Plant Archives Vol. 17 No. 2, 2017 pp. 1630-1634 ***ISSN 0972-5210***

STABILITY ANALYSIS IN HIGH ALTITUDE SINGLE CROSS MAIZE HYBRIDS UNDER TEMPERATE NICHES

Syed Towseef Ahmad, G. Ali, Z.A. Dar*[1], M.A. Bhat, I. Abidi, A.A.Lone, M.A. Ahangar, Kamaldin, R.A. Lone and A.R. Vaid

RRS and FoA, Wadura (SKUAST-K)- 193201.
Dryland Agriculture Research Station, Budgam (SKUAST-K) 190025

Abstract

Eleven maize hybrids along with one check were evaluated across three locations spread over different agro-climatic zones of Jammu and Kashmir that differ in soil type, altitude and mean annual rainfall during *Kharif* 2016. The experiment was laid out in a randomized complete block design with three replications. Stability parameters and contrasting role played by genotype, environment and G × E interaction in multi-locational variety trials were considered and analyzed. Stability parameters such as mean (X), regression coefficient (b_i) and deviation from regression (S^2d_i), as suggested by Eberhart and Russell (1966) was evaluated in order to assess the stability of these hybrids for various characters under consideration. Analysis of variance revealed that the hybrids possessed highly significant variability for all the traits under study. The mean squares due to environments were also significant for all the traits except Cob height (cm), Cob length (cm) and Cob diameter (cm), indicating that the environments selected were random and were different in agro-climatic conditions. Interaction of genotypes with the environment (G × E) was observed to be significant for all the traits, which revealed linear response of the genotypes to environmental changes. Thus the genotypes differed considerably for stability for the traits under investigation over the locations. Based on the stability parameters of Eberhart and Russell (1966) model, hybrids H1, H2, H5 and H10 were identified as most stable, H2 and H5 were average adapted to poor and high input environments respectively in terms of grain yield stability. Highest mean performance for Grain Yield (q/ha) was observed to be in H2 (81.55 q/ha) which was surpassing the check SMH-1 (76.22) by 7 %.

Key words: Environment, genotype, maize, hybrids, stability, regression.

Introduction

Maize (*Zea mays* L.) originated in Central America & Mexico and evolved from Teosinte (*Zea mays mexicana*) (de Wet and Harlan, 1972). It belongs to monocot family Poaceae. It is one of the well-known cereal crops that can be successfully grown in many parts of the world over a wide range of environmental conditions and ranks first in terms of cultivate area, total production and consumption (FAO, 2016). About 75 per cent of this area is in developing countries, where maize is widely grown for human consumption. The suitability of maize to diverse environments is unmatched by any crop as the expansion of maize to new areas and environment still continues, as it has a range of plasticity. Differential yield response of cultivars from one environment to another is called genotype x environment interaction (GEI) and can be studied, described, and interpreted by statistical models (Crossa, 1990; Vergas *et al.*, 1999). Developing crop cultivars that perform well across a wide range of environmental conditions has long been a major challenge to plant breeders. In practice, genotype × e-nvironment interaction complicates the identification of superior genotypes (Allard and Bradshaw, 1964). Genotype × environment interaction is important in the development and evaluation of plant varieties since it reduces the genotypic stability values under diverse environments (Hebert *et al.*, 1995). For plant breeders, large genotype × environment interaction impedes progress from selection and has important implications for testing and cultivar release. Genotype × environment interactions are of major importance because they provide information about the effect of different environments on cultivar performance and have a key role for assessment of performance stability of the breeding materials (Moldovan *et al.*, 2000). The improvement of cultivars or varieties, which can be adapted to a wide range of diversified environments, is the ultimate goal of a plant breeders in crop improvement program. It results

****Author for correspondence***

in genotype rank changes from an environment to another, a difference in scale among environments, or a combination of these two situations (Aycicek and Yildirim, 2006). The adaptability of a variety over diverse environments is usually tested by the degree of its interaction with different environments under which it is planted. When assessing grain yield of a set of cultivars in a multi-environment trial, changes are commonly observed in the relative yield performance of cultivars with respect to each other across sites. Statistically, G × E interactions are detected as a significantly different pattern of responses among the genotype across environments and biologically, this will occur when the contributions (or level of expression) of the genes regulating the trait differ among environments (Basford and Cooper, 1998). Stability analysis is frequently used to explore genotype × environment interaction, but the results can be extremely sensitive to changes in the genotypes tested across years.

