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The Effect of Good Agricultural Practices on Yield Characteristics of Black Cumin Genotypes

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ABSTRACT

Black cumin (*Nigella sativa* L.) is an annually flowering medicinal plant from the Ranunculaceae family. The objective of this study was to reveal the yield characteristics of a substantial number of black cumin (*Nigella sativa* L.) genotypes under good agricultural practises without fertilization or spraying. The study was carried out in Ankara/Haymana reflecting semi-arid agricultural area of Central Anatolia in 2019 and 2020. Different black cumin genotypes collected and obtained from different agroecological regions such as Egypt, India, Pakistan, Syria, Ethiopia, Türkiye (Konya, Afyonkarahisar, Denizli, Burdur, Ankara, Diyarbakır, Bursa, Kırıkkale provinces) and a commercial cultivar (Çameli) were used and compared. The genotypes gave very different responses in terms of seed yield and yield components. The average data of the two years varied between 17.3-36.14 cm for plant height, 1.59-2.52 for branches/plant, 1.50-2.62 for pods/plant, 29.87-54.64 for seeds/capsule, 2.08-3.08 g for thousand-seed weight, 11.80-31.48 cm for first pod height and 259.6-501.0 kg/ha for seed yield. The yield was affected by climatic changes to a great extent between 259.6 kg/ha and 501.0 kg/ha in terms of seed yield. As a result of the study, these prominent genotypes were considered promising for future variety breeding and other studies.

Keywords: Black cumin, Seed yield, Genotype, Cultivar, Good agriculture practices (GAP)

1. Introduction

Nigella is a plant genus belonging to the Ranunculaceae family and includes a total of 20 species (Seçmen et al. 2000). Although 12 of such species are spread in Türkiye, black cumin seeds (*Nigella sativa* L.) is a globally well-known and widely used for flavoring and medicinal purposes. The recent increase in the cultivation and production of black cumin in the worldwide is a result of its growing popularity as a health supplement, with its seeds and oil offering a range of benefits to human health. Due to valuable phenolic compounds and antioxidant capacity, the fixed oil and secondary metabolites contained in the seed are widely used in medicine and traditional medicine today (Lutterodt et al. 2010). The composition of the seed includes 30-45% fixed oil, 0.01-0.5% essential oil, 20-30% protein, alkaloids and saponins (Kılıç 2016; Kamçı 2019). The unsaturated fatty acids present in black cumin seeds are predominantly linoleic, oleic, and palmitoleic acids, collectively accounting for approximately 79-82% of the total fatty acid composition (Asil & Konuşkan 2021; Orhan & Eroğlu 2024). Linoleic acid represents the most abundant of these acids. The essential oil of the plant was found to contain primarily thymoquinone (TQ), dithymoquinone (DTQ), thymohydroquinone (THQ), and thymol (THY) (Ghosheh et al. 1999). While black cumin seeds are used as flavouring in some foods such as pastry, cheese, pickles, and bakery products, their fixed oil and essential oil have an important role in the areas of health, food technology, cosmetics, and perfumery. As evidenced by pharmacological studies, thymoquinone, a prominent component of the essential oil, exhibits a multitude of effects, including anti-tumour, anti-bacterial, anti-oxidant, antihistamine, antidiabetic, antihypertensive, anti-inflammatory, and antimicrobial activities, as well as antifungal activity. Additionally, there is substantial evidence to suggest that thymoquinone can bolster immune system function (Rahim et al. 2022).

Nigella sativa L. is annual species originated from arid and semi-arid zones (D'Antuno et al. 2002). Dry farming conditions cause low seed yield and quality losses of black cumin in the world. It is widely grown in Thrace, Northern Anatolia, Central Western Anatolia, Lakes Region and Mediterranean regions of Türkiye. It is sown as winter in temperate regions and as summer in regions with harsh climates of Türkiye. Optimal conditions for sowing are an ambient temperature of 5 °C to 8 °C and 60% soil moisture (Rahman et al. 2020).

Due to increasing demand, there have been significant increases in black cumin production and export in Türkiye between 2012 and 2023. From 2012 to 2023, its cultivation area, production, and exports increased in general (2012; 2 299 decare, 161 tonnes, 2023: 53 358 decare, 5 386 tonnes), with the highest cultivation area (108 029 decare) and yield (10 089 tonnes) being realized in 2022 and the highest export revenue in 2021 (1 020.876 tonnes, 3 189 836 US dollars). In 2017, the year with the highest imports, 5 500.803 tons of black seed worth 5 558 042US dollars were purchased (Anonymous 2021).

However, because of black cumin production is still inadequate in Türkiye, it is necessary to expand cultivation area and to increase seed yield. New black cumin varieties with superior yield/quality characteristics, suitable for mechanization and compatible with the different agroecological conditions of Türkiye, should be also immediately bred.

Environment (edaphic factors: chemical properties of the soil such as structure, water availability and air content, nutrient uptake, soil reaction (pH); orographic factors: elevation (height above sea level), direction as well as slope exposure of the cultivation area; biotic factors: microorganisms, fungi and bacteria in the soil), climatic factors (temperature, light, water, CO_2, wind, precipitation), and agronomic practices (planting time/depth/frequency, fertilization, spraying) affect the yield and quality characteristics of black cumin. The cultivation of medicinal plants and spices within the scope of good agricultural practices is an important factor that increases the chances of competition in foreign markets and export value. The market value of medicinal and aromatic plant species and pharmaceuticals grown naturally and organically is significantly higher. While the interests of the country are protected by offering safe products to foreign markets, citizens are ensured to consume healthy, quality, and reliable products domestically. It ensures a decrease in the production costs of producers and an increase in their earnings. In addition, it serves to take necessary measures for a sustainable world thanks to its environmentally sensitive agricultural production method that protects natural resources. In this regard, the World Health Organization (WHO) has prepared Good Agricultural and Collection Practices (GACP) (2003) specifically for medicinal plants in line with the requests of member countries. Good agricultural practices (IOSTA2013) are also regulated separately for spices. In these studies, detailed explanations are given on the techniques and precautions necessary for the proper cultivation, collection, and processing of quality products. To ensure the quality of products, production must be carried out in strict compliance with GAP (Good Agricultural Practice) and GMP (Good Manufacturing Practice) rules. The effective and correct use of the plant in different industrial branches will only be possible through the development of quality, efficient, and standardized black cumin varieties and the cultivation of the plant following organic and good agricultural practices.

The plant's high adaptability has enabled its cultivation in diverse climatic zones across the country. Based on data from official records, it was cultivated in 5 provinces in 2012 but increased to 34 provinces in 2022. The black cumin plant, which occupies a significant position in the country's historical narrative, represents a crucial source of revenue from herbal exports. The foreign exchange inflow clearly demonstrates that our country's black cumin plant is of superior quality and commands a higher price in the foreign market than competing plants from other countries. However, since it is a black cumin variety developed by 2024, it is primarily cultivated by local populations. Therefore, it is very important to determine the important yield characteristics of local and introduced black cumin genotypes of different regions of Türkiye where the plant is grown most intensively in terms of sustainable agriculture with good agricultural practices.

