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STABILITY ANALYSES FOR DOUBLE CROPPING IN SOYBEAN [(*Glycine max* L.) Merrill]

Emre ILKER[1], Mehmet KOCATURK[2], Abdullah KADIROGLU[2], Metin ALTINBAS[1], Aliye YILDIRIM[1], Gulsum OZTURK[1], Hakan YILDIZ[1]*

[1]Ege University, Faculty of Agriculture, Department of Field Crops, Izmir, TURKEY
[2]Bati Akdeniz Agricultural Research Institute, Antalya, TURKEY
**Corresponding author: emre.ilker@ege.edu.tr*

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ABSTRACT

Double crop agriculture is a great advantage for the coastal Mediterranean climate. Although a number of soybean varieties have been recommended for cultivation, the information on the stability for double cropping is lacking for the agro-climatic conditions of Mediterranean coastal zone. Ten high-yielding advanced soybean [*Glycine max* (L.) Merr] lines and four registered soybean varieties having maturity group III and IV (ARISOY, ATAEM7, BRAVO and NOVA) were evaluated for double cropping in different regions and years (2014, 2015 and 2016 in Izmir-Bornova, 2015 and 2016 in Antalya-Aksu). The F test was first applied to check differences of the deviation variances from the zero. In addition, statistics of ecovalance (W_i^2) and stability variance (σ_i^2), estimating the contribution of a genotype to total Genotype x Environmental interaction (GxE), were estimated. As a result of this research, two different conclusions were determined. If sufficient water is provide (500-700 mm) BATEM 306 and BATEM 317 lines can be grown, otherwise, the other two (BATEM 207 and BATEM 223) can be suitable to grow in the regional conditions.

Keywords: Double cropping, soybean, stability

INTRODUCTION

Phenotypically stable genotypes are of great importance, because the environmental condition varies from year to year or region to region. Wide adaptation to the particular environment and consistent performance of recommended genotypes is one of the main objectives in breeding programme. The existence of interactions between genotype and environment (GxE) is a major problem for the breeder in making a reliable estimate of the performances of the genotypes across environments (Fox et al., 1997). An ideal variety is a genotype that has high mean yield and exhibits very little yield change in different environments. Therefore, stability analyses are important part of the breeding programs. Understandably, breeders are primarily concerned with high yielding and stable cultivars as possible since cultivar development is a time consuming and endeavor (Akcura et al., 2006). Linear regression is a model most often used in the studies of adaptability and stability, and provides important information for cultivar recommendation.

Soybean planted area estimate for 2018 is 22.000 hectares and production is projected at 85.000 metric tons in Turkey, down due to the increase in cotton planting in the Cukurova Region where the Mediterranean climate dominates like Izmir and Antalya regions. In the Cukurova region, where ninety-five percent of the local soybean crops are grown, soybeans have to compete with wheat, corn, and cotton (Sirtioglu, 2017). However average soybean yield of Turkey is 4370 kg ha^{-1}, the world average soybean yield is 2620 kg ha^{-1} (Ilker, 2017). For this reason, it is necessary to determine the appropriate soybean genotypes for the regions suitable for double crop, which may be an alternative to the Cukurova region. This situation is also important for other countries that have coast to the Mediterranean.

Although a number of soybean varieties have been recommended for growing, the information on the stability for double cropping is lacking for the agro-climatic conditions of Mediterranean coastal zone. Therefore, there is necessity to evaluate and identify the potential genotypes having consistent performance under different environments and to select the genotypes on the basis of stability parameters for high yielding.

MATERIALS AND METHODS

Ten high-yielding early advanced soybean lines [*Glycine max.* (L.) Merr] (Table 1) and four registered soybean varieties having maturity group III and IV (ARISOY, ATAEM7, BRAVO and NOVA) were evaluated in five environments (2014, 2015 and 2016 in Izmir-Bornova, 2015 and 2016 in Antalya-Aksu). The experiments were carried out in randomized complete block design with four replications. Each plots consisted of 4 rows 5 m long. The seeds inoculated with *Bradyrhizobium japonicum* bacteria, were sown in June after wheat harvest by hand over 45 plants per square meter. Before planting, 200 kg ha^{-1} of DAP (36 kg ha^{-1} N, 92 kg ha^{-1} P) fertilizers were applied in all environments. Irrigation was performed six times with sprinkler irrigation system.

