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Morphological characterization and relationships among some important wild and domestic Turkish mustard genotypes (*Brassica* spp.)

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Abstract: Mustards occupy an important place among oilseed species due to their considerable economic and nutritional value and multiple uses. This study made use of 77 mustard genotypes collected from the USDA gene bank and diverse ecologies of Turkey to determine the extent of morphologic variability among them. The genotypes were screened to select genotypes appropriate for use in mustard breeding programs during 2015–16 and 2016–17 under the Mediterranean rainfed conditions of Yenimahalle (spring sowing and autumn sowing) and Haymana (spring sowing). Cluster analysis showed significant diversity among the genotypes. Promising genotypes with different genetic backgrounds for spring and autumn sowing included *BJ-A2*, *BJ-A99*, *BJ-A20*, *BJ-AC1*, and *BJ-AK* and *BJ-A2*, *BJ-A3*, *BJ-AK*, *BJ-A10*, *BJ-B26*, *BJ-B5*, *BJ-AC1*, and *BJ-A14*, respectively. The study concludes that a systematic selection of genotypes from a group of mustard genotypes pooled for crude oil content and seed yield traits could establish a favorable base and facilitate breeding targeted against biotic and abiotic stress in advanced spring and autumn breeding programs.

Key words: *Brassica* spp., mustard, oil, seed yield, morphological characterization

1. Introduction

The genus *Brassica*, family Brassicaceae (Cruciferae), comprises a diverse number of plant species and provides one of the most extensive and varied range of end products used by human beings. Their seeds are among the oldest recorded spices with use and cultivation dating to 5000 years BC (Raymer, 2002; Watson and Preedy, 2010; Campbell et al., 2016).

The dicotyledonous family Brassicaceae has 338 genera and 3709 species (Warwick et al., 2006). Brassicaceae includes economically important industrial oilseed, spice, vegetable, and fodder crops and exhibits extreme morphological diversity and many crop species (Li et al., 2017). *Brassica rapa* L. (rapeseed), *B. juncea* L. (brown mustard), *B. arvensis* L. (charlock), and *B. nigra* L. (black mustard) are some of the important species of the family Brassicaceae. *Brassica juncea* and *B. rapa* are used as an oilseed crop and leafy vegetable, respectively (Warwick et al., 2006; Sadia et al., 2009). Generally, *B. nigra* and *B. arvensis* are used to induce resistance against biotic stress (tolerance to insects, diseases, and pests), abiotic resistance (soil salinity, acidity, and drought tolerance, etc.), and early maturation (Rollins, 1981).

Brassica rapa [AA (n: 10)] and *B. nigra* [BB (n: 8)] are two basic diploid species among these examples that lead to the amphidiploid species *B. juncea* [AABB (n: 18)] through interspecific hybridization of *B. rapa* × *B. nigra*, as modeled in U's triangle (Nagaharu, 1935; Gomez-Campo et al., 1999; Li et al., 2017).

Information on diversity and relationships among and within landraces is desirable for the identification, conservation, and utilization of genetic resources in any breeding program in mustard (Rabbani et al., 1998) and rape (Ilyasi et al., 2018). Previous studies have shown that a number of breeders have screened a large volume of material in oilseed crops, studying morphologic and genetic variability before direct introduction or hybridization for a specific program (Ali et al., 2003; Azam et al., 2013; Neeru et al., 2015; Naheed et al., 2016; Jan et al., 2017).

Seed yield and oil quality of mustard are affected by genetic, ecological, and agronomic conditions such as plant density, irrigation, sowing time, and fertilizer (Johnson et al., 2003). Mustard plants behave differently under different sowing seasons. Temperature is a major factor affecting crop growth, development, and productivity. Mustard is known to grow both in places where winters are mild with a late autumn and where winters are hard (Wu et al., 2011). Rapeseed and mustard cultivars are classified as winter or spring types according to the vernalization required to induce flowering. Winter cultivars are usually

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high-yielding compared to spring cultivars, but they can only be grown profitably in areas where they can survive winter (Butruille et al., 1999).

The aim of the current study was to screen morphologically diverse and superior wild and domestic Turkish mustard genotypes belonging to 4 species for subsequent use in hybridization and as breeding parent lines.

2. Materials and methods

2.1. Plant material

The study utilized 77 mustard genotypes from 4 *Brassica* species as research material. These were selected from different mustard genotypes obtained from the USDA gene bank and genotypes collected from diverse ecologies in Turkey. Detailed information about the *Brassica* species used in the study is given in Table 1.

2.2. Field experiments, observations, and data analysis

All genotypes were sown during the 2015–16 and 2016–17 growing seasons at experimental fields located in Yenimahalle (spring and autumn) (39°57′ 20.776′′N, 32°48′ 49.154′′; 925 m altitude) and Haymana (spring) (39°26′ 18.87′′N, 32°22.691′′; 1050 m altitude) under characteristic semiarid climatic and rainfed ecological conditions.

Meteorological data pertaining to the vegetation period (from September to August) of 2015–16 and 2016–17 and long-term climatic conditions of Yenimahalle and Haymana are given in Table 2.

Soil analysis during 2015–16 and 2016–17 was performed on random soil samples collected from depths of 0–20 cm and 21–40 cm (Table 3).

Each genotype was sown in a 3-rowed plot of 3 m in length with unreplicated row spacing of 30 cm (Kayaçetin et al., 2018). Utilizing 5 randomly selected plants, all genotypes were characterized as follows: days to emergence, days to 50% flowering, days to harvest, plant height, plant lateral branches, plant pods, thousand-seed weight, seed yield, and crude oil content. Growth parameters including seed weight and yield of individual genotypes were measured in middle single rows for each genotype. All genotypes were grown under natural conditions without fertilizer or pesticides to measure their potential under natural conditions. The study used 77 genotypes in the experiment. As *B. rapa* could not transform from the vegetative to generative phase at either location during 2 years of spring sowing, only 60 genotypes were evaluated through cluster analysis for seed yield and crude oil content. Similarly, due to cold damage, results could not be obtained for the *BJ-A20* and *BJ-AC2* genotypes of *B. juncea* during both years in autumn sowing. Therefore, only 75 genotypes were cluster-evaluated during autumn sowing.

The seeds of these genotypes were harvested upon achieving ~8.5% moisture content at maturity (CFIA, 1999). The quantitative parameters were measured as follows (Öğütçü, 1979):

1) Days to emergence: Number of days from seed sowing until 75% of plants had at least 1 flower plant^{-1}.
2) Days to 50% flowering: Number of days from seed sowing until 50% of plants showed at least 1 flower plant^{-1}.
3) Days to harvest: Number of days from seed sowing until 75% of plants of the genotype had dried or turned yellow before seed maturation.
4) Plant height (cm): Distance from soil surface to top of plant at maturity.
5) Number of lateral branches plant^{-1} at maturity (branches plant^{-1}).
6) Number of pods plant^{-1} at maturity (pods plant^{-1}).
7) Thousand-seed weight (g): Weight of 100 randomly selected dried seeds was calculated and then converted to 1000-seed weight by multiplying by 10.
8) Seed yield (g): Total seed weight of individual genotypes at ~8.5% moisture content.
9) Crude oil content (%): Powdered mustard samples (10 g) from each genotype were hexane-extracted using a Gerhard 2000 apparatus to determine oil content.

2.3. Statistical analysis

The experimental data for seed yield and oil content were cluster analyzed using JMP statistical software.[1] Averages of the remaining quantitative traits were evaluated to assess variation among genotypes.

3. Results

Seed yield and crude oil content data pertaining to spring sowing for Yenimahalle (Table 4; Figure 1), spring sowing for Haymana (Table 5; Figure 2), and autumn sowing for Yenimahalle (Table 6; Figure 3) were subjected to cluster analysis using average values for seed yield and crude oil content from data pooled over 2 years. Mean values based on the morphological characteristics mentioned in Section 2.2 are shown in Table 7 (Yenimahalle location for spring sowing), Table 8 (Haymana location for spring sowing), and Table 9 (Yenimahalle location for autumn sowing).

3.1. Yenimahalle spring sowing

Cluster analysis based on seed yield and crude oil content traits divided the 60 genotypes into 4 clusters (Figure 1, Table 4). The maximum number of genotypes (21) was present in group II, followed by 14 in group III and 19 in group IV.

Group I consisted of 6 genotypes that were separated based on high seed yield and medium oil content (Table 7). The genotypes *BJ-AK* and *BJ-AC1* were superior, with increases of 14.3% and 11.0% in seed yield compared to mean seed yield, respectively.

[1]https://www.jmp.com

Table 1. Information on the country of origin and seed color of *Brassica* genotypes.