Materials and Methods

Eleven maize hybrids along with one check (SMH-1) were evaluated in a Randomized Block Design with three replications at each location, having a plot length of 4 m with inter and intra row spacing of 75 cm and 20 cm respectively during *Kharif*-2016 across three locations spreading over different agro-climatic zones of Jammu and Kashmir, *viz.*, Mountain Crop Research Station (MCRS), Larnoo Anantnag, Dryland Agriculture Research Station (DARS), Budgam and Main Campus, SKUAST-K, Shalimar Srinagar. The sowing was completed during the second fortnight of April at all the locations and recommended package of practices was followed to raise the crop. Data were recorded on plot basis for Plant height (cm), No. of Cobs plant^{-1}, Cob Height (cm), Cob Length (cm), Cob Diameter (cm), 100 Kernel weight (g), Grain Yield (q/ha). Seed yield of each hybrid was calculated at 15 per cent moisture content and converted into q/ha. Five plants were tagged randomly for recording observations for each entry for all the quantitative characters. Mean of five plants for each entry in each replication was worked out for each character at each location and used for statistical analysis. Stability parameters for different characters were computed using the regression approach of Eberhart and Russell (1966).

Results and Discussion

The analysis of variance of pooled data (table 1) indicated significant differences among hybrids for all the traits studied suggesting the presence of variability among hybrids. The mean squares due to environments were also significant for all the traits except cob height (cm), Cob Length (cm) and Cob diameter (cm), indicating that the environments selected were random and were different in agro-climatic conditions. Interaction of genotypes with the environment (G × E) were observed to be significant for the traits *viz.*, No. of cobs plant^{-1} and Grain Yield (q/ha), indicating differential response of the hybrids to varying environments. The variance due to environment + (genotype × environment) was significant for all the characters except Plant height (cm), No. of cobs plant^{-1}, cob height (cm) and Cob Length (cm). Partitioning of (environment + (G × E)) interaction into environment (linear), G × E (linear) and pooled deviation revealed that mean square due to environment (linear) was significant for all the traits except Plant height (cm), No. of cobs plant^{-1}, cob height (cm) and Cob Length (cm), which confirmed that significant differences existed between environments and had shown that environment effects were additive. Similarly, G × E (linear) was significant for characters *viz.,* 100 Kernel weight (g) and Grain Yield (q/ha) which revealed linear response of the genotypes to environmental changes. The mean squares due to pooled deviation (non-linear) were significant for all the traits revealing that the non-linear component was important for these traits which contributed to total G × E interaction Thus the genotypes differed considerably for stability for the traits under investigation over the environments. Significant mean squares have been reported for most the traits in maize genotypes over environments by Mani and Singh (1999), Agarwal *et al.* (2000), Dodiya and Joshi (2003), Kumar and Singh (2004), Nadagoud *et al.* (2012), Abera *et al.* (2013) Puttaranaik *et al.* (2016). Similarly, significant [environments + (genotype × environment)] variances were reported by Sain *et al.* (1987), Arun kumar and Singh (2004) and Kaundal and Sharma (2006). Nadagoud *et al.* (2012). In case of environment (linear) significant mean squares were reported by Nadagoud *et al.* (2011), Puttaranaik *et al.* (2016), The variance due to genotype × environment (linear), genotype (G), environments (E) were found significant for various traits by Nadagoud *et al.* (2012), Both linear and non-linear components of genotype × environment interaction were reported to be significant by Dev *et al.* (2010). The variance due to genotypes´ environments (linear) was found significant for various traits by Dass *et al.* (1987), Kaundal R. and Sharma B. K. (2006). Significant mean squares for pooled deviation (non-linear) regarding various traits have been reported by Puttaranaik *et al.* (2016) evaluated newly developed maize hybrids in over locations belonging to three different zones in order to identify high yielding and stable hybrid.

