Assessing the yield stability of nineteen chickpea (Cicer Arietinum L.) genotypes grown under multiple environments in south-eastern Anatolia, Turkey

Article *in* Applied Ecology and Environmental Research · November 2018

DOI: 10.15666/aeer/1606_79897997

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ASSESSING THE YIELD STABILITY OF NINETEEN CHICKPEA (*CICER ARIETINUM* L.) GENOTYPES GROWN UNDER MULTIPLE ENVIRONMENTS IN SOUTH-EASTERN ANATOLIA, TURKEY

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(Received 15th Aug 2018; accepted 10th Oct 2018)

Abstract. The identification of high performance stable genotypes is essential for increasing sustainable chickpea production in Turkey. Hence, nineteen chickpea genotypes were examined for stability assessment in different environments in Southeastern Anatolia, Turkey. Chickpea genotypes were sown in early spring and planted in the winter. The analysis of variance showed that the genotypes and locations were significantly differed in the majority of the studied characters. The regression coefficient, deviations of the regression coefficients, coefficient of variation, ecovalence and stability variance were calculated for chickpea genotypes. The stability parameters were varied by the planting dates and environments in which the chickpea genotypes were grown. Among the studied chickpea genotypes, genotype 'FLIP98-143C' was considered as high grain yield and low *b* value and produced the minimum deviation regarding the regression, genotypic variance, coefficient of variation, ecovalence and stability variance. Therefore, the genotype 'FLIP98-143C' may be used as a stable and high yielding variety in the future and also it may be used in future breeding programs to develop good varieties.
Keywords: *regression coefficient, chickpea, genotype, stability variance, seed yield*

Introduction

Chickpea (*Cicer arietinum* L.) is one of the major essential legumes used as food and feed which is grown in 10 million hectares in a wide range worldwide. It supports an essential source of vegetable protein and fixes atmospheric nitrogen into the soil (Adeel et al., 2012). It is an essential grain legume crop of Southeastern Anatolia, Turkey, and it is widely grown in rotation with winter cereals. Chickpea is grown both in winter and early/late spring in Turkey (Karakoy, 2012; Dogan et al., 2015), although several genotypes have good yield performance, when they are grown in various planting dates. They produced low yield due to anthracnose (*Ascochyta blight*) disease and drought stress environment. Therefore, they could show different performances in various environments. Mega environments help to identify the most appropriate cultivars that can be recommended for the relevant areas within the mega-environment in one or more tested locations.

The susceptibility of existing varieties to fluctuations of the environment is a major factor that is responsible for low yield and yield instability (Adeel et al., 2012). Because of the widespread presence of genotype and environment interactions, yield stability has taken much louder voice to develop the dropping yield of crops. There is some vital trait to calculate yield stability (Ludlow and Muchow, 1990; Adeel et al., 2012). The genotypes used in the current study have been high or low yielding in previous years in only one location, but their performances in different environments are very important to be concerned as a new variety for region under investigation (Yadav et al., 2016). Plant breeders have used the stability to produce a genotype that indicates a relatively constant yield, independent of environmental conditions (Sabaghnia et al., 2012).

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1606_79897997

The stability traits to identify genotypes with stable performance across different environments (Shafi et al., 2012) according to Eberhart and Russel (1966) methods. Several models for the statistical measurement to evaluate the stability have been reported by research studies (Wricke, 1962; Finlay and Wilkinson, 1963; Eberhart and Russell, 1966; Francis and Kannenberg, 1978), but single method could not adequately explain cultivar performance across environments (Mohebodini et al., 2006). Finlay and Wilkinson (1963) used the coefficient of regression (*b*) as a stability parameter. They reported the regression coefficients can be used to describe the response of various cultivars to environments. The coefficient of variation (Francis and Kannenberg, 1978) is used to select cultivars that produce both high yield and low variance (a small among-environment variance). Wricke's ecovalance (1962) suggested using genotype environment interactions for each genotype as a stability measure. Shukla (1972) used stability variance of genotypes to determine the stability of a genotype. So, keeping these views in mind, the present study was designed to examine the yield stability under different environments and different stability parameters in order to identify chickpea genotypes with stable performance across various environments in Southeastern Anatolia, Turkey.

