EVALUATION OF SOME BLACK CUMIN SEED (*NIGELLA SATIVA L.*) GENOTYPES IN TERMS OF QUALITY PARAMETERS AT DIFFERENT PLANTING PERIODS UNDER MARDIN ECOLOGICAL CONDITIONS

EVALUACIÓN DE ALGUNOS GENOTIPOS DE SEMILLAS DE COMINO NEGRO (NIGELLA SATIVA L.) EN TÉRMINOS DE PARÁMETROS DE CALIDAD EN DIFERENTES PERÍODOS DE SIEMBRA BAJO LAS CONDICIONES ECOLÓGICAS DE MARDIN

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ABSTRACT

This research was carried out with 3 repetitions according to the randomized blocks trial design in winter and summer planting periods of 2018-2019 and 2019-2020 in order to determine the agronomic and quality characteristics of some black cumin genotypes at different sowing periods under Mardin ecological conditions. Çameli variety and 18 different black cumin seed genotypes were used in the study and some quality parameters were examined. According to the results obtained from the research, it was determined that fatty oil ratio varied between 32.45-39.02% and fatty oil yield varied between 12.94-42.72 kg da-1 in winter planting. In summer planting; fatty oil ratio ranged between 33.99-38.13% and fatty oil yield ranged between 9.69-25.18 kg da-1. As a result of the study, it was determined that Eskişehir-5 (G9) genotype performed better than other varieties and genotypes in terms of fatty oil yield under Mardin ecological conditions. Due to the early increase in temperature in Mardin conditions, quality parameters decreased in summer planting compared to winter planting. Therefore, winter planting is recommended as the most suitable planting time for black cumin cultivation under Mardin conditions.

Keywords: Black cumin; genotype; fatty oil; thymoquinone.

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RESUMEN

Esta investigación se realizó con 3 repeticiones según el diseño de ensayo en bloques al azar en los periodos de siembra de invierno y verano de 2018-2019 y 2019-2020 con el fin de determinar las características agronómicas y de calidad de algunos genotipos de comino negro. en diferentes periodos de siembra bajo condiciones ecológicas Mardin. condiciones. En el estudio se utilizaron la variedad Çameli y 18 genotipos diferentes de semillas de comino negro y se examinaron algunos parámetros de calidad. De acuerdo a los resultados obtenidos de la investigación se determinó que la relación de aceite graso varió entre 32.45-39.02% y el rendimiento de aceite graso varió entre 12.94-42.72 kg da-1 en siembra de invierno. En la siembra de verano; la relación de aceite graso osciló entre 33,99 y 38,13 % y el rendimiento de aceite graso osciló entre 9,69 y 25,18 kg da-1. Como resultado del estudio, se determinó que el genotipo Eskişehir-5 (G9) se desempeñó mejor que otras variedades y genotipos en términos de rendimiento de aceite graso en las condiciones ecológicas de Mardin. Debido al aumento temprano de la temperatura en las condiciones de Mardin, los parámetros de calidad disminuyeron en la siembra de verano en comparación con la siembra de invierno. Por lo tanto, se recomienda la siembra de invierno como el momento de siembra más adecuado para cultivar comino negro en las condiciones de Mardin.

Palabras clave: Comino negro; genotipo; aceite graso; timoquinona.

INTRODUCTION

Humankind has used the plants around it from the past to the present in many fields from food to beverage, from animal feed to fuel, from cosmetics to medical field. Medicinal and aromatic plants in the plant kingdom have a wide range of uses due to the active substances they contain in their structures (Bayram et al., 2010). The use and trade of these plants, which are found in the natural flora of our country, are widely performed. Recently, the cultivation of medicinal and aromatic plants for commercial purposes has also started to become widespread. In the cultivation of medicinal and aromatic plants, it is necessary to maximize the quality as well as high yield. While the desired quality and standardization of plants produced by man can be achieved, it is an undeniable fact that it is difficult to obtain the same quality and standard product from plants collected from nature. In this context, in order to ensure continuity in standardization and quality, the plants collected from nature should be cultivated and their production should be based on the most appropriate agricultural method (Koşar, 2019).

Black cumin is widely cultivated in Thrace, Northern Anatolia, Central Western Anatolia Region, Lakes Region and Mediterranean Region in Turkey. Although black cumin shows many differences in agricultural and quality characteristics according to the regions where it is cultivated, generally in the structure of the seed, it contains 0.4-0.45% essential oil, 32-40% fatty oil, 16-19.9% protein, 33.9% carbohydrates, 5.5% saponins, alkaloids and fibers, 1.79%-3.44% tannins and minerals. While there are unsaturated fatty acids such as linoleic acid, oleic acid and linolenic acid in its fatty oil, it contains palmitic acid, stearic acid and myristic acid from saturated fatty acids (Güllü and Avcı, 2013). Black cumin essential oil contains bioactive substances such as thymoquinone, p-cymene, nigellonethyllinoleate, α-thujen, thymol, α-pinene, carvacrol, trans-anethol, β-pinene. Thymoquinone, which makes up 25-60% of this oil, is one of the most important and most active phytochemicals of black cumin seeds and increases the anti-histamine and antioxidant effect of black cumin essential oil (Baydar, 2013; Bulca, 2014).