Once the genotype × environment interactions was found to be significant, the next test is to identify stable genotypes, which interact less with the environments. Many stability models have been developed to identify the stable genotype. Eberhart and Russelll (1966) model is the one which has been used in maize and in other crops by several workers. An ideal genotype is the one possessing high mean performance, with regression coefficient around unity (b_i=1) and deviation from regression (S^2d_i) close to zero. The linear regression is regarded as the measure of linear response of a particular genotype to the changing environment. If the regression coefficient (b_i) is greater than unity, the genotype is said to be highly sensitive to environmental fluctuations but adapted to high yielding environments. If the regression coefficient (b_i) is equal to unity, it indicates the average sensitivity to environmental fluctuations and adaptable to all environments. If the regression coefficient (b_i) is less than unity, it indicates less sensitivity to environmental changes and if this is accomplished by a high mean value, then the genotype is said to be better adapted for poor conditions. The non-significant linear (b_i) and non-linear (S^2d_i) estimates indicate average stability of genotypes across different environments, whereas significant b_i and non-significant S^2d_i values indicate stability to specific environments. However the significance of S^2d_i estimate, irrespective of whether the corresponding b_i estimate is significant or non-significant would suggest that the behaviour of the genotype is unpredictable. In the present investigation, the stability of genotypes to various characters of maize were judged on the basis of deviation from regression (*bi*) and due consideration was also given to their mean performance and linear response. The results of stability are representing in table 2 and 3.

For plant height, none of the hybrids had a stable performance over environments. While genotypes *viz.,* H1, H2, H3, H4, H5, H6, H8, H10 and SMH1 had bi value more than unity and non-significant deviation from regression except H7 and H9 indicating their suitability for all environments under study with unpredictable performance. The hybrids H5, H8, H9, H10 and SMH1 were found stable because of high mean, non significant deviation. The present findings are in agreement with Sharma and Saikia R.B. (2001), Singh *et al.* (2009) and Lata *et al.* (2010).

For cob placement, only one hybrid H5 was stable having regression near unity and non significant deviations for regression but exhibited slightly lesser cob placement

Table 1: Pooled Analysis of variance for stability analysis (Eberhart and Russell, 1966) in maize over three locations.

Source of variation	d.f.	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear diameter (cm)	Cobs Plant^{-1}	100-kernel weight (g)	Grain yield (qha^{-1})
Hybrid (H)	10	200.738**	179.59**	3.058 **	0.17391**	0.250**	1.649 **	23.73 **
Environments (E)	22	0.616	0.669	0.299	0.00572	0.000	1.969 **	24.04 **
Hybrid × environment (H×E)	2	0.139	0.889	0.263	0.00071	0.000**	19.892**	245.26**
Environment + (H ×E)	20	0.664	0.647	0.303	0.00623	0.000**	0.177	1.945 *
Environment (linear)	1	0.279	1.779	0.526	0.00141	0.000**	39.78**	490.5 **
H × E (linear)	10	0.424	0.528	0.416	0.00368	0.000**	0.267 *	3.288 **
Pooled deviation (non linear)	11	0.821*	0.696	0.172	0.00797	0.000	0.079	0.547
Pooled error	60	0.338	0.726	0.196	0.00429	0.000	0.321	0.462

Table 2: Stability parameters for plant height, Cob height, Cob length and Cob diameter in different hybrids pooled over locations.

