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Original Article

The Effect of Different Types of vermicompost fertilizers in some Physical properties of the soil in Al – Hasaka Governorate

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Abstract

Vermicompost represents one of the most important eco-friendly organic fertilizers due to its effective role in improving the physical, chemical, and biological properties of soils, as well as enhancing agricultural production in a sustainable manner, particularly in areas suffering from soil fertility degradation. Cumin is considered one of the major economic crops in Al-Hasakah Governorate, as it requires suitable nutritional and environmental conditions to achieve high productivity and superior quality. This study was conducted over two agricultural seasons (2023–2024) and (2024–2025) in Al-Hasakah Governorate in Syria, with the aim of evaluating the effect of different types of vermicompost derived from (sheep, cow, and horse manure), applied at graded rates (0.3, 0.6, 0.9, and 1.2) t ha-1 on selected physical soil properties. The experiment was carried out using a factorial design based on a randomized complete block design (RCBD) with three replications. Field measurements included bulk density, particle density, total porosity, solid space percentage, and field capacity. The results showed significant improvements in all physical properties with the use of vermicompost compared to the control. Bulk density gradually decreased with increasing compost rates. The treatment with horse manure vermicompost at 1.2 t/ha recorded the best results, reducing bulk density by 9.61%, increasing total porosity by 7.67%, and enhancing maximum field capacity by 7.68%. Although particle density showed slight changes, they were statistically significant in some high-rate treatments, reflecting the cumulative effect of the added organic matter. Moreover, horse manure vermicompost proved superior in enhancing soil physical properties, followed by cow vermicompost and then sheep vermicompost.

Keywords: Vermicompost, Soil physical properties, Bulk density, Porosity, Field capacity.

Introduction

Soil fertility and its capacity to support plant growth are among the most critical factors influencing agricultural productivity. However, in recent decades, soils have experienced significant degradation due to multiple factors, most notably the excessive reliance on chemical fertilizers and inappropriate agricultural management practices, in addition to harsh climatic conditions in arid and semi-arid regions. These factors have collectively contributed to

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the decline of organic matter content, deterioration of soil structure, and reduced water and nutrient retention capacity (Pandey *et al.*, 2008; Albiach *et al.*, 2000). Consequently, recent trends in sustainable agriculture have increasingly emphasized the use of organic fertilizers, particularly vermicompost, as an environmentally safe alternative to improve soil properties and support crop production under such challenges. Vermicompost is the product of the biological decomposition of organic materials through the interaction of earthworms and microorganisms. It is characterized by a fine texture, high porosity, good aeration, and excellent water-holding capacity, creating a favorable environment for root development and improving the general structure of the soil (Edwards & Burrows, 1988). Furthermore, vermicompost contains most macro- and micronutrients in readily available forms, such as nitrates, phosphates, soluble potassium, calcium, and magnesium, making it a complete nutrient source for plant growth (Orozco *et al.*, 1996).

Numerous studies have indicated that vermicompost application leads to noticeable improvements in soil physical properties, such as reducing bulk density, increasing porosity, and enhancing water infiltration and aeration (Ismail, 2005). Vermicompost has also been shown to promote soil aggregation and improve structural stability, thereby reducing erosion (Edwards *et al.*, 2010). These effects are largely attributed to changes in organic carbon content, increased microbial and enzymatic activity, and enhanced biological processes that support plant growth (Atiyeh *et al.*, 2002). Although vermicompost has gained global attention, most previous studies were conducted on neutral or acidic soils, while alkaline soils rich in calcium carbonate have been largely overlooked (Stevenson, 1994). This presents a gap in understanding the effectiveness of vermicompost under such conditions. Soils in Al-Hasakah Governorate, located in northeastern Syria, are typically alkaline and characterized by a high content of calcium carbonate. These soils suffer from poor structure and declining fertility due to long-term conventional agricultural practices and the limited use of organic amendments. Therefore, the present study aims to assess the impact of different types of vermicompost fertilizers derived from cow, sheep, and horse manure on selected physical properties of the soil in Al-Hasakah Governorate. These properties include bulk density, porosity, and water-holding capacity, which are essential indicators of soil health and productivity. By exploring the behavior of vermicompost in calcareous soils, this study contributes to promoting sustainable soil management practices in arid and semi-arid agricultural regions.

