A BREEDING STUDY TO DEVELOP EARLY MATURING SOYBEAN CROSSES SUITABLE FOR DOUBLE CROPPING

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ABSTRACT

The present research was undertaken to evaluate of soybean hybrids environmental interaction and adaptability on Mediterranean region conditions. Seven advanced (F7) soybean cross breeding lines (KB-67, KS-39, KS-14, KS-12, KS-11, KS-10, KS-2) selected from the Kunitz x SS-201 and Kunitz x Bert crosses populations based on earliness and yield characteristics in the preliminary trials and three soybean varieties (Bravo, Nova and Arisoy) were tested in the trial in four replications in 2017 and 2018 according to the randomized block trial design. The analysis of variance revealed significant variations for all characters. According to research findings the yield of lines and varieties 2017 and 2018 varied from 1008.38-1567.13 kg ha⁻¹ and 1018.94-1367.00 kg ha⁻¹ respectively and KS-39 advanced soybean line had the highest grain yield in terms of two years average. The highest plant height (95.55 cm) was obtained from KS 11 and the lowest plant height (78.80 cm) from Bravo variety. According to the two-year average data, KB-67 (129.62 pods per plant) and KS-39 (114.70 pods per plant) lines were the genotypes with the highest number of pods in the plants. The number of flowering days varied between 32.50 days and 36.75 days according to the two-year averages, and the KS-12 genotype was the earliest flowering genotype. The lines KS-10 (103.38) and KS-12 (103.50) came to the fore as the genotypes with the earliest maturation days. Among the lines tested in the experiment, KS-11 in terms of plant height, KS-14 in terms of first pod height and 100-seed weight and KS-39 in terms of the number of seeds per pod were the lines that showed the best performance.

Keywords: Adaptability, environmental interaction, soybean lines, Mediterranean region.

INTRODUCTION

Soybean is one of the most valuable plant cultivated over the world and is well known as an industrial plant because of rich content in minerals and vitamins has been used over 400 years (Yildirim, 2017). In addition to being a raw material for biofuel production and an indispensable protein source for the animal nutrition sector, it is also a major source of protein and fatty acids in human and animal nutrition. Soybean meal (SBM) is the most commonly used protein source in the animal feed industry (Baker, 2020). High protein content and widespread availability make soybean meal a good source of protein in animal diets (Easter and Kim, 1999). As a source of oil, protein, biodiesel, etc., soybean (Glycine max L. Merr.) is the fourth widely grown crop in the world (Ikker et al., 2018b).

World population is expected to grow by over a third, or 2.3 billion people, between 2009 and 2050 and can up to 10 billion According the best optimistic predictions, for feeding a world with 9.1 billion population in year of 2050, we will have to increase overall food production by 70%. This implies need production to almost double in the developing countries. On the other hand, urbanization is foreseen to continue and account for urban areas to 70% of world population until 2050. Nowadays agriculture must face with the multiple challenges like increasing demands for food to feed a growing population, have to producing more foodstock for a potentially huge bioenergy market, using sustainable production methods and adapting to climate change. The availability of land and fresh water show a similar picture, there are insufficient and very unevenly distributed in global. Soybean cultivars can be classified as commodity type, which are used for edible or industrial oil and animal feed, and food-type, which are used for human consumption. Developing cultivars with desired seed size and appearance depends on the type of soy food for which the soybeans are destined (Jegadeesa and Yu, 2020). Whereas the major breeding targets for food grade soybeans are high protein, carbohydrates and sucrose content, soybean seed with a high content of high protein content and oil content are preferred for feed industry.

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and food-type, which are used for human consumption. Developing cultivars with desired seed size and appearance depends on the type of soy food for which the soybeans are destined. Whereas the major breeding targets for food grade soybeans are high protein, carbohydrates and sucrose content, soybean seed with a high content of high protein content and oil content are preferred for feed industry. Soybean yield is a complex quantitative trait and is highly affected by environmental condition. Many analyses under different climate change conditions indicates that climate change may significantly reduce yields in the long run (Porter et al., 2014). On the other hand, availability of genetic variability for soybean offers to improve new soybean varieties by hybridization or assisted breeding. There is an increasing many number of countries or regions, reaching alarming levels of water scarcity of in the world. In Mediterranean climate conditions, soybean can be produced as a double crop. Because of this trends market demand for food would continue to grow and it is expected that the demand for cereals, for both food and animal feed uses be projected to reach some 3 billion tons by 2050, up from today’s nearly 2.1 billion tons. Turkey should produce more soybean to reduce soybean imports. Although not a major share of Turkey in world soybean production is ahead of many countries in terms of soybean yield. Soybean has an important place in the Mediterranean Region in terms of planting area and production.

