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Full Length Research Paper

Genotype by environment interactions, stability, and heritability of seed yield and certain agronomical traits in soybean [*Glycine max* (L.) Merr.]

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This research was aimed to (1) evaluate genotypic yield performances of eight soybean genotypes, (2) determine their stability parameters and (3) estimate variance components and heritabilities of yield and yield-related traits. Eight soybean genotypes were evaluated in two locations (Mustafakemalpasa and Gorukle) of Southern Marmara Region, Turkey during two years (2000 and 2001), to identify patterns of genotype by environment interactions and their stabilities in terms of seed yield and yield-related components. Seed yield and its components are affected by plant genotype and environmental conditions. Plot data for plant height, first pod height, number of pods per plant, number of seeds per plant, number of seeds per pod, 1000 seed weight and seed yield were observed at all the four trials. There were significant differences between genotypes of one or two years at each location for all the traits. Significant differences among years or between locations were obtained in terms of all traits. Genotype x environment interactions at all the traits were highly significant. Thus the stabilities of eight soybean genotypes were different for all the traits. According to the stability parameters, none of the genotypes were stable for seed yield. Genotypes, Hodgson-78, A-3127, Ataem-1, Corsoy and SA-88 were considered as having high adaptability to good environments while Mitchell, Ataem-2 and Etae-8 adapted to poor conditions in terms of seed yield. Genetical components of variance at all the traits were highly significant. Genotype x location x year interaction variances were also found significant at all the traits except first pod height. The estimates of heritabilities with limited phenotypic variance definition were 0.14, 0.14, 0.21, 0.004, 0.13, 0.30 and 0.26 for plant height, number of seeds per pod, 1000 seed weight, first pod height, number of seeds per plant, number of pods per plant and seed yield, respectively. The heritabilities with complete phenotypic variance definition were 0.05, 0.05, 0.04, 0.003, 0.07, 0.19 and 0.20 for the same traits, respectively. Moderate or low heritabilities estimated for all the traits showed that family selection method could be used instead of individual selection in the breeding programs for improving seed yield and its components.

Key words: Soybean, genotype by environment interaction, adaptation, stability, heritability, agronomical traits.

INTRODUCTION

Use of stable cultivars over several environments for high seed yield and quality characteristics is important for many crops in dry land conditions. Minimal changing in precipitation throughout summer season can result in great increases in crop yield when cultivars are unstable for yield performance.

When cultivars are tested in terms of seed yield at the multi-environmental trials, great differences are commonly observed in yield performance over environments. This differential yield response of cultivars from one environment to another is called Genotype x Environment (G x E) interaction (Allard, 1960; Vargas et al., 1998). The

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Table 1. Mean air temperature and total monthly precipitation in 1999, 2000 and 2001 years and in long-year average (1928/86).

Month	Temperature (℃)				Precipitation (mm)			
	1999	2000	2001	Long year	1999	2000	2001	Long year
March	9	8	14	8	71	96	49	69
April	14	15	14	13	25	109	86	60
May	18	18	18	18	8	49	65	52
June	23	22	24	22	74	16	17	30
July	26	26	28	25	1	9	2	25
August	25	25	26	24	40	11	13	18
September	21	21	23	20	12	82	42	40
October	16	15	17	16	34	128	0	56
Total					265	500	274	350

stability of seed yield in different crops has been statistically evaluated through analysis of G x E interaction in cultivar-adaptation trials conducted over several environments (Crossa, 1990; Piepho, 1998). Effective identification of superior genotypes is generally complicated by the presence of G x E interactions, whereby cultivar relative yields vary across different environments. In many crops, variations of genotypes in time to flowering is a source of genotype x environment interaction and requires appropriate consideration. In general, unfavorable conditions in time to flowering differently affects productivity and growing of commercial cultivars in production areas. Thus, genotypes least effected from changed environmental conditions especially in flowering period can remain present in yield performance. The effect of unfavorable environmental conditions on yield performance is stronger in drought areas.

Soybean (*Glycine max* L.Merrill) is grown in Turkey on 23 x 10^3 hectares and seed production is insufficient for national seed and oil requirements. Import of soybean as seed or unrafined oil has rapidly increased recently. Although request for soybean seed increased, sowing area has been limited in the country. More probably, higher demand to soybean will encourage soybean production again. Therefore, the trials on stability and adaptability of soybean cultivars or lines is more emphasized in Turkey.

Stability has been investigated using various procedures. A commonly used method for modelling statistical interaction is a simple regression of the cultivar performance on the site index (Yates and Cochran, 1938; Finlay and Wilkinson, 1963; Eberhart and Russel, 1966).

The objectives of our study were to (i) examine the influence of genotype, environment and genotype x environment interactions on seed yield and certain yield components of eight soybean genotypes, (ii) evaluate seed yield and certain agronomic traits of soybean genotypes, (iii) determine their stability parameters, and (iv) predict the broad sense heritabilities in terms of certain traits observed.

MATERIALS AND METHODS

Eight soybean genotypes (Ataem-1, Ataem-2, A-3127, Corsoy, Hodgson-78, Mitchell, Sa-88 and Etae-8) were grown at Mustafakemalpaşa and Gorukle sites, Bursa, during two years (1999-2000 and 2001-2002, respectively). Five of genotypes are commercial cultivars and three genotypes are experimental, new bred lines.