Species	No.	Genotype	Seed color	No.	Genotype	Seed color
Brassica juncea	1	*BJ-A2-Turkey, İzmir*	Brown	23	*BJ-B16-Canada*	Brown
	2	*BJ-A3-Turkey*	Brown	24	*BJ-B17-Canada*	Brown
	3	*BJ-A4-Turkey*	Brown	25	*BJ-B18-United States, California*	Yellow
	4	*BJ-A5-Turkey, Tekirdağ*	Brown	26	*BJ-B20-Russian Federation*	Yellow-brown
	5	*BJ-A6-Turkey, Kayseri*	Brown	27	*BJ-B21-Russian Federation*	Brown
	6	*BJ-A7-Turkey, Tekirdağ*	Brown	28	*BJ-B22-China, Xizang*	Brown
	7	*BJ-A9-Turkey, Tekirdağ*	Brown	29	*BJ-B23-Pakistan*	Brown
	8	*BJ-A10-Turkey, Kırklareli*	Brown	30	*BJ-B24-Germany*	Brown
	9	*BJ-A11-Turkey, Edirne*	Brown	31	*BJ-B25-Germany*	Brown
	10	*BJ-A12-Turkey*	Brown	32	*BJ-B26-Italy, Calabria*	Yellow
	11	*BJ-A14-Turkey, Tekirdağ*	Brown	33	*BJ-B27-United States, Minnesota*	Brown
	12	*BJ-B4-Turkey*	Brown	34	*BJ-B28-United States, Minnesota*	Brown
	13	*BJ-B5- Turkey, Tekirdağ*	Brown	35	*BJ-B30-India*	Brown
	14	*BJ-B6-India*	Brown	36	*BJ-B31-India*	Brown
	15	*BJ-B7-India, Rajasthan*	Brown	37	*BJ-B32- India*	Brown
	16	*BJ-B8-Pakistan, Punjab*	Brown	38	*BJ-B33- India*	Brown
	17	*BJ-B9- Pakistan, Punjab*	Brown	39	*BJ-AC1- India*	Brown
	18	*BJ-B10-India*	Brown	40	*BJ-AC2- India*	Yellow
	19	*BJ-B12-Pakistan*	Brown	41	*BJ-A99-India*	Yellow
	20	*BJ-B13-China*	Yellow	42	*BJ-A20-India*	Yellow
	21	*BJ-B14-China*	Brown	43	*BJ-AK-Turkey, Konya*	Brown
	22	*BJ-B15-Pakistan*	Brown			
Brassica nigra	44	*BN-A15-Turkey, Burdur*	Brown	50	*BN-A21-Turkey, Ankara*	Brown
	45	*BN-A16-Turkey*	Brown	51	*BN-B37-Israel*	Brown
	46	*BN-A17-Turkey*	Brown	52	*BN-B36-Israel*	Brown
	47	*BN-A18-Turkey*	Brown	53	*BN-B38-Turkey, Burdur*	Brown
	48	*BN-A19-Turkey*	Brown	54	*BN-B53-Italy*	Brown
	49	*BN-A20-Turkey*	Brown			
Brassica rapa	55	*BR-A27-Turkey*	Brown	63	*BR-A38-Turkey, Bursa*	Brown
	56	*BR-A28-Turkey, Samsun*	Brown	64	*BR-A39-Turkey, Kocaeli*	Brown
	57	*BR-A29-Turkey, Samsun*	Brown	65	*BR-A40-Turkey, Tokat*	Brown
	58	*BR-A31-Turkey, Edirne*	Brown	66	*BR-A42-Turkey, İstanbul*	Brown
	59	*BR-A32-Turkey, Balıkesir*	Brown	67	*BR-A43-Turkey, Tekirdağ*	Brown
	60	*BR-A33-Turkey, Balıkesir*	Brown	68	*BR-A46-Turkey, Tekirdağ*	Brown
	61	*BR-A36-Turkey, Bursa*	Brown	69	*BR-A48-Turkey, Tekirdağ*	Brown
	62	*BR-A37-Turkey, Bursa*	Brown			
Brassica arvensis	70	*BA1-Turkey, Kırşehir*	Brown	74	*BA6-Turkey, Koçhisar*	Brown
	71	*BA2-Turkey, Tokat*	Brown	75	*BA7-Turkey, Şanlıurfa*	Brown
	72	*BA3-Turkey, Haymana*	Brown	76	*BA8-Turkey, Tekirdağ*	Brown
	73	*BA4-Turkey, Kazan*	Brown	77	*BA9-Turkey, Ankara*	Brown

All flowers are yellow.

Table 2. Monthly meteorological data of *Brassica* during growing seasons in the study areas.

Location	Climatic factors	Years	September	October	November	December	January	February	March	April	May	June	July	August	Total or average
Yenimahalle	Precipitation (mm)	Long years	17.5	31.8	34.2	42.0	40.2	33.0	36.7	46.7	49.9	34.2	14.3	13.1	393.6
		2015–16	6.1	42.4	22.2	5.7	53.9	39.5	52.0	19.6	51.3	21.1	0.0	39.4	353.2
		2016–17	11.1	4.0	23.7	47.9	28.1	7.5	46.1	19.8	96.2	102.8	0.0	13.0	400.2
	Relative humidity (%)	Long years	49.1	60.5	69.7	76.5	76.4	70.7	63.2	59.0	56.5	52.1	45.1	45.3	60.3
		2015–16	39.3	65.1	61.2	77.4	77.9	69.5	62.3	45.9	59.2	45.2	35.4	42.5	56.7
		2016–17	45.4	53.9	53.8	74.1	76.4	66.5	59.6	49.8	55.7	58.3	38.4	45.8	56.5
	Average temperature (°C)	Long years	19.0	13.1	6.8	2.3	0.4	2.3	6.4	11.5	16.2	20.3	23.8	23.5	12.1
		2015–16	23.3	14.4	8.6	0.0	0.5	7.3	8.2	14.9	15.4	22.8	25.5	25.7	13.9
		2016–17	19.2	13.7	6.9	–0.3	–1.3	3.1	8.1	11.2	15.7	20.3	25.5	24.7	12.2
	Maximum temperature (°C)	Long years	32.6	27.6	19.7	13.9	11.9	14.7	21.4	25.7	29.3	33.6	36.2	35.8	36.2
		2015–16	34.6	26.4	21.2	13.2	15.0	21.3	23.4	28.1	29.3	36.9	38.1	36.6	38.1
		2016–17	32.9	28.1	21.5	10.1	9.2	18.7	19.9	27.2	29.2	35.8	38.3	37.8	38.3
	Minimum temperature (°C)	Long years	6.6	1.1	–3.8	–8.2	–11.5	–9.9	–5.9	–0.8	4.1	8.1	11.4	11.5	–11.5
		2015–16	13.8	2.3	–1.8	–9.6	–15.5	–6.1	–2.4	0.5	5.9	9.2	12.7	13.3	–15.5
		2016–17	5.3	–0.1	–4.9	–9.7	–10.5	–12.0	–1.5	–1.0	5.0	9.0	14.2	13.3	–10.5
Haymana	Precipitation (mm)	Long years	16.2	7.0	7.2	43.6	42.2	4.5	16.3	12.8	45.3	13.4	1.2	15.5	225.2
		2015–16	4.0	39.9	10.3	2.2	54.7	28.0	32.0	12.9	45.1	9.3	0.1	18.2	256.7
		2016–17	10.7	19.2	20.0	33.8	20.2	5.4	32.6	14.8	27.8	25.2	0.4	26.2	236.3
	Relative humidity (%)	Long years	49.5	66.1	75.4	84.9	88.6	82.1	72.7	64.7	61.9	57.4	43.4	43.3	65.8
		2015–16	48.2	78.0	68.5	86.2	90.9	82.0	76.1	52.6	60.0	47.7	39.9	45.5	64.6
		2016–17	49.5	54.8	56.1	72.4	77.4	70.1	62.1	54.4	56.9	57.6	41.8	48.5	58.5
	Average temperature (°C)	Long years	17.7	11.1	5.4	0.8	–1.4	0.8	4.7	9.5	14.3	18.6	22.8	22.6	10.6
		2015–16	21.1	12.5	6.9	–2.0	–1.5	5.1	5.8	12.0	12.8	19.3	22.4	22.6	11.4
		2016–17	16.1	11.3	4.4	–2.9	–4.8	–0.3	5.2	8.2	13.0	17.3	22.6	22.1	9.4
	Maximum temperature (°C)	Long years	31.9	25.2	19.2	14.4	11.1	14.2	20.4	23.6	27.4	31.8	35.8	34.9	35.8
		2015–16	33.9	25.6	18.8	12.6	13.8	20.1	22.3	27.2	26.9	31.8	36.1	34.0	36.1
		2016–17	30.2	25.9	19.9	10.0	3.7	13.9	17.7	23.2	27.4	33.7	35.4	34.2	35.4
	Minimum temperature (°C)	Long years	4.8	0.1	–7.4	–10.8	–15.5	–12.4	–7.7	–2.2	2.6	6.7	9.8	10.1	–15.5
		2015–16	9.7	1.3	–3.6	–11.5	–27.5	–8.3	–5.7	–1.3	4.0	5.7	9.7	10.2	–27.5
		2016–17	1.9	–1.1	–8.1	–14.6	–17.4	–17.5	–4.4	–3.2	3.6	5.7	10.9	10.2	–17.4

Data were obtained from the Ankara Meteorology Station.