Materials and methods

The current research was conducted in Southeast Anatolia, Turkey on chickpea genotypes to compare and identify the most stable and high yielding genotypes during 2015-2016 growing seasons. Experiment was conducted in multiple environments in Southeastern Anatolia, Diyarbakir (altitude: 674 m), Silvan (altitude: 840 m), Hazro (altitude: 1050 m) and Kiziltepe (altitude: 498 m), Turkey. Silvan and Hazro are colder and rainier than Diyarbakir and Kiziltepe, and in Kiziltepe due to evaporation plant growth has a shorter period than in other locations (*Table 1*).

The materials for the present study comprised a total of 19 genotypes of chickpeas (*Cicer arietinum* L.) tested in a randomized complete block design with four replications. The genotypes including nine hybrid genotypes in F_7 generation (D2-5, D2-8, D1-3, D2-6, D1-13, D1-14, D1-28, R4 and R6 from crosses Konya × Balikesir, Konya × ILC3279, ILC3279 × Balikesir and Diyar 95 × ILC 482), four ICARDA genotypes (FLIP97-254C, FLIP98-206C, FLIP98-143C and FLIP99-34C) selected from the drought tolerance collection, one local genotype (N5-5 from Diyarbakir chickpea production areas) and Turkish chickpea varieties (Diyar 95, Arda, Azkan, Gokce and Cagatay).

The genotypes were planted in six rows at 4 m length, with 45 cm spacing and with a seed rate of 55 seed m^{-2}. Planting was done in winter, planting was performed 27 December, 2014 and 20 November, 2015 in Diyarbakir, and 22 November, 2015 in Kiziltepe. Early spring planting was performed 18 February in Diyarbakir, 15 February in Kiziltepe, 17 February in Hazro, and 19 February in Silvan in the 2016 growing season. Fertilization was applied over 30 kg ha^{-1} N and 50 kg ha^{-1} P_2O_5 in planting time. The agronomic and cultural practices prevailing with the local requirements were done at each location. Plants were harvested 5.4 m^2, and the treatments were hand harvested at the end of June. Seed yield per plot (g) data were collected from different locations and converted to kg per hectare (kg ha^{-1}).

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1606_79897997

Table 1. *Meteorological data of experimental areas. (Source: Turkish State, Meteorological Service/Ankara)*

	Average temperature (°C)				**Average humidity (%)**				**Total precipitation (mm)**			
	Hazro	**Silvan**	**D.bakir**	**K.tepe**	**Hazro**	**Silvan**	**D.bakir**	**K.tepe**	**Hazro**	**Silvan**	**D.bakir**	**K.tepe**
2015												
January	2.8	3.6	2.0	5.2	74.4	85.5	92	64.1	138.4	95.8	66.6	60.0
February	5.0	6.4	5.0	6.7	77.2	79.7	92.5	66.8	113.8	92.5	65.8	111.0
March	7.9	9.3	7.6	10.1	69.7	72.6	86.2	57.9	154.7	117.5	122.2	149.9
April	11.7	13.3	12.1	14.5	67.1	68.1	79.7	51.0	82.8	66.0	42.4	46.3
May	19.0	20.5	18.9	22.5	47.9	48.4	59.2	33.4	14.5	23.8	28.5	49.7
June	25.4	27.3	25.6	28.5	29.3	27.2	36.4	24.2	6.9	4.60	3.4	3.7
Nov.	10.6	11.1	9.5	10.2	54.2	62.5	62.7	53.1	22.7	13.7	9.0	95.6
Dec.	5.3	5.9	3.8	7.5	53.3	61.0	61.6	72.2	33.8	22.2	23.2	100.4
2016												
January	1.3	2.4	1.1	5.3	82.2	90.1	82.5	74.1	73.4	71.3	79.2	143.4
February	7.3	8.9	7.9	11.1	72.9	75.4	75.2	67.3	74.6	76.2	62.2	68.8
March	9.0	10.5	9.7	12.0	67.6	64.7	70	66.2	60.8	134.0	39.6	86.4
April	15.4	19.9	15.7	17.5	50.4	51.2	59.9	58.3	40.0	52.3	18	38.5
May	18.2	27.4	19.9	21.0	49	51.3	56.1	53.0	45.1	52.1	38.2	21.4
June	25.1	32.2	26.8	29.1	31.4	28.6	35.1	26.5	19.2	6.0	4.2	0.0

