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Full Length Research Paper

Effect of genotype and environment interaction on oil and protein content of soybean (*Glycine max* (L.) Merrill) seed

Funda Arslanoglu*, Selim Aytac and Emel Karaca Oner

Department of Field Crops, Faculty of Agriculture, Ondokuz Mayıs University, 55139 Samsun, Turkey.

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This study investigated the crude oil and protein contents of soybean cultivated in different environments in the Middle Black Sea region of Turkey. Field experiments were conducted at 8 sites (Erbaa, Turhal, Carsamba, Bafra, Gokhoyuk, Suluova, Kabalı, Boyabat) with differing environments during two years; the study used a randomized complete blocks design with three replications and eight soybean cultivars (Flint, Apollo, Savoy, Amsoy 71, Macon, Ap2292, SA88, A3127). The effects of the genotype, environment and their interactions on crude oil and protein content of soybean see-ds were found to be statistically significant (p<0.01). Among the genotypes, Savoy had the highest protein content (33.98%) and SA88 had the highest oil content (21.80%). Whereas among the environments, the highest oil content (22.04%) and the highest protein content (35.26%) were found at Suluova and Gokhoyuk environments, respectively. In terms of genotype × environment interaction, the highest protein content was determined at Gokhoyuk environment with Ap2292 genotype (38.57%), and the lowest at Turhal environment with Flint genotype (29.25%). The two highest oil contents were obtained from Flint and SA88 genotypes at the Bafra environment, while the lowest was determined in the A3127 genotype (18.28%) at the Turhal environment. Correlation analysis showed a very important negative correlation between oil and protein content (r^2=-0.557) in terms of genotype × environment interaction.**

Key words: Soybean (*Glycine max* (L.) Merrill), genotype, environment, protein, oil content.

INTRODUCTION

Soybean (*Glycine max* (L.) Merrill) is an important crop with high quality protein and oil content (Arioglu, 2007). Due to the carbohydrate, ash, several minor components and nutritional characteristics of its seeds, soybeans are used in human and stock nutrition, quality cooking oil, as a good protein source (Yogendra et al., 2005; Rajcan et al., 2005) as well as in various industrial branches. The oil content in soybean seeds varies between 15 and 22% and the protein content between 36 and 40% (Arioglu, 2007). In 2009, soybean production covered 10,512 ha, yielding approximately 38,500 t within Turkey (FAO, 2010). This production only meets 0.02% of need of Turkey. Soybean is grown as the main agricultural crop in the Middle Black Sea Region, and as the second crop in the Aegean, Marmara, Mediterranean (Cukurova) and Southeastern Anatolia regions of Turkey. However, the varying regional ecological conditions found throughout Turkey mean that it is extremely important to select appropriate cultivars for each environment. The plants are directly affected by factors such as high temperature, day length and relative humidity, and their potential yields may not be realized in all environments (Uncu and Arioglu, 2005). The interaction between the genetic structure of a plant and environmental factors is called genotype × environment interaction. Plant breeders make use of genotype × environment interactions for the identification of high yield cultivars of the required quality. Although, the relationship between seed quality and seed yield is not known exactly (Yin and Vyn, 2005), previous

*Corresponding author. E-mail: farslanoglu@gmail.com. Tel:+90362 312 19 19 (1378).

studies have reported the effect of factors such as climatic conditions, soil characteristics, agronomic practice, genotypic characteristics (Piper and Boote, 1999), water stress (Noureldin et al., 2002) on the oil and protein content of soybean. Generally, oil content increases while protein content decreases in areas with high temperatures (Kane et al., 1997; Gunasekera et al., 2006). According to Miladinovic et al. (2006), the oil and protein content of soybean seeds grown in environments at similar latitudes had significant differences. Similar results were reported by Ning et al. (2003), who cultivated 5 soybean genotypes in 11 different environments. Sogut (2006) found significant effect of interaction between year and environment on oil and protein content in soybean seed. Ojo et al. (2002) reported that genotype × environment interaction was significant for oil and protein content. Sudaric et al. (2006) mentioned that protein content was affected by environmental changes, and that the effect of genotype × environment interaction on oil content was less than the effect of year and genotype.