Antalya-Aksu location has a well-drained and silty-loamy structure of alluvial soil with pH 7.5 whereas Izmir-Bornova has a heavy soil structure with clay-silt soil at 0-20 cm depth and clay-loamy structure at 20-40 cm depth and pH 7.6. The climate data for the experimental years and locations are presented in Table 2.

The combined analysis of variance was performed for the mean grain yield values of fourteen soybean genotypes in Izmir and Antalya locations in 2014 and 2015 and in 2016 only in Izmir ecological conditions (Steel and Torrie, 1980). In the current research, analysis of variance was performed over five environments accepted each combination of Year x Location as an environment. Firstly, the mean squares of the genotype x environment interaction were partitioned into their components and analysis of variance for stability.

Secondly, the regression coefficient (b_i) of mean value of a genotype on the mean value of all genotypes in each environment (environmental index value) and deviations from this regression (S^2_{di}) were estimated (Eberhart and Russel, 1966).

The F test was first applied to check differences of the deviation variances from the zero. In addition, statistics of ecovalance (W_i^2) and stability variance (σ_i^2), estimating the contribution of a genotype to total Genotype x Environmental interaction (GxE), were estimated (Wricke, 1962; Shukla, 1972).

Table 1. Advanced Soybean Lines and Registered Varieties Evaluated in Five Environments

Advanced lines (F_9)	Pedigree	Advanced lines (F_9)	Pedigree
BATEM 207	Ataem-6 x A-3935	BDUS-04	Umut 2002 x Sprite 87
BATEM 223	J-357 x 9392	KAMA	Macon x Apollo
BATEM 306	Ataem-6 x ETAE-8	KANA	NE 3297 x AP 2292
BATEM 317	Prota x Ap- 2292	KASM-02	Sprite 87 x Macon
BDSA 05	Sprite 87 x Apollo	KASM-03	Sprite 87 x Macon
Registered varieties: ARISOY, ATAEM7, BRAVO and NOVA			

Table 2. The climate data for the experimental years and locations

IZMIR												
	Average temp. (°C)				Relative humidity (%)				Precipitation (mm)			
Months/Years	2014	2015	2016	LT	2014	2015	2016	LT	2014	2015	2016	LT
June	25	24,6	27,5	25,5	52.2	52.2	47.9	52,9	40,3	30,9	2,8	9,9
July	28,2	28,7	29,3	28	47.7	47.7	44.5	51,2	0,9	0,2	0.0	1,7
August	28,3	29,3	28,9	27,6	54.0	54.0	51.0	53,9	21,1	1.0	0,4	2,9
September	24	26,4	24,7	23,6	55.5	55.5	50.1	58,0	10,9	12,9	8,6	13,9
October	19,3	19,7	19,4	18,7	63.2	63.2	57.7	64,0	56	48,1	0,5	43,6

ANTALYA									
	Average temp. (°C)			Relative humidity (%)			Precipitation (mm)		
Months/Years	2015	2016	LT	2015	2016	LT	2015	2016	LT
June	25.3	24.0	26.0	55.7	68.4	63.0	1.0	5.0	6.0
July	27.5	27.7	29.0	68.9	66.1	63.0	0.0	0.0	2.0
August	27.5	28.6	28.0	69.0	67.7	65.0	5.0	0.0	2.0
September	25.0	25.4	25.0	64.5	77.8	67.0	20.0	32.0	26.0
October	20.0	20.9	20.0	68.5	69.9	66.0	120.0	102.0	86.0

LT: Long Term

RESULTS AND DISCUSSION

The results of analysis of variance across five environments showed that genotype, environment, and GxE interactions were significant (p<0.01) (Table 3). These results indicated that soybean genotypes had significant differences for mean grain yields over different environments.

