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Research Article

Stability analysis in maize (*Zea mays L.*)

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Abstract
Thirteen maize genotypes were assessed for their stability under different environments for eleven characters. G x E interaction was linear in nature for days to 50% of flowering, Days to 50% of silking, days to maturity, Ear girth (cm), The number of grains per row per ear, fodder yield per plant and grain yield per plant. None of the genotypes exhibited average stability for all characters. However, the hybrids LMH12004, LMH12008, LMH12009 and LMH12010 recorded average stability for grain yield per plant. The hybrids LMH12002 and LMH12006 recorded below the average stability and adaptabilities to the favourable environment for grain yield per plant.

Keywords
G x E interaction, stability .

INTRODUCTION

Maize is a monoecious and allogamous plant by nature. Being a C_4 plant it is physiologically more efficient and possess higher grain yield potential. The capacity of any crop to perform well over a range of environments is as important as its yield potential and also its performance over a wide range of environmental conditions. Phenotypic stability parameters are useful to measure the adaptability and stability of crop cultivars which can be exploited to identify genotypes suitable for low, average and high yielding environments and to combat with climate change. The present investigation aims in identifying stable maize genotypes for further exploitation.
Material and Methods

The experimental material for the present investigation consists of ten promising maize hybrids along with three checks. The details of the genotypes included in experiment are presented in **Table 1**.

Genotypes were sown under rainfed condition at three locations *viz.,* Experimental Farm, Department of Agricultural Botany, College of Agriculture Latur (E_1), Oilseed Research Sub Station, Ambajogai (E_2), and Agriculture Research Station, Badnapur (E_3) during *Kharif* 2012 in a randomized block design with three replications. The sowing was carried out at the spacing of 60 cm and 30 cm between the rows and plants, respectively.

Table 1. Name of the hybrids and checks Hybrids: 10 Checks: 3

1	LMH12001
2	LMH12002
3	LMH12003
4	LMH12004
5	LMH12005
6	LMH12006
7	LMH12007
8	LMH12008
9	LMH12009
10	LMH12010

Checks: 3

1.	Maharaja	MKV, Parbhani
2.	Karveer	MKV, Parbhani
3.	Pinnacle	MKV, Parbhani

The method of sowing followed was dibbling. The first thinning was done after 10 days of sowing by retaining two seeds per hill and second was done after 20 days of sowing leaving one healthy seedling per hill. The recommended fertilizer dose, weeding and other cultural operations were followed as per schedule so, as to maintain the healthy plant stand of the crop. Data were recorded on randomly selected five competitive plants from each genotype per replication for the characters *viz*., Days to 50% of flowering, Days to 50% of silking, Days to maturity, Plant height, Ear height (cm), Ear length (cm), Ear girth (cm), The number of kernel rows per ear, The number of grains per row per ear, 100-grain weight (g), fodder yield per plant and grain yield per plant. The data were statistically analyzed from Indostat services following Eberhart and Russel (1966)model.

RESULTS AND DISCUSSION

Pooled analysis of variance for twelve characters over three environments revealed that the mean sum of squares due to hybrids were significant for all the characters under all the environments for all characters except fodder yield per plant. Variances due to G x E interaction were highly significant for all the characters except ear height indicating the differential response of hybrids in the expression of this character in varying environments. The existence of G x E interaction was observed for all other characters *viz.* days to 50 per cent of tasseling, days to 50 per cent of silking, days to maturity, plant height, ear length, ear girth kernel rows number, the number of grains per row, 100 grain weight, fodder yield per plant and grain yield / plant. Similar findings for these traits were earlier reported by Nadagoud*et.al.* (2012), significant G x E interaction for grain yield was reported by Cvarkovic*et al.* (2009), Karadavut and Akilli (2012),Worku*et.al.*(2001) and Nirmal Raj R. *et.al.* (2019).

