



Effects of Different Organic Fertilizer Compositions (Leonardite and Vermicompost) on Chickpea (*Cicer arietinum* L.) Yield and Macro-Micro Nutrient Content

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ABSTRACT

Background: Organic fertilizers (leonardite and vermicompost) applied to soil have a positive impact on plant nutrient uptake and productivity. Understanding the effects of different organic fertilizer application rates on the legume chickpea (*Cicer arietinum* L.) is a crucial aspect of crop production that should not be overlooked.

Methods: The research was carried out in a farmer's field in the Artuklu district of Mardin during two growing seasons (2022-2023 and 2023-2024). Vermicompost was used at VC₁:150, VC₂:200, VC₃:250 and VC₄:300 kg da⁻¹, while Leonardite was used at L₁:50, L₂:100, L₃:200 and L₄:400 kg da⁻¹. Examined how various techniques used for chickpea affected its nutrient content and yield. Statistical analyses were performed to assess the significance of year, application and year*application interaction.

Result: The analyses indicated that year and application significantly affected most parameters, while the year*application interaction was generally not significant. Nutrient contents in chickpea plants varied as follows: total nitrogen (N) 2.98-3.61%, phosphorus (P) 3010-3833 mg kg⁻¹, potassium (K) 6625-7086 mg kg⁻¹, copper (Cu) 6.13-10.07 mg kg⁻¹, manganese (Mn) 21.8-24.1 mg kg⁻¹, iron (Fe) 51.7-70.1 mg kg⁻¹ and zinc (Zn) 30.9-38.6 mg kg⁻¹. Grain yield ranged from 148.3 to 183.7 kg da⁻¹, with annual means of 156.0 and 170.0 kg da⁻¹, respectively. The lowest yield was observed in the control, whereas the highest yield was achieved with 400 kg da⁻¹ leonardite application.

Key words: Chickpea (*Cicer arietinum* L.), Leonardite, Macro, Micro elements, Vermicompost, Yield.

INTRODUCTION

Legumes play a crucial role in human nutrition, especially in developing countries (Temba *et al.*, 2016). Legumes are a cheap source of protein, especially in low-income countries. They are considered a healthier and more affordable option when protein sources in animal foods are high cost or unavailable (Egesel *et al.*, 2006; Acharya *et al.*, 2006; Lisciani *et al.*, 2024). These plants play an important role not only in human food but also as animal feed (Kassie *et al.*, 2009; Akibode and Maredia, 2012; Cömert-Acar *et al.*, 2019). In addition to protein, they are rich in some nutritional minerals, fiber, carbohydrates and vitamins (Latham, 1997; Roy *et al.*, 2010). In addition to their powerful antioxidant properties, bioactive peptides in chickpeas have been reported to increase angiotensin-converting enzyme activity (Xue *et al.*, 2015; Otağ and Hayta, 2016; Çetiner and Bilek, 2018). Chickpeas, which hold an important place as an edible snack seed for humans and as animal feed, are plants that are well-adapted and suitable for production in arid and semi-arid areas (Üstün and Gülümser, 2003; Gül *et al.*, 2006; Kayan *et al.*, 2014). Chickpeas are particularly vital for their protein content today, especially given the current challenges of malnutrition in human nutrition (Wells *et al.*, 2020; Nathawat *et al.*, 2024). In recent years, the use of organic fertilizers has gained great importance for soil improvement and organic farming (Timsina, 2018; Uçar, 2019; Uçar *et al.*, 2020a;

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Ceritoglu *et al.*, 2021; Singh *et al.*, 2022; Begum *et al.*, 2025).

MATERIALS AND METHODS

The study was conducted using the local chickpea variety Diyar-95, which was released in 1995 and originally bred in 1992 at the GAP International Agricultural Research and Training Center in Diyarbakır. Plants reached 50-75 cm in height, produced 19-28 pods per plant (with a mean of 1.7 seeds per pod), flowered 145-158 days after sowing in winter cultivation and reached physiological maturity within 182-204 days. Seeds were cream-colored, shaped like a "ram's head," and had a 100-seed weight of 40-45 g.