The most important factors determining the yield in plant growing are the genetic structure of the plant and the ecological environment as well as determining the appropriate variety for the regional conditions. As in many plants, the main purpose of black cumin is to determine the genotypes with high quality factors besides maximum yield. Accordingly, obtaining efficient and high quality products in the ecological conditions of each region/region can be achieved by determining varieties with high yield potential as well as appropriate cultivation techniques. It is aimed to increase economic efficiency on the basis of success in plant breeding studies. Knowing in advance the superior productivity, quality characteristics, physiological and some morphological characteristics of black cumin, which has the desired characteristics in the plant population under environmental conditions, forms the basis of breeding studies.

There are studies in the literature to determine the yield, agronomic and quality characteristics of different black cumin genotypes. Toma et al. (2010) stated in their study that the essential oil of black cumin seeds contained alpha-pinene (13.75%), limonene (2.55%), p-cymene (43.58%), carvacrol (2.53%) and thymoquinone (1.65%). Kara et al. (2015) determined the effects of five different black cumin populations on seed yield, some characteristics related to yield, essential oil contents and fatty oil ratio. Ertaş (2016) determined the yield and quality parameters of six different black cumin genotypes in Tokat Kazova ecological conditions. Kılıç and Arabacı (2016) investigated the effect of black cumin planted at different planting times and different seed amounts on yield and quality in Aydın ecological conditions. Bıyık (2018) determined the yield and quality parameters in his study with 27 different black cumin genotypes in Tokat Niksar ecological conditions. Koşar and Özel (2018) conducted a study to determine the characterization of black cumin cultivars and populations in Şanlıurfa ecological conditions. Palabıyık et al. (2018) conducted a study to determine both fatty and essential oil components and yield characteristics of ten different black cumin populations in Eskişehir ecological conditions. In the study conducted by Bayhan (2019) in Samsun ecological conditions, oil ratio varied between 21.75-29.74%; protein content varied between 21.63-22.57%; oil yield varied between 6.06-28.28 kg da-1; protein ratio varied between 6.40-21.03. Selicioğlu (2018) conducted a research with 8 different black cumin genotypes to determine the herbal and agricultural characteristics of the black cumin plant in Kırşehir Boztepe ecological conditions. Kal (2019) determined the content of black cumin oil by GC-MS in the black cumin plant obtained from Amasya and Yozgat provinces. Kamçı (2019) conducted a study to determine the effects of different planting time and irrigation practices applied to black cumin plant on agronomy and quality in Diyarbakır ecological conditions. Örmek (2019) conducted a study to determine the black cumin line and populations suitable for the dry conditions of Mardin province. Özdemirel (2019) determined the yield and quality characteristics of black cumin in his study conducted in Bursa ecological conditions. Yiğitbaşı (2019) carried out a study to determine the effects of black cumin species on yield and some quality characteristics in both dry and irrigated conditions at different planting times in Konya ecological conditions.

In this study, it was aimed to reveal the quality criteria related to both fatty oil and oil components of different varieties and genotypes in black cumin, which has an important place among medicinal and aromatic plants in Mardin province, and to contribute to the economy of the region and the country by identifying genotypes that are compatible with the ecological conditions of the region, resistant to negative factors, productive and of high quality.

MATERIAL AND METHOD

Material

In the research, a total of 19 black cumin genotypes (*Nigella sativa* L.) which were Çameli variety registered by the Gateway Agricultural Research Institute in 2014, Adana (G1), Amasya (G2), Burdur (G3), Burdur-1 (G4), Diyarbakır (G5), Eskişehir (G6), Eskişehir-3 (G7), Eskişehir-4 (G8), Eskişehir-5 (G9), İzmir (G10), Konya (G11), Mersin (G12), Samsun (G13), Syria (G14), Şanlıurfa (G15), Şanlıurfa-1 (G16), Tokat (G17) and Tokat-2 (G18), were used.

The research was carried out in the farmer's land in Köprübaşı village of Kızıltepe district of Mardin Province in winter and summer seasons in 2018-2019 and 2019-2020 planting periods. The trial site is located 23 km south of Kızıltepe district.

Method

The trial was carried out in the farmer's land in Köprübaşı village of Kızıltepe district of Mardin Province according to randomized blocks divided parcels trial design with 3 repetitions. In the trial, planting periods (winter-summer) were placed in main parcels and genotypes were placed in sub parcels. The parcels were formed by 5 rows with a length of 4 m, the distance between the rows was established to be 30 cm, the distance between the parcels was 1 m and the distance between the blocks was 2 m. All the observation and measurement data were taken from the remaining parts after removing the edge effect from each parcel.

The trial area was made ready for planting with gobble disk array and rototiller by making deep ploughing. The first year planting (winter-summer) was carried out on 25 December 2018 and 28 February 2019, and the second year (winter-summer) planting was carried out on 25 November 2019 and 20 February 2020, at suitable weather conditions and when the soil was tempered, and 2 kg per decare weighed seeds were planted by hand in rows opened with a marker at a depth of 1-2 cm.