The analysis of variance for stability parameters **Table (2)** revealed that the variances due to environment + (genotype x Environment) interaction were highly significant for all the traits except ear height indicating that the hybrids interacted significantly with environments. Further the environment (linear) was highly significant for all characters except fodder yield per plant indicating the presence of linear variation among hybrids. Similar results were reported by Nadagoud*et.al*. (2012). The high magnitude of environment (linear) effect in comparison to genotype x environments (linear) for all the characters observed may be responsible for adaptation in relation to yield and yield contributing components of maize. Worku*et.al*. (2001) also reported the similar findings.

Table 2. Analysis of variance for stability in genotypes of maize

Source of variation	DF	Days to 50% tasseling	Days to 50% silking	Days to maturity	Plant height (UNIT)	Ear height Unit	Ear length Unit	Ear girth Unit	Kernel rows no.	No. of grains /row	100 grain weight (gm)	Fodder yield/ plant (gm)	Grain yield /plant (gm)
		Mean sum of squares											
Genotype	12	1.475*	1.339*	2.949**	19.211**	4.737	1.687**	0.175**	0.353**	2.246*	2.131**	10.084*	11.986*
Environment+ (Genotype x Environment)	26	2.206**	3.023**	1.147**	10.856*	8.072	1.288**	0.049**	0.125**	6.272**	2.265**	15.642**	61.215**
Environment (linear)	1	16.187**	21.506**	5.527**	56.043**	92.91**	27.79**	0.116**	0.242*	85.580**	16.434**	4.011	1086.425**
Genotype x Environment (linear)	12	2.899**	2.399**	1.012*	7.007	5.704	0.203	0.070**	0.049	4.270**	1.001	25.886**	30.783**
Pooled deviation	13	0.491	0.504	0.256	3.487	4.256*	0.096	0.012	0.031	0.786	0.467	0.093	4.247
Pooled error	72	0.440	0.464	0.385	4.273	2.044	0.208	0.029	0.057	0.535	0.406	1.597	2.973

Estimates of regression coefficient and the deviation from the regression (**Table 3**) showed a wide range of values for each character. The phenotypic stability of the hybrid was measured by three parameters *viz.* mean performance over the environments, linear regression and deviations from the regression function. A stable hybrid should have the high mean performance, unit linear regression (bi) and deviation from the regression (S^2di) as small as possible (Eberhart and Russell,1966).

In the present investigation hybrids LMH12002, LMH12003, LMH12005, LMH12006 were identified as early hybrids for 50% tasseling while LMH12004 was late but were stable since they possessed (bi) nearer to unity and non significant (S^2di). With respect to days to 50% of silking LMH12006, LMH12007 were stable and identified as early hybrids for 50% of silking while the hybrids LMH12005 and LMH12010 were late stable hybrids as they possessed (bi) nearer to unity and non significant (S^2di). The hybrids LMH12004 and LMH12003 were stable hybrids for days to maturity but were late in maturity. As regards with the plant height the hybrids LMH12002, LMH12004, LMH12005 and LMH12006 showed a wider adaptability and had a high mean and regression coefficient nearer to unity indicating their stable performance over all the environments.

For ear height the hybrids LMH12002, LMH12007 and LMH12008 with high mean, regression coefficient (bi) nearer to unity and non significant deviation from the regression coefficient (S^2di) indicates stable performance over all environmental conditions while the hybrids

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Table 3.Estimates of stability parameters for yield and yield components in Maize