The aim of this study was to determine the effect of genotype × environment interaction on the oil and protein contents of soybean genotypes grown in different environments.

MATERIAL AND METHODS

The research area was situated in the Middle Black Sea region of Turkey. Soybean production is established in some parts of the region. Experimental environments were selected in the provinces of Amasya (Gokhoyuk and Suluova district), Tokat (Erbaa and Turhal district), Samsun (Carsamba and Bafra district) and Sinop (Kabalı village and Boyabat district). This study was conducted for over 2 years (2004 and 2005) at eight locations representing the different environments. However, during 2005, the seedlings at the Suluova environment were damaged by strong and warm winds; the experiments at the Carsamba environment were canceled because the plants were eaten by rabbits; these experiments were repeated in 2006. Therefore, the 2nd year climate and soil data of these two environments were obtained during 2006. The cultivars used were in the following maturity groups (MG) of I (Savoy and Ap2292), II (Amsoy 71, Apollo, Flint) and III (A3127, SA88, Macon). Previous research indicated that cultivars in the II, III and IV maturity groups performed very well in Turkey's climatic conditions in terms of growth period (Arioglu, 2007). However, for the Middle Black Sea region, which lies in the north of Turkey and has a shorter vegetation period, the early flowering soybean cultivars included in the 0, I and II maturity groups were found to be more suitable (Ozcelik et al., 2001).

The seeds were inoculated with *Brady rhizobium* bacteria culture for high seed yield. They were then sown in a randomized complete block design with three replications. Each plot was four rows wide and 4 m long with 70 cm row-to-row spacing and plant-to-plant distance was maintained as 5 cm. Sowing was completed between 24th May and 3rd June in both years. Fertilization, irrigation and weed control followed standard cultural practice (Arioglu, 2007; Bilgili et al., 2005). The harvests were completed in both years between the dates, 15th October (in Erbaa environment) and 5th November (in Carsamba and Kabalı environments).

In all of the environments where the experiments were conducted, the structure of the soil was clay and clay loamy. The soil was semi-limey in Amasya (Gokhoyuk and Suluova environments); limey in Tokat (Erbaa and Turhal environments); limey and semi-limey in Samsun (Carsamba and Bafra environments); very limey in Sinop (Kabalı and Boyabat environments) and the levels of soil organic matter in all environments were found to be sufficient for growing soybean (Laboratory of Soil and Water Research Institute, Samsun, Turkey).

The latitudes, longitudes and altitudes of the research environments are shown in Figure 1.

Samsun (Carsamba and Bafra) and Sinop (Kabali) provinces exhibit the moderate climatic characteristics of the Middle Black Sea region. They have similar characteristics, being relatively hot and arid in the summer and cool and wet in the winter. Sinop (Boyabat), Tokat (Turhal and Erbaa) and Amasya (Suluova and Gokhoyuk) provinces exhibit an intermediate climatic character between the Middle Black Sea region and terrestrial climate; summers are hot and arid and winters are cold. Monthly temperature and rainfall data during the growing season of the two research years were obtained from the local weather stations at the eight environments, and are shown in Figures 2 and 3.

As shown in Figure 2, July and August (soybean flowering and seed filling period) receive very little rainfall. However, rainfall was higher in the Bafra, Carsamba, Kabalı and Boyabat environments, especially throughout the harvest period of September to November.

The highest temperatures were observed in July and August at the all study environments. The temperature began to decline in September and dropped below 8°C at all environments in November except in Carsamba, Bafra and Kabalı environments, which are influenced by temperate climate (Figure 3).

Proportional moisture values were recorded as 74.0 to 73.8% in Sinop and Samsun environments and 60 to 65% in Amasya and Tokat environments.