Fertilizer amounts used in the trial area were determined according to the soil analysis results, and 6 kg of pure phosphorus and 6 kg of nitrogen were applied per decare. All of the phosphorus was given with the planting, while some of the nitrogen was given during planting and the other part was given as top fertilizer in the form of urea during the stemming period of the plants. In the first year plantings, due to the long duration of seasonal precipitation, sprinkler irrigation was applied once in the trial area, and in the second year plantings, sprinkler irrigation was applied twice according to the needs of the plants.

In the periods after the black cumin plants emerged, weed control was carried out with a hand hoe between the rows and manually on the rows. This process was applied in a timely and controlled manner depending on the weed density during the development period of the plants.

The time when the plants in the plot turned yellow and the capsules turned brown was determined as the harvest time. After removing the edge effect in each parcel, depending on the early and late varieties, the harvest was done manually in June for the winter plantings and in July for the summer plantings. Harvested plants were put into sacks and beaten, considering the parcel numbers, and threshing was carried out.

The quality parameters of fatty oil and oil components determined in the research are given below.

Fatty Fat Ratio (%): The oil ratio of the samples whose dry weight was determined by grinding the seed samples from each parcel was determined by extraction method in the soxhlet device.

Fatty Oil Yield (kg da^{-1}): Oil yields per decare were determined by using parcel yield and fatty oil ratios.

Fatty Acid Composition (%): Gas Chromatography (GC-FID) system was used to determine the oil composition of the oils taken by cold extraction.

Thymoquinone Concentration (ppm): 100 µL of oil sample was taken, dissolved in 10 ml of n-hexane, and then filtered and determined in a Shimadzu brand QP2010 model GC-MS device (1 µL).

The method created in the analysis part of the device: Column RXI-5MS Length: 30 m, Thickness: 0.25µm, Diameter: 0.25 mm, Max. Temperature: 330^{o}C, Temperature Program Increase rate ^{o}C/min, Temperature (°C): 40.0, Waiting period (min): 2.00, Increase rate: 6.00 ^{o}C/min, Temperature (°C): 120.0, waiting period (min): 0.00; Increase rate 15.00 oC/min, Temperature (°C): 240.0, waiting period (min): 10.00, Injection temperature: 250 °C, Injection Mode: Split Flow Control mode: Pressure; Pressure: 50.0 kPa, Split rate:100, Ion Source Temperature: 220.00°C, Interface Temperature: 250.00°C, Start time: 17.20min, End time: 17.80min, Reading mode: SIM; mass/loading(m/z) ratios: 164.00; 121.00; 93.00; 136.00.

The results of the research were analyzed using the SPSS 22.0 statistical analysis program. The differences between the means were determined according to the Duncan test.

RESULTS AND DISCUSSION

Fatty Oil Ratio

When the variance analysis results of the fatty oil ratio of different black cumin genotypes in Table 1 were examined, genotype and planting time were found to be statistically significant at the $p \leq 0.01$ level. Planting time x genotype, year x genotype and year x planting time x genotype interactions were also found to be statistically significant at the $p \leq 0.01$ level.

Table 1.Variance analysis results of average fatty oil ratio values in different black cumin genotypes planted (Summer-Winter) between 2018-2020

VARIATION SOURCE	SUM OF SQUARES	DEGREE OF FREEDOM	MEAN SQUARES	F
YEAR	0.035	1	0.035	0.502NS
BLOCK	0.353	2	0.177	2.544 NS
PLANTING TIME	5.005	1	5.005	73.762**

VARIATION SOURCE	SUM OF SQUARES	DEGREE OF FREEDOM	MEAN SQUARES	F
PLANTING TIME X YEARS	7.803	1	7.803	115.008**
ERROR 1	5.157	76	**0.068**	
GENOTYPE	166.309	18	9.239	133.009**
PLANTING TIME X GENOTYPE	279.206	18	15.511	228.614**
YEAR X GENOTYPE	43.880	18	2.438	35.093**
YEAR X PLANTING TIME X GENOTYPE	31.523	18	1.751	25.811**
ERROR 2	5.140	74	0.069	
GENERAL	544.411	227		
CV (%)	2.43			

Note: (**) p≤0.01 statistically significant, (*) p≤0.05 statistically significant, (N.S.): not statistically significant.

In Table 2, the difference between the results of the average fatty oil ratio in different black cumin genotypes planted (Summer-Winter) between 2018 and 2020 was grouped by applying Duncan test.

