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Determination of yield and agronomic traits and correlation analysis in F3 soybean crosses

Soya fasulyesi F3 melezlerinde verim ve tarımsal özelliklerin belirlenmesi ve korelasyon analizi

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ABSTRACT

This study was conducted under the ecological conditions of İzmir-Bornova in 2019 to assess certain agronomic traits of F_3 generation soybean hybrids and to find selection criteria for the early generation. The experiment, established using a randomized complete block design with three replications, evaluated 12 soybean hybrids alongside three control cultivars. Observations were made for grain yield, plant height, first pod height, days to flowering, days to maturity, thousand-grain weight, number of pods per plant, and grains per pod. Results showed that the hybrid lines A1337 x A38 (4879.8 kg ha^{-1}) and Tüm 15-2 (4877.7 kg ha^{-1}) had higher yield potential per hectare than the control cultivars and other crosses. The highest first pod height was observed in the A1337 x A38 line (14.89 cm), while the Tüm 15-4 line had the highest thousand-grain weight (198.04 g). The Tüm 15-1 line (119.3 days) stood out for earliness. According to correlation analysis, the number of pods per plant and the number of days to flowering positively affected the grain yield. However, since strong correlations ($r \geq 0.5$) could not be obtained in these hybrid populations, selection criteria could not be determined.

Key Words: Soybean, grain yield, correlation, yield components

ÖZ

Bu çalışma, F_3 generasyonundaki soya melezlerinde verim ve bazı agronomik özelliklerin belirlenmesi ve erken generasyonda bir seleksiyon kriteri belirleyebilmek amacıyla 2019 yılında İzmir-Bornova ekolojik koşullarında yürütülmüştür. Tesadüf blokları deneme desenine göre üç tekrarlamalı olarak kurulan denemede, üç kontrol çeşidi ile birlikte 12 F3 soya melezi araştırmaya konu olmuştur. Tane verimi, bitki boyu, ilk bakla yüksekliği, çiçeklenmeye gün sayısı, olgunlaşma gün sayısı, bin tane ağırlığı, bitki başına bakla sayısı ve bakla başına tane sayıları gözlemlenmiştir. Elde edilen sonuçlar, A1337 x A38 (4879.8 kg ha^{-1}) ve Tüm 15-2 (4877.7 kg ha^{-1}) melez hatlarının, kontrol çeşitlere ve diğer melezlere göre daha yüksek verim potansiyeline sahip olduğunu göstermiştir. En yüksek ilk bakla yüksekliği A1337 x A38 hattında (14.9 cm) gözlenirken, bin tane ağırlığı ise Tüm 15-4 hattında (198.0 g) en yüksek olmuştur. Erkencilik bakımından Tüm 15-1 hattı (119.3 gün) ön plana çıkmıştır. Korelasyon analizine göre bitki başına bakla sayısı ve çiçeklenme gün sayısı tane verimini pozitif etkilemiştir. Ancak bu melez populasyonlarda güçlü korelasyonlar ($r \geq 0.5$) elde edilemediği için seleksiyon kriteri belirlenememiştir.

Anahtar Kelimeler: Soya, tane verimi, korelasyon, verim komponentleri

Introduction

Soybean (*Glycine max* L.) is a self-pollinating, annual legume adapted to short-day conditions, with a robust taproot system complemented by strong lateral roots. It features an upright, hardy, hairy stem, trifoliate compound leaves, and spherical seeds with a distinctive black hilum. Originating approximately 5.000 years ago in the plains of China and Manchuria, soybeans have played a significant role in the dietary practices of Asian societies. In the 1690s, after residing in Japan for two years, German botanist Engelbert Kaempfer was the first to introduce soy to Europe. By 1740, soybean seeds were being cultivated in the Paris botanical garden. Soybean was introduced to Türkiye in the 1930s and was initially grown exclusively in the Black Sea region. However, with the implementation of the Second Crop Project in the 1980s, its cultivation spread to the Aegean and Mediterranean regions.

