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Effects of Different Organic Fertilizers on Yield and Yield-Related Characteristics in Black Cumin (*Nigella sativa* L.) Cultivation Under the Ecological Conditions of Tokat, Türkiye

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ABSTRACT

This research was carried out during the 2022 and 2023 growing seasons on Agricultural Research and Application Fields of Tokat Gaziosmanpaşa University. The study aimed to investigate the effects of different organic fertilizers and application rates on the yield and yield-related characteristics of black cumin (*Nigella sativa* L.). The experiment was designed using a split plot arrangement in a randomized complete blocks design with three replications. The main plots were assigned to five organic fertilizer types: Leonardite, Vermicompost, Solid Humus, Chicken Manure and Sheep Manure, while the subplots included in the same way in all fertilizer forms four fertilizer doses (0, 150, 300 and 600 kg/da). The study utilized "Çameli" variety, the only registered *Nigella sativa* L. variety in Turkiye. Key parameters examined over both years included plant height (cm), number of branches per plant (number), number of capsules per plant (number), number of grains per capsule (number), thousand seed weight (g), seed yield (kg/da). The results; revealed that the average plant height ranged from 39.76 to 54.33 cm, the number of branchers per plant, ranged from 6.22 to 6.35, the number of capsules per plant ranged from 13.43 to 14.88, the number of seed per capsule ranged from 98.56 to 104.00, thousand seed weight varied between 2.50 and 3.11 g, seed yield ranged from 135.26 to 135.41 kg/da. Statistically significant differences ($p<0.01$) were observed for all examined characteristics. Based on the two-year results the application of chicken manure at 300 kg/da was identified as the most effective treatment, significantly enhancing plant height, capsule number and thousand seed weight. This finding reveals that the use of organic fertilizer in black cumin cultivation is an important alternative for farmers who want to both increase yield and prefer a natural production method.

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Introduction

Black cumin (*Nigella sativa* L.) is an annual plant belonging to the Ranunculaceae family native to Southern Europe and Western Asia, across Mediterranean countries. It is commonly used in the Turkish food industry and cuisine to flavor and garnish bakery products (Ceylan, 1997). The harvested part of the is its black seeds, which mature within capsules. These seeds are 2-3 mm in length triangular in shape and characterized by a bitter taste (Toptas, 2008). According to Baydar (2013), black cumin grows upright with a taproot system, a herbaceous, light-colored stem and a height ranging from 20 to 60 cm. Its leaves are arranged alternately in a three-part structure along the main stem, with each main and lateral branch terminating in a flower. The flowers, which haves 5 pointed, light blue petals, and rich in nectar frequently visited by bees. In Turkiye, the cultivation area of black cumin expanded significantly from 2.299 da in 2012, to 83.915 da in 2023, representing an approximately 37 fold increase. Similarly, production volume rose from 161 tons in 2012 to 5.386 tons in 2023, marketing a 34 fold increase. Black cumin yield in Turkiye fluctuates annually, ranging from 70 to 119 kg per decare (TUIK, 2024). While black cumin production was limited to 5 provinces in 2012, it expanded to 27 provinces by 2023. According to 2023 data, the highest production was recorded in Uşak province, which contributed 2109 tons (32.7% of total production), followed by Burdur with 1.141 tons (17.7%), and Çorum with 762 tons (11.8%). The remaining 37.8% of production was distributed among other provinces. In 2023, Tokat province produced 30 tons of black cumin with an average yield 111 kg/da, 17th nationally black cumin production (TUIK, 2024). In recent years, increasinge global pollution has brought the importance of organic agriculture to the forefront, both internationally and nationally. To secure a larger share of the global market, countries are implementing laws and regulations aimed at promoting

organic agriculture. These efforts align with the goals of sustainable soil use reducing environmental pollution, and meeting the growing global demand for organic products.