Materials and Methods

Site and Time of the Study:

The research was conducted over two agricultural seasons (2023–2024) and (2024–2025) on lands belonging to the Agricultural Extension Unit in Bezzara, affiliated with the Directorate of Agriculture in Hassakeh

Governorate. The study site is located in the second stability zone at latitude of 36.5876° N and a longitude of 40.8387° E. The experimental field, located at 36°35'15.3"N, 40°50′19.5″E, is at an elevation of 452 meters above sea level. The area receives an average annual rainfall of approximately 350 mm and represents an important agricultural area for the cultivation of crops such as cumin.

Prior to applying any treatments, soil samples were collected from various locations within the experimental field at a depth of 0–30 cm to determine the initial physical and chemical properties of the soil during the study period. These samples were combined and homogenized to form a composite sample representative of the site then analyzed to determine its physical and chemical characteristics .

Preparation of Vermicompost:

The vermicompost produced in a dedicated manufacturing unit prepared in small plastic containers to provide an optimal environment for the activity and reproduction of the red earthworm Eisenia fetida. For each type of manure (sheep, cow, horse), a total amount of 100 kg was prepared, consisting of approximately 90 kg of compost and about 10 kg of dry organic materials, such as fallen tree leaves, paper scraps, newspapers, shredded wheat straw, dry plant residues, torn pieces of paper bags, and small pieces of dried palm fronds, forming a layer that occupied approximately half of the container volume.

To improve the physical structure of the organic material and enhance aeration, around 500 g of a sand-soil mixture was added. The mixture was moistened with water until the moisture content reached approximately 60–70%, equivalent to a wet, wrung-out sponge, which is optimal for worm activity. The carbon-to-nitrogen (C: N) ratio was adjusted to the ideal range of 25:1–30:1 to enhance biological decomposition and accelerate the production of high-quality vermicompost. Subsequently, approximately 2,000 individuals of E. fetida were introduced into each container, corresponding to roughly 5 kg (Lazcano *et al.*, 2008), and plant-based kitchen residues were evenly distributed over the surface of the organic material. Undesirable materials, such as citrus peels, onions, garlic, and meat residues, were avoided due to their negative impact on worm health and attraction of insects. The added organic residues were slightly warm to promote biological activity and reduce unpleasant odors.

During the preparation period, which lasted approximately 8–10 weeks, moisture and aeration were regularly monitored through periodic turning and ventilation openings to ensure sufficient oxygen availability, while maintaining the temperature within the range of 20–28 °C, optimal for worm reproduction and digestion. The maturity of the vermicompost was confirmed by observing the dark color, characteristic earthy odor, and homogeneity of the material, resulting in the production of mature, uniform vermicompost rich in beneficial organic matter, capable of consuming approximately 2.5 kg of organic material daily per batch of 2,000 worms. The prepared vermicompost was later used in the experiment after its chemical properties.

Field Experiment:

Land preparation began in late November of each year, with two successive plowing operations carried out to a depth of 25–30 cm, followed by two soil pulverization operations to break up soil clods and improve surface leveling. Afterwards, an additional two plowing passes were conducted, and the soil surface was carefully leveled. The 450-square-meter field was then divided into experimental plots according to the experimental design.

In early January, vermicompost was applied approximately one week before sowing. The designated quantity for each treatment (0.3, 0.6, 0.9, and 1.2) t ha^{-1} was evenly distributed over the surface of the plots and incorporated into the topsoil to a depth of 10–15 cm, ensuring interaction between the organic matter and the soil. Surface broadcasting without incorporation was not adopted, as mixing enhances compost-soil integration and stimulates microbial activity. Approximately two weeks before harvest, soil samples were collected from a depth of 0–20 cm within the root zone. Five random holes were dug in each experimental plot, and the samples were combined into a composite sample was sent for the necessary physical and chemical analyses according to the objectives of the study.

