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*Original scientific article*

# DETERMINATION OF THE GROWTH AND YIELD TRAITS OF SOME MUSTARD SPECIES UNDER SEMI-ARID CENTRAL ANATOLIAN CONDITIONS

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*Brassica nigra*, and *B. juncea*, are two economically important species that are used as spices; and *B. juncea*, *B. rapa* ssp., *oleifera*, and *B. nigra* are used for industrial seed oil. The potential of 16 *Brassica* genotypes's comparison with 2 standard varieties was done in terms of their phenology, morphology, and yield performance under autumn-sown conditions during 2019-20 and 2020-21 under semi-arid climatic conditions of Central Anatolia, in Ankara, Türkiye. The experiment was performed in a randomized complete-block design with four replications. The results indicated statistically significant genotypes × years interaction among all genotypes for plant height, number of branches, number of pods, number of seeds, 1000-seed weight, seed yield, and crude oil yield of *Brassica* spp. Seed emergence, rosette formation stage, 50% flowering, and 50% pod formation of *Brassica* spp. varied according to species and years. While the maximum and minimum crude oil yields of 1222 kg ha$^{-1}$ were obtained from Standard 2 (*B. napus*-Excalibur) and 313 kg ha$^{-1}$ from the Bn4 genotype; the Br2 (1123 kg ha$^{-1}$), Br3 (1042 kg ha$^{-1}$), Br6 (1093 kg ha$^{-1}$), Br5 (949 kg ha$^{-1}$) *B. rapa* ssp., *oleifera* and Bj3 (893.3 kg ha$^{-1}$) *B. juncea* genotypes appeared superior in performance compared with the other genotypes. These genotypes can be further exploited in various improvement programs through selection and hybridization.

*Keywords: Brassica juncea*, *B. rapa* ssp. *oleifera*, *Brassica nigra*, phenology, morphology, and yield

## INTRODUCTION

*Brassica juncea*, *B. rapa* ssp. *oleifera* and *B. nigra* L. (family *Brassicaceae* or *Crucifereae*) are among the important annual plant species and genetic resources that are morphologically very distinct and economically valued as spice (seed) and diesel (industrial seed oil). Previous studies suggest that *B. juncea* L. (brown mustard), *B. rapa* ssp. *oleifera* (field

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mustard or turnip rape), and *B. nigra* L. (black mustard) can be grown during autumn in Ankara, Türkiye (KAYACETIN *et al*., 2022).

Mustard has potential as an important raw material in the spice and energy sectors. KAYACETIN (2019) indicated that 25-35% vegetable oil is produced from mustard seeds. Black mustard has the sharpest flavor in terms of usage among species, whereas brown mustard is used to produce Dijon mustard (PALLE-REİSCH *et al*., 2013). There are very few reports from Türkiye about the use of local genotypes as spices and their adaptability for the biodiesel industry (YESİLYURT *et al*., 2019). It is important that these species are cultivated and brought into agriculture. These are considered non-edible oils due to the high value (30-40%) of erucic acid (C22:1) and are considered potential low-cost sources for biodiesel production (REZANIA *et al*., 2022; KAYACETIN, 2023).

The United Nations Food and Agriculture Organization (FAO) and the Organization for Economic Cooperation and Development (OECD) have evaluated the latest developments in the production of biofuels, oilseeds and other products during the 2012-2021 period. It has been reported that these plant species play a key role in sustainable agricultural systems. Gradually share of agricultural crops for the production of biofuel is increasing day by day. A careful estimate predicts that the demand for biofuel production will increase by 60% in the next 40 years, with a 5% increase in the use of arable lands during this period. The report also asserts the need to increase the use of plants for energy fuel production in addition to their use for nutrition (FAO, 2009). This practice will increase product diversity in crop production. The cold and dry stress that occurs from time to time in areas where oilseeds are produced has negative effects on the yield of oil crops. Oilseed plants should be grown in autumn according to industry needs to increase their production (KAYACETIN *et al*., 2022). Genotypic differences play a major role in the adaptation of crops to specific environments (NOWOSAD *et al*., 2016) resulting in variable responses against different genotypes. Several breeders have studied and screened a number of *Brassica* crops and studied genetic and morphologic variabilities for direct introduction or their hybridization for specific purposes (ABBADI and LECKBAND, 2011; KATCHE *et al*., 2019; KAYACETIN, 2019). Seed and crude oil yield per hectare is one of the most important traits that could improve the efficiency of production of any seed crop. Mustard seed yield and quality of oil are influenced by agronomic, genetic, and environmental conditions, sowing time, irrigation, fertilizer application, and plant density (BOCIANOWSKI *et al*., 2019). Sometimes specified genotypes do not exhibit the same phenotypic characteristics and yield performance under varying environmental conditions. The breeding of a cultivar is an important tool, to increase agricultural production. A successful breeding program relies on the genetic diversity of a crop to achieve the goals of producing high-yielding and resistant varieties (TARIQ *et al*., 2020).