To determine the protein and oil contents, a 25 g sample of dry seeds from each plot was finely ground. Nitrogen (N) was determined by micro-kjeldahl technique for each environment and genotype. Crude protein content (N × 5.71) was calculated by using 5.71 as the conversion factor (Bilgili et al., 2005). Oil content was extracted with n-hexane using Automatic Soxtherm apparatus. Oil percentage was determined by weight differences (Kumar et al., 2006). Seed protein content and oil content were expressed on a dry matter basis.

Statistical analysis

The data obtained was analyzed using analysis of variance (ANOVA) by combining the data collected over the years and environments. When assessing the interaction between genotype and environment, genotype was selected as the main variable. The means were compared by using least significant difference (LSD) at a level of 1% (Yurtsever, 1984).

RESULTS AND DISCUSSION

The results of this study indicated that there were significant ($p<0.01$) differences between the genotypes, environments and genotype × environment interactions for crude protein and oil content in soybean seeds (Tables 1 and 2). Making comparisons in genotype by environment interaction with significant effect on protein and oil content ($p<0.01$), genotype was selected as the main variable.

The lowest protein content in soybean seeds of 30.89% was determined in the Turhal environment, while the

Figure 1. Latitude, longitude and altitude of each experimental environment

highest protein content of 35.26% was found in the Gokhoyuk environment. Protein content varied between 31.81 (Amsoy 71) and 33.98% (Savoy) among the genotypes (Table 1). The standard deviations and protein content of genotypes in terms of genotypes × environment interaction are given in Figure 4. The results showed that the highest protein contents were determined with A3127 genotype (37.37%) in Erbaa environment, Savoy (32.45%) and Ap2292 (32.09%) genotypes in the Turhal environment; SA88 (36.41%) and Savoy (36.55%) genotypes in the Carsamba envi-

