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RESEARCH ARTICLE

Effect of chemical and organic fertilizers on the yield and quality attributes and nutrient composition in lentil

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ABSTRACT

The importance of lentil (*Lens culinaris* Medik.) as a crop with valuable nutritional content is expected to increase with the growing global population; therefore, this research was conducted in 2019-2020 and 2020-2021 to evaluate the effects of organic (vermicompost, chicken manure, and farm manure) and inorganic (S and diammonium phosphate [DAP]) fertilizers on the yield and nutrient content of the lentil 'Çağıl'. The study used no fertilizer control, chemical fertilizer (140 kg ha^{-1} DAP 18-46), sulfate fertilizer (30 kg S ha^{-1}), and organic fertilizers such as chicken manure (2 t ha^{-1}), farm manure (20 t ha^{-1}), and vermicompost (2 t ha^{-1}). The experiment was designed as a randomized block with three replicates. According to results, S fertilizer was found to significantly improve plant height, 1000-grain weight, grain yield, protein ratio, S and Fe content. It was predicted that farmyard manure significantly improves the grain nutrient properties (P, Cu, K, Mg, Mn, and Zn) of lentil compared to other treatments. The S fertilizer increased plant height (55.1 cm), thousand-grain weight (33.6 g), grain yield (2065 kg ha^{-1}), and protein ratio (33.1%); additionally, farmyard manure application was found to enhance the nutrient content of lentil grains, including P (4056.7 mg kg^{-1}), Cu (16.15 mg kg^{-1}), K (8926.3 mg kg^{-1}), Mg (985.1 mg kg^{-1}), Mn (15.3 mg kg^{-1}), and Zn (35.0 mg kg^{-1}). It is recommended to use a combination of S fertilizer and organic fertilizers such as farmyard manure to enhance environmental sustainability, maintain soil fertility, and improve yield and nutrient content in lentil production.

Key words: Biofortification, grain legumes, *Lens culinaris*, nutrient uptake, organic farming, sustainable agriculture.

INTRODUCTION

Global climate change affects agricultural production worldwide, and increasing temperatures are one of the most important stress factors limiting the production and quality of pulses, which are economically important. With a decrease in agricultural production, the increasing world population will face the problem of malnutrition in the future. Red lentils have a high protein and mineral content, play an important role in nutrition, strengthen the immune system, and meet food needs. Turkey is important in terms of plant genetic resources and is a natural genetic center for lentil (*Lens culinaris* Medik.) varieties (Köse et al., 2017). The genetic centers of lentil cultivation are Palestine, Syria, and Türkiye (Singh et al., 2020). Lentils are one of the most important edible grain legumes in terms of a balanced and healthy diet. Namba-Santiago et al. (2023) suggested that the grain of lentils is rich in protein, vitamins, fiber and minerals. Lentil leaves a N-rich soil for the crop planted after it via biological N fixation; however, root nutrients such as N, Ca, P, and K remain in the soil root zone as a result of decomposition (Ahmad et al., 2022). For sustainable agriculture, the amount of organic matter is important for soil fertility, protection, and sustainability. In Türkiye, the percentage of organic matter in agricultural production areas has been gradually decreasing over the years owing to mistakes in soil tillage, crop rotation, and chemical fertilizer application, and has started to fall below 1% (Yağmur and Okur, 2018). Vegetable, animal, and other organic wastes are very important sources of fertilizer to increase the declining organic matter in the soil. Animal and vegetable wastes such as cattle, sheep, goat, chicken, pigeon, bat, earthworm, seaweed manure, slurry, tea waste, and garbage compost play an important role in enriching the soil with organic matter (Uçar, 2019). Because the waste left by legumes in the soil after harvesting is rich in N, they decompose in a short time and turn into humus. Thus, legumes leave better soil for cultivated plants (Toğay et al., 2005). The objective of organic farming is to enrich biodiversity, the biological cycle, and biological activity in the soil to ensure the social, ecological, and economic sustainability of natural systems (Samman et al., 2008).