The current study aimed to screen 18 diverse and morphologically superior cultivated *Brassica* genotypes for use in breeding programs in Turkey.

## MATERIAL AND METHODS

*Experimental location, climate, and soil traits*

The experiment was conducted during the autumn seasons of 2019-20 and 2020-21 at the experimental fields of the Field Crops Central Research Institute in Ankara, Turkey located at Ikizce (39°26′ 18.87″N, 32°22.691″; 1050 m altitude). The average monthly total precipitation, average relative humidity, minimum, maximum, and average temperatures noted during the autumn growing seasons for long terms, 2019-20 and 2020-21, are given in Figure 1. There was a total of 391.9, 269.6, and 273.6 mm of precipitation, an average temperature of 10.5, 10.5, and 12.0 °C, and an average humidity of 63.9% 58.3%, and 65.5%, respectively. The minimum temperature in the mean of the last 21 years (-17.9 °C) was higher compared to the temperature during 2019-20 (-12.2 °C) and 2020-21 (-15.3 °C). The maximum temperature in 2019-20 (35.5 °C) and 2020-21 (37.6 °C) was lower compared to the meteorological data average of the last 21 years (40.4 °C).

The soil analysis results during 2019-20 and 2020-21, by taking soil samples at a depth of 0-20 cm showed low organic matter (1.63% and 1.97%), mild alkalinity (pH 7.4 and 7.7), limey (28% and 30%), and clay-loam soils during both years (Table 1).

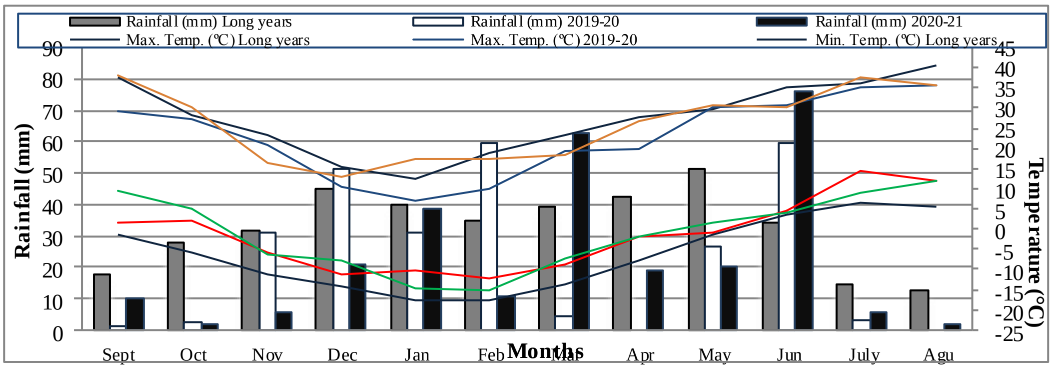


Figure 1. Some meteorological data about the vegetation period (September to August)

*Table 1. Analysis of soil samples belonging to the experimental area for two years*

| year | depth (cm) | texture | in water-saturated soil EC (dS $m^{-1}$) | pH | limey $CaCO_3$ (%) | phosphorus (kg $ha^{-1}$) | potassium (kg $ha^{-1}$) | organic substance (%) |
|---|---|---|---|---|---|---|---|---|
| 2020 | 0-20 | Clay loamy | 1.18 | 7.4 | 28 | 197 | 1550 | 1.63 |
| 2021 | 0-20 | Clay loamy | 0.64 | 7.7 | 30 | 45 | 3060 | 1.97 |

*Plant material and experimental design*

The experiment consisted of a randomized complete-block design with four replicates. The seeding rate was adjusted to reach a density of about 200 plants per $m^2$. The yield from a plot of 10.8 $m^2$ was calculated on the basis of the $ha^{-1}$ yield. The seeds were sown at a depth of ~2-3 cm during both years of the experiment.

The study utilized 16 mustard genotypes from three *Brassica* species (*B. juncea*, *B. nigra*, and *B. rapa* ssp. *oleifera*) and two standards (Standard1-*B. juncae* ISCI-99 and Standard 2-*B. napus* Excalibur) as research material (Table 2). The experimental land was prepared with a one- pass disc-harrow and plowed before sowing the seeds. This selection consisted of mustard genotypes collected from several locations in Turkey and the USDA gene bank. The genotypes constituting the material of the study were characterized by the Field Crops Central Research Institute, Ankara, Türkiye, and brought to the yield experiment using the "Pure Line Selection Method". Nitrogen, phosphorus, and sulfur was used at rates of 100, 50, and 35 kg $ha^{-1}$, in the same sequence (FRANZEN and LUKACK, 2007; GRANT *et al*., 2007). Both phosphorus and sulfur fertilizers were applied before sowing. The total nitrogen fertilization was done at the time of sowing and rosette formation.