The aim of this study is to determine the effect of good agricultural practices on the yield characteristics of 31 advanced black cumin genotypes of different origins under ecological conditions of Ankara province, the use of the genotypes with superior characteristics as a source in later variety breeding studies and raising awareness among farmers about the positive effects of good agricultural practices on the producer, the consumer, and human-environment-animal health.

2. Material and Methods

2.1. Plant material

30 genotypes of black cumin with different agronomic and morphological characteristics were obtained from domestic local populations (Ankara, Burdur, Bursa, Denizli, Konya, Eskişehir, Afyonkarahisar, Diyarbakır, Kırıkkale provinces), from international gene banks of different countries (Syria, Egypt, India, Pakistan, Ethiopia). Moreover, 'Çameli' black cumin seed variety registered by the Transitional Zone Agricultural Research Institute in 2014 were also genotype (Table 1).

2.2. The experimental area and its characteristics

This research was carried out in 2019 and 2020 in the trial fields of the Field Crops Central Research Institute (FCRI) Research and Application Farm/Ankara/Türkiye. The research area is located at an altitude of 1055 m above sea level and 39°36'55.8"N latitude and 32°40'34.1"E longitude points. The experimental plots were 5 m long, 30 cm between rows and 5 rows per plot. The seed rate was calculated as 15 kg per hectare. A distance of 250 cm was left between blocks (replications) and 50 cm between plots. The experiment was conducted in 2019 in an area that was left fallow after wheat harvest in the previous year and in 2020 in an area where Tef *(Eragrostis tef* [Zucc.] Trotter) was planted the year before. At the onset of autumn rains, the soil was plowed with a moldboard plow at a depth of 15-18 cm for stubble-plowing, and sweep and harrow was used before planting in early spring (in March). The sowing process was carried out on March 12-13, 2019, and March 4-5, 2020, by hand sowing in the rows opened with the marker. While irrigation was carried out once in May 2019, irrigation was not carried out in 2020 due to heavy rainfall. As regards the weed population, the weeds within the plots were removed by hand once before the isolation covers were laid and once after the covers were removed, and the weeds between the replications were removed twice with the help of a rotavator.

Table 1- Genotypes of black cumin used in the study

GN	*Origin*	*GN*	*Origin*
1	Denizli[1]	17	Seed Exchange[4]
2	Denizli[1]	18	Seed Exchange [4]
3	Burdur[1]	19	Seed Exchange [4]
4	Burdur[1]	20	Seed Exchange [4]
5	Ethiopia[2]	21	India[2]
6	Syria[2]	22	Bursa/ Keles/Yatıbaşı Köyü[1]
7	Egypt[2]	23	Gazi Osmanpaşa Üniv. Faculty of Agriculture
8	Syria[2]	24	Afyonkarahisar[1]
9	Denizli[3]	25	USDA- Pakistan
10	Burdur/Yeşilova-Merkez Kayadibi[3]	26	USDA- Egypt
11	Burdur/ Kemer-Elmacık-Olukderesi[3]	27	Burdur[1]
12	Konya/ Akören/Kayasu[3]	28	Kırıkkale/Halitli Köyü[1]
13	Konya/Meram/Evliyatekke[3]	29	Ankara[1]
14	Konya/ Akören/Kayasu[3]	30	Ankara[1]
15	Diyarbakır[1]	31	Çameli (cultivar)
16	Syria[2]		

GN: Genotype Numbers; [1] Local black cumin genotypes obtained from different producers cultivating *Nigella sativa* L; [2] Black cumin genotypes obtained from abroad through company Naturoil; [3] Local black cumin genotypes obtained through provincial agriculture and forestry directorates; [4] Black cumin genotypes obtained from companies Bağda (GN:17), Bahartat (GN: 18), Destan (GN: 19) and Lokman (GN: 20)

2.3. *Soil and climate characteristics of the experimental area*

An isolation study was carried out on June 12-13, 2019, and June 1-3, 2020, against the danger of foreign pollination of the black cumin plant, and the trial was preserved with gauze until the end of flowering. Within the scope of good agricultural practices, no commercial fertilizer was applied, and chemical treatment was not carried out against diseases and pests. The plants were harvested by hand between August 2-10, 2019, and between July 23-August 5, 2020. Plant height, first pod height, number of branches per plant, and number of pods per plant were calculated for 10 plants randomly selected from each plot by excluding 1 row from the edges and 0.5 m from the plot ends; the number of seeds per pod was calculated for randomly selected 20 plants; and seed yield per decare was calculated based on the plot yield.

According to the results of the analysis of the soil samples taken from 0-20 cm depth of the trial site before planting; the soil of the trial year 2019 showed a clayey (C) texture, while the trial year 2020 showed a clayey-loamy (CL) texture. Soil pH was 7.95-7.73 in 2019 and 2020, respectively, and was classified as slightly alkaline. The lime content was 30.5% and 30.0%, which are considered to be very calcareous, while the salt content (0.60 and 0.64 dS/m) was considered to be non-saline. In both trial years (in order of years); available organic matter (1.55-1.97%), phosphorus (P: 4.50-4.50 kg/da), manganese (Mn: 2.99-3.03 ppm) and zinc (Zn: 0.28-0.30 ppm) contents were at low levels, copper (Cu: 1.29-1.33 ppm) was at an adequate level, iron (Fe: 3.43-3.38 ppm) was at moderate level, magnesium (Mg: 921-905 ppm) and calcium (Ca: 7118-7420 ppm) were at a good level, and potassium (K: 207-306 kg/da) amount was at a level considered high.

The region has a typical continental climate, and the average temperatures (14.4 ºC -15.0 ºC) during the 6-month vegetation period from the beginning of March to the end of August in 2019 and 2020 were 1 ºC lower in 2019, and 0.4 ºC lower in 2020, than the long-term meteorological observation averages (LTA) (Table 2). A comparison of the LTA with the 2019-2020 period revealed notable discrepancies in the monthly minimum and maximum temperatures, whereas the monthly average temperatures exhibited a greater degree of similarity.

Accordingly, the monthly average temperature was highest in August (20.7 ºC) in 2019, July (23.1 ºC) in 2020 and August (22.5) for LTA. In addition, August (27.6 ºC) in 2019, July (30.6 ºC) in 2020 and July (39.6 ºC) in 2020 were the months with the highest average maximum temperature; March was recorded as the month with the lowest average minimum temperature in 2019-2020 and for LTA (-1.0 °C, -0.1 °C and -13.6 ºC, respectively).

