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Investigation of the Potential of Growing Some Early-Season Soybean Genotypes as Alternative Crops Under the Ecological Conditions of Sivas

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HIGHLIGHTS

- In this study, twenty-five soybean genotypes and five registered soybean varieties (Arısoy, Traksoy, Samsoy, Soyanam and Ataem-7) were used as materials.
- With this study, it is thought that Arısoy, Traksoy, Samsoy, Soyanam, Ataem-7 varieties and ÜNV-7, ÜNV-11, ÜNV-20 genotypes can be successfully grown in Sivas climate conditions.
- However, in order to reach definitive conclusions, further studies are needed in different climate conditions and for many years.

Abstract

Soybean is of strategic importance among oilseed crops due to its versatile uses and its ability to meet the growing demand for vegetable oils driven by the rapidly increasing global population. In Türkiye, soybean production remains far below the required levels to meet domestic demand, resulting in a growing reliance on imports each year. However, Türkiye has the potential for soybean production, given its favorable climate and soil conditions. To increase production, the development of local cultivars and the expansion of planting areas are essential. Specifically, including soybean in crop rotation systems in regions such as Central Anatolia, where the crop can be easily grown and developing new high-yield, high-quality varieties suited to these areas, will be crucial steps in boosting domestic production. This study aimed to evaluate the agro-morphological characteristics of several early-maturing soybean genotypes in the Sivas ecological conditions during the summer growing season and to explore soybean as an alternative crop. In this study, twenty-five soybean genotypes and five registered soybean varieties (Arısoy, Traksoy, Samsoy, Soyanam and Ataem-7) were used as materials. The study was conducted over one year during the 2023 soybean growing season at the Agricultural R&D Center trial field of Sivas University of Science and Technology. The field trial was set up according to a randomized block design with three replications. The obtained data showed that the days to first flowering ranged from 74.67 to 82.33 day and the days to maturity varied between 158 and 160 day. Additionally, the number of lateral branches ranged from 2.47 to 7.34 piece, the first pod height varied from 8.14 to 23.80 cm and the number of pods per plant ranged from 41.40 to 155 pods plant^{-1}. The number of seeds per pod ranged from 2.47 to 3.11 piece and the pod weight varied from 0.10 to 0.36 g. The 100-seed weight was determined to be an average of 7.14 g. Significant statistical differences at the 5% level were observed

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for plant height, first pod height, number of pods per plant, number of seeds per pod, number of lateral branches, pod length, pod width, pod weight, and 100-seed weight. Based on these findings, it can be concluded that the varieties Arısoy, Traksoy, Samsoy, Soyanam, Ataem-7 and the genotypes ÜNV-7, ÜNV-11, ÜNV-20 can be successfully cultivated in the climatic conditions of Sivas. However, it is emphasized that further studies over multiple years and in different climatic conditions are necessary to draw definitive conclusions.

Keywords: *Glycine max* L.; agro-morphological characteristics; adaption; breeding

