Research Article

Genotype-Environment Interaction and Phenotypic Stability Analysis for Yield of Corn Cultivar

Ufuk Karadavut* and Aslı Akilli

University of Ahi Evran, Agricultural Faculty, Campus of Aşıkpaşa-Kırşehir/Turkey

*Corresponding Author's email: ukaradavut@ahievran.edu.tr

Abstract

The aim of this study was to determine the genotype-environment (GE) interaction and also to determine stable corn cultivar for grain yield in Turkey. The study was carried out from 2 years and 3 different locations around the Central and South Anatolia Region. GE interaction was analyzed by linear regression techniques. Stability was estimated by the Eberhart and Russell methods. According to the stability analysis, it's seen that the cultivar 3 was the most stable for grain yielding. Among the cultivars, the highest grain yield was obtained from cultivar 3 (9.4 t ha^{-1}) at across environments. This genotype had regression coefficient (b_i =1) around unity and deviations from regression values (δ_{ij} =0) around zero; considering that they are responsive to environment changes and they can be recommended for favorable environments.

Key words: Corn, *Zea mays* L., grain yield, stability

Introduction

Corn (*Zea mays* L.) is one of the leading world cereals both in terms of production and productivity concerns. Corn crops possess great genetic diversity and can be grown across varied agro-ecological zones (Ferdu et. al., 2002). The improved genotypes should have the characteristics of adaptability across a range of diverse environment unstable varieties are major source of risks (Javed et. al., 2006). The phenotypic performance of a genotype is not the same under divers' agro ecological conditions (Ali et. al., 2003). Phenotypic stability is the most important for the selection of crop varieties as well as for breeding programs.

Genotype-Environment (GE) interaction is extremely important in the development and evaluation of plant varieties, because they reduce the genotypic stability values under diverse environments (Hebert et. al., 1995). The concept of stability has been determined in several ways and through several biometrical methods (Lin et. al., 1986; Crossa, 1990). The widely used one is the regression methods (Romagosa and Fox, 1993). The stability of varieties was defined by high mean yield and regression coefficient ($b_i = 1.0$) and deviates from regression as small as possible ($S_{di}^2 = 0$).

A number of stability studies have been carried out on different crop plants in Turkey (Yıldırım et. al., 1992; Özdemir et. al., 1999; Kara, 2000; Ülker et. al., 2001; Akçura et. al., 2004, Genç, at. al., 2005; Kaya, et. al., 2006). However, very little information is available on stability of corn varieties. Some genotypes show highly specific response over a range of environments. The objective of present study was to evaluate and identify the genotypes with under adaptation over a range of environments and yield performance.

Materials and Methods

Six corn genotypes were evaluated during 2004-2005 across 6 locations (Konya/Center, Hatay/Kırıkhan and Yozgat/Sarıkaya) under rain fed conditions. Genotypes were analyzed by a randomized complete block design (RCBD) with 4 replications. The names of cultivars are TTM 8119 (G1), MAT 97 (G2), DK 585 (G3), TTM 815 (G4), P 3394 (G5) and PIAVE (G6). Each genotype was sown on four row plot (5.0 meter long and 0.75 meter apart). The central two rows were used for observations. The yield was determined and expressed in ton per hectar (t ha^{-1}). All field conditions such as growing season, environments, soil properties, fertilization treatments, the rainfall at each location during the growing period and sowing date and harvest date are summarized in Table 1.

Table 1 Site description and agronomic details

Code	Growing season	Environments	Soil Properties	Fertilization (kg ha^{-1}) N	Fertilization (kg ha^{-1}) P_2O_5	Rainfall (mm)	Sowing date	Harvest date
E1	2004	Konya/Center	pH; 8.1, clayel, alluvial	100[a]+50[b]	120[a]	284	08.05.04	11.11.04
E2	2004	Yozgat/Sarıkaya	pH; 7.9, clayel, alluvial	100+50	120	355	05.05.04	13.11.04
E3	2004	Hatay/Kırıkhan	pH; 6.9, organic, alluvial	100+50	120	616	10.04.04	07.09.04
E4	2005	Konya/Center	pH; 8.1, clayel, alluvial	100+50	120	269	13.05.05	09.11.05
E5	2005	Yozgat/Sarıkaya	pH; 7.9, clayel, alluvial	100+50	120	338	10.05.05	12.11.05
E6	2005	Hatay/Kırıkhan	pH; 6.9, organic, alluvial	100+50	120	555	08.04.05	11.09.05

a; with sowing, b; stem elongation

A combined three factor analysis of variance was performed on data collected for all locations and years using the statistical model;

$$Y_{ijkl} = \mu + g_i + p_j + t_k + (gp)_{ij} + (gt)_{ik} + (tp)_{ik} + (gpt)_{ijk} + e_{ijkl}$$

where, Y_{ijkl} is the i^{th} observation on the l^{th} cultivar in j^{th} location in the k^{th} year. The first four terms are the mean and main effects of cultivar, location and years. The next three terms are the first order interaction and finally the micro environmental deviation within locations and years. It is usually assumed that cultivars and locations are fixed effects and years random effects, so that the model is mixed effects model.

Data were analyzed across all locations and years using pooled data. To characterize genotypic stability the following linear regression model was also used (Eberhart and Russell, 1966);

$$Y_{ij} = \mu + b_i L_j + \delta_{ij} + \varepsilon_{ij}$$

where; Y_{ij} ; the mean for the genotypes *i* at location *j*.

μ ; the general mean for genotype.

b_i ; the regression coefficient for the i^{th} genotype at a given location index which measures the response of a given genotype to varying location.