*Table 2. List of Brassica spp. genotypes used in this study*

| Species | No | Genotype | Origin | No | Genotype | Origin | No | Genotype | Origin |
|---|---|---|---|---|---|---|---|---|---|
| *Brassica juncea* | 1 | Bj1 | Turkey | 4 | Bj4 | Russia | 7 | Bjo5 | Russia |
| | 2 | Bj2 | Kirklareli, Turkey | 5 | Bjo1 | Russia | | | |
| | 3 | Bj3 | Kayseri, Turkey | 6 | Bjo2 | United States | | | |
| *Brassica nigra* | 8 | Bn1 | Turkey | 9 | Bn3 | Turkey | 10 | Bn4 | Ankara, Turkey |
| *B. rapa* ssp. *oleifera* | 11 | Br1 | Tekirdag, Turkey | 13 | Br3 | Tekirdag, Turkey | 15 | Br5 | Tokat, Turkey |
| | 12 | Br2 | Bursa, Turkey | 14 | Br4 | Turkey | 16 | Br6 | Tekirdag Turkey |
| Standart | 17 *B. juncea* | S1-ISCI-99 | India | 18 *B. napus* | S2-Excalibur | France | | | |

*Studied traits*

Phenotypic: Both vegetative and generative growth observations were taken at the beginning and the end of respective developmental stages. The data about phenotypic observations included days to emergence from sowing (d), days to rosette formation from emergence (d), days to 50% flowering from emergence (vegetative growth stage) (d), and induction of 50% pod formation from seed emergence time (generative growth stage) (d) as noted following KAYACETIN (2019).

Morphologic: Plant height, number of branches, number of pods per plant, number of seeds per pod, 1000-seed weight, and yield (seed yield and oil yield) in this study were determined as described by KAYACETIN (2019). At the time of seed ripening, the plants in every plot were harvested. Seed yield (kg $ha^{-1}$) and crude oil yield (kg $ha^{-1}$) were also calculated (KAYACETIN, 2023).

Statistical Analysis: The data about all morphological and yield traits (%) were analyzed using analysis of variance (ANOVA) from the JMP Statistical software. Significant differences among the group means were separated using LSD (SALL *et al*., 2017).

## RESULTS AND DISCUSSION

*Phenotypic traits*

*Brassica* species were sown during the 2019-20 autumn on September 15, 2019, followed by two irrigations to facilitate emergence. In general, losses of 3-10%, 6-18%, and 11-26% were detected in *Brassica* genotypes entering winter at the right time and showed more resistance to cold. Winter damage was determined to be between 10-16% in the two standard varieties. It is observed that temperature drops up to -13 ºC in winter causes a high level of cold-based damage.

*Table 3. According to Brassica spp. sowing, emergence, flowering and harvest date*

| Year | Species | Sowing dates | Emergence dates | 4-6 leaves rosette dates | 50% flowering dates | 50% pod formation dates | Harvest dates |
|---|---|---|---|---|---|---|---|
| 2019-20 | *B. rapa* ssp. *oleifera* | 15-September-2019 | 11-October-2019 | 12-November-2019 | 25-April-2020 | 10-May-2020 | 27-June-2020 |
| | *B. juncea* | 15-September-2019 | 11-October-2019 | 12-November-2019 | 11-May-2020 | 26-May-2020 | 1-July-2020 |
| | *B. nigra* | 15-September-2019 | 18-November-2019 | 25-December-12.2019 | 25-May-2020 | 25-June-2020 | 28-July-2020 |
| | S1-ISCI-99 | 15-September-2019 | 11-October-2019 | 12-November-2019 | 11-May-2020 | 26-May-2020 | 1-July-2020 |
| | S2-Excalibur | 15-September-2019 | 11-October-2019 | 12-November-2019 | 11-May-2020 | 26-May-2020 | 1-July-2020 |
| 2020-21 | *B. rapa* ssp. *oleifera* | 25-September-2020 | 10-November-2020 | 1-January-2021 | 30-April-2021 | 5-May-2021 | 16-July-2021 |
| | *B. juncea* | 25-September-2020 | 10-November-2020 | 1-January-2021 | 15-April-2021 | 31-May-2021 | 20-July-2021 |
| | *B. nigra* | 25-September-2020 | 28-November-2020 | 15-January-2021 | 18-April-2021 | 15-May-2021 | 10-August-2021 |
| | S1-ISCI-99 | 25-September-2020 | 20-November-2020 | 1-January-2021 | 15-April-2021 | 31-May-2021 | 20-July-2021 |
| | S2-Excalibur | 25-September-2020 | 20-November-2020 | 1-January-2021 | 15-April-2021 | 31-May-2021 | 20-July-2021 |