In this context, the use of organic fertilizers plays a crucial role in reducing reliance on nitrogen and phosphorous based commercial fertilizers. Organic fertilizers have been shown to increase organic matter content improve water retention and nutrient uptake by plants, and positively impact the physical and chemical properties of soils (Bachman and Metzger, 2008). Most studies in this field focus on regional adaptations, yield and quality in relation tp different varieties and genotypes.

This study aimed to investigate the effects of 5 different organic fertilizers and 4 fertilizer doses on the yield and yield components of organically grown black cumin during the summer season in Tokat and its surrounding regions.

Materials and Methods

The research was carried out at the Agricultural Research and Application Fields of Tokat Gaziosmanpaşa University during the 2022 and 2023 growing seasons. The experimental site is situated at an altitude of 623 meters above sea level, between 40° 33' North latitude and 36° 47' East longitude. Soil analysis results of the experimental field during both years are given in Table 1.

The soils of the experimental field had a clayey-loam particle size distribution with a neutral pH. The soil is low in organic matter and available phosphorus, but sufficient in potassium. Additionally, the site has a high lime content.

The experiment utilized the Çameli variety of *Nigella sativa* L., a registered variety included in Turkey's national variety list. Çameli is a medium-sized variety with a thousand seed weight of 2.5 g and an average fixed oil content of 25% when processed via cold pressing. This variety was officially registered by the Eskişehir Transitional Zone Research Institute on April 8, 2014 (Turkish Ministry of Agriculture and Forestry, 2014).

The experimental design consisted of three randomized complete blocks, each divided into subplots to accommodate the split plot treatments. In the experiment, the main plots were allocated to the fertilizers, while the fertilizer doses were applied to the subplots. Planting was carried out manually on April 9, 2022 and April 15, 2023. Each plot was 4 meters long, consisting of 6 rows spaced 30 cm (total plot area 7.2 m^2), and 3.60 g of seed was planted in each row, following a planting density of 3 kg/da (Yilmaz et al., 2019). A 1 meter gap between plots and blocks were separated by 2 meters. Organic fertilizers used in the study were leonardite, vermicompost, solid humus, chicken manure and sheep manure. Four different fertilizer doses (0, 150, 300 and 600 kg/da) were applied in the same way in all fertilizer forms to all plots 10 days before planting. As part of the maintenance procedures, manual hoeing was conducted to control weeds when the plants had 3-4 leaves, and weed control was repeated every 15 days. Irrigation was performed using the sprinkler method, primarily during the early morning hours in summer and in dry periods with careful attention to soil moisture status. Harvesting took place manually on August 10, 2022, and August 15, 2023, when the plant capsules begun to turn brown. To minimize edge effects, 0.25 m from the top and bottom of the plots and one row from the sides were excluded from observation (3.5 x 0.30 x 4 = 4.2 m^2). The following parameters were assessed in black cumin plants: plant height (cm), number of branches per plant, number of capsules per plant, number of grains per capsule, thousand seed weight (g) and seed yield (kg/da). The data obtained were analyzed using variance analysis with the IBM SPSS 21.0 software (International Business Machines, Statistical Package for the Social Sciences). Duncan's multiple comparison test was applied to determine the differences between the means (Yurtsever, 1984).

Results and Discussion

The results of this research, which investigated the effects of different organic fertilizers and fertilizer doses on the yield and yield-related characteristics of the black cumin plant, are presented in Table 4, 5, 6, 7, 8 and 9.

Plant Height

The plant varied between 35.40-44.10 cm in 2022, with an average height of 39.76 cm. In 2023, the plant height ranged from 47.87 to 59.10 cm, with an average plant height of 54.33 cm. Over both years, the plant height varied between 41.64 and 51.60 cm, with an average of 47.05 cm.

Table 1. Soil analysis results of the trial area for 2022 and 2023.