Table 3. Soil sample features from experimental areas.

Location	Year	Depth (cm)	Texture	Saturation content (%)	Total salt (%)	pH	Lime (%)	Phosphorus (P)	Potassium (K)	Organic substance (%)
Yenimahalle	2016	0–20	Clay loamy	56.0	0.014	8.00	7.5	8.3	174.7	1,15
		20–40	Clay loamy	62.0	0.015	7.97	7.0	9.1	187.8	1,36
		Average		59.0	0.015	7.99	7.3	8.7	181.2	1.26
	2017	0–20	Clay loamy	56.0	0.025	7.81	5.3	9.3	126.0	1.35
		20–40	Clay loamy	56.0	0.025	7.81	5.2	10.5	240.0	1.28
		Average		56.0	0.025	7.81	5.3	9.9	183.0	1.32
Haymana	2016	0–20	Clay loamy	69.0	0.018	7.97	27.2	7.9	244.5	1.34
		20–40	Clay loamy	66.0	0.025	8.10	28.5	4.8	170.4	1.10
		Average		67.5	0.022	8.04	27.9	6.4	207.5	1.22
	2017	0–20	Clay loamy	57.0	0.031	7.85	28.1	3.6	255.0	1.56
		20–40	Clay loamy	62.0	0.028	7.94	32.3	9.2	179.0	1.06
		Average		59.5	0.030	7.90	30.2	6.4	217.0	1.31

Data were obtained from the Soil Fertilizer and Water Resources Institute.

Table 4. Cluster groups in *Brassica* genotypes sown at Yenimahalle, spring sowing, for seed yield and oil content.

Cluster	Genotypes	Species
Group I	*BJ-A2, BJ-A99, BJ-B28, BJ-A20, BJ-AC1, BJ-AK*	*Brassica juncea*
Group II	*BJ-A5, BJ-B21, BJ-A7, BJ-B22, BJ-B5, BJ-B16, BJ-B26, BJ-B33, BJ-A9, BJ-B25, BJ-B27, BJ-B14, BJ-B30, BJ-B23, BJ-B7, BJ-B12, BJ-B10, BJ-B24, BJ-B15, BJ-B17, BJ-B20*	*Brassica juncea*
Group III	*BJ-A3, BJ-A4, BJ-B6, BJ-B13, BJ-A6, BJ-A10, BJ-B4, BJ-A11, BJ-B8, BJ-B31, BJ-B9, BJ-B32, BJ-AC2, BJ-B18*	*Brassica juncea*
Group IV	*BN-A15, BN-A18, BN-B37, BN-B38, BN-A17, BA3, BA4, BA8, BN-A21, BN-B36, BA9, BN-A19, BN-A20, BN-A16, BA6, BA2, BN-B53, BA7, BA1*	*Brassica nigra* *Brassica arvensis*

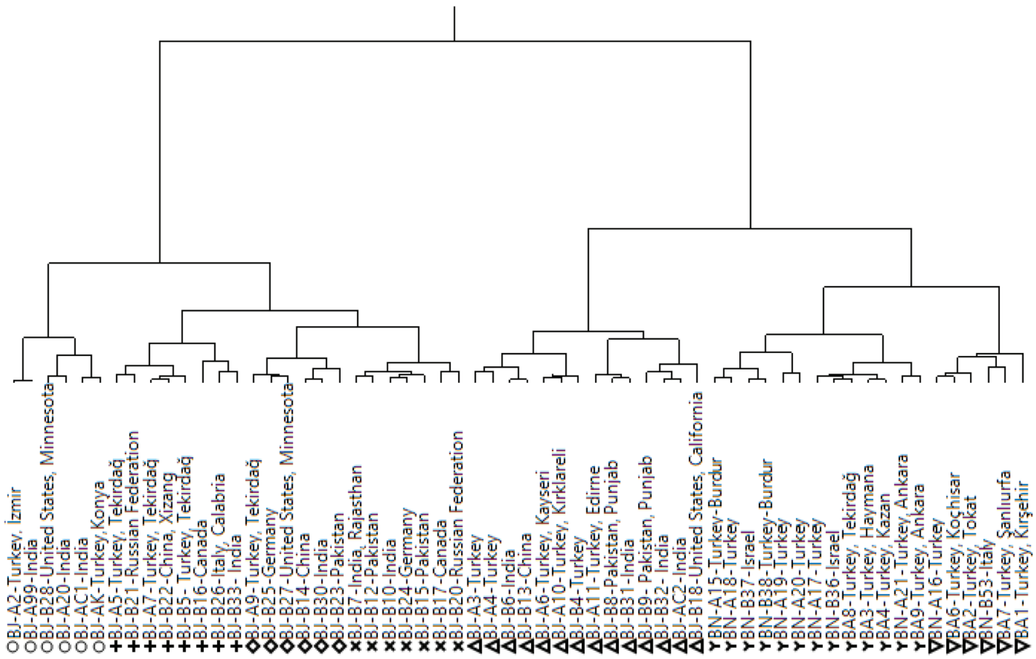

Figure 1. Dendrogram showing the relationship among 60 genotypes of *Brassica* in Yenimahalle spring sowing for seed yield and oil content.

Table 5. Cluster groups in *Brassica* genotypes sown at Haymana, spring sowing, for seed yield and oil content.

Cluster	Genotypes	Species
Group I	*BJ-A2, BJ-AK, BJ-B21, BJ-A20, BJ-A11, BJ-AC1, BJ-A99, BJ-B5, BJ-B22, BJ-B14, BJ-B25, BJ-A3, BJ-A5, BJ-B12, BJ-A7, BJ-B7, BJ-B15, BJ-B16, BJ-B24, BJ-A9, BJ-B27, BJ-B10, BJ-B20, BJ-B23*	*Brassica juncea*
Group II	*BJ-A4, BJ-B8, BJ-B28, BJ-A6, BJ-B13, BJ-B4, BJ-B9, BJ-AC2, BJ-B17, BJ-B18, BJ-B26, BJ-B33, BJ-B30, BJ-B32, BJ-B31*	*Brassica juncea*
Group III	*BN-A17, BN-A18, BN-A19, BN-A20, BN-A15, BN-A16, BA4, BN-A21, BN-B37, BN-B36, BA3, BA8, BN-B38, BN-B53, BA6, BA2, BA9, BA1, BA7*	*Brassica nigra* *Brassica arvensis*

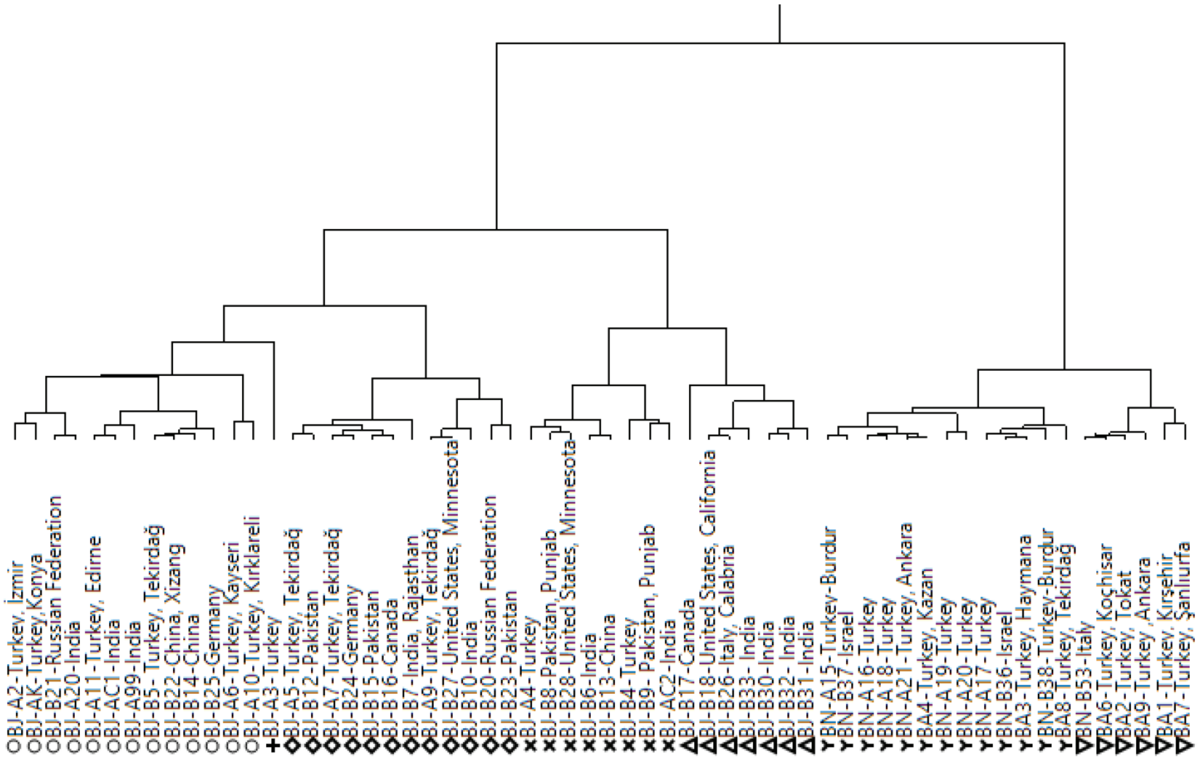

Figure 2. Dendrogram showing the relationship among 60 genotypes of *Brassica* in Haymana spring sowing for seed yield and oil content.