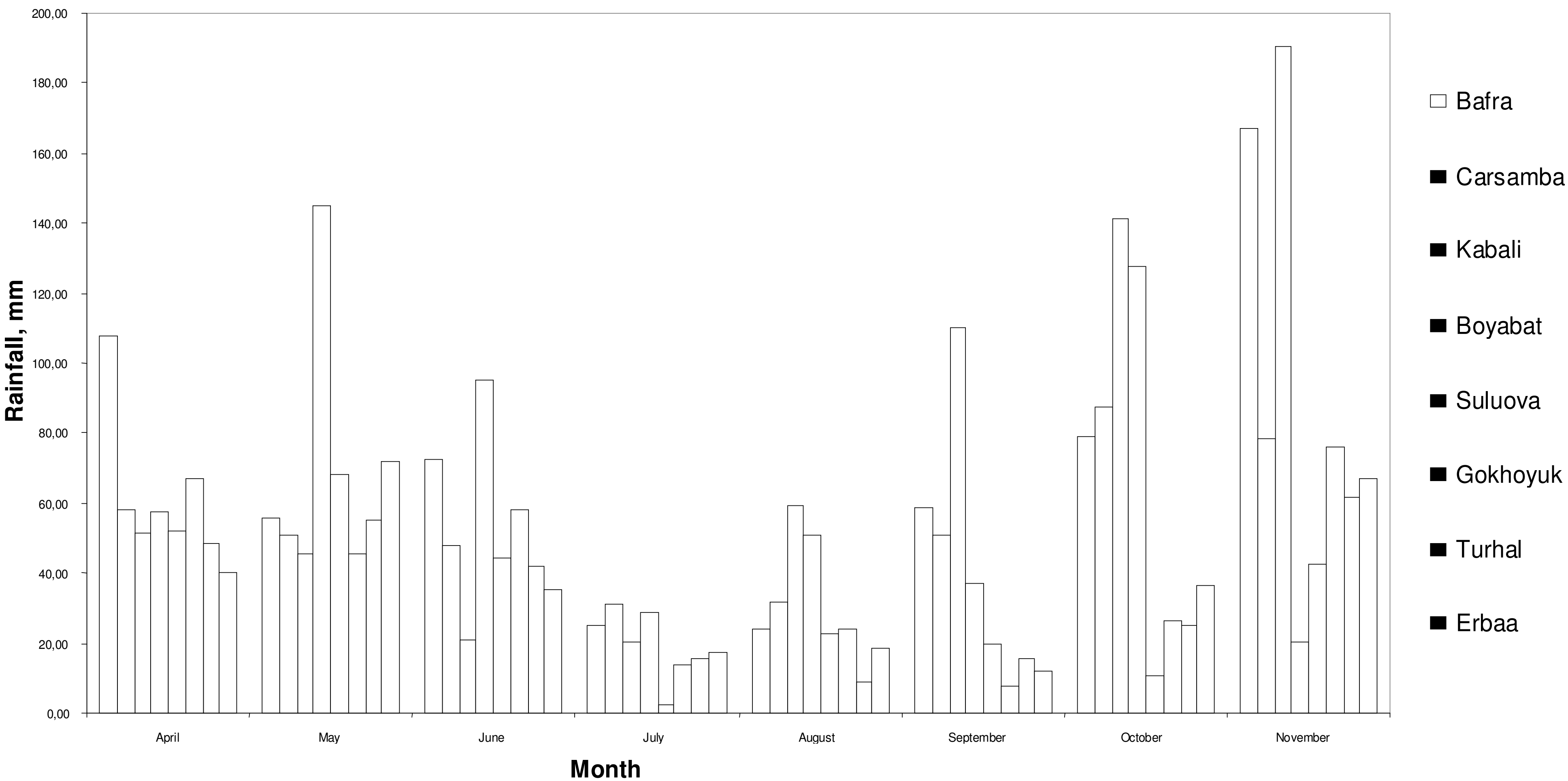

Figure 2. Average monthly rainfall during growing season of two study years.

ronment; Savoy (35.28%) and Ap2292 (34.65%) genotypes in the Bafra environment; Ap2292 (38.57 and 33.35%, respectively) genotype in the Gokhoyuk and Suluova environments; Savoy (32.61%) and SA88 (32.47%) genotypes in the Kabalı environment, and A3127 (33.50%) and Ap2292 (32.87%) genotypes in the Boyabat environment. Among all the environments, the lowest protein content was obtained from the Flint genotype (29.25%) in the Turhal environment (Table 1 and Figure 4). The highest oil content of 22.04% was determined in the Suluova and the lowest by 20.42% in Gokhoyuk among the environments. The oil content of genotypes varied between 20.52 and 21.80%. The highest oil content obtained from Amsoy 71, Flint and SA88 genotypes were placed in the same statistical group (Table 2). Oil content of genotypes in different environment and standard deviations are shown in Figure 5. The environments was examined separately, all of genotypes except

