

Investigation of yield and quality characteristics of *Nigella sativa* L. and *Nigella damascena* L. at different sowing times in Eastern Anatolia conditions, Türkiye

Doğu Anadolu koşullarında *Nigella sativa* L. ve *Nigella damascena* L.'nin farklı ekim zamanlarında verim ve kalite özelliklerinin araştırılması

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ARTICLE INFO	ABSTRACT
Article history: Received / Geliş: 10.10.2025 Accepted / Kabul: 15.12.2025 Keywords: Black cumin Fixed-essential oil rate <i>Nigella</i> sp. Seed yield Sowing time Anahtar Kelimeler: Çörekotu Ekim zamanı <i>Nigella</i> sp. Sabit-uçucu yağ oranı Tohum verimi ✍ Corresponding author/Sorumlu yazar: Ahmet YENİKALAYCI a.yenikalayci@alparslan.edu.tr Makale Uluslararası Creative Commons Attribution-Non Commercial 4.0 Lisansı kapsamında yayınlanmaktadır. Bu, orijinal makaleye uygun şekilde atıf yapılması şartıyla, eserin herhangi bir ortam veya formatta kopyalanmasını ve dağıtılmasını sağlar. Ancak, eserler ticari amaçlar için kullanılamaz. © Copyright 2022 by Mustafa Kemal University. Available on-line at https://dergipark.org.tr/tr/pub/mkutbd This work is licensed under a Creative Commons Attribution-Non Commercial 4.0 International License.  	The value of the black cumin plant is increasing daily due to its pharmacological properties. The most economically widespread species are <i>Nigella sativa</i> L. and <i>Nigella damascena</i> L. This study was conducted in 2022 to determine the yield and quality characteristics of <i>Nigella sativa</i> L. and <i>Nigella damascena</i> L. at different sowing times under the Eastern Anatolia conditions. The experiment was conducted using a split-plot design with three replications. In terms of examined traits, plant height was determined as 25.5 - 36.0 cm, number of branches per plant as 3.70 - 6.23, number of capsules per plant as 4.7 - 17.9, number of seeds per capsule as 27.67 - 77.73, 1000-grain weight as 1.72 - 2.97 g, seed yield as 584 - 1282 kg ha⁻¹, oil ratio as 13.24 - 23.40 %, oil yield as 84.9 - 284.7 kg ha⁻¹, essential oil ratio as 0.18 - 0.54 % and essential oil yield as 1.43 - 6.77 kg ha⁻¹. Black cumin was superior to Damascus black cumin in terms of all examined botanical and agronomic traits. The best sowing time for <i>N. sativa</i> was the first sowing (April 25), while for <i>N. damascena</i> it was the third sowing (May 25). Both species showed differences in seed and oil yields. ÖZET Çörekotu bitkisinin değeri farmakolojik özelliklerinden dolayı her geçen gün artmaktadır. Ekonomik açıdan en yaygın olan türler çörekotu (<i>Nigella sativa</i> L.) ve Şam çörekotu (<i>Nigella damascena</i> L.)'dur. Bu çalışma Doğu Anadolu koşullarında çörekotu (<i>Nigella sativa</i> L.) ve Şam çörekotu (<i>Nigella damascena</i> L.) türlerinin farklı ekim zamanlarında verim ve kalite özelliklerini belirlemek amacı ile 2022 yılında yürütülmüştür. Deneme bölünmüş parseller deneme desenine göre 3 tekrarlamalı olarak gerçekleştirilmiştir. İncelenen özellikler bakımından her iki türde bitki boyu 25.5 - 36.0 cm, dal sayısı 3.70 - 6.23 adet/bitki, kapsül sayısı 4.7 - 17.9 adet/bitki, kapsüldeki tohum sayısı 27.67 - 77.73 adet, 1000 tane ağırlığı 1.72 - 2.97 g, tohum verimi 584 - 1282 kg ha⁻¹, sabit yağ oranı % 13.24 - 23.40 sabit yağ verimi 84.9 - 284.7 kg ha⁻¹, uçucu yağ oranı % 0.18 - 0.54 uçucu yağ verimi % 01.43 - 6.77 kg ha⁻¹ aralığında tespit edilmiştir. Çörekotu incelenen tüm bitkisel ve tarımsal özellikler yönünden Şam çörekotuna göre üstünlük göstermiştir. Ekim zamanı olarak en iyi sonuçlar çörekotunda 1. Ekim (25 Nisan), şam çörekotunda ise 3. Ekim (25 Mayıs) zamanından elde edilmiştir. Her iki tür dekara tohum verimi ve sabit yağ oranı bakımından farklılık göstermiştir.
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INTRODUCTION

The black cumin has been used for medicinal purposes and as food additive in many regions of the World, particularly in South Asia and North Africa, since ancient times. In recent years, scientific research has focused on black cumin species, especially on their medicinal properties.