Stability parameters

The regression coefficient (*bi*) was measured according to Finlay and Wilkinson (1963) to determine the stability. According to Eberhart and Russell (1966), the regression coefficients approximating one coupled with (S^2d) of zero indicate average stability. Ecovalence (W^2i) as suggested by Wricke (1962) was calculated to further illustrate stability. The GE interaction effect for genotype i, squared and summed across all environments, is the stability estimated for genotype i. A low ecovalence (W^2i) value indicates high relative stability. An unbiased estimate using stability variance (σ^2i) of genotypes was measured according to Shukla (1972). The stability was estimated by combining the use of coefficient of variation (*CVi*) and mean yield (Francis and Kannenberg, 1978).

Results and discussion

The analysis of variance of chickpea genotypes at different locations (*Table 2*) was significant for seed yield. Variance analysis was performed for each environment, and genotypes and genotypes x environments interactions were significant for grain yield. Grain yield ranks were given in *Table 2*. Understanding the nature of genotype and environment interactions is essential in plant breeding programs because a positive significant genotype and environment interaction can extremely impair efforts to identify the superior genotypes related to new crop release and improvement programs (Danyali et al., 2012; Hasan and Deb, 2017).

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
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Table 2. *Grain yield rank over environments on chickpea genotypes*

Genotypes	Spring planting				Winter planting	
	Diyarbakir	**Silvan**	**Hazro**	**Kiziltepe**	**Diyarbakir**	**Kiziltepe**
D2-5	15	16	9	15	10	9
D2-8	18	9	17	8	17	2
D1-3	19	7	18	18	5	19
D2-6	9	6	7	12	19	12
D1-13	13	8	12	14	18	16
D1-14	12	13	16	17	15	18
D1-28	8	14	15	16	14	15
R4 (ILC 482 x FLIP 83-47C)	6	5	11	7	13	6
R6 (FLIP 83-47Cx ILC 482)	4	10	10	5	9	4
N5-5	7	15	6	6	11	17
FLIP97-254C	14	3	4	13	1	13
FLIP98-206C	1	17	3	2	8	7
FLIP98-143C	2	2	8	3	7	8
FLIP99-34C	3	1	14	4	2	14
Diyar 95 (FLIP 83-47C)	17	19	19	19	12	10
Arda	5	4	5	11	3	3
Azkan	16	18	13	9	4	1
Gokce	11	11	1	1	16	11
Cagatay	10	12	2	10	6	5
Genotype	**	**	**	**	**	**
Genotype* environment	**				**	

**Significance level at 0.01 probability

The differences among genotypes for yield ranks in all environments were significant, ICARDA originated genotypes, FLIP98-143C, FLIP98-206C and FLIP99-34C, were identified as top genotypes in three environments in early spring planting. D2-5, D2-8, D1-3, D2-6, D1-13, D1-14 and D1-28 had low yield in all locations, due to their parents sensitivity to anthracnose. Late maturing genotypes were exposed to terminal drought in the region, ICARDA genotypes had small seeds, short plant height and early maturing, therefore, these genotypes were more advantageous than other varieties in spring planting. Varieties Arda and Azkan were identified as top cultivars in winter planting, these winter varieties, Arda and Azkan, always had high yielding in winter sowing due to high tolerance to anthracnose (*Ascochyta blight*). Since Diyar 95 (FLIP 83-47C) had matured later than all other varieties, it had low efficiency at both planting times. Kan et al. (2010) and Erdemci (2012) recorded that when the interaction is significant and rank of genotypes performance changes, genotypes should be bred for each location, and the optimum way is to identify lines that reveal higher performance annually. These findings indicated that these parameters could be used as a substitute for one another in genotypes and environment interactions studies of chickpea. Significant genotype and environment interaction was also recorded by Arshad et al. (2003) and Bakhsh et al. (2006) in chickpea, by Janković et al. (2017) in *Phleum pratense* (L.) and EL-Shawy et al. (2017) in Barley. Gauch and Zobel (1988) reported

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DOI: http://dx.doi.org/10.15666/aeer/1606_79897997

that, the low variance of genotypic effect could be due to proximity of genetic potential of the examined genotypes.