In this study, it was aimed to determine the high yielding and early maturing genotypes suitable for double crop in the soybean breeding program, which has been carried out for many years, within the scope of the variety development project suitable for the Mediterranean climate zone.

### MATERIALS AND METHODS

50 single plants were selected separately from two F5 bulk populations (Kunitz x SS-201 and Kunitz x Bert crosses) which obtained from the soybean breeding project carried out in Izmir Bornova in 2014. The selected lines were planted in rows with a length of 5 m and a row length of 70 cm in 2015, with 45 plants per m², in augmented design, together with five replications of 6 control varieties (Arısoy, Nova, Sa88, Umut-2002, Bravo, Ataem-7). Among the genotypes cultivated in the augmented design, 7 soybean lines that stand out in terms of maturation days and flowering days were selected. Seven advanced soybean lines and three registered varieties having early maturity (Bravo, Nova, and Arısoy) were evaluated in two trials laid out in 2017 June22 and 2018 June 26. Field trial was conducted in a randomized complete block design (RCBD) with four replications. Each plot consisted of 4 rows 5 m long. The seeds inoculated with *Bradyrhizobium japonicum* bacteria, were sown in June after wheat harvest by hand over 45 plants per square meter. Before planting, 200 kg ha⁻¹ of DAP (36 kg ha⁻¹ N, 92 kg ha⁻¹ P) fertilizers were applied in all environments. Irrigation was performed four times with sprinkler irrigation system. Bornova is located (Latitude 38°28’ and Longitude 27°13’) in the western part of Turkey at Aegean Sea with altitude of 27 m and dominated by the Mediterranean climate conditions.

The climatic data during the 2017-2018 growing period in experimental area were presented in Table 1. The experimental area has a heavy soil structure with clay-silt soil at 0-20 cm depth and clay-loamy structure at 20-40 cm depth (Ozturk and Yildirim, 2020). The soil test indicated a pH of 7.63 with 1688 kg ha⁻¹ of K₂O and 7.40 kg ha⁻¹ of P₂O₅. In addition, the organic matter content of the soil was very low (1.52%) and the lime content was 7.60% (Ozturk, 2021).

### RESULTS AND DISCUSSION

100 lines selected from F5 bulk populations of Kunitz x SS-201 and Kunitz x Bert hybrid combinations were tested with 5 control varieties on the basis of Augmented trial design in 2015 (Table 2). Variance analysis showed that seven crossed genotypes are statistically superior or similar to the control varieties in terms of flowering and maturation times. These genotypes were selected according to 7% selection intensity for repeated trials.

Table 1. The climatic data during the 2017-2018 growing period in experimental area (Anonymous, 2018)

| Months/Years | Average temp. (°C) | Relative humidity (%) | Precipitation (mm) |
|-------------|--------------------|-----------------------|-------------------|
|             | 2017 | 2018 | 2017 | 2018 | 2017 | 2018 |
| June        | 19.8 | 20.7 | 56.2 | 55.6 | 1.8  | 29.7 |
| July        | 23.4 | 23.3 | 46.5 | 53.4 | 1.4  | 0.3  |
| August      | 24.0 | 24.1 | 49.4 | 55.8 | 0.3  | 5.8  |
| September   | 17.4 | 19.7 | 56.8 | 58.7 | 0.9  | 2.7  |
| October     | 12.9 | 14.4 | 60.7 | 70.9 | 45.7 | 39.7 |

Table 2. Mean squares for days for flowering (DFF) and days for maturity (DFM) of the data obtained from the experiment set up in the augmented design in 2015.

| Source      | Df | DFM, day | DFF, day |
|-------------|----|----------|----------|
| Genotypes (G) | 4  | 3.53*    | 6.453    |
| Block       | 5  | 0.367**  | 4.333*   |
| Error       | 20 | 0.787    | 1.553    |

ns: non significant, *: significant at 0.05 level, **: significant at 0.01 level
Of the selections made according to early flowering and early maturation times (data were not shown), only one (KB-67) belonged to the Kunitz x Bert hybrid combination, while the other 6 promising combinations were obtained from Kunitz x SS-201 F5 hybrids.