Türkiye has rich in *Nigella* species. While there are 22 different *Nigella* species worldwide, 19 taxa belonging to the *Nigella* genus are found in Türkiye. Of these, *Nigella lancifolia* HUB.-MOR., *Nigella arvensis* L. var. *anatolica* M. ZOHARY, and *Nigella arvensis* L. var. *oblanceolata* P.H. DAVIS are endemic, while the other 16 taxa are not endemic (Bakiş et al., 2011). *N. sativa* is the most widely produced in the world, followed by *N. damascena*.

Albakry et al., (2022) found that *N. sativa* seeds contain high-quality oil and protein, as well as important minerals such as potassium, calcium, phosphorus, magnesium, zinc, iron, and copper. Black cumin seeds have also an important source of compounds with positive health effects, including oleic acid, linoleic acid, tocopherols, polyphenols, and thymoquinone. The reported composition was 5.02 % moisture, 21.07 % crude protein, 39.02 % crude fat, 3.02 % ash, 6.01 % fiber, and 25.86 % carbohydrates.

Black cumin seeds are beneficial for various diseases, including chronic headaches, back pain, hypertension, diabetes, infections, inflammation, and stroke (Randhawa & Alghamdi, 2011; Yimer et al., 2019). The seed oil, which contains high levels of linoleic, oleic, and linolenic fatty acids, has antioxidant, anticancer, antitumor, anti-inflammatory, antimicrobial, antidiabetic, immunostimulatory and gastroprotective properties (Khan et al., 2011; Ahmad et al., 2013).

N. sativa essential oil has been reported to have therapeutic effects, including antioxidant, anti-allergic, anti-inflammatory, anti-cancer, hypoglycemic, hypotensive, hypolipidemic, and immunomodulatory properties, due to its very high levels of thymoquinone and various bioactive compounds (Aksu et al., 2021; Zielińska et al., 2021). The main component of the volatile oil obtained from black cumin seeds is thymoquinone, the most bioactive compound, which showing a wide range of therapeutic benefits (Haseena et al., 2015).

N. damascena seeds contain various medicinal essential oil components, including β -elemene, damascenine, germacrene A, α -pinene, β -pinene, p-cymene, myrcene, and limonene (Fico et al., 2004; Wajs et al., 2009; Sieniawska et al., 2018). The main components, β -elemene and damascenine, exhibit antitumor, analgesic, antiproliferative (Bekemeier et al., 1968), and anti-inflammatory effects in human neutrophils (Sieniawska et al., 2018). Additionally, β -elemene has been reported to have a synergistic effect with anticancer drugs (Zhao et al., 2007).

In Türkiye, 10.089 tons of *Nigella* seeds were produced on 108.029 decares of land in 2022, but this amount fell by 50% over the next two years. In 2024, 4.572 tons of *Nigella* seeds were produced on 55.997 decares of land. Although *Nigella* seed import figures vary from year to year, in 2021, 785 tons of *Nigella* seed were exported, generating \$ 2.101 million in revenue. In the same year, 2.018 tons of *Nigella* seed were imported, costing \$ 2.166 million in foreign exchange (Anonymous, 2024).

This study was conducted in Muş Province, which has Türkiye 's third-largest plain. The agricultural potential of Muş Province will further increase with the construction of the Alparslan II Dam and the establishment of closed irrigation systems in the plain, after which polyculture farming will be adopted. Researching the yield potential and characteristics of the Çameli black cumin variety, the first registered variety of *N. sativa* developed in our country, will be beneficial for promoting this variety. This study aimed to determine the appropriate sowing times for black cumin (*Nigella sativa* L.) and Damascus black cumin (*Nigella damascena* L.) species under Muş conditions, with the goal of enriching the crop rotation in Muş, offering alternative products to producers, and investigating yield and quality characteristics.