Two experiment locations, Gorukle and Mustafakemalpaşa, are located in the Southern Marmara Region of Turkey, with average 713 mm annual rainfall and 14.4℃ mean monthly temperature. Total precipitation obtained at the growing period of soybean is about 37% of annual precipitation. There were little differences between meteorological data of each location during the experimental years. According to the climatic observations, 1999 and 2001 were substantially drier than 2000 growing season in both locations (Table 1, Figure 1). The soil structures of two locations are very different: Mustafakemalpaşa has a clay loam with alluvial characteristics, but it is heavy clay at Gorukle. In Gorukle, the soils of experimental fields had 0.1% total nitrogen content (Kjelddahl method), 0.40 kg/ha phosphorus (Olsen method, P_2O_5), 5.70 kg/ha exchangeable potassium (ammonium acetate method, K_2O) and 1.9% organic matter (Walchey-Black Method). On the other hand, the soils of Mustafakemalpaşa contained 0.1% total nitrogen, 0.41 kg/ha phosphorus, 7.70 kg/ha exchangeable potassium and 3.0% organic matter. The soils were slightly alkaline in reactions (pH = 7.2 - 7.4).

The experiments were designed in a randomized complete block design with three replications in each site and year. In both years, plantings were made in mid-April at Mustafakemalpaşa and in late-April at Gorukle. The genotypes were planted in four-row plots 6 m long with a row spacing of 0.65 m within the plot. The seeding rate was 33 seeds/m. Plot size was 13 m^2 at harvest time. 60 kg of nitrogen per hectare and 60 kg of phosphorus per hectare as composed fertilizer (20:20:0) were applied prior to sowing and a further 60 kgN/ha was added when the plants were at vegetative growth stage (V_2). After emergence, Fusilade was sprayed at a rate of 0.20 cc/m^2 for weed control. All the plants were irrigated three times at different growth periods such as vegetative growth stage (V_2), beginning bloom (R_1) and full pod stage (R_4). The plots were irrigated from deficit moisture content of 0 - 90 cm soil layer to field capacity at each growth stage. Hand hoing was done after irrigations. Plots were harvested by hand in October and then threshed by plot harvester for seed yield and other seed traits determinations.

The traits measured in each experiments were: plant height at harvest, first pod height, number of pods per plant, number of

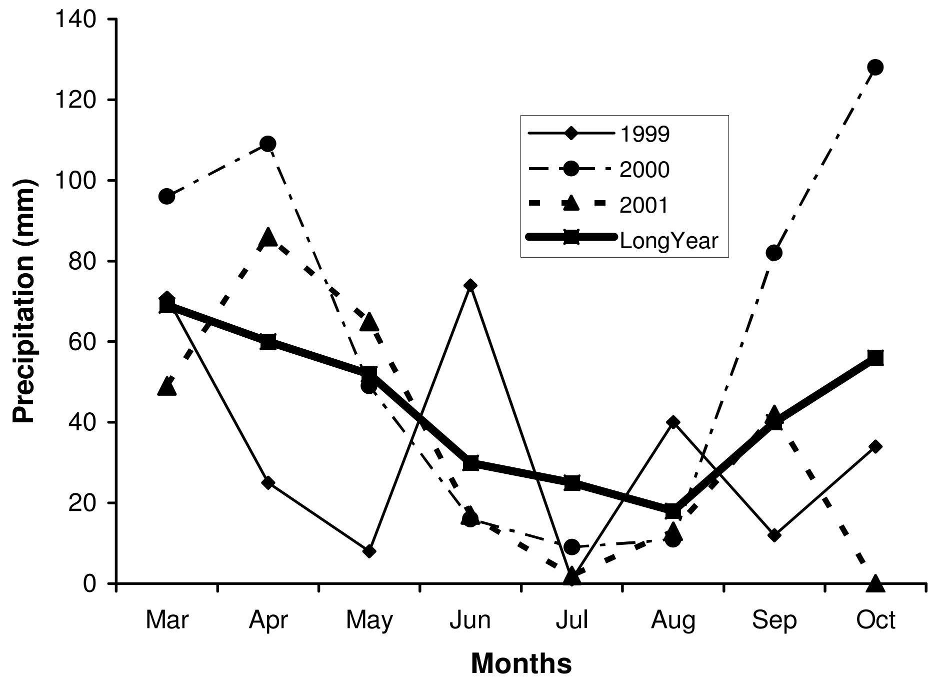

Figure 1. Total monthly precipitation in the year 1999, 2000, 2001 and in long-year average (1928/86) at Bursa.

seeds per plant, number of seeds per pod, 1000 seed weight and seed yield. The data were analyzed as a randomized complete block design. All the data were subjected to analyses of variance for each trait using MSTAT-C (version 2.1, Michigan State University 1991). Results of ANOVA of single experiments were combined over locations and years to get components of variance and calculate heritabilities. The significance of the genotypes, locations and years were determined at the 0.05 and 0.01 probability levels using appropriate F-values. For multiple comparations of means, the F-protected least significant difference (LSD) was calculated at the 0.05 probability level according to Steel and Torrie (1980).

In the study repeated over locations and years of eight genotypes, variance components were estimated by the following linear model;

$$X_{ijkl} = \mu + G_i + B_{jkl} + L_k + Y_l + GL_{ik} + GY_{il} + LY_{kl} + GLY_{ikl} + E_{ijkl}$$

Where; X_{ijkl} = Observed value, μ = general mean, G_i = effect of genotype, B_{jkl} = effect of replication (block), L_k = effect of location, Y_l = effect of year, $GL_{ik}+GY_{il}+LY_{kl}+GLY_{ikl}$ = effects of Genotype x Location, Genotype x Year, Location x Year, and Genotype x Location x Year interactions, respectively. E_{ijkl} = residual effects or experimental error. Additionally, g, r, l, y are numbers of geneotypes, replications, locations and years, respectively (in the study, g = 8, r = 3, l = 2 and y = 2).
Variance components were estimated using expected mean squares of the analysis of variance as pointed out Table 2.