Experimental Design:

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. It included 13 treatments consisting of different application rates (0.3, 0.6, 0.9, and 1.2) t ha^{-1} of three types of vermicompost (sheep manure, cow manure, and horse manure), in addition to a control treatment. This resulted in a total of 39 experimental units. Each plot covered an area of 10 m^2, with appropriate spacing maintained between treatments and between replications.

Analyses and Measurements:

The component analyses were conducted at the laboratories of the Agricultural Scientific Research Center in Damascus, within the Soil Research Department.

Soil Analyses:

Physical Analyses:

Mechanical Composition: Determined using the hydrometer method and the soil texture will be identified based on the USDA soil texture triangle.

Bulk Density (ρB): Measured using the paraffin wax method.

Particle Density (ρb): Determined by the pycnometer method (Black and Hartge, 1986).

Total Porosity: Calculated based on the relationship between bulk density and particle density:

Porosity= (1- PB / Pb) *100

Air Porosity: Calculated as the difference between total porosity and field capacity moisture content on a volumetric basis.

% Solid space = (ρB/ρb) *100

% Field Capacity = (WW–Wd) / Wd*100

Chemical Analyses:

Soil Reaction (pH): Measured using a pH meter on the saturated paste extract.

Electrical Conductivity (EC): Determined using a conductivity meter on the saturated paste extract.

%Organic Carbon: It was determined using the wet oxidation method with potassium dichromate.

Calcium Carbonate: Determined using a calcimeter.

Total nitrogen (N): Using the Kjeldahl method (Bremner and Mulvaney, 1982). Available

Total nitrogen (N): Using the Kjeldahl method (Bremner and Mulvaney, 1982).

Available phosphorus: Using the Olsen method (Olsen et al., 1954).phosphorus: Using the Olsen method (Olsen et al., 1954).

Exchangeable sodium and potassium: They were measured using a flame photometer.

Total sulfur: It was determined using a spectrophotometer at a wavelength of 420 nm.

The micronutrients (Fe, Zn, Mn, and Cu) were determined using an Atomic Absorption Spectrophotometer (AAS).

Statistical Analysis:

The experimental data were analyzed using the GenStat statistical software. Analysis of variance (ANOVA) was performed to test the significance of differences among treatments. Mean comparisons were carried out using the Least Significant Difference (LSD) test at a significance level of 0.05.

Results and discussion

The effect of Different Types of compost on the produced vermicompost:

The results of the chemical analysis of the different types of vermicompost reveal significant variations in their nutritional and chemical properties, reflecting the influence of the original raw material on the quality of the final product.

Table (1): Chemical Properties of Vermicompost Derived from Sheep, Cow, and Horse Manure.

Substrate used	PH	EC (ds/m)	C (%)	N (%)	C: N	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)
Sheep dung	7.2	2.6	16.89	1.49	11.3	1.36	1.26	2.77	0.63	0.1	595	265	185	46
Cow dung	7.5	1.29	32.25	2.98	11.77	1.42	1.48	5.91	1.02	0.15	502	253	381	178
Horse dung	7.97	1.07	39.51	1.62	22.16	0,54	0.83	1.6	0.47	0.08	209	98	174	127

Sheep manure vermicompost is characterized by a moderate pH (7.2) and relatively high electrical conductivity (2.6 dS/m), reflecting a higher salt concentration that may pose limitations for salt-sensitive crops. It contains moderate carbon content (16.89%) and an adequate nitrogen concentration (1.49%), resulting in a low C: N ratio (11.34:1), which indicates good maturity and efficient organic matter decomposition. Furthermore, it provides a balanced supply of macronutrients, including phosphorus (1.36%), potassium (1.26%), and calcium (2.77%).

Cow manure vermicompost, in contrast, has a higher carbon content (32.25%) and a notably high nitrogen concentration (2.98%), yielding a moderate C: N ratio (10.82:1). It exhibits a near-neutral pH (7.5) and relatively low electrical conductivity (1.29 dS/m). This type is particularly rich in calcium (5.91%) and magnesium (1.02%), in addition to adequate levels of phosphorus, potassium, and essential micronutrients such as zinc and copper. These properties enhance its potential to improve soil fertility and sustain crop productivity.