Organic matter plays an important role in soil vitality and fertility. The effect of organic matter can be direct or indirect. Organic matter plays a direct role as a source of plant nutrients and indirectly influences the physical and chemical properties of the soil. Excessive chemical fertilization in agriculture leads to a decrease in some nutrients in the soil and excessive accumulation of others. The best way to keep soil organic matter at maximum levels is through organic fertilization (Ceritoglu et al., 2018; Fan et al., 2023). This study aimed to determine the effect of organic and inorganic fertilizers on the yield, quality, and nutrient content of grain compared to conventional fertilization by applying organic and inorganic fertilizers to lentil plants in our region. The main objective of agricultural production, which plays an important role in the economy of the country and the region, is to produce efficient, high-quality, and reliable products for the growing world population. It is very important to study the effects of organic and chemical fertilization in Türkiye and the world, which has an important place in terms of edible grain legumes, in terms of sustainable agriculture. In this study, our main objective was to contribute to the sustainable agricultural production of our region in particular, and our country in general, with practices that are more protective of human health than chemical fertilizer applications, by capturing the benefits of organic fertilization in our region.

MATERIALS AND METHODS

Experimental materials

This study was conducted in Mardin province (37°16’35’’ N, 40°21’52’’), Southern Anatolia, Türkiye, under dry conditions during the 2019-2020 and 2020-2021 growing seasons. ‘Çağıl’ lentil (*Lens culinaris* Medik.), the most cultivated lentil cultivar in Mardin and its surroundings, was used in the experiment. The study employed both chemical (diammonium phosphate and S) and organic (chicken manure, vermicompost, and farmyard manure) fertilizers. Diammonium phosphate (DAP), which is a compound fertilizer containing two important plant nutrients, N and phosphate, was used as the chemical fertilizer. The DAP fertilizer used in the study contained 18% N and 46% phosphorus pentoxide (P_2O_5) and 80% granulated S (30 kg S ha^{-1}) was used in the experiment.

Experimental conditions

Soil analyses from various depths in the study area revealed a clayey loamy soil structure with a pH of approximately 8 and an alkaline reaction. The organic matter content was low, whereas the lime and K contents were high. The P content was low in the lower soil layer. Physicochemical characterization of experimental soil is given in Table 1.

Table 1. Some properties of the < 2 mm fraction of the top 0-20 and 0-40 cm of soil used for each site. CL: Clay-loam. Source: Soil-Plant Analysis Laboratory (Mardin Artuklu University, Mardin, Türkiye).

Depth	Sand	Silt	Clay	Texture	pH	Limestone	P	K	Organic matter
cm	————	%	————			%	ppm	me 100 g^{-1}	%
0-20	26.9	33.7	39.4	CL	7.83	16.8	6.17	2.84	1.28
0-40	28.5	35.3	36.2	CL	8.07	13.5	4.14	1.23	1.70

The monthly average precipitation and temperature values for the seasons in which the study was conducted are presented in Table 2. During the study period, the average temperature in 2019-2020 was 12.4 °C, while in 2020-2021 it was 13.8 °C, both of which were higher than the long-term average of 11.2 °C. Precipitation was 619.7 mm in 2019-2020 but decreased significantly to 273.0 mm in 2020-2021, which was below the long-term average for both years. The relative humidity was 56.2% in 2019-2020 and decreased to 46.2% in 2020-2021 (Table 2).

Table 2. Monthly and long-term averages of temperature rainfall and humidity values of Mardin, Türkiye. LTA: Long-term average.

	Temperature (°C)			Rainfall (mm)			Humidity (%)		
Months	2019-2020	2020-2021	LTA	2019-2020	2020-2021	LTA	2019-2020	2020-2021	LTA
November	13.5	12.1	11.1	21.5	35.7	71.6	38.1	55.8	55.8
December	7.2	7.5	5.3	148.6	40.8	110.2	74.1	59.2	65.9
January	3.5	6.4	3.0	75.9	99.2	116.4	71.9	54.2	68.7
February	3.8	7.8	4.1	102.8	25.5	104.0	71.3	54.6	65.6
March	10.7	8.8	7.9	157.3	62.6	97.0	65.1	58.0	60.3
April	14.1	17.3	13.4	51.6	7.1	82.8	59.8	38.3	55.3
May	19.9	23.8	19.4	30.5	2.1	46.5	43.5	26.6	44.3
June	26.3	26.9	25.5	31.5	0.0	6.5	26.0	22.6	31.9
Total				619.7	273.0	635.0			
Average	12.4	13.8	11.2				56.2	46.2	56.0

