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Genotype x environment interaction of some dry bean (*Phaseolus vulgaris* L.) genotypes

Omer Sozen[1]*, Ufuk Karadavut[2], Huseyin Ozcelik[3], Hatice Bozoglu[4] and Mevlut Akcura[5]

Department of Field Crops,
Faculty of Agriculture, University of Ahi Evran, Kirsehir, Turkey.
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ABSTRACT

Beans are grown in different environments. The most important issue in bean agriculture is to increase seed yield as expected in other plants. As well reported so far, environmental factors such as rain, heat, their timing and topography affect yield and yield quality in dry beans. So, this study was conducted in 2011-2015 in Samsun (Ambarkopru and Gelemen) and Kirsehir (Mucur and Cogun) locations in order to investigate the effects of the environmental factors on dry bean. For this aim, 20 dry bean genotypes (7 cultivars and 13 pure lines) were used as plant materials. Results showed that G5, G11 and G15 genotypes were close to ideal genotypes. When the year was considered as the environmental factor, the ideal production year was in 2013 with respect to yield and yield quality, concluding that climate changes between years affected yield parameters in dry bean genotypes.

Key words: Dry bean, Environments, GGE-Biplot analysis, Stability, Genotypes.

INTRODUCTION

As the world population increases, the running studies on meeting the increasing food demand has been proportionately increased. Especially, the food sources that can meet the protein requirement of the increasing population should be enrcouraged. Since animal-protein supply has been ever-decreasing and its cost has been ever-increasing, in today's conditions, it is clear that vegetable-proteins have had further importance. Edible legumes are the main vegetable-protein sources. Dry bean is one of the most important legume. This legume grain contains about 22-24% protein, mineral matter and vitamin-rich contents, being an important agriculture product for human nutrition as referring "both meat and bread" (Sozen, 2012).

Dry bean yield is affected by many factors. Especially, the environmental factors including rain and ambient temperature, their impact times and topographic properties play important roles on dry bean seed yield and quality.

Besides, abiotic stress factors such as drought and high temperature decreased yield dramatically because they are widespread and occur almost every year (Sofi and Saba, 2016).

The most important issue in plant production is to increase the yield. This situation enforces the breeders to know the genetic factors as well as the environmental factors. These factors, alongside their separate impact, can also interact with each other and increase or decrease the impact of the latter. Thus, it is crucial to know the Genotype x Environment interaction in breeding studies. The reactions of genotypes under different conditions can be determined with trials in different environments. By this way, the genotypes that showed minimal change under different environmental conditions can be chosen. Genetic improvement is maintained by focusing on these genotypes, especially. Some researchers described "yield" as the function of genotype-environment interaction (Arain *et al.,* 2011; Balapure *et al.,* 2016).

Ozberk (1990) stated that selecting a cultivar under environmental conditions where Genotype x Environment interaction is not significant is very easy, whereas under conditions where it is significant, different cultivars should be chosen for each different environmental condition since selection is too difficult. In their 3-year study on oat genotypes in 3 different environments, Genc *et al.* (2005) used different stability methods and found out that, the genotypes yielding similar amounts showed small changes. According to Chowdhary *et al.* (2002), it has to be taken consideration that genetic sources with high genetic variety can only show their properties after long periods and breeding

*Corresponding author's e-mail: eekim_55@hotmail.com
[1]Department of Field Crops, Faculty of Agriculture, University of Ahi Evran, Kirsehir, Turkey
[2]Biometry and Genetic Unit, Faculty of Agriculture, University of Ahi Evran, Kirsehir, Turkey
[3]Black Sea Agricultural Research Institute, Samsun, Turkey, [4]Department of Field Crops, Faculty of Agriculture, University of Ondokuz Mayýs, Samsun, Turkey, [5]Department of Field Crops, Faculty of Agriculture, University of Onsekizmart, Canakkale, Turkey
-These authors contributed equally to this study.

studies. They are attributed to the fact that genetic capacity may not be instantly observable in all environments.

In the current study, it was aimed to evaluate the performance and stability properties of dry bean genotypes, which were grown during a 5-year period under ecological conditions of Samsun and Kirsehir in Turkey.

MATERIAL AND METHODS

This study was conducted for 5 years in different environments by using 20 dry bean genotypes, 7 registered and 13 lines. The characteristics of soils and climate data in the environments are given in Table 1 and 2.