1. Introduction

Soybean (*Glycine max* L.) is a significant livelihood source in many countries, particularly in China and Korea and stands out as an oilseed crop with extensive global applications (Bakal et al. 2017). It is a nutrient-rich source, with high protein and fat content. In kitchens, soybeans are used in various forms, such as soy milk, soy sauce, soy flour and soybean oil. Additionally, due to its high fiber content, it facilitates digestion, supports heart health and is commonly preferred in diets. Furthermore, soybeans have been shown to improve metabolism and reduce the risk of diabetes. Soybean holds a prominent place in the oilseed category globally, with its versatility and the growing demand for plant-based oils being key factors in this importance (Arıoğlu et al. 2012; Güngör and Üstün 2015; Boerema et al. 2016; Nadeem et al. 2021a). In Türkiye, however, soybean production is insufficient to meet domestic demand and this gap is filled by increasing imports each year. Despite having the necessary climate and soil conditions for soybean production, insufficient domestic cultivation has led to higher imports. This gap could be closed by promoting soybean planting and developing locally adapted high-yield, high-quality varieties. To increase domestic production, it is necessary to include soybean in crop rotation in regions like Central Anatolia, where the crop can be grown easily and to develop varieties that perform well in these areas. Genotype, environment and genotype × environment interactions significantly affect yield and quality in soybeans (Erbil and Gür 2017; Gül and Arslanoğlu 2020; Okcu 2020; Nadeem et al. 2021b). Due to the rapid increase in global population and demand for plant oils, soybean cultivation has gained considerable importance. In 2010, global production of oilseeds was 832 million tons, rising to 1.102 billion tons by 2019. Soybean's extensive use has made it the second-largest oilseed crop after palm, with 3.409 million tons produced. Soybean is the leading oilseed in terms of planted area (11.525 million hectares) and is second in terms of production (3.047 million tons). According to 2019 data, approximately 1.205 million hectares, or 37.37% of the global oilseed planting area, is covered by soybeans (FAO 2022).

This study aims to evaluate the agro-morphological characteristics of some early-maturing soybean genotypes during the summer growing season under the ecological conditions of Sivas Province. The goal is to explore the potential of soybean as an alternative crop. This research is expected to make significant contributions to expanding soybean cultivation areas in Türkiye and to the economy of local farmers.

2. Materials and Methods

In this study, twenty-five soybean genotypes and five registered soybean varieties (Arısoy, Traksoy, Samsoy, Soyanam and Ataem-7) were used as materials. The study was conducted over one year during the 2023 soybean growing season at the Agricultural R&D Center trial field of Sivas University of Science and Technology. The field trial was set up according to a randomized complete block design with three replications. In the trial, each genotype was planted in 5-meter plots with 4 rows, 70 cm row spacing and 10 cm plant spacing. Along with sowing, 6 kg da^{-1} of nitrogen (N) and 8 kg da^{-1} of phosphorus (P_2O_5) were applied. The planting was carried out on May 16, 2023, taking into account the climatic conditions of the region. During the growing season, weed control, irrigation and all necessary maintenance operations were performed as required based on climatic conditions. A drip irrigation system was used for irrigation. The soil properties of the trial field at the Agricultural R&D Center of Sivas University of Science and Technology are presented in Table 1.

The soil at the location where the study was conducted is a silty clay loam with a pH value of 7.28. It is characterized by low organic matter content (1.7%), high potassium levels (93.59 kg da^{-1}), low phosphorus

(P_2O_5), lime content (19.6) and low salt content (0.33%). During the study, there were no issues with groundwater and the land was adequately drained (Table 1).

Table 1. The soil characteristics of the experimental site at the Sivas Science and Technology University, Agricultural Research and Development Center

Depth	Texture	pH	Lime (% CaCO3)	Salt (%)	Phosphorus (P_2O_5 kg da^{-1})	Potassium (K_2O kg da^{-1})	Organic Matter Content (%)
0-30 cm	Silty clay loam	7.28	19.6	0.33	3.40	93.59	1.7

Table 2. The climate data for Sivas province during the 2023 growing season, along with long-term climate data, are presented*

	Total Precipitation (mm)		Average Temperature (˚C)		Average Relative Humidity (%)	
Months	**2023**	**Long Term**	**2023**	**Long Term**	**2023**	**Long Term**
April	74.8	33.7	9.1	8.9	92.8	62.3
May	56.4	54.7	13.0	13.5	93.6	61.1
June	51.4	43.4	17.3	17.0	95.3	58.3
July	3.0	6.2	20.1	20.0	82.8	54.0
August	3.6	4.5	23.4	20.3	76.6	53.0
September	4.3	17.8	19.2	16.3	72.3	62.0
October	7.6	36.8	18.4	10.9	74.5	64.0
Total/Average	201.1	197.1	17.21	15.27	83.99	59.24