Nine different components of variance were calculated using their appropriate MS contributing them. For example , genotypic component was estimated using equation.

$$\hat{\sigma}^2_G = \frac{M_5 - M_6 - M_7 + M_8}{rsy}$$

Interaction component between location and year (σ^2_{LY}) was calculated with the following equation:

$$\hat{\sigma}^2_{LY} = \frac{M_3 - M_4 - M_8 + M_9}{rg}$$

Two types of heritability were estimated as with complete and limited phenotypic variance definition as suggested by Gordon et al. (1972). These were calculated using the following equations:

1. Heritability with complete phenotypic variance definition (h_1^2)

$$h_1^2 = \frac{\hat{\sigma}^2_G}{\hat{\sigma}^2_R + \hat{\sigma}^2_L + \hat{\sigma}^2_Y + \hat{\sigma}^2_{LY} + \hat{\sigma}^2_G + \hat{\sigma}^2_{GY} + \hat{\sigma}^2_{GL} + \hat{\sigma}^2_{GYL} + \hat{\sigma}^2_E}$$

2. Heritability with limited phenotypic variance definition (h_2^2)

$$h_2^2 = \frac{\hat{\sigma}^2_G}{\hat{\sigma}^2_G + \hat{\sigma}^2_{GY} + \hat{\sigma}^2_{GL} + \hat{\sigma}^2_{GYL} + \hat{\sigma}^2_E}$$

All the terms at the denominators and nominators are estimates of the varince components determined in the study.
Stability analysis was applied for each trait using the stability parameters as proposed by Finlay and Wilkinson (1963) and Eberhart and Russell (1966). These parameters were regression coefficients of the genotype means over environments on the environmental indices (environmental means in the study) and mean squares of deviations from regressions. In the study, it is assumed that two years and two locations made four different environments.

Table 2. Sources of variation, calculated mean squares(MS) and their excpected values.

Source	df	MS	Expected mean squares
Locations (L)	(l-1)	M_1	$\sigma^2 + g\sigma_R^2 + r\sigma_{GLY}^2 + ry\sigma_{GL}^2 + rg\sigma_{LY}^2 + rgy\sigma_L^2$
Years (Y)	(y-1)	M_2	$\sigma^2 + g\sigma_R^2 + r\sigma_{GLY}^2 + rl\sigma_{Gy}^2 + rg\sigma_{LY}^2 + rsg\sigma_Y^2$
Y x L	(l-1)(y-1)	M_3	$\sigma^2 + g\sigma_R^2 + r\sigma_{GLY}^2 + rg\sigma_{LY}^2$
Blocks in Y and L	ly(r-1)	M_4	$\sigma^2 + g\sigma_R^2$
Genotypes (G)	(g-1)	M_5	$\sigma^2 + r\sigma_{GLY}^2 + rl\sigma_{Gy}^2 + ry\sigma_{GL}^2 + rsy\sigma_G^2$
G x L	(g-1)(l-1)	M_6	$\sigma^2 + r\sigma_{GLY}^2 + ry\sigma_{GL}^2$
G x Y	(g-1)(y-1)	M_7	$\sigma^2 + r\sigma_{GLY}^2 + rs\sigma_{GY}^2$
G x Y x L	(g-1)(y-1)(l-1)	M_8	$\sigma^2 + r\sigma_{GLY}^2$
Error	ly(g-1)(r-1)	M_9	σ^2

1. Coefficient of regression (b_i) for the genotype *i* was calculated by the following formula:

$$b_i = \frac{\sum_{j=1}^{m} Y_{ij} X_J - \frac{(Y_{i.})(X_.}{m}}{\sum_{j=1}^{m} X_j^2 - \frac{X_.^2}{m}}$$

In this equation of regression coefficient, *i* and *j* indices explain genotype (i = 1....8) and environment (j = 1....4), respectively. In addition *m* was the number of environments.

2. Mean squares of deviations from regression ($S_{d_i}^2$) were calculated subtracting the regression SS from total SS of genotype or dependent variable with following formula:

$$S_{d_i}^2 = \frac{1}{(m-2)}\left[(\sum_{j=1}^{m} Y_{ij}^2 - \frac{Y_{i.}^2}{m}) - b_i^2 (\sum_{j=1}^{m} X_j^2 - \frac{X_.^2}{m}) \right]$$

where b_i^2 was square of regression coefficient for the i th genotype

Mean regression coefficient ($\bar{b}$) calculated over single regression coefficients(b_i) of genotypes was considered as equal to 1 ($\bar{b}$ =1) because the environment means were used as environmental indices in the study (Finlay and Wilkinson, 1963).

In general, genotypes with b_i-values; (1) < 0.70 were considered unresponsive to different environments or had above average stability, (2) between 0.70 and 1.30 had average stability, and (3) >1.30 were considered responsive to good environments or had below average stability (Linn and Binns, 1985; Primomo et al., 2002).