*Brassica* species were sown on September 25, 2020, and in 2020-21. There was insufficient rain from September to mid-October, therefore irrigation was done during this period to ensure seed germination and emergence. Despite irrigation, plants could not enter the winter within the targeted period, resulting in significant cold based damage that varied among the genotypes. Since the emergence of *B. juncea* and *B. rapa* ssp. *oleifera* was completed in mid-November, these genotypes entered the winter in the early rosette stage, and especially *B. juncea* was adversely affected by this situation. *B. juncea* genotypes, showed 41.5% and 52.8% winter emergence. *B. nigra* genotypes, entered the winter in the early rosette stage inducing a little cold damage. In general, survival rates between 54.2-58.6% and 69.8-76.5% were determined in *B. rapa* ssp. *oleifera* and *B. nigra* genotypes. Significant winter damage of 35.1% to 29.5% was noted in Standard1 and Standard 2, respectively (Table 4). It is detected that temperature drops to -15.3 ºC during the winter months caused the cold damage that was higher due to the inability of the species to enter winter at the right time. The first or earliest flowering among all species occurred in *B. rapa* ssp. *oleifera* genotypes. Despite the emergence at Ankara during 2020-21, the species were adversely affected by the air temperatures falling to -14.9 and -15.3 ºC in January and February, respectively. The data about phenological observations are given in Table 3. Statistically similar phenological observations were noted among the genotypes used in the study; therefore, Table 3 and Table 4 were prepared on the basis of their results.

The emergence time varied depending on the genotypes. Their emergence time ranged from 26-64 days during 2019-20; to 46-64 days during 2020-21 (Table 4). The average temperature between September and December was warmer during 2019-20 (11.4 ºC) compared to the temperature noted during 2020-21 (8.9 ºC), but the total precipitation between these months was considerably lower during 2020-21 (38 mm) in comparison to 2019-20 (85.8 mm), which had a significantly negative influence on the yield. Because the most effective factors for the seeds to germinate and emerge are soil temperature and humidity (SALIMI, 2009; KAYACETIN, 2019). Although the duration to reach the 4-6 leaf rosette stage varied according to the species, the time to enter the rosette stage was 32-37 days during 2019-20 and 42-52 days during 2020-21. Depending on the change in the emergence times of the species, the times of entering the rosette stage varied over two years. The genetic structures and environmental conditions of the species affected the time of their entering the rosette stage. The genotypes entered 50% flowering in 189-213 days in the autumn sowing of 2019-20 and 134-176 days during the autumn sowing of 2020-21. It is obvious that significant differences in terms of temperature and precipitation during both years influenced this parameter, which affected the flowering period during both years. Although the flowering period is significantly affected by climatic conditions, low temperatures are assumed to prolong the flowering period (KAYACETIN, 2019). In addition, the flowering period decreased proportionally with the prolongation of the emergence period. Therefore, the vegetative period was shortened, and the yield values were negatively affected. The genetic structures and environmental conditions of the species were also effective in inducing differences in flowering (GIZLENCI, 2017). 50% pod formation dates range from 212-228 days during 2019-20, and 176-229 days during 2020-21 depending on the genotypes. The shifts in weather conditions had differential effects on the plant growth patterns of the species that were included in this study. Harvest varied according to species between 253-264 days during 2019-20, and 242-255 days during 2020-21. Climatic conditions are effective on the vegetation period; it was determined that the maturation was completed in a shorter time, especially with the increase in temperature (WU *et al*., 2011). It is assumed that the differences between species are due to the pleiotropic effect of genotypes caused by long-term shifts in temperatures, weather patterns (climate), and differential weather conditions during the carrying out of the experiments.