MATERIALS and METHODS

Materials

The *N. sativa* Çameli variety used in the study was obtained from the Eskişehir Transitional Zone Agricultural Research Institute Directorate. It is the first black cumin variety registered in Türkiye, in 2014. The *N. damascena* variety was obtained from the Field Crops Department, Faculty of Agriculture, Çukurova University.

Methods

Experimental site and climate, soil conditions

The field trial was conducted at the Research and Application Field of the Faculty of Applied Sciences, (coordinates 38°77'39" north and 41°42' 69" east), Muş Alparslan University, during the 2022 production season. The soil at the trial site is clay-loam in texture, with a pH of 6.61, organic matter content of 2.21 %, and available P₂O₅ at 2.20 kg da⁻¹. The climate during the April–November period of the trial included an average temperature of 11.05 °C, precipitation of 395.8 mm, and average relative humidity of 58.7 %. Precipitation during this period was lower than the long-term average of 758.9 mm, the average temperature was 1.7 °C higher than the long-term average, and the relative humidity was similar. Precipitation measured 32 mm in April, 91.6 mm in May, and 16 mm in June, with no precipitation in July or August. Because precipitation stopped from mid-June onward, irrigation was performed every 10 days during the summer.

Experimental design and treatments

In the study, two species black cumin (*Nigella sativa* L.) and Damascus black cumin (*Nigella damascena* L.)—were sowing at six different sowing times using a split-plot design with three replications. Sowing times were assigned to the main plots and species to the subplots. Plots had 30 cm between rows, a length of 4 m, and four rows per plot, with observations made in the middle two rows. Seed was sown at a rate of 2 kg da⁻¹. Before sowing, 20-20-0 compound fertilizer was applied at a rate of 8 kg da⁻¹ of N and P.

Six different sowing times were used in the experiment. The first sowing was on April 25, the second on May 10, the third on May 25, the fourth on June 9, the fifth on June 24, and the sixth on July 9, 2022. The harvests were as follows: the first harvest on August 23, the second harvest on September 1, the third harvest on September 20, the fourth harvest on September 30, and both the fifth and sixth harvests on November 20, 2022. Due to weak plant growth and insufficient plants for harvest in the fifth and sixth sowing times, these sowing times were not included in the study.

Methods used in oil analysis and component analysis

In this study, fixed and volatile oil analyses were conducted at the Bingöl University Central Laboratory Application and Research Center. Volatile oils were extracted from 100 g samples of ground both species seeds using a Neo-Claevenger device.

VELP Scientifica ser 148 solvent extractor device analysis conditions

Solvent: Hexane; Plate temperature: 130 °C; Immersion time: 120 min; Washing time: 60 min; Recovery time: 60 min.

In the study, plant height (cm), number of branches per plant, number of capsules per plant, number of seeds per capsule, weight per thousand seeds (g), seed yield (ha⁻¹), fixed oil content (%), fixed oil yield (ha⁻¹), volatile oil content (%), and volatile oil yield (ha⁻¹) were measured.

Data evaluation: The data obtained from the research were analyzed using the MSTAT-C package to perform variance analysis. Significant means were grouped according to the Duncan multiple comparison test.

RESULTS and DISCUSSIONS

Data on the characteristics examined in the study investigating the yield and quality traits of black cumin (*Nigella sativa* L.) and Damascus black cumin (*Nigella damascena* L.) at different sowing times under Muş conditions are presented in Table 1.

Table 1. Average values of characteristics examined by sowing time in *Nigella sativa* and *Nigella damascena*
Çizelge 1. *Nigella sativa* ve *Nigella damascena*'da ekim zamanlarına göre incelenen özelliklerin ortalama değerleri