Registration trials reported a mean yield of 150-200 kg da⁻¹ with no disease incidence (Anonymous, 2025). Leonardite and vermicompost were used as organic fertilizers. Leonardite contained 20% organic matter and 20% total humic+fulvic acids, with a low pH (4.5) and 20% moisture, enhancing nutrient availability. Vermicompost had a richer composition with 55% organic matter and 42% ash. Detailed properties of these fertilizers are presented in Table 1.

Fertilizer analyses were carried out in the central research laboratory of Mardin Artuklu University. The experiment was carried out during the 2022-2023 and 2023-2024 growing seasons in a farmer's field in Yukarı Aydınlı, Artuklu, Mardin. Selected soil physical and chemical properties are shown in Table 2.

Long-term climate data (1941-2024) indicated that Mardin has a Mediterranean-like climate, characterized by hot, dry summers and cold, rainy winters. The mean annual temperature was 16.2°C, with July (29.8°C) and August (29.7°C) being the hottest months and January (3.1°C) and February (4.2°C) the coldest. A summary of the long-term climate data is presented in Fig 1.

The experiment followed a split-plot design in randomized blocks with three replications (27 plots). Each plot measured 1×5 m (5 m²), with five rows spaced 20 cm apart and 350 seeds m² were sown by hand. Leonardite was applied at L₁: 50, L₂: 100, L₃: 200 and L₄: 400 kg da⁻¹ and vermicompost at VC₁: 150, VC₂: 200, VC₃: 250 and VC₄: 300 kg da⁻¹, along with a control (C₀). Measurements were taken from the central area of each plot (0.6×4 m = 2.4 m²) to minimize edge effects. Chickpea planting was carried out on November 20, 2022 and November 22, 2023 and harvests were carried out on May 20, 2023 and May 25, 2024. After grinding, plant samples were subjected to microwave-assisted wet ashing (HNO₃+H₂O₂) and the concentrations of P, K, Cu, Mn, Fe and Zn were determined using ICP-AES. Nitrogen (N) content was measured by the Kjeldahl method (Bremner, 1996). Analysis of variance (ANOVA) was used to evaluate the effects of different fertilizer applications and mean differences were compared using Waller-Duncan's multiple range test (p≤0.05). Statistical analyses were performed using SPSS 22.0.

RESULTS AND DISCUSSION

Changes in N, P and K concentrations in chickpea under organic fertilizer applications

According to the statistical analysis, N and P concentrations in chickpea were significantly affected by both year and organic fertilizer application (p≤0.01), whereas their interaction (year*application) was not significant. On the other hand, potassium concentration did not show any significant variation with respect to year, application, or their interaction (Table 3).

Nitrogen (N)

The effect of different doses of leonardite and vermicompost on total %N in chickpea varied between 2.98% and 3.61%, with the first-year mean being 3.16% N and the second-year mean 3.40% N. When overall mean was examined, the lowest nitrogen content (3.00% N) was recorded in the control plots, while the highest (3.46% N) was observed in plots receiving 400 kg da⁻¹ leonardite (Table 3). Applications of leonardite and vermicompost resulted in higher nitrogen values compared to the control plots. This can be explained by the decomposition of organic materials providing nitrogen to the soil and increasing plant nitrogen uptake through mineralization processes. Azizzadeh *et al.* (2016) stated that leonardite

Table 1: Properties of leonardite and vermicompost fertilizers used in the experiment.

Property	Leonardite	Vermicompost
Organic matter (%)	20.0	55.0
Total humic + Fulvic acid (%)	20.0	12.0
Moisture (%)	20.0	40.0
pH	4.50	7.20
Ash content (%)	-	42.0
Total N (%)	2.00	1.60
P ₂ O ₅ (%)	0.35	2.20
Ca (%)	0.28	5.00
Mg (%)	0.19	1.20
Fe (%)	-	1.50
Mn (mg kg ⁻¹)	65.2	73.0

Table 2: Some chemical and physical properties of the experimental soil.