Experimental layout

Fertilization practices are: T1: Control (no fertilizer), T2: Vermicompost 2 t ha^{-1}, T3: Farm manure 20 t ha^{-1}, T4: Chicken manure 2 t ha^{-1}, T5: Sulfur 30 kg S ha^{-1}, and T6: DAP 18-46 fertilizer 140 kg ha^{-1}. Organic fertilizers were treated 2 wk ago from planting time and mixed into experimental soils by rolling stalk chopper to provide decomposition of organic material.

The research was laid out in a randomized complete block design with four replicates. The distance between plots and blocks was set at 1.5 m. Row spacing was set at 20 cm, and each plot consisted of 5 rows (Kraska et al., 2020). With a plot width of 1 m and a plot length of 5 m, each plot was established as 5 m^2. Seeds were manually sown to avoid infection. The 80 kg ha^{-1} seed material was sown to each plot (Erman et al., 2021). Weed populations were managed to eliminate them before reaching the critical threshold that could cause damage to lentil. Herbicides or insecticides were not used within the scope of the study in both seasons.

Laboratory analyses

Grain protein content was determined by taking 0.25 g each subplot sample and analyzing the % N content using the micro-Kjeldahl method. Grain protein content was determined by taking 0.25 g each subplot sample and analyzing the % N content using the micro-Kjeldahl method. The protein ratio was then calculated by multiplying this figure by 6.25, according to Kjeldahl's method (Kjeldahl, 1883). Macro- and micro-elemental analyses were conducted at the Mardin Artuklu University Central Research Laboratory. The grain samples were weighed to approximately 0.25 g after harvesting the plants. The samples were subjected to wet digestion in a microwave oven (Mars Xpress). To the samples, 8 mL 65% HNO_3 and 2 mL H_2O_2 were added and baked for 30 min. The final volume was made up to 20 mL with pure water and filtered through blue band filter paper (Hussain et al., 2008). Macro and micro elemental analyses of these samples were carried out using inductively coupled plasma optical emission spectroscopy (ICP-OES) (ICP-20113107, Scientific, UK).

Statistical analysis

The data were subjected to ANOVA using the program JMP 5.0 statistical package according to the completely randomized design, and the LSD (0.05) multiple comparison test was used to compare the means.

RESULTS AND DISCUSSION

Agronomic and yield attributes as well as macro and micronutrient concentrations of lentil seeds were investigated under different organic and inorganic treatment conditions in the experiment. The impact of treatments was significant ($p < 0.05$ or 0.01) on the characters examined in both the 2019-2020 and 2020-2021 seasons. However, according to the combined ANOVA for years, the only characteristic significantly affected by treatments was plant height. Additionally, the Year × Fertilizer interaction significantly influenced only the concentration of Zn in grains. The ANOVA table for the traits examined is given in Table 3.

Table 3. ANOVA of the effects of organic fertilizer and inorganic fertilizers on the investigated properties in lentil. $^{*}P < 0.05$, $^{**}P < 0.01$, ^{ns}nonsignificant difference.