Reviewed Features	<i>N. sativa</i>				<i>N. damascena</i>				LSD $p \leq 0.05$
	1.st time	2.nd time	3.rd time	4.th time	1.st time	2.nd time	3.rd time	4.th time	
Plant H	36.0 a	31.9 cd	33.9 bc	26.6 e	31.0 d	30.6 d	34.3 ab	25.5 e	1.895
Average	32.0 a				30.3 b				0.9475
NBranch	6.13	5.60	3.70	3.86	5.40	6.23	3.96	4.90	0.8710
Average	4.83				5.13				NS
NCapsul	15.97 a	17.90 a	8.23 bc	10.43 b	5.80 cd	7.77 c	4.73 d	6.57 cd	2.318
Average	13.13 a				6.22 b				1.159
NSCapsul	51.07 c	77.73 a	50.60 c	60.07 b	38.07 d	38.47 d	27.67 e	37.23 d	6.379
Average	59.87 a				35.37 b				3.189
1000GW	2.93 a	2.97 a	2.61 c	2.78 b	2.20 d	2.27 d	1.72 f	1.85 e	0.8420
Average	2.82 a				2.01 b				0.0421
SYield	128.2 a	118.5 a	86.3 c	78.7 cb	79.6 cd	102.1 b	58.4 e	72.1 d	12.52
Average	103.0 a				78.0 b				6.260
FOC	22.79	20.48	21.59	23.40	13.24	15.62	14.54	16.25	
Average	22.07				14.91				
FOYield	28.47 a	24.27 b	18.64 c	18.42 c	10.54 e	15.94 d	8.49 f	11.72 e	2.034
Average	22.45 a				11.67 b				1.017
EOC	0.54	0.39	0.28	0.23	0.18	0.33	0.45	0.22	
Average	0.36				0.30				
EOYield	0.68 a	0.46 b	0.24 d	0.18 e	0.14 e	0.34 c	0.26 d	0.16 e	0.0595
Average	0.39 a				0.22 b				0.2977

Plant H: Plant height (cm), **NBranch:** Number of branches (per plant), **NCapsul:** Number of capsules (per plant), **NSCapsul:** Number of seeds in capsule (number/capsule), **1000GW:** 1000 grain weight (g), **SYield:** Seed yield (kg da^{-1}), **FOC:** Fixed oil content (%), **FOYield:** Fixed oil yield (kg da^{-1}), **EOC:** Essential oil content (%), **EOYield:** Essential oil yield (kg da^{-1}), **NS:** No significant

Plant height (cm)

Plant height values were statistically significant for species, sowing time, and the species $\times$ sowing time interaction. As shown in Table 1, plant height for black cumin and Damascus black cumin ranged from 25.5 to 36 cm depending on the sowing time. The highest plant height was observed in black cumin at the first sowing time, and the lowest in Damascus black cumin at the fourth sowing time. Black cumin was taller than Damascus black cumin. In his study conducted Yiğitbaşı (2019), *N. sativa* exhibited a taller plant height compared to *N. damascena*. Plant height values

were higher in the 1st and 3rd sowing times. In the 4th sowing time, plant height values were the lowest for both species. The plant height values obtained in the experiment are close to those reported by some researchers (Ürüšan, 2016 (22-47.7 cm), Selicioğlu, 2018 (22-30 cm), Özdemirel, 2019 (25-50 cm), Beyzi & Karer, 2020 (33-56 cm), İnan, 2020, Keser & Gedik, 2021 (25-45 cm), Ulusu & Şahin, 2021 (25-37 cm), Bozdemir, 2022 (14.9-43.6 cm), Karakaşlı, 2022), higher than those reported by others (Örmek, 2009 (11.5-19.4 cm), Akgören, 2011 (16-25 cm)), and lower than those reported by some (Telci, 1995 (42-53 cm), İpek et al., 2005, Özel et al., 2009 (69-88 cm), Baytöre, 2011 (34-53 cm), Taqi, 2013 (42-43 cm), Tektaş, 2015 (63.8-70.3 cm), Ertaş, 2016 (45.4-47.6 cm), Kılıç, 2016 (39-79 cm), Beyzi, 2018 (33-56 cm), Bıyık, 2018 (41-57 cm), Kamçı, 2019 (37-67 cm), Güneş, 2021 (44-75 cm). It is lower than the findings of some researches; such as Sağlık (2020) (34.9-76.5 cm). These variations may be due to differences in climate, soil, variety, species, and cultivation techniques.

