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RESEARCH NOTE

Stability analysis of single cross hybrids for grain yield in maize (*Zea mays* L.)

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Assessment of the stability of a maize hybrid to different environments is useful for recommending particular hybrid for commercial production and should be considered a requirement for breeding programmes. Totally, 48 single cross experimental maize hybrids developed from 16 lines and three testers in Line X Tester design were evaluated at three diverse environments, *viz.,* Arabhavi, Agriculture Research Stations of Nippani and Main Agricultural Research Station (MARS) Dharwad (Northern transition zone) in Karnataka, for their grain yield stability. The hybrids along with 3 checks; GH-0727, CP-818 and NK-6240 were sown in Randomised Block Design across the three locations during kharif-2016. Stability analysis was run using Windostat Version 8.1 following Eberhart and Russell (1966) model. Out of all the hybrids, two of them out crossed the performance of the best check (NK-6240). The hybrids; GH-1514 (91 q/ha) and GH-1532 (83 q/ha) had the best mean values but their regression values were significantly differed from unity. Their stability is high in favourable environments as evident from their high regression value.

Keywords: Hybrid, Maize, Stability

Maize (*Zea mays* L.) is an important crop globally and in India, it is the third most important cereal after wheat and rice in terms of area and production. The global average productivity of maize is 5500 kg/ha and India's productivity is 2510 kg/ha. Maize production is dominated by Karnataka, producing 15 per cent of India's maize while Tamil Nadu has the highest productivity of 6549 kg/ha. In Karnataka, maize occupies an area of 1.17 mha, with the production of 3.26 mt and average productivity is 2773 kg/ha (Anon., 2016). The acreage has increased consistently but production pattern has been erratic owing to the variations in the yield. One of the reasons for this can be the lack of stable hybrids that can consistently give high yield over diverse environments with a minimum fluctuation. The presence of genotype by environment interaction is of major concern to plant breeders, since, large interaction can reduce yield and complicate identification of superior cultivars. Using stable genotypes for high grain yield is important in sustainable agriculture (Kang and Gorman, 1989).

Stable performance of maize hybrids in multi-environment trials is critical to sustain food production. Thus it is important to repeat an experiment at diverse environments to obtain valid data taking into account the environment variations and select for the genotypes with a less G x E interaction. The strategy for reducing G x E interaction involves selecting cultivars with a better stability across a wide range of environments in order to better predict behavior. Parametric models based on simple linear regression analysis are among the most widely used to identify superior cultivars and include the method proposed by Eberhart and Russell (1966), which interprets the variance of the regression deviations (S^2_{di}) as a measure of cultivar stability and the linear regression co-efficient (b_i) as a measure of the cultivar adaptability. Therefore, knowledge of G x E interaction and yield stability are important for breeding new cultivars with improved adaptation to environmental constraints prevailing in the target environments (Mahajan *et al.,* 1991). The present research study was conducted to identify stable and high yielding experimental single cross hybrids for their grain yield stability over different environments.

In order to execute the experiment , 16 promising CIMMYT and IIMR based germplasm lines, that were selected on the basis of their test weight and per se performance were crossed with 3 testers (CM-111, CM-500 & PA-15) to produce 48 experimental single cross hybrids were in Line x Tester design in *Rabi*-2015. These single cross hybrids were evaluated for their grain yield stability, at three different locations; Agriculture Research Station, Arabhavi of Northern dry zone (zone-3), Agriculture Research Station, Nippani and Main Agricultural Research Station (MARS), Dharwad of the Northern Transition zone (zone-8) of Karnataka. Diversity prevailed with respect to the environment among the locations considered in this experiment. These 48 hybrids, the 16 lines, 3 testers along with 3 checks; GH-0727, CP-818 and NK-6240 were sown in Randomised Block Design in 3 replications across the three locations during Kharif-2016. Recommended agronomic practices were followed and harvesting was done after 120 days of sowing and grain yield was recorded taking into account the moisture percentage at the time of harvest. Stability analysis was run on Windostat, version 8.1 following Eberhart and Russell (1966) model.