RESULTS AND DISCUSSION

Analysis of variance

The combined analysis of variance indicated that the main effects of year (Y), location (L) and genotype (G) were significant for all traits studied (Table 3). The Y x L interaction was only significant for number of seeds per plant, number of seeds per pod, 1000 seed weight and seed yield. The G x Y interaction was significant for the other traits, excluding plant height and number of seeds per plant. On the other hand, the interaction between genotype and location (G x L) affected all the characters, except number of seeds per pod. Also, triple interaction (G x LxY) was found significant for all of the traits, except first pod height and number of pods per plant (Table 3).

Agronomic performance of soybean genotypes

Comparisons were made between soybean genotypes used in terms of important agronomical traits in the study. Eight soybean genotypes were significantly different from the traits observed (Table 4). According to the results obtained over years and locations , the mean values of genotypes for plant height, first pod height, number of pods per plant, number of seeds per plant, number of seeds per pod, 1000 seed weight and seed yield ranged between 61.5 and 82.3 cm, 13.0 and 17.5 cm, 31.7 and 53.1 pods/plant, 81.3 and 137.2 seeds/plant, 1.94 and 2.23 seeds/pod, 173.2 and 194.1 g and 1550 and 2244 kg/ha, respectively. Genotypes, Hodgson-78, Ataem-1, Corsoy and A-3127 were higher in seed yield than the others. The lowest yielding genotypes were Mitchell and Etae-8 which were also lowest mean values in the other traits measured. In general, the highest yielding genotypes had the highest means in terms of agronomical traits (Table 4). Similar results were obtained in previous local studies also (Isler et al., 1997; Karaaslan et al., 1999; Sogut et al., 2001). In another study, Xinhai et al. (1999) reported that mean values of soybean F_4 progenies ranged from 118.3 to 121.7 cm for plant height;

Table 3. Results of analysis of variance for seed yield and yield components observed from trials conducted in two years and two locations under Bursa conditions (mean square).

Source	DF	Plant height	First pod height	No.of pods/ plant	No.of seeds/ plant	No.of seeds/ pod	1000 seed weight	Seed yield
Year(Y)	1	2276**	13.4*	2392**	39087**	0.91**	19571**	4904
Location(L)	1	7876**	79.7**	426**	5276**	3.16**	1496**	336458**
Y x L	1	14	0.1	9	2740**	0.61**	7373**	13769*
Replication (Y, L)	8	120*	1.1	94*	253	0.01	64	1340
Genotype (G)	7	446**	24.3**	606**	4783**	0.12**	783**	90313**
G x Y	7	76	8.2*	143**	2854?	0.07*	333**	25938**
G x L	7	295**	19.5**	139**	1001**	0.03	213**	37368**
G x Y x L	7	130*	3.7	42	488*	0.07*	172**	37998**
Error	56	51	3.3	35	199	0.03	53	3329

*,**:Significant at the 0.05 and 0.01 probability levels, respectively.

150.2 to 155.2 pods/plant for pods per plant, 300.0 to 309.3 seeds/plant for seeds per plant and 18.45 to 19.55 g for seed yield per plant.

There were significant differences between year and location means for all of the traits, except seed yield. But no significant differences were found between year means for seed yield. In 2001, most of the genotypes gave higher mean values in terms of number of pods per plant, number of seeds per plant and number of seeds per pod relative to results of 1999 and 2000. The highest means for the other traits were obtained in 1999 or 2000. At Gorukle, genotypes had higher performance for all traits studied, except plant height and first pod height relative to the results of second location (Table 4).

Temperature and precipitation are important environmental factors that have a great impact on soybean yield. Temperature and precipitation could be the underlying factors that have contributed to the year effect in this research. Therefore, temperature and precipitation differences at growing season of soybean between 1999 and 2001 years were considered (Table 1). In general, 1999 and 2001 seasons were substantially drier than 2000. On the other hand, temperatures at growing season of soybean plants were slightly changed across the years. These climatic conditions likely contributed to most of the differences observed among years (Figures 1 and 2).

Stability parameters of soybean genotypes

Genoype x environment interaction in multiple-location and multiple-year trials can be partitioned in to G x L, G x Y and G x Y x L interactions (Comstock and Moll, 1963). Our results indicated that performances of genotypes in terms of traits studied were different at each location and year. Therefore, G x Y, G x L and G x Y x L interactions were found significant (Table 3). For example, all the genotypes, except Mitchell and Etae-8, were high yielding in 2000, while differences between genotypes were not significant in 1999 at Mustafakemalpaşa location for seed yield. Although, all genotypes, except Ataem-2, Mitchell and Etae-8, had high yield in 2000, the genotypes Hodgson-78, A-3127 and Corsoy gave higher seed yield relative to the remaining genotypes in 2001 at Gorukle site. The significant G x Y and G x L interactions reflected changes in the rank of the genotypes for seed yield (Table 4, Figure 3).

The first trait measured in the study was the plant height observed at harvesting time. The mean plant heights of genotypes were ranged between 61.5 and 82.4 cm. Among genotypes used in the study, Corsoy gave the tallest plants while Mitchell had the shortest plants. The regression coefficients (b_i) of genotypes for plant height ranged between 0.291 and 1.625. The genotypes Ataem-1, Corsoy and Sa-88 had regression coefficients near to 1.0 and minimal $S^2_{d_i}$ values for plant height (Table 5). These genotypes could be considered as having high adaptability to all environments. The genotypes Corsoy, Sa-88, and Ataem-2 for first pod height; Corsoy and Hodgson-78 for number of pods per plant; Ataem-1 for number of seeds per plant; Ataem-2 and Hodgson-78 for number of seeds per pod and Ataem-2 for 1000 seed weight gave b_i values near to 1.0 and minimal $S^2_{d_i}$ values have higher mean values than the general mean. Therefore, these genotypes were considered as stable in response to different environments according to Finlay and Wilkinson (1963) and Eberhard and Russell (1966).