Feature	2022	2023	Qualification Status	Source
Sand (%)	20.41	21.33		
Clay (%)	41.61	40.39	Clayey Loam	(Gee ve Bauder, 1986)
Silt (%)	37.98	38.28		
pH	7.0	7.0	Neutral	(Richards, 1954)
EC (mmhos/cm)	100	130	Low	(Richards, 1954)
Lime (%)	12.12	12.79	High	(Bayraklı,1986)
Organic Matter (%)	1.91	1.88	Low	(Walkley ve Black, 1934)
P_2O_5 (kg/da)	1.03	0.97	Insufficient	(Olsen ve Sommers, 1982)
K_2O (kg/da)	57.1	77.14	Sufficient	(Carson,1980)
Mg (ppm)	350.9	320.2	Sufficient	(Thomas,1982)
Zn (ppm)	0.39	0.57	Insufficient	(Lindsay ve Norvell, 1978)
Fe (ppm)	13.0	12.77	Sufficient	(Lindsay ve Norvell, 1978)
Mn (ppm)	5.11	5.32	Sufficient	(Lindsay ve Norvell, 1978)
Cu (ppm)	2.04	2.78	Sufficient	(Lindsay ve Norvell, 1978)
$CaCo_3$ (%)	8.6	9.8	Middle	(Thomas,1982)

According to the analysis results of the soil sample taken from 0-30 cm depth of the trial area, the soil of the trial area has a clayey-loamy structure, its average pH is neutral, it is poor in organic matter and available phosphorus, sufficient in potassium and rich in lime.

Table 2. Climate data for the trial area for 2022 and 2023.

Meteorological Data	Years	April	May	June	July	August	September	Average
Average Temperature (°C)	2022	15.1	15.3	20.9	21.0	25.6	20.5	19.58
	2023	12.4	15.6	20.3	22.3	25.2	20.2	19.33
	1951-2023	12.4	16.3	19.6	22.1	22.3	18.8	18.58
Average Rainfall (mm)	2022	29.6	34.7	84.1	0.1	1.1	28.6	29.70
	2023	118.3	52.8	74.5	41.3	2.2	9.2	49.72
	1951-2023	52.8	59.1	39.1	11.8	8.5	8.2	29.92

Source: Tokat Meteorology Directorate, 2023.

Table 3. Organic fertilizers applied in the experiment and their properties.

Serial No.	Fertilizers	Contents	By Mass (%)
1	Leonardite	Organic Matter	20 %
		Total Humic+Fulvic Acid	20 %
		Max Moisture	20 %
		pH	3.5 - 5.5
		Total Nitrogen	2 %
2	Vermicompost	Organic Matter	35 %
		Total Humic+Fulvic Acid	20 %
		Max Moisture	35 %
		pH	6.5 - 8.5
		Total Nitrogen	1.2 %
3	Solid Hummus	Organic Matter	40 %
		Total Humic+Fulvic Acid	5 %
		Max Moisture	20 %
		pH	7.9 – 9.9
		Total Nitrogen	2 %
4	Chicken Manure	Organic Matter	50 %
		Total Humic+Fulvic Acid	30 %
		Max Moisture	20 %
		pH	5.5 – 7.5
		Total Nitrogen	3.5 %
5	Sheep Manure	Organic Matter	40 %
		Total Humic+Fulvic Acid	5 %
		Max Moisture	20 %
		pH	7.5 – 9.5
		Total Nitrogen	2 %

The highest plant height in both years was obtained with chicken manure at a dose of 300 kg/da, while the lowest was obtained with leonardit at control (Table 4). The increased plant height in the second year can be attributed to higher spring rainfalls, which positively influenced plant height. Arabaci and Bayram (2005) also reported that plants benefiting from spring rain tend to grow taller. In different studies, plant height values in black cumin were observed as 32.5–55.8 cm by Faydaci (2019), 24.13-44.93 cm by Inan (2020), 30.23-35.77 cm by Can (2021), 17.1-33.5 cm by Bozdemir et al. (2022), and 38.73-47.80 cm by Karer and Beyzi (2022).

