(-5.74)	0.99	-9.49
42.	CML 359 x POP 31 Q_2	49.22(-0.83)	1.78	2.53**	51(-1.06)	1.90	2.80**	84.67(-2.70)	2.03**	-1.89	63.03(-6.83)	1.01	-9.39
43.	POP 31 Q_2 x Early yellow	48(-2.05)	1.80	4.66**	50.11(-1.95)	1.72	5.14*	84.44(-2.93)	1.73	-0.71	48.84(-21.02)	0.92	-9.41
44.	POP 31 Q_2 x POP 445	47.67(-2.38)	0.60	0.24	49.67(-2.39)	0.61	0.22	85.22(-2.15)	0.95	-0.11	71.47(1.61)	0.92	-9.46
45.	POP 445 x Early yellow	48.89(-1.16)	2.38	5.59**	50.89(-1.17)	2.41	5.31*	85.11(-2.26)	2.56	0.59	61.38(-8.48)	0.88	-8.17

46.	K-25 (Check 1)	52.89(2.84)	1.29	1.48*	55.33(3.27)	1.41	1.73*	91.44(4.07)	0.42*	-1.89	65.19(-4.67)	0.95	-9.47
47.	GA -85 (Check 2)	51.11(1.06)	1.14	1.21*	53.11(1.05)	1.14	1.28*	88.56(1.19)	0.86	-0.21	57.76(-12.10)	0.80	-8.14
48.	NAVJYOT 3 (Check 3)	52.78(2.73)	0.89	0.40	54.78(2.72)	0.90	0.36	92.67(5.30)	1.05	-1.21	44.11(-25.75)	0.98	-5.02
Parents													
49.	EARLY YELLOW (P1)	51(0.95)	1.04	1.53*	53.11(1.05)	0.95	1.21*	86.56(-0.81)	1.17	-0.82	62.03(-7.83)	0.98	-9.42
50.	POP- 445 (P2)	50.33(0.28)	0.76	0.52	52.33(0.27)	0.76	0.56	85.78(-1.59)	1.04	1.24	51.29(-18.57)	0.85	-9.29
51.	POP -31 Q2 (P3)	50.67(0.62)	1.85	-0.28	52.67(0.61)	1.86*	-0.29	87(-0.37)	1.82	15.67**	67.85(-2.01)	1.01	-8.86
52.	CML -359 (P4)	49.67(-0.38)	1.27	-0.25	51.67(-0.39)	1.28	-0.26	87.78(0.41)	1.13	1.91	61.14(-8.72)	0.88	-9.30
53.	CM 129 (P5)	50(-0.05)	0.88	-0.22	52.33(0.27)	0.89	-0.23	90.33(2.96)	0.36	-0.97	83.68(13.82)	1.09	-7.55
54.	LM 13 (P6)	50.67(0.62)	0.48	-0.09	52.67(0.61)	0.48	-0.08	88.78(1.41)	0.57	1.10	68.57(-1.29)	0.96	-9.37
55.	CM- 124 (P7)	50.78(0.73)	0.38	-0.21	52.89(0.83)	0.29	-0.28	87.78(0.41)	0.89	3.24	51.98(-17.88)	0.90	-9.17
56.	DMR QPM-28 (P8)	53.22(3.17)	0.78	-0.28	55.56(3.50)	0.29	-0.28	91(3.63)	1.04	-0.39	51.76(-18.10)	0.92	-8.92
57.	CML- 41 (P9)	51.44(1.39)	1.72	1.39*	53.44(1.38)	1.73	1.50*	90.33(2.96)	1.41	1.70	61.03(-8.83)	0.94	-9.20
58.	HKI-193-2 (P10)	51.67(1.62)	0.39*	-0.31	54(1.94)	0.39*	-0.31	89(1.63)	1.10	9.04*	66.26(-3.60)	0.97	-6.31
Mean		**50.05**	-	-	**52.06**	-	-	**87.37**	-	-	**69.86**	-	-

*Significant at 5% level of significance; **Significant at 1%level of significance.

Table 4.Environmental indices for different characters in maize across the environments

Characters	Environmental indices		
	E_1	E_2	E_3
Days to 50 % tasselling	-1.67	-0.10	1.77
Days to 50 % silking	-1.64	-0.12	1.76
Days to 50 % brown husk	3.77	-0.32	-3.45
Plant height	38.17	5.16	-43.33
Cob length	2.26	-0.20	-2.06
Cob girth	1.38	-0.01	-1.36
Kernel rows/Cob	1.51	1.09	-2.61
Number of kernels/ row	4.72	0.36	-5.08
Grain yield/ plant	4.03	3.05	-7.08
Biological yield	11.97	0.90	-12.87
Harvest index	0.34	1.36	-1.70
Chlorophyll content (SPAD)	3.57	3.06	-6.63
Leaf Relative Water Content	4.01	-3.18	-0.83
Flag leaf area/ plant	23.43	-3.98	-19.45
Leaf area/ plant	425.28	57.39	-482.67
Leaf area index	0.35	0.05	-0.40
Leaf area ratio	8.84	-1.71	-7.13
Specific leaf weight	0.24	0.03	-0.28
Specific leaf area	-6.11	-0.81	6.92

E_1=Environment 1, E_2=Environment 2 and E_3=Environment 3

IV.CONCLUSION

Yield and its related traits should be taken into account while selecting and evaluating genotypes for stability performance across the environments. To measure stability of genotypes across the environments, deviations from regression (S^2di) appeared to be more important criteria than regression coefficient (βi). It was also emphasized that the linear regression (βi) may simply be regarded as a measure of response of particular genotype and deviations from regression (S^2di) should be given more weightage as a measure of stability[29].Six hybrids *viz.*, CML 41 x Early yellow, CML 41 x CML 359, DMR-QPM-28 x CM 129, DMR-QPM-28 x LM-13, CM- 124 x CM 129, LM-13 x CM 129 had positive phenotypic index (P_i>1), regression coefficient near to unity (βi≈1) and non-significant deviation from regression (s^2di) there by indicating its stability over all environments, therefore these hybrids were considered suitable and stable in performance in different environments for high grain yield per plant. The hybrid POP 31 Q_2 x POP 445 however, showed negative phenotypic index (P_i<1), regression coefficient near to unity (βi≈1) and non-significant deviation from regression (s^2di) there by indicating its stability over all environments and suitability for early maturity.The result also indicated that the genotypes interacted differently towards the different environment conditions, indicating the possibility to develop environment specific hybrids. The distribution of rainfall during the growing period and the date of sowing also may be determining factors for the performance of maize genotypes for stability performance of yield and other quantitative traits.

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