Property	Test soil	References
pH	7.72	Kacar, 1995
Texture	Clay-Loam	Bouyoucus, 1952
Salt (%)	0.18	Soil Survey Staff, 1951
CaCO ₃ (%)	33.4	Loeppert <i>et al.</i> , 1996
Organic Matter (%)	1.09	Kacar, 1995
Available P (mg P ₂ O ₅ kg ⁻¹)	12.8	Olsen <i>et al.</i> , 1954
Available K (mg K ₂ O kg ⁻¹)	70.8	Richards 1954
Fe (mg kg ⁻¹)	24.2	Lindsay and Norvell,1978 (DTPA)
Cu (mg kg ⁻¹)	2.72	
Mn (mg kg ⁻¹)	55.4	
Zn (mg kg ⁻¹)	9.80	

applied wheat increased N and K concentrations. Joshi *et al.* (2013) observed an increase in protein and oil content in cereal grains following vermicompost application. Leonardite applications in *Allium sativum* L. plant had a positive effect especially on P and K concentrations (Sarıyıldız, 2020) and similarly, Akinremi *et al.* (2000) reported an increase in the concentrations of some macro (N, P and K) elements in bean, canola and wheat plants as a result of leonardite applications.

Phosphorus (P)

The effect of organic fertilizer applications on P in chickpea plants varied between 3010-3833 mg P kg⁻¹, with a mean of 3438 mg P kg⁻¹ in the first year and 3651 mg P kg⁻¹ in the second year. Considering the overall means, the lowest P content (3372 mg P kg⁻¹) was observed in vermicompost applied at 150 kg da⁻¹, while the highest P content (3697 mg P kg⁻¹) was obtained with 300 kg da⁻¹ vermicompost applications (Table 3). Vermicompost application has been reported to increase N, P, K, Mn, Zn, Fe and S concentrations in lettuce (Özen and Sönmez, 2019). Another study on tomato

plants showed that vermicompost significantly enhanced nutrient contents in plant tissues, with increases of 55% in K, 73% in P, 32% in Fe and 36% in Zn compared to the control plots (Azarmi *et al.*, 2008). Leonardite applications have also been shown to positively influence P content in maize plants (Kaya *et al.*, 2020).

Potassium (K)

The effect of different doses of leonardite and vermicompost on K in chickpea plants ranged from 6625 to 7086 mg K kg⁻¹, with the first-year mean being 6804 mg K kg⁻¹ and the second-year mean 6921 mg K kg⁻¹. Considering the overall means, the lowest K content (6711 mg K kg⁻¹) was observed in the control plots, while the highest K content (6997 mg K kg⁻¹) was obtained with 400 kg da⁻¹ leonardite application (Table 3). Vermicompost has been reported to increase K content in spinach (Gökmen Yılmaz *et al.*, 2012; Demirer, 2019). David *et al.* (2014) reported that leonardite promotes root development in maize, increasing protein content and N, P and K uptake. Duval *et al.* (1998) also indicated that leonardite supports plant growth and

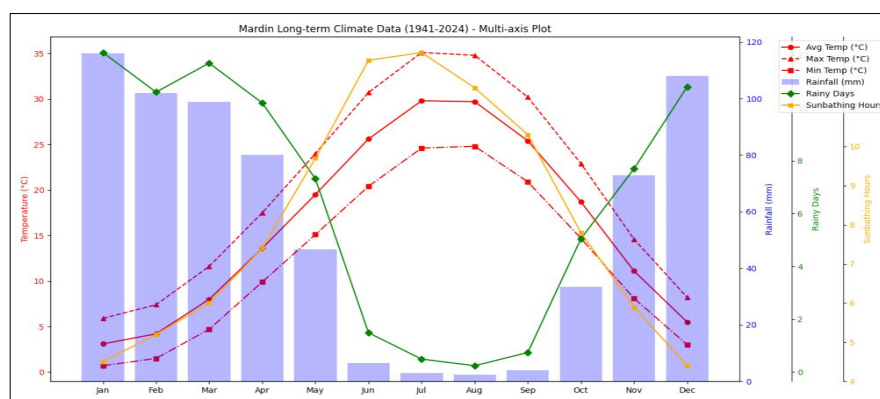


Fig 1: Long-term Mardin climate data.

Table 3: Effect of organic fertilizer applications on N, P and K its concentration in chickpea.