The analysis of variance for stability (Table 1) revealed that there was significant difference among the genotypes across environments for the important characters like days to 50 per cent tasselling, days to 50 per cent silking, plant height, ear height, cob length, cob girth, number of kernel rows per ear, number of kernels per row, 100 grain weight and grain yield per hectare. This shows that there is variability among the genotypes with respect to these characters. Genotype x Environment (Lin.) component was significant for traits, *viz.* days to 50 per cent tasselling, days to 50 per cent silking, cob length, cob girth, shelling percentage, 100 grain weight and grain yield. The significance of (G x E) demonstrated that genotypes responded differently to variation in environmental conditions. It is indicated that variation in stability of different cultivars performance was mainly due to genotype × environment interaction.

Table1. Pooled analysis of variance (ANOVA) for stability of different quantitative traits

Sources of variation	Degrees of freedom	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
Genotypes	69	8.96**	9.12**	251.36**	120.3**	3.71**	0.06**	1.36**	16.32**	3.34	9.89*	645.89**
Env.+(Gen.* Env.)	140	3.01**	4.18**	162.39	52.27	2.64**	0.08**	0.59	0.59	5.90**	4.28	284.23**
Environments	2	18.0**	1.11**	3014.8**	814.7**	41.13**	4.71**	1.25	1.25	164.32**	6.61	11652.9**
Gen.* Env.	138	2.79**	4.23**	121.05	41.22	2.08**	0.02**	0.58	0.58	3.60**	4.25	119.46
Environments(Lin.)	1	36.0**	2.22**	6029.7**	1629.5**	82.26**	9.42**	2.50*	2.50*	328.64**	13.22	23305.84*
Gen.* Env.(Lin.)	69	5.5**	8.46**	121.71	39.32	3.40**	0.03**	0.64	0.64	7.21**	5.39*	143.64*
Pooled Deviation	70	0	0	118.67	42.49	0.74	0.05	0.51**	0.51	4.92**	3.06	93.93**
Pooled Error	414	1.52	1	95.42	40.61	0.68	0.02	0.24	0.24	1.87	2.34	49.11
Total	209	4.9	5.8	191.76	74.75	2.99	0.08	0.84	0.84**	9.34	6.28	403.63

*- Significant at 1% ** - Significant at 5%

X1-Days to 50 per cent tasselling X5- Cob length X9- Shelling percentage
X2- Days to 50 per cent silking X6- Cob girth X10-100 grain weight
X3- Plant height X7- Number of kernel rows per cob X11-Grain yield
X4- Ear height X8- Number of kernels per row

Environmental index shows the deviation of that specific environment's mean from the overall mean. Thus a higher value of environmental index favours the higher expression of the character. The mean, range and environmental index of each of the 11 traits studied at individual locations is furnished in Table 2.The environmental index for grain yield was highest in case of ARS, Arabhavi (13.36) then followed by MARS, Dharwad (-0.96) and the least favourable was ARS, Nippani (-12.39). This was reflected in the expression of this trait in the genotypes with a mean of 75 q/ha, 49.3 q/ha and 60.7 q/ha respectively in the three environments. The range was highest in case of ARS, Arabhavi (60-113 q/ha), ARS, Nippani (34-77 q/ha) and MARS, Dharwad (32-95 q/ha). Fig. 1(a) shows the environmental index with their grain yield per hectare, the respective values for the three environments have been pointed out.

According to Eberhart and Russell (1966) model of stability analysis, a stable variety is one which has above average mean yield, a regression coefficient of unity (b_i =1) and non-significant mean square for deviations from regression (S^2_{di} =0). High value of regression (b_i >1) indicates that the variety is more responsive for input rich environment, while, low value of regression (b_i <1), is an indication that the variety may be adapted in poor environment. The phenotypic stability of genotypes was estimated by mean performance over environments, the regression coefficient (b_i) and deviation from regression (S^2_{di}). The promising hybrids that had high mean yield and their respective stability parameters have been furnished in Table 3.