Regression coefficient and mean yield in chickpea

The stability performances of the chickpea genotypes for different planting dates summarized for the regression co-efficient (*b*) and grain yield in *Table 3*. Grain yield was ranged from 820 kg ha^{-1} to 1415.5 kg ha^{-1} in early spring planting, from 1252.0 kg ha^{-1} to 1989.0 kg ha^{-1} mean in winter planting. Some genotypes were produced higher seed yield than some check varieties in spring planting. Regression co-efficient (*b*) values ranged from -1.3 to 3.8 in early spring planting, and it ranged from -0.9 to 2.5, and stability performance for genotypes varied by planting time and location.

The high b value and high grain yield were estimated for eight genotypes in early spring planting, two genotypes in winter planting. It was estimated that the high regression co-efficient (*b*) and high grain yield values could be produced with a great number of experimental environment. Genotypes of the group fitted the definition of the ideal cultivar (Eberhart and Russell, 1966; Mart et al., 2005).

Table 3. *The regression co-efficient (b) and grain yield in chickpea*

Genotypes	**SPRING**		**Winter**	
	Yield (kg ha^{-1})	**b**	**Yield (kg ha^{-1})**	**b**
D2-5	1088	1.1	1617	0.9
D2-8	1062	-1.3	1689	-0.9
D1-3	1002	-1.0	1416	2.5
D2-6	1237	1.3	1430	0.4
D1-13	1156	0.9	1252	1.3
D1-14	1079	1.2	1274	1.6
D1-28	1118	1.7	1378	1.1
R4	1270	1.1	1567	0.4
R6	1289	1.6	1741	0.4
N5-5	1247	1.8	1365	2.0
FLIP97-254C	1285	0.4	1716	2.0
FLIP99-34C	1389	0.2	1652	0.9
FLIP98-143C	1415	1.1	1644	1.0
FLIP98-206C	1382	3.8	1641	2.4
Diyar 95 (FLIP 83-47C)	820	0.5	1544	0.6
Arda	1316	1.5	1938	0.9
Azkan	1040	0.1	1989	0.2
Gokce	1341	0.9	1469	0.5
Cagatay	1275	1.9	1744	0.8
Mean	1201		1582	

Three genotypes in spring planting and eighteen genotypes in winter planting had low *b* value but above average yields. The group quite dominated in the winter varieties. Winter planting is usually produced high yield, but anthracnose disease caused yield fluctuations over the environments. The group has responsive to the good

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DOI: http://dx.doi.org/10.15666/aeer/1606_79897997

environmental conditions (Eberhart and Russell, 1966), therefore, if late winter sowing is applied in these genotypes, high yield can be obtained taking benefit of the mechanism of being avoided by the disease. Varieties Arda, Azkan and Cagatay for winter planting, genotypes FLIP97-254C and FLIP99-34C for both planting date were significant genotypes (*Table 3*). Stability in the seed yield was earlier reported by several researchers (Abbas et al., 2008; Atta and Shah, 2009).

Five genotypes in spring planting and three genotypes in winter planting had a low *b* value and below average yields. Azkan had higher yielding in winter planting than in spring planting, Diyar 95 showed poor performance in both planting dates due to late maturing and sensitivity to anthracnose. The group demonstrated a tendency to perform poorly in unfavorable conditions (Eberhart and Russell, 1966). The genotypes of greatest interest would be those with the lowest Pi values, most of which were due to genetic variation (Lin and Binns, 1988).

The stability performances of the chickpea genotypes for all environments are summarized for the regression co-efficient (*b*) and grain yield in *Table 4*.