Table 6. Cluster groups in *Brassica* genotypes sown at Yenimahalle, autumn sowing, for seed yield and oil content.

Cluster	Genotypes	Species
Group I	*BJ-A2, BJ-A3, BJ-AK, BJ-A10, BJ-B26, BJ-B5, BJ-AC1, BJ-A14*	*Brassica juncea*
Group II	*BJ-A4, BJ-A5, BJ-A7, BJ-A6, BJ-A9, BJ-B21, BJ-B16, BJ-B20, BJ-B17, BJ-B7, BJ-B15, BJ-B12, BJ-B10, BJ-B27, BJ-B23, BJ-B24, BJ-A11, BR-A43, BJ-B13, BR-A28, BJ-B8, BR-A48, BJ-B28, BJ-B6, BJ-B9, BJ-B18, BJ-B14, BJ-B22, BJ-B25, BJ-B30, BJ-B33, BJ-B31, BR-A38, BR-A39, BR-A46, BJ-B32, BR-A31, BR-A42, BJ-A99, BN-A15, BN-A16, BN-A19, BN-A20*	*Brassica juncea* *Brassica rapa* *Brassica nigra*
Group III	*BJ-A12, BA2, BA3, BN-A18, BNA21, BJ-B4, BN-B36, BN-B38, BR-A32, BN-A17, BR-A29, BR-A27, BN-B37, BA4, BR-A33, BR-A37, BR-A40, BN-B53, BR-A36, BA8, BA1, BA7, BA6, BA9*	*Brassica juncea* *Brassica rapa* *Brassica nigra* *Brassica arvensis*

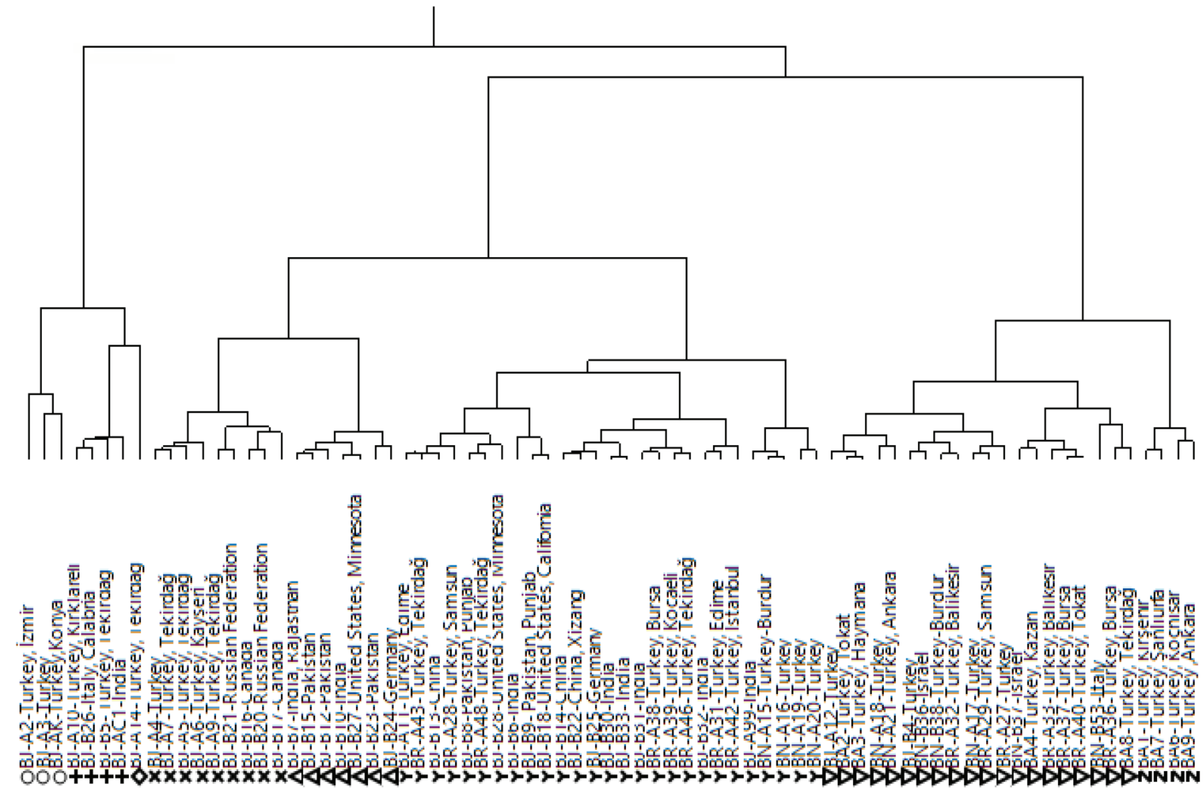

Figure 3. Dendrogram showing the relationship among 75 genotypes of *Brassica* in Yenimahalle autumn sowing for seed yield and oil content.

The genotypes of group II had medium seed yield and high crude oil content while those of group III had low seed yield and low crude oil content when a comparison was made among genotypes. Genotypes *BJ-B17* and *BJ-20* were the most promising, with increases of 5.8% and 5.1%, respectively, in crude oil content compared to mean crude oil content in group II.

Group IV genotypes were characterized by low seed yield and low crude oil content and included *B. nigra* and *B. arvensis* (Table 7).

3.2. Haymana spring sowing

Cluster analysis showed 3 different groups (Table 5). Group I consisted of 26 genotypes for seed yield and crude oil content, while group II and group III consisted of 15 and 19 genotypes, respectively (Figure 2; Table 5).

The genotypes of group I (*B. juncea*) could be separated by high seed yield and high crude oil content, group II (*B. juncea*) by medium seed yield and medium crude oil content, and group III (*B. nigra* and *B. arvensis*) by low seed yield and low crude oil content.

Genotypes *BJ-A3*, *BJ-AK*, *BJ-A2*, *BJ-B23*, and *BJ-A9* were the most promising in group I, increasing seed yield by 47.8%, 28.6%, 18.5%, 13.8%, and 10.0%, respectively, compared to mean seed yield. Genotypes *BJ-B20*, *BJ-B23*, and *BJ-B7* were the superior genotypes, increasing crude oil content by 9.4%, 7.9%, and 5.7%, respectively, compared to mean crude oil content in group II (Table 8).

3.3. Yenimahalle autumn sowing

Cluster analysis based on seed yield and oil content traits divided 75 genotypes into 3 groups (Table 6). The maximum number of genotypes (43) was present in group II, followed by group III (24) and group I (8) in descending order (Figure 3; Table 6).

The genotypes of group I could be distinguished by high seed yield and high crude oil content and belonged to *B. juncea*.

Group II genotypes included those with medium seed yield and high crude oil content belonging to *B. juncea*, *B. nigra*, and *B. rapa*.

Group III genotypes included those with low seed yield and low crude oil content: *B. juncea*, *B. nigra*, *B. rapa*, and *B. arvensis*. Genotypes *BJ-A2*, *BJ-AK*, and *BJ-A3* were the most promising genotypes, with respective seed yield increases of 33.2%, 13.2%, and 11.1% compared to mean seed yield in group I.

Genotypes *BJ-A10*, *BJ-B26*, *BJ-B5*, *BJ-AC1*, and *BJ-A14* were valuable for seed yield, as well. Genotypes *BJ-B17*, *BJ-B6*, and *BJ-A6* were superior genotypes, with respective oil

Table 7. Brassica genotypes sown at Yenimahalle, spring sowing, for morphologic characteristics, seed yield, and oil content.