Soybean seeds are reported to contain high levels of protein (36-45%), fat (18-24%), carbohydrate (26%), and minerals (18%) (Yildirim et al., 2023). Soybean oil is also rich in vitamins A, B1, B2, C, D, E, and K and minerals such as Ca, Fe, and Zn (Arioglu, 2007). Lecithin, abundantly found in soybean oil, is key in balancing HDL (good cholesterol) and LDL (bad cholesterol) levels in the blood. Thanks to its high unsaturated fat content, soybean oil is widely used to produce mayonnaise, salad oil, sauces, and hydrogenated margarine (Weiss, 2000; Ray et al., 2008). Regarding production volume, cultivation area, and global trade, soybean ranks among the most important oilseed crops worldwide. It represents over 50% of total oilseed crops and is a critical source of protein and oil for human consumption. Additionally, soybean meal is an essential feed ingredient for poultry, livestock, and dairy animals due to its high crude protein content. In Türkiye, soybeans can be cultivated as a primary and secondary crop. Approximately 80% of the total soybean production area is concentrated in Adana, Osmaniye, and Mersin (Anonymous, 2019). Türkiye imports 93% of its soybean supply, spending around 1.4 billion dollars annually on 2.5 million tons of imported soybeans. Domestic production should be economically incentivized to decrease this dependency, and a wider range of soybean varieties should be made available to farmers.

The primary goal in soybean breeding is to increase grain yield per unit area and develop highly adaptable varieties. In long-term breeding studies, it is essential to identify selection criteria that can reduce the breeder's workload. Predicting a difficult-to-measure trait or a post-harvest trait through another trait that is closely correlated and easier to observe can significantly streamline the breeding process. For this reason, understanding the relationships between yield and other characteristics and establishing selection criteria is crucial. A study by Micke (1979) found that identifying the components that either enhance or limit yield and then applying selection to introduce variation in these areas can guide breeders toward successful outcomes in improving yield and other quantitative characteristics.

This study aimed to evaluate the grain yield and adaptability of F_3 soybean crosses and the correlations among agronomic traits to establish selection criteria for early-generation selection.

Material and Methods

Study Area

The study materials consisted of 12 F3 soybean crosses derived by the pedigree method from an F2 segregating population developed by the Batı Akdeniz Agricultural Research Institute (Tüm 15-1, Tüm 15-2, Tüm 15-3, Tüm 15-4, Tüm 15-5, Tüm 15-6 and Tüm 15-7) and the Field Crops Department of Bursa Uludağ University Faculty of Agriculture (A27 x Yeşilsoy, A1224 x A38, A27 x A38, A1224 x Loredo, A1337 x A38) along with three control varieties (Arısoy, ATAEM5, Yeşilsoy). The F3 lines, their parent lines, and control varieties are shown in Table 1.

Table 1. The F_3 lines with their parents and control varieties

Genotypes (F3)	Parents	Control varieties
Tüm 15-1	Arısoy-ATAEM11	Arısoy
Tüm 15-2	ATAEM20-ETAE8	ATAEM5
Tüm 15-3	Dare-Bonus	Yeşilsoy
Tüm 15-4	AP200-Clark63	
Tüm 15-5	ATAEM7-S4240	
Tüm 15-6	SGI3129-Crawford	
Tüm 15-7	ATAEM5-JMS2382	
A27 x Yeşilsoy	A27-Yeşilsoy	
A1224 x A38	A1224 – A38	
A27 x A38	A27 – A38	
A1224 x Loredo	A1224 – Loredo	
A1337 x A38	A1337 – A38	

The experiment was conducted in the trial fields of Ege University, an area characterized by a Mediterranean coastal climate. Soil samples from the experimental site were collected and analyzed at Ege University (Yildirim et al., 2023). Table 2 provides the properties of the soil in the study area. The trial plots featured clay-loam soil, comprising 30.0% clay, 38.2% silt, and 32.8% sand (0–40 cm depth). The soil was medium-textured, slightly alkaline, low in organic matter, high in total nitrogen content, and had a calcareous structure.

Table 2. Physical and chemical characteristics of soil at the experimental area

		Depth of the soil (cm)	
Parameters	Unit	0–20	20–40
Texture		Clayey-loam	Clayey-loam
Sand	%	35.05	35.05
Silt	%	32.22	32.22
Clay	%	33.00	33.00
pH		8.11	7.22
Organic matter	%	1.43	1.96
$CaCO_3$	%	21.02	21.94
Total N	mg kg^{-1}	0.068	0.095

The trial area is situated at an altitude of 29 meters and features clayey soil that is low in organic matter and has an alkaline reaction (pH 7.4). Table 3 presents the climate data for the past 20 years and the 2019 growing season. The average temperature during the vegetation period in Izmir over many years is 25.9 °C. A comparison of the monthly temperature averages for the research year with long-term averages indicates a 0.3 °C increase in 2019 relative to the 20-year average. However, during the flowering period (June and July), the temperature averages were lower than the long-term average.