Number of Branches

The number of branches per plant was not significantly different for 2023. In 2022, the number of branches per plant varied between 4.97 and 7.43, with an average of 6.22 branches. In 2023, this number ranged from 5.30 to 7.23, with an average of 6.35 branches. Over two years, the number of branches per plant varied between 5.17 and 7.28, with an average of 6.28 branches. The higher average number of branches in 2023 can be attributed to increased spring rainfall in that year compared to 2022, which generally contributed to greater branching. The highest number of branches per plant in 2023 was obtained with the application of 300 kg/da chicken manure (Table 5). Branching in black cumin is a desirable trait up to a certain threshold, as both branch and capsule numbers positively influenced seed yield. Yilmaz (2008) reported that branching in black cumin is influenced by a both genotype and environmental factors, while Kucukemre (2009) highlighted that environmental conditions, planting density, soil nutrients, humidity, irrigation, rainfall and light all play a role in branching development. In other different studies, the number of branches values were obtained as 2.77-4.63 branches per plant by Kosar and Ozel (2018), 5.46-7.46 branches per plant by Sarac (2019), 4.2-3.2 branches per plant by Yilmaz et al. (2019), 3.5-6.2 branches per plant by Faydaci (2019), 2.67-5.30 branches per plant by Inan (2020), 5.85-9.00 branches per plant by Saglik (2020), 4.07-5.25 branches per plant by Can (2021), 3.92-5.18 branches per plant by Abay (2021).

Number of Capsules

The number of capsules per plant ranged from 8.10 to 21.47 in 2022, with an average of 13.43. In 2023, varied between 10.17 and 23.10, with an average of 14.88. Over two years, the number of capsules per plant varied between 9.14 and 22.29, with an average of 14.16.

Table 4. Plant heights (cm) of black cumin in different fertilizer and fertilizer dose applications in 2022, 2023 and two-year averages

Plant height (cm)					
2022					
Fertilizers/Doses	Control	150 kg/da	300 kg/da	600 kg/da	Average
Leonardite	35.40f	38.77cde	40.20bcd	37.20ef	37.89D
Vermicompost	35.70f	39.23cde	42.10ab	38.27de	38.83CD
Solid Humus	38.20de	40.17bcd	40.47bc	39.27cde	39.53BC
Chicken Manure	38.33de	43.57a	44.10a	40.07bcd	41.52A
Sheep Manure	38.57cde	39.60cd	43.20a	42.77a	41.04AB
Average	37.24D	40.27B	42.01A	39.52C	39.76B
2023					
Fertilizers/Doses	Control	150kg/da	300kg/da	600kg/da	Average
Leonardite	47.87g	52.27ef	52.63ef	53.34def	51.53C
Vermicompost	51.63f	53.85def	55.57cd	57.60abc	54.66B
Solid Humus	52.07f	52.70ef	52.50ef	54.30de	52.89C
Chicken Manure	52.23ef	58.10ab	59.10a	58.47ab	56.98A
Sheep Manure	51.83f	56.60bc	56.63bc	57.37abc	55.61AB
Average	51.13C	54.70B	55.29B	56.22A	54.33A
Two-Year Average					
Fertilizers/Doses	Control	150kg/da	300kg/da	600kg/da	Average
Leonardite	41.64j	45.52gh	46.42gh	45.27h	44.71C
Vermicompost	43.67i	46.54fgh	48.83cd	47.94def	46.74B
Solid Humus	45.14h	46.44gh	46.49fgh	46.79efg	46.21B
Chicken Manure	45.28h	50.83ab	51.60a	49.27cd	49.25A
Sheep Manure	45.20h	48.10de	49.92bc	50.07bc	48.32A
Average	44.18C	47.49B	48.65A	47.87B	47.05

The difference between values marked with the same letter is statistically insignificant.

Table 5. Branch numbers (number) in black cumin seed with different fertilizer and fertilizer dose applications in 2022, 2023 and two-year averages.