This study was conducted in randomized block design with 3 replicated parcels sized 5-m with 5 rows. The inter-row distance was 50 cm in each parcel and the intra-row distance was 8-cm so that each row contained 63 seeds. Seeds were sown in May. The first-year, second-year, third-year, fourth-year and fifth-year plantings were carried out in May on 13th, 12th, 18th, 7th and 5th, by the years respectively. Fertilizing was applied as 15 kg diammonium phosphate (DAP) in each plot. Cultural treatments were applied throughout the season. The environment, genotype and Genotype x Environment interactions were computed in the randomized block experiment by using the GLM (General Linear Model) module of SAS Institute (1999) statistical software. Since Genotype x Location interaction was significant, proc REG was used to perform its stability analysis.

Data were analyzed by GGE biplot analysis to perform the graphical analysis of the data (Yan and Tinker, 2006). The plotted graphics show the optimum genotypes, the ranking of the genotypes and environments and the ideal environments.

RESULTS AND DISCUSSION

The yields of 20 different dry bean genotypes grown in five different environments are given in Table 3. Table showed that their yields were varied depending on environments. The higher yields in E1, E2, E3, E4 and E5 were obtained from G-15 with 2294,6 kg, G-15 with 2289,1 kg, G-9 with 2027,3 kg, G-5 with 2135,6 kg and G-1 with 2084,0 kg, respectively.

The highest yield was obtained in E1 with 1583,9 kg ha^{-1}, followed by E2 with 1574,8 kg ha^{-1}. The lowest yield was obtained in E4 with 1451,9 kg; E1, E2 and E3 were in the same group (a), whereas E4 (c) and E5 (b) were in other groups. The average values of the genotypes in terms of environment showed that the Genotype-15 ranked in the first place with 1920,6 kg ha^{-1}, followed by the Genotype-5 with 1806,9 kg ha^{-1}. The lowest yield was obtained from the Genotype-12 with 1170,1 kg.

The environmental condition contributed to observed variance as 72.18%, Genotype x Environment

Table 1: Physical and chemical properties of soils in trial areas*

Soil Properties	Samsun (Ambarkopru and Gelemen location)						Kirsehir (Mucur and Cogun location)			
	2011		2012		2013		2014		2015	
	Analysis		Analysis							
	Value	Grade	Value	Grade	Value	Grade	Value	Grade	Value	Grade
Saturation	64	loamy	88	loamy	62	loamy	67	loamy	69	loamy
Power of Hydrogen (pH)	7.22	neutral	7.41	neutral	7.58	neutral	7.57	neutral	7.44	neutral
Total Salt (%)	0.549	salty	0.079	saltless	0.478	salty	0.018	saltless	0.026	saltless
Calcium Carbonate (%)	2.90	calcareous	0.85	low calcareous	4.15	calcareous	8.7	calcareous	9.7	calcareous
Phosphorus (kg da^{-1})	18.0	high	21.7	high	22.5	high	6.37	medium	7.26	medium
Potassium Oxide (kg da^{-1})	34	low	125	high	31	low	202	high	214	high
Organic Matter (%)	1.81	low	2.43	medium	1.88	low	1.56	low	1.68	low

*Black Sea Agricultural Research Institute Soil Department Laboratory Results

Table 2: Climate data in Samsun and Kirsehir*

	Months	**Average Temperature (⁰C)**				**Total Rainfall (mm)**				**Average Relative Humidity (%)**			
		2011	2012	2013	Long Years	2011	2012	2013	Long Years	2011	2012	2013	Long Years
Samsun	May	15.0	17.5	16.7	15.4	66.1	34.4	55.6	51.1	84.1	82.3	79.3	79.4
	June	20.6	21.9	21.4	20.3	49.6	24.4	19.6	48.0	76.9	76.4	76.2	77.1
	July	24.3	24.0	23.8	23.3	26.0	96.0	68.5	31.8	77.9	77.1	76.2	76.7
	August	23.4	23.0	22.6	23.5	14.2	179.6	32.4	36.7	74.4	78.0	77.4	74.6
	September	19.8	20.1	19.7	20.0	39.1	113.0	80.5	52.9	77.3	80.4	79.9	76.9
	Aylar	Average Temperature (⁰C)				Total Rainfall (mm)				Average Relative Humidity (%)			
		2014	2015	Long Years		2014	2015	Long Years		2014	2015	LongYears	
Kirsehir	May	16.9	16.4	16.2		46.6	39.2	10.7		59.5	57.5	56.2	
	June	20.8	18.9	20.6		36	161.4	13.9		51.6	65.6	50.9	
	July	27.6	24.9	24.8		13	20.6	2.9		33.6	41.5	38.4	
	August	28.2	25.9	24.9		17	11.8	1		33.6	45.4	37.6	
	September	20.1	23.8	19.6		30.4	1	2.6		50.8	41.1	43.3	