*Table 4. Average values of phenological observations discussed in the study*

| | Ratio of winter survival (%) | | Days to emergence | | Days to 4-6 leaves rosette stage | | Days to 50% flowering | | Days to 50% pod formation | | Days to harvest | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Species* | 2019-20 | 2020-21 | 2019-20 | 2020-21 | 2019-20 | 2020-21 | 2019-20 | 2020-21 | 2019-20 | 2020-21 | 2019-20 | 2020-21 |
| *B. rapa* ssp. *oleifera* | 89.9-96.8 | 54.2-58.6 | 26 | 46 | 32 | 52 | 197 | 171 | 212 | 176 | | 248 |
| *B. juncea* | 81.6-93.6 | 41.5-52.8 | 26 | 46 | 32 | 52 | 213 | 134 | 228 | 202 | 264 | 252 |
| *B. nigra* | 74.2-89.5 | 69.8-76.5 | 64 | 64 | 37 | 48 | 189 | 171 | 220 | 229 | 253 | 255 |
| S1-ISCI-99 | 90.2 | 35.1 | 26 | 56 | 32 | 42 | 213 | 176 | 228 | 192 | 264 | 242 |
| S2-Excalibur | 88.2 | 29.5 | 26 | 56 | 32 | 42 | 213 | 176 | 228 | 192 | 264 | 242 |

*Morphologic traits*

The plant height, number of branches, number of pods, number of seeds, 1000-seed weight, seed and crude oil yield results showed significant differences among genotypes during two years of the study ($p < 0.01$) (Table 5).

Statistically significant differences were found between the two years in terms of the studied traits of *Brassica* spp. The plant height (166.7 cm) and the number of branches (6.3 branch plant$^{-1}$) of the first year were higher compared to the plant height (118.5 cm) and the number of branches (6.0 branch plant$^{-1}$) of the second year (Table 5). Whereas the number of pods in the second year (394.3 pod plants$^{-1}$) was higher compared to the number of pods in the first year (300.0 pod plants$^{-1}$), the number of seeds, 1000-seed weight, seed yield, and crude oil yield in the first year (16.2 seed pod$^{-1}$, 2.1 g, 283.6 kg ha$^{-1}$, and 89.5 kg ha$^{-1}$) was higher compared to second year (14.5 seed pod$^{-1}$, 2.0 g, 222.2 kg ha$^{-1}$ and 59.5 kg ha$^{-1}$). This difference was due to higher rainfall during the growing period of plants in the second year.

The maximum plant height was detected at 251.1 cm in the Bn1 genotypes, while the minimum plant height was obtained as 82.3 in the Bn4 genotypes in the first year. There are morphologically different genotypes of *B. nigra*. The longest and shortest plant height values belonged to *B. nigra* genotypes. The result confirmed the general situation, as the development process progressed well in the first year of the experiment. However, during the second year of the experiment, the plant height of the genotypes and the two standard cultivars was determined quite less, especially in *B. juncea* and *B. rapa* ssp. *oleifera* species due to the problems experienced during the emergence and growth of the standard cultivars. The maximum and minimum number of branches (8.9 and 4.5 branch plant$^{-1}$) were noted on Bn4 and Br5 genotypes, respectively in the second trial years. The number of branches is an important criterion that has a positive effect on yield. Each increase in the number of side branches increases chlorophyll contents and photosynthesis in plants that ended up in a higher seed yield. Therefore, yield reductions caused by differential losses in the plant rows could be compensated partially or fully (SHRIEF *et al*., 1990). The maximum number of pods was determined as 820.3 pods plant$^{-1}$ on the Bn3 genotype in the second year, while the minimum number of pods was determined as 201.1 pod plant$^{-1}$ on the Br6 genotype in the first year. The maximum and minimum number of seeds in the pod were determined from the Standard 2 cultivar with 26.1 seed pod$^{-1}$ and from Bn4 with 5.2 seed pod$^{-1}$ in the first year. The maximum 1000-seed weight was detected in the Standard 2 cultivar with value of 3.5 g in the first year, the minimum 1000-seed weight of 0.6 g was found using the Bn1, Bn2, and Bn3 genotypes during both years. The maximum seed yield was obtained with 4896.5 kg ha$^{-1}$ from the S2 standard cultivar in the first year, while the minimum seed yield of 1107.9 kg ha$^{-1}$ were obtained from the Bn4 genotype in the first year. The maximum and minimum crude oil yields of 1708.9 kg ha$^{-1}$ was obtained from the S2 variety and 271.4 kg ha$^{-1}$ from the Bn1 genotype in the first year. Crude oil yield is an interaction of crude oil ratio and seed yield per hectare. Crude oil yield is the result of the interaction of the crude oil ratio with the cultivation of the soil crop. Although the Br2 (1123.4 kg ha$^{-1}$), Br3 (1041.7 kg ha$^{-1}$), Br6 (1092.5 kg ha$^{-1}$) and Bj3 (893.3 kg ha$^{-1}$) genotypes showed lower performance than the oil yield of the S2 variety (1708.9 kg ha$^{-1}$), they showed very high performance. In the genotypes where the number of plants per square meter was low due to winter mortality in autumn sowing, a thousand seed weight was significantly higher. The results revealed that morphological features show great differences due to the genetic characteristics of the genotypes, environmental factors, and the application of cultural practices (SHEKHAWAT *et al*., 2012; GIZLENCI, 2017). The fact that there is variation in oil content in genotypes and species is also important for future breeding studies (CHAUHAN *et al*., 2010; VEDNA *et al*., 2010; PATEL *et al*., 2012; PRIYAMEDHA KUMAR and HAIDER, 2017; MNDOLWA *et al*., 2019).