Hybrids	Plant height (cm)			Cob height (cm)			Cob length (cm)			Cob diameter (cm)		
	(X)	b_i	S^2d_i	(X)	b_i	S^2d_i	(X)	b_i	S^2d_i	(X)	b_i	S^2d_i
H1	223.73	-1.57	1.02	101.66	2.09	0.12	24.27	3.08	-0.20	5.95	0.97	0.01
H2	223.83	-2.34	-0.34	112.77	1.74	-0.25	25.66	1.01	-0.09	5.35	-3.14	0.01
H3	216.00	10.00	-0.03	104.88	4.41	-0.69	23.55	5.10	0.85*	5.56	-5.50	0.01*
H4	216.27	1.97	-0.23	102.55	1.42	0.14	26.16	2.00	-0.18	5.52	4.71	0.01
H5	204.22	1.56	-0.36	103.66	1.02	-0.24	26.55	1.15	0.01	5.58	0.79	0.00
H6	204.50	-6.19	0.16	95.22	2.41	-0.26	25.22	-0.54	-0.09	5.27	-2.36	0.00
H7	206.22	0.45	1.92*	114.77	0.65	-0.50	24.61	-2.62	-0.18	5.36	7.07	0.00
H8	204.72	1.88	-0.11	115.11	-2.48	1.91	24.05	-3.08	-0.20	5.73	-1.57	0.00
H9	202.42	-0.45	1.92*	114.05	0.79	-0.03	24.05	2.62	-0.18	5.96	12.57	0.01
H10	205.16	4.45	0.85	96.44	-0.35	-0.67	25.05	0.30	0.03	5.40	1.57	0.00
SMH-1	204.72	1.24	0.17	96.55	-0.74	0.15	23.66	-3.00	-0.14	5.38	-3.93	0.00
Mean	210.16	-	-	105.24	-	-	24.80	-	-	5.54	-	-
SE (±)	0.6	5.7	-	0.6	2.1	-	0.29	1.89	-	0.0631	7.87	-

Table 3: Stability parameters for Cobs Plant^{-1}, 100-kernel weight, Grain yield in different hybrids pooled over locations.

Hybrids	Cobs Plant^{-1}			100-kernel weight(g)			Grain yield (qha^{-1})		
	(X)	b_i	S^2d_i	(X)	b_i	S^2d_i	(X)	b_i	S^2d_i
H1	1.00	0.50	0.00	24.00	0.74	-0.28	76.33	1.07	-0.54
H2	1.00	0.98	0.00	24.05	1.20	-0.29	81.55	0.70	-0.42
H3	1.00	0.34	0.00	25.30	0.89	-0.28	75.55	1.18	-0.44
H4	1.00	0.55	0.00	24.16	0.69*	-0.32	78.33	1.32**	-0.58
H5	1.20	0.76	0.00	25.33	1.13	-0.30	76.66	1.17	-0.57
H6	1.00	0.38	0.00	26.00	1.38	-0.31	72.00	0.80	0.20
H7	2.00	0.32*	0.00	24.33	0.64	-0.25	80.77	1.03	-0.58
H8	1.20	0.35	0.00	24.88	0.70	0.21	73.88	1.16	0.09
H9	1.20	0.45	0.00	24.66	1.23	-0.22	76.33	0.38	3.49*
H10	1.20	0.25	0.00	26.11	1.27	-0.26	74.50	0.98	-0.57
SMH-1	1.20	0.67	0.00	25.00	1.13	-0.30	76.22	1.18	-0.44
Mean	**1.18**	0.20		**24.89**	**-**	**-**	**76.56**	**-**	**-**
SE (±)	**0.0000**			**0.19**	**0.14**	**-**	**0.52**	**0.110**	**-**

height (103.6) than the population mean. The regression coefficient was more than unity and deviation from regression was non-significant for H1, H2, H3, H4 and H6 hybrids, indicating their suitability for all environments under study with unpredictable performance. The results are supported by the findings of Mahajan *et al.* (1991), Arun and Singh (2004), Jai Dev *et al.* (2009), Lata *et al.* (2010). Rahman *et al.* (2010), Vijay *et al.* (2012).

Among the hybrids H6 and H10 for cob length recorded high mean value with regression coefficient less than unity and non-significant deviation from regression indicating average stability across the locations and better adapted to poor conditions. The hybrid H2, H4 and H5 exhibited high mean for cob length with regression coefficient higher than unity and non-significant deviation from regression except H3 that showed significant deviation from regression revealing that they were specifically suited to favourable environments. Similar finding on identifying stable genotype for cob length using Eberhart and Russel's stability analysis was reported by Kaundal and Sharma (2006), Nadagoud *et al.* (2012), Karadavut and Akilli (2012).