Groups	Genotypes	Days to emergence	Days to 50% flowering	Days to maturity	Plant height (cm)	Number of lateral branches (branches $plant^{-1}$)	Number of pods (pods $plant^{-1}$)	Thousand-seed weight (g)	Seed yield (g)	Crude oil content (%)
Group I	*BJ-A2-Turkey, İzmir*	8.0	63.0	101.0	89.7	5.2	91.2	1.5	158.3	24.3
	BJ-B28-United States, Minnesota	8.0	60.0	101.5	119.3	5.0	111.9	1.8	169.1	26.4
	BJ-AC1-India	8.0	58.5	101.0	88.6	5.4	205.2	2.1	203.2	25.4
	BJ-A99-India	8.0	62.5	105.0	144.0	5.8	116.3	1.6	157.2	24.2
	BJ-A20-India	8.0	63.0	104.5	122.4	5.2	122.5	2.0	178.5	26.1
	BJ-AK-Turkey, Konya	8.0	62.5	102.0	108.4	4.4	108.5	2.4	209.0	25.7
	Mean	8.0	61.6	102.5	112.1	5.1	125.9	1.9	179.2	25.3
	Max.	8.0	63.0	105.0	144.0	5.8	205.2	2.4	209.0	26.4
	Min.	8.0	58.5	101.0	88.6	4.4	91.2	1.5	157.2	24.2
Group II	*BJ-A5-Turkey, Tekirdağ*	8.0	63.0	101.0	100.5	4.4	96.6	1.8	114.1	26.8
	BJ-A7-Turkey, Tekirdağ	8.0	63.0	101.0	89.8	4.0	104.1	1.8	94.1	26.0
	BJ-A9-Turkey, Tekirdağ	8.0	63.0	101.0	103.7	4.0	75.0	1.7	133.3	25.9
	BJ-B5- Turkey, Tekirdağ	8.0	63.0	99.0	95.0	6.5	102.1	2.2	99.6	25.8
	BJ-B7-India, Rajasthan	8.0	60.0	99.0	103.2	4.8	105.4	2.2	131.4	27.4
	BJ-B10-India	8.0	60.0	100.0	119.8	4.3	91.1	2.1	125.7	27.8
	BJ-B12-Pakistan	8.0	61.0	100.0	108.5	4.7	106.4	2.1	134.8	27.8
	BJ-B14-China	8.0	63.5	100.0	116.8	4.8	90.3	1.6	138.5	26.8
	BJ-B15-Pakistan	8.0	61.0	100.0	128.3	5.7	147.8	1.8	115.1	27.4
	BJ-B16-Canada	8.0	63.5	101.5	122.7	4.7	97.1	1.7	80.2	28.2
	BJ-B17-Canada	8.0	63.5	106.0	132.1	4.7	83.9	1.6	108.5	28.6
	BJ-B20-Russian Federation	8.0	63.5	102.0	139.0	6.0	120.7	2.4	128.6	28.4
	BJ-B21-Russian Federation	8.0	63.5	102.0	129.5	4.3	77.2	2.1	109.4	26.2
	BJ-B22-China, Xizang	8.0	60.0	102.0	99.1	5.0	100.8	1.9	92.8	26.2
	BJ-B23-Pakistan	8.0	60.0	101.0	104.6	4.3	102.3	2.3	158.4	27.0
	BJ-B24-Germany	8.0	63.5	101.0	125.0	4.8	78.8	2.4	119.0	27.7
	BJ-B25-Germany	8.0	63.5	101.0	112.7	5.5	85.3	1.7	147.8	25.6
	BJ-B26-Italy, Calabria	8.0	60.0	101.0	77.9	5.0	56.8	1.6	79.8	27.0
	BJ-B27-United States, Minnesota	8.0	60.0	101.0	123.7	5.2	116.9	2.1	144.4	26.0
	BJ-B30-India	8.0	60.0	101.5	92.8	4.0	81.9	2.4	133.7	26.9
	BJ-B33- India	8.0	63.5	101.0	99.5	4.9	140.5	2.4	63.1	26.6
	Mean	8.0	62.0	101.1	110.7	4.8	98.1	2.0	116.8	27.0
	Max.	8.0	63.5	106.0	139.0	6.5	147.8	2.4	158.4	28.6
	Min.	8.0	60.0	99.0	77.9	4.0	56.8	1.6	63.1	25.6

Table 7. Continued.

Group III	*BJ-A3-Turkey*	8.0	63.0	101.0	87.6	4.2	112.5	1.7	115.3	24.2
	BJ-A4-Turkey	8.0	63.0	101.0	93.0	5.2	68.8	1.8	105.3	24.9
	BJ-A6-Turkey, Kayseri	8.0	63.0	101.0	92.5	4.3	78.3	1.7	100.5	23.2
	BJ-A10-Turkey, Kırklareli	8.0	63.0	101.0	104.5	4.2	65.7	1.6	109.4	23.2
	BJ-A11-Turkey, Edirne	8.0	63.0	101.0	102.9	4.7	102.8	1.7	80.9	24.9
	BJ-B4-Turkey	14.5	63.0	99.0	95.8	5.3	130.5	1.8	106.3	22.8
	BJ-B6-India	8.0	60.0	99.0	96.4	4.2	86.5	2.3	94.7	24.1
	BJ-B8-Pakistan, Punjab	8.0	60.0	99.0	90.6	4.2	81.8	2.5	72.5	25.1
	BJ-B9- Pakistan, Punjab	8.0	60.0	99.0	89.9	3.9	75.2	2.5	70.6	23.8
	BJ-B13-China	8.0	61.0	100.0	130.5	5.3	106.6	1.9	95.8	23.9
	BJ-B18-United States, California	17.0	64.5	102.0	83.3	5.0	73.1	2.2	67.4	22.3
	BJ-B31-India	8.0	60.0	101.5	78.5	4.5	80.0	1.5	67.2	24.9
	BJ-B32- India	8.0	60.0	101.5	72.5	3.5	89.0	2.2	60.9	23.4
	BJ-AC2-India	8.0	62.5	101.0	107.3	6.9	218.4	4.0	59.3	23.2
	Mean	9.1	61.9	100.5	94.7	4.7	97.8	2.1	86.1	23.8
	Max.	17.0	64.5	102.0	130.5	6.9	218.4	4.0	115.3	25.1
	Min.	8.0	60.0	99.0	72.5	3.5	65.7	1.5	59.3	22.3
Group IV	*BN-A15-Turkey, Burdur*	15.5	63.0	109.0	72.0	3.2	40.0	0.7	12.9	22.9
	BN-A16-Turkey	15.5	85.0	117.5	85.3	4.3	38.7	0.5	22.7	20.7
	BN-A17-Turkey	15.5	85.0	117.5	87.5	3.8	37.6	0.6	31.8	22.9
	BN-A18-Turkey	15.5	85.0	117.5	87.5	4.0	52.7	0.8	15.1	23.2
	BN-A19-Turkey	15.5	85.0	117.5	79.7	4.5	57.5	0.7	10.1	25.0
	BN-A20-Turkey	15.5	85.0	117.5	73.5	5.0	56.7	0.7	24.0	24.7
	BN-A21-Turkey, Ankara	15.5	85.0	117.5	87.6	4.7	127.1	0.6	22.1	22.2
	BN-B37-Israel	12.0	60.0	108.0	71.7	5.5	65.5	0.9	19.4	23.7
	BN-B36-Israel	12.0	60.0	108.0	64.0	4.0	64.0	1.1	27.1	22.5
	BN-B38-Turkey, Burdur	12.0	60.0	108.0	63.7	4.4	74.0	1.1	19.3	23.9
	BN-B53-Italy	16.0	61.0	101.5	79.9	6.0	179.8	0.9	49.3	21.0
	BA1-Turkey, Kırşehir	8.0	63.0	103.0	49.9	3.3	37.7	1.0	4.5	19.3
	BA2-Turkey, Tokat	8.0	62.5	103.0	62.7	4.5	28.5	1.2	8.4	21.2
	BA4-Turkey, Kazan	8.0	62.0	105.0	54.2	3.8	37.7	1.2	40.5	22.6
	BA6-Turkey, Koçhisar	8.0	62.0	103.0	62.6	4.2	59.0	1.2	18.7	21.1
	BA7-Turkey, Şanlıurfa	8.0	62.0	101.0	54.2	3.8	37.7	1.0	38.3	19.9
	BA8-Turkey, Tekirdağ	8.0	62.5	103.0	75.2	3.8	77.6	0.8	34.1	22.5
	BA9-Turkey, Ankara	8.0	62.0	101.0	71.1	4.0	29.6	1.1	10.9	22.2
	BA3-Turkey, Haymana	8.0	62.5	103.0	61.8	4.0	48.1	1.1	40.2	22.8
	Mean	11.8	69.1	108.5	70.7	4.2	60.5	0.9	23.6	22.3
	Max.	16.0	85.0	117.5	87.6	6.0	179.8	1.2	49.3	25.0
	Min.	8.0	60.0	101.0	49.9	3.2	28.5	0.5	4.5	19.3
		9.5	64.2	103.4	94.4	4.6	88.9	1.7	86.4	24.6
		17.0	85.0	117.5	144.0	6.9	218.4	3.9	209.0	28.6
		8.0	58.5	99.0	49.9	3.2	28.5	0.5	4.5	19.3
Mean		9.5	64.2	103.4	94.4	4.6	88.9	1.7	86.4	24.6
Yenimahalle spring sowing Max.		17.0	85.0	117.5	144.0	6.9	218.4	3.9	209.0	28.6
Min.		8.0	58.5	99.0	49.9	3.2	28.5	0.5	4.5	19.3

Table 8. Brassica genotypes sown at Haymana, spring sowing, for morphologic characteristics, seed yield, and oil content.