Number of branches per plant

Sowing time was significant at the 1 % level for branch number, other treatments were not statistically significant. As shown in Table 1, the number of branches per plant in black cumin and Damascus black cumin ranged from 3.70 to 6.23, depending on sowing time. The highest number of branches per plant was found in Damascus black cumin at the second sowing time, while the lowest was found in black cumin at the third sowing time. The highest number of branches was observed in the second sowing time, and the lowest in the third sowing time. More branching was observed in Damascus black cumin. After May, the number of branches decreased significantly in both species. The branch number values obtained in the experiment were close to those reported by some researchers; Telci (1995) (4.1-5.2 branches/plant), Özel et al. (2002) (4.13 branches/plant), Örmek (2019) (2.4-4.6 branches/plant), Koşar et al. (2013) (3.5–5.1 branches/plant), Ertaş (2016) (4.15–5.27 branches/plant), Ürüšan (2016) (3.9–6.7 branches/plant), Selicioğlu, (2018) (2.3-4 branches/plant), Kamçı /2019) (4.4-5.6 branches/plant), Keser & Gedik (2021) (4.5-7.3 branches/plant) and Ulusu & Şahin (2021) (2.33–5.60 branches/plant). They were lower than the values reported by some researchers, such as Tektaş (2015) (6.70–8.17 branches/plant) and Tonçer & Kızıl (2004) (4.1-9.1 branches/plant), and higher than those reported by others, including Özel et al. (2009) (2.30–4.43 branches/plant), Taqi (2013) (2.5–3.1 branches/plant), Selicioğlu (2018) (2.3–4 branches/plant), Koşar & Özel (2018), Güneş (2021) (3.2-5 branches/plant), Bozdemir (2022) (1.3-3.1 branches/plant). This variation in the number of branches can be attributed to species, sowing time, ecological conditions, and differences in the cultural practices applied.

Number of capsules per plant

For capsule number values, species, sowing time, and the species × sowing time interaction were statistically significant at the 1 % level. The number of capsules per plant in black cumin and Damascus black cumin ranged from 4.73 to 17.90, depending on sowing time. The highest number of capsules was observed in black cumin at the second sowing time, while the lowest was observed in Damascus black cumin at the third sowing time. According to sowing times, the lowest number of capsules was found in the 3rd sowing time. The capsule number was higher in black cumin, with 13.13 capsules per plant. The capsule count obtained in the experiment was higher than the values reported by some researchers; Özel & Demirebilek (2000) reported 1.50–4.06 capsules per plant, Turan (2014) reported 3.53 – 4.05 capsules per plant, and some researchers reported consistent values (Koşar et al., 2013 (5.7-10.5 capsules per plant), Baytöre & Yaver, 2014 (5.2-7.2 capsules per plant), Tavas et al., 2014 (8.08 capsules per plant), Ertaş, 2016 (7.9-9.4 capsules per plant), Kılıç, 2016 (16.1 capsules per plant), Ürüšan, 2016 (5.5-19.8 capsules per plant), Bıyık, 2018 (8-15 capsules per plant), Özdemirel, 2019 (5.3-8 capsules per plant), Ulusu & Şahin (2021), while it was lower than the values reported by others (Özgüven & Şekeroğlu, 2007, Tektaş, 2015).

Number of seeds per capsule

Seed number values per capsule were statistically significant at the 1 % level for species, sowing time, and the species $\times$ sowing time interaction. As shown in Table 1, the number of seeds per capsule ranged from 27.67 to 77.73, depending on sowing time in black cumin and Damascus black cumin. The highest number of seeds per capsule was observed in black cumin at the second sowing time, while the lowest was observed in Damascus black cumin at the second sowing time at the third sowing time. In both types, the lowest number of seeds per capsule was observed at the third sowing time. The data obtained in our experiment are close to the values reported by some researchers (Özel et al., 2009 (53-89 number/capsule), Akgören, 2011 (60-94 number/capsule), Safaei et al., 2014 (61.4-58.7 number/capsule), Ürüşan, 2016 (62-117 number/capsule), Örmek, 2019 (24.3-39.8 number/capsule), İnan, 2020 (51.9-66.1 number/capsule), Bozdemir, 2022 (29.8-54.6 number/capsule)), but lower than those reported by others (Tektaş, 2015 (81.6-90.8 number/capsule), Kılıç, 2016 (91.9-104 number/capsule), Keser, 2019 (96-309 number/capsule), Kızılyıldırım, 2019 (110-126 number/capsule), Özdemirel, 2019 (60.6-89.2 number/capsules), Saraç, 2019 (85-103 number/capsule). These differences may stem from variations in variety, type, climate and soil.