Table 2- Meteorological data of long years and growing season of 2019 and 2020 at Ankara

Climatic Factors	***Years***	***Month***							
		March	***April***	***May***	***June***	***July***	***August***	***Average***	***Total***
Minimum Temperature (°C)	2019	-1.0	2.4	8.6	13.6	12.5	14.0	8.3	-
	2020	-0.1	2.3	6.4	10.8	15.1	14.8	8.2	-
	LY	-13.6	-5.1	-0.1	4.7	2.8	5.9	-0.9	-
Maximum Temperature (°C)	2019	11.2	14.0	21.9	25.7	26.8	27.6	21.2	-
	2020	12.2	14.3	20.2	24.2	30.6	30.5	22.0	-
	LY	24.5	28.0	31.7	34.9	39.6	38.4	32.9	-
Average Temperature (°C)	2019	4.6	7.8	15.0	18.7	19.2	20.7	14.4	-
	2020	5.6	8.2	13.2	17.2	23.1	22.7	15.0	-
	LY	5.1	9.7	14.4	18.6	22.1	22.5	15.4	-
Relative Humidity (%)	2019	58.5	61.3	55.2	59.6	50.2	47.1	55.3	-
	2020	60.6	54.7	56.2	53.8	42.3	37.5	50.9	-
	LY	72.0	64.3	63.1	59.3	46.4	45.6	58.5	-
Precipitation (mm)	2019	20.6	23.4	3.8	15.0	31.8	9.2	-	103.8
	2020	14.8	26.0	42.8	27.4	0.6	0.0	-	111.6
	LY	42.1	24.3	47.8	38.9	10.1	8.7	-	171.9
Soil Temperature 5 cm (°C)	2019	10.6	14.6	23.7	27.3	28.8	28.9	22.3	-
	2020	11.0	15.7	22.0	24.0	33.8	34.4	23.5	-
	LY	5.9	10.9	16.6	21.3	25.1	25.8	17.6	-
Soil Temperature 10 cm (°C)	2019	8.7	12.1	19.3	23.9	25.1	25.4	19.1	-
	2020	9.0	13.0	18.6	20.9	27.7	28.0	19.5	-
	LY	6.0	10.8	16.2	20.6	24.5	25.1	17.2	-

Data were obtained from Turkish State Meteorological Service, Ankara

Total precipitation levels in 2019 and 2020 were 103.8 mm and 111.6 mm, respectively. Total precipitation levels during the experiment, was lower than the long-term average. The distribution of precipitation over the vegetation period was irregular in both trial years. The relative humidity in 2019 was 3.2% lower than the long-term average and the relative humidity in 2020 was 7.6% lower than the long-term average. In 2019, there was heavy rainfall and hail on June 12, flood damage from excessive rainfall on June 21-22, and heavy rainfall on July 15-19; in 2020, it was very cold between March 13-20 and there was heavy snowfall on March 18-19. In addition, rainfall was above climate norm and continuous throughout June.

2.4. Experimental design and statistical analysis

The study was designed according to the Randomized Complete Block Experimental Design with 3 replications for two years. All data were subjected to analysis of variance (ANOVA) using the MSTAT-C computer based Statistical software packages (Anonymous 1990). The significant differences between the group means were separated using The Duncan's Multiple Comparison test (Yurtsever 1984).

3. Results and Discussion

3.1. Plant height (cm)

According to the results of the combined analysis in terms of plant height, there were significant differences between years and genotypes at 1% level, while the differences in terms of year x genotype interactions were statistically insignificant. The difference between genotypes for both years was found to be significant at 1% level, and the difference between replications was found to be statistically insignificant in 2019 and significant at 5% level in 2020.

Plant height of the genotypes varied between 14.90-28.71 cm in 2019 and 19.15-43.57 cm in 2020, while this value was between 17.03-36.14 cm in the combined analysis (Table 3). In both years and as a result of the combined analysis, genotype number 1 (2019: 28.71 cm, 2020: 43.57 cm, combined: 36.14 cm) was the tallest, and genotype number 11 (2019: 14.90 cm, 2020: 19.15 cm, combined: 17.03 cm) was the least tall genotype.

The differences in the results of the research can be explained by the differences in the climate and soil conditions of the ecology where the studies were carried out, the genetic structure of the genotypes used, and the cultural practices. In 2019, very low precipitation and irregular temperature during the first growth period caused the plant to be stressed and shorten the vegetative development, and quickly transition to the generative period, which resulted in a plant height shorter than the one in 2020 (average plant height in 2019: 20.21 cm, and in 2020: 30.39 cm). The fact that the trial was carried out with good agricultural practices and that no fertilizers were used may be considered as the reason for the lower results of the study compared to some previous studies. Especially NPK fertilizers demonstrated a more pronounced and substantial influence on black cumin height compared to other fertilizers and it was found that an average of 6-8 kg nitrogen and 4 kg phosphorus provided optimal growth (Shah 2004; Özgüven & Şekeroğlu 2007; Tunçtürk et al. 2012; Yimam et al. 2015; Sağlık 2020).

Sowing time is another trait that affects yield and yield components. In general, it has been observed that winter sowing in regions with favourable climates has a positive effect on plant height since it is exposed to more water regime and the growing period covers a longer period (Tonçer & Kızıl 2004; Özel et al. 2009; Tektaş 2015; Kılıç & Arabacı 2016; Keser 2019; Saraç 2019). Narrow row spacing is another cultural practice that has a positive effect on plant height. Because the plant's height increases as it will compete with others to benefit from the light. Accordingly, early sowing increased plant height, while plant height decreased with delayed sowing. It is seen that plant height is an important criterion in the selection of productive lines and in minimizing yield loss, especially in machine harvesting.

3.2.First pod height (cm)

According to the combined analysis results, the differences between years and genotypes and the year x genotype interactions were found to be significant at 1% level. According to the results of the analysis of variance of the first pod height data, performed separately for 2019 and 2020, a significant difference between genotypes was detected at 1% level in both years, while the difference between replications was insignificant in 2019 but significant at 5% level in 2020.

The first pod height of the genotypes varied between 9.02-22.03 cm (year average: 14.42 cm) in 2019 and 14.35-40.93 cm (year average: 26.85 cm) in 2020, while this value was between 11.80-31.48 cm in the combined analysis. As a result of the analysis made for both years and the combined analysis, genotype number 1 (2019: 22.03 cm, 2020: 40.93 cm, combined: 31.48 cm) was the black cumin genotype with the highest first pod height, while the genotype with the lowest first pod height was found to be genotype number 17 (2019: 9.02 cm) in 2019 and genotype number 11 (2020: 14.35 cm, combined: 11.80 cm) both in 2020 and as a result of the combined analysis (Table 3).

As a result of the research, our findings regarding the first pod height values obtained from black cumin genotypes (9.02-40.93 cm) were close to and shorter than the values reported by Şahin (2013) (16.9-41.6 cm), and similar to and longer than the results of Keser (2019) (15.00-29.56 cm), Kızılyıldırım (2019) (19.76-29.40 cm) and Bozdemir et al. (2022) (11.6-26.6 cm).