*Samsun and Kirsehir Provincial Meteorology Directorate

Table 3: Yields of 20 dry bean genotypes in different environments (kg ha^{-1})

Genotypes	**Genotype Number**	**Environments (L)** E1 (2011)	**E2 (2012)**	**E3 (2013)**	**E4 (2014)**	**E5 (2015)**	**Mean**
Zulbiye	**1**	1722,8	1513,3	1175,1	1828,8	**2084,0**	1664,8
Onceler 98	**2**	1984,5	1621,6	1933,1	1498,6	1623,0	1732,1
Yunus 90	**3**	1272,4	1270,0	1652,8	1200,8	1510,9	13814
Goynuk 98	**4**	1399,8	1535,8	1417,4	1641,8	1632,6	1525,5
Noyanbey 98	**5**	1637,4	1657,0	1699,6	**2135,6**	1904,9	1806,9
Sahin 90	**6**	1593,3	2078,8	1310,9	1606,5	1650,3	1647,9
Akdag	**7**	1756,5	1561,0	1568,3	1498,4	1644,0	1605,6
A.13	**8**	1270,9	1088,8	1563,8	1283,6	1290,7	1299,6
A.14	**9**	1694,8	1641,9	**2027,3**	1206,9	1253,6	1564,9
A.20	**10**	1434,4	1574,5	1771,6	1668,3	1587,0	1607,2
A.27	**11**	1687,3	**1844,4**	1821,1	1557,2	1768,9	1735,8
A.40	**12**	1079,1	1189,9	1357,9	1106,2	1117,2	11701
A.107	**13**	1862,3	1466,1	1386,2	957,4	1053,8	1345,2
A.341	**14**	1398,3	1342,4	1526,9	1225,2	1186,6	1335,9
A.349	**15**	**2294,6**	2289,1	1594,1	1806,2	1619,1	**1920,6**
A.367	**16**	1941,4	1882,3	1455,6	1312,1	1236,4	1565,6
A.378	**17**	1516,4	1393,0	1544,6	1878,6	1893,4	1645,2
K.1084	**18**	1381,2	1631,2	1507,0	1124,3	1286,4	1386,0
K.1133	**19**	1492,4	1686,3	1488,9	1215,4	1235,9	1423,8
K.1154	**20**	1259,4	1149,3	14348	1287,8	1441,3	1284,5
Enviromental Mean	1583,9 a	1574,8 a	1568,5 a	1451,9 c	1501,0 b		

16.67% and genotype 11.15%. Environment variance was 4.32-fold higher than the Genotype x Environment interaction variance, while it was 6.47-fold higher than the genotype variance. This shows that environment was the prominent factor affecting yield. Hinsta and Abay (2013) and Mehari *et al.* (2015) determined similar variations.

Genotype x Environment interaction also reveals the adaptation limits of genotypes (Asfaw, 2008). High yielded genotypes to different environments show high adaptation abilities. Since the magnitude of variation also gives insight into its impact, it should be further evaluated (Adjei *et al.,* 2002).

Symmetrical biplot polygon graphic of Genotype x Environment interaction is given in Figure 1. Genotype yield-based distribution graphic of Genotype x Environment interaction is given in Figure 2. As seen in figure 1, G5, G8, G12, G13 and G15 are on the diagonal lines. G5 and G15 showed high yields on the high endpoints, whereas other genotypes fell into the endpoints of low yield. According to these results, the end-values of the genotypes also reveal their special adaptation limits. This is important to find the best fit in environments, as emphasized by Yan and Tinker (2006). As genotypes approach the center, their adaptation ability increases; as they move away from the center, their adaptation ability decreases (Meng *et al.,* 2016). While the genotypes were distributed to five separate sections, environments were distributed to two sections. This shows that the variation within environments was lower than the variation among the genotypes (Mustapha *et al.,* 2014).