The highest environmental index (13.36) for grain yield was recorded in ARS, Arabhavi environment, so this environment showed the highest mean for grain yield (74.33 q/ha). Out of the 48 hybrids, only two of them outcrossed the performance of all the checks. The hybrids: GH-1514 (91.32q/ha) and GH-1532 (83.02 q/ha) had the best mean values but their regression values were significantly differing from unity. The adaptability is more in the favorable environments as evident from their high regression value. ARS, Arabhvai fared well in giving the best yields, this can be owed to the lower insect infestation (as compared to MARS, Dharwad) and scheduled irrigation facilities (rainfed in case of ARS, Nippani). Grain yield has been described as a complex phenotypic trait in plants because it is a final aggregate product of many interwoven physiological and developmental traits controlled by different arrays of genes. Being final product of complex physiological and development processes from sowing to maturity seed yield recorded highest variation across the locations. Vijay *et al.* (2012) and Kaundal and sharma (2006) also reported same results in their studies, which is endorsed the present investigation. Other genotypes like GH-1517 (80.74 q/ha), GH-1505 (78.18 q/ha) and GH-1547 (74.9 q/ha) had regression value nearer to unity with non-significant deviation. These hybrids can perform in a stable manner across environments. Fig. 1 (b) represents the various genotypes with their mean grain yield against their regression

Table 2. Mean, range and environmental index for traits in maize at different locations

Traits	Mean	Range	Env. index					
	E1	E2	E3	E1	E2	E3	E1	E2	E3
Days to 50 per cent tasseling	59.9	60.4	60.9	57-64	58-64	59-64	-0.341	0.889	1.23
Days to 50 per cent silking	61.3	61.2	61.0	59-65	59-67	59-66	0.396	0.431	-0.729
Plant height (cm)	161.6	168.3	174.7	146-184	157-194	142-205	-6.603	-0.082	6.521
Ear height (cm)	81.9	84.7	79.7	69-97	75-102	69-103	2.974	-3.725	0.751
Cob length (cm)	16	15.3	16.6	14-23	12.0-18.0	14-20	-0.070	-0.729	0.799
Cob girth (cm)	4.4	4.1	4.6	4.2-6.7	4.0-5.0	4.0-5.0	-5.258	-1.958	7.126
Number of kernel rows per cob	14.1	14.12	14.3	7.6-15	11.0-17.0	13-16	-0.04	-0.109	0.149
Number of kernels per row	33.9	32.4	35.4	31-40	26-40	30-42	-1.29	-0.832	2.122
Shelling percentage (%)	83.3	82.4	84.9	77-86	79-87	82-87	-0.242	-1.041	1.282
100 grain weight (g)	32.4	31.9	32.2	27-37	28-37	27-37	0.246	-0.328	0.082
Grain yield (q/ha)	75.0	49.3	60.7	60-113	34-77	32-95	13.36	-12.391	-0.969

E1- ARS, Arabhavi E2- ARS, Nippani E 3 - MARS, Dharwad

Table 3.Stability parameters of the promising hybrids based on grain yield (q/ha) environments and mean over locations