Table 2. Results of the average fatty oil ratio in different black cumin genotypes planted (Summer-Winter) between 2018-2020 and the resulting groups (%)

GENO-TYPE/ VARIETY	YEARS				PLANTING TIME		AVERAGE
	1 YEAR		2 YEARS				
	WINTER	SUMMERY	WINTER	SUMMERY	WINTER	SUMMERY	
G1	34.45 hı	35.50 ı	35.62 gh	36.43 cd	35.03 fg	35.97 ef	35.50 k
G2	36.06 df	35.90 gı	37.39 c	36.28 cd	36.72 b-e	36.09 d-f	36.41 e
G3	39.89 a	35.65 hı	38.15 b	34.19 f	39.02 a	34.92 g	36.97 c
G4	38.16 b	36.55 ce	39.41 a	35.95 cd	38.78 a	36.25 c-e	37.52 b
G5	31.57 j	36.76 c	33.32 k	35.75 de	32.45 ı	36.26 c-e	34.35 n
G6	35.71 dg	36.33 df	37.16 cd	35.42 e	36.44 c-e	35.87 ef	36.16 fg
G7	35.60 eg	35.86 gı	38.12 b	34.49 f	36.86 b-d	35.17 g	36.02 gh
G8	35.37 g	35.98 f-h	36.63 e	36.28 cd	36.00 d-f	36.13 d-f	36.07 g
G9	38.14 b	36.54 c-e	39.28 a	37.17 b	38.71 a	36.86 bc	37.78 a
G10	38.09 b	34.59 j	36.04 f	33.69 g	37.06 b-d	34.14 h	35.60 jk
G11	38.19 b	37.30 b	36.92 de	36.26 cd	37.56 b	36.78 b-d	37.17 fg
G12	34.67 h	37.16 b	36.12 f	37.26 b	35.40 f	37.21 b	36.30 ef
G13	36.07 de	36.71 cd	35.44 h	36.44 c	35.76 ef	36.58 b-e	36.17 fg
G14	33.94 ı	37.68 a	32.86 l	38.58 a	33.40 h	38.13 a	35.76 ıj
G15	34.51 hı	36.33 d-f	33.71 j	34.60 f	34.11 gh	35.47 fg	34.79 m
G16	35.41 fg	35.88 g-ı	34.48 ı	36.34 c	34.94 fg	36.11 d-f	35.53 k
G17	36.01 df	34.42 j	37.11 cd	33.55 g	36.56 b-e	33.99 h	35.27 l
G18	37.29 c	35.53 ı	35.94 fg	34.58 f	36.62 b-e	35.06 g	35.84 hı
CAMELI	36.31 d	36.16 e-g	38.31 b	36.07 cd	37.31 bc	36.11 d-f	36.71 d
AVERAGE	36.08	36.15	36.42	35.75	36.19	35.94	

Note: Differences between means with the same letters are not significant.

The fatty oil ratio of different black cumin genotypes varied between 31.57- 39.89% in the winter planted genotypes in the first year, the lowest (31.57%) was obtained from G5 genotype and the highest (39.89%) was obtained from G3 genotype, while the fatty oil ratio of the summer planted genotypes varied between 34.42-37.68%, the lowest (34.42%) was obtained from G17 genotype and the highest (37.68%) was obtained from G14 genotype.

In the 2nd year, in the winter planted genotypes, it varied between 32.86-39.41%, the lowest (32.86%) was obtained from G14genotype and the highest (39.41%) was obtained from G4 genotype; in the summer planted genotypes, it varied between 33.55-38.58%, the lowest (33.55%) was obtained from G17 genotype and the highest (38.58%) was obtained from G14 genotype.

In terms of planting times between the two-year averages, it showed an average change of 32.45%-39.02% in the genotypes planted in the winter period, the lowest (32.45%) was obtained in the G5 genotype, and the highest (39.02%) was obtained in the G3 genotype. It varied between 33.99% and 38.13% in the genotypes planted during the summer season, the lowest (33.99%) was obtained from G17 genotype, and the highest (38.13%) was obtained from G14 genotype.

The combined averages of the two-year planting times varied between 34.35-37.78%, the lowest (34.35%) was obtained from genotype G5 and the highest (37.78%) was obtained from genotype G9. The lowest (35.75%) and the highest (36.42%) fatty oil contents of genotype and variety averages were obtained from 2nd year summer planting and 2nd year winter planting, respectively.

One of the factors that reveal the quality of black cumin seeds is the fatty oil ratio. The fatty oil ratio can vary between 30% and 45% (Baytop, 1984). It was stated that one of the reasons for the difference in oil values between genotypes in black cumin was due to the different genetic structures (Ürüşan, 2016).

As a result of this research, the average values obtained regarding the fatty oil ratio of different black cumin genotypes were determined as 31.57%-39.89% in winter planting in the first year, 34.42%-37.68% in summer planting, 32.86%-39.41% in winter planting in the second year, and 33.55-38.58% in summer planting. Considering other studies conducted in this direction, the fatty oil ratios in black cumin were found as; 35.03-38.10% in winter sowing in the province of Mardin by Örmek (2019), 36.42-40.17% in winter planting in Şanlıurfa ecological conditions by Koşar and Özel (2018) as a result of their study to determine the characterization of black cumin varieties and populations. As a result of the study in which 6 different black cumin genotypes were used, Ertaş (2016) determined the fatty oil ratios as 37.5% in winter planting, 37.6% in summer planting in Tokat Kazova conditions.