While the genotypes with the highest first pod height were the same genotypes in both trial years, the difference in the genotypes with the lowest first pod height is explained by the statistically significant year x genotype interactions in the averages of the locations. In other words, the height of the first pod has varied over the years. In addition, as is the case in plant height, also the height of the first pod depends on the genotype structure of the black cumin plant and may vary according to cultural practices (plant density, irrigation, fertilization, sowing time, winter and summer planting) and ecological conditions. In general, it was determined that genotypes with higher plant height also had higher first pod height, which was in a positive relationship. Therefore, the genotypes with the tallest and shortest plant height were also the genotypes with the highest and lowest first pod height.

The height of the first pod is a highly desirable criterion for mechanization in black cumin crops. The fact that the plant is suitable for machine harvesting is very important in terms of reducing labor costs and saving time. Erskine et al. (1988) reported that the height of the first pod should be at least 12 cm for machine harvesting in lentil plants, which have similar phenotypic characteristics. Accordingly, it is seen that all genotypes included in our trial can be harvested with a combined harvester according to the results of the 2020 trial and combined analyses (considering that the actual performance of the plant could not be observed due to climatic negativities experienced in 2019).

Table 3- Average yield values from different black cumin genotypes in Ankara conditions and the resultant groups

Genotypes	*Plant height (cm)*			*First pod height (cm)*			*Thousand-seed weight (g)*		
	2019	*2020*	*2019-2020*	*2019*	*2020*	*2019-2020*	*2019*	*2020*	*2019-2020*
1	28.71 a	43.57 a	36.14 a	22.03 a	40.93 a	31.48 a	2.84 af	2.22 jm	2.53 fı
2	25.67 ab	31.23 bj	28.45 bg	21.20 ab	29.00 bı	25.10 df	2.93 ad	2.60 cg	2.77 ag
3	23.57 ae	39.60 ad	31.58 ac	18.70 ac	34.87 ae	26.78 ad	2.84 af	2.52 eh	2.68 cg
4	21.17 bı	39.03 ad	30.10 ae	16.31 be	35.93 ad	26.12 ae	2.50 ch	2.58 dg	2.54 fı
5	18.33 ej	32.29 aı	25.31 cj	13.17 dj	29.03 bı	21.10 ek	2.88 ae	2.60 cg	2.74 bg
6	20.20 bj	34.37 ag	27.28 bh	15.13 ch	28.94 bı	22.03 cı	3.06 ac	2.59 cg	2.83 af
7	16.08 hj	23.00 gk	19.54 ıl	11.97 ej	18.46 jm	15.21 ln	3.04 ac	2.77 ad	2.90 ae
8	16.47 gj	22.67 gk	19.57 ıl	9.88 hj	16.43 km	13.15 mn	3.06 ac	2.68 be	2.87 ae
9	24.26 ad	42.78 ab	33.52 ab	17.80 ad	37.97 ac	27.88 ab	2.67 ag	2.28 ıl	2.48 gj
10	23.40 ae	37.80 ae	30.60 ad	17.70 ad	31.47 bg	24.58 bg	1.89 h	2.27 ıl	2.08 k
11	14.90 j	19.15 k	17.03 l	9.25 j	14.35 m	11.80 n	3.25 a	2.90 ab	3.08 a
12	21.17 bı	23.43 gk	22.30 fl	15.10 cı	23.47 fm	19.28 gl	2.29 eh	2.07 ln	2.18 jk
13	22.67 bf	25.50 fk	24.08 dk	17.40 ad	25.63 ek	21.52 cj	2.18 gh	2.07 ln	2.13 k
14	21.00 bı	25.99 fk	23.49 el	15.20 ch	22.18 gm	18.69 hm	2.20 gh	2.03 mn	2.11 k
15	19.40 cf	25.13 fk	22.27 gl	13.83 cj	19.70 ım	16.77 ın	2.63 bg	2.52 eh	2.58 eh
16	16.81 fj	25.00 fk	20.90 hl	10.40 fj	21.55 hm	15.97 kn	2.53 bg	2.54 dh	2.54 fı
17	16.10 hj	28.00 dk	22.05 gl	9.02 j	23.80 fl	16.41 jn	2.98 ad	2.67 cf	2.83 af
18	14.94 j	22.43 hk	18.69 jl	9.25 j	17.67 jm	13.46 mn	3.13 ab	2.69 be	2.91 ad
19	15.03 j	19.83 jk	17.43 kl	9.68 ıj	16.43 km	13.06 n	3.10 ac	2.98 a	3.04 ab
20	15.63 ıj	21.73 ık	18.68 jl	9.10 j	17.35 jm	13.23 mn	2.57 bg	2.71 be	2.64 cg
21	24.53 ac	33.58 ah	29.06 be	18.10 ad	28.73 cı	23.41 bh	2.25 fh	1.95 n	2.10 k
22	19.43 cj	41.19 ac	30.31 ad	13.37 cj	38.20 ab	25.78 bf	2.72 ag	2.58 dg	2.65 cg
23	23.73 ae	38.81 ae	31.27 ac	18.20 ad	35.68 ad	26.94 ac	2.42 dh	1.93 n	2.18 jk
24	21.60 bh	33.07 aı	27.33 bh	15.33 cg	32.33 af	23.83 bh	2.21 gh	2.14 kn	2.18 jk
25	18.40 dj	30.27 ck	24.33 dj	13.43 cj	29.20 bh	21.31 dk	2.93 ad	2.42 gl	2.68 cg
26	19.23 cj	39.43 ad	29.33 be	14.70 cı	35.81 ad	25.26 bf	2.73 ag	2.18 km	2.46 gj
27	21.67 bh	36.40 af	29.03 bf	16.03 be	35.69 ad	25.86 bf	2.21 gh	2.23 ım	2.22 ık
28	22.00 bg	28.93 dk	25.47 cı	15.43 cf	25.41 fl	20.42 fl	2.52 bg	2.08 ln	2.30 hk
29	20.63 bj	30.20 ck	25.41 cj	14.77 cı	26.60 dj	20.68 el	2.77 ag	2.45 fı	2.61 dh
30	18.41 dj	20.49 jk	19.45 ıl	10.00 gj	16.03 lm	13.01 n	3.10 ac	2.82 ac	2.96 ac
31	21.23 bı	27.07 ek	24.15 dk	15.44 cf	23.55 fm	19.50 gl	2.84 af	2.33 hk	2.58 dh
Mean	20.21	30.39	25.30	14.42	26.85	20.63	2.69	2.43	2.56
LSD (0.05)	5.86**	11.78**	6.74**	5.43**	9.43**	5.54**	0.61**	0.23**	0.33**
CV (%)	17.77	23.74	23.32	23.04	21.51	23.51	13.91	5.72	11.36

**: indicate statistical differences at P≤0.01, means within a column having different letters are significantly different by Duncan's Multiple Comparison Test

3.3. Thousand-seed weight (g)

According to the combined analysis results, the differences between years and genotypes were found to be significant at 1% level, while no statistically significant difference was found between year x genotype interactions. According to the results of the analysis of variance performed separately for the years 2019 and 2020 with the thousand-seed weight data, the difference between genotypes was found to be significant at 1% level for both years, while the difference between replications was found to be insignificant in 2019 and significant at 1% level in 2020.