Genotype	Days to 50% Tasseling			Days to 50% silking			Days to maturity			Plant height			Ear height			Ear length		
	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di
LMH12001	53.944	0.42	0.43	57.289	0.05	0.34	91.22	1.00	3.99**	237.11	3.04	-3.84	90.65	1.66	18.12**	17.52	0.45	-0.11
LMH12002	53.222	0.87	-0.60	57.00	0.26	4.45**	92.05	0.83	-1.18*	243.17	0.83	-0.47	92.36	0.89	-2.02	17.74	0.88	-0.15
LMH12003	53.778	1.00	-0.39	56.944	0.72	-6.01**	92.72	0.86	-0.22	236.38	1.49	50.19**	91.61	1.59*	-1.56	17.75	1.01	-0.10
LMH12004	55.333	0.47	-0.36	58.278	0.86	4.53**	93.94	0.57	-0.28	237.94	0.82	-3.55	93.02	0.39*	2.25	17.85	0.89	-0.06
LMH12005	53.333	1.01	-0.13	57.056	1.39	-0.08	91.11	1.87	1.38*	241.22	0.74	-7.21	92.48	3.67	-1.74	17.20	0.52	-0.17
LMH12006	53.556	1.01	-0.29	56.500	0.78	-0.33	91.55	3.52	-0.30	240.27	0.95	-1.65	93.38	1.41	-1.93	16.66	0.92	-0.15
LMH12007	53.611	1.92	0.30	56.333	1.00	-0.48	92.16	3.84	-0.18	242.66	2.32	10.07	92.89	1.00	-17.10	17.16	1.15	0.05
LMH12008	53.500	1.48	0.18	55.833	1.79	0.71	91.16	1.53	-0.32	245.27	2.95*	-4.38	93.96	0.93	-1.35	17.88	0.93	-0.49
LMH12009	54.389	4.27*	-0.48	57.444	3.62	3.22**	91.00	0.86	1.48*	240.15	-0.63*	12.69	85.65	0.13	17.56**	17.23	1.08	-0.02
LMH12010	55.222	1.84	-0.43	57.556	1.89	-0.03	93.05	-1.37	-0.05	238.88	-0.83	8.93	91.86	0.75	2.16	17.66	1.17	-0.17
Maharaja	53.333	0.42	-0.47	56.444	0.22	-0.45	93.66	0.74	-0.06	239.31	1.39	6.15	90.38	1.36	2.38	16.96	0.92	-0.15
Karveer	53.667	1.24	0.99	57.056	1.47	0.51	92.55	-1.41	-0.26	241.38	-0.17	2.98	90.46	1.01	-1.77	17.02	0.91	0.18
Pinnacle	54.500	2.66	0.23	57.889	1.74	3.45**	92.83	-0.13	0.78	240.05	1.41	-3.55	90.18	-0.08	2.93	17.18	0.48	0.38
Mean	53.953			57.048			92.23			240.52			91.45			17.36		

Table 3contd…

Genotype	Ear girth			Kernel rows no.			No. of grains /row			100 grain weight (gm)			Fodder yield/plant gm			Grain yield /plant gm		
	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di
LMH12001	12.65	-3.26*	-0.03	13.86	1.45	-0.06	29.75	0.11	5.00**	23.35	0.87	-0.31	199.28	0.79	-0.42	108.52	2.17*	-2.56
LMH12002	13.06	-1.84	0.01	14.07	0.56	0.08	29.91	-0.23	0.89	22.97	2.04	3.44**	183.96	-3.25	-0.86	113.16	1.01	-0.86
LMH12003	13.55	0.90	-0.01	14.15	-0.30	0.11	30.61	0.65	-0.12	24.56	0.79	2.37*	190.31	0.56	-7.48	113.22	1.15	43.94**
LMH12004	13.26	0.83	-0.03	14.75	1.00	-0.57	30.64	0.75	-0.48	24.50	0.58	-1.81	189.95	-9.82	0.89	108.84	0.79	-2.48
LMH12005	13.27	4.80	-0.02	14.19	1.82	0.23	30.73	0.24	3.40**	24.97	0.82	-0.24	195.28	-1.98	-1.54	112.05	0.18	9.99*
LMH12006	12.41	-2.82*	0.12*	14.18	4.84	0.61**	29.95	1.72	0.12	23.41	1.48	-0.07	192.59	5.27	4.52	109.73	1.17	0.22
LMH12007	12.64	3.74	-0.03	14.34	1.95	-0.02	28.59	2.01	0.36	24.45	1.80	12.41**	201.97	12.30	3.15	111.00	1.90*	-2.58
LMH12008	12.69	3.05*	-0.02	15.04	-1.64	0.11	27.87	2.19*	-0.52	23.12	1.43*	4.65**	192.25	-5.99	7.50*	108.35	0.66	-2.01
LMH12009	13.93	0.72	-0.02	14.87	1.00	-0.05	30.62	0.54	-0.75	25.02	0.86	-0.18	203.84	13.88	8.94*	114.90	0.84	-2.88
LMH12010	13.11	1.98	-0.03	14.44	-0.90	0.03	29.47	1.15	3.49**	21.96	2.08*	-0.41	190.23	-7.37	13.57**	108.29	0.68	-1.69
Maharaja	13.03	-1.95	-0.02	14.11	-0.08	0.16	28.00	1.42	-0.46	24.71	0.10	-0.21	196.98	3.78	3.26	105.46	-0.08	7.52
Karveer	12.58	0.70	-0.02	13.96	2.21	0.19*	28.32	1.53	5.82**	23.09	2.01	0.58	191.65	18.45	1.10	107.99	0.82	16.92*
Pinnacle	12.66	4.18	-0.01	14.21	1.02	0.38**	28.01	1.61	0.66	24.01	-0.09	0.82	188.17	-6.14	23.15**	106.55	1.18	34.29**
Mean	12.98			14.35			29.42			23.85			193.57			109.85		