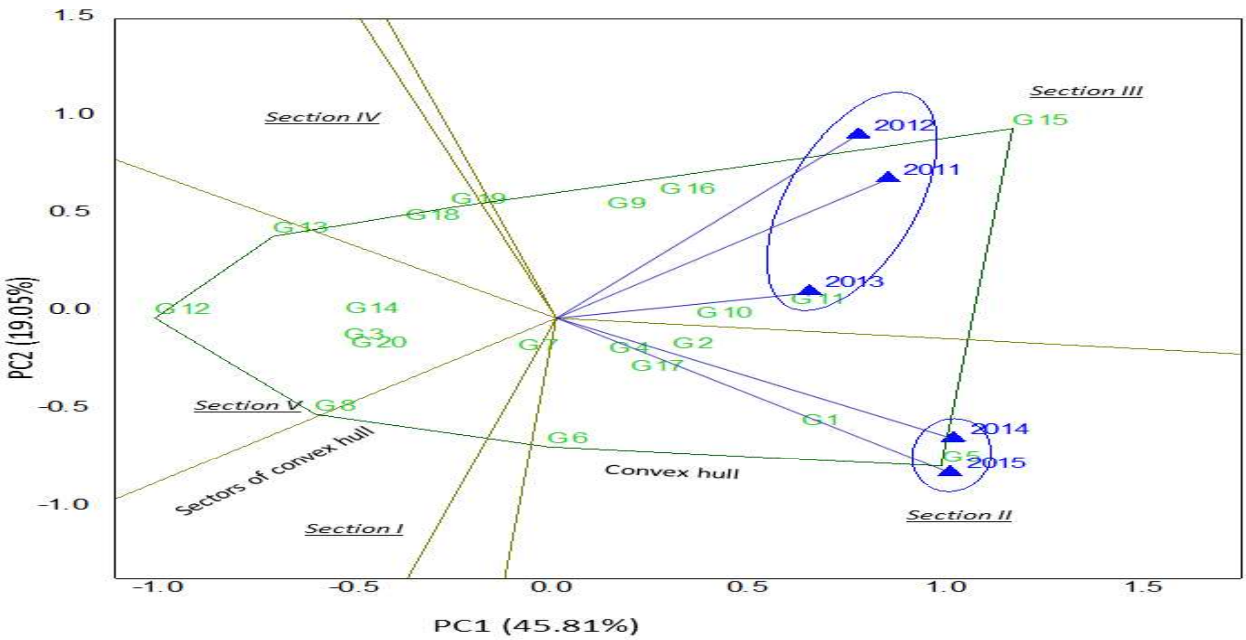

Figure 1: Polygon view of GGE biplot showing cultivar yielded best in different environments