When Table 3 was examined, it was seen that different groups were formed among the genotypes according to the results of the 2019 and 2020 trials and combined analysis. The thousand-seed weight of the genotypes varied between 1.89-3.25 g (year average: 2.69 g) in 2019 and 1.93-2.98 g (year average: 2.43 g) in 2020, while this value was between 2.08-3.08 g in the combined analysis. The genotype with the highest thousand-seed weight was number 11 (3.25 g) in 2019, number 19 (2.98 g) in 2020, and number 11 (3.08 g) in the combined analysis. The black cumin genotype with the lowest thousand-seed weight was genotype 10 (2019: 1.89 g, combined: 2.08 g) in 2019 and in the combined analysis, and genotype number 23 (1.93 g) in 2020.

In previous studies, it was observed that fertilization had a significant effect on black cumin and that especially with soil-available phosphorus, higher amounts of dry matter and thus higher thousand-seed weight were obtained in plants (Tunçtürk et al. 2011). The results of various studies indicate that the application of NPK (Nataraja et al. 2003; Shah 2004) and, on occasion, vermicompost (Sağlık 2020) has a beneficial impact on thousand-grain weight. Although the research was carried out within the scope of good agricultural practices and the soil in which the genotypes were grown had insufficient organic matter and phosphorus content, it is seen that the majority of the genotypes included in the trial had higher thousand-seed weights than the trial material included in many research results.

The findings of various studies indicate that seed time (Mahmood et al. 2012; Bayhan 2019) and sowing frequency (Ahmed & Haque 1986; Geren et al. 1997; Abdolrahimi et al. 2012) have a significant impact on the number of branches, capsules, and weeds per plant and per unit area, which in turn affects thousand-grain weight. Despite the plant being sown at the optimal time for Ankara (summer) and at a frequency that permitted its growth, the variability in climate had a considerable impact on the thousand-grain weight, as evidenced in this study.

All these research results demonstrate that thousand-seed weight is one of the most important yield and quality factors and it varies depending on the plant's genetic structure, cultivation techniques (irrigation and irrigation method, amount and type of fertilization, planting density and time, number of seed sown, sowing frequency), climatic factors and soil properties.

3.4. Number of branches per plant (branch/plant)

According to the combined analysis results, while the differences between years were found to be significant at 1% level, no statistically significant difference was found between year x genotype interactions and genotypes. According to the results of the analysis of variance performed separately for the years 2019 and 2020 using the data on the number of branches; while no statistically significant difference was found in terms of any source of variation in 2019, a statistically significant difference was found only between the replications at the 1% level in 2020.

The number of branches of the genotypes varied between 1.77-3.13 branch/plant in 2019 (year average: 2.12 branch/plant) and between 1.37-2.25 branch/plant in 2020 (year average: 1.76 branch/plant), while this value was between 1.59-2.52 branch/plant in the combined analysis. The most branched genotype was genotype number 1 (2019: 3.13 branch/plant, combined: 2.52 branch/plant) in 2019 and in the combined analysis, and genotype number 22 (2.25 branch/plant) in 2020; while the least branched genotype was genotype number 29 (1.77 branch/plant) in 2019 and genotype number 19 (2020: 1.37 branch/plant, combined: 1.59 branch/plant) in 2020 and in the combined analysis (Table 4).

Table 4- Average yield values from different black cumin genotypes in Ankara conditions and the resultant groups

Genotypes	*Number of branches per plant (branch/plant)*			*Number of pods per plant (pods/plant)*		
	2019	**2020**	**2019-2020**	**2019**	**2020**	**2019-2020**
1	3.13 a	1.90 ad	2.52 a	3.26 a	1.98 bd	2.62 a
2	2.40 ad	1.70 ad	2.05 ad	2.23 be	1.73 be	1.98 ce
3	2.00 cd	1.90 ad	1.95 bd	2.14 be	1.77 be	1.95 ce
4	2.37 ad	1.99 ad	2.18 ac	2.07 be	2.08 bd	2.08 bd
5	2.03 cd	2.00 ad	2.01 ad	2.33 bd	1.97 bd	2.15 ad
6	1.97 cd	2.03 ac	2.00 ad	2.07 be	2.20 b	2.13 ad
7	2.08 bd	1.50 cd	1.79 bd	1.86 ce	1.63 be	1.75 ce
8	2.13 bd	1.82 ad	1.98 bd	1.78 de	1.87 be	1.82 ce
9	2.13 bd	2.20 ab	2.17 ac	2.06 be	3.00 a	2.53 ab
10	1.81 d	1.78 ad	1.79 bd	2.07 be	2.17 bc	2.12 ad
11	1.90 cd	1.55 cd	1.73 cd	2.00 be	1.45 de	1.73 ce
12	1.83 cd	1.69 ad	1.76 cd	2.04 be	1.73 be	1.88 ce
13	2.32 bd	1.67 ad	1.99 ad	1.94 ce	1.60 be	1.77 ce
14	2.32 bd	1.61 ad	1.96 bd	2.08 be	1.53 be	1.81 ce
15	2.60 ac	1.53 cd	2.07 ad	2.83 ab	1.65 be	2.24 ac
16	2.15 bd	1.93 ad	2.04 ad	1.82 ce	1.94 be	1.88 ce
17	1.89 cd	1.83 ad	1.86 bd	1.93 ce	2.03 bd	1.98 ce
18	1.80 d	1.73 ad	1.77 bd	1.74 de	1.71 be	1.72 ce
19	1.81 d	1.37 d	1.59 d	1.73 de	1.67 be	1.70 de
20	1.87 cd	1.60 bd	1.73 cd	1.75 de	1.72 be	1.73 ce
21	2.17 bd	1.57 bd	1.87 bd	2.00 ce	1.73 be	1.87 ce
22	2.10 bd	2.25 a	2.18 ac	1.87 ce	2.19 b	2.03 be
23	2.54 ad	2.03 ac	2.28 ab	2.37 bd	2.08 bd	2.22 ac
24	1.90 cd	1.70 ad	1.80 bd	1.94 ce	1.70 be	1.82 ce
25	2.16 bd	1.70 ad	1.93 bd	1.84 ce	1.73 be	1.79 ce
26	2.10 bd	1.80 ad	1.95 bd	1.86 ce	2.03 bd	1.95 ce
27	1.93 cd	1.67 ad	1.80 bd	1.83 ce	1.82 be	1.82 ce
28	1.87 cd	1.40 cd	1.64 d	1.77 de	1.28 e	1.52 e
29	1.77 d	1.69 ad	1.73 cd	1.50 e	1.51 ce	1.50 e
30	2.82 ab	1.60 bd	2.21 ac	2.59 ac	1.69 be	2.14 ad
31	1.79 d	1.86 ad	1.83 bd	1.97 ce	2.00 bd	1.98 ce
Mean	2.12	1.76	1.94	2.04	1.84	1.94
LSD (0.05)	0.78	0.65	0.52	0.80	0.68*	0.53*
CV (%)	22.54	22.56	23.57	24.01	22.68	23.73

*: indicate statistical differences at P≤0.05, means within a column having different letters are significantly different by Duncan's Multiple Comparison Test

Seed yield is directly affected by the number of branches, number of pods, number of seeds in pods, and thousand-seed weight. Branching in black cumin is desirable up to a certain point. In this study, when different black cumin populations were compared, the differences between them were due to environmental and climatic factors (as years and replications were significant, while genotypes were insignificant) and the ability of the material to adapt to these factors, rather than their genotypic characteristics.