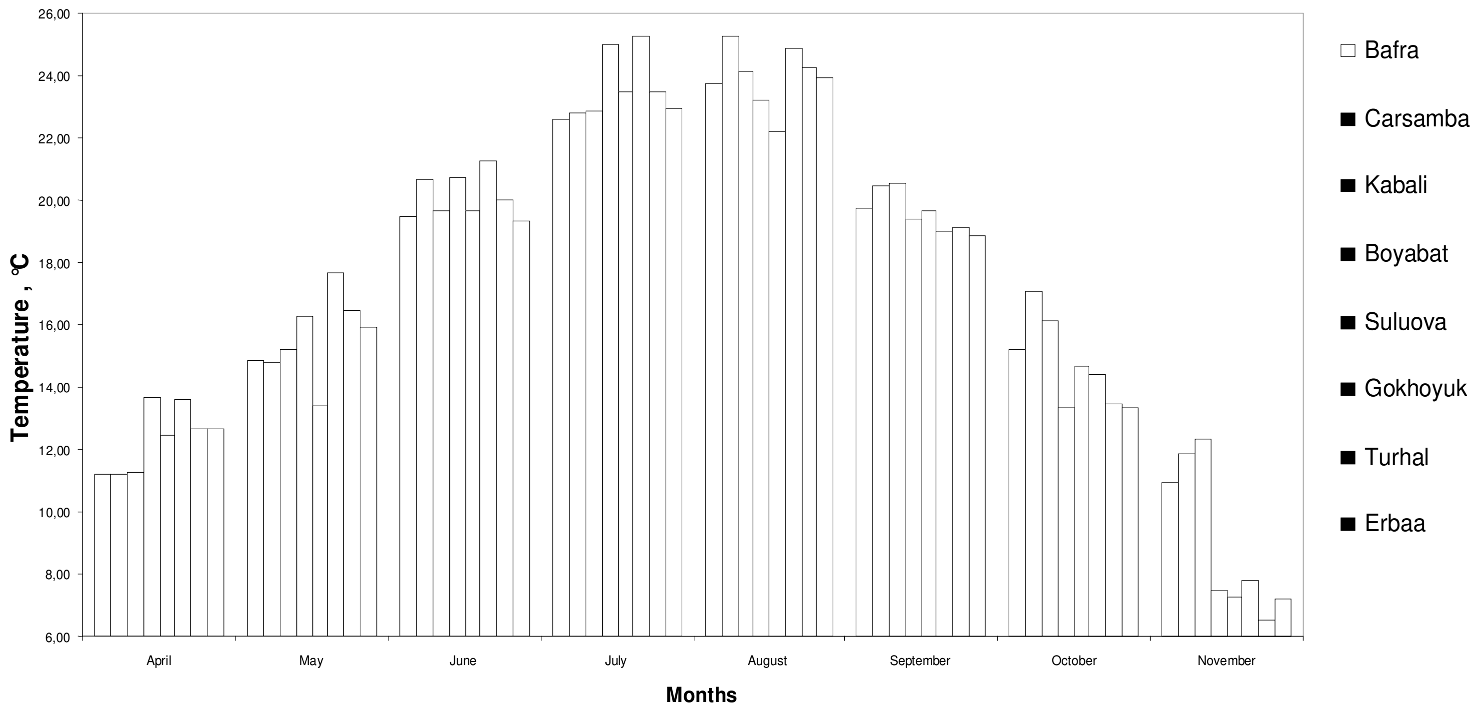

Figure 3. Monthly average temperature during growing season of two study years

Table 1. The effect of genotype × environment interaction on protein content of soybean seeds.

Genotype	Environment								Mean
	Erbaa*	Turhal	Carsamba	Bafra	Gokhoyuk	Suluova	Kabalı	Boyabat	
Savoy	34.07	32.45	36.55	35.28	36.62	32.95	32.61	31.25	33.98 ^{a}
AP2292	32.55	32.09	32.56	34.65	38.57	33.75	31.87	32.87	33.62 ^{b}
Amsoy 71	30.96	29.96	32.57	33.53	34.88	32.57	30.58	29.43	31.81 ^{f}
Apollo	35.20	31.06	35.59	31.56	34.22	30.59	31.09	29.42	32.35 ^{e}
Flint	34.99	29.25	33.20	32.01	34.62	30.74	31.71	32.29	32.35 ^{e}
A3127	37.37	31.72	33.79	33.00	34.19	32.32	31.37	33.50	33.41 ^{c}
SA88	32.96	30.51	36.41	34.03	35.44	32.23	32.47	32.49	33.32 ^{c}
Macon	34.25	30.09	34.98	33.23	33.57	33.27	32.26	31.86	32.94 ^{d}
Mean**	34.04 ^{c}	30.89 ^{g}	34.46 ^{b}	33.41 ^{d}	35.26 ^{a}	32.31 ^{e}	31.74 ^{f}	31.64 ^{f}	

LSD (P<0.01) genotype = 0. 241; environment = 0.241, genotype × environment interaction = 0.679.
* Means of location were average of two years; ** there were no differences at 0.01 probability levels between averages with same superscripts.

