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Determination of the Agricultural Performance of Soybean (*Glycine max* L. Merr.) Genotypes Under the Ecological Conditions of Konya in Türkiye[(§)]

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ABSTRACT

Soybean (*Glycine max* L. Merr.) is an important legume-oilseed crop cultivated worldwide for its higher protein and quality vegetable fat content. In Türkiye, a significant portion of the demand for soybeans is met through imports. This situation necessitates the identification of high-performance genotypes adapted to ecological conditions of Türkiye. This study was carried out to identify soybean genotypes that can be grown under the ecological conditions of Konya, which has high agricultural production potential. Eight soybean varieties (Nova, Defiance, NE 3399, A 3935, ATAEM 7, Çetinbey, Atakişi and Arısoy) and four breeding lines (BDS 07, BDS 11, BDS 21 and BDS 25) were evaluated in a randomized block design with three replications in field trials under irrigated conditions during the 2021 and 2022 growing seasons. Observations were recorded for grain yield, thousand-grain weight, seed oil, ash and protein content, plant height, number of branches and pods per plant, and first pod height. Analysis of variance results showed statistically significant differences between genotypes for most of the examined characteristics ($p < 0.01$). The highest grain yield was produced by BDS 25 (5,881 kg ha^{-1}) followed by BDS 11 (5,859 kg ha^{-1}) while Defiance variety (4,077 kg ha^{-1}) produced the lowest grain yield. The Atakişi variety had the highest protein content (37.48%) followed by Çetinbey (37.34%), while the highest oil content was found in the BDS 21 line (18.6%) closely followed by the Atakişi and NE 3399 varieties (18.4%). The findings indicate that these genotypes (BDS 25, BDS 11, Atakişi and BDS 21) are promising for soybean cultivation under Konya's ecological conditions and could contribute to increasing domestic soybean production in Türkiye.

Keywords: Soybean, genotypes, adaptation, yield, agronomic traits

Introduction

Soybean (*Glycine max* L. Merr.) is one of the most important legume-oilseed crops cultivated worldwide due to its high protein (35-42%) and oil (18-22%) content (Arıoğlu, 2014). As a major source of plant-based protein and oil, soybean is widely used both as a direct food ingredient in human nutrition and as a high-quality protein feed in animal nutrition. In addition, utilization of soybean in the vegetable oil industry, food products, biodiesel production, and various industrial applications makes it a versatile and high value-added agricultural commodity worldwide (Hartman et al., 2011; Pagano and Miransari, 2016; Wilcox, 2004). Furthermore, the symbiotic nitrogen-fixing capacity of soybean contributes significantly to soil fertility, enhancing sustainability in crop rotation systems (Leggett et al., 2017; Salvagiotti et al., 2008).

The global demand for soybean is increasing markedly due to population growth, rising consumption of animal protein, and the expanding use of vegetable oils. In the year 2023/2024 production season, total soybean production of about 397 million tons was obtained from cultivated area of about 139 million hectares (FAO, 2025; USDA, 2026) making soybean as the world's top oilseed

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crop in terms of both cultivated area and production volume. The global demand of soybean is increasing due to growing demand from the feed industry, as well as from food, biofuel, and industrial sectors (USDA, 2026).

Brazil, United States and Argentina are the leading producer and exporters of soybean contributing approximately 80% of global production (USDA, 2026). China is the world's largest soybean importer and plays a decisive role in global trade flows (Gale et al., 2019; Peng et al., 2026; OECD-FAO, 2023).

As of 2020, national soybean production was approximately 150–160 thousand tons, which is far from meeting the domestic demand. In Türkiye, domestic demand for soybean is more than 3 million tons against the production of only about 150-160 thousand tons (Başalma et al., 2025; TÜİK, 2025). The demand in the country is increasing due to rising demand for plant-based protein and the expansion of the feed industry. This gap is currently being filled through imports of soybean and soybean products.

Soybean production in Türkiye is mainly concentrated in the Çukurova Region, with limited area in the Mediterranean and Black Sea regions. The crop faces stiff competition with maize, cotton and sunflower (Arıoğlu, 2014; Arıoğlu et al., 2016). This situation necessitates the expansion of soybean cultivation into new ecological zones and the identification of high-yielding genotypes well adapted to regional conditions.