Groups	Genotypes	Days to emergence	Days to 50% flowering	Days to maturity	Plant height (cm)	Number of lateral branches (branches plant^{-1})	Number of pods (pods plant^{-1})	Thousand-seed weight (g)	Seed yield (g)	Crude oil content (%)
Group I	*BJ-A2-Turkey, İzmir*	18.0	70.0	112.0	90.7	5.2	150.2	2.2	210.8	25.4
	BJ-AK-Turkey, Konya	18.0	70.0	112.0	110.6	4.2	104.5	2.6	240.7	25.9
	BJ-B21-Russian Federation	18.0	70.0	115.0	119.8	3.8	83.5	2.5	196.6	26.8
	BJ-A20-India	18.0	75.0	112.0	114.9	5.0	131.6	2.6	203.3	26.6
	BJ-A11-Turkey, Edirne	18.0	70.0	112.0	93.2	4.7	127.7	2.4	156.4	25.9
	BJ-AC1-India	18.0	70.0	112.0	82.9	3.9	104.0	2.1	149.7	25.7
	BJ-A99-India	18.0	70.0	112.0	140.1	4.0	116.1	2.5	154.7	24.9
	BJ-B5- Turkey, Tekirdağ	18.0	70.0	112.0	105.2	5.7	137.2	2.4	154.0	26.3
	BJ-B22-China, Xizang	18.0	70.0	112.0	97.2	5.2	107.7	2.3	148.4	26.4
	BJ-B14-China	18.0	70.0	112.0	108.8	4.2	107.8	2.7	150.2	26.7
	BJ-B25-Germany	18.0	70.0	115.0	98.2	4.8	117.8	2.5	162.2	26.9
	BJ-A6-Turkey, Kayseri	18.0	70.0	112.0	104.4	5.4	169.3	2.4	180.3	24.2
	BJ-A10-Turkey, Kırklareli	18.0	70.0	112.0	104.8	5.0	161.3	2.4	166.6	23.1
	BJ-A3-Turkey	18.0	70.0	112.0	108.5	5.5	207.8	2.3	329.5	25.9
	BJ-A5-Turkey, Tekirdağ	18.0	70.0	112.0	96.3	4.2	150.9	2.4	128.9	27.3
	BJ-B12-Pakistan	18.0	70.0	112.0	111.3	4.5	114.8	2.3	134.1	27.6
	BJ-A7-Turkey, Tekirdağ	18.0	70.0	112.0	97.9	4.4	167.8	2.3	145.3	27.7
	BJ-B15-Pakistan	18.0	70.0	112.0	96.5	4.3	184.8	2.9	132.4	28.3
	BJ-B16-Canada	18.0	70.0	115.0	109.2	4.3	120.0	2.3	134.0	28.0
	BJ-B7-India, Rajasthan	18.0	70.0	112.0	96.0	4.3	126.2	2.7	126.2	28.8
	BJ-A9-Turkey, Tekirdağ	18.0	70.0	112.0	116.6	5.3	208.8	2.5	191.0	27.9
	BJ-B27-United States, Minnesota	18.0	70.0	112.0	113.2	4.4	117.7	2.4	187.7	27.9
	BJ-B10-India	18.0	70.0	112.0	113.0	4.2	149.7	2.6	171.4	27.9
	BJ-B20-Russian Federation	18.0	70.0	115.0	109.3	5.0	122.5	2.9	174.1	30.0
	BJ-B23-Pakistan	18.0	70.0	112.0	90.0	3.9	116.8	3.0	199.4	29.5
	BJ-B24-Germany	18.0	70.0	115.0	121.3	4.4	96.3	2.4	143.5	28.0
	Mean	18.0	70.0	113.0	105.9	4.5	132.2	2.5	171.9	27.2
	Max.	18.0	75.0	115.0	140.1	5.7	208.8	3.0	329.5	30.0
	Min.	18.0	70.0	112.0	82.9	3.8	83.5	2.1	126.2	24.9

Table 8. Continued.

Group II	*BJ-A4-Turkey*	18.0	70.0	112.0	102.2	5.0	182.7	2.2	123.5	25.6
	BJ-B8-Pakistan, Punjab	18.0	70.0	112.0	90.5	4.2	116.0	2.6	96.0	25.5
	BJ-B28-United States, Minnesota	18.0	70.0	112.0	95.3	4.9	79.7	2.9	105.7	25.8
	BJ-B6-India	18.0	70.0	112.0	89.2	3.5	129.0	2.4	102.9	24.6
	BJ-B13-China	18.0	70.0	112.0	118.3	4.7	87.3	2.2	102.5	24.9
	BJ-B4-Turkey	18.0	70.0	112.0	100.5	4.3	103.0	2.4	115.5	23.4
	BJ-B9- Pakistan, Punjab	18.0	70.0	112.0	96.0	4.0	118.9	2.5	74.1	23.8
	BJ-AC2-India	18.0	71.0	112.0	99.1	5.9	227.1	4.6	86.0	22.8
	BJ-B17-Canada	18.0	72.0	115.0	99.1	4.8	85.5	1.8	24.8	29.3
	BJ-B18-United States, California	20.5	70.0	115.0	63.9	4.7	85.3	2.6	24.1	25.2
	BJ-B26-Italy, Calabria	18.0	70.0	112.0	94.0	4.2	106.0	1.7	25.9	27.0
	BJ-B33- India	18.0	70.0	112.0	57.0	4.2	88.0	2.1	44.7	26.7
	BJ-B30-India	18.0	70.0	112.0	63.4	3.3	84.5	2.7	61.1	25.6
	BJ-B32- India	18.0	70.0	112.0	77.5	4.2	67.6	2.3	67.1	25.9
	BJ-B31-India	18.0	70.0	112.0	80.5	4.4	64.1	1.8	76.1	26.3
	Mean	18.2	70.2	112.4	88.4	4.4	108.3	2.5	75.3	25.5
	Max.	20.5	72.0	115.0	118.3	5.9	227.1	4.6	123.5	29.3
	Min.	18.0	70.0	112.0	57.0	3.3	64.1	1.7	24.1	22.8
Group III	*BN-A15-Turkey, Burdur*	26.5	91.0	116.0	60.0	3.5	54.5	0.7	13.6	24.0
	BN-B37-Israel	21.5	91.0	116.0	63.6	5.9	55.5	1.1	21.5	23.0
	BN-A16-Turkey	26.5	91.0	116.0	66.7	5.0	71.8	0.9	15.8	23.5
	BN-A18-Turkey	26.5	91.0	116.0	85.6	4.3	76.9	0.9	11.0	24.4
	BN-A21-Turkey, Ankara	26.5	91.0	116.0	68.2	4.5	61.4	1.3	7.0	22.6
	BA4-Turkey, Kazan	18.0	70.0	112.0	103.0	4.5	36.3	1.4	9.0	23.7
	BN-A19-Turkey	26.5	91.0	116.0	78.6	5.4	80.9	0.6	7.5	24.5
	BN-A20-Turkey	26.5	91.0	116.0	88.7	4.9	68.2	0.7	5.5	25.0
	BN-A17-Turkey	26.5	91.0	116.0	62.3	5.5	81.0	0.7	25.6	24.7
	BN-B36-Israel	21.5	91.0	116.0	69.0	4.2	62.0	1.2	37.7	22.9
	BA3-Turkey, Haymana	18.0	70.0	112.0	55.7	4.7	120.3	1.6	40.2	22.8
	BN-B38-Turkey, Burdur	21.5	91.0	116.0	52.0	4.2	71.8	1.1	34.3	22.2
	BA8-Turkey, Tekirdağ	18.0	70.0	112.0	62.7	4.0	121.6	1.2	55.1	22.6
	BN-B53-Italy	18.0	88.0	116.0	59.2	5.4	105.7	1.5	30.5	21.6
	BA6-Turkey, Koçhisar	18.0	70.0	112.0	56.7	3.5	65.1	1.4	26.8	21.5
	BA2-Turkey, Tokat	18.0	70.0	112.0	64.0	4.2	77.6	2.0	25.5	21.7
	BA9-Turkey, Ankara	18.0	70.0	112.0	57.7	3.8	75.2	1.1	37.1	21.4
	BA1-Turkey, Kırşehir	18.0	70.0	112.0	45.9	3.2	33.3	1.3	12.4	20.2
	BA7-Turkey, Şanlıurfa	18.0	70.0	112.0	67.6	3.7	106.1	1.5	45.0	20.2
	Mean	21.7	82.0	114.3	66.7	4.4	75.0	1.2	24.3	22.8
	Max.	26.5	91.0	116.0	103.0	5.9	121.6	2.0	55.1	25.0
	Min.	18.0	70.0	112.0	45.9	3.2	33.3	0.6	5.5	20.2
Haymana spring sowing	Mean	19.2	73.5	113.0	89.1	4.5	109.2	2.1	101.0	25.2
	Max.	26.5	90.5	116.0	140.1	5.9	227.1	4.6	329.5	30.0
	Min.	18.0	69.5	112.0	45.9	3.2	33.3	0.6	5.5	20.2