According to Tavas et al. (2014), branching in black cumin is a yield component determined by genotype rather than ecological conditions, but according to Yılmaz (2008), it is a trait depending on genotype and environment. Plant density (the number of seeds sown per unit area, inter-row spacing) and sowing time (winter or summer planting), agronomic treatments such as the application of different fertilizer types in varying doses, irrigation, climate (humidity-precipitation), and light exposure are among the important factors that affect branching.

In the relevant studies, it was determined that sparse sowing generally encourages branching in plants (Ceylan 1979), and in general, the number of branches decreases as the number of seeds increases (Tektaş 2015). It has been reported that the number of branches and thus seed yield values increase significantly with a certain level of increase in different intra-row spacing applications (plant density) (Das et al. 1992; El Deen & Ahmed 1997).

It has been established by many studies that the number of branches is higher in winter planting than in summer planting because winter planting is exposed to more soil moisture and precipitation and removes nutrients from the soil for a longer period. In many studies on winter planting, it has been reported that there are significant differences among black cumin populations in terms of branch number (Tonçer & Kızıl 2004; Mahmood et al. 2012; Tektaş 2015; Kılıç & Arabacı 2016; Bayhan 2019; Kamçı 2019; Kızılyıldırım 2019; Özdemirel & Kaçar 2021; Saraç 2019).

In the fertilizer trials, it was observed that the application of nitrogen fertilizer had a positive effect on the number of plant branches, increasing nitrogen doses up to a certain level increased the number of plant branches, and at higher nitrogen doses, the average number of plant branches decreased slightly. It has been reported by some researchers that nitrogen and phosphorus applications had positive effects on the development and yield of black cumin plants and that increasing nitrogen and phosphorus doses increased the number of plant branches (El Deen & Ahmed 1997; Tunçtürk et al. 2012; Shah 2004; Özgüven & Şekeroğlu 2007; Sultana et al. 2019). The highest number of branches in extreme fertilizer trials was obtained from chicken manure application by Sağlık (2020).

The black cumin genotypes in the study differed from the previous studies in terms of the number of branches. This may be attributed to the differences in the genotypes used in the studies and the fact that they were genotypes with less branching capacity, the adverse conditions experienced in the climate in the years when the studies were carried out, and the difficulties experienced in the adaptation of the genotypes to these conditions, the application of cultivation techniques (not using fertilizer due to good agricultural practices, high weed density) and soil properties.

3.5. Number of pods per plant (pods/plant)

According to the results of the combined analysis, there were significant differences between years at 1% level and between genotypes at 5% level, while no statistically significant difference was found between year x genotype interactions. According to the results of the analysis of variance performed separately for the years 2019 and 2020 using the data on pod number; while no statistically significant difference was found in terms of any source of variation in 2019, a statistically significant difference was found between genotypes and replications at the 5% level in 2020.

The number of genotype pods varied between 1.50-3.26 pods/plant in 2019 (year average: 2.04 pods/plant) and between 1.28-3.00 pods/plant in 2020 (year average: 1.84 pods/plant), while this value was between 1.50-2.62 pods/plant in the combined analysis. The genotype with the highest number of pods was genotype number 1 (2019: 3.26 pods/plant, combined: 2.62 pods/plant) in 2019 and in the combined analysis, and genotype number 9 (3.00 pods/plant) in 2020; while the genotype with the lowest number of pods was genotype number 29 (1.50 pods/plant) in 2019 and in the combined analysis, and genotype number 28 (1.28 pods/plant) in 2020 (Table 4).

Pod number is one of the important yield factors related to branching in black cumin plants. Since the plant has a branched structure and each branch ends with a pod; the increase in the number of branches means a higher number of pods. Therefore, according to the results of the combined variance analysis, it is expected that the genotype with the maximum number of branches is the genotype with the maximum number of pods. Some agronomic and cultural practices have been very effective in the number of pods. It was observed that fertilizer applications of N, P and K (Geren et al. 1997, Mohamed et al. 2000; Nataraja et al. 2003; Özgüven & Şekeroğlu 2007; Shah 2007; Tunçtürk et al. 2012; Ali et al. 2015; Tulukçu 2011; Yimam et al. 2015; Muhammad et al. 2017; Sağlam 2018; Kızılyıldırım 2019), kinetin and gibberellic acid (Shah 2004), biofertilizer application (Sen et al. 2018) and chicken manure application (Sağlık 2020) significantly increased the number of pods. In studies conducted with plant density, it has been proved by various studies (Ahmed & Haque 1986; Das et al. 1992; El Deen & Ahmed 1997; Geren et al. 1997; Tonçer & Kızıl 2004; Özel et al. 2009; Abdolrahimi et al. 2012; Baydar 2013) that the increase in branching and thus the number of pods increases the yield in plants sowed with certain inter-row spacing. Sowing time was also effective in the increase in the number of pods, and it was determined that in general, winter planting (Tonçer and Kızıl 2004; Özel et al. 2009; Mahmood et al. 2012; Tektaş 2015; Bayhan 2019; Kızılyıldırım 2019; Saraç 2019) produced more pods.

The herb growth of the plants was limited because the study was carried out in an arid/semi-arid region and the course of the climate was unfavorable and irregular. Genetic differences among genotypes, their different responses to environmental and climatic factors, agronomic practices (fertilizer-free cultivation), and soil structure had a significant effect on the number of pods. Therefore, the values obtained were generally lower than some values reported in the literature.

3.6. Number of seeds per pod (seeds/pod)

According to the combined analysis results, significant differences were found between genotypes at 1% level, while no statistically significant difference was found between year x genotype interactions and years. According to the results of the analysis of variance performed separately for the years 2019 and 2020 using the data on the number of seeds per pod; while there was no statistically significant difference between the replications in 2019, a statistically significant difference was found at 1% level between the replications and at 5% level between genotypes in 2020.

The number of seeds per genotype pod was 25.71-56.74 seeds/pod in 2019 (year average: 41.33 seeds/pod) and 31.57-57.03 seeds/pod in 2020 (year average: 41.68 seeds/pod), while this value was between 29.87-54.64 seeds/pod in the combined analysis. The genotype with the highest number of seeds per pod was genotype number 1 in 2019 (56.74 seeds/pod), and genotype number 9 in 2020, and in the combined analysis (2020: 57.03 seeds/pod, combined: 54.64 seeds/pod), while the genotype with the lowest number of seeds per pod was the black cumin genotype number 30 (2019: 25.71 seeds/pod, combined: 29.87 seeds/pod) in 2019 and number 11 (31.57 seeds/pod) in 2020 (Table 5).