Table 3. The climatic data during the growing period in the experimental area (Anonymous, 2020)

	Average Temp. (°C).		Total precipitation (mm)	
Months	2019	Long term	2019	Long term
May	21.4	22.0	28.6	31.4
June	23.9	26.0	2.9	14.4
July	26.8	28.6	0.3	3.0
August	29.7	28.5	0.0	6.7
September	29.5	24.2	31.7	23.5
Mean-Total	26.2	25.9	63.5	79.0

The field experiment was arranged in a randomized complete block design with three replications. The plots were 2 meters long, and each genotype was manually sown on May 15, 2019, as the main crop, in 2 rows with a row spacing of 70 cm, accommodating 45 plants per m². Irrigation was carried out four times using a sprinkler irrigation system. Diammonium phosphate fertilizer was applied to the trial area at 180 kg per hectare after planting. Agronomic observations were conducted on ten plants per plot, and the harvest occurred on September 15, 2019. After harvest, soybean plants were threshed using threshing machinery to separate the grain. Data were recorded for plant height (cm), first pod height (cm), days to maturity, days to flowering, thousand-grain weight, number of pods per plant, number of grains per pod, and grain yield. Variance analysis for the collected data was performed using the TOTEMSTAT statistical package (Acikgoz et al., 2004). Differences between genotype means were assessed using the LSD test (Steel and Torrie, 1980). Correlation analysis, suggested by Dewey and Lu (1959), was applied to evaluate the relationships among agronomic traits.

Results and Discussion

Descriptive Statistics of Soil Properties

The bulk density ranged between 1.16 and 1.74 g cm^{-3}, with a mean value of 1.45 g cm^{-3} (Table 1). Bulk density can significantly vary depending on soil organic matter content, texture, aggregation, and pore structure of soils (Chaudhari et al., 2013). Although the coefficient of variability (CV) value of 8.35% indicates a relatively narrow range of variation, the minimum and maximum bulk density values suggest significant differences in soil compaction. Bulk density was low enough to pose no risk in some areas, while it was high enough to potentially hinder root development and plant growth in other areas. The variability in bulk density within the study area can be attributed to soil texture, organic matter content, and stoniness. Additionally, differences in soil management practices play a significant role; while some orchards undergo soil tillage at least six to eight times per year, others experience little to no tillage, contributing to the observed variations. Clay content varies between 10% and 62.5% and sand content ranges from 17.1% to 75%. The high variability in clay (CV = 26.2%) and sand content (CV = 38%) (Budak et al., 2025) is a key factor contributing to the variation in bulk density.

The frequency of soil tillage operations, coupled with the diversity of implements used (such as plows, cultivators, and disc harrows), plays a crucial role in modulating soil bulk density. In this context, Fallahzade et al. (2020) demonstrated that traditional tillage methods markedly reduce surface soil bulk density in pistachio orchards in Iran. Complementing these findings, Salem et al. (2015) observed that conventional tillage practices lead to a significantly greater decline in bulk density compared to more conservative approaches, such as reduced or no-till systems. Moreover, Topa et al. (2021) revealed that the long-term impacts of tillage are depth-dependent; while the surface layer (0-10 cm) experiences a reduction in bulk density, deeper soil layers exhibit a significant increase.

The skewness and kurtosis values provide insight into the distributional characteristics of the soil parameters measured. For SOC and SOCS, the skewness values of 0.73 and 0.77, respectively, indicate a moderate positive skew. This suggests that both datasets have a slight asymmetry, with a tendency for a longer right tail, which may reflect the presence of higher value outliers or a clustering of lower values. In addition, the kurtosis values for SOC (1.07) and SOCS (1.05) imply that these distributions are moderately leptokurtic, meaning they are somewhat more peaked with heavier tails than a normal distribution. This characteristic can have implications for statistical analyses, as it suggests a higher probability of extreme values compared to a mesokurtic (normal) distribution (Hayes et al., 2022). In contrast, skewness (0.22) and kurtosis (-0.03) of BD indicate a distribution that is nearly symmetrical and close to normal in terms of tail weight and peakedness.