Table 2. The effect of genotype × environment interaction on oil content of soybean seeds.

Genotype	Environment								Mean
	Erbaa*	Turhal	Carsamba	Bafra	Gokhoyuk	Suluova	Kabalı	Boyabat	
Savoy	21.77	21.73	20.88	19.50	20.31	21.71	22.53	20.91	21.17 [cd]
AP2292	22.26	21.37	21.11	21.04	18.44	20.89	19.59	19.44	20.52 [f]
Amsoy 71	21.83	20.50	22.50	21.66	21.02	22.48	20.89	22.10	21.62 [ab]
Apollo	19.37	21.30	18.55	22.29	20.99	21.90	21.18	22.26	20.98 [de]
Flint	21.78	22.71	21.94	23.06	21.01	22.62	20.41	20.21	21.72 [ab]
A3127	20.79	18.29	21.94	21.79	20.40	22.05	19.92	21.06	20.73 [ef]
SA88	21.84	22.75	20.80	22.75	20.06	22.80	22.13	21.30	21.80 [a]
Macon	21.47	21.62	20.66	20.57	21.88	21.88	22.21	22.32	21.48 [bc]
Mean**	21.39 [bc]	21.29b [cd]	21.00 [d]	21.58 [b]	20.42 [e]	22.04 [a]	21.11 [cd]	21.20 [cd]	

LSD (*P*<0.01); genotype = 0.325; environment = 0.325; genotype × environment interaction = 0.915.
* Means of location were average of two years; ** there were no differences at 0.01 probability levels between averages with same superscripts.