There was no stable genotype for seed yield, because regression coefficients of genotypes were significantly greater or smaller than 1.0 and they had high $S^2_{d_i}$ values. The regression coeffi-cients of genotypes for seed yield ranged between 0.296 and 1.910. The genotypes Hodgson-78, A-3127, Ataem-1 and Corsoy had greater b_i values than 1.0 and higher seed yield than general mean and so these genotypes were approved as having high adaptability especially to the favorable envi-ronments. On

Table 4. Mean of agronomical traits for eight soybean genotypes tested at two locations in Bursa during 1999 to 2001.

Genotypes	Plant height (cm)					Fist pod height (cm)					Number of pods per plant				
	M.Kemalpaşa		Görükle		Genotype mean	M.Kemalpaşa		Görükle		Genotype mean	M. Kemalpaşa		Görükle		Genotype mean
	1999	2000	2000	2001		1999	2000	2000	2001		1999	2000	2000	2001	
Ataem-1	72.6 ab	84.2 c	56.7 bc	77.4	72.7 bcd	14.5 b	19.1 a	15.3	17.3 ab	16.6 a	39.6 ab	48.3 bc	58.6 a	53.4 bc	49.9 ab
Corsoy	79.5 a	96.7 a	73.7 a	79.6	82.4 a	16.5 ab	17.4 a	14.7	18.4 a	16.7 a	44.9 ab	50.1 ab	42.1 b	52.2 bc	47.3 b
Sa-88	80.7 a	84.7 c	62.3 ab	70.9	74.7 bc	18.8 a	18.7 a	16.7	15.8 ab	17.5 a	39.9 ab	41.1 bc	36.4 b	43.0 d	40.1 c
Hodgson-78	76.9 ab	89.5 abc	73.7 a	64.3	76.1 b	17.3 a	18.3 a	14.7	15.0 b	16.3 a	38.9 ab	47.8 bc	53.6 a	57.5 ab	49.4 ab
Ataem-2	76.2 ab	93.5 ab	48.3 c	62.3	70.1 cd	17.2 a	17.5 a	15.3	14.3 bc	16.1 ab	48.2 a	63.1 a	40.3 b	60.6 a	53.1 a
Mitchell	63.7 c	63.3 d	53.7 bc	65.4	61.5 e	11.8 c	11.0 b	14.3	14.8 b	13.0 c	35.3 bc	52.1 ab	34.4 bc	61.6 a	45.8 b
A-3127	76.4 ab	92.8 abc	56.0 bc	58.3	70.8 bcd	18.6 a	19.2 a	12.0	15.8 ab	16.4 a	27.2 c	39.1 bc	38.1 b	50.6 c	38.7 c
Etae-8	81.2 a	86.4 bc	44.0 c	61.9	68.4 d	16.7 ab	16.6 a	14.0	11.3 c	14.6 b	27.9 c	35.1 c	27.1 c	36.6 d	31.7 d
Year mean	75.9	86.4	58.5	67.5		16.4	17.2	14.6	15.4		37.7 d	47.1 b	41.3 c	51.9 a	
Location mean		81.1 a		63.0 b			16.8 a		15.0 b			42.4 b		46.6 a	

Table 4. Contd.

Genotypes	Number of seeds per plant					Number of seeds per pod					1000 seed weight (g)				
	M.Kemalpaşa		Görükle		Genotype Mean	M.Kemalpaşa		Görükle		Genotype Mean	M.Kemalpaşa		Görükle		Genotype Mean
	1999	2000	2000	2001		1999	2000	2000	2001		1999	2000	2000	2001	
Ataem-1	111.9 a	122.2 bc	128.7 a	147.3 bc	127.3 ab	2.0	1.7 d	2.2 a	2.4 d	2.1 c	185 bc	188 a	216 ab	184 a	193 a
Corsoy	95.7 abc	88.5 c	89.3 c	107.2 de	95.2 d	2.1	1.8 cd	2.1 a	2.4 d	2.1 abc	195 ab	182 ab	203 bc	169 bc	187 b
Sa-88	73.4 cde	89.1 c	68.3 d	94.5 e	81.3 e	1.9	2.3 a	2.2 a	2.5 bc	2.2 a	196 ab	180 abc	207 bc	160 cd	186 b
Hodgson-78	94.5 abc	99.2 c	122.6 a	161.5 ab	119.5 bc	1.9	2.0 bcd	2.2 a	2.7 a	2.2 ab	206 a	169 cd	227 a	176 ab	194 a
Ataem-2	108.8 ab	177.3 a	106.9 b	155.9 ab	137.2 a	2.0	2.1 ab	2.1 a	2.6 b	2.2 ab	188 bc	170 bcd	224 a	172 b	189 ab
Mitchell	67.9 de	155.8 ab	65.0 d	175.2 a	115.9 bc	1.9	1.8 bcd	1.9 b	2.4 cd	2.0 cd	180 cd	167 d	216 ab	150 e	176 c
A-3127	86.5 bcd	97.1 c	84.5 c	165.7 ab	108.5 c	1.7	2.0 bc	2.2 a	2.4 cd	2.1 bcd	167 d	169 bcd	206 bc	153 de	177 c
Etae-8	53.9 e	100.8 c	61.2 d	126.8 cd	85.7 de	1.7	1.8 bcd	1.9 b	2.3 d	1.9 d	186 b	174 bc	194 c	158 de	173 c
Year mean	86.6 c	116.3 b	90.7 c	141.7 a		1.9 c	1.9 c	2.1 b	2.5 a			175 c	211 a	165 d	
Location mean		101.4 b		116.2 a			1.9 b		2.3 a			180.4 b		188.3 a	