The Central Anatolia Region, and particularly the Konya Plain, is considered a potential production basin for soybean cultivation due to availability of agricultural land, irrigation opportunities, and suitability for crop rotation systems. Nevertheless, the semi-arid climate conditions characterized by high summer temperatures and low precipitation may pose limitations for soybean cultivation in Konya Province. Factors associated with climate change such as rising temperatures, irregular precipitation patterns, and water scarcity have intensified genotype X environment interactions in soybean production (Ray et al., 2015). In this context, evaluating genotype performance across different ecologies is of critical importance for the development of sustainable production strategies. These environmental conditions have a significant influence on key agronomic traits such as grain yield, protein content and oil concentration (Acikgoz et al., 2009; Yan et al., 2000).

Numerous studies have demonstrated significant differences among genotypes for yield, yield components, and quality traits under diverse ecological conditions as well as the decisive role of genotype X environment interactions (Gauch, 2013; Yan and Kang, 2002). Research conducted in Türkiye has similarly reported differences in yield and quality characteristics of soybean genotypes under varied environmental conditions across regions (Bakkal et al., 2017; Kocatürk et al., 2019). Sowing time and row spacing, together with genetic potential have been reported to significantly affect yield components (Yılmaz et al., 2022; Barış et al., 2020). However, comprehensive evaluations of genotype performance under continental and semi-arid ecologies such as Konya remain limited. Therefore, identifying genotypes with high yield and quality traits that are well adapted to the Konya ecology will be of great importance for developing alternative cropping patterns in the region.

The findings are expected to contribute scientifically to the development of suitable cultivar recommendations for regional producers and to strategies aimed at reducing the national deficit in oilseed production.

Materials and Methods

Plant Material

Twelve soybean (*Glycine max* (L.) Merr.) genotypes evaluated in the study comprised eight registered cultivars (Defiance, Nova, ATAEM 7, NE 3399, Arısoy, A 3935, Atakişi, and Çetinbey) and four advanced Bahri Dağdaş breeding lines (BDS 11, BDS 07, BDS 25, and BDS 21).

Experimental Site and Soil Characteristics

Field experiments were conducted over two consecutive growing seasons (2021-2022) at the Selçuk University Sarayönü Vocational School, Sarayönü District of Konya Province, Türkiye. The experimental site is situated at 38.264° N latitude, 32.406° E longitude and an altitude of 1055 m above sea level.

The soil of the experimental field (30 cm depth) was clay loam in texture, slightly alkaline in reaction (pH 8.12), with a medium level of organic matter content (2.33%) and a high $CaCO_3$ (22.07) concentration (Table 1).

Climatic Conditions

Average daily maximum temperatures in both years were approximately 34-36°C during July and August.

Summer temperatures in 2021 (35,7-35,8°C) were higher as compared with 2022 (34,1-34,4°C).

Precipitation during summer months was lower and in June was relatively higher than long term average in both years. Total rainfall received during the crop season in both years was below long-term averages, and rainfall was unevenly distributed across months.

Cultural Practices

The experiment was conducted in a randomized complete block design (RCBD) with three replications. Each plot consisted of five rows, each 5 m in length, with a row spacing of 40 cm and an intra-row spacing of 5 cm (gross plot size 10 m^2). Sowing was performed manually.

At sowing, diammonium phosphate fertilizer (DAP, 18-46%) was applied at a rate of 150 kg ha^{-1}. Sowing was carried out on 18 May 2021 and 13 May 2022. Prior to sowing, seeds were inoculated with *Bradyrhizobium japonicum*.

Crop was harvested on 26 October 2021 and 1 November 2022. Irrigation was applied using a drip irrigation system in six applications, each lasting five hours. Weed control was performed mechanically. To avoid border effects, the first and last rows of each plot were excluded from measurements and observations. After excluding two rows from each border of the experimental plots and 50 cm from both ends of the plot lengths, the remaining net plot size evaluated was 4,8 m^2. Measurements and evaluations were performed on 10 randomly selected plants from this net plot area. Agronomic traits such as grain yield, plant height, first pod height, and number of pods per plant were determined according to the methodology of the International Soybean Program (INTSOY) (Bek and Arıoğlu, 2005). Statistical analyses were conducted using JMP software (Altınyüzük and Öztürk, 2017).

Results and Discussion

Plant Height

The results indicated statistically significant differences among soybean genotypes for plant height ($P < 0.01$). The plants of ATAEM 7, BDS 11, and BDS 25 genotypes attained the highest and statistically similar plant heights (85.3-87.4 cm), whereas Defiance exhibited significantly lowest plant height (62.0 cm) and was on par with NE 3399, A 3935, BDS 21 and Çetinbey (Table 4).