Characteristics	2019-2020	2020-2021	Years(combined)	Year × Fertilizer
Plant height	132.97^{**}	118.65^{**}	112.36^{*}	1.80^{ns}
1000 Grain weight	2.03^{**}	3.26^{**}	0.05^{ns}	0.77^{ns}
Grain yield	1314.33^{**}	1133.09^{**}	589.68^{ns}	8.40^{ns}
Protein ratio	3.04^{**}	4.73^{**}	0.34^{ns}	0.13^{ns}
P	83382.90^{**}	115699.00^{**}	1547.11^{ns}	66972.50^{ns}
Cu	3.99^{**}	2.40^{*}	0.56^{ns}	0.44^{ns}
K	827010.00^{**}	1123827.00^{**}	1167.40^{ns}	37319.70^{ns}
Mg	4160.52^{**}	4166.64^{**}	111.65^{ns}	662.77^{ns}
S	22798.20^{**}	32577.40^{**}	8773.44^{ns}	2509.04^{ns}
Mn	2.79^{*}	3.34^{**}	0.13^{ns}	0.72^{ns}
Fe	16.28^{**}	10.91^{*}	2.00^{ns}	2.17^{ns}
Zn	32.06^{**}	9.89^{*}	12.15^{ns}	8.31^{**}
Ca	7543.48^{**}	4643.38^{**}	148.84^{ns}	200.97^{ns}

Plant height

The combined analysis results showed that the control treatment had the lowest plant height of 36.6 cm, whereas the highest average plant height value of 55.1 cm was obtained with the S treatment (Table 4). Parsak (2006) reported that the highest plant height was obtained from the highest dose of S application in his study using different doses of P and S in lentil. Zeidan (2007) indicated that organic fertilizer increased plant height and Shivakumar (2001) reported that increasing doses of S fertilizer increased plant height in their studies on chickpea and the tallest plants were obtained from the highest dose of S application. The results obtained by these researchers were similar to those of this study.

1000-grain weight

The impact of fertilization on 1000-grain weight was significant at a 1% level in both years. However, the combined and Year × Fertilization interactions were insignificant (Table 3). According to the combined analysis results, vermicompost application resulted in the lowest 1000-grain weight of 31.2 g. In contrast, the highest mean value of 33.6 g was obtained with S application, which was similar to that of chicken manure. However, the statistical analysis did not reveal any significant difference between them (Table 4). Zeidan (2007) reported an increase in the thousand grain weight of lentil due to organic fertilization. Similarly, Yeşilbaş and Togay (2021) found that 1000-grains weight was lowest in the control plots and highest in the chicken manure treated plots in lentil. Çığ et al. (2024) investigated the effects of chicken manure on 1000-grain weight of lentil. The results indicated that the 1000-grain weight significantly increased in the plots treated with chicken manure compared to the control plots.

Table 4. Values for plant height, thousand grain weight, and grain yield resulting from organic and inorganic fertilization in lentil. For each row within each treatment means followed by the same letter do not differ significantly at the 5% probability level following. DAP: Diammonium phosphate.

Application	Plant height			1000-grain weight			Grain yield		
	2019-2020	2020-2021	Mean	2019-2020	2020-2021	Mean	2019-2020	2020-2021	Mean
	cm			g			$kg\ ha^{-1}$		
Farm manure	48.9	46.0	47.5^{c}	32.4	32.2	32.3^{b}	1769.0	1694.0	1732.0^{C}
DAP	44.2	41.0	42.6^{d}	31.8	32.1	32.0^{bc}	1670.0	1631.0	1651.0^{D}
Control	38.7	34.5	36.6^{e}	31.7	31.2	31.5^{cd}	1541.0	1466.0	1504.0^{E}
Sulphur	57.7	52.4	55.1^{a}	33.5	33.7	33.6^{a}	2116.0	2015.0	2065.0^{A}
Vermicompost	45.2	43.0	44.1^{d}	31.3	31.0	31.2^{d}	1723.0	1622.0	1677.0^{CD}
Chicken manure	52.2	48.9	50.6^{b}	33.0	33.1	33.1^{a}	1970.0	1865.0	1918.0^{B}
Mean	47.8^{A}	44.3^{B}	46.1	32.3^{A}	32.2^{A}	32.3	1798.0^{A}	1717.0^{A}	1758.0
Year (LSD)	2.97	3.43	0.3	1.0	1.17	0.9	14.19	9.4	13.0
Fertilizer (LSD)			2.1			2.17			0.8
Year × Fertilizer (LSD)			3.0			1.0			11.0
CV, %			3.83			1.86			3.76