In the combined years (2020 and 2021), the maximum plant height was found in the Bn1 genotype with 225.5 cm, while the minimum plant height was obtained in the Br2 genotype with 122.7 cm (Table 5). The maximum number of branches was obtained from the Bn1 genotype with 8.3 branch plant$^{-1}$, while the minimum number of branches was determined from the Br5 genotype with 5.0 branch plant$^{-1}$. Whereas the maximum number of pods was determined with the 585.5 pod plant$^{-1}$ Bn3 genotype, the minimum number of pods was determined with the Br6 with 233.9 pod plants$^{-1}$. The maximum number of seeds was detected in the S2 variety with 22.3 seed pod$^{-1}$, while the minimum number of seeds in the pod was noted in the Bn4 genotype with

6.7 seed pod$^{-1}$. The maximum and minimum 1000-seed weights of 3.5 and 0.6 g were obtained from S2 variety and Bn1 genotype in the same order.

*Table 5. Effect of the genotypes on plant height, number of branches, number of pods, number of seeds, 1000-seed weight, seed and crude oil yield of Brassica spp. Number of pods plant$^{-1}$*

| | Plant height (cm) | | | Number of branches (branch plant$^{-1}$) | | | Number of pods (pod plant$^{-1}$) | | | Number of seeds (seed pod$^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Genotype | 2020 | 2021 | Mean | 2020 | 2021 | Mean | 2020 | 2021 | Mean | 2020 | 2021 | Mean |
| Br1 | 153.0f-h | 107.6i | 130.3c-e | 6.2c-g | 6.7b-e | 6.4bc | 324.8d-i | 489.3bc | 407.1b-d | 18.5b-e | 16.8c-f | 17.7b-d |
| Br2 | 141.4i | 84.0lm | 122.7e | 6.0d-h | 6.2c-g | 6.1b-d | 297.8d-j | 364.0d-f | 330.9c-g | 21.8b | 18.0c-e | 19.9b |
| Br3 | 152.2f-h | 86.3lm | 124.7e | 6.8b-e | 6.0d-h | 6.4bc | 296.6d-j | 297.0d-j | 296.8d-h | 18.1c-e | 16.3c-f | 17.2cd |
| Br4 | 145.6h | 202.9b | 120.1e | 6.5b-f | 5.7d-h | 6.1b-d | 233.7g-j | 304.2d-j | 268.9f-h | 19.6bc | 16.5c-f | 18.0bc |
| Br5 | 151.3f-h | 103.8i-k | 122.2e | 5.5e-h | 4.5h | 5.0d | 343.6d-g | 329.9d-i | 336.7c-f | 16.3c-f | 16.8c-f | 16.6c-e |
| Br6 | 156.4e-h | 105.3ij | 122.4e | 5.5e-h | 5.3e-h | 5.4cd | 201.1j | 266.7e-j | 233.9h | 19.5bc | 16.4c-f | 18.0bc |
| Bn1 | 257.1a | 91.0j-m | 225.5a | 8.7a | 8.0ab | 8.3a | 386.3c-e | 771.8a | 579.0a | 7.6h | 7.4h | 7.5g |
| Bn3 | 257.0a | 99.7i-l | 225.4a | 7.8a-c | 8.5a | 8.1a | 350.8d-g | 820.3a | 585.5a | 6.3h | 7.6h | 6.9g |
| Bn4 | 82.3m | 96.8i-m | 138.5cd | 4.8gh | 8.9a | 6.8b | 209.8ij | 552.8b | 381.3b-d | 5.2h | 8.2h | 6.7g |
| Bjo1 | 171.2de | 97.5i-m | 127.6de | 5.4e-h | 5.3e-h | 5.4cd | 243.2f-j | 255.5f-j | 249.3gh | 16.2d-f | 14.5fg | 15.4de |
| Bjo2 | 158.2e-g | 103.9i-k | 122.3e | 6.7b-e | 5.0f-h | 5.8b-d | 352.0d-g | 231.4g-j | 291.7e-h | 16.5c-f | 15.6e-g | 16.0c-e |
| Bjo5 | 172.5de | 97.3i-m | 187.7b | 6.1d-h | 4.8gh | 5.4cd | 319.0d-j | 550.0b | 434.5b | 16.7c-f | 8.2h | 12.4f |
| Bj1 | 175.9d | 94.5i-m | 139.8c | 7.2a-d | 5.5e-h | 6.4bc | 356.0d-f | 336.9d-f | 346.4c-f | 17.1c-f | 12.3g | 14.7ef |
| Bj3 | 171.0de | 93.0i-m | 138.1cd | 5.9d-h | 6.0d-h | 6.0b-d | 397.1cd | 349.8d-g | 373.4b-e | 15.6e-g | 17.1c-f | 16.3c-e |
| Bj4 | 159.3e-g | 88.5k-m | 125.2e | 6.4b-f | 5.5e-h | 5.9b-d | 321.6d-i | 303.0d-j | 312.3d-h | 17.4c-f | 16.0ef | 16.7c-e |
| Bj9 | 156.9e-h | 193.9bc | 128.3c-e | 5.4e-h | 5.0f-h | 5.2d | 218.1h-j | 315.7d-j | 266.9f-h | 17.2c-f | 17.9c-e | 17.5cd |
| S1-ISCI-99 | 177.3d | 193.9bc | 137.0cd | 6.3b-g | 5.0f-h | 5.6cd | 284.0d-j | 298.5d-j | 291.3e-h | 16.0ef | 17.3c-f | 16.6c-e |
| S2-Excalibur | 163.0d-f | 194.8b | 130.3c-e | 5.9d-h | 5.8d-h | 5.8b-d | 265.9f-j | 260.6f-j | 263.2f-h | 26.1a | 18.4b-e | 22.3a |
| | 166.74a | 118.57b | | 6.3 | 6.0 | | 300.05b | 394.3a | | 16.2a | 14.5b | |
| CV (%) | | | 8.28 | | | 18.42 | | | 24.64 | | | 15.45 |