* Sivas Provincial Meteorology Directorate

The climatic data for Sivas Province during the 2023 growing season, as well as long-term averages, are presented in Table 2. Sivas has a continental climate characterized by hot and dry summers and cold, snowy winters. The basic climatic values, such as total precipitation, average temperature and average relative humidity for the study period, are shown in Table 2. During the trial months, the total precipitation was lowest in July (3.0 mm) and highest in April (74.8 mm). In 2023, the lowest average temperature occurred in April (9.1 °C), while the highest average temperature was observed in August (23.4 °C). The lowest average relative humidity was recorded in September (72.3%) and the highest average relative humidity occurred in June (95.3%). In this study, several morphological characteristics of soybean genotypes and varieties were investigated, including days to flowering (50%), days to maturity, plant height, first pod height, number of pods per plant, number of seeds per pod, number of branches, pod length, pod width, pod weight and 100-seed weight. The obtained data were subjected to analysis of variance using the MSTATC statistical software and the differences between means were grouped using the Least Significant Difference (LSD) test ($p \leq 0.05$).

3. Results and Discussion

The data for the first flowering day count, days to maturity, plant height, number of branches, first pod height and number of pods per plant for the soybean genotypes and varieties studied are presented in Table 3.

Upon examining Table 3, it is observed that the number of days to first flowering in the soybean genotypes and varieties ranged from 74.67 to 82.33 days, with an average of 79.55 days. The difference in the number of days to first flowering among the samples was found to be statistically significant at the 5% level (Table 3). One of the most important factors affecting the growth and development of soybeans is day length. Soybean is a short-day plant and as the day length increases, the time to begin flowering also extends. Late-maturing soybean varieties are more sensitive to day length and tend to produce more flowers under long-day conditions. Ünal (2007) reported that the flowering period for the soybean lines obtained through

hybridization ranged from 35.00 to 45.00 days. Other similar studies reported that the days to flowering ranged from 79.47 to 80.72 days (Hızlı et al. 2023), from 38.9 to 42.7 days in 2018 and from 37.7 to 40.7 days in 2019 (Erbil 2020). The results of our study on flowering time are similar to some of the studies, while differing in others. These differences may be due to factors such as sowing time, day length, genetic structure, varieties used, growing regions and climatic conditions (Erbil 2020; Zhang et al. 2001).

Table 3. The data for the soybean genotypes and varieties, including the first flowering day (days), days to maturity (days), plant height (cm), first pod height (cm), number of sub-branches (piece) and number of pods per plant (pods plant^{-1}), as well as the groups formed based on the results of the analysis of variance, are presented.