Table 4. Results of variance analysis (mean squares) of yield and some agricultural characteristics of 12 soybean crosses in F_3 generation and three registered soybean varieties

Source	DF	PH	FPH	NDF	NDM	NPP	NGP	TGW	GY
Block	2	217.9	0.4	5.4	1.9	317.9	0.2*	34.2	1509.1
Genotypes	14	647.1 **	33.4**	72.5**	217.4**	7023.7**	0.1*	1218.3**	21604.9**
Error	28	131.9	1.8	1.6	8.2	200.4	0.04	39.2	1005.9

*, **: Significant at probability levels of 0.05 and 0.01, respectively

PH: plant height, FPH: first pod height, NDF: number of days to flowering, NDM: number of days to maturity, NPP: number of pods per plant, NGP: number of grains per pod, TGW: thousand-grain weight, GY: grain yield.

According to the LSD grouping shown in Table 5, the highest plant height was recorded for the A1224 x A38 line (107.17 cm), followed by the A1337 x A38 line (99.83 cm). The control variety Arısoy (81.00 cm) also performed better than other crosses and control varieties. The lowest plant height was observed in the A1224 x Loredo cross (55.48 cm). The soybean crosses generally exhibited higher plant height performance than the three control varieties. Notably, two crosses involving the A38 parent had the highest plant height values, with one exceeding the general average by 34 cm and 26 cm taller than the tallest control variety. Among the control varieties, Arısoy showed the highest plant height (81.00 cm). The results align with those reported in previous studies (Homer et al., 2000; Karasu et al., 2002; Arslanoglu et al., 2005; Acar, 2014; Demir, 2016; Kireker, 2018), though they differ from findings in other studies (Cinsoy et al., 2005; Karaaslan, 2011; Ay, 2012).

Notably, 90% of the total variation in first pod height in the study was attributable to differences between genotypes (Table 4), indicating significant variability among genotypes for this trait. First-pod height is significant for mechanical harvesting suitability. In this study, the highest first pod height was recorded in the A1337 x A38 cross (14.89 cm), followed by A1224 x A38 (13.90 cm) and Tüm-15-1 (12.74 cm) F_3 crosses. These three genotypes had the highest first pod height values among the control varieties and other crosses (Table 5). Consistent with the plant height results, two of the crosses involving the A38 parent (A1337 x A38 and A1224 x A38) were found to have the highest first pod height values, with one measuring 5 cm above the general average and 2 cm taller than the tallest control variety. Among the three control varieties, Arısoyexhibited the highest first pod height (12.37 cm). The findings align with previous studies (Unal and Onder, 2008; Mert and Ilker, 2016; Yildirim and Ilker, 2018), while other researchers have reported lower first pod height values (Gulluoglu et al., 2016; Kireker, 2018; Kocatürk, 2019).

Table 5. LSD grouping and mean values of yield and agronomic characteristics of control varieties and 12 soybean crosses in the F_3 generation