Previous studies have also reported that soybean plant height is largely controlled by genetic factors, while environmental conditions play a substantial role in the expression of this trait (Board and Kahlon, 2011; Yang et al., 2021). Shorter genotypes are considered advantageous for mechanical harvesting and contribute to improved production reliability whereas plants with greater height may be more prone to lodging.

First Pod Height

Significant differences were observed among soybean genotypes for both first branch height and first pod height ($P < 0.05$). The highest first pod height was recorded in BDS 25 and BDS 21 genotypes, while the lowest value was observed in the Defiance cultivar (Table 4). First pod height is a critical agronomic trait for mechanical harvesting of soybean (Board and Kahlon, 2011; Bakal et al., 2020). The non-significant year effect and the absence of a significant year X genotype interaction indicate that these traits are more strongly governed by genotypic factors.

Number of Branches and Pods

Statistically significant differences were observed for number of branches and number of pods per plant among soybean genotypes. BDS 21, BDS 25 and Atakişi genotypes produced higher number of branches, whereas BDS 11, Atakişi and BDS 25 produced higher numbers of pods per plant (Table 4). ATAEM 7 and Defiance produced the lowest number of branches and pods per plant, respectively. The number of branches and pods is directly related to the photosynthetic efficiency of plants and their capacity to form generative organs (Board and Kahlon, 2011; Board et al., 1992).

Thousand-Seed Weight (g)

To determine the thousand-seed weight of the genotypes, four separate sets of 100 seeds were weighed individually to calculate the average 100-seed weight, and the resulting value was multiplied by 10.

Genotypes showed significant differences ($P < 0.01$) in thousand-seed weight. Earlier study also reported that seed weight is a trait under strong genetic control and shows considerable variation among cultivars (Ogunbayo et al., 2014).

The highest thousand-seed weight (156 g) was recorded in BDS 25 genotype, followed by BDS 07 and Çetinbey. The lowest thousand-seed weight (approximately 113 g), was observed in the Atakişi cultivar. Thousand-seed weight has a high heritability and represents an important yield component that can be improved through selection (Ramya et al., 2010). Significant effect of year on Thousand-seed indicates that seed weight traits are also influenced by environmental conditions and climatic variability during the growing season. Seed size, which is directly related to thousand-seed weight, is among the key physical quality parameters determining suitability for the feed and food industries. Cultivars with larger seeds are preferred by industry due to higher flour yield, better milling properties, and lower processing losses (Elgün and Ertugay, 2011). In this context, genotypes such as BDS 25, BDS 07, and Çetinbey, which exhibited higher thousand-seed weight, can be considered to have greater potential for use in the feed and food industries.

Multi-environment field trials have demonstrated significant differences among genotypes regarding seed weight and related quality traits ($P<0.01$). These interactions provide valuable guidance for breeding programs and cultivar selection for industrial use (Gökdere et al., 2023).

Grain Yield

Significant differences were observed among soybean cultivars for grain yield ($P < 0.05$. The year X cultivar interaction was significant, indicating that yield rankings of genotypes varied between years. Mean yield values ranged from 4077 to 5881 kg ha^{-1}, with the higher yields obtained from the BDS 11, BDS 25, and Nova cultivars.

Similar differences in yield and yield components and positive correlation among number of pods per plant, 100-seed weight, and the number of seeds per pod of soybean genotypes were reported earlier (Nget et al., 2022). Furthermore, genotype X environment interactions have been shown to significantly affect yield performance, with environmental variability altering the yield rankings of genotypes (Addae-Frimpomaah et al., 2025; Pospišil and Pospišil, 2024).

Quality Parameters

Protein Content (%)

Protein content ranged from 32.30% to 37.48%. The highest protein content was recorded in the Atakişi genotype (37.48%), followed by Çetinbey (37.34%), BDS 25 (37.09%), and Defiance and BDS21 (both 36.97%). The lowest protein content was observed in the Arısoy genotype (32.30%). In general, genotypes with higher protein content are considered more valuable for both human consumption and the feed industry.

The higher protein content observed in some genotypes is an important quality characteristic because soybean protein is a primary determinant of nutritional value for both human food and animal feed. Consequently, the development and selection of high-protein genotypes remain major objectives in soybean breeding programs (Chiluwal, 2025; Liu et al., 2023; Singer et al., 2023; Shi et al., 2023).

Ash Content (%)

Ash content ranged from 4.89% to 7.23%. The highest ash content was recorded in the NE 3399 genotype (7.23%), followed by Çetinbey (6.73%), Defiance (6.71%), and BDS 25 (6.53%). The lowest ash content was observed in the BDS 11 genotype (4.89%). Since ash content reflects the total mineral content of the seed, genotypes with higher ash content can be considered richer in mineral nutrients.