As a result of the study conducted by Keser (2019) in the ecological conditions of Kahramanmaraş, fatty oil ratios were found as 28.66-38.00% in winter planting, 18.00-28.33% in summer planting. In the study carried out by Bayhan (2019) in Samsun ecological conditions, it was found as 29.74% in winter planting and 21.75% in summer planting. Tektaş (2015) determined the fatty oil ratio as 27.90-41.20% in winter planting in Harran Plain climate conditions, Kılıç and Arabacı (2016) determined the fatty oil ratio as 38.17% in winter planting in different planting times and different seed amounts in Aydın ecological conditions. In the study conducted with 8 different black cumin genotypes by Selicioğlu (2018) in Kırşehir Boztepe ecological conditions, it was found as 33.8%-35.5% in summer planting.

Fatty Oil Yield

When the variance analysis results of the fatty oil yield of different black cumin genotypes in Table 3 were examined, the year, genotype and planting time were found to be statistically significant at the p≤0.01 level. Planting time x genotype, year x genotype and year x planting time x genotype interactions were found to be statistically significant at the p≤0.01 level.

Table 3.Variance analysis results of average fatty oil yield values in different black cumin genotypes planted (Summer-Winter) between 2018-2020.

VARIATION SOURCE	SUM OF SQUARES	DEGREE OF FREEDOM	MEAN SQUARES	F
YEAR	17.937	1	17.937	36.150**
BLOCK	1.818	2	0.909	1.83NS
PLANTING TIME	3480.958	1	3480.958	7925.911**
PLANTING TIME X YEARS	23.380	1	23.380	53.236**
ERROR 1	33.378	76	0.439	
GENOTYPE	7627.112	18	423.728	853.984**
PLANTING TIME X GENOTYPE	1361.974	18	75.665	172.285**
YEAR X GENOTYPE	587.267	18	32.626	65.754**
YEAR X PLANTING TIME X GENOTYPE	234.295	18	13.016	29.637**
ERROR 2	36.717	74	0.496	
GENERAL	13404.838	227		
CV(%)	29.7			

Note: (**) p≤0.01 statistically significant, (*) p≤0.05 statistically significant, (N.S.): not statistically significant.

In Table 4, the difference between the results of the average fatty oil yield in different black cumin genotypes planted (Summer-Winter) between 2018 and 2020 were grouped using the Duncan test.

Table 4. Results of the average fatty oil yield in different black cumin genotypes planted (Summer-Winter) between 2018-2020 and the resulting groups (kg da^{-1}).

GENOTYPE/ VARIETY	YEARS				PLANTING TIME		AVERAGE
	1. YEAR		2. YEAR				
	WINTER	SUMMERY	WINTER	SUMMERY	WINTER	SUMMERY	
G1	18.20 hı	12.96 hı	23.60 ef	15.07 f	20.90 e	14.01 hj	17.46 ı
G2	29.13 d	11.35 j	27.57 d	12.52 gh	28.35 c	11.93 ıl	20.14 f
G3	15.14 lm	9.19 k	15.97 h	11.69 h	15.56 gh	10.44 kl	13.00 k
G4	16.90 jk	18.11 e	21.99 f	15.09 f	19.44 ef	16.60 e-g	18.02 h
G5	17.25 ıj	14.46 g	13.56 ı	12.39 gh	15.40 gh	13.43 h-j	14.42 j
G6	30.31 c	25.95 a	33.49 b	22.05 b	31.90 b	24.00 ab	27.95 b
G7	33.97 b	21.75 c	31.79 c	14.77 f	32.88 b	18.26 d-f	25.57 c
G8	23.13 g	12.70 ı	26.86 d	18.83 d	25.00 d	15.76 f-h	20.38 f
G9	37.10 a	23.42 b	48.34 a	26.94 a	42.72 a	25.18 a	33.95 a
G10	16.16 kl	12.08 ıj	13.84 ı	8.49 j	15.00 gh	10.29 kl	12.64 k
G11	24.71 f	21.23 c	26.42 d	19.34 d	25.56 cd	20.28 cd	22.92 d

GENOTYPE/ VARIETY	YEARS				PLANTING TIME		AVERAGE
	1. YEAR		2. YEAR				
	WINTER	SUMMERY	WINTER	SUMMERY	WINTER	SUMMERY	
G12	29.82 cd	15.95 f	27.08 d	20.34 c	28.45 c	18.14 d-f	23.30 d
G13	15.79 l	12.83 ı	19.07 g	10.08 ı	17.43 fg	11.46 jl	14.44 j
G14	27.90 e	20.11 d	24.17 e	17.22 e	26.04 cd	18.66 de	22.35 e
G15	18.94 h	19.85 d	12.87 ıj	16.50 e	15.90 gh	18.17 d-f	17.04 ı
G16	25.73 f	13.79 gh	22.09 f	11.61 h	23.91 d	12.70 ı-k	18.31 h
G17	25.66 f	16.00 f	22.91 ef	12.76 g	24.29 d	14.38 g-ı	19.34 g
G18	14.14 m	11.59 j	11.74 j	7.79 j	12.94 h	9.69 l	11.32 l
CAMELI	33.68 b	24.04 b	31.81 c	21.06 c	32.74 b	22.55 bc	27.65 b
COVER.	23.88	16.70	23.96	15.50	23.43	15.74	

Note: Differences between means with the same letters are not significant.