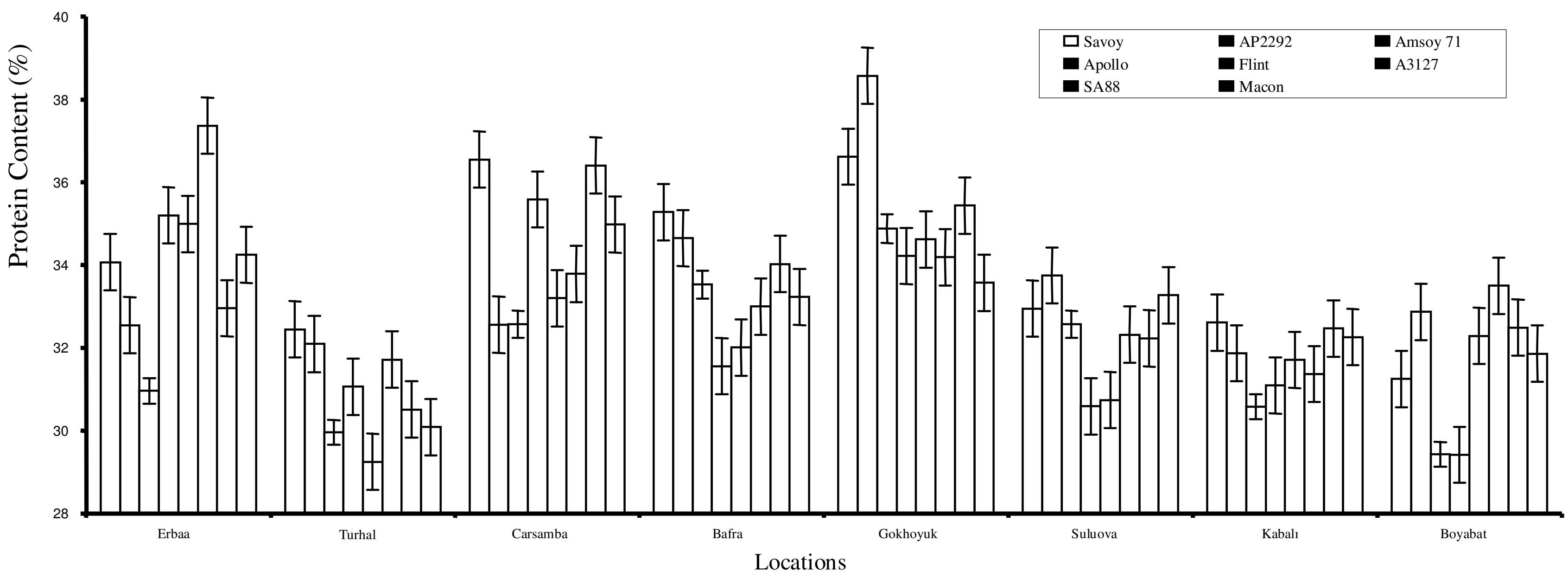

Figure 4. The protein content of soybean genotypes in different environments and standard deviations.