Treatment	N (%)		Mean	P (mg kg ⁻¹)		Mean	K (mg kg ⁻¹)		Mean
	1 st year	2 nd year		1 st year	2 nd year		1 st year	2 nd year	
C ₀	2.98	3.02	3.00 ^B	3398 ^{f-h}	3367 ^{gh}	3383 ^C	6625	6798	6711
L ₁	3.10	3.28	3.19 ^{AB}	3487 ^{d-h}	3583 ^{b-f}	3535 ^{AB}	6944	7034	6989
L ₂	3.04	3.41	3.23 ^{AB}	3509 ^{d-h}	3680 ^{a-d}	3594 ^{AB}	6813	6902	6858
L ₃	3.28	3.56	3.42 ^A	3568 ^{c-f}	3543 ^{c-h}	3556 ^{AB}	6893	7071	6982
L ₄	3.30	3.61	3.46 ^A	3627 ^{b-e}	3600 ^{b-e}	3613 ^{AB}	6908	7086	6997
VC ₁	3.13	3.29	3.21 ^{AB}	3010 ⁱ	3733 ^{a-c}	3372 ^C	6659	6831	6745
VC ₂	3.27	3.41	3.34 ^A	3357 ^h	3783 ^{ab}	3570 ^{AB}	6872	6694	6783
VC ₃	3.14	3.53	3.33 ^A	3427 ^{e-h}	3733 ^{a-c}	3580 ^{AB}	6870	7047	6959
VC ₄	3.15	3.49	3.32 ^A	3560 ^{c-g}	3833 ^a	3697 ^A	6653	6826	6739
Mean	3.16	3.40		3438	3651		6804	6921	
Year		21.3 ^{**}			63.3 ^{**}			1.63 ^{n.s.}	
Application		3.01 ^{**}			6.89 ^{**}			0.77 ^{n.s.}	
Year*application		0.57 ^{n.s.}			9.85 ^{n.s.}			0.18 ^{n.s.}	

Means in the same column followed by different letters are significantly different at the 5% level.

(**): statistically significant at p≤0.01, (n.s.): not significant.

enhances the availability of several nutrients in the soil, especially N, P and K.

Changes in Cu and Mn concentrations in chickpea under organic fertilizer applications

The statistical analysis revealed that Cu concentration in chickpea was significantly affected by year ($p \leq 0.01$), whereas application and the year*application interaction had no significant effect. In contrast, Mn concentration was significantly influenced by application ($p \leq 0.05$), while no significant effects were observed for year and for the year*application interaction (Table 4).

Copper (Cu)

The effect of different doses of leonardite and vermicompost on Cu in chickpea plants ranged from 6.13 to 10.07 mg

Cu kg⁻¹, with the first-year mean of 7.56 mg Cu kg⁻¹ and the second-year mean of 8.87 mg Cu kg⁻¹. Overall means indicated that the lowest Cu content (7.11 mg Cu kg⁻¹) was obtained in the control plots, whereas the highest Cu content (9.05 mg Cu kg⁻¹) was observed with 100 kg da⁻¹ leonardite application (Table 4). Leonardite and vermicompost applications provided higher Cu contents in plants compared to the control plots. This may be due to the ability of organic materials to enhance Cu solubility in the soil (Römheld and Marschner, 1991; Marschner, 2012). In a study on cherry trees, leonardite applications were reported to increase N, P, K, Ca, Mg, Fe, Cu, Zn and Mn contents (Demirer, 2019). Additionally, Zırğ and Eren (2025) reported that vermicompost applications at different doses increased Cu levels in two wheat cultivars compared to the respective control applications.

Table 4: Effect of organic fertilizer applications on Cu and Mn its concentration in chickpea.