The fatty oil yield of different black cumin genotypes varied between 14.14-37.10 kg da^{-1} in the 1st year winter planted genotypes, the lowest (14.14 kg da^{-1}) was obtained from G18 genotype and the highest (37.10 kg da^{-1}) was obtained from G9 genotype. It varied between 9.19-25.95 kg da^{-1} in summer planted genotypes, the lowest (9.19 kg da^{-1}) was obtained from G3 genotype, and the highest (25.95 kg da^{-1}) was obtained from G6 genotype.

It varied between 11.74-48.34 kg da^{-1} in genotypes planted in winter in the second year, the lowest was obtained (11.74 kg da^{-1}) from G18 genotype, the highest (48.34 kg da^{-1}) was obtained from G9 genotype. It varied between 7.79-26.94 kg da^{-1} in summer planted genotypes, the lowest (7.79 kg da^{-1}) was obtained from G18 genotype and the highest (26.94 kg da^{-1}) was obtained from G9 genotype.

In terms of planting times between two-year averages, it showed a change between 12.94-42.72 kg da^{-1} in winter genotypes, the lowest (12.94 kg da^{-1}) was in G18 genotype and the highest (42.72 kg da^{-1}) was obtained from G9 genotype. It varied between 9.69-25.18 kg da-1 in the genotypes planted during the summer period, the lowest (9.69 kg da-1) was obtained from the G18 genotype, and the highest (25.18 kg da-1) was obtained from the G9 genotype.

The combined averages of the two-year planting times varied between 11.321-33.95 kg da^{-1}, the lowest (11.321 kg da^{-1}) was obtained from G18 genotype, and the highest (33.95 kg da^{-1}) was obtained from G9 genotype. The lowest (15.50 kg da^{-1}) and the highest (23.96 kg da^{-1}) fatty oil yields of genotype and variety averages were obtained from 2nd year summer planting and 2nd year winter planting, respectively.

There is a positive relationship between oil ratio and seed yield per decare, which is one of the most important factors determining fixed oil yield. All factors affecting seed yield and oil rate (variety, climate, cultural processes, planting time, etc.) also indirectly affect oil yield (Akgören, 2011). When the fatty oil yields of the genotypes used in the experiment were examined, it was seen that the highest average was in the G9 genotype in both years, and it is possible to say that this is due to the seed yield in the genotype.

As a result of this research, the average values of the fatty oil yield of different black cumin genotypes were 14.14-37.10 kg da^{-1} in winter planting, 9.19-25.95 kg da^{-1} in summer planting the first year, 11.74- 48.34 kg da^{-1} in winter planting and 7.79-26.94 kg da^{-1} in summer planting in the second year.

As a result of the study in which 6 different black cumin genotypes were used, Ertaş (2016) determined the fatty oil yield as 20.6 kg da^{-1} in winter planting, 13.8 kg da^{-1} in summer planting in Tokat Kazova conditions.

In summer planting, Bıyık (2018) determined the fatty oil yield as 31.6-55.6 kg da^{-1} in Tokat Niksar conditions whereas Selicioğlu (2018) determined as 19.7-43.3 kg da^{-1} in Kırşehir Boztepe conditions and Özdemirel (2019) determined as 12.13-27.27 kg da^{-1} in Bursa conditions. Kamçı (2019) found the fatty oil yields as 48.94 kg da^{-1} in winter planting and 6.12 kg da^{-1} in summer planting in Diyarbakır conditions. The fatty oil yields were found as 28.28 kg da^{-1} in winter planting and 6.06 kg da^{-1} in summer planting in the study carried out by Bayhan (2019) in Samsun. Koşar and Özel (2018) determined the fatty oil yield as 15.14-43.59 kg da^{-1} in winter planting.

It was seen that the results obtained in the studies were similar to the results of the study, had high and low values. The observed differences may be due to reasons such as the effect of ecological conditions and the genetic structure of the seed.

Fatty Acids Composition (%)

In the study, the fatty acid composition of black cumin genotypes was also determined. Palmitic and stearic acid are the most common saturated fatty acids found in vegetable oils, while linoleic acid and oleic acid are unsaturated fatty acids. Accordingly, it was determined that the most oil components in black cumin genotypes were Palmitic acid, Stearic acid, Oleic acid and Linoleic acid.

The average Palmitic acid ratio was between 12.4% and 13.8% among the genotypes in winter planting in the first and second years, the highest (13.8%) was obtained from G2 genotype, and was between 12.3% and 13.7% among the genotypes planted in summer and the highest (13.7%) was obtained from G10 genotype. The stearic acid ratio was between 2.26% and 3.84% in winter planting, and the highest (3.84%) was obtained from G18 genotype, while it was between 2.15% and 3.61% and the highest (3.61%) was in G16 genotype among the genotypes planted in summer. Oleic acid ratio was between 21.8% and 23.7% in winter planting according to genotypes and the highest (23.7%) was obtained from G18 genotype whereas it was between 22.1% and 26.0% among summer planted genotypes and the highest (26.0%) was obtained from G5 and G16 genotypes. The linoleic acid ratio was between 57.7% and 61.3% in winter planting, and the highest (61.3%) was obtained from G10 genotype, while it was between 54.8% and 59.4% and the highest (59.4%) was in G16 genotype among the genotypes planted in summer.