Among the hybrids for cob diameter H3 exhibited significant deviation from linearity (S^2d_i) indicated that the performance of the genotypes over environments unpredictable for this character. The hybrids *viz.,* H4, H2, H6, H7, H9 and H10 were suitable for rich environment because of high mean and high regression coefficient value indicated average performance. H1, H5, H8 and SMH1 were identified for poor environment for the ear diameter character because high mean mean with regression coefficient less than unity and non-significant deviation from regression Similar findings were obtained by Arun kumar and Singh (2004), Karadavut and Akilli (2012) and Nadagaud *et al.* (2012).

For 100 kernel grain weight the two Hybrids H6 and H10 recorded high mean value with bi value greater than one and non-significant deviation from regression. This suggests that these two hybrids are more suitable for favourable environments with good crop management. However H4 had significant deviation from regression coefficient indicating their below average sensitivity to environments with unpredictable performance. H3 and H5 had high mean with regression coefficient (bi<1) and non significant deviation from regression revealing that they are average in stability. The other set of genotypes were found to be unstable for expression of this trait as they are showing significant deviation from regression values. Arun *et al.* (2004b) also reported same results in their studies.

For Cobs per plant, Hybrid H2 recorded bi and S^2d_i value nearer to unity and zero and non-significant deviation from regression was therefore stable one, but exhibited slightly lesser number of cobs mean than the population mean. All other hybrids have bi value less than unity and non-significant deviation from regression except H7. H7 possess significant bi value and non significant deviation from regression (S^2d_i) indicates stability to specific environments. For the yield (q/ha) character all the hybrids except H4 showed non-significant *bi* values indicating stable performance of the genotypes over the environments. The values of S^2d_i were non-significant for all the crosses except H9. Hybrids H1 and H7 were stable hybrids across locations based on stability parameters of regression coefficient and non-significant nearer to 1 and zero and The hybrids H2, H5 were average in stability exhibited adaptability to poor environment because high mean performance and the value of regression coefficient lower than the unity indicating that these genotypes exhibit average performance over the environments. The hybrids H6, H9 and H10 were having low mean value and regression coefficient less than 1 showed greater G × E interactions over locations, results are in agreement with the result of Arunkumar and Singh (2004), Karadavut and Akilli (2012) and Nadagaud *et al.*

(2012).

In conclusion, hybrids H1, H2, H5 and H10 were identified as most stable hybrids based on stability analysis across locations for yield and other desirable traits, however further evaluation both spatially and temporally should be done with increased number of locations to validate the stability. Hybrids selected in the present study were diverse and random. These hybrids possessed significant variation for all the traits. Non-linear component of S^2d_i (representing deviation from the regression slope) was non-significant in most of the cases and thus the prediction of stability was more or less accurate. Stability of hybrids for the various yield and yield related traits revealed that the hybrids H2, H5, H7 and H8 were having higher productivity and were average in stability across all the environments. Stability of Grain Yield (q/ha) across the environments revealed that two hybrids H2 and H5 were average adapted to poor and high input environments respectively. Highest mean performance for Grain Yield (q/ha) was observed to be in H2 (81.55 q/ha) which was surpassing the check SMH1 (76.22) by 7%.

Acknowledgement

Authors are highly thankful to the Department of Genetics and Plant Breeding, SKUAST-K, FoA Wadura, Sopore, Jammu and Kashmir and Dryland Agriculture Research Station (DARS) Budgam, J&K for material sharing and analysis.

References

Abera, W., J.B. Rensburg, J-Van., M.T. Labuschagne and H. Maartnes (2013). Genotype × environment interactions and yield stability of new maize in Ethiopia. *South African Journal Plant Soil,* **21(4)**: 251-254.

Agarwal, P., S.S. Verma and S.N. Mishra (2000). Phenotypic stability for different quanititative traits in maize hybrids. *Indian Journal Agric. Research,* **34**: 107-111.

Allard, R.W. and A.D. Bradshaw (1964). Implication of genotype environment interactions in applied plant breeding. *Crop Science,* **4** : 503-508.

Arunkumar and N.N. Singh (2004). Stability studies of inbred and single crosses in maize. *Annual Agriculture Research,* **25:** 142-148.

Aycicek, M. and T. Yildirim (2006). Adaptability and performances of some bread wheat (*Triticum aestivum* L.) Genotypes in the Eastern Region of Turkey. *International Journal of Science & Technology,* **1(2)**: 83-89.