Number of branches (n/p)					
2022					
Fertilizers/Doses	Control	150kg/da	300kg/da	600kg/da	Average
Leonardite	5.27ef	5.97cde	5.57def	5.63c-f	5.61B
Vermicompost	5.33ef	7.33a	7.50a	7.57a	6.93A
Solid Humus	4.97f	5.73c-f	5.63c-f	5.77c-f	5.53B
Chicken Manure	5.10f	7.43a	7.33a	6.43bc	6.57A
Sheep Manure	5.03f	6.30bcd	6.93ab	7.57a	6.46A
Average	5.14B	6.55A	6.59A	6.59A	6.22A
2023^{ns}					
Fertilizers/Doses	Control	150kg/da	300kg/da	600kg/da	Average
Leonardite	5.33	6.10	7.10	6.33	6.22
Vermicompost	5.50	6.60	6.53	6.39	6.26
Solid Humus	5.67	6.33	6.17	6.03	6.05
Chicken Manure	5.90	7.13	7.23	7.03	6.82
Sheep Manure	5.30	6.77	6.89	6.60	6.39
Average	5.54 B	6.59 A	6.78 A	6.48 A	6.35 A^{+}
Two-Year Average					
Fertilizers/Doses	Control	150 kg/da	300 kg/da	600 kg/da	Average
Leonardite	5.30fg	6.04de	6.34cd	5.98def	5.91BC
Vermicompost	5.42efg	6.97abc	7.02abc	6.98abc	6.59A
Solid Humus	5.32fg	6.03de	5.90def	5.90def	5.79C
Chicken Manure	5.50efg	7.28a	7.28a	6.73abc	6.70A
Sheep Manure	5.17g	6.54bcd	6.91abc	7.09ab	6.42AB
Average	5.34B	6.57A	6.69A	6.54A	6.28

The difference between values marked with the same letter is statistically insignificant; ns : It is not significant at $p<0.01$ level; + : There is no statistically significant difference ($P<0.01$) between means shown with the same letters in the same row.

Table 6. Number of capsules (number) per plant in black cumin with different fertilizer and fertilizer dose applications in 2022, 2023 and two-year averages.

Number of capsules (n)					
2022					
Fertilizers/Doses	Control	150 kg/da	300 kg/da	600 kg/da	Average
Leonardite	8.10j	10.47ghi	11.23fgh	10.23hi	10.01E
Vermicompost	9.80i	14.40d	12.53e	12.17ef	12.23C
Solid Humus	8.23j	11.47efg	12.30ef	12.67e	11.17D
Chicken Manure	9.83i	21.43a	21.47a	18.77b	17.88A
Sheep Manure	10.03hi	18.20bc	18.23bc	17.10c	15.89B
Average	9.20C	15.19A	15.15A	14.19B	13.43B
2023					
Fertilizers/Doses	Control	150kg/da	300kg/da	600kg/da	Average
Leonardite	10.17j	13.83efg	13.15fgh	13.10gh	12.56C
Vermicompost	11.67hij	17.67c	15.20de	15.10ef	14.91B
Solid Humus	10.37j	12.60ghi	13.20fgh	12.60ghi	12.19C
Chicken Manure	11.63hij	21.43ab	23.10a	21.07b	19.31A
Sheep Manure	11.10ij	17.13cd	18.14c	15.42de	15.45B
Average	10.99C	16.53A	16.56A	15.46B	14.88A
Two-Year Average					
Fertilizers/Doses	Control	150kg/da	300kg/da	600kg/da	Average
Leonardite	9.14i	12.15g	12.19g	11.67gh	11.29E
Vermicompost	10.74h	16.04d	13.87e	13.64ef	13.57C
Solid Humus	9.30i	12.04g	12.75	12.64fg	11.68D
Chicken Manure	10.73h	21.43a	22.29a	19.92b	18.59A
Sheep Manure	10.57h	17.67c	18.19c	16.26d	15.67B
Average	10.09C	15.86A	15.86A	14.82B	14.16

The difference between values marked with the same letter is statistically insignificant.