Table 3. Analysis of variance for grain yield stability of 14 soybean genotypes were grown in 5 environments.

Sources of variation	Degrees of freedom	Mean square
Blocks/Environments	15	1557.90
Genotypes (G)	13	6146.44**
Environments (E)	4	91675.60**
G x E	52	3362.58**
Linear	13	2703.35
Deviations	39	3582.32**
Error	195	911.59

**: Significant at 1% probability by the F-test.

Different researchers reported the presence of significant GxE interactions for grain yield, both in different soybean populations and lines (Schutz and Bernard, 1967; Caylak et al., 1994; Ustun et al., 2003; Hossein et al., 2003; Koraddi et al., 2017; Liu et al., 2017) and different legume species (Singh and Mehra, 1980; Ibrahim and Ruckenbauer, 1987; Waldia et al., 1988; Singh and Bejiga, 1990; Altinbas and Sepetoglu, 1994; Ozdemir and Engin, 1996; Sabanci, 1996; Ozdemir et al., 1999; Bozoglu and Gulumser, 2000; Altinbas and Sepetoglu, 2003; Sayar et al., 2013).

The variance due to of deviation from the regression, which is one of the two components the GxE interaction, was found to be significant (p<0.01) (Table 3). Accordingly, there were significant differences among soybean genotypes in terms of S_d^2 values. In order to identify genotypes of high adaptability in Mediterranean climatic conditions, it would be appropriate to use deviations from regression as a measure of stability. Koraddi et al. (2017) pointed out that while linear component of the GxE interaction was insignificant, they informed significant deviation variance in similar soybean populations including advanced lines. Hossain et al. (2003) has determined that both are important. Also, researchers working in other legume species such as Singh and Mehra (1980) in chickpea (*Cicer arientum* L.), Ozdemir et al. (1999) in lentil (*Cicer arietinum* L.), Ibrahim and Ruckenbauer (1987) and Altinbas and Sepetoglu (1994) in fava bean (*Vicia faba* L.) determined only the variance due to deviation from regression to be significant for grain yield.

Mean yields of environments (Table 4) varied between 2.63 t ha^{-1} (Antalya) and 3.66 t ha^{-1} (Izmir). Pfahler and Linskens (1979); stated that sufficient differences between the environments should be found in order to determine performance stability of the genotypes and this is considerable and necessary factor for the usefulness of regression analysis. It was observed that these conditions realized in this study because the mean yield of the Izmir locations were significantly higher than those of Antalya in the two growing years (2014 and 2015).

Table 4. Means grain yield (t ha^{-1}) of 14 soybean genotypes and variation intervals for 5 environments

Environment code	Crop year	Locations	Mean yield	Highest yield	Lowest yield	Variation interval
E1	2014	Antalya	2.63	3.19	2.03	1.16
E2	2014	Izmir	3.66	4.03	2.91	1.12
E3	2015	Antalya	3.07	3.64	2.71	0.93
E4	2015	Izmir	3.50	3.99	2.72	1.27
E5	2016	Izmir	3.09	3.52	2.42	1.10

LSD (0.05) 0.11

The mean values obtained from five environments for grain yield and the estimated stability statistics for each of the genotypes are presented in Table 5. Yield of the genotypes varied between 2.85 t ha^{-1} (BDUS 04) and 3.47 t ha^{-1} (BATEM 223). It was determined that the first four genotypes had significantly higher yield values than the general average. The ability to adapt to different environmental conditions at the phenotypic level is divided into two categories: biological and agronomic (Becker, 1981). In terms of agricultural production, agronomic stability is desirable. In this context, agronomic or dynamic stability is acceptable if a genotype has a performance at the expected yield level in one of the target environments. Becker and Leon (1988) reported that the regression coefficient (b_i) is appropriate for both biological and agronomic stability, whereas the deviations variance of regression (S^2_{di}) and ecovalance value (W_i^2) represent agronomic stability. Eberhart and Russel (1966) reported that a genotype with a high mean yield across all environments as well as a regression coefficient of around 1.0 and a statistically insignificant deviation from zero is ideal for stability. In this case, it is obvious that the ecovalance (W_i^2) and the stability variance (σ_i^2) values should be as low as possible in order to have a strong stability (Shukla, 1972; Nguyen et al., 1980; Lin et al., 1986; Yue et al., 1990).