According to Ahmed and Haque (1986) and Arslan (1994), the factors to be taken into consideration in terms of yield in black cumin plants are the number of branches obtained from unit area, the number of pods, thousand-seed weight and the number of seed per pod. When the findings of the study were compared with the previous studies, it was observed that the number of seeds per pod may vary due to the genetic differences of black cumin populations as well as the cultivation in different regions (different soil structures and climate) and under different conditions and cultivation technique practices. In addition, the size of the seeds in the pod affects the number of seeds in the pod, while the size of the pods affects the number of seeds in the pod.

Although black cumin plant can tolerate water deficit (Ghamarnia et al. 2010), it has been observed that adequate irrigation, especially when rainfall is insufficient until the flowering period, has a rather positive effect on the number of seeds per pod as well as on many yield criteria of the plant (Safaei et al. 2014; Arslan 2015).

In general, winter sowing has a higher number of seeds per pod than summer sowing, the reason for which is considered to be the removal of the nutrients as well as the moisture needed from the soil for a longer period. In general, it was determined that as the vegetation period shortened, the number and weight of seeds per plant decreased. Indeed, D'Antuono et al. (2002) reported that the vegetation period was effective on the number of seeds per plant in black cumin depending on sowing time. It has been observed that many fertilizer trials had positive effects on the number of seeds per pod besides increasing the number of pods per plant. Researchers found that the application of N-P and K (Geren et al. 1997; Nataraja et al. 2003; Mollafilabi et al. 2010; Ali et al. 2015; Yimam et al. 2015), organic fertilizers (Ghiyasi et al. 2017), chicken manure (Sağlık 2020) bio-fertilizer (Sen et al. 2018) and kinetin and gibberellic acid (Shah, 2004) at different levels had positive effects on the number of seeds per pod in different ecologies.

Many researchers have reported based on their studies that plant density, one of the agronomic practices, directly affects black cumin yield, number of branches, number of pods, thousand-seed weight, and number of seeds per pod (Ahmed & Haque 1986; Das et al. 1992; Geren et al. 1997; Mollafilabi et al. 2010).

In the study, a positive relationship was found between the number of seeds per pod and thousand-seed weight, and the genotypes with minimum and maximum values were similar genotypes.

3.7. Seed yield (kg/ha)

According to the results of the combined analysis, significant differences were found at 1% level between genotypes and year x genotype interactions, while no statistically significant difference was found between years. According to the results of the analysis of variance performed for the years 2019 and 2020 using seed yield data; the differences between genotypes for both years were found to be statistically significant at the 1% level, and the differences between the replications for 2020 were found to be statistically significant at the 5% level.

When Table 5 was examined, it was seen that different groups were formed among the genotypes according to the results of 2019 (year average: 378.9 kg/ha), 2020 (year average: 367.8 kg/ha), and combined analysis. The highest seed yield was obtained from genotype number 4 with 624.4 kg/ha-501.0 kg/ha in 2019 and in the combined analysis, respectively, and from genotype number 7 with 507.9 kg/ha in 2020. The lowest seed yield was given by genotype number 30 (188.2 kg/ha) in 2019, genotype number 11 (238.9 kg/ha) in 2020, and genotype number 21 (259.6 kg/ha) in the combined analysis (Table 5).

Since the seed is the part used in the black cumin plant, the most important target in terms of yield is seed yield. According to the results of many studies, seed yield is directly related to the number of branches, number of pods, number of seeds per pod, and thousand-seed weight. In the studies carried out in different ecologies, including the above-mentioned, various studies conducted with different black cumin populations, the differences in seed yield are due to the differences in ecological conditions (precipitation, temperature, etc.) as well as genotypes and agricultural practices (soil preparation, irrigation, fertilization, weeding, spraying, plant density, seed quantity, harvest time, etc.).

Ceylan (1987) reported that the most suitable pre-plant for black cumin seed is hoe crops, that it should be sown after these crops, that the soil should be prepared very well just before sowing as in other small-seeded plants and that sowing as early as possible in spring for summer planting is the first step to be taken in terms of yield. In general, in places where the climate is suitable, winter planting makes the yield three times more productive than summer planting (Bayhan 2019). The general principle here is that the plant is exposed to more water and nutrients in the soil and that it can avoid water stress and develop adequately. Failure to meet the water needs of the plant on time, in sufficient quantity and frequency, with the most appropriate method during dry times can have a great impact on yield. Studies have shown that the best yield results are obtained when 100% of the water requirement of the plant is met by a drip irrigation system every two days (El-Mekawy 2012; Ghamarnia & Jalili 2013; Nadeem et al. 2013). Weed species, density, timing and number of times weeds are controlled, and harvest time are other factors affecting yield (Nadeem et al. 2013; Amirnia & Rezaei-Chiyaneh 2016).

Another factor that is as effective as water in plant growth and therefore yield and quality is micro-macro plant nutrients and their ratios in the soil. According to Dinç et al. (1988), in the climate zone in which our country is located, the clay, lime, and pH of the soils are high, and the organic matter content of the soils is low. These chemical properties of the soil structure limit the benefits of phosphorus to plants (Mengel & Kirkby 1987; Rodriguez et al. 2000). In particular, phosphorus deficiency leads to a significant decrease in dry weight and leaf area of plants and thus adversely affects plant growth and photosynthesis (Colomb et al. 2000; Rodriguez et al. 2000). Nitrogen, one of the macronutrients, is also an important contributing factor to plant growth, development and yield (Shah 2004). For this reason, in cases where plant nutrients are insufficient, external supplementation, that is, fertilization is an extremely important, positive parameter in terms of yield.

In different studies conducted in and outside the country on *Nigella sativa* L. plant, it was reported that plant density, sowing frequency, inter-row and intra-row spacing, and seed amount (Tonçer & Kızıl 2004; Özel et al. 2009; Abdolrahimi et al. 2012; Tektaş 2015; Kılıç & Arabacı 2016; Saraç 2019); sowing time and winter-summer planting (Tektaş 2015; Mahmood et al. 2012; Haq et al. 2015; Sultana et al. 2019; Bayhan 2019; Kamçı 2019; Keser 2019; Gülhan & Taner 2020); irrigation program, time, frequency, method and growing under dry/water conditions (Ghamarnia et al. 2010; Al-Kayssi et al. 2011; El-Mekawy 2012; Ghamarnia & Jalili 2013; Nadeem et al. 2013; Safaei et al. 2014; Amirnia & Rezaei-Chiyaneh 2016; Şenyiğit & Arslan 2018; Yiğitbaşı 2019); different chemical treatments such as N-P-K and kinetin and gibberellic acid (Mohamed et al. 2000; Nataraja et al. 2003; Shah 2004; Özgüven & Şekeroğlu 2007; Mollafilabi et al. 2010; Rana et al. 2012; Tunçtürk et al. 2011-2012; Rasool et al. 2014; Ali et al. 2015; Tulukçu 2011; Yimam et al. 2015; Ghiyasi et al. 2017; Horvat et al. 2017; Muhammad et al. 2017; Sağlam 2018; Sultana et al. 2019; Sağlık 2020) had positive and significant effects on yield.