Ash content is commonly regarded as an indicator of the total mineral content of seeds. Therefore, genotypes with higher ash content are generally considered to possess greater concentrations of essential mineral nutrients, which contributes positively to their nutritional quality (Sonia et al., 2024; Singer et al., 2023).

Oil Content (%)

Oil content ranged from 16.40% to 18.60%. The highest oil content was recorded in the BDS 21 genotype (18.60%), followed by NE 3399 and Atakişi, both with 18.40%. The lowest oil content was observed in the BDS 11 genotype (16.40%). Genotypes with higher oil content are considered more advantageous for vegetable oil production.

Genotypes with higher seed oil content are generally considered more desirable for vegetable oil production because oil concentration is one of the major determinants of the economic value of soybean. Consequently, improving seed oil content remains a key objective of soybean breeding programs aimed at food, feed, and industrial applications (Li et al., 2026; Kim et al., 2024; Vargas-Almendra et al., 2024).

Conclusions

The results of this study demonstrated significant differences among cultivars for plant height, first pod height, number of branches, number of pods, and thousand-seed weight. The significant cultivar X year interaction for yield indicates that cultivars respond differently under varying environmental conditions. Overall, the BDS 11 and BDS 25 genotypes, along with the Nova cultivar, stood out in terms of high yield and favorable morphological traits, indicating good adaptation to the region. Consequently, ecological conditions similar to Konya Plain, Nova, BDS 11 and BDS 25 genotypes can be recommended for grain yield, while Atakişi cultivar and BDS 21 genotype can be recommended for higher oil and protein content.

When the quality parameters, namely protein, oil, and ash contents, were evaluated together, considerable differences were observed among the soybean genotypes. Atakişi stood out for its superior nutritional quality, exhibiting both the highest protein content (37.48%) and a high oil content (18.40%). BDS 21 was distinguished by the highest oil content (18.60%), together with high protein (36.97%) and relatively high ash (6.05%) contents. BDS 25 can also be considered a promising genotype due to its high protein (37.09%) and ash (6.53%) contents, as well as its highest 1000-seed weight. Although NE 3399 exhibited the highest ash content (7.23%) and high oil content (18.40%), its protein content (33.28%) was lower than that of the other outstanding genotypes. In contrast, BDS 11 had the lowest ash (4.89%) and oil (16.40%) contents but produced one of the highest seed yields (5,859 kg ha^{-1}), indicating a different balance between seed quality and productivity. These findings demonstrate that the genotypes possess distinct advantages depending on their intended use whether for high protein, high oil or high mineral content.

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Table 1. Soil properties of the experimental area.

Texture	pH	EC (mS/cm^{-1})	Lime (%)	Organic Matter (%)	Phosphorus (kg/da)	Potassium (kg/da)
Clay Loam	8.12	2.77	22.07	2.33	3.42	153.75

Table 2. Mean monthly temperatures and cumulative rainfall of the experimental site for the crop years 2021-2022.

Meteorological Parameters	Years	Months											
		Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Mean Daily Maximum Temperature (°C)	2021	18.8	19.9	21.5	28.1	31.2	30.6	35.7	35.8	30.5	26.2	21.9	16.3
	2022	13.5	12.5	18.8	28.5	30.9	30.2	34.1	34.4	33.3	31.9	19.9	16.3
	Long-term averages	20.6	21.5	26.8	31.5	35.0	37.2	40.1	40.5	38.8	33.3	24.9	20.4
Mean Air Temperature (°C)	2021	2.7	2.6	3.9	11	18.3	17.4	23.1	22.7	16.4	11.1	8	1.8
	2022	-2.4	0	-0.7	12.9	14.1	19.1	20.7	23.7	18.7	11.6	7.9	4.4
	Long-term averages	1.6	3.7	7.9	13.0	17.4	21.8	25.3	25.7	20.6	14.4	8.0	3.6
Mean Daily Minimum Temperature (°C)	2021	-11.7	-15.7	-6.7	-3.5	5.4	4.1	10.7	9	3.6	-3.6	-8.6	-20.2
	2022	-22.5	-15.6	-15.3	-4.9	1.6	10.3	7.3	11.8	1	-2.8	-3.5	-4.8
	Long-term averages	-18.0	-14.7	-7.7	-3.8	2.5	9.2	13.1	12.9	5.1	0.1	-7.7	-16.2
Rainfall (mm)	2021	20.3	0.4	60.7	12.9	2.9	71.4	14.4	12	38.5	0.7	22.1	25.6
	2022	18.2	19.8	10.3	3	20	27.9	20.4	9.7	4.4	26.2	6.9	21.9
	Long-term averages	45.32	24.24	33.88	25.80	35.69	35.80	6.44	6.69	17.93	29.85	34.01	43.42

Source: TİGEM (Gözlü Agricultural Enterprise Directorate) meteorological station - TSMS (Turkish State Meteorological Service)

Table 3. Analysis of Variance for the effects of treatments on agronomic traits.