Varieties	First Flowering (day)	Number of Days to Maturity (day)	Plant Height (cm)	Number of Sub-Branches (piece)	First Pod Height (cm)	Number of Pods Per Plant (pods plant^{-1})
Arısoy	79.00 a-c	158.00	113.3 b-c	3.96 h-k	23.80 a	41.40 m
Traksoy	74.67 c	158.00	90.2 g-j	3.27 k-l	18.40 c-g	59.93 k-l
Samsoy	77.33 a-c	158.00	87.20 h-l	4.87 e-ı	19.00 b-f	155.5 a
Soyanam	76.00 b-c	158.00	95.20 f-h	4.57 f-k	14.00 h-m	91.07 e-h
Ataem-7	82.00 a	158.00	103.7 c-f	3.40 j-l	17.73 c-h	62.00 j-l
4	82.00 a	158.00	111.5 b-d	4.38 f-k	18.27 c-g	65.87 j-l
5	77.67 a-c	159.00	110.3 c-d	4.20 g-k	19.80 b-e	71.93 ı-l
6	81.33 a-b	159.00	82.07 j-m	4.73 e-j	15.05 g-l	69.78 j-l
7	82.00 a	160.00	90.20 g-j	4.73 e-j	17.73 c-h	73.13 ı-k
8	82.33 a	159.00	103.0 d-f	3.93 h-k	18.27 c-g	87.27 f-ı
9	82.00 a	158.00	107.2 c-e	3.65 ı-l	13.27 j-m	69.33 j-l
10	82.33 a	160.00	98.67 e-g	4.33 f-k	21.20 a-d	58.80 k-l
11	77.67 a-c	159.00	128.5 a	3.48 j-l	22.47 a-b	61.27 j-l
12	75.67 b-c	158.00	121.1 a-b	2.47 l	21.47 a-c	41.40 m
ÜNV-2	82.00 a	159.00	88.11 h-l	7.34 a	17.61 d-h	75.67 h-j
ÜNV-3	79.00 a-c	159.00	83.13 j-m	4.40 f-k	8.67 n-o	104.1 c-e
ÜNV-4	82.33 a	158.00	89.80 g-k	6.60 a-b	11.43 l-o	108.1 c
ÜNV-5	80.00 a-c	160.00	94.47 f-ı	3.64 ı-l	16.80 e-j	76.42 g-j
ÜNV-6	78.33 a-c	159.00	80.13 k-n	6.27 a-d	13.80 ı-m	57.40 l
ÜNV-7	81.00 a-b	158.00	93.85 f-ı	5.43 b-g	14.28 h-m	107.0 c-d
ÜNV-8	82.00 a	159.00	79.80 l-n	5.27 b-h	13.07 j-m	91.60 d-g
ÜNV-11	76.67 a-c	159.00	84.82 ı-m	6.62 a-b	14.51 h-m	99.09 c-f
ÜNV-12	78.33 a-c	158.00	83.87 j-m	4.93 d-ı	11.00 m-o	98.13 c-f
ÜNV-13	79.67 a-c	160.00	68.33 o	5.00 c-ı	17.50 d-ı	105.2 c-e
ÜNV-15	75.67 b-c	158.00	80.22 k-n	4.94 d-ı	19.33 b-f	131.2 b
ÜNV-16	80.00 a-c	159.00	75.08 m-o	5.65 b-f	12.35 k-n	65.13 j-l
ÜNV-17	81.33 a-b	158.00	76.75 m-o	7.25 a	15.17 g-l	112.1 c
ÜNV-18	79.67 a-c	158.00	75.74 m-o	5.98 a-e	14.30 h-m	76.03 g-j
ÜNV-19	79.33 a-c	159.00	71.97 n-o	5.47 b-g	8.14 o	58.0 k-l
ÜNV-20	79.33 a-c	158.00	87.20 h-l	6.33 a-c	15.61 f-k	103.9 c-e
Average	79.55	158.63	91.85	4.90	16.13	85.16
F value	1.92*	NS	17.92**	6.27**	8.45**	24.39**
Mean square	8.512	0.00	37.201	0.711	5.270	92.086
LSD (%)	4.768	-	9.969	1.378	3.752	15.68

*: $p<0.05$, **: $p<0.01$

The number of days to maturity ranged from 158 to 160 days. There was no statistically significant difference between the varieties and genotypes regarding the number of days to maturity. ÜNV-10, ÜNV-5 and ÜNV-13 were identified as the genotypes that reached the latest harvest maturity (Table 3). In a study by Erbil (2020), the physiological maturity period ranged from 119.2 to 135 days, while Malik et al. (2011) reported the average physiological maturity period as 101.18 days. The findings in our study are partially similar to those reported in other studies.

The average plant height of the soybean genotypes and varieties used in the study was determined to be 91.85 cm. The lowest plant height was found in the ÜNV-13 genotype at 68.33 cm, while the highest plant height was recorded in genotype 11 at 128.5 cm (Table 3). The difference in plant height values was statistically significant at the 1% level (Table 3). Similar studies have reported plant heights ranging from 64 to 118 cm (Bakoğlu and Ayçiçek 2005), from 71.3 to 121.6 cm (Erbil 2020) and from 41.17 to 57.50 cm (Mert and İlker 2016). Özer (2021) found plant heights of 65.58 to 74.50 cm in the first year and 37.67 to 48.08 cm in the second year of his study.