the other hand, Ataem-1,Corsoy and Hodgson-78 had also significantly higher $S^2_{d_i}$ values. Other genotypes Ataem-2, Sa-88, Mitchell and Etae-8 could be considered as having adaptability to poor environmental conditions (Table 5 and Figure 3). Our results did not support the conclusion of Yothasiri et al. (2000) and Primomo et al. (2002) that genotypes with higher stability or good adaptability in a wide range of environment were found for seed yield or fatty acid levels. Discordance among results was probably due to differences of genetic material and environmental conditions in these studies. Cultivars showed differential yield response from one environment to another and also climatic data changed over years and locations in the present study. However, our results are in agreement with those of

Table 4. Contd.

Genotypes	Seed yield (Kg/ha)				
	M.Kemalpaşa		Görükle		Genotype Mean
	1999	2000	2000	2001	
Ataem-1	1802	1831 a	2692 a	2217 bc	2135 ab
Corsoy	1713	1887 a	2497 a	2362 ab	2115 ab
Sa-88	1948	1910 a	2453 a	2024 cd	2084 b
Hodgson-78	1879	1782 a	2897 a	2420 a	2244 a
Ataem-2	1733	1791 a	1490 b	2066 cd	1769 c
Mitchell	1717	1499 b	983 b	2092 cd	1573 d
A-3127	1796	1792 a	2469 a	2390 ab	2112 ab
Etae-8	1618	1472 b	1117 b	1994 d	1550 d
Year mean	1776 c	1745 c	2075 b	2195 a	
Location mean		1761 b		2135 a	

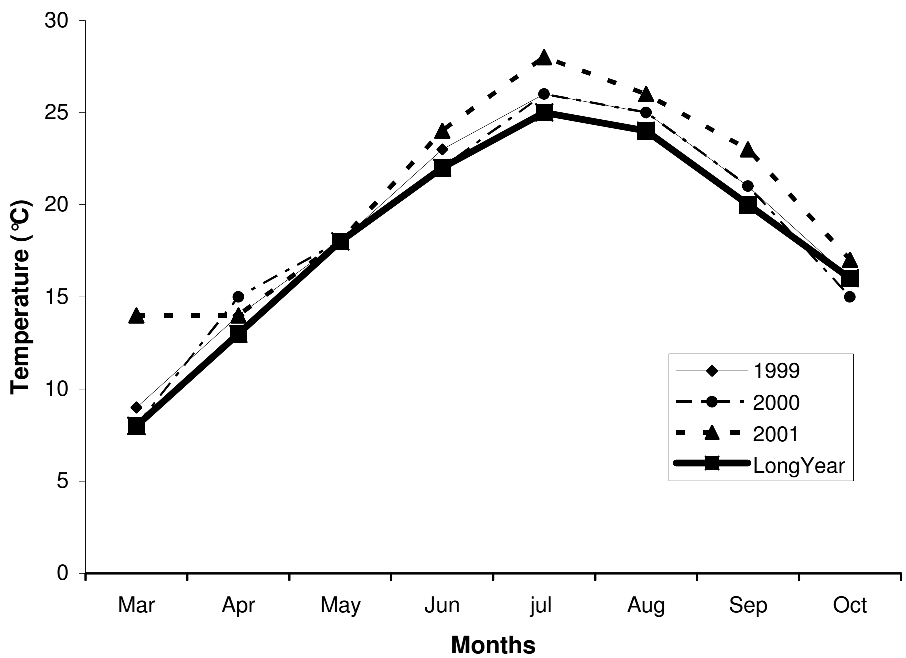

Figure 2. Mean air temperature in 1999, 2000, 2001 years and in long-year average (1928/86) at Bursa.

Dashiell et al. (1994), Chandrakar et al. (1998), and Rajanna et al. (1999) who reported that genotype x environment inte-raction was significant for seed yield. Also, our findings corresponds to that of Tadesse et al. (1997) who reported that some cultivars had high yields under favourable envi-ronments, while others adapted to poor environments.

Components of variance and heritabilities

Estimated components of variance contributing to G x E interaction were found significant for all traits investigated (Table 6). The largest source of G x E interaction for plant height was the G x L and G x Y x L variance components. The genetic variance for plant height also had a significantly high value. Also, the L and Y variance components into total (phenotypic) variance were significantly high level. Thus for plant height, heritability with complete phenotypic variance definition was low (0.050), but heritability with limited phenotypic variance definition was relatively higher value (0.14).

For first pod height, error (E) variance component was the largest component of the total variance, and G x L variance component had second large contribution. How-

Table 5. Stability parameters (b_i and $S^2_{d_i}$) and mean values of eight soybean genotypes for the traits observed.