Source of Variation (SV)	df	Plant Height (cm)	First Pod Height (cm)	Number of Branches per Plant	Number of Pods per Plant	Thousand-Seed Weight (g)	Grain Yield (kg ha^{-1})
Replication	2	55.04	33.39	1.14	87.29	317.38	46700.1
Year	1	6952.17*	249.57	25.92	369.46	8383.51*	26692.8
Error 1 (Rep X Year)	2	125.23	111.17**	4.22**	356.89**	357.70	41379.4*
Genotype	11	378.19**	35.83*	2.20**	97.93*	949.91**	19927.6*
Year X Genotype	11	45.83	9.61	0.49	42.30	144.97	18487.2*
Error 2	44	114.96	13.65	0.51	40.93	112.77	8575.4
Coefficient of Variation (CV, %)	-	14.08	19.42	25.01	23.79	8.17	19.02

**Significant at P <0.05; **Significant at P < 0.01.*

Table 4. Effects of treatments on the performance of soybean genotypes.

Genotype	Plant Height (cm)	First Pod Height (cm)	Number of Branches per Plant	Number of Pods per Plant	Thousand-Seed Weight (g)	Grain Yield (kg ha^{-1})	Protein (%)	Ash (%)	Oil (%)
Defiance	62.0 e	14.5 d	2.75 b-d	21.6 c	129.3 b-e	4077 c	36.97	6.71	17.15
Nova	74.7 b-d	17.6 b-d	2.68 cd	25.9 bc	118.2 ef	5198 ab	34.47	5.27	16.50
ATAEM 7	87.4 a	20.0 a-c	1.60 e	24.8 c	116.5 f	5058 a-c	34.64	5.04	16.95
NE 3399	68.7 de	17.6 b-d	3.05 a-d	26.2 bc	129.1 c-e	4447 bc	33.28	7.23	18.40
Arısoy	78.9 a-c	18.9 bc	3.13 a-d	27.5 bc	119.7 ef	5040 a-c	32.30	5.11	17.10
A 3935	68.6 de	19.3 bc	3.03 a-d	27.2 bc	123.3 d-f	4253 bc	33.32	5.46	17.05
Atakişi	74.1 b-e	16.1 cd	3.43 a-c	32.3 ab	113.3 f	4435 bc	37.48	4.92	18.40
BDS 07	82.8 a-c	20.1 a-c	2.43 de	27.1 bc	141.6 b	4740 bc	35.93	5.71	17.05
BDS 11	85.3 ab	19.4 bc	2.38 de	36.0 a	134.8 b-d	5859 a	34.88	4.89	16.40
BDS 21	72.5 c-e	21.2 ab	3.83 a	24.1 c	136.7 bc	4580 bc	36.97	6.05	18.60
BDS 25	85.7 ab	24.0 a	3.57 ab	28.2 bc	155.7 a	5881 a	37.09	6.53	16.70
Çetinbey	73.2 b-e	19.4 bc	2.57 d	22.0 c	141.4 bc	4855 a-c	37.34	6.73	16.50

References

Acikgoz, E., Sincik, M., Karasu, A., Tongel, O., Wietgrefe, G., Bilgili, U., Oz, M., Albayrak, S., Turan, Z. M., and Goksoy, A. T. (2009). Forage soybean production for seed in mediterranean environments. *Field Crops Research*, *110*(3), 213-218. https://doi.org/10.1016/j.fcr.2008.08.006

Addae-Frimpomaah, F., Amenorpe, G., Sossah, F. L., Adazebra, G. A., Amiteye, S., Adjebeng-Danquah, J., Nelimor, C., Yirzagla, J., Amoako, O. A., and Amoatey, H. (2025). Genetic variability, heritability, and genetic gain for yield and associated traits in recently introduced soybean genotypes in the guinea savannah zone of Ghana. *Australian Journal of Crop Science*, *19*(5), 489-500. https://doi.org/10.3316/informit.T2025070300000100514249057

Altınyüzük, H., and Öztürk, Ö. (2017). Soya çeşitlerinin Çukurova koşullarında II. ürün olarak verim ve kalite özelliklerinin incelenmesi. *Selcuk Journal of Agriculture and Food Sciences*, *31*(3), 101-110. https://doi.org/10.15316/SJAFS.2017.41 (In Turkish).