| | 1000-seed weight (g) | | | Seed yield (kg ha$^{-1}$) | | | Crude oil yield (kg ha$^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|
| Genotype | 2020 | 2021 | Mean | 2020 | 2021 | Mean | 2020 | 2021 | Mean |
| Br1 | 1.9k | 2.1ij | 2.0i | 3657bc | 1948jk | 2802c-e | 993d-f | 464m-o | 729fg |
| Br2 | 1.9k | 2.4e-g | 2.1h | 3831bc | 2685e-g | 3258ab | 1402c | 845f-h | 1123ab |
| Br3 | 2.0jk | 2.3gh | 2.2f-h | 4058b | 2293g-j | 3175a-c | 1406b | 677g-k | 1042bc |
| Br4 | 2.0jk | 2.4e-g | 2.2f-h | 3487c | 2113h-j | 2800c-e | 1045b | 669h-l | 857de |
| Br5 | 2.0jk | 2.4e-g | 2.2f-h | 3785bc | 2553e-h | 3169a-c | 1135c | 764f-i | 949cd |
| Br6 | 2.0jk | 2.5d-f | 2.2f-h | 4080b | 2630e-h | 3355ab | 1463b | 722f-i | 1093bc |
| Bn1 | 0.6n | 0.6n | 0.6j | 1108m | 1983i-k | 1545h | 271p | 504l-o | 388jk |
| Bn3 | 0.7n | 0.6n | 0.7j | 1402lm | 2455e-j | 1928g | 380op | 621i-n | 501ij |
| Bn4 | 0.8lm | 0.6n | 0.7j | 2910d-f | 2164g-j | 1227h | 77q | 549j-o | 313k |
| Bjo1 | 2.4f-h | 2.2hi | 2.3d-f | 3571bc | 2013i-k | 2792de | 1066c | 458no | 762ef |
| Bjo2 | 2.6cd | 2.3gh | 2.4cd | 2875d-f | 2160g-j | 2518ef | 800f-h | 530k-o | 665f-h |
| Bjo5 | 2.9b | 0.9l | 1.9i | 1519k-m | 1142m | 1330h | 517k-o | 277p | 397jk |
| Bj1 | 2.3gh | 2.3gh | 2.3d-f | 2373f-j | 2188g-j | 2280fg | 712g-j | 518k-o | 615g-i |
| Bj3 | 2.3gh | 2.5d-f | 2.4cd | 3315cd | 2923de | 3119b-d | 1062cd | 725f-i | 893d |
| Bj4 | 2.3gh | 2.4e-g | 2.3d-f | 2511e-i | 2420e-j | 2465ef | 888d-f | 598i-n | 743ef |
| Bj9 | 2.7bc | 2.4e-g | 2.6b | 2140h-j | 2218g-j | 2179fg | 632h-m | 530k-o | 581hi |
| S1-ISCI-99 | 2.6de | 2.3gh | 2.5cd | 2149g-j | 1933j-l | 2041g | 551j-n | 519k-o | 535i |
| S2-Excalibur | 3.5a | 2.5d-f | 3.0a | 4897a | 2188g-j | 3542a | 1709a | 735f-i | 1222a |
| Mean | 2.1a | 2.0b | | 2836a | 2222b | | 895a | 595b | |
| CV(%) | | | 5.83 | | | 14.97 | | | 16.08 |