Table 9. *Brassica* genotypes sown at Yenimahalle, autumn sowing, for morphologic characteristics, seed yield, and oil content.

Groups	Genotypes	Days to emergence	Days to 50% flowering	Days to maturity	Plant height (cm)	Number of lateral branches (branches $plant^{-1}$)	Number of pods (pods $plant^{-1}$)	Thousand-seed weight (g)	Seed yield (g)	Crude oil content (%)
Group I	*BJ-A2-Turkey, İzmir*	19.0	202.0	268.0	125.6	10.7	268.0	2.7	373.7	28.5
	BJ-A3-Turkey	19.0	205.0	268.0	124.7	13.2	519.3	2.7	280.7	30.1
	BJ-AK-Turkey, Konya	19.0	234.0	268.0	137.6	8.3	204.3	3.1	287.7	27.8
	BJ-A10-Turkey, Kırklareli	19.0	204.0	268.0	122.1	10.7	299.5	2.9	208.7	27.4
	BJ-B26-Italy, Calabria	19.0	205.0	263.0	70.1	17.8	220.9	1.7	204.8	27.9
	BJ-B5- Turkey, Tekirdağ	19.0	205.0	268.0	155.2	13.2	357.5	2.4	209.9	26.8
	BJ-AC1-India	19.0	205.0	268.0	92.7	10.0	375.0	1.2	179.3	27.3
	BJ-A14-Turkey, Tekirdağ	19.0	205.0	268.0	78.6	14.6	272.0	2.2	252.0	23.1
	Mean	19.0	208.0	267.0	113.3	12.3	314.6	2.4	249.6	27.3
	Max.	19.0	234.0	268.0	155.2	17.8	519.3	3.1	373.7	30.1
	Min.	19.0	202.0	263.0	70.1	8.3	204.3	1.2	179.3	23.1
Group II	*BJ-A4-Turkey*	19.0	202.0	268.0	113.2	9.7	195.3	2.9	142.0	29.2
	BJ-A7-Turkey, Tekirdağ	19.0	204.0	268.0	120.8	9.0	153.8	3.1	138.6	28.8
	BJ-A5-Turkey, Tekirdağ	19.0	204.0	268.0	122.1	8.2	191.5	2.9	156.7	29.1
	BJ-A6-Turkey, Kayseri	19.0	205.0	268.0	136.5	12.8	266.7	2.8	158.7	28.5
	BJ-A9-Turkey, Tekirdağ	19.0	207.0	268.0	129.0	7.6	130.8	2.7	118.3	28.5
	BJ-B21-Russian Federation	19.0	205.0	268.0	156.7	10.0	213.5	2.6	114.0	28.9
	BJ-B16-Canada	19.0	205.0	268.0	160.2	9.7	176.7	2.7	99.7	29.4
	BJ-B20-Russian Federation	19.0	205.0	268.0	155.9	9.7	219.7	2.7	107.1	29.8
	BJ-B17-Canada	19.0	205.0	268.0	134.0	7.5	257.7	2.3	137.7	30.0
	BJ-B7-India, Rajasthan	19.0	205.0	268.0	144.0	7.7	262.5	2.6	59.0	28.8
	BJ-B15-Pakistan	19.0	205.0	268.0	139.0	7.5	208.0	2.2	57.7	29.1
	BJ-B12-Pakistan	19.0	205.0	268.0	165.6	7.9	217.6	2.5	47.8	28.8
	BJ-B10-India	19.0	205.0	268.0	141.7	7.5	250.7	2.5	72.4	28.8
	BJ-B27-United States, Minnesota	19.0	205.0	266.0	137.1	6.7	211.0	2.1	72.8	29.0
	BJ-B23-Pakistan	19.0	205.0	268.0	127.2	6.7	140.5	3.0	60.4	29.4
	BJ-B24-Germany	19.0	205.0	268.0	125.5	6.9	132.7	2.1	53.4	30.0

Table 9. (Continued).

Group II	*BJ-A11-Turkey, Edirne*	19.0	206.0	268.0	119.5	7.4	215.7	3.0	71.2	26.3
	BR-A43-Turkey, Tekirdağ	19.0	244.0	281.0	77.2	6.5	160.3	1.9	62.1	26.4
	BJ-B13-China	19.0	205.0	268.0	139.0	8.0	169.2	2.4	63.6	26.1
	BR-A28-Turkey, Samsun	19.0	195.0	247.0	73.9	9.7	204.3	2.4	61.2	26.8
	BJ-B8-Pakistan, Punjab	19.0	205.0	268.0	127.6	8.0	159.0	3.0	81.0	26.8
	BR-A48-Turkey, Tekirdağ	19.0	195.0	247.0	75.7	7.2	175.7	2.1	89.1	26.8
	BJ-B28-United States, Minnesota	19.0	206.0	266.0	69.0	4.7	230.7	2.8	84.4	26.2
	BJ-B6-India	19.0	205.0	268.0	140.5	7.7	170.6	2.6	117.0	27.0
	BJ-B9- Pakistan, Punjab	19.0	205.0	268.0	133.8	7.7	172.7	2.9	112.2	26.2
	BJ-B18-United States, California	19.0	205.0	268.0	130.7	7.5	230.5	2.7	111.2	26.0
	BJ-B14-China	19.0	205.0	268.0	147.3	9.2	287.4	2.3	85.6	28.0
	BJ-B22-China, Xizang	19.0	205.0	268.0	117.0	7.8	243.0	2.7	92.4	27.8
	BJ-B25-Germany	19.0	205.0	268.0	135.3	9.8	207.2	2.4	94.0	28.2
	BJ-B30-India	19.0	206.0	266.0	64.3	5.3	135.3	2.6	73.5	27.9
	BJ-B33- India	19.0	206.0	268.0	58.5	4.5	188.0	1.8	75.5	28.0
	BJ-B31-India	19.0	206.0	268.0	82.3	6.5	141.0	2.6	71.9	27.1
	BR-A38-Turkey, Bursa	19.0	195.0	247.0	86.5	6.2	211.7	2.2	68.4	27.4
	BR-A39-Turkey, Kocaeli	19.0	195.0	247.0	88.8	6.0	195.9	2.3	82.7	27.3
	BR-A46-Turkey, Tekirdağ	19.0	195.0	247.0	77.4	7.9	106.7	2.0	78.4	27.5
	BJ-B32- India	19.0	206.0	268.0	90.4	7.0	137.5	2.4	57.9	27.6
	BR-A31-Turkey, Edirne	19.0	195.0	247.0	74.1	6.2	183.9	2.0	47.5	27.6
	BR-A42-Turkey, İstanbul	19.0	195.0	247.0	83.2	5.8	160.4	1.7	44.1	28.1
	BJ-A99-India	19.0	206.0	268.0	157.4	6.8	211.5	0.5	38.6	26.5
	BN-A15-Turkey-Burdur	19.0	199.0	253.0	70.0	5.0	78.0	0.7	32.4	26.8
	BN-A16-Turkey	19.0	199.0	253.0	165.3	8.0	191.4	0.5	31.1	26.7
	BN-A19-Turkey	19.0	199.0	253.0	152.2	5.9	134.0	0.5	9.4	27.0
	BN-A20-Turkey	19.0	199.0	253.0	117.1	4.5	109.2	0.5	5.7	27.4
	Mean	19.0	216.0	271.0	117.7	7.5	187.0	2.3	80.0	27.8
	Max.	19.0	244.0	281.0	165.6	12.8	287.4	3.1	158.7	30.0
	Min.	19.0	202.0	266.0	58.5	4.5	78.0	0.5	5.7	26.0

Table 9. (Continued).