Analysis of variance was performed for control genotypes and selected cross genotypes according to the randomized complete block design in the next trial years 2017 and 2018. Since the year interaction is important for many agronomical traits, the combination over the years was not applied. Results from the analysis of variance for all traits demonstrated that differences among mean values for all genotypes and both growing years (environments) were significant. Besides, there were significantly genotype x year interactions for all traits indicated that differences among average values of genotypes were affected differently for two years except days for maturity, days for flowering, and number of grain per pods (Table 3).

Table 3. Mean squares for grain yield (GY), plant height (PH), First pod height (FPH), pods per plant (PPP), days for flowering (DFF), days for maturity (DFM), 100-seed weight (HKW), and grain per pods (GPD).

| Source         | Df | GY, t ha\(^{-1}\) | PH, cm | FPH, cm | PPP (number) |
|----------------|----|-------------------|--------|---------|--------------|
| Genotypes (G) | 9  | 152479.891**      | 201.772** | 38.568** | 1596.751**   |
| YxG           | 9  | 402385.966**      | 293.88** | 7.134**  | 619.335**    |
| Years         | 1  | 47709.552**       | 646.385** | 317.206** | 8422.434**   |
| Block         | 3  | 1447.911**        | 99.977** | 2.911**  | 17.442**     |
| Error         | 57 | 1460.267          | 44.32   | 1.177    | 71.007       |

Table 4. The means of soybean lignin and varieties and LSD groups of grain yield (GY), plant height (PH), First pod height (FPH), pods per plant (PPP).

| Genotypes | 2017 | 2018 | Mean | 2017 | 2018 | Mean | 2017 | 2018 | Mean | 2017 | 2018 | Mean |
|-----------|------|------|------|------|------|------|------|------|------|------|------|------|
| BRAVO     | 3.79D| 3.14E| 3.60 | 74.90| 82.70| 78.80E| 14.33C| 15.48D| 14.905| 132.15B| 79.65E| 105.9 |
| NOVA      | 3.91D| 3.14F| 3.53 | 77.90| 84.20| 81.05D| 11.40D| 14.60D| 13.00 | 116.90C| 80.90D| 98.9 |
| ARISOY    | 3.86D| 3.34E| 3.60 | 82.95| 87.55| 85.28BCDE | 12.48D| 19.50B| 15.99 | 91.85EF | 76.05E| 83.95 |
| KB-67     | 2.87G| 3.16F| 3.02 | 83.45| 83.50| 83.48CDE | 12.40D| 13.88E| 13.14 | 150.15A| 109.10AB| 129.625 |
| KS-39     | 4.47A| 3.90A| 4.18 | 82.10| 84.25| 83.18CDE | 15.30BC| 18.85BC| 17.075| 112.90CD| 116.50A| 114.7 |
| KS-14     | 3.19F| 3.65BC| 3.42 | 87.00| 91.55| 89.28ABC | 17.03A| 21.80A| 19.415| 103.10DE| 99.23BC| 101.165 |
| KS-12     | 3.19F| 2.61G| 2.90 | 73.85| 85.90| 79.88DE | 12.25D| 17.48C| 14.865| 98.80EF| 89.70CD| 94.25 |
| KS-11     | 4.28B| 3.73B| 4.01 | 93.35| 95.75| 94.55A | 14.40BC| 17.65C| 16.025| 102.29DF| 86.88DE| 94.585 |
| KS-10     | 3.50E| 3.60BC| 3.55 | 88.15| 92.85| 90.50AB | 15.45BC| 19.40B| 17.425| 91.10F | 78.45DE| 84.775 |
| KS-2      | 0.70C| 0.53CD| 3.80 | 80.20| 92.45| 86.53BC | 15.88AB| 22.10A | 18.99 | 100.53F | 78.10DE| 89.315 |
| LSD       | 0.153| 0.620 | 1.527| 11.857|

According to the variance analysis results, it was determined that the variation between genotypes in terms of plant height was statistically significant and the genotype x year interaction had an insignificant mean square. Over the two trial years, the KS-11 (94.5 cm) crossed genotype had the highest average plant height, and KS-10 (90.5 cm), which is also another crossed genotype, took the second place. The data shows that the average plant height of the three cultivars tested as control cultivars was lower than the advanced lines (Table 4).