Arıoğlu, H. H. (2014). *Yağ bitkileri yetiştirme ve ıslahı*. Çukurova Üniversitesi Ziraat Fakültesi Yayınları (No. 220, Ders Kitapları No. A-70). (In Turkish).

Arıoğlu, H., Bakal, H., Güllüoğlu, L., Kurt, C., and Onat, B. (2016). Ana ürün koşullarında yetiştirilen bazı yerfıstığı çeşitlerinin önemli agronomik ve kalite özelliklerinin belirlenmesi. *Tarla Bitkileri Merkez Araştırma Enstitüsü Dergisi*, *25*(Özel Sayı-2), 24-29. https://doi.org/10.21566/tarbitderg.281656 (In Turkish).

Bakal, H., Gulluoglu, L., Onat, B., and Arıoglu, H. (2017). The effect of growing seasons on some agronomic and quality characteristics of soybean varieties in Mediterranean Region in Turkey. *Turkish Journal of Field Crops*, *22*(2), 187-196. https://doi.org/10.17557/tjfc.356213

Bakal, H., Kenetli, A., and Arıoglu, H. (2020). The effect of plant density on pod yield and some agronomic characteristics of different growthtype peanut varieties (*Arachis hypogaea* L.) grown as a main crop. *Turkish Journal of Field Crops*, *25*(1), 92-99. https://doi.org/10.17557/tjfc.748671

Barış, M., Tunçtürk, M. ve Söğüt, T. (2020). Ekim zamanı uygulamalarının bazı soya fasulyesi (Glycine max (L.) Merrill) çeşitlerinde verim ve verim özelliklerine etkisi. ISPEC Tarım Bilimleri Dergisi, 4(4), 717-731. https://doi.org/10.46291/ISPECJASvol4iss4pp717-731 (In Turkish).

Başalma, D., İşler, N., Arslan, M., Göksoy, A. T., Sincik, M., Arslanoğlu, F., Önemli, F., Öztürk, Ö., Arslan, H., Day, S., and Kayaçetin, F. (2025). Yağlı tohumlar üretiminde mevcut durum ve sürdürülebilirlik. *Türkiye Ziraat Mühendisliği X. Teknik Kongresi Bildiriler Kitabı*, *1*, 430-455. (In Turkish).

Bek, D., and Arıoğlu, H. (2005). Çukurova koşullarında farklı soya genotiplerinin adaptasyon ve verim potansiyellerinin saptanması. *Türkiye VI. Tarla Bitkileri Kongresi*, *2*, 1101-1105. (In Turkish).

Board, J. E., Kamal, M., and Harville, B. G. (1992). Temporal importance of greater light interception to increased yield in narrow-row soybean. Agronomy Journal, 84(4), 575-579. https://doi.org/10.2134/agronj1992.00021962008400040006x

Board, J. E., and Kahlon, C. S. (2011). Soybean yield formation: What controls it and how it can be improved. In H. A. El-Shemy (Ed.), *Soybean physiology and biochemistry* (pp. 1-36). InTechOpen.

Chiluwal, A. (2025). US soybean seed protein concentrations-Current status, challenges, and some potential crop management solutions. *Agronomy Journal*, *117*(1), e21731. https://doi.org/10.1002/agj2.21731

Elgün, A., Ertugay, Z., 2011. Tahıl işleme teknolojisi, Atatürk Ünv. Ziraat Fakültesi Yayınları, No:718, Erzurum, 411 s.

FAO. 2025. Agricultural production statistics- 2010-2024. FAOSTAT Analytical Briefs, No. 121. Rome. https://doi.org/10.4060/cd8035en

Gale, F., Valdes, C., and Ash, M. (2019). *Interdependence of China, United States, and Brazil in soybean trade* (OCS-19F-01). USDA, Economic Research Service. https://www.ers.usda.gov/media/10166/ocs-19f-01.pdf?v=57181

Gauch, H. G., Jr. (2013). A simple protocol for AMMI analysis of yield trials. *Crop Science*, *53*(5), 1860-1869. https://doi.org/10.2135/cropsci2013.04.0241.