Basford, K.E and M. Cooper (1998). Genotype × environment interactions and some considerations of their implications for wheat breeding in Australia. *Australian Journal of Agricultural Research,* 153-174.

Crossa, J. (1990). Statistical analysis of multilocation trials. *Advances in Agronomy,* **44**: 55-85.

Dass, Sain, Mohinder Singh, Ashok, K., Sarial and Aneja, D.R. (1987). Stability analysis in maize. *Crop Research,* **14**: 185-187.

de Wet, J.M.J. and J.R. Harlan (1972). Origin of maize: The tripartite hypothesis, *Euphytica,* **21**: 271-279.

Dev, J., S.K. Guleria, S. Lata, V. Kalia, A. Singh, C.L. Bhardwaj, V. Kumari and B.C. Sood (2010). Influence of G × E interaction on seed yield and related traits in maize. *International Journal of Agricultural Sciences,* **6(1)**: 54-57

Dodiya, N.S. and V.N. Joshi, (2003). Genotype × environment interaction and stability analysis for yield and maturity in maize (*Zea mays* L.). *Crop Research* Hisar, **26(1)**: 110-113.

Eberhart, S.A. and W.A. Russell (1966). Stability parameters for comparing varieties. *Crop Science,* **6**: 36-40.

FAO. 2016. FAOSTAT. www.fao.org.

Hebert, Y., C. Plomion and N. Harzic (1995). Genotype x environment interaction for root traits in maize as analyzed with factorial regression models. *Euphitica,* **81**: 85-92.

Jai, Dev., R.K. Chahota, S.K. Guleria, S. Lata, V. Kalia, Anand Singh, Vedna Kumari, J.K. Jenjiha and B.C. Sood (2009). Phenotypic stability analysis of maize hybrids – 2005. *Internat. J. Agric Sci.,* **5(1)** : 239-242.

Karadavut, U. and A. Akilli (2012). Genotype-environment interaction and phenotypic stability analysis for yield of corn cultivar. *Greener J. Agric. Sci.,* **2(5)**: 220-223.

Kaundal, R. and B.K. Sharma (2006). Genotype × environment interaction and stability analysis for yield and other quantitative traits in maize (*Zea mays* L.) under rainfed and high rainfall valley areas of the submontane. *Research on Crops,* **7(1)** : 171-180.

Kumar, A. and N.N. Singh (2004). Identification of yield contributors through path analysisin maize. *Annual Agriculture Research,* **25(3)**: 448-450.

Lata, S., S. Guleria, Jai Dev, G.B. Katna, C. Sood, V. Kalia and Anand Singh (2010). Stability analysis in maize (*Zea mays* L.) hybrids across locations. *Electronic Journal of Plant Breeding* **1**(3): 239- 243.

Mahajan, Y., A.S. Khehra and S.S. Pal (1991). Stability analysis in maize over diverse seasons. *Crop Research,* **4**: 267-284.

Mani, V. P. and N.K. Singh (1999). Stability analysis of yield in maize. *Indian Journal Agriculture Science,* **69**: 34-35.

Moldovan, V., M. Moldovan and R. Kadar (2000). Item from Romania. *S.C.A. Agricultural Research Station,* 3350.

Nadagoud, V.K., R.C. Jagadeesha, M.C. Wali and R.M. Kachapur (2012). Genetic studies on stability among maize inbred lines. *Karnataka J. Agric. Sci.,* **25(1)**: 124-126.

Puttaramanaik, Pavan, R. Nagabhushana, H.B. Hemareddy and H.C. Lohithaswa (2016). Genotype × Environment Interaction For Yield And Its Attributing Traits In Single Cross Hybrids Of Maize (*Zea Mays* L.) In Southern Karnataka. *International Journal of Agriculture Sciences,* **58(8)**: 3231-3235.

Rahman, H., Durreshawar., S. Ali, F. Iftikhar, I.H. Khalil1, S.M.A Shah and H. Ahmad (2010). Stability analysis of maize hybrids across North west of Pakistan. *Pakistan Journal Botany,* **42(2)**:1083-1091.