Thousand-seed weight

Thousand-seed weight values were statistically significant at the 1 % level for variety, sowing time, and the variety $\times$ sowing time interaction. Values ranged from 1.72 to 2.97 g. The lowest value was observed in the third sowing time for Damascus black cumin, while the highest thousand-seed weight was recorded in the second sowing time for black cumin. Among sowing times, the highest thousand-seed weight was 2.62 g in the second sowing time. In sowings after May, thousand-seed weight values for both types decreased. The data obtained in this experiment are consistent to values reported by most researchers (Telci, 1995 (2.13-2.46 g), Akgören, 2011 (1.21-2.62 g), Arslan et al., 2011 (1.9-2.0 g), Baytöre, 2011 (1.9-.2.3 g), Tektaş, 2015 (2.4-2.9 g), Ertaş, 2016 (2.47-2.67 g), Ürüşan, 2016 (2.5-3.5 g), Bıyık, 2018 (2.1-2.8 g), Kılıç, 2016 (1.85-2.59), Selicioğlu, 2018 (1.95-2.96 g), Kızılyıldırım, 2019 (2.40-2.47 g), Özdemirel, 2019 (2.2-3.4 g), Saraç, 2019 (2.58-2.93 g), Beyzi & Karer, 2020 (2.4-2.7 g), Ulusu & Şahin, 2021 (2.31-2.84 g), Keser & Gedik, 2021 (2.1-3.4 g), Güneş, 2021 (2.2-2.9 g), Bozdemir, 2022 (1.8-3.2 g)).

Seed yield

Seed yield, species, sowing time, and the interaction between species and sowing time were statistically significant at the 1 % level. As shown in Table 1, seed yield ranged from 58.4 to 128.2 kg da⁻¹. The lowest value, 58.4 kg da⁻¹, was recorded at the third sowing time for Damascus black cumin, while the highest seed yield, 128.2 kg da⁻¹, was observed at the first sowing time for black cumin. For both types, the highest average seed yield was 110.3 kg da⁻¹ in the second sowing period, while the lowest was 72.4 kg da⁻¹ in the third sowing period. Seed yields for both types decreased significantly in sowing after May. Seed yields were consistent with the findings of some researchers (Tonçer & Kızıl, 2004 (59.5-82.8 kg da⁻¹), Akgören, 2011 (90-188 kg da⁻¹), Taqi, 2013 (82.8-126.9 kg da⁻¹), Turan, 2014 (87-111 kg da⁻¹), Tektaş, 2015 (71.9-118.7 kg da⁻¹), Selicioğlu, 2018 (58-122 kg da⁻¹), Kamçı, 2019 (19-162 kg da⁻¹), Saraç, 2019 (52-125 kg da⁻¹), Beyzi & Karer 2020 (57-104 kg da⁻¹), Ulusu & Şahin, 2021 (46-114 kg da⁻¹)), higher than those reported by some (Ertuğrul, 1986 (27 kg da⁻¹), Özel et al., 2002; Arslan et al., 2011 (16.6-60 kg da⁻¹), Baytöre, 2011 (28-43 kg da⁻¹), Ertaş, 2016 (30-54 kg da⁻¹), Kılıç, 2016 (28-89 kg da⁻¹), Keser & Gedik, 2021 (15-39 kg da⁻¹), Güneş, 2021 (28-68 kg da⁻¹), Bozdemir, 2022 (25.9-50.1 kg da⁻¹), and lower than those reported by others (Özgüven & Tansı, 1989 (135-140 kg da⁻¹), Telci, 1995 (104-151 kg da⁻¹), Koç, 1999 (131-162 kg da⁻¹), Özel et al., 2009 (140-248 kg da⁻¹), Bıyık, 2018 (117-191 kg da⁻¹). These differences may be due to climate, soil and cultivation techniques.