Gökdere, H. İ., Yılmaz, A. B., Tekin, M., Yeken, M. Z., and Çiftçi, V. (2023). Ekmeklik buğday (*Triticum aestivum* L.) genotiplerinin dane verimi ve bazı önemli kalite özellikleri için Trakya Bölgesinde bulunan farklı çevrelerde testlenmesi. *Journal of the Institute of Science and Technology*, *13*(4), 3040-3052. https://doi.org/10.21597/jist.1358515 (In Turkish).

Hartman, G. L., West, E. D., and Herman, T. K. (2011). Crops that feed the world 2. Soybean-worldwide production, use, and constraints caused by pathogens and pests. *Food Security*, *3*(1), 5-17. https://doi.org/10.1007/s12571-010-0108-x.

Kim, J., Scaboo, A., Rainey, K. M., Fritschi, F. B., and Bilyeu, K. (2024). Redesigning soybean with improved oil and meal traits. *Theoretical and Applied Genetics*, *137*(9), Article 218. https://doi.org/10.1007/s00122-024-04732-8

Kocaturk, M., Cubukcu, P., Goksoy, A. T., Sıncık, M., Ilker, E., Kadıroglu, A., Vurarak, Y., Sahın, Y., Karakus, M., and Akgun Yıldırım, U. (2019). GGE biplot analysis of genotype X environment interaction in soybean grown as a second crop. *Turkish Journal of Field Crops*, *24*(2), 145-154. https://doi.org/10.17557/tjfc.615175.

Leggett, M., Diaz-Zorita, M., Koivunen, M., Bowman, R., Pesek, R., Stevenson, C., and Leister, T. (2017). Soybean response to inoculation with *Bradyrhizobium japonicum* in the United States and Argentina. *Agronomy Journal*, *109*(3), 1031-1038. https://doi.org/10.2134/agronj2016.04.0214.

Li, H., Sun, J., Zhang, Y., Wang, N., Li, T., Dong, H., Yang, M., Xu, C., Hu, L., Liu, C., Chen, Q., Foyer, C. H., and Qi, Z. (2026). Soybean oil and protein: Biosynthesis, regulation and strategies for genetic improvement. *Plant, Cell & Environment*, *49*(7), 3730-3746. https://doi.org/10.1111/pce.15272

Liu, S., Liu, Z., Hou, X., and Li, X. (2023). Genetic mapping and functional genomics of soybean seed protein. *Molecular Breeding*, *43*(4), Article 29. https://doi.org/10.1007/s11032-023-01373-5

Nget, R., Aguilar, E. A., Cruz, P. C. S., Reaño, C. E., Sanchez, P. B., Reyes, M. R., and Prasad, P. V. V. (2022). Responses of soybean genotypes to different nitrogen and phosphorus sources: Impacts on yield components, seed yield, and seed protein. *Plants*, *11*(3), 298. https://doi.org/10.3390/plants11030298.

OECD/FAO. (2023). *OECD-FAO agricultural outlook 2023-2032*. OECD Publishing. https://doi.org/10.1787/08801ab7-en.

Ogunbayo, S. A., Sié, M., Ojo, D. K., Sanni, K. A., Akinwale, M. G., Toulou, B., Shittu, A., Idehen, E. O., Popoola, A. R., Daniel, I. O., and Gregorio, G. B. (2014). Genetic variation and heritability of yield and related traits in promising rice genotypes (*Oryza sativa* L.). *Journal of Plant Breeding and Crop Science*, *6*(11), 153-159. https://doi.org/10.5897/JPBCS2014.0457.

Pagano, M. C., and Miransari, M. (2016). The importance of soybean production worldwide. In M. Miransari (Ed.), *Abiotic and biotic stresses in soybean production* (pp. 1-26). Academic Press. https://doi.org/10.1016/B978-0-12-801536-0.00001-3

Peng, D., Zhang, H., Zhang, Y., Yu, L., Chen, M., Chen, J. M., You, L., Li, P., Liu, J., Zhang, X., Arvor, D., Kuchler, P., Huang, J., Zhang, H., Hao, P., Huang, J., Shi, Z., Wang, F., Song, K., Zhang, B. (2026). Global soybean trade dynamics: Drivers, impacts, and sustainability. *The Innovation*, *7*(2), Article 101124. https://doi.org/10.1016/j.xinn.2025.101124

Pospišil, A., and Pospišil, M. (2024). Soybean yield and yield components depending on a sowing rate and sowing date. *Poljoprivreda*, *30*(2), 10-16. https://doi.org/10.18047/poljo.30.2.2

Ramya, P., Chaubal, A., Kulkarni, K., Gupta, L., Kadoo, N., Dhaliwal, H. S., Chhuneja, P., Lagu, M., and Gupta, V. (2010). QTL mapping of 1000-kernel weight, kernel length, and kernel width in bread wheat (*Triticum aestivum* L.). *Journal of Applied Genetics*, *51*(4), 421-429. https://doi.org/10.1007/BF03208872.