Genotypes	Plant height			First pod height			No.of pods/plant		
	Mean (cm)	b_i	$S^2_{d_i}$	Mean (cm)	b_i	$S^2_{d_i}$	Mean	b_i	$S^2_{d_i}$
Ataem-1	72.7	0.850	158.0	16.6	0.850	14.5*	49.9	0.544	243.1**
Corsoy	82.4	0.765	72.1	16.7	0.649	8.7	47.3	0.649	22.5
Sa-88	74.7	0.827	19.4	17.5	1.083	3.2	40.1	0.317*	17.3
Hodgson-78	76.1	0.667	207.4*	16.3	1.502*	0.5	49.4	0.963	129.3
Ataem-2	70.0	1.625*	0.4	16.1	1.100	3.0	53.0	1.318	208.3**
Mitchell	61.5	0.291**	72.9	13.0	-1.518**	2.4	45.8	2.045**	53.9
A-3127	70.8	1.402*	88.7	16.4	2.769**	4.1	38.7	1.438	47.2
Etae-8	68.4	1.574*	114.3	14.6	1.566	14.3	31.7	0.725	13.9
MEAN	72.1	1.000		15.9	1.000		44.5	1.000	
Genotypes	**No.of seeds/plant**			**No.of seeds/pod**			**1000 seed weight**		
	Mean	b_i	$S^2_{d_i}$	**Mean (cm)**	b_i	$S^2_{d_i}$	**Mean (g)**	b_i	$S^2_{d_i}$
Ataem-1	127.3	0.486	299.9	2.05	0.949	0.096	193.2	0.672*	191.8
Corsoy	95.2	0.225*	185.8	2.09	0.721	0.117*	187.0	0.690*	103.8
Sa-88	81.3	0.459*	75.8	2.23	0.794	0.126*	185.9	0.944	230.2*
Hodgson-78	119.5	0.883	1922.3**	2.20	1.421	0.001	194.1	1.232	504.9**
Ataem-2	137.2	1.066	2170.7**	2.21	0.934	0.021	188.6	1.177	183.8
Mitchell	115.9	2.160**	1270.8**	2.02	1.023	0.057	173.4	1.509**	156.1
A-3127	108.5	1.387	1028.9**	2.08	1.156	0.108*	177.1	1.093	20.7
Etae-8	85.7	1.333	59.3	1.94	1.001	0.009	173.2	0.683	162.2
MEAN	108.8	1.000		2.10	1.000		184.0	1.000	
Genotypes	**Seed yield**								
	Mean (Kg/ha)	b_i	$S^2_{d_i}$						
Ataem-1	2135	1.417	3346.1**						
Corsoy	2115	1.520	1186.2*						
Sa-88	2084	0.611	1996.8**						
Hodgson-78	2244	1.910**	3955.0**						
Ataem-2	1769	0.270*	2352.6**						
Mitchell	1573	0.296*	9473.3**						
A-3127	2112	1.576**	590.4						
Etae-8	1550	0.400*	5579.5**						
MEAN	1948	1.000							

*,** Significant at the 0.05 and 0.01 probability levels, respectively.

ever, the genetic variance component (G) was small-er than the other components. The heritabilities as h_1^2 and h_2^2 for first pod height were 0.003 and 0.004, respectively. Fist pod height was the attribute with the smallest heritability in the study.

For the number of pods per plant, year (Y) and genetic (G) variance components were more large than the other components. Heritabilities with complete or limited phenotypic variance definition were low or moderate level (0.188 and 0.302, respectively).

The largest source of total variance for number of seeds per plant was the Y variance component, followed by the G x Y, G, and G x Y x L variance components. Heritabilities estimated for this trait were 0.068 and 0.132, as the h_1^2 and h_2^2, respectively.

For the number of seeds per pod, the highest proportion into phenotypic variance had the L variance component, followed by the Y x L, G x Y x L, and G variance components. Both heritabilities (h_1^2 and h_2^2) were low values (0.055 and 0.142, respetively).

The most important components of the phenotypic variance for 1000 seed weight were the Y x L, G x Y x L and G variance components. Heritability with complete phenotypic variance definition (h_1^2) was low (0.048) due