Table 4. *Stability parameters of eight environments of chickpea*

No	Genotypes	Yield (kg ha^{-1})	b	δij^2	s^2i	CVi	W^2i	σ^2i
1	D2-5	1257	1.3	372057	162286	32.1	375935	69.1
2	D2-8	1179	0.9	1217089	226177	40.3	1247130	229.3
3	D1-3	1131	1.6	893903	293017	47.9	1033625	190.1
4	D2-6	1251	0.6	347671	72915	21.6	402633	74.0
5	D1-13	1132	0.8	547150	119494	30.5	595140	109.4
6	D1-14	1079	1.1	821106	195439	41.0	856249	157.5
7	D1-28	1136	1.0	787111	177021	37.1	766296	140.9
8	R4	1439	0.6	127974	41530	14.2	162182	29.8
9	R6	1545	0.9	264503	90093	19.4	280890	51.7
10	N5-5	1268	1.0	537097	141305	29.7	504197	92.7
11	FLIP97-254C	1522	0.9	540129	129469	23.6	507535	93.3
12	FLIP99-34C	1636	0.6	895976	151244	23.8	979596	180.1
13	FLIP98-143C	1564	0.7	98667	45738	13.7	127859	23.5
14	FLIP98-206C	1574	1.4	372322	179760	26.9	476039	87.5
15	Diyar 95	1207	1.4	383498	181356	35.3	494338	90.9
16	Arda	1698	1.3	633148	199585	26.3	716542	131.8
17	Azkan	1559	1.5	1274112	327314	36.7	1394703	256.5
18	Gokce	1461	0.4	264941	48181	15.0	472200	86.8
19	Cagatay	1538	1.1	216911	109125	21.5	254471	46.8
	Mean	1377						

Mean: mean grain yield; bi: regression coefficient (Finlay and Wilkinson, 1963); CVi: coefficient of variation (Francis and Kannenberg, 1978); s^2i: genotypic variance; W^2i*: Wricke's* ecovalence (Wricke, 1962); σ^2i: stability variance (Shukla, 1972); δij^2: deviation from the regression (Eberhard and Russel, 1966)

Stability parameters were evaluated separately (*Table 4*); Wricke's (1962) stability parameter W^2i, the genotypes FLIP98-143C with lower ecovalance (W^2i) was considered to be stable. The stability variance (σ^2i) indicated that the genotypes FLIP98-

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
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143C and R4 had the lowest variance across the environments, while the genotype Azkan, D2-8 and D1-3 had the maximum $\sigma^2 i$. The genotypes FLIP98-143C and R4 were stable while the genotypes Azkan, D2-8 and D1-3 were unstable. The genotypes FLIP98-143C, R4 and Gokce according to Francis and Kannenberg (1978) stability parameter (*CVi*) were stable genotypes, and these genotypes produced a low *CVi* and high yield (*Table 4*). The correlation among stability estimates of the various models may indicate if more evaluates should be achieved to improve confidence in the estimation of genotypes performances (Mahtabi et al., 2014).

Genotype FLIP98-143C with produced high grain yield and low *b* value achieved the minimum deviation from the regression (δij^2), genotypic variance, coefficient of variation, ecovalence and stability variance. It was observed that genotype FLIP98-143C had high yield and $b = 1$ value in winter planting, similarly it indicated high yield and *b* value in early spring planting, therefore, it may be identified as a new line for location under investigation studied in early spring. However, if there is no risk of anthracnose disease, in less rainy environments, it can be suggested for winter planting. Genotype R4, which produced high seed yield and low *b* value achieved the lowest deviation from the regression, genotypic variance, coefficient of variation, ecovalence and stability variance. Genotype R4 may be recommended if precipitation is sufficient in spring season. According to Asrat et al. (2008), genotypes with high ecovalence mean and large assessed values are appropriate for high input conditions.

Conclusion

The results of the present study indicated that the chickpea genotypes differed for yield regarding stability. Based on the stability parameters, it was concluded that, genotype 'FLIP98-143C' was considered as high grain yield and low *b* value and produced the minimum deviation regarding the regression, genotypic variance, coefficient of variation, ecovalence and stability variance. Therefore, the genotype 'FLIP98-143C' may be used to release as a stable and high yielding variety in the future and also may be used in future breeding programs to develop good varieties.

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