Treatment	Cu (mg kg ⁻¹)		Mean	Mn (mg kg ⁻¹)		Mean
	1 st year	2 nd year		1 st year	2 nd year	
C ₀	7.17	7.06	7.11	23.2	23.7	23.4 ^{AB}
L ₁	7.37	8.70	8.03	22.4	22.8	22.6 ^{AB}
L ₂	8.03	10.07	9.05	23.0	23.5	23.3 ^{AB}
L ₃	8.20	9.60	8.90	23.3	24.1	23.7 ^A
L ₄	7.47	9.40	8.43	23.6	24.1	23.9 ^A
VC ₁	6.13	9.63	7.88	23.2	23.7	23.5 ^{AB}
VC ₂	7.87	8.63	8.25	22.3	22.7	22.5 ^{AB}
VC ₃	8.07	8.13	8.10	21.8	22.3	22.1 ^B
VC ₄	7.70	8.60	8.15	22.3	22.7	22.5 ^{AB}
Mean	7.56	8.87		22.8	23.3	
Year		19.0 ^{**}			2.97 ^{n.s.}	
Application		1.58 ^{n.s.}			2.18 [*]	
Year*application		1.49 ^{n.s.}			0.02 ^{n.s.}	

Means in the same column followed by different letters are significantly different at the 5% level.

(*): statistically significant at $p \leq 0.05$, (**): statistically significant at $p \leq 0.01$, (n.s.): not significant.

Table 5: Effect of organic fertilizer applications on Fe and Zn its concentration in chickpea.

Treatment	Fe (mg kg ⁻¹)		Mean	Zn (mg kg ⁻¹)		Mean
	1 st year	2 nd year		1 st year	2 nd year	
C ₀	61.6 ^{a-d}	62.1 ^{a-d}	61.8 ^{AB}	33.2 ^{e-f}	30.9 ^g	32.1 ^D
L ₁	57.7 ^{b-d}	61.2 ^{a-d}	59.4 ^{BC}	34.8 ^{b-f}	36.9 ^{a-d}	35.8 ^{A-C}
L ₂	53.6 ^{cd}	56.9 ^{b-d}	55.2 ^{BC}	34.0 ^{c-g}	36.0 ^{a-f}	35.0 ^{BC}
L ₃	66.1 ^{ab}	70.1 ^a	68.1 ^A	36.5 ^{a-e}	38.6 ^a	37.6 ^A
L ₄	52.5 ^d	55.7 ^{b-d}	54.1 ^C	35.7 ^{a-f}	37.9 ^{ab}	36.8 ^{AB}
VC ₁	60.0 ^{a-d}	63.6 ^{a-c}	61.8 ^{AB}	35.2 ^{b-f}	37.3 ^{a-c}	36.3 ^{A-C}
VC ₂	51.7 ^d	54.8 ^{cd}	53.3 ^C	34.0 ^{c-g}	36.1 ^{a-f}	35.0 ^{BC}
VC ₃	58.7 ^{b-d}	62.2 ^{a-d}	60.5 ^{BC}	33.8 ^{d-g}	35.9 ^{a-f}	34.9 ^{BC}
VC ₄	58.7 ^{b-d}	62.3 ^{a-d}	60.5 ^{BC}	33.0 ^f	34.9 ^{b-f}	33.9 ^{CD}
Mean	57.9	61.0		34.5	36.1	
Year		4.80 [*]			12.2 ^{**}	
Application		4.75 ^{**}			5.71 ^{**}	
Year*Application		0.06 ^{n.s.}			1.16 ^{n.s.}	

Means in the same column followed by different letters are significantly different at the 5% level.

(*): statistically significant at $p \leq 0.05$, (**): statistically significant at $p \leq 0.01$, (n.s.): not significant.

Manganese (Mn)

The effect of different doses of leonardite and vermicompost on Mn in chickpea plants ranged from 21.8 to 24.1 mg Mn kg⁻¹, with the first-year mean of 22.8 mg Mn kg⁻¹ and the second-year means of 23.3 mg Mn kg⁻¹. Overall mean showed that the lowest Mn content (22.1 mg Mn kg⁻¹) was observed in the 250 kg da⁻¹ vermicompost application, whereas the highest Mn content (23.9 mg Mn kg⁻¹) was obtained with 400 kg da⁻¹ leonardite application (Table 4). Leonardite applications at 200 and 400 kg da⁻¹ and vermicompost at 150 kg da⁻¹ increased Mn content compared to the control plots. However, in other applications, Mn content was generally lower. This may be due to the high organic matter input, which can enhance Mn binding in the soil and limit its uptake by plants (Römheld and Marschner, 1991; Marschner, 2012). It has

Table 6: Effect of organic fertilizer applications on yield of chickpea (kg da⁻¹).