Table 4. The data for the soybean genotypes and varieties, including the number of seeds per pod (seeds), pod weight (g), pod length (cm), pod width (cm) and 100-seed weight (g), as well as the groups formed based on the results of the analysis of variance, are presented.

Varieties	The Number of Seeds Per Pod (piece)	Pod Weight (g)	Pod Length (cm)	Pod Width (cm)	100-Seed Weight (g)
Arısoy	3.07 a-c	0.29 a-f	4.67 a-c	0.91 a-d	8.34 c-g
Traksoy	3.13 a	0.36 a	4.88 a-b	0.93 a-d	11.33 a
Samsoy	2.93 a-d	0.32 a-c	4.45 a-d	0.90 a-d	8.37 b-g
Soyanam	2.93 a-d	0.29 a-f	4.37 a-e	0.89 a-d	8.39 b-g
Ataem-7	3.00 a-c	0.34 a-b	4.99 a	1.07 a-b	8.45 b-f
4	2.84 c-d	0.23 f-ı	4.72 a-c	1.07 a-b	4.02 m
5	2.95 a-d	0.23 f-ı	4.60 a-d	1.01 a-c	6.34 h-l
6	2.98 a-d	0.21 g-ı	3.67 e-f	0.81 b-e	5.28 j-m
7	3.04 a-c	0.24 d-ı	4.63 a-d	0.94 a-d	6.53 h-k
8	2.99 a-c	0.20 ı	4.23 b-f	0.87 a-d	6.82 g-j
9	2.83 c-d	0.21 h-ı	4.60 a-d	0.95 a-d	4.29 m
10	2.88 b-d	0.20 ı	4.45 a-d	0.92 a-d	4.35 m
11	3.05 a-c	0.29 a-f	4.24 a-f	0.95 a-d	3.94 m
12	2.87 b-d	0.28 b-h	4.67 a-c	1.04 a-b	4.24 m
ÜNV-2	2.74 d	0.20 ı	2.11 h-ı	0.46 g-h	8.14 d-g
ÜNV-3	2.87 b-d	0.26 c-ı	4.29 a-f	0.86 a-d	11.37 a
ÜNV-4	2.89 b-d	0.23 e-ı	4.12 c-f	0.86 a-d	6.06 ı-l
ÜNV-5	2.92 a-d	0.28 b-g	4.12 c-f	0.87 a-d	8.46 b-f
ÜNV-6	2.92 a-d	0.26 c-ı	4.69 a-c	0.75 c-f	6.48 h-l
ÜNV-7	3.01 a-c	0.34 a-b	4.22 b-f	0.88 a-d	9.92 a-b
ÜNV-8	3.01 a-c	0.25 d-ı	4.54 a-d	0.86 a-d	9.00 b-e
ÜNV-11	3.04 a-c	0.30 a-e	3.88 d-f	0.94 a-d	9.85 a-c
ÜNV-12	2.95 a-d	0.28 b-h	4.71 a-c	0.88 a-d	7.55 e-ı
ÜNV-13	2.47 e	0.10 j	2.86 g-h	0.54 e-h	4.41 m
ÜNV-15	2.87 b-d	0.22 g-ı	2.17 h-ı	0.42 h	7.06 f-ı
ÜNV-16	3.00 a-c	0.34 a-b	4.47 a-d	1.10 a	9.61 b-d
ÜNV-17	2.97 a-d	0.25 d-ı	1.97 ı	0.51 f-h	5.16 k-m
ÜNV-18	3.00 a-c	0.31 a-d	4.16 b-f	0.70 d-g	7.79 e-h
ÜNV-19	3.11 a-b	0.25 d-ı	2.23 h-ı	0.54 e-h	4.93 l-m
ÜNV-20	2.97 a-d	0.24 e-ı	3.55 f-g	0.73 d-g	7.67 e-h
Average	2.94	0.26	4.04	0.83	7.14
F value	2.12**	5.58**	3.50**	10.82**	15.25**
Mean square	0.022	0.002	0.029	0.214	0.928
LSD (%)	0.24	0.07309	0.7561	0.2783	1.574