The highest number of capsules per plant in 2022 was obtained with the 150 kg/da and 300 kg/da chicken manure, while in 2023, the highest number was obtained with 300 kg/da chicken manure (Table 6). The number of capsules in black cumin is directly correlated with branching, with more branches leading to a higher number of capsules (Baytore, 2011; Ozyilmaz et al, 2017). In previous studies were obtained number of capsules as 15.4-18.2 pieces/plant by Yilmaz et al. (2019), 2.87-4.70 pieces/plant by Can (2021) and 3.89-4.38 pieces/plant by Karer and Beyzi (2022).

Number of Seeds in Capsule

The number of seeds per capsule varied between 86.40 and 114.87 in 2022, with an average of 98.56. In 2023, ranged from between 86.87 to 115.03, with an average of 104.00. Over two years, the number of seeds in the capsule varied between 90.07-111.23, with an average of 101.28. The highest number of seeds in per capsule in 2022 was obtained with the application of 150 kg/da chicken manure, while in 2023, the highest number was obtained with 300 kg/da chicken manure (Table 7). The number of seeds per capsule is influenced by genotype and climatic conditions, and can also vary depending on the size of the capsules and seed. In previous studies, Faravani et al. (2012) were obtained values of 38.9-50.66 pieces/capsule, Inan (2020) 51.97-66.13 pieces/capsule, Saglik (2020) 28.50-55.07 pieces/capsule, Abay (2021) 80.21-69.77 pieces/capsule, Karer and Beyzi (2022) 64.94-75.52 pieces/capsule.

1000 Seed Weight

The thousand seed weight varied between 2.82 and 3.28 g in 2022, with an average of 3.11 g. In 2023, it ranged from 2.42 to 2.56 g, with an average of 2.50 g. Over two years, the thousand seed weight varied between 2.62 and 2.92 g, with an average of 2.80 g. The highest thousand seed weight in 2022 was obtained with the application of 150 kg/da chicken manure, while in 2023, the highest thousand seed weight was obtained with the application of 300 kg/da chicken manure (Table 8). The analysis conducted between 2022 and 2023 revealed, a general decrease in thousand seed weight. This decrease is consistent with the observation that the seeds in the capsules were larger in 2022, corresponding to higher thousand seed weight. The primary reasons for this reduction are believed to include the higher precipitation during the capsule formation period in 2023 compared to the previous year, as well as factors such as soil quality. In the second year of the study increased rainfall contributed to a higher weed population. Mubeen et al. (2009) stated one of the factors affecting thousand seed weights is weed density in planting areas, with an increase in weed density leading to a reduction in thousand seed weight. In the studies conducted by different researchers values were found; Tektas (2015) 2.90-2.40 g, Kosar and Ozel (2018) 1.81-3.16 g, Inan (2020) 2.50-2.64 g, Yilmaz et al. (2019) 2.1-2.8 g, Sarac (2019) 2.59-2.94 g, Faydaci (2019) 2.1-3.1 g, Can (2021) 2.45-3.35 g.

Seed Yield

Since black cumin seeds are primarily used as a medicinal and aromatic plant, seed yield is a key factor determining overall productivity. Seed yield is directly affected by the number of branches, capsules, seeds capsule and thousand seed weight (Yilmaz et al., 2019). Seed yield for 2022 varied between 74.73 and 209.31 kg/da with an average of 135.26 kg/da. Seed yield in 2023 varied between 101.11- and 184.96 kg/da, with an average of 135.41 kg/da.

Table 7. Number of seeds (number) per capsule in black cumin with different fertilizer and fertilizer dose applications in 2022, 2023 and two-year averages.