Crosses and Check varieties	PH (cm)	FPH (cm)	NDF (day)	NDM (day)	NPP	NGP	TGW (g)	GY kg ha^{-1}
A27 x Yeşilsoy	59.30 de	5.55 ef	44.33 ab	140 c	137.00 cd	2.39 abc	136.93 ef	3627.0 d
A1224 x A38	**107.17 a**	13.90 ab	44.00 ab	143.33 c	167.79 ab	2.31 a-d	142.00 e	3854.8 cd
A1337 x A38	99.83 ab	**14.89 a**	44.33 ab	141.67 c	153.59 bc	2.07 b-e	146.80 de	**4879.8 a**
A1224 x Loredo	55.48 e	6.46 e	42.67 b	141 c	174.78 ab	2.40 ab	161.67 c	4365.0 abc
A38 x A27	76.94 cd	6.45 ef	44.33 ab	142.33 c	**184.08 a**	2.42 a	161.40 c	4590.0 ab
Tüm 15-1	58.58 de	12.74 abc	**33.33 ef**	**119.33 a**	82.85 e	2.04 de	131.27 fg	2578.5 ef
Tüm 15-2	66.28 cde	7.60 e	34.00 def	**121 a**	128.62 d	**2.44 a**	162.27 c	**4877.7 a**
Tüm 15-3	62.67 cde	11.00 cd	35.33 cde	124.67 b	124.47 d	2.05 cde	130.87 fg	4418.8 ab
Tüm 15-4	71.77 cde	6.67 e	35.33 cde	132 b	72.55 ef	2.12 a-e	**198.07 a**	2162.5 f
Tüm 15-5	61.88 cde	4.20 f	**33.00 f**	**122.33 a**	77.83 ef	2.26 a-e	125.47 g	2852.7 e
Tüm 15-6	70.93 cde	11.15 cd	34.00 def	128 b	77.47 ef	1.93 e	140.47 ef	3852.9 cd
Tüm 15-7	80.02 c	11.60 cd	34.00 def	128.33 b	42.41 g	2.07 b-e	173.53 b	4628.1 ab
Arısoy	81.00 bc	12.37 bcd	37.00 c	130 b	55.97 fg	2.06 b-e	124.27 g	3655.2 d
ATAEM 5	68.70 cde	10.13 d	36.00 cd	131 b	40.57 g	1.94 e	156.87 cd	4686.6 ab
Yesilsoy	71.67 cde	11.97 bcd	45.00 a	143 c	116.33 d	2.15 a-e	156.40 cd	4201.6 bc
Means	72.81	9.78	38.44	132.53	109.09	2.18	149.88	3948.7
LSD (5%)	19.21	2.25	2.14	4.78	23.67	0.34	10.47	53.04

PH: plant height, FPH: first pod height, NDF: number of days to flowering, NDM: number of days to maturity, NPP: number of pods per plant, NGP: number of grains per pod, TGW: thousand-grain weight, GY: grain yield.

The lowest number of days to flowering was recorded in the variety Tüm 15-5 (33 days). Among the F_3 crosses involving the Batı Akdeniz Agricultural Research Institute (Tüm 15-1, Tüm 15-2, Tüm 15-3, Tüm 15-4, Tüm 15-5, Tüm 15-6, and Tüm 15-7 were earlier genotypes than Bursa-derived genotypes in terms of flowering duration. Overall, it was observed that the F_3 soybean lines exhibited more extended flowering periods compared to the control varieties. The flowering days in the experiment varied from 33 to 45 days. These findings are consistent with results from previous research (Unal, 2007; Tugay and Atikyilmaz, 2009; Acar, 2014; Caliskan and Aytekin, 2017; Kocatürk, 2019). It was determined that the genotypes crossbred according to Bursa ecological conditions flowered later. It is estimated that higher yields could be achieved by planting these genotypes as the main crop under Mediterranean climate conditions. There were statistically significant differences between genotypes regarding the number of days to maturity (Table 4). According to the LSD results, the earliest maturing genotypes were the Tüm 15-1, Tüm-15-2, and Tüm 15-5 cross combinations, maturing 8 to 12 days earlier than the control varieties (Table 5). It was noted that the number of days to maturity and the number of days to flowering increased in combinations involving the A38 parent. In this experiment, the average number of days to maturity ranged from 119.33 to 143.33 days. These findings align with previous studies (Acar, 2014) but differ from research conducted in the Çukurova Region and the provinces of Bursa and Niğde (Demir, 2016; Caliskan and Aytekin, 2017; Altinyuzuk, 2017).

The experiment observed a significant variation among genotypes for thousand-grain weight (TGW) values, with statistically significant differences at the 99% probability level (Table 4). The highest TGW value (198.07 g) was recorded in the Tüm 15-4 soybean cross, followed by Tüm 15-7 (173.53 g). The next best group included Tüm 15-2 (162.27 g), A1224 x Loredo (161.67 g), and A38 x A27 (161.40 g). The TGW performance of the three soybean varieties registered in Türkiye was notably low, with the Arısoy variety having the lowest TGW value among all genotypes. This study's findings align with previous research results (Unal and Onder, 2008; Cetin and Oztürk, 2012; Yildirim, 2018; Kocatürk, 2019).