Grain yield

In terms of grain yield, fertilization had a significant effect in both years at a 1% level. However, the combined and Year × Fertilization interactions were found to be insignificant (Table 3). According to the combined analysis results, the control treatment had the lowest average grain yield of 1504 kg ha^{-1}, while the S treatment had the highest grain yield of 2065 kg ha^{-1} (Table 4). Singh and Kumar (1996) and Singh et al. (1998) found that increasing S doses increased lentil grain yield per unit area in India. Kesli (2009) also reported a positive correlation between S dose and plant grain yield. Warman and Havard (1998) investigated the effect of chemical and organic fertilizers on maize grain yield and found that organic fertilizer applications yielded higher than chemical fertilizer applications. However, it should be noted that while some studies have reported lower yields with the use of chemical fertilizers, others have found that organic fertilizers can result in higher yields. For example, Moraditochaee et al. (2014) and Janmohammadi et al. (2015) both reported increased yields with the application of organic fertilizers compared to control plots in their respective studies. Ceritoglu and Erman (2020) pointed out that the addition of vermicompost up to 7500 kg ha^{-1} promoted grain yield in lentil.

Protein ratio

The effect of fertilization on protein content was significant at a 1% level in both years. However, the combined and Year × Fertilization interactions were found to be insignificant (Table 3). The control fertilizer application resulted in the lowest mean value of 29.9%, while the S application resulted in the highest mean value of 33.1% (Table 5). Sekhon et al. (1998) reported that increasing doses of S fertilization led to an increase in grain protein content. Singh et al. (1998) reported that S fertilization in acidic soils resulted in the highest protein content. In contrast, Tolanur (2008) and Moraditochaee et al. (2014) found that organic fertilizer applications increased N content in grain compared to control and inorganic fertilizer applications. These results are consistent with the findings of this study.

Grain P content

The effect of fertilization on the P ratio was significant at the 1% level in both years. However, the combined and Year × Fertilization interactions were nonsignificant (Table 3). According to the combined analysis results, the control treatment had the lowest mean value of 3559.7 mg kg^{-1}, whereas the farm manure treatment had the highest mean value of 4056.7 mg kg^{-1} (Table 5). Saket et al. (2014) investigated the impact of organic and inorganic fertilization on yield parameters in lentils. The study revealed that the grains in the control plots had the lowest P content, whereas the plots treated with farmyard manure had the highest. In a study on chickpeas, Doğan and Çığ (2023) reported similar findings, with the lowest grain P content in control plots and the highest in plots treated with farm fertilizer.

Table 5. Values for protein ratio, P, and Cu resulting from organic and inorganic fertilization in lentil. For each row within each treatment means followed by the same letter do not differ significantly at the 5% probability level following. DAP: Diammonium phosphate.

Application	Protein ratio			P			Cu		
	2019-2020	2020-2021	Mean	2019-2020	2020-2021	Mean	2019-2020	2020-2021	Mean
	%			mg kg^{-1}			mg kg^{-1}		
Farm manure	31.6	31.2	31.4^{C}	4025.0	4082.3	4053.7^{A}	16.23	16.07	16.15^{A}
DAP	32.4	32.3	32.4^{B}	3952.0	3932.3	3942.2^{B}	13.80	14.07	13.93^{B}
Control	30.1	29.6	29.9^{D}	3575.3	3544.0	3559.7^{E}	12.80	13.67	13.23^{C}
Sulphur	33.0	33.1	33.1^{A}	3755.0	3738.3	3746.7^{C}	13.57	14.13	13.85^{BC}
Vermicompost	31.3	31.0	31.2^{C}	3759.7	3744.3	3752.0^{C}	14.33	13.73	14.03^{B}
Chicken manure	32.2	32.4	32.3^{B}	3693.3	3640.3	3666.8^{D}	14.10	14.67	14.38^{B}
Mean	33.8^{A}	31.6^{A}	31.7	3793.4^{A}	3780.3^{A}	3786.8	14.39^{A}	14.14^{A}	14.26
Year (LSD)	0.52	0.55	0.8	118.35	83.39	41.0	0.63	1.25	0.9
Fertilizer (LSD)			0.4			68.0			0.7
Year × Fertilizer (LSD)			0.5			96.0			0.9
CV, %			0.93			1.48			3.84