L_j ; the environmental index, which is defined as the mean deviation for all genotypes at a given location from the overall mean.

δ_{ij} ; the deviation from regression for the i^{th} genotype at the j^{th} location.

ε_{ij} ; the mean for experimental error.

Two stability parameters were calculated based on the regression coefficient. Regression performance of each genotype in different locations calculating means over all the genotypes. The regression coefficient (b_i) and mean square deviation (δ_{ij}) were estimated by Sing and Chadhary (1979). The significant of the regression coefficients were determined using the 't test' and coefficient of determination (R^2)were computed by individual linear regression analysis (Pinthus, 1973). All statistical analysis was performed using the SAS program (SAS Institute, 1999).

Result and Discussion

Mean grain yield varied among environments and ranged from 6.41 t ha^{-1} for environments 2 to 9.46 t ha^{-1} for environment 3 (Table 2). Pooled analysis of variance for grain yield (t ha^{-1}) of corn genotypes, variance component for grain yield and broad sense heritability are given Table 3.

Table 2. The range of grain yield (t ha^{-1}) in environments

Code	Growing season	Environments	Mean	Maximum grain yield	Minimum grain yield	Range
E1	2004	Konya/Center	8.12	10.22	6.78	3.44
E2	2004	Yozgat/Sarıkaya	6.41	7.56	5.11	2.45
E3	2004	Hatay/Kırıkhan	9.46	11.26	6.54	4.72
E4	2005	Konya/Center	7.58	8.14	5.89	2.25
E5	2005	Yozgat/Sarıkaya	6.76	7.41	5.65	1.76
E6	2005	Hatay/Kırıkhan	8.84	9.36	6.27	3.09

Table 3. Analysis of variance among 6 corn genotypes.

Source of variation	df	Sum of square	Mean square	F values
Year (Y)	1	3947056	3947056	6.28*
Location (L)	5	315916875	63183375	100.52**
Year x Location (YxL)	5	545629976	109125995	173.61**
Rep. (Location xYear)	24	31269074	1302878	2.07*
Genotype (G)	5	48661475	9732295	15.48**
Year x Genotype (YxG)	5	14176196	2835239	4.51**
Location x Genotype (LxG)	25	74262215	2970488	4.72*
Year x Location x Genotype (YxLxG)	25	27670814	1106833	1.76
Error	120	75429159	628576	
Total	215	1136962840		

* significant at 0.05, ** significant at 0.01 probability level.

The location, year x location, genotype and year x genotype were highly significant (P<0.01), whereas year, location x genotype and year x location x genotype were small significant (P<0.05).

The presence of genotype x year's interaction indicates that particular genotypes tended to rank differently in grain yields at different years, while the small genotype x location interaction indicates a small effect of the location on the relative productivity.

The mean yield of six corn genotypes ranged from 6.41 t ha^{-1} to 7.51 t ha^{-1} and the highest grain yield was obtained from genotype G3 and G5 (Table 4). It was emphasized that both linear (b_i) and non-linear (δ_{ij}) components of GE interactions are necessary for judging the stability of a genotype (Eberhard and Russel, 1966).

Table 4. Estimates of stability and adaptability parameters of grain yield (t ha^{-1}) for six corn Cultivars at 6 environments.

Code	Cultivars	Environments	Mean grain yield (t ha^{-1})	b_i	δ_{ij}	R^2
G1	TTM 8119	Konya/Center	6.95	1.08**	0.275	0.86
G2	MAT 97	Yozgat/Sarıkaya	6.59	1.44*	0.402	0.91
G3	DK 585	Hatay/Kırıkhan	7.51	1.02	0.176	0.88
G4	TTM 815	Konya/Center	7.08	0.96**	0.211	0.86
G5	P 3394	Yozgat/Sarıkaya	7.32	0.67*	0.456	0.84
G6	PIAVE	Hatay/Kırıkhan	6.41	0.89	0.315	0.90

A regression coefficient (b_i) approximately 1.0 coupled with a value δ_{ij} of zero indicates average stability (Eberhart and Russell, 1966). Regression values above 1.0 describe genotypes with higher sensitivity to environmental change (below average stability) and greatly specify adaptability to high yielding environments. A regression coefficient below 1.0 provides a measurement of greater resistance to environmental change (above average stability), and this increases the specificity to adaptability to low yielding environments (Wachira et. al., 2002).

Linear regression for the average grain yield of a single genotype on the average yield of all genotypes in each environments resulted in regression coefficient (b_i values) ranging from 0.67 to 1.44 for grain yield. This large variation in regression coefficient explains different responses of genotypes to environmental changes (Akçura et. al.2005).The regression coefficients of genotype 6 for grain yield was non-significant (b_i =1.0) and had a small deviation from regression (δ_{ij}) and this possessed fair stability. Genotypes with high mean yield, a regression coefficient equal to the unity (b_i =1.0) and small deviation from regression (δ_{ij} =0) are considered stable (Finlay and Wilkinson, 1963; Eberhard and Russel, 1966). Genotypes G1, G3 and G4 were the most stable for grain yield. Because their regression coefficients were close to unity and they had lower deviation from regression. R^2 Values were as high as 0.84 and 0.91, confirming their stability.

Conclusion

Among this genotypes genotype 3 could be considered the most stable genotype. Genotype 5 is insensitive to environmental changes and has adapted to the poor environments. The in dined stable genotype should be recommended for a wide range of environments while the genotype which proved to be suitable for high yielding or low yielding environments, should be recommended for the respective areas.

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