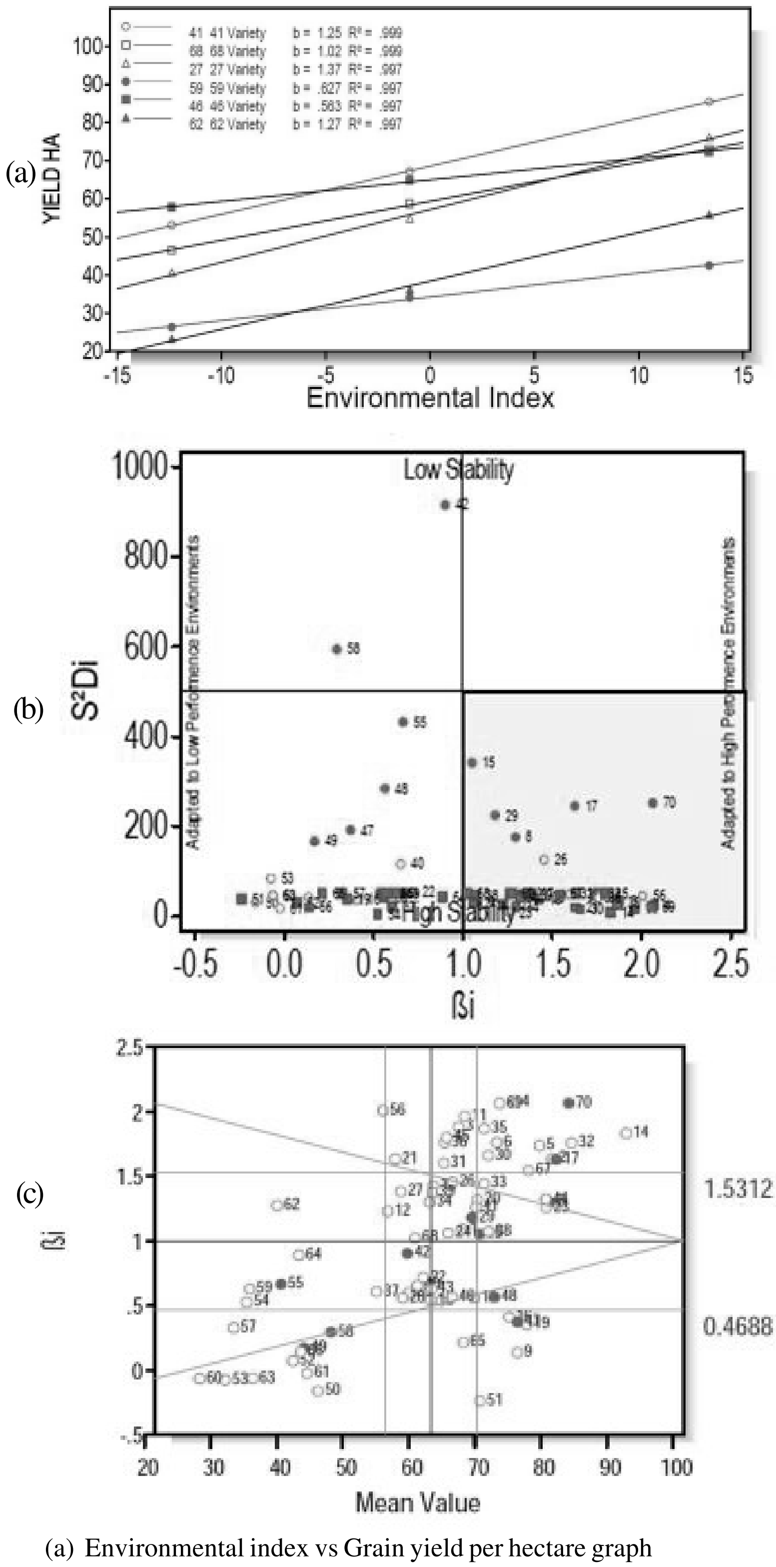
			Grain yield (q/ha)			
Hybrids	E1	E2	E3	Pooled	b_i	S^2d_i
GH-1514	113.36	65.67	94.92	91.32	1.64	-50
GH-1532	106.75	61.6	80.76	83.02	1.74	-40
GH-1517	96.26	52.76	93.19	80.74	1.29	-187*
GH-1502	102	59.93	78.3	80.08	0.14	41.4
GH-1508	102.47	70.51	66.21	79.73	1.85	-14
GH-1523	93.21	60.16	84.31	79.22	1.65	230
GH-1544	97.95	64.19	75.31	79.15	0.36	-37
GH-1505	102.39	57.98	74.19	78.18	1.27	3.55
GH-1519	79.61	70.18	79.01	76.27	1.76	-49
GH-1547	85.5	77.3	61.8	74.9	1.33	-38
CHECKS						
GH-0727	81.89	53.15	71.48	68.84	1.62	-50.97
CP818	97.64	44.13	74.67	72.15	2.06	-20.35
NK6240	103.89	49.18	94.8	82.62	2.06	-20.35
Env. Index	13.36	-12.39	-0.96			

E1- ARS, Arabhavi E2- ARS, Nippani E3- MARS, Dharwad

Table 4. Top performing hybrids and three checks based on their grain yield (q/ha) across environments along with their respective other quantitative traits