* and ** Significant at 5% and 1% level , respectively.

LMH12005 and LMH12006 had regression coefficient more than unity (bi>1) with high mean and non significant deviation from the regression coefficient (S^2di) revealed their adaptabilities to better environment. In respect of ear length, the hybrids LMH12002, LMH12003, LMH12004 and LMH12008 exhibited high mean with regression coefficient nearer to unity (bi≈1) and with non-significant deviation from the regression (S^2di) revealed wider adaptability over all the environments. In respect to ear girth the hybrids LMH12003, LMH12004 and LMH12009 recorded regression coefficient nearer to unity which indicates wider adaptability over all environments. The hybrids LMH12004 and LMH12009 had a high mean with regression coefficient (bi) nearer to unity indicating a wider adaptability for kernel row number, while hybrids LMH12007 and LMH12005 had a high mean with regression coefficient greater than unity (bi>1) which revealed their adaptability specially to the better environments for this trait.

The hybrids LMH12003, LMH12004 and LMH12009 exhibited high mean with regression coefficient nearer to unity (bi≈1) with non significant deviation from the regression coefficient (S^2di) indicating wider adaptability over environments for the number of grains per row, also the hybrids LMH12006 and LMH12007 had regression coefficient greater than unity (bi>1) revealed that their adaptability specially to the better environments.

For 100 grain weight the hybrids LMH12004, LMH12006 and LMH12009 were more stable across the environments and identified with high mean value, regression coefficient nearer to unity and non-significant deviation from the regression (S^2di), while the hybrid LMH12001 had low 100 grain weight with regression coefficient nearer to unity and non- significant deviation from the regression (S^2di) indicating adaptability to the poor environment only.

For fodder yield per plant the hybrids LMH12001 and LMH12003 recorded regression coefficient nearer to unity indicating a wider adaptability for this character, while the hybrids LMH12006 and LMH12007 recorded a high mean, regression coefficient (bi) greater than unity with non significant (S^2di) and can be considered as specially adapted to the better environment. The hybrids LMH12004, LMH12008, LMH12009 and LMH12010 recorded more than average stability indicating their adaptabilities to favorable environment, while the hybrids LMH12002 and LMH12006 had a high mean, regression coefficient (bi) greater than unity with non significant (S^2di) regarded as specially adapted to the better environment, Nadagoud*et. al*. (2012), Karadavut and Akilli (2012) Worku *et.al*. (2001), Sowmya H.H. *et.al*(2018) and Matin MQI. *et.al.* (2017) also reported the similar findings for seed yield per plant.

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