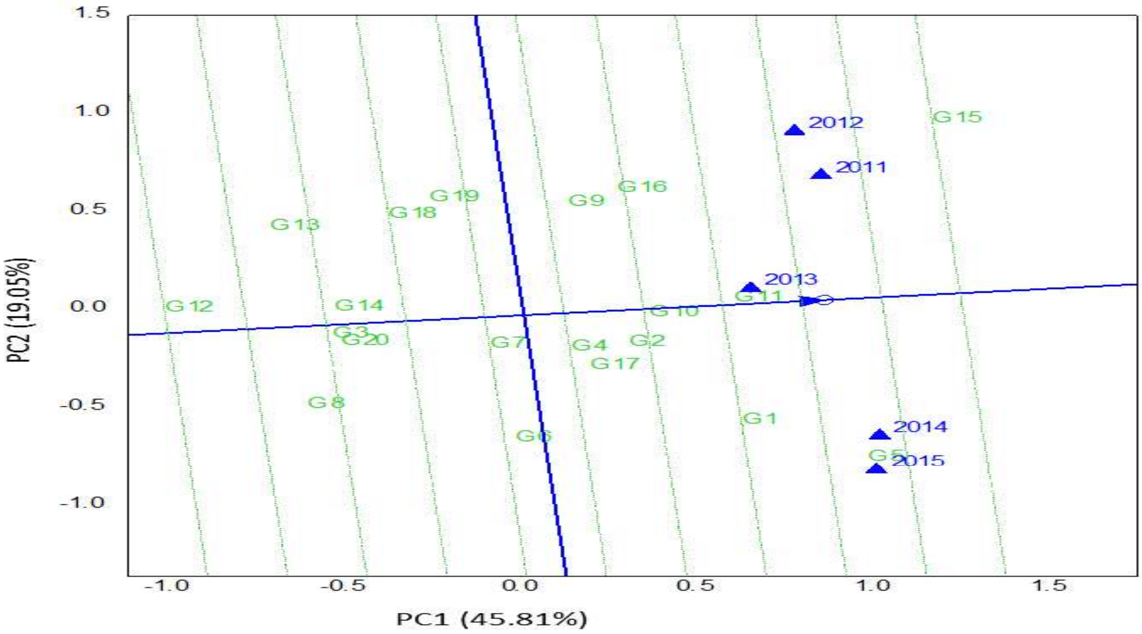

Figure 2: Created GGE biplot graphic by yields

Figure 2 reveals that the genotypes at the high-ends can more clearly manifest themselves. In this figure, the stability of the genotypes was evaluated based on their proximity to the average environment axis. Among the genotypes that were closer to the average environment axis and on the right-side of the graphic, G11 was the genotype possessing the highest general adaptation ability, while G5 and G15 had the highest special adaptation ability. Mulusew *et al.* (2008) described locations as predictable environments and years as unpredictable environments which are source of variances. They stated that when Genotype x Environment interaction is significant, the breeders should either breed cultivars in desired environmental conditions or breed cultivars in well-adaptable environmental conditions (Akcura *et al.,* 2005). In the present study, years were accepted as the environments. Accordingly, when we regard it as unpredictable environment, it can be said that the observed differences are expected (Viana and Cruz, 2002). Although, the analyses of yield trials in different environments with conventional methods can provide information on Genotype x Environment interactions. However, they fail to provide sufficient information on the stability measurements of genotypes. Thus, the stability parameters of genotypes with changing environmental conditions provide valuable and detailed information on their stabilities (Khan *et al.,* 2007). In addition, the genotype closest to the ideal environment shows the highest adaptation ability.

One of the most important advantages of GGE biplot analysis method in multi-environmental trials is the ability of evaluating the best genotype with respect to its responses to trial environments. According to this evaluation, the distributions of genotypes based on ideal environments are given in Figure 3. Figure 3 shows that there is no genotype that can be viewed as the ideal genotype; however, the G5, G11 and G15 genotypes can be viewed as preferable genotypes, since they were closest to the ideal. Furthermore, G1 and G10 genotypes had adaptation abilities close to the preferable adaptation ability, whereas other genotypes showed lower adaptation abilities.

G12 genotype showed the poorest reaction to changed environmental conditions, followed by G13 and G18 genotypes. The ideal genotype is the genotype that has the highest yield irrespective to its breeding environment or loses its productivity at minimum level. However, it should be noted that the trials carried out in different environments do not give always the ideal genotypes for implementing to practice (Yan and Kang, 2003). Ideal genotypes are usually

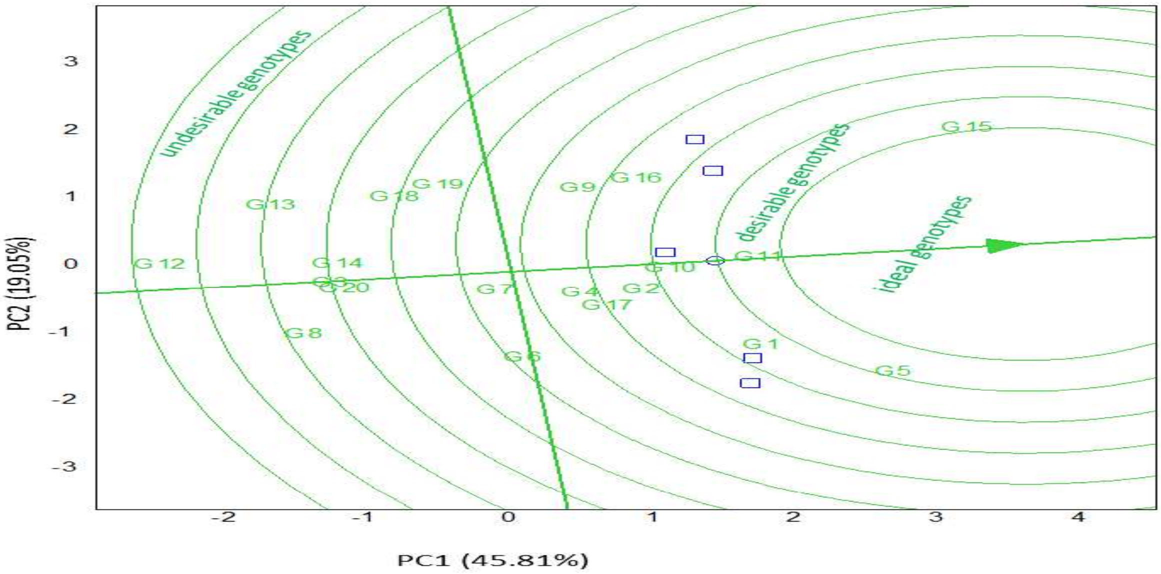

Figure 3: Distribution of genotypes for GGE biplot analysis and ideal environment