First pod height (FPH) is an important trait associated with reducing grain loss in machine harvesting. Therefore, it is desired to be high. Although the interaction is important for this trait, it was understood that the averages of the leading genotypes in both years were in the same statistical groups. It was observed that especially KS-14 among the crossed lines improved by selections, showed a very high performance (19.4 cm), followed by KS-2 (18.9 cm) and KS-10. It was determined that the FPH averages of these genotypes were higher than the control cultivars and had significant FPH values.

The LSD groups related to the number of pods in the plant, which is one of the most important characteristics that determine and affect the yield, are shown in Table 4. While the number of pods per plant of the genotypes included in the experiment varied between 91.10 and 150.15 (KB-67) in 2017, it varied between 76.05 and 116.50 (KS-39) in 2018. The number of pods per plant was higher in the first year of the study. According to the mean yield of two-years, KB-67 was the advanced line with the highest number of pods, while the KS-39 was the second promising genotype for this trait. In this study, a statistically significant statistical result could not be reached for the number of grains (GPP) per pod (Table 3). It was determined that the average GPP values of the genotypes were generally very similar to each other (Table 5).
In this study, the number of flowering days of the genotypes varied between 32.50 days and 36.75 days, according to the two-year averages. While KS-12 genotype was the earliest flowering genotype, it was determined that three registered cultivars with KS-10 and KS-14 lines were in the same statistical group as KS-12 and had early flowering characteristics. Although these genotypes are in the same statistical group as the control varieties Bravo, Nova and Arisoy, when the interaction groupings are examined, it was determined that the second year KS-12 had a shorter flowering period than all other genotypes (Table 4). Similarly, KS-10 and KS-12 soybean lines were determined to be the earliest maturing genotypes statistically in this study.

Variations in terms of 100-seed weights were found statistically significant. Although the interaction was found to be significant according to the years, it can be said that this situation is due to the fact that the KS-2 genotype, which is a crossed advanced line, has a relatively low 100-grain weight value in the second year compared to the first year. Besides, with the average temperature values in the vegetation period of 2018 September and October being 2 degrees higher than in 2017, a general decrease trend was observed in the hundred-seed weights of all genotypes. The 100-seed weight of soybean varieties and lines ranged from 13.48 g to 20.4 g in 2017 and varied between 12.60-19.73 g in 2017. The two-year average 100-seed weight ranged between 13.08-20.06 g (Table 5). The highest hundred grain weight value was clearly obtained from the KS-14 crossed line.

The results were significant with a 1% probability between genotypes, between years and for genotype x environment interaction, while the difference between replications was insignificant for grain yield (Table 3). Considering the average grain yield values, it was determined that the KS-39 line was the genotype with the highest grain yield with 4.47 t ha⁻¹ in 2017 and 3.90 t ha⁻¹ in 2018 and 4.18 t ha⁻¹ over the two years (Table 4). Following this, KS-11, which is statistically superior to other genotypes in terms of grain yield, has a grain yield of 4.01 t ha⁻¹ over an average of two years. However, it has been determined that this promising genotype has a longer maturation period than the others, and therefore it may be beneficial to re-evaluate it under main product conditions instead of second crop conditions. Finally, in this study, the grain yield varied between 2.90 t ha⁻¹ and 4.18 t ha⁻¹, and control varieties Bravo and Arisoy cultivars stood out with 3.60 t ha⁻¹ (Table 4). It was indicated that genotypes of the present study are highly promising lines and shows superiority than those researchers’ Ilker et al. (2018a) who reported grain yield ranged from 2.5-3.4 t ha⁻¹ in the same growing conditions in İzmir. Mariani et al. (2012) who reported soybean grain yield between 2.5 t ha⁻¹ and 2.8 t ha⁻¹ in northern Rio Grande do Sul State conditions on the other hand, current results showed similarities with the findings of Ilker (2017) and the results of Gulluoglu et al. (2016) who reported that soybean yield can reach 4000 kg ha⁻¹ and more in double cropping conditions at Adana province.

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