*: $p<0.05$, **: $p<0.01$

In this study, the number of sub-branches, first pod height and number of pods per plant ranged from 2.47 to 7.34 piece, 8.14 to 23.80 cm and 41.40 to 155 (pods plant^{-1}), respectively (Table 3). The differences among these three traits were statistically significant at the 1% level (Table 3). Bakoğlu and Ayçiçek (2005) reported that the first pod height ranged from 12 to 31 cm, with an average of 18.57 cm; the number of branches ranged

from 1 to 3, with an average of 1.93; and the number of pods per plant ranged from 21 to 76, with an average of 44.30. Mert and İlker (2016) reported that the number of pods per plant ranged from 36.33 to 48.33. Hızlı et al. (2023) observed the first pod height to be an average of 5.37 cm and the number of branches to be 4.02. Erbil (2020) reported that the first pod height ranged from 3.1 to 8 cm in 2018, while Civelek (2006) found first pod height values between 3.95 and 8.81 cm in a study conducted in Samsun. Arslan (2007) reported that the first pod height ranged from 10.3 to 22.8 cm in the main crop and from 4.3 to 9.3 cm in the second crop.

Upon examining Table 4, the number of seeds per pod and pod weight ranged from 2.47 to 3.11 seeds per pod and from 0.10 to 0.36 g, respectively. Bakoğlu and Ayçiçek (2005) found the number of seeds per pod to range from 2 to 3.90. The average pod length and pod width of the soybean genotypes and varieties were determined to be 4.04 cm and 0.83 cm, respectively (Table 3). The differences among the number of seeds per pod, pod weight, pod length and pod width were statistically significant at the 1% level (Table 4).

In this study, the average 100-seed weight was determined to be 7.14 g. The lowest 100-seed weight was observed in genotype number 11, with a value of 3.94 g, while the highest 100-seed weight was found in genotype ÜNV-3, with a value of 11.37 g (Table 4). This difference between genotypes was found to be statistically significant at the 1% level. In a study by Erbil (2020), the thousand-seed weight of soybean genotypes was determined to be 155.89 g in 2015 and 155.53 g in 2016. Bakal et al. (2021) reported that the 1000-seed weight of soybean varieties ranged from 160.0 to 155.2 g under different treatments. Bakoğlu and Ayçiçek (2005) found that the 100-seed weight ranged from 6 to 17 g. Research has emphasized that seed weight can be influenced by various factors such as genotype, environmental conditions, sowing time and cultural practices and it is one of the most important indicators of yield. Furthermore, it has been stated that seed size can vary significantly among genotypes.

4. Conclusions

The results obtained from this study indicate that the expansion of soybean cultivation areas could provide significant economic benefits for regional farmers. Accordingly, it has been concluded that the varieties Arısoy, Traksoy, Samsoy, Soyanam, Ataem-7, along with genotypes ÜNV-7, ÜNV-11 and ÜNV-20, can be successfully cultivated under the climatic conditions of Sivas province. Both field and laboratory studies have shown that these varieties and genotypes are well-suited to the agroecological conditions of Sivas. However, to make a definitive evaluation and obtain long-term results, further studies under varying climatic conditions over different years are necessary. Such long-term and comprehensive research is crucial for ensuring the sustainability of soybean production and for the development of regional agricultural policies. In this context, it is believed that expanding soybean production areas more widely is necessary to increase domestic production, improve production efficiency and contribute to the local economy.

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