Treatment	Yield		Mean
	1 st year	2 nd year	
C ₀	148.3 ⁱ	150.6 ^{hi}	149.4 ^F
L ₁	150.7 ^{hi}	165.7 ^{de}	158.2 ^E
L ₂	151.0 ^{hi}	166.1 ^d	158.6 ^E
L ₃	155.0 ^g	170.5 ^c	162.8 ^C
L ₄	167.0 ^{cd}	183.7 ^a	175.4 ^A
VC ₁	154.0 ^{gh}	169.4 ^{cd}	161.7 ^{CD}
VC ₂	151.7 ^{g-i}	166.8 ^{cd}	159.3 ^{DE}
VC ₃	160.3 ^f	176.4 ^b	168.4 ^B
VC ₄	162.0 ^{ef}	178.2 ^b	170.1 ^B
Mean	156.0	170.0	
Year		778 ^{**}	
Application		102 ^{**}	
Year*Application		8.77 ^{**}	

Means in the same column followed by different letters are significantly different at the 5% level.

(**): statistically significant at $p \leq 0.01$.

been reported that leonardite applications increased fruit yield in tomato plants and positively affected Fe, Zn and Mn contents in leaves (Topcuoglu and Onal, 2006).

Changes in Fe and Zn concentrations in chickpea under organic fertilizer applications

The statistical analysis indicated that Fe concentration in chickpea was significantly affected by year ($p \leq 0.05$) and application ($p \leq 0.01$), whereas the year*application interaction was not significant. Similarly, Zn concentration was significantly influenced by both year and application ($p \leq 0.01$), while no significant effect was observed for the year*application interaction (Table 5).

Iron (Fe)

The effect of different doses of leonardite and vermicompost on Fe in chickpea plants ranged from 51.7 to 70.1 mg Fe kg⁻¹, with the first-year mean of 57.9 mg Fe kg⁻¹ and the second-year mean of 61.0 mg Fe kg⁻¹. Overall means indicated that the lowest Fe content (53.3 mg Fe kg⁻¹) was observed with 200 kg da⁻¹ vermicompost, while the highest Fe content (68.1 mg Fe kg⁻¹) was obtained from 200 kg da⁻¹ leonardite application (Table 5). Except for the 200 kg da⁻¹ leonardite application, all other applications generally showed a decrease in Fe levels compared to the control. This suggests that different doses may have variable effects on the amount of soluble Fe in the soil. Similar studies have reported that leonardite applications to rice soil have positive effects on yield and some yield parameters, including macronutrient (P and Mg) and micronutrient (Fe, Mn, Cu and Zn) concentrations (Litardo *et al.*, 2022). Many researchers have reported that vermicompost applications to soil generally lead to increases in Fe concentrations in mustard (DeKock *et al.*, 1960), soybean (Cieschi *et al.*, 2019), wheat (Zirig and Eren, 2025) and lettuce (Adiloğlu *et al.*, 2015).

Zinc (Zn)

The effect of Leonardite and vermicompost applications with different structures on Zn in chickpea plants varied

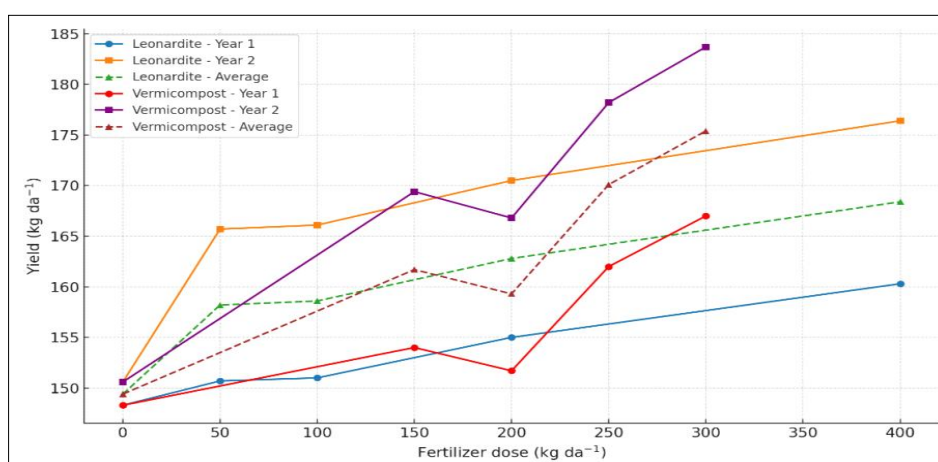


Fig 2: Effect of organic fertilizer applications on chickpea yield.