Fixed oil content

The fixed oil content ranges from 13.24 % to 23.40 %. The lowest value, 13.24 %, was observed in Damascus black cumin during the first sowing time, while the highest value, 23.40 %, was found in black cumin during the fourth sowing period. According to sowing times, the fixed oil content in the seeds increased slightly as the sowing time was delayed, reaching 19.83 %. According to species, black cumin contained more fixed oil (22.07 %). Most researchers have reported higher values than our findings (Akgül, 1993 (30-40 %), Telci, 1995 (34.4-41.4 %), Akgören, 2011 (19-26 %), Arslan et al., 2011 (21.7-31.5 %), Örmek, 2009 (35-38 %), Taqi, 2013 (18.8-41 %), Tektaş, 2015 (27.9-41.2 %), Ertaş, 2016 (37 %), Kılıç, 2016 (32-38 %), Ürüsan, 2016 (36-41 %), Selicioğlu, 2018 (33-38 %), Farhan et al., 2021 (43.7 %), Güneş, 2021 (33.9-38.1 %), Ulusu & Şahin, 2021 (34-36 %), Bozdemir, 2022 (22.2-40.6 %)), but some values are consistent with these (D'Antuono et al., 2002 (19-22.7 %), Kızılyıldırım, 2019 (21.8-22.8 %), Saraç, 2019 (21.7-24.2 %), Beyzi & Karer, 2020 (11.94-19.34 %)).

Fixed oil yield

For fixed oil yield, species, sowing time, and their interaction were statistically significant at the 1 % level. Fixed oil yield ranged from 8.49 to 28.47 kg da⁻¹, with the lowest yield of 8.49 kg da⁻¹ in Damascus black cumin at the third sowing time and the highest yield of 28.47 kg da⁻¹ in black cumin at the first sowing time. The highest fixed oil yield was recorded at the second sowing time. Black cumin produced a higher fixed oil yield than Damascus black cumin. The data we obtained on fixed oil yield were consistent to the values reported by some researchers (Arslan et al., 2011 (3.6-18.9 kg da⁻¹), Taqi, 2013; Kılıç & Arabacı, 2016; Ertaş, 2016 (13-21 kg da⁻¹), Kılıç, 2016 (9.9-34.8 kg da⁻¹), Kamçı, 2019 (6-48 kg da⁻¹), Özdemirel, 2019 (12-27 kg da⁻¹), Güneş, 2021 (9.6-25.1 kg da⁻¹), Ulusu & Şahin, 2021 (15-41 kg da⁻¹), Bozdemir, 2022 (5.2-23.0 kg da⁻¹), but lower than those reported by others (Telci, 1995 (36.7-52.7 kg da⁻¹), Turan, 2014 (32-43 kg da⁻¹), Bıyık, 2018 (31.6-55.6 kg da⁻¹)). There is a positive relationship between oil content and seed yield per decare, which is an important factor affecting fixed oil yield. All factors affecting seed yield and oil content, such as species, climate, cultural practices, and sowing time, indirectly affect oil yield (Akgören, 2011).

Essential oil content

As shown in Table 1, the volatile oil content ranged from 0.18 % to 0.54 %, with the lowest value of 0.18 % found in Damascus black cumin during the first sowing and the highest value of 0.54 % found in black cumin during the first sowing. The essential oil content on the 1st, 2nd, and 3rd sowings was higher than in the fourth sowing. Among the species, black cumin had a higher essential oil content. According to the test results, the essential oil content is close to the values reported by some researchers (Özgüven & Tansı, 1989 (0.36-0.49 %), Burits et al., 2000 (0.41-0.44 %), Özel et al., 2009 (0.24-0.43 %), Akgören, 2011 (0.05-0.40 %), Çamlıca & Yıldız, 2019, Keser & Gedik, 2021 (0.08-0.6 %) and lower than those reported by others (Ertuğrul, 1986, Ashraf et al., 2006 (0.72 %), Kızılyıldırım, 2019 (0.6-0.84 %), Aksu et al., 2021 (0.4-1.2 %), Aysabar, 2021 (0.58-1.12 %), Zielińska et al., 2021 (0.4-2.5 %), according to Tektaş 2015 (0.08-0.20 %) findings, it was found to be high. Some researchers have reported that oil content is influenced by the plant's genetic structure, sowing time, climatic factors, and cultural practices (Ürüsan, 2016; Herlina et al., 2017).

Essential oil yield

Species, sowing time, and the species × sowing time interaction were statistically significant at the 1 % level for essential oil yield. Essential oil yields for both species ranged from 0.143 to 0.677 kg da⁻¹. The highest yield was found for black cumin at the first sowing time, while the lowest was found for Damascus black cumin at the first sowing time. Average essential oil yields (0.41-0.17 kg da⁻¹) decreased with delayed sowing times. Higher essential oil yield was obtained in the black cumin species than in Damascus black cumin. Essential oil yields in black cumin

were close to values reported by some researchers (Özgüven & Tansı, 1989; D'Antuono et al., 2002; Yiğitbaşı, 2019), but lower than those reported by others such as Ashraf et al. (2006). It has been reported that drought and the length of the vegetation period affect essential oil yield in *N. damascena* (Yiğitbaşı, 2019).