Considering other studies conducted in this direction, Amin et al. (2010) found linoleic acid 50.2%, oleic acid 19.9% and stearic acid 2.5% in black cumin. Babayan et al. (1978) determined that black cumin contained 12.08% of palmitic acid, 3.11% of stearic acid, 2.53% of eicosadienoic acid, 0.7% of linolenic acid and 0.16% of myristic acid. Nergiz and Ötleş (1993) reported that black cumin seeds contained 21.9% of oleic acid, 11.4% of palmitic acid, 2.9% of stearic acid and 1.2% of myristic acid.

Uras (2009), stated that black cumin seeds included 51.60% of linoleic acid, 13.50% of oleic acid, 13.50% of palmitic acid. Toma et al. (2013) stated in their study that black cumin fixed oil components were 63.71% of linoleic acid, 19.42% of oleic acid and 8.92% of palmitic acid. Gholizade et al. (2018) evaluated 32 different Iranian local genotypes in their study and reported that the main components were linoleic acid (57.50%), oleic acid (21.80%), palmitic acid (13.20%) and stearic acid (2.40%). The findings of the researchers were similar to the results of our study, and it was seen that there were high and low values. The difference in this state may vary depending on the fact that the fatty acid composition of vegetable oils is not always under standard conditions; there are characteristic differences depending on the species and varieties, and many other factors. For this reason, it is important to know how the fatty acid components of oil crops will change as a result of what conditions and what effect they will show in terms of oil quality. The distribution and position of fatty acids in the oil directly affect the quality of the oil, its importance in nutrition, and its technological and processing values. At the same time, knowing the compositions of these fatty acids, it will be possible to produce the black cumin plant according to the usage purposes of the oils by growing it in suitable regions (Karaca and Aytaç, 2007).

Thymoquinone Concentration

Thymoquinone values determined in the seed fatty oil of 19 different black cumin seed genotypes (18 genotypes and 1 variety) are given in Table 5.

Table 5. Thymoquinone concentrations (ppm) in seed oil in different black cumin genotypes planted (Summer-Winter) between 2018-2020.

GENOTYPE/ VARIETY	1. YEAR		2. YEAR		AVERAGE	
	WINTER	SUMMERY	WINTER	SUMMERY	WINTER	SUMMERY
G1	471.2	3783.7	483.5	3892.2	477.3±6.1	3837.9±54.3
G2	6591.6	2611.3	6736.7	2783.4	6664.2±72.6	2697.4±86.1
G3	8635.8	1632.9	9245.2	1543.8	8940.5±304.7	1588.4±44.5
G4	2118.7	3879.1	2012.9	3945.2	2065.8±52.9	3912.2±33.1
G5	1011.0	2482.3	1156.1	2506.5	1083.6±72.6	2494.4±12.1
G6	7610.5	1545.8	8111.3	1654.8	7860.9±250.4	1600.3±54.5
G7	4517.9	2650.3	4188.0	2578.5	4352.9±164.9	2614.4±35.9
G8	1775.5	2335.3	1692.1	2362.0	1733.8±41.7	2348.6±13.3
G9	8174.5	2334.5	7856.7	2276.6	8015.6±158.9	2305.6±28.9
G10	1135.1	595.3	1025.4	602.1	1080.3±54.8	598.7±3.4
G11	10626.7	3760.5	9523.3	3826.1	10074.9±551.7	3793.3±32.8
G12	2230.2	2184.8	2168.1	2212.3	2199.2±31.1	2198.5±13.8
G13	2446.3	2188.7	2378.9	2078.5	2412.6±33.7	2133.6±55.1
G14	1180.5	4877.8	1021.4	4783.4	1100.9±79.5	4830.5±47.2
G15	1814.3	2461.6	1934.7	2585.6	1874.5±60.2	2523.6±61.9
G16	433.5	3309.3	487.3	3216.3	460.4±26.9	3252.7±46.5

GENOTYPE/ VARIETY	1. YEAR		2. YEAR		AVERAGE	
	WINTER	SUMMERY	WINTER	SUMMERY	WINTER	SUMMERY
G17	5383.3	5079.8	5173.2	4892.5	5278.2±105.0	4986.2±93.7
G18	2067.6	7843.9	1939.4	7787.3	2003.5±64.1	7815.6±28.3
CAMELI	7484.4	3278.4	7691.2	3193.7	7587.8±103.4	3236.1±42.3

In the first year winter planting, thymoquinone values of different black cumin genotypes varied between 433.5-10626.7 ppm, the lowest (433.5 ppm) was obtained from G16 genotype and the highest (10626.7 ppm) was obtained from G11 genotype. In the first year summer planting, it varied between 595.3-7843.9 ppm among the genotypes planted, and the lowest (595.3 ppm) was obtained from G10 genotype, while the highest (7843.9 ppm) was obtained from G18 genotype.