Ray, D. K., Gerber, J. S., MacDonald, G. K., and West, P. C. (2015). Climate variation explains a third of global crop yield variability. *Nature Communications*, *6*(1), Article 5989. https://doi.org/10.1038/ncomms6989

Salvagiotti, F., Cassman, K. G., Specht, J. E., Walters, D. T., Weiss, A., and Dobermann, A. (2008). Nitrogen uptake, fixation and response to fertilizer N in soybeans: A review. *Field Crops Research*, *108*(1), 1-13. https://doi.org/10.1016/j.fcr.2008.03.001

Shi, D., Hang, J., Neufeld, J., Zhao, S., and House, J. D. (2023). Effects of genotype, environment and their interaction on protein and amino acid contents in soybeans. *Plant Science*, *337*, Article 111891. https://doi.org/10.1016/j.plantsci.2023.111891

Singer, W. M., Lee, Y.-C., Shea, Z., Vieira, C. C., Lee, D., Li, X., Cunicelli, M., Kadam, S. S., Khan, M. A. W., Shannon, G., Mian, M. A. R., Nguyen, H. T., and Zhang, B. (2023). Soybean genetics, genomics, and breeding for improving nutritional value and reducing antinutritional traits in food and feed. *The Plant Genome*, *16*(4), Article e20415. https://doi.org/10.1002/tpg2.20415

Soni, K., Frew, R., and Kebede, B. (2024). A review of conventional and rapid analytical techniques coupled with multivariate analysis for origin traceability of soybean. Critical reviews in food science and nutrition, 64(19), 6616-6635.

Soni, K., Frew, R., and Kebede, B. (2024). A review of conventional and rapid analytical techniques coupled with multivariate analysis for origin traceability of soybean. *Critical Reviews in Food Science and Nutrition*, *64*(19), 6616-6635. https://doi.org/10.1080/10408398.2023.2171961.

TÜİK. (2025). *Bitkisel üretim istatistikleri*. Türkiye İstatistik Kurumu. https://veriportali.tuik.gov.tr/tr/statistical-themes

USDA. (2026). *World agricultural supply and demand estimates* (WASDE-673). U.S. Department of Agriculture. https://www.fas.usda.gov/data/wasde

Vargas-Almendra, A., Ruiz-Medrano, R., Núñez-Muñoz, L. A., Ramírez-Pool, J. A., Calderón-Pérez, B., and Xoconostle-Cázares, B. (2024). Advances in soybean genetic improvement. *Plants*, *13*(21), Article 3073. https://doi.org/10.3390/plants13213073

Wilcox, J. R. (2004). World distribution and trade of soybean. In R. M. Shibles, J. E. Harper, R. F. Wilson, and R. C. Shoemaker (Eds.), *Soybeans: Improvement, production, and uses* (3rd ed., Vol. 16, pp. 1-14). American Society of Agronomy. https://doi.org/10.2134/agronmonogr16.3ed.c1

Yan, W., Hunt, L. A., Sheng, Q., and Szlavnics, Z. (2000). Cultivar evaluation and mega-environment investigation based on the GGE biplot. *Crop Science*, *40*(3), 597-605. https://doi.org/10.2135/cropsci2000.403597x

Yan, W., and Kang, M. S. (2002). *GGE biplot analysis: A graphical tool for breeders, geneticists, and agronomists*. CRC Press.

Yang, Q., Lin, G., Lv, H., Wang, C., Yang, Y., and Liao, H. (2021). Environmental and genetic regulation of plant height in soybean. *BMC Plant Biology*, *21*(1), Article 63. https://doi.org/10.1186/s12870-021-02836-8.

Yılmaz, A., Yılmaz, H., Soydemir, H. E., and Çiftçi, V. (2022). Soya (Glycine max L.)'da PGPR ve AMF uygulamalarının verim özellikleri ve protein içeriğine etkisi. *International Journal of Agriculture and Wildlife Science*, *8*(1), 108-118. https://doi.org/10.24180/ijaws.1077704 (in Turkish).