between 30.9 and 38.6 mg Zn kg⁻¹. The first year mean was determined to be 34.5 mg Zn kg⁻¹ and the second year mean was determined to be 36.1 mg Zn kg⁻¹. Overall means indicated that the lowest Zn content (32.1 mg Zn kg⁻¹) was observed in the control, while the highest Zn content (37.6 mg Zn kg⁻¹) was obtained from the 200 kg da⁻¹ leonardite application (Table 5). The applications generally increased Zn content compared to the control. Zinc is a critical micronutrient for plant metabolism and this increase suggests that organic amendments can enhance Zn availability (Alloway, 2008; Marschner, 2012). Leonardite applications have been reported to positively affect yield and yield parameters (grain/stem ratio, harvest index) in rice (Litardo *et al.*, 2022). The presence of organic matter can dissolve otherwise insoluble Zn forms, improving its bioavailability (Smith, 2009). Vermicompost applications have been reported to promote growth, improve soil properties and increase Zn concentrations in various crops (Eryüksel, 2016). Furthermore, organic ligands in soil may lead to the formation of organic Zn complexes, which can either enhance or limit Zn uptake by plants (Hamzah Saleem *et al.*, 2022).

Yield

Statistical analysis of the study indicated that year, application and the year*application interaction were all significant at the p≤0.01 level (Table 6).

The effects of different doses of leonardite and vermicompost on the yield of chickpea plants ranged from 148.3 to 183.7 kg da⁻¹, with the first-year mean being 156.0 kg da⁻¹ and the second-year mean 170.0 kg da⁻¹. Considering overall means, the lowest yield (149.4 kg da⁻¹) was obtained in the control plots, while the highest yield (175.4 kg da⁻¹) was achieved with 400 kg da⁻¹ leonardite application (Table 6 and Fig 2). Vermicompost applications have been reported to support root development, facilitate nutrient uptake and thereby increase yield. Moreover, the nutrients it contains are present in higher amounts and in more readily soluble forms compared to normal compost (Padmavathamma *et al.*, 2008; Pattnaik and Reddy, 2010). Organic materials have been noted to enhance soil organic matter content, positively affecting plant growth and consequently crop yield (Verlinden *et al.*, 2009; El-Sayed *et al.*, 2011). Research on leonardite applications in chickpea (*Cicer arietinum* L.) has shown positive effects on plant height, first pod height, number of pods, number of seeds per pod, 100-seed weight and seed yield, with the 100 kg da⁻¹ dose providing the highest values and higher doses potentially being beneficial (Uçar *et al.*, 2020). Leonardite applications have also been reported to increase yield and yield parameters in faba bean (*Vicia faba* L.) (Uçar *et al.*, 2021).

CONCLUSION

Within the scope of this two-year study, the effects of leonardite and vermicompost applications on the nutrient

content (N, P, K, Cu, Mn, Fe and Zn) and yield of chickpea (*Cicer arietinum* L.) were investigated. The findings indicate that both the applications and the annual variations produced significant results. Analysis of yield data provided important insights into the year, the treatment and how they interact. Control plots had the lowest yields, while plots receiving 400 kg da⁻¹ leonardite and 250 to 300 kg da⁻¹ vermicompost had significantly higher yields. This suggests that organic matter can contribute to better chickpea growth by making the soil more fertile. It's important to note that leonardite has a greater impact on yield, which is crucial. Investigating the cumulative effects of long-term applications on soil organic matter content, nutrient dynamics and biological activity is recommended for future studies.

Disclaimers

The views and conclusions expressed in this article are solely those of the author and do not necessarily represent the views of the affiliated institution. The author is responsible for the accuracy and completeness of the information provided, but does not accept any liability for any direct or indirect losses resulting from the use of this content.

Conflict of interest

The author declares that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

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