Grain Cu content

Fertilization had a significant effect on Cu content in both years at a 1% level, as shown in Table 3. However, the combined and Year × Fertilization interactions were found to be insignificant. Based on the combined analysis results presented in Table 5, the control treatment had the lowest mean value of 13.23 mg kg^{-1}, while the farm manure treatment had the highest mean value of 16.15 mg kg^{-1}. It is worth noting that Cu is essential for the utilization of Fe in the body and the functioning of enzymes. The daily requirement for Cu is between 0.6 and 2.0 mg. Karayel et al. (2020) found that the highest Cu content in chickpea plants was obtained in the control plot and farmyard manure treatments. In contrast, Doğan et al. (2021) reported that the lowest Cu content in the grain was obtained in the control plots, while the Cu content was high in organic fertilizer applications in their study on corn plants with organic and inorganic fertilizer sources.

Grain K content

Concerning the K ratio, fertilization had a significant effect in both years at a 1% level. However, the combined and Year × Fertilization interactions were found to be insignificant (Table 3). Based on the combined analysis results, the control treatment had the lowest mean value of 7345.2 mg kg^{-1}, while the farmyard manure treatment had the highest mean value of 8926.3 mg kg^{-1} (Table 6). Saket et al. (2014) conducted a study to investigate the impact of organic and inorganic fertilization on yield parameters in lentil. The results showed that the lowest K content in the grain was obtained from the control plots, while the highest K content was obtained in plots where farmyard manure was applied. Similarly, Doğan and Çığ (2023) found that the grain K content was lowest in the control plots and highest in the plots where farmyard manure was applied in their study on chickpea.

Grain Mg content

The impact of fertilization on Mg content was found to be significant at a 1% level in both years. However, the combined and Year × Fertilization interactions were insignificant (Table 3). According to the combined analysis results, the control application had the lowest mean value of 883.0 mg kg^{-1}, while the farm manure application had the highest mean value of 985.1 mg kg^{-1} and was in the same group as the vermicompost application (Table 6). Magnesium is an essential element for chlorophyll synthesis during photosynthesis and aids in N fixation during nodule formation in legumes. According to Papenbrock et al. (2000), Mg acts as the central atom of the chlorophyll molecule. In their study, Doğan et al. (2021) found that both organic and inorganic fertilizer sources had a positive impact on the Mg ratio in grain in both types of fertilizer applications. The control plots had the lowest Mg ratio in grain. In their study on maize, Dogan et al. (2019) found that the plots without fertilizer had the lowest Mg ratio in grain, while the highest Mg ratio was observed in plots treated with chicken manure, farm manure, and commercial fertilizer. However, our findings are partially consistent with the study conducted by Yağmur and Okur (2018). They reported an increase in the total Mg ratio of corn plant leaves with increasing application doses of compost and barnyard manure in the green parts of the plant under greenhouse conditions. Erman et al. (2024) indicated that organic fertilization promoted micro and macronutrient uptake and restricted the accumulation of heavy metals in barley straw and seeds.

Table 6. Values for K, Mg, and S resulting from organic and inorganic fertilization in lentil. For each row within each treatment means followed by the same letter do not differ significantly at the 5% probability level following. DAP: Diammonium phosphate.