An examination of Table 4 confirms a significant variation (p = 0.99) among soybean genotypes for the number of pods per plant. According to the LSD test results comparing mean values, the highest number of pods per plant (184.08) was observed in the A38 x A27 cross (Table 5). The F3 genotype A1337 x A38, which included the A38 parent as the paternal contributor and the A1224 x Loredocross, had the second-highest pod counts among all genotypes. Overall, the average number of pods in control varieties was lower than that of the crosses. Arslanoglu et al. (2005) reported in their study conducted under second-crop conditions in Samsun and Sinop provinces that the number of pods per plant ranged from 87.03 to 156.47 units. Similarly, Dede and Acar (2019) investigated the effects of various doses of soil (0, 10, 20, 40 kg ha^{-1}) and foliar (0, 4, 8 kg ha^{-1}) zinc applications on soybean yield components under the ecological conditions of Ordu province in 2016, finding that the number of pods per plant ranged from 62.03 to 118.40 units.

The trial revealed significant variation in the number of grains per pod among the genotypes. An LSD test was conducted to compare mean values. The highest number of grains per pod was recorded in the Tüm 15-2 (2.44) and A38 x A27 (2.42) F_3 soybean crosses. The other genotypes in group ab included A1224 x Loredo (2.40) and A27 x Yesilsoy (2.39). The lowest number of grains per pod was observed in the Tüm 15-6 (1.93) soybean cross and the ATAEM 5 (1.94) control variety. Among the control varieties, Yesilsoy had the highest number of grains per pod (2.15). A comparison between the F_3 crosses and control varieties indicated that the differences in the number of grains per pod were generally small, with relatively close values. These results align with previous studies (Karasu et al., 2002; Acar, 2015; Ilker, 2017; Sevilmis and Arioglu, 2019) but differ from findings in research conducted in the Eastern Anatolia Region (Bakoglu and Aycicek, 2005). This variation could be attributed to differences in the genotypes of the soybean varieties and lines used in the experiment and the influence of different climatic conditions on grain formation.

In this study, which utilized 12 soybean F_3 crosses and three control varieties, statistically significant differences were found among the genotypes regarding grain yield (Table 4). Genotype differences accounted for 90% of the total variation in grain yield, indicating substantial variability among F_3 crosses and genotypes. According to the LSD grouping presented in Table 5, the highest grain yields were observed in the A1337 x A38 (4880 kg ha^{-1}) and Tüm 15-2 (4878 kg ha^{-1}) F3 crosses. These were followed by ATAEM 5 (4687 kg ha^{-1}), Tüm 15-7 (4628 kg ha^{-1}), A38 x A27 (4590 kg ha^{-1}), and Tüm 15-3 (4419 kg ha^{-1}). The Tüm 15-4 (2162 kg ha^{-1}) cross recorded the lowest grain yield. Among the control varieties, ATAEM 5 had the highest yield (4687 kg ha^{-1}). The analysis revealed that the top-yielding F3 crosses exceeded the yield of the highest-performing control variety by 19 kg ha^{-1}, and the general average was 93 kg ha^{-1} higher. Grain yield in the trial ranged from 2162 kg ha^{-1} to 4880 kg ha^{-1}. The results align with previous studies (Homer et al., 2000; Arslan and Arıoğlu, 2003; Ünal and Önder, 2008; Tuğay and Atikyılmaz, 2009; Mert and Ilker, 2016; Senyiğit et al., 2015; Bakal et al., 2016; Onat et al., 2017). However, the findings differ from those of other researchers (Tayyar and Gül, 2007; Karaaslan, 2011). Homer et al. (2000), in their study to identify suitable soybean varieties for the transition and coastal regions of the Black Sea under main crop conditions, reported grain yields ranging from 1197 kg ha^{-1} to 4933 kg ha^{-1} Arslan and Arioglu (2003), in their study conducted in 2000 and 2001 with 13 different soybean varieties under the conditions of Hatay's Amik plain, reported grain yields ranging from 2735 kg ha^{-1} to 4653 kg ha^{-1} and from 1621 kg ha^{-1} to 2905 kg ha^{-1}, respectively, depending on the year. Tugay and Atikyılmaz (2009), who studied 12 soybean lines and four standard varieties over 2 years (2006-2007) in Menemen and Beydere, stated that grain yield in Beydere in 2006 ranged between 3470 kg ha^{-1} and 4790 kg ha^{-1}. Mert and Ilker (2016) conducted a study in Aksaray province, characterized by a typical steppe climate with hot, dry summers and cold, dry winters. They found grain yields varied between 2811 kg ha^{-1} and 4984 kg ha^{-1} when evaluating yield and agronomic traits of soybean varieties under main crop conditions. Bakal et al. (2016), in their 2013 and 2014 studies in the Çukurova Region under second crop conditions using 14 soybean lines, reported grain yields between 3050-4724 kg ha^{-1} and 3338-4695 kg ha^{-1}, respectively. Onat et al. (2017) found seed yields ranging from 4340-5120 kg ha^{-1} and 2930-4200 kg ha^{-1} in their 2015 and 2016 study assessing the impact of high temperatures on yield parameters of soybean varieties in the Mediterranean Region under second crop conditions. Although our study's findings are consistent, variations in cultural practices, environmental conditions, genotypic differences, and planting times have led some researchers to report higher or lower yield values compared to this study.