Hybrids	X11	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10
GH-1514	91.3	61.5	61.8	181.8	87.1	16.79	4.64	15.58	36.55	83.93	30.67
GH-1532	83.0	59.7	61.5	181.1	87.8	16.01	4.48	14.40	36.05	84.35	31.17
GH-1517	80.7	63.3	64.2	181.3	89.7	16.49	4.61	15.68	33.85	83.38	34.67
GH-1502	80.1	60.3	60.7	185.6	90.0	16.99	4.45	14.60	36.55	84.48	31.83
GH-1508	79.7	61.0	61.2	183.1	90.7	17.67	4.56	15.53	35.90	84.60	32.83
GH-1523	79.2	62.0	62.3	173.7	83.2	15.31	4.47	14.00	32.60	83.19	32.33
GH-1544	79.2	61.0	62.0	162.1	72.6	16.32	4.52	15.03	35.55	84.30	34.17
GH-1505	78.2	64.2	65.7	185.2	88.6	16.05	4.51	14.27	35.45	83.95	31.17
GH-1519	76.3	62.5	63.3	177.7	90.9	18.60	4.49	14.73	39.75	85.10	33.67
GH-1547	74.9	61.7	61.7	175.1	81.8	13.98	4.46	15.00	32.30	82.38	31.17
Checks											
GH-0728	58	59	161	76	14.94	4.24	13.87	33.00	82.18	27.38	68.84
CP-818	64	64	173	82	16.41	4.32	13.58	35.80	83.93	33.16	72.15
NK-6240	60	60	163	80	16.26	4.54	13.96	34.10	81.56	36.16	82.62

X1- Days to 50 per cent tasselling
X2- Days to 50 per cent silking
X3- Plant height (cm)
X4- Ear height (cm)
X5- Cob length (cm)
X6- Cob girth (cm)
X7- Number of kernel rows per cob
X8- Number of kernels per row
X9- Shelling percentage (%)
X10- 100 grain weight (g)
X11- Grain yield (q/ha)



(a) Environmental index vs Grain yield per hectare graph
(b) Mean value (grain yield per hectare) vs *bi* (regression value) graph
(c) Mean value (grain yield per hectare) vs standard deviation graph

Fig.1. Stability parameters of different genotypes

values. A minimum value of deviation is always desirable with a stable genotype. The hybrids; GH-1514 and GH-1532 had a low deviation. The mean grain yields of the genotypes against their respective CV have been shown in fig. 1 (c). The mean values of the test weight were high in each location. One of the better performing hybrids was GH-1532 with a test weight of 32.8 g and b_i value of 0.7, indicating its adaptability to unfavourable environment. Top performing hybrids and three checks based on their grain yield (q/ha) across environments along with their respective other quantitative traits are furnished in Table 4.

Traits like cob length and cob girth characters directly contribute to the grain yield. The range for the trait of cob length was higher in case of ARS, Arabhavi as evident from the environmental index (5.18). Out of the identified promising genotypes GH-1514 had a cob length of 16.79 cm and cob girth was 4.64 cm which is higher than GH-1532, contributing its high yield. But a higher value of cob length was seen in GH-1508, *i.e.,* 17.67 cm. The best environment for the expression of cob girth was MARS, Dharwad with an environmental index of 7.12. Similar findings were also reported by Karadavut and Akilli (2012), Vijay *et al.* (2012) and Nagabhushan *et al.* (2013). Number of kernel rows per ear and number of kernels per row had the highest environmental index in ARS, Nippani environment, exhibiting higher values of this trait. The hybrid showing highest number of kernel rows per ear was GH-1517 (15.7 rows) but had very high level of regression value, implying that it is not stable across environments. Number of kernels per row was highest in GH-1519 (39.75) but with a regression value of 1.7. Kaundal and Sharma (2006) also made similar observations thus confirmed the present results. Shelling percentage was almost the same at all the locations with a little variation with a mean of 82.4-84.9 at all the three environments but comparatively the environmental index was higher at MARS, Dharwad. It can be concluded from the study that hybrids; GH-1514 and GH-1532 have out crossed the performance of all the checks as indicated by pooled analysis. These hybrids can be forwarded for further evaluation and trials in future breeding programmes.

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