Group III	*BJ-A12-Turkey*	19.0	206.0	268.0	86.5	16.7	286.7	2.0	54.4	24.7
	BA2-Turkey, Tokat	19.0	234.0	268.0	87.1	6.7	204.3	0.4	60.5	24.4
	BA3-Turkey, Haymana	19.0	234.0	268.0	81.6	6.5	204.3	1.5	60.4	24.5
	BN-A18-Turkey	19.0	241.0	281.0	141.8	4.8	122.2	0.8	28.1	24.9
	BN-A21-Turkey, Ankara	19.0	241.0	281.0	160.0	6.0	221.5	0.8	41.4	24.4
	BJ-B4-Turkey	19.0	202.0	268.0	121.2	7.4	205.7	2.3	65.0	25.4
	BN-B36-Israel	19.0	199.0	253.0	75.5	6.0	145.5	2.0	66.8	25.8
	BN-B38-Turkey, Burdur	19.0	199.0	253.0	85.3	6.5	127.7	2.1	51.6	25.2
	BR-A32-Turkey, Balıkesir	19.0	199.0	253.0	80.6	6.0	157.3	1.9	58.9	25.1
	BN-A17-Turkey	19.0	199.0	253.0	156.7	7.2	202.5	0.7	40.9	25.4
	BR-A29-Turkey, Samsun	19.0	199.0	253.0	87.3	6.0	175.5	1.9	40.4	25.7
	BR-A27-Turkey	19.0	199.0	253.0	79.0	6.8	127.5	1.6	37.9	26.1
	BN-B37-Israel	19.0	199.0	253.0	73.3	14.7	301.7	2.19	91.2	24.9
	BA4-Turkey, Kazan	19.0	234.0	268.0	78.9	3.8	204.3	1.6	89.1	24.4
	BR-A33-Turkey, Balıkesir	19.0	199.0	253.0	72.2	6.0	197.3	2.0	67.5	25.0
	BR-A37-Turkey, Bursa	19.0	199.0	253.0	80.5	6.7	170.5	2.1	79.0	25.1
	BR-A40-Turkey, Tokat	19.0	199.0	253.0	77.8	5.7	124.5	2.6	80.6	25.1
	BN-B53-Italy	19.0	199.0	253.0	75.1	6.2	352.7	1.7	118.6	23.5
	BR-A36-Turkey, Bursa	19.0	199.0	253.0	70.0	5.3	195.5	2.1	67.6	23.9
	BA8-Turkey, Tekirdağ	19.0	234.0	268.0	74.9	4.8	204.3	1.5	76.3	23.4
	BA1-Turkey, Kırşehir	19.0	234.0	268.0	104.7	8.0	204.3	1.9	58.9	21.7
	BA7-Turkey, Şanlıurfa	19.0	234.0	268.0	67.3	7.7	204.3	1.8	49.6	22.0
	BA6-Turkey, Koçhisar	19.0	234.0	268.0	74.0	4.5	204.3	1.7	78.7	22.0
	BA9-Turkey, Ankara	19.0	234.0	268.0	77.2	4.3	204.3	1.6	89.6	22.8
	Mean	19.0	236.0	275.0	90.4	6.8	197.9	1.7	64.7	24.4
	Max.	19.0	244.0	281.0	160.0	16.7	352.7	2.6	118.6	26.1
	Min.	19.0	202.0	268.0	67.3	3.8	122.2	0.4	28.1	21.7
Mean Yenimahalle autumn sowing Max. Min.										

content increases of 15.4%, 14.7%, and 8.8% compared to mean crude oil content in group II (Table 9).

The highest yield and crude oil content among these species was detected in *B. juncea* under both spring and autumn sowing conditions. In general, seed yield in *B. nigra* and *B. arvensis* under spring sowing was quite low at both locations, whereas the seed yield of *B. rapa*, *B. nigra*, and *B. arvensis* under autumn sowing was very low.

Tables 7–9 show various morphological traits such as plant height, branches, pods, and thousand-seed weight that displayed significant variations. Average values for these characteristics in *B. juncea* genotypes were significantly higher compared to those in other *Brassica* species.

A comparison with average values in spring sowing showed that all parameters had variation at both the Yenimahalle and Haymana locations (Tables 7 and 8). In addition, all values of all parameters between spring and autumn sowings showed variations at the Yenimahalle location (Tables 7 and 9).

Grouping was not associated with other traits due to morphological differences. Thus, it cannot be generalized that all genotypes of the same origin would always exhibit low diversity. In addition, geographical origins of the genotypes were not always related in the groups.

4. Discussion

The results of this study showed that the dendrograms grouped all genotypes belonging to a species into 3 or 4 clusters for each location or season based on similarity.

The dendrograms display a series of morphological similarities and differences among genotypes. This information reveals great variations among the tested genotypes, which may help in the selection of more stable mustard lines for development of new breeding populations and cultivars with narrower or wider adaptability.

Development of high-yielding genotypes requires knowledge of existing genetic variation related to yield and yield components (Jan et al., 2017). Since identification of morphologically based variation is important for effective evaluation and utilization of genotypes in a breeding program, screening is the only valid way to develop new cultivars for crop improvement (Gupta et al., 1991; Rabbani et al., 1998; Neeru et al., 2015; Jan et al., 2017). It is clear from the cluster analysis that the mustard genotypes used in this study have great potential to foster new cultivars, and understanding their plastic behavior could facilitate an understanding of yield components and aid in the development of planning strategies for future mustard breeding.

Seed yield and oil content are complex characters that can be determined by components reflecting positive or negative effects. In this study, the data reflect high levels of variation for seed yield and crude oil content, in line with previous studies, and confirm the desirability of predetermining the diversity and plasticity, based on desired morphological traits, of experimental genotypes entering breeding programs (Singh et al., 1987; Rukhsana et al., 2005; Marjanovic-Jeromela et al., 2007; Carpio et al., 2011; Shathi et al., 2012; Khan et al., 2014).

According to these results, different species of *Brassica* may possess important variations, in different sowing seasons and years and across locations, for plant height, plant branches, plant pods, thousand-seed weight, seed yield, and crude oil content due to differences in temperature, humidity, and precipitation, in agreement with Christensen et al. (1985), Ilyasi et al. (2018), and Kayaçetin et al. (2018). During the present investigation the range of each parameter facilitated an understanding of the immediate extent of diversity among the genotypes.

The results of this study showed that genotypes belonging to *B. juncea* were superior in morphological characteristics including seed yield and crude oil content compared to other species. Utilizing the magnitude of genetic variation available in the gene pool of *Brassica* species and screening the promising genotypes *BJ-A2*, *BJ-A99*, *BJ-A20*, *BJ-AC1*, and *BJ-AK* (spring sowing) and *BJ-A2*, *BJ-A3*, *BJ-AK*, *BJ-A10*, *BJ-B26*, *BJ-B5*, *BJ-AC1*, and *BJ-A14* (autumn sowing) for higher seed yield and crude oil content showed their potential for use in breeding programs, in agreement with Singh and Chakraborty (2003) and Iqbal et al. (2008). Going forward, this will have a significant positive effect on the performance of different related industries.

Seed yield, oil content, and the rest of the quantitative traits among genotypes at the Yenimahalle and Haymana locations showed significant variation among genotypes between autumn and spring sowing. Furthermore, seed yield and crude oil content of the genotypes increased in autumn sowing compared to the oil content observed during spring sowing over 2 years. Spring sowing, seed yield, and crude oil percentage changed between the Yenimahalle and Haymana locations. Differences in seed yield and crude oil percentage could be derived from variation in ecological conditions including air temperature and precipitation among years and locations, in agreement with Saran and Giri (1987), Shafii et al. (1992), Walton et al. (1999), and Kayaçetin et al. (2018).

Measurement of morphological variation is important for finding the best genotypes under field conditions. Identification of relationships among genotypes with a multivariate approach could lead to a better understanding of the genotypes and their behavior. The selected genotypes can be used for advanced research or for producing high oil content-yielding cultivars for spring and autumn conditions in breeding programs. Comparison of seed yield and crude oil content based on cluster analysis revealed the extent of diversity among the identified mustard genotypes in this study. The genotypes *BJ-A2*, *BJ-A99*, *BJ-A20*, *BJ-AC1*, and *BJ-AK* and the genotypes *BJ-A2*, *BJ-A3*, *BJ-AK*, *BJ-A10*, *BJ-B26*, *BJ-B5*, *BJ-AC1*, and *BJ-A14* showed stability for spring and autumn sowing, respectively. This information may be useful for effective mustard breeding.

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