Correlation analysis was conducted on the data for the eight traits examined in the experiment. The results, including the correlation coefficients and significance levels for traits that showed relationships with each other, are presented in Table 6.

Table 6. Correlation coefficients and significance levels were determined between the traits

Trait	GY	TGW	PH	FPH	NPP	NGP	NDF
TGW	0.041	1					
PH	0.204	0.037	1				
FPH	0.204	-0.181	0.505 **	1			
NPP	0.321 *	-0.005	0.163	-0.104	1		
NGP	0.122	0.102	0.139	-0.345 *	0.474 **	1	
NDF	0.295 *	0.045	0.293 *	0.082	0.712 **	0.296	1
NDM	0.273	0.196	0.322 *	0.092	0.585 **	0.188	0.917 **

*, **: Significant at probability levels of 0.05 and 0.01, respectively
PH: plant height, FPH: first pod height, NDF: number of days to flowering, NDM: number of days to maturity, NPP: number of pods per plant, NGP: number of grains per pod, TGW: thousand-grain weight, GY: grain yield.

A significant positive relationship was found between grain yield and both the number of pods per plant (0.321*) and the number of days to flowering (0.295*). Additionally, there was a significant positive correlation between plant height and first pod height (0.505**), number of days to flowering (0.293*), and number of days to maturity (0.322*). A significant negative correlation was observed between first pod height and the number of grains per pod (-0.345*). Furthermore, a significant positive correlation was identified between the number of pods per plant and the number of grains per plant (0.474**), the number of days to maturity (0.585**) and a significant positive correlation (0.917**) was found between the number of days to flowering and the number of days to maturity. Similar findings have also been reported in previous studies on soybean (Malik et al. 2007; Li et al. 2013; Akram et al. 2016; Mochado et al. 2017). Akram et al. 2016 reported that soybean yield/plant was positively and significantly correlated with the yield/plant number of branches/plant, pod length, number of pods/plant, number of seeds/plant, and 100-seed weight.

Conclusion

As a result of this research conducted in Izmir province, located in the Coastal Mediterranean Climate Zone, involving 12 F_3 generation soybean lines and three control varieties, it was found that the F_3 crosses A1337 x A38 (4880 kg ha^{-1}) and Tüm 15-2 (4878 kg ha^{-1}) showed promising potential for grain yield. These two F_3 crosses demonstrated superior yield performance compared to the control varieties in early-generation tests. Among the control varieties, ATAEM 5 had the highest grain yield (4687 kg ha^{-1}). This variety, along with the F_3 crosses Tüm 15-7 (4628 kg ha^{-1}), A38 x A27 (4590 kg ha^{-1}), and Tüm 15-3 (4419 kg ha^{-1}), exhibited statistically similar yield performance.

Correlation analysis results indicated that the agronomic traits with a positive and significant relationship with grain yield were the number of pods per plant and the number of days to flowering. Our findings demonstrated that an increase in the number of pods per plant and the number of days to flowering positively affects grain yield. However, as values greater than r = 0.5 are required to establish an alternative selection criterion to grain yield in soybean breeding, whether these traits can serve as reliable selection criteria has not been definitively determined.

Conflict of Interest

We declare that there is no conflict of interest between us as authors of this article.

Author Contributions:

All three authors contributed to the conduct of the experiment and the findings. The first author was involved in setting up the experiment, growing the plants, and making observations and measurements. The second author contributed to the planning and execution of the experiment and statistical analysis of the data. The third author contributed to the planning of the experiment, data collection, and literature review.

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