Application	K			Mg			S		
	2019-20	2020-2021	Mean	2019-2020	2020-2021	Mean	2019-2020	2020-2021	Mean
	mg kg^{-1}			mg kg^{-1}			mg kg^{-1}		
Farm manure	8785.3	9067.3	8926.3^{A}	977.3	992.9	985.1^{A}	1925.0	1894.0	1909.5^{C}
DAP	7839.7	7703.7	7771.7^{C}	924.1	928.3	926.2^{B}	1894.3	1946.7	1920.5^{C}
Control	7347.3	7343.0	7345.2^{E}	880.7	885.2	883.0^{C}	1838.3	1860.0	1849.2^{D}
Sulphur	7615.3	7604.0	7609.7^{D}	940.2	915.9	928.1^{B}	2088.3	2158.3	2123.3^{A}
Vermicompost	8335.0	8192.0	8263.5^{B}	973.9	960.1	967.0^{A}	1905.3	1977.0	1941.2^{C}
Chicken manure	7737.3	7818.3	7777.8^{C}	9118	946.8	929.3^{B}	1986.3	1989.0	1987.7^{B}
Mean	7943.3^{A}	7954.7^{A}	7949.0	934.7^{A}	938.2^{A}	936.4	1939.6^{A}	1970.8^{A}	1955.2
Year (LSD)	142.4	296.8	99.0	4.82	25.23	8.0	68.15	67.97	41.0
Fertilizer (LSD)			154.0			23.0			45.0
Year × Fertilizer (LSD)			218.0			32.0			64.0
CV, %			3.84			2.03			2.03

Grain S content

The impact of fertilization on the S ratio was significant at a 1% level in both years. However, the combined and Year × Fertilization interactions were found to be insignificant (Table 3). According to the combined analysis results, the control treatment had the lowest mean value of 1849.2 mg kg^{-1}, while the S fertilizer treatment had the highest mean value of 2123.3 mg kg^{-1} (Table 6). Kesli (2009) and Dogan et al. (2015) found that increasing the S dose resulted in a higher amount of S in the plant's grain. Furthermore, Saket et al. (2014) discovered that both organic and inorganic fertilizer applications significantly increased nutrient uptake in the grain compared to the control.

Grain Mn content

In terms of Mn content, fertilization had a significant effect in both years at a 1% level. However, the combined and Year × Fertilization interactions were found to be insignificant (Table 3). Based on the combined analysis results, the control application had the lowest mean value of 13.1 mg kg^{-1}, while the highest mean value of 15.6 mg kg^{-1} was obtained from the S fertilizer application, which was in the same statistical group as the farm fertilizer application (Table 7). Doğan et al. (2021) reported that the control plots had the lowest mean values of Mn content in corn grain. The highest mean values were obtained in standard and organic fertilizer applications, which were in the same group. These findings are consistent with those of Dogan et al. (2019), who found that the Mn content in grain was lowest in plots without fertilizer and highest in plots with commercial fertilizer. The Mn content was also high in plots with chicken manure and farm manure, but the difference was nonsignificant. Therefore, our findings support the previous research to some extent.

Table 7. Values for Mn, Fe, and Zn resulting from organic and inorganic fertilization in lentil. For each row within each treatment means followed by the same letter do not differ significantly at the 5% probability level following. DAP: Diammonium phosphate.

Application	Mn			Fe			Zn		
	2019-2020	2020-2021	Mean	2019-2020	2020-2021	Mean	2019-2020	2020-2021	Mean
	mg kg^{-1}			mg kg^{-1}			mg kg^{-1}		
Farm manure	15.4	15.1	15.3^{AB}	77.6	75.0	76.3^{BC}	36.4^{ab}	33.6^{cd}	35.0^{AB}
DAP	14.1	14.3	14.2^{C}	75.8	76.1	76.0^{C}	34.0^{bc}	33.7^{bc}	33.9^{B}
Control	13.1	13.1	13.1^{D}	72.9	73.7	73.3^{D}	29.6^{e}	31.0^{dc}	30.3^{C}
Sulphur	15.8	15.5	15.6^{A}	79.4	78.6	79.0^{A}	38.1^{a}	34.8^{bc}	36.5^{A}
Vermicompost	14.7	14.4	14.6^{BC}	78.1	77.5	77.8^{AB}	38.4^{a}	34.9^{bc}	36.6^{A}
Chicken manure	14.6	16.1	15.3^{AB}	78.2	78.2	78.2^{A}	34.8^{bc}	36.4^{ac}	35.6^{AB}
Mean	16.6^{A}	17.8^{A}	14.7	77.0^{A}	76.5^{A}	76.8	35.2^{A}	34.1^{B}	34.6
Year (LSD)	1.69	0.5	0.9	2.42	2.53	1.1	3.0	2.8	1.4
Fertilizer (LSD)			0.8			1.9			1.6
Year × Fertilizer (LSD)			1.2			2.7			2.3
CV, %			4.69			1.77			4.61