Table 5. Means grain yield ($\bar{x}$) and stability parameter estimates of 14 soybean genotypes grown in 5 environments.

Genotype	$\bar{x}$ (t ha^{-1})	b_i	S_d^2	W^2	σ^2
ARISOY	3.06	0.93	215.29	681.07	91.55
ATAEM-7	3.07	0.76	2566.86**	8075.46	1846.16
BRAVO	3.18	0.73	843.28*	3009.43	644.05
NOVA	3.08	0.93	2497.90**	7525.96	1715.77
KAMA	3.07	1.82	63.99	4608.83	1023.57
KANA	3.22	1.22	1277.21**	4134.61	911.04
KASM-02	3.24	1.08	1019.36**	3098.64	665.22
KASM-03	3.32	0.97	1098.24**	3302.93	713.69
BATEM 207	3.33$^+$	0.87	289.45	981.41	162.82
BATEM 223	3.47$^+$	0.60	52.79	1201.45	215.04
BATEM 306	3.35$^+$	1.14	188.47	686.99	92.96
BATEM 317	3.42$^+$	1.28	307.39	1425.12	268.11
BDSA 05	3.03	1.12	701.10*	2200.69	452.15
BDUS 04	2.85	0.57	521.26	2780.94	589.83
Mean:	3.19				
LSD (0.05)	0.19				

*,**: Significantly different from zero at the 0.05 and 0.01 probability levels respectively.
+: Significantly different from the overall average (3.19).

Accordingly, four genotypes (BATEM 207, BATEM 223, BATEM 306, and BATEM 317) with significantly higher mean yields than the general mean are appeared to have in significant S_d^2 values (Table 5). According to W^2 statistic that expresses the magnitude of the contribution to the GxE interaction, the four genotypes have lowest W^2 values together with ARISOY, registered variety. In addition, it is possible to say that high yielding and strong stability are combined in these genotypes due to having relatively lower σ^2 values when compared to other genotypes in this study. Pham and Kang (1988) reported that the W^2 and σ^2 statistics are similar in terms of ranking the genotypes according to stability.

Yue et al. (1990) suggested that regression coefficients show stability as well as genotypic responses to environmental changes and as consequence adaptability to certain environments. Two of the four genotypes with strong stability (BATEM 207 and BATEM 223) were found to be numerically lower than 1.0, while the other two (BATEM 306 and BATEM 317) had b_i values greater than 1.0. Accordingly, it can be suggested that the genotypes BATEM 306 and BATEM 317 show better adaptability to favorable environments for the double crop soybean production. BATEM 207 and BATEM 223 had relatively better yielding ability in environments where double crop soybean growing conditions were unfavorable. However, these two genotypes appear to be unable to provide the expected yield increase in response to the improvement in growing environments due to regression coefficients lower than 1.0.

CONCLUSION

Soybean is usually cultivated as a second crop in ecological conditions where the Mediterranean climate condition. In this study carried out at 5 environments in Izmir and Antalya locations, the ripening periods of four genotypes which were determined as stable, varied between 111-114 days (no data were presented). It is also possible to say that these varieties which are included in the highest yield group can be used safely under double crop cultivation. However, irrigation is necessary to achieve the expected yield potential in the aforementioned regions. If sufficient water (500-700 mm) for soybean production can be grown BATEM 306 and BATEM 317 lines, otherwise the other two (BATEM 207 and BATEM 223) can be advice to grow in the regional conditions.

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