Among the genotypes planted in winter in the second year, it varied between 483.5-9523.3 ppm, the lowest (483.5 ppm) was obtained from G1 genotype and the highest (9523.3 ppm) was obtained from G11 genotype. Among the genotypes planted in summer, it varied between 602.1-7787.3 ppm, the lowest (602.1 ppm) was obtained from G10 genotype, and the highest (7787.3 ppm) was obtained from G18 genotype.

Among the two-year averages, the average of the genotypes planted in the winter period varied between 477.3-10074.9 ppm, the lowest (477.3 ppm) was obtained from G1 genotype and the highest (10074.9 ppm) was obtained from G11genotype. Among the summer planted genotypes, it varied between 598.7-7815.6 ppm, the lowest (598.7 ppm) was obtained from G10 genotype G10 and the highest (7815.6 ppm) was obtained from G18 genotype.

Thymoquinone is the most abundant bioactive molecule in black cumin essential oil. In its structure, there is an isopropyl group attached to the quinone ring at the 2 position and a methyl group attached to the 5 position. At room temperature, it is yellow in color and has a crystalline structure. When the thymoquinone molecule is exposed to light, it dimerizes by giving a (2+2) cycloaddition reaction and turns into dithymoquinone. Therefore, it should be stored in suitable conditions. Thymoquinone, which is an oil-soluble and hydrophobic molecule, has been determined to be stable in an acidic environment (Islam et al., 2016; Sicker et al., 2019). The amount of thymoquinone molecule in black cumin seeds may vary according to regions.

Al-Saleh et al. (2006) stated in their study on black cumin seeds supplied from five different countries that the highest amount of thymoquinone was 3098.5 mg kg^{-1} in Ethiopian seeds and the lowest amount was 1274.6 mg kg^{-1} in Sudanese seeds. Işık et al. (2017) determined that thymoquinone concentrations were between 9.806-376.192 ppm in black cumin seeds, 18.121-226.276 ppm in seed oils and 13.459-740.098 ppm in seed oil capsules and these values were lower than the values in our study. Toma et al. (2010), determined thymoquinone as 1.65%, Palabayık (2018) reported the highest thymoquinone content as 67.7% in the genotypes he studied. Kal (2019) determined the thymoquinone ratio as 11.08% to 15.02% in black cumin seeds obtained from different regions. In a study conducted in Konya, Yiğitbaşı (2019) reported that while the ratio of thymoquinone was 17.98% in *N. sativa* species, thymoquinone was not found in *N. damascena* species. Gholizade et al. (2016) studied with Iranian local black cumin genotypes and determined the thymoquinone ratio as 14.68% in the Arak genotype, which had the highest seed and oil yield. The difference in this situation may depend on the genetic structure of the genotypes used, breeding techniques and environmental conditions.

CONCLUSION

This research was carried out in Mardin ecological conditions in order to determine the quality characteristics of 1 variety (Çameli) and 18 genotypes of black cumin in different planting periods between 2018 and 2020.

Fatty oil ratio varied between 31.57- 39.89% in winter planting and 34.42-37.68% in summer planting in the first year. In the second year, it varied between 32.86-39.41% in winter planting and 33.55-38.58% in summer planting.

Fatty oil yield varied between 14.14-37.10 kg da-1 in winter planting and 9.19-25.95 kg da-1 in summer planting in the first year. In the second year, it varied between 11.74-48.34 kg da-1 in winter planting and 7.79-26.94 kg da-1 in summer planting.

Fatty acids composition; It was found that the ratios of Palmitic acid, Oleic acid and Linoleic acid in terms of saturated and unsaturated fatty acids of black cumin genotypes were higher than other fatty acids. In the study, the average palmitic acid ratio was between 12.4%-13.8% in the first and second year winter planting genotypes, and between 12.3%-13.7% in the summer planting, oleic acid was between 21.8-23.7% in the winter planting and 22.1-26.0% in the summer planting, linoleic acid was between 57.7-61.3% in winter planting and between 54.8-59.4% in summer planting.

Thymoquinone concentration; Thymoquinone values in seed fatty oil of different genotypes of black cumin seed varied as 433.5-10626.7 ppm among the genotypes planted in winter in the first year and 595.3-7843.9 ppm among the genotypes planted in summer. In the second year, it was 483.5-9523.3 ppm among the genotypes planted in winter and 602.1-7787.3 ppm among the genotypes planted in summer.

As a result of the study, positive results can be obtained in both yield and quality with the appropriate genotypes to be selected in accordance with all the observations examined. Especially suitable planting time causes yield increases in black cumin. Accordingly, it has been observed in our study that winter plantings are ahead of summer plantings in terms of yield and quality in Mardin ecological conditions. Because the plant fully develops in winter planting, it branches better and binds more capsules. As a result of the study, it was determined that Eskişehir-5 (G9) genotype performed better than other cultivars and genotypes in terms of fatty oil yield in Mardin ecological conditions. Due to the early increase in temperatures in Mardin conditions, yield and other characteristics decreased in summer planting compared to winter planting. For this reason, the most suitable planting time for black cumin cultivation in Mardin conditions is recommended as winter planting.

EXPLANATION

The data used in this article were obtained from Zübeyir Güneş's doctoral thesis.

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