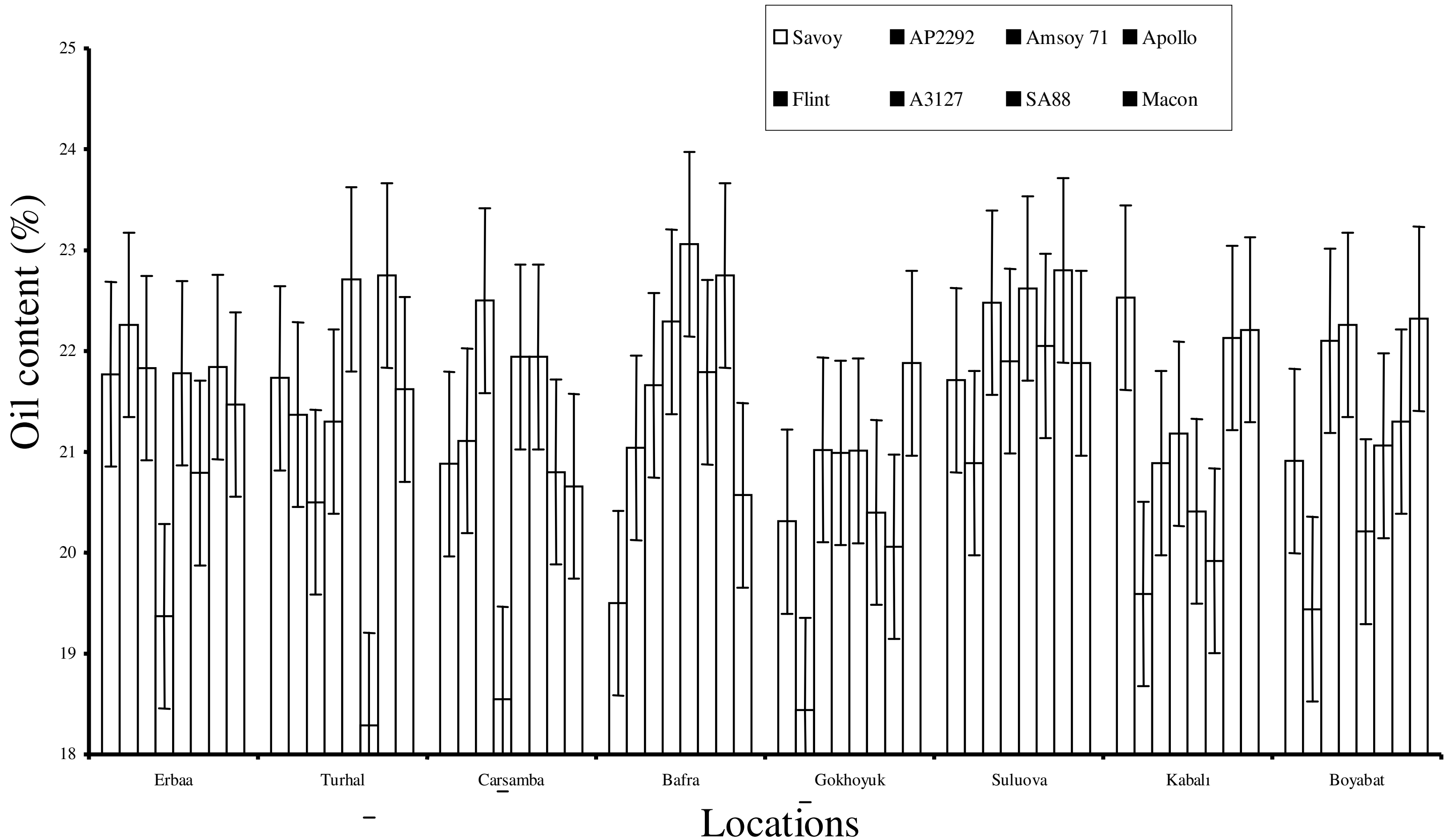

Figure 5. The oil content of genotypes in different environments and standard deviations.

A3127 and Apollo genotypes were placed in statistically same group in Erbaa, oil content varied between 19.37 and 22.26%. The SA88 and Flint genotypes in Turhal and Bafra environments; Amsoy 71, A3127 and Flint genotypes in Carsamba environment; Flint, SA88 and Apollo genotypes in Bafra environment; Amsoy 71, Apollo, Flint and Macon genotypes in Gokhoyuk environment; all genotypes except Ap2292 in Suluova environment; Macon, SA88, and Savoy genotypes in Kabalı environment, and Apollo, Amsoy 71 and Macon genotypes in Boyabat environment which had the highest oil content and were placed in the same statistical group ($p<0.01$).

In terms of genotype and environment interaction, the highest oil content in soybean seeds were determined in the Flint genotype

(23.06%) in the Bafra environment, and the lowest was found in the A3127 genotype (18.29%) in the Turhal environment (Table 2 and Figure 5). Due to the differing performance of genotypes in different environments, the genotype × environment interaction was found to be statistically significant ($p<0.001$).

Kumar et al. (2006) investigated the effect of environment on physical properties and biochemical composition of soybean seeds and statistical significant ($p<0.001$) were found on protein and oil content effect of environment, genotype and genotype × environment interaction. Even within the different environments of one region, there are differences in terms of quality criteria. Oil and protein content of soybean seeds are inversely related (Sogut, 2006; Ray et al., 2006; XiuRong et al., 2006). In this study, as shown Figures 34 and 45, while the protein content of soybean seeds was found to be higher in Gokhoyuk than in other environments, oil content was found to be lower. In this study, generally, protein content increased in environments that produced lower oil content. Correlation analysis showed a very important negative correlation between oil and protein content (r^2 = -0.557**). The results obtained from this study are similar to the findings of previous studies (Miladinovic et al., 2006; Dayong et al., 2004; Ojo et al., 2002; Malik et al., 2006).

The quality of soybean seed varies with environmental conditions encountered during the maturity and seed-filling period, particularly temperature and rain (Fresoli et al., 2004; Fieldsend et al., 2000; Pipolo et al., 2004). In studies conducted with soybean cultivars in different maturity groups in various environments, the seed yield, genotype, environment and genotype × environment interaction was found to be significant. Previous researchers reported that seed yield and protein content were affected more than oil content by environment conditions (Sudaric et al., 2006; Gurdeep-Sing et al., 2001). Several studies reported that environmental conditions had the greatest effect on the oil and protein content of soybean seeds (Ning et al., 2003; Zhang et al., 2005; Fehr et al., 2003).

Conclusion

In this study, conducted for two years within eight different environments with different soil and climate characteristics, the oil content of soybean varied from 18.29 to 23.06% and protein content varied from 29.25 to 38.57%. While Gokhoyuk and Carsamba environments showed superior properties in terms of protein content, Suluova and Bafra environments showed higher oil content. Among the genotypes, Savoy genotype showed good performance in terms of protein content, whereas SA88 and Amsoy 71 genotypes performed well in terms of oil content. It is concluded that for each environment appropriate genotypes should be selected considering the oil and protein content as well as purpose of usage.

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