Number of seeds in the capsule (n)					
2022					
Fertilizers/Doses	Control	150 kg/da	300 kg/da	600 kg/da	Average
Leonardite	86.40j	94.17ghi	104.30c	96.40fg	95.32D
Vermicompost	90.70i	102.03cd	100.10de	96.13fg	97.24C
Solid Humus	93.27ghi	101.13cde	103.50cd	98.17ef	99.02B
Chicken Manure	92.43hi	114.87a	107.93b	102.53cd	104.44A
Sheep Manure	94.37gh	96.23fg	98.17ef	98.33ef	96.78CD
Average	91.43D	101.69B	102.80A	98.31C	98.56B
2023^{ns}					
Fertilizers/Doses	Control	150kg/da	300kg/da	600kg/da	Average
Leonardite	94.43	100.43	112.41	106.43	103.43
Vermicompost	91.20	112.27	115.03	112.15	107.66
Solid Humus	86.87	97.45	105.45	110.63	100.10
Chicken Manure	94.27	104.93	114.53	109.03	105.69
Sheep Manure	93.83	104.22	109.53	104.80	103.10
Average	92.12C	103.86B	111.39A	108.61AB	104.00A
Two-Year Average					
Fertilizers/Doses	Control	150kg/da	300kg/da	600kg/da	Average
Leonardite	90.42h	97.30e-h	108.36ab	101.42b-f	99.37B
Vermicompost	90.95h	107.15a-d	107.57abc	104.14a-e	102.45AB
Solid Humus	90.07h	99.29d-g	104.48a-e	104.40a-e	99.56B
Chicken Manure	93.35gh	109.90a	111.23a	105.78a-d	105.07A
Sheep Manure	94.10fgh	100.23c-g	103.85a-e	101.57b-f	99.94B
Average	91.78C	102.77B	107.10A	103.46B	101.28

The difference between values marked with the same letter is statistically insignificant; ns : It is not significant at p<0.01 level; + : There is no statistically significant difference (P<0.01) between means shown with the same letters in the same row.

Table 8. Thousand seed weights (g) of black cumin in different fertilizer and fertilizer dose applications in 2022, 2023 and two-year averages.

1000 seed weight (g)					
2022					
Fertilizers/Doses	Control	150kg/da	300kg/da	600kg/da	Average
Leonardite	2.82h	3.17a-e	3.13a-f	3.18a-d	3.08BC
Vermicompost	3.05def	3.15a-f	3.24abc	3.04def	3.12AB
Solid Humus	3.00fg	3.02efg	3.07def	2.87gh	2.99C
Chicken Manure	3.09c-f	3.28a	3.27a	3.26ab	3.23A
Sheep Manure	3.06def	3.26ab	3.16a-f	3.11b-f	3.15AB
Average	3.00C	3.17A	3.17A	3.09B	3.11A
2023					
Fertilizers/Doses	Control	150kg/da	300kg/da	600kg/da	Average
Leonardite	2.42f	2.53ab	2.49c	2.54ab	2.50B
Vermicompost	2.45ef	2.49c	2.49c	2.48cd	2.48C
Solid Humus	2.43ef	2.50c	2.51bc	2.53ab	2.49BC
Chicken Manure	2.46de	2.55a	2.56a	2.55a	2.53A
Sheep Manure	2.46de	2.49c	2.51bc	2.51bc	2.49BC
Average	2.44C	2.51B	2.52AB	2.53A	2.50B
Two-Year Average					
Fertilizers/Doses	Control	150kg/da	300kg/da	600kg/da	Average
Leonardite	2.62i	2.85a-d	2.81c-f	2.86a-d	2.79BC
Vermicompost	2.75fgh	2.82c-f	2.87abc	2.76e-h	2.80B
Solid Humus	2.72gh	2.76e-h	2.79d-g	2.70h	2.74C
Chicken Manure	2.78e-h	2.91ab	2.92a	2.91ab	2.88A
Sheep Manure	2.76e-h	2.88abc	2.84b-e	2.81c-f	2.82B
Average	2.72C	2.84A	2.84A	2.81B	2.80

The difference between values marked with the same letter is statistically insignificant.

Table 9. Seed yields (kg/da) of black cumin in different fertilizer and fertilizer dose applications in 2022, 2023 and two-year averages.