**, significantly different at 0.01 level of significance using LSD test

The maximum and minimum seed yields of 3542.0 kg ha$^{-1}$ and 1227.3 kg ha$^{-1}$ were obtained from the S2 variety, and the minimum seed yield was determined from the Bn4 genotype. Whereas the maximum crude oil yield was determined to be 1221.7 kg ha$^{-1}$ from the S2 variety, the minimum crude oil yield was obtained with 313.0 kg ha$^{-1}$ in Bn4 genotypes (Table 5). The results revealed that differences determined in terms of yield and morphological traits among the species and genotypes in this study are consistent with the findings of GIZLENCI (2017) and GUNASEKERA *et al*. (2006).

## CONCLUSION

The *Brassica juncea*, *B. nigra*, and *B. rapa* ssp. *oleifera* genotypes used in the study were grown during autumn under semi-arid climatic and rainfed ecological conditions in Ankara, Türkiye, during 2019-20 and 2020-21. The results of the study indicated that

- Growth, development, and yield showed a significantly important interaction among years and genotypes.

- Significant interaction among years and genotypes was reflected in the maximum seed (4897 kg ha$^{-1}$) and crude oil yield (1709 kg ha$^{-1}$) detected using Standard 2 (*B. napus*-Excalibur) in 2019-20, the maximum seed (2923 kg ha$^{-1}$) and crude oil yield (845 kg ha$^{-1}$) were noted for Bj3 and Br2 genotypes in 2020-21, in the same order. These values were higher during the first year compared to the values noted during the second year.

- The Bj3 (*B. juncea*) and Br2, Br3, Br5 and Br6 (*B. rapa* ssp. *oleifera*) genotypes showed reduced values compared to the Standard2 variety in the first year. The standard varieties were more affected by negative growth conditions in the second year and showed yield and quality performance close to or below these genotypes.

- The potential new variety or the Br2, Br3, Br5, Br6 and Bj3 genotypes were more stable to environmental changes during two years and appeared superior in performance for seed and crude oil yield with higher values compared to the other genotypes.

- The genotypes can be further exploited in variety improvement programs through selection and hybridization.

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## ODREĐIVANJE OSOBINA RASTA I PRINOSA NEKIH VRSTA SLAČICA U POLUSUŠNIM USLOVIMA CENTRALNE ANADOLIJE

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Izvod

*Brassica nigra* i *B. juncea* su dve ekonomski važne vrste koje se koriste kao začini; i *B. juncea, B. rapa* ssp., *B. oleifera* i *B. nigra* se koriste za ekstrakciju industrijskog ulja iz semena. Poređenje potencijala 16 genotipova *Brassica* sa 2 standardne sorte urađeno je u pogledu njihove fenologije, morfologije i prinosa u uslovima jesenje setve tokom 2019-20 i 2020-21 u polu-aridnim klimatskim uslovima Centralne Anadolije, u Ankari, Turska. Eksperiment je izveden u randomizovanom kompletnom blok dizajnu sa četiri ponavljanja.

Rezultati su ukazali na statistički značajnu interakciju genotip × godina između svih genotipova za visinu biljke, broj grana, broj mahuna, broj semena, masu 1000 semena, prinos semena i prinos sirovog ulja *Brassica* spp. Pojava semena, faza formiranja rozete, 50% cvetanja i 50% formiranje mahuna *Brassica* spp. varirala je prema vrsti i godinama. Dok su maksimalni i minimalni prinosi sirovog ulja od 1222 kg ha-$^{1}$ dobijeni iz Standarda 2 (*B. napus*-Ekcalibur) i 313 kg ha-$^{1}$ iz genotipa Bn4; Br2 (1123 kg ha-$^{1}$), Br3 (1042 kg ha-$^{1}$), Br6 (1093 kg ha-$^{1}$), Br5 (949 kg ha-$^{1}$) *B. rapa* ssp., oleifera i Bj3 (893,3 kg ha-$^{1}$) *B. juncea* genotipovi su izgledali superiorniji u performansama u poređenju sa drugim genotipovima. Ovi genotipovi se mogu dalje koristiti u različitim programima poboljšanja kroz selekciju i hibridizaciju.

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