Rather than the genetic structure of the materials included in the experiment, their response to the adverse climatic factors experienced in the years of the study, insufficient organic matter and macronutrients in the soil, and the lack of fertilization and spraying within the framework of good agricultural practices caused the yield results to be lower than some of the previous research results.

Table 5- Average yield values from different black cumin genotypes in Ankara conditions and the resultant groups

Genotypes	***Number of seeds per pod (seeds/pod)***			***Seed yield (kg/ha)***		
	2019	**2020**	**2019-2020**	**2019**	**2020**	**2019-2020**
1	56.74 a	52.01 ab	54.37 ab	573.4 ac	369.0 ag	471.2 ac
2	45.67 af	39.11 bf	42.39 ch	516.1 ad	283.3 eg	399.7 aı
3	43.78 bg	45.13 af	44.46 bg	442.5 cf	289.4 eg	365.9 ck
4	43.07 bg	46.98 ae	45.02 ag	624.4 a	377.7 ag	501.0 a
5	36.80 eı	49.19 ac	42.99 ch	272.0 gk	435.2 ad	353.6 dk
6	43.23 bg	48.44 ad	45.84 ae	366.9 dj	414.1 af	390.5 bı
7	34.21 fı	36.25 cf	35.23 fı	423.9 cg	507.9 a	465.9 ac
8	37.35 dı	40.82 bf	39.09 eı	453.1 be	392.6 af	422.8 ag
9	52.25 ac	57.03 a	54.64 a	493.1 ad	376.0 ag	434.5 af
10	48.61 ae	49.92 ac	49.26 ad	421.9 cg	380.2 af	401.1 ah
11	38.44 dı	31.57 f	35.00 gı	440.5 cf	238.9 g	339.7 dk
12	45.10 ag	39.53 bf	42.32 dh	461.1 ae	305.4 dg	383.2 bj
13	47.59 ae	34.80 df	41.19 dh	399.0 dh	280.4 eg	339.7 dk
14	42.88 bg	37.97 cf	40.43 dh	371.9 dı	275.5 fg	323.7 gk
15	40.00 ch	32.13 f	36.06 eı	517.3 ad	363.4 bg	440.4 ae
16	39.90 ch	36.70 cf	38.30 eı	229.2 ık	500.8 ab	365.0 ck
17	32.63 gı	40.11 bf	36.37 eı	456.5 be	496.3 ac	476.4 ab
18	36.90 dı	39.60 bf	38.25 eı	300.4 ek	373.2 ag	336.8 dk
19	29.00 hı	39.38 bf	34.19 hı	239.8 hk	373.1 ag	306.5 hk
20	32.72 gı	40.94 bf	36.83 eı	203.3 jk	438.0 ad	320.6 gk
21	49.80 ad	41.46 bf	45.63 ae	205.7 jk	313.4 dg	259.6 k
22	41.97 cg	47.16 ae	44.56 ag	611.9 ab	278.4 fg	445.2 ad
23	55.02 ab	50.04 ac	52.53 ac	319.6 ek	419.8 ae	369.7 bj
24	41.72 ch	40.04 bf	40.88 dh	372.9 dı	360.7 bg	366.8 ck
25	39.27 dh	37.94 cf	38.61 eı	305.6 ek	485.1 ac	395.4 aı
26	44.11 ag	36.35 cf	40.23 dh	388.9 dı	279.6 eg	334.2 ek
27	40.95 ch	44.20 af	42.58 ch	265.0 gk	382.2 af	323.6 gk
28	41.85 ch	33.77 ef	37.81 eı	270.6 gk	311.0 dg	290.8 ık
29	33.08 fı	39.48 bf	36.28 eı	285.6 fk	369.1 ag	327.4 fk
30	25.71 ı	34.02 ef	29.87 ı	188.2 k	373.7 ag	281.0 jk
31	40.81 ch	49.92 ac	45.37 af	324.6 ek	358.7 cg	341.7 dk
Mean	41.33	41.68	41.50	378.9	367.8	373.3
LSD (0.05)	12.92**	14.02*	10.17**	164.5**	140.7**	109.5**
CV (%)	19.14	20.59	21.45	26.59	23.42	25.68

*, **: indicate statistical differences at P≤ 0.05, P≤ 0.01 respectively; means within a column having different letters are significantly different by Duncan’s Multiple Comparison Test

4. Conclusions

This study investigated the effect of good agricultural practices method on yield characteristics of black cumin genotypes of different origins at the advanced yield stage. Increasing black cumin production in our country can only be achieved by increasing its areas of cultivation. The development of varieties with superior characteristics and high yield potential in foreign pollinated plants, such as black cumin, increases the yield in terms of seed per unit area. It is important to grow the plant with good agricultural practices widely accepted in the world or by using the organic farming method, in order to prevent toxicity to human health and natural habitat and at the same time to support the producer economically. As in all cultured plants, yield and other yield-related characteristics in black cumin cultivation vary depending on climatic factors, soil properties, and cultivation techniques, apart from the genetic characteristics of the plant. Therefore, this study also aimed to provide information to black cumin producers and consumers on the effects of reliable and human-nature-friendly good agricultural practices and black cumin cultivation on yield and other yield criteria. The present study also elucidated morphological, and genetic characteristics of 31 genotypes and to determine the best one.

In conclusion, it is known that the genetic base of the *Nigella* genus in the world is limited and shows very low genetic variation. The narrow genetic base makes breeding studies of black cumin difficult. However, a high level of variation was found among black cumin genotypes in terms of yield and yield parameters. Environment conditions markedly influence the expression of most phenotypic traits. It was also determined in our study that variations in climate and the physical and chemical properties of the experimental soil were highly influential on the results. The genotypes 4 (501.0 kg/ha), 17 (476.4 kg/ha), 1(471.2 kg/ha), and 7 (465.9 kg/ha), stand out in terms of seed yield. Our results suggest that these genotypes can be shown as promising genotypes that can be cultivated in Ankara and similar ecological and can be used in breeding studies. Moreover, it is very important to repeat the study under different climatic and soil conditions in order to eliminate the negative results of the experiment arising from climatic variability and thus to determine the actual performance of the black cumin genotypes. Diversification of studies to determine organic fertilization and other agricultural factors suitable for organic and good agricultural practices in black cumin cultivation, and the development of efficient and high-quality varieties will contribute greatly to the socio-economic development of the regions where the plant is grown and to the national economy.

It will be also useful for the construction of a black cumin germplasm collection for providing for breeding programs. The present characterization strategies will help to black cumin breeding programmes for breeding of F1 hybrids with desired traits.

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