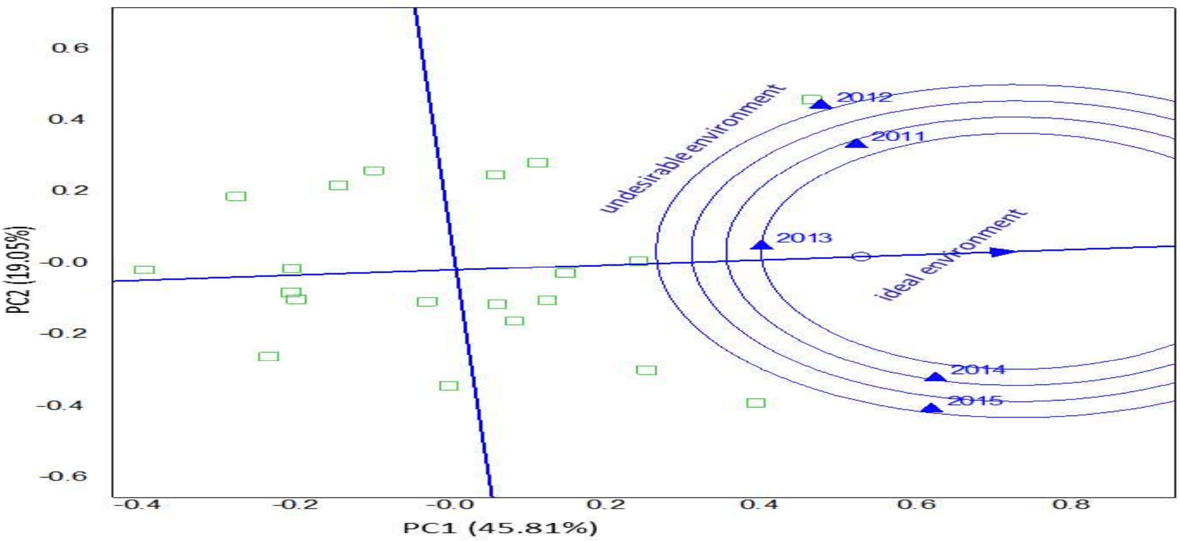

Figure 4: GGE biplot figure for ideal enviromental condition

located in the first concentric circle and as the diameter of the circle expands, the ideal properties decrease (Mulugeta *et al.,* 2012). Ideal genotypes are especially used in breeding studies to compare other genotypes. Genotypes may be included in further breeding studies based on their proximity to ideal genotype. The genotypes which are too far from the ideal are excluded from breeding studies at the beginning (Verma *et al.,* 2016). The present results were in agreement with the results of Shabana *et al.* (2007) and Ashango *et al.* (2016). Tseyaga *et al.* (2012) reported that dry bean yields were significantly affected by genotype and environmental factors, suggesting that these factors should be taken into consideration when evaluating the genotypes.

Figure 4 shows the trial years by using the GGE biplot method in terms of ideal environments. As seen in the figure, 2013 was the year that had the most ideal properties, followed by 2014 and 2011; 2012 was an unfavorable environment, whereas 2015 fell into the limits of non-ideal environment. Ideal environment is considered the most determinant factor for Genotype x Environment interaction studies (Choudhary and Haque, 2010). As stated above, the ideal environment is usually in the first concentric circle referring the year 2013. In 2013, the ecological conditions can be viewed as the best condition to grow genotypes. In general, the differences among the years were considerably high. This wide variation also increased the differences in their impacts on yields. Similar results were obtained by Hinsta *et al.* (2011) and Farshadfar (2008), who carried out different studies to determine the impact of different environments and obtained similar results (Yan *et al.,* 2007; Karadavut *et al.,* 2010; Tamene and Tades, 2014).

CONCLUSION

Current Genotype x Environment interaction studies have been conducted to determine the reactions of genetically uniform species to phenotypically different environments. Different genotypes have had different genetic potentials. Therefore, the reactions of 20 dry bean genotypes to 5 different environments (years) were evaluated. The present results showed that G5, G11 and G15 genotypes were close to ideal genotypes, whereas G8, G12 and G13 genotypes were far from the ideal and showed undesired reactions.

Moreover, G8, G12 and G13 genotypes showed lower adaptation abilities to the changed environments and therefore, should not be suggested for future breeding studies. When considered years as environments, the ideal environment was in 2013. However, this year was undesirable environment for the genotypes. The high level of differences among the years showed that climatic change during 5 years.

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