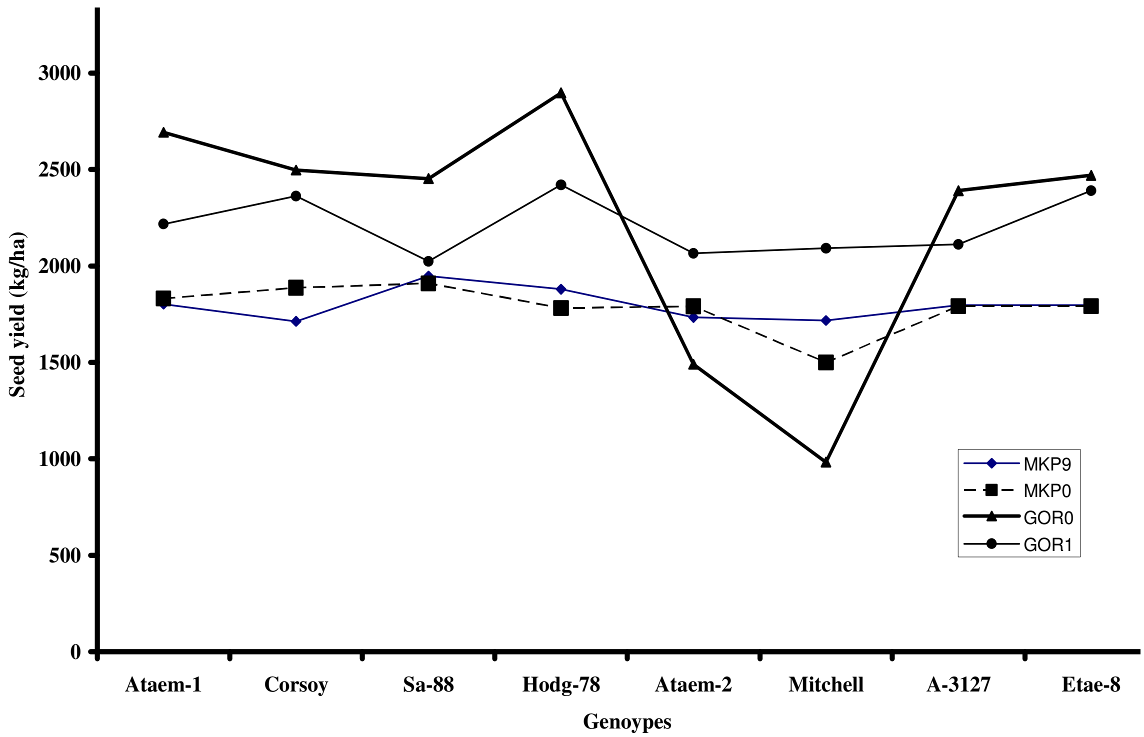

Figure 3. Seed yeilds of eight soybean genotypes over environments (MKP9 and MKP0 denotes seed yields of 1999 and 2000, respectively).

to significantly higher Y x L interaction. But, the h_2^2 was slightly higher (0.213).

The G x Y x L variance component was found to be the most important source of total variance for seed yield. The second and third largest source of total variance were the L and G variance components, respectively. The highest heritability estimates in the study were obtained from seed yield with 0.199 and 0.267 (h_1^2 and h_2^2, respectively). Seed yield is a quantitative characters. It is called complex character because it is controlled by many genes. The variation within a quantitative character is due to its complex inheritance and to the influence of the environment (Fehr, 1978).

As a result, moderate or low heritabilities for all characters were found in the present study. Johnson et al. (1955a) found moderate heritability for the number of pods. In addition, Brim (1973) estimated heritabilities of 73 to 84% for plant height. Melquiades and Reyes (1990) reported that seed yield per plant, plant height at harvesting, number of branches and number of pods per plant had heritabilities of 28.6, 2.1, 38.3, and 32.9%, respectively.

Conclusion

In conclusion, this study has provided evaluation of the environmental and agronomic performance of certain soybean genotypes. Also, hertitabilities of some agronomical traits were predicted using phenotypic variance components in the study.

The G x Y, G x L and G x Y x L effects were significantly found for seed yield and the other traits studied. Temperature and prepicipation were environmental factors that had a major impact on soybean yield. In general, 1999 was substantially drier than 2000 and 2001 growing seasons. These climatic conditions likely contributed to most of the differences observed among years. Stability analysis, demonstrated that there was no stable genotype for seed yield whereas some genotypes were considered as having high adaptability to the favorable environments and the other genotypes to the unfavorable environment conditions. The Genotype x Environment (G x E) variance components were the most important source of total or phenotypic variance for all traits observed. Thus, the heritability estimates for all characters were found moderately low or low levels.

In summary, the low or moderately low heritabilities and large G x E interactions indicated that seed yield and other agronomical traits are inherited quantitatively in soybean. Selection progress for improved soybean yield and yield components will be small but possible. Thus, using family selection method could increase success in breeding programmes for improved seed yield.

Table 6. Estimates of variance components and heritabilities of certain agronomical traits for eight soybean genotypes tested at two Bursa locations during 1999 to 2001.

Estimates	Plant height	First pod height	No. of pods/plant	No. of seeds/plant	No.of seeds/pod	1000 seed weight	Seed yield
Variance cmponents							
$\hat{\sigma}^2_y$	48.2**±38.7	0.18 ±0.24	47.5**±40.7	707.9**±667.1	0.006±0.018	250.8±163.8	6.6±51.6
$\hat{\sigma}^2_L$	160.3**±130.0	1.33*±1.37	6.7±7.4	42.1±101.7	0.054*±0.055	-123.3±127.9	673.6**±572.2
$\hat{\sigma}^2_{YL}$	-7.7±3.4	-0.06 ±0.08	-3.8±7.0	91.5±93.8	0.023*±0.021	299.5*±250.8	-92.7±88.2
$\hat{\sigma}^2_R$	8.7 ±6.8	-0.28±0.09	7.3 ±5.3	6.8±14.9	-0.002±0.001	1.3±3.8	-24.8±10.7
$\hat{\sigma}^2_G$	17.1** ±21.8	0.03±1.27	30.5**±86.9	117.9**±223.1	0.007**±0.006	34.1**±35.1	541.7**±50.7
$\hat{\sigma}^2_{GY}$	-9.0 ±11.8	0.75±0.71	16.7±11.7	394.3*±227.5	0.0002±0.008	26.8±29.5	-201.0±92.1
$\hat{\sigma}^2_{GL}$	27.5 ±25.3	2.62*±1.56	16.1±11.5	85.4±87.5	-0.006±0.006	6.7±21.5	-10.5±90.8
$\hat{\sigma}^2_{GYL}$	26.5*±20.7	0.14 ±0.62	2.4±7.0	96.5*±77.7	0.013*±0.011	39.7**±27.3	1155.6**±182.7
$\hat{\sigma}^2_E$	50.7 ±9.4	3.35 ±0.62	35.3±6.5	198.8±36.9	0.03±0.006	53.1±9.8	332.9±61.8
Heritabilities							
h^2_1 (Full)	0.050	0.003	0.188	0.068	0.055	0.048	0.199
h^2_2 (Limited)	0.140	0.004	0.302	0.132	0.142	0.213	0.267

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