Grain Fe content

Fertilization significantly affected the Fe content in both years at a 1% level, as shown in Table 3. Nonsignificant interactions were found between year and fertilization. The control treatment had the lowest mean value of 73.3 mg kg^{-1}, while the S fertilizer treatment had the highest mean value of 79.0 mg kg^{-1}, according to the combined analysis results presented in Table 7. Iron deficiency in food can cause health problems such as anemia, dizziness, weakness, loss of appetite, shortness of breath, inability to maintain body temperature, and cognitive disorders (Saldamlı and Sağlam, 1998). Adult men require 12 mg Fe daily, while women require 18 mg. Therefore, it is important to consume Fe-rich foods. In their study on sunflowers, Yağmur et al. (2021) reported that the Fe ratio was significantly higher in the organic fertilizer application plots compared to the control plots. Similarly, Dogan et al. (2019) found that the Fe ratio was highest in the parcel where commercial fertilizer was applied, and lowest in the parcels without fertilizer. Karayel et al. (2020) reported an increase in Fe content in chickpea plants with the application of organic fertilizer. Similarly, Karaman et al. (2012) demonstrated that organic fertilizers increase the availability of macro-nutrients in the soil and regulate the absorption of micro-nutrients by plants, which in turn affects yield and quality. Our findings partially support these results.

Grain Zn content

The impact of fertilization on the Zn content in grain was found to be significant at a 1% level for both years, as well as for the Year × Fertilization interaction. However, it was nonsignificant for the combined years analysis (Table 3). According to the combined analysis results, the control application had the lowest mean value of 30.3 mg kg^{-1}, while the vermicompost application had the highest mean value of 36.6 mg kg^{-1}. Both studies were grouped with the S fertilizer application (Table 7). In a similar study on chickpea plants, Karayel et al. (2020) reported an increase in grain Zn levels with the use of organic fertilizers. Dogan et al. (2019) found that organic fertilizers significantly increased the concentrations of K, Ca, Cu, Fe, Mn, Zn, Ni and Mg.

The importance of studies aimed at increasing the macro and microelement contents, which are crucial for human nutrition, is well understood in terms of food safety. Many researchers acknowledge that legume genetic resources can be utilized to enhance the microelement content in plant breeding studies. Additionally, the use of fertilizers and appropriate agronomic practices are also crucial in this regard. Increasing the macro and micro contents in lentil grain can significantly improve the nutritional quality of human diets.

CONCLUSIONS

The use of chemical fertilizers is a growing global concern due to its significant negative impact on the environment and economy. The pollution caused by chemical fertilizers in drinking water has a permanent and devastating effect on the population living in the ecosystem. The elimination of these negative consequences can take a very long time and may sometimes be impossible. Promoting the use of environmentally friendly products is of utmost importance. Organic sources are important for sustainable agriculture and the environment. It is essential to expand the use of organic fertilizers. This will protect living organisms in the ecosystem, including humans. Organic farming practices should be developed to increase food security, especially in our region and ultimately in our country. The application of farmyard manure residues as fertilizer resulted in a significant increase in grain yield and concentrations of N, P, K, Cu, Fe, Mn, Zn, S, and Mg. No changes were made to the original content. In our country, where fertilizer resources are limited, organic applications to widely cultivated crops, such as field crops, would be extremely beneficial for the economy, environment, and soil structure. Therefore, this study examined the effects of fertilizer applications and their properties on obtaining better results.

Author contribution

Conceptualization: S.D., Y.D. Methodology: S.D., Y.D. Software: S.D. Validation: Y.D. Formal analysis: F.Ç. Investigation: S.D., Y.D. Resources: S.D., Y.D. Data curation: S.D., Y.D. Writing-original draft: F.Ç. Writing-review & editing: S.D., Y.D., F.Ç. Visualization: F.Ç. Supervision: F.Ç. Project administration: Y.D. All co-authors reviewed the final version and approved the manuscript before submission.

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