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This study was conducted in the experimental field of the Faculty of Applied Sciences at Muş Alparslan University during the 2022 summer production season, using six different sowing times for two black cumin species (*Nigella sativa* L. and *Nigella damascena* L.). Because the number of plants available for harvest was insufficient for the fifth and sixth sowing times, these sowing times were not evaluated. In this study, plant height, number of branches per plant, number of capsules, number of seeds per capsule, thousand grain weight, seed yield, fixed oil content, fixed oil yield, essential oil content, and essential oil yield were investigated in different sowing time applications of black cumin and Damascus black cumin under Eastern Anatolia conditions. The results are summarized below.

1. Plant height: The highest plant height values for *Nigella sativa* L. and *Nigella damascena* L. under Muş ecological conditions were obtained from the first sowing at the end of April and the second and third sowings in May. Plant height values were higher for *Nigella sativa* than for *Nigella damascena*.
2. Number of branches: The first and second sowing times produced the highest branch counts for both species. More branches were observed in *Nigella sativa*.
3. Number of capsules per plant: The second sowing time resulted in the highest capsule count for both species. The number of capsules per plant was higher in *Nigella sativa*.
4. Seed count per capsule: The highest seed count in both species was observed at the second sowing time, May 10. black cumin seed was superior to Damascus black cumin seed.
5. Thousand seed weight: For thousand seed weight, May 10 (the second sowing time) was the most suitable sowing time for both species. Black cumin had the highest thousand seed weight.
6. Seed yield: April 25 (the first sowing time) produced the highest seed yield for black cumin, while May 10 (the second sowing time) produced the highest seed yield for Damascus black cumin. Seed yields were higher for black cumin.
7. Fixed oil content: In both species, fixed oil yields increased slightly with delayed sowing. Black cumin had a higher fixed oil yield.
8. Fixed oil yield: In both species, fixed oil yield per decare was highest for black cumin at the first sowing time and for Damascus black cumin at the second sowing time, parallel to the seed yield per decare. Because black cumin has a higher seed yield per decare than Damascus black cumin, fixed oil yield per hectare was also higher.
9. Essential oil content: Essential oil content decreased with delayed sowing time in black cumin. The highest essential oil content was observed in damascus black cumin at the third sowing time (May 25), followed by a sharp decline in later sowings.
10. Essential oil yield: Parallel to seed yield per decare, essential oil yield was highest in black cumin at the first sowing time and in damascus black cumin at the second sowing time. Because black cumin has a higher seed yield per decare than damascus black cumin, its essential oil yield per decare was also higher.

Recommendations

This study, conducted to determine the appropriate sowing times for *Nigella sativa* L. and *Nigella damascena* L. under Muş conditions, indicates the following:

- The optimal sowing dates for *Nigella sativa* L. are from late April to early May, while for *Nigella damascena* L., sowing should occur slightly later, between May 10 and May 30.
- *Nigella sativa* L. produces more seeds per decare than *Nigella damascena* L., making it more economical to cultivate.

- Yields of *Nigella damascena* L. can be increased through the development of new cultivars and improved cultivation techniques.

Research should be conducted on mechanization-based cultivation techniques for *Nigella sativa* in Muş, including sowing, harvesting, and weed control.

- *Nigella sativa* can be recommended as an alternative crop to enrich crop rotations under irrigated conditions in Muş. In addition, the construction of the Alparslan II Dam in Muş and the establishment of closed irrigation systems in the plain are expected to contribute to product diversity and can be increased the province's agricultural potential.

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STATEMENT OF CONFLICT OF INTEREST

This article is from Irfan ÖZDEMİR's master's thesis entitled "Investigation of The Yield and Quality Characteristics of Common Black Cumin (*Nigella sativa* L.) and Damascus Black Cumin (*Nigella damascena* L.) At Different Sowing Times Under Muş Conditions" at Muş Alparslan University. The authors declare that they have no conflict of interest.

AUTHOR'S CONTRIBUTIONS

The contribution of the authors is equal.

STATEMENT OF ETHICS CONSENT

Ethical approval is not applicable, because this article does not contain any studies with human or animal subjects.

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