Seed yield (kg/da)					
2022					
Fertilizers/Doses	Control	150kg/da	300kg/da	600kg/da	Average
Leonardite	122.12fg	129.79ef	127.92efg	122.07fg	125.48C
Vermicompost	107.13h	141.82de	148.38d	153.46d	137.70B
Solid Humus	74.73i	125.85fg	121.95fg	117.62fgh	110.04D
Chicken Manure	107.45h	193.99b	209.31a	192.90b	175.91A
Sheep Manure	78.25i	114.92gh	147.22d	168.25c	127.16C
Average	97.94C	141.27B	150.96A	150.86A	135.26A
2023					
Fertilizers/Doses	Control	150kg/da	300kg/da	600kg/da	Average
Leonardite	105.39ij	127.06efg	136.43de	125.40g	123.57D
Vermicompost	101.11j	121.19gh	126.38fg	135.38def	121.02D
Solid Humus	108.65ij	144.05cd	137.75d	125.39g	128.96C
Chicken Manure	120.63gh	171.03b	184.96a	171.35b	161.99A
Sheep Manure	112.70hi	135.72def	152.38c	165.16b	141.49B
Average	109.70D	139.81C	147.58A	144.54B	135.41A^{+}
Two-Year Average					
Fertilizers/Doses	Control	150kg/da	300kg/da	600kg/da	Average
Leonardite	113.76k	128.43g-j	132.18fgh	123.74i-j	124.52D
Vermicompost	104.12l	131.51f-i	137.38ef	144.42de	129.36C
Solid Humus	91.69m	134.95fg	129.85f-i	121.51jk	119.50E
Chicken Manure	114.04k	182.51b	197.14a	182.13b	168.95A
Sheep Manure	95.48m	125.32hij	149.80d	166.71c	134.33B
Average	103.82C	140.54B	149.27A	147.70A	135.33

The difference between values marked with the same letter is statistically insignificant. $^{+}$There is no statistically significant difference ($P<0.01$) between means shown with the same letters in the same row.

Over two years, seed yield varied between 91.69 and 197.14 kg/da, with an average of 135.33 kg/da. The highest seed yield for both yields was obtained with the application of chicken manure at a fertilizer dose of 300 kg/da (Table 9). Fertilizer application had a significant impact on seed yield, with chicken manure resulting in higher yields compared to other fertilizer types. Furthermore, increasing fertilizer doses generally led to higher seed yields. That the effectiveness of chicken and sheep manure, in increasing seed yield can be attributed to their high nutrient content compared to other organic fertilizers. In previous studies, seed yield was obtained as 71.90-118.77 kg/da by Tektas (2015), 117.7-191.3 kg/da by Yilmaz et al. (2019), and 97.60-117.36 kg/da by Abay (2021).

Conclusion

The long-term use of chemical fertilizers disrupts the biological balance of the soil and can lead to significant issues in the cultivation of medicinal and aromatic plants. Therefore, the application of organic fertilizers is crucial in the cultivation of important crops like black cumin, as it helps promote sustainable agricultural practices by protecting soil health and ensuring the production of products that are safe for human consumption. In this study, which evaluated the effect of different organic fertilizers and fertilizer doses on black cumin cultivation, it was observed that organic fertilizers generally had a positive effect. Chicken manure and a fertilizer dose of 300 kg/da were the most prominent applications.

Black cumin is a medicinal and aromatic plant, with its seeds being the primary product. Therefore, seed yield is a critical factor in its cultivation. In this study, it was observed that the different organic fertilizer treatments has a significant impact on seed yield. The results demonstrated that organic fertilizer applications substantially increased black cumin seed yield. This finding reveals the importance of using organic fertilizers in black cumin cultivation, offering an effective alternative for farmers seeking to increase yields while opting for natural production methods.

Declarations

Author Contribution Statement

Abdulkadir Acar: Conducted the study, data collection, review, formal analysis, and writing the original draft. Yasin Bedrettin Karan: Management, supervision, review, editing, and statistical analysis of the study.

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Conflict of Interest

"We declare that the authors have no conflict of interest."

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