Horse manure vermicompost shows the highest pH (7.97) and the lowest electrical conductivity (1.07 dS/m). It contains the highest carbon content (39.51%) but relatively low nitrogen (1.62%), leading to a high C: N ratio (24.39:1). This indicates the presence of more stable, less decomposed organic matter. Nutrient concentrations including phosphorus, potassium, calcium, magnesium, iron, and manganese are comparatively lower. Accordingly, horse manure vermicompost is more suitable for improving soil organic matter quality and enhancing carbon sequestration, though it may require supplementation with nitrogen or other nutrients to provide a balanced fertility profile for optimal plant growth.

Effect of Different Types of Vermicompost on the Bulk Density of the Studied Soil (g/cm³):

Soil bulk density is a critical physical property that reflects the cohesion of soil particles and the volume of pore spaces between them, directly affecting soil fertility and its capacity to retain water and air. A decrease in bulk density typically indicates an improvement in soil structure, contributing to enhanced root growth and crop development. Vermicompost is considered an organic amendment that helps modify the physical properties of soil by increasing organic matter content and reducing particle cohesion. Therefore, evaluating the effects of different types and application rates of vermicompost on bulk density is essential to understanding its role in improving soil fertility and enhancing agricultural crop productivity.

Table (2) illustrates the results of soil bulk density under the effect of applying different types of vermicompost produced from livestock wastes (sheep, cows, and horses) at increasing rates (0.3, 0.6, 0.9, and 1.2) t/ha during two consecutive growing seasons (2023–2024) and (2024–2025).

Table (2) shows the effect of vermicompost treatments on the bulk density of the soil.

Average	2025-2024			Average	2024-2023			
	Horse manure vermicompost	Cow manure vermicompost	Sheep manure vermicompost		Horse manure vermicompost	Cow manure vermicompost	Sheep manure vermicompost	Type / quantity kg/dunum
1.29 d	1.29 g	1.29 g	1.29 g	1.31 e	1.31 e	1.31 e	1.31 e	Control
1.253 c	1.23 cd	1.26 ef	1.27 fg	1.28 d	1.25 d	1.29 e	1.3 e	300
1.233 b	1.20 b	1.24 de	1.26 ef	1.2633 c	1.24 cd	1.26 d	1.29 e	600
1.2244 b	1.19 b	1.23 cd	1.2533 ef	1.2367 b	1.21 ab	1.24 cd	1.26 d	900
1.1989 a	1.16 a	1.21 bc	1.2267 cd	1.22 a	1.19 a	1.22 bc	1.2567 d	1200
	1.214 a	1.246 b	1.26 c		1.24 a	1.2640 b	1.2833 c	Average
type=0.00514 Quantity=0.0063 type*Quantity=0.01148				type=0.00518 Quantity=0.00669 type*Quantity=0.01158				LSD 0.05
R 1.2				R 1.3				CV%

Note: In each column or row, values sharing the same letters are not significantly different at ($P \leq 0.05$).

The results indicated significant differences among the treatments in terms of the type and quantity of vermicompost applied. In general, the amendments contributed to reducing soil bulk density compared to the control treatment (without addition). However, some differences between treatments were not statistically significant, reflecting a noticeable similarity in their effects. This finding is consistent with previous studies that reported similar impacts on soil physical properties. Nevertheless, all treatments showed a tendency toward reducing bulk density, highlighting the cumulative and sustainable effect of vermicompost application, as confirmed by several studies on the influence of organic matter on soil (Singh *et al.*, 2017; Maheshwarappa *et al.*, 1999; Marinari *et al.*, 2000; Manickam, 1993; Bazzoffi *et al.*, 1998).

In the season (2023–2024), the highest average bulk density was recorded in the control treatment (1.31 g/cm³), while values gradually decreased with increasing vermicompost rates, reaching the lowest value in the 1.2 t/ha horse vermicompost treatment (1.19 g/cm³), representing a 9.16% reduction. The same trend was observed in the season (2024–2025), where the highest average bulk density was 1.29 g/cm³ in the control, decreasing to 1.16 g/cm³ in the 1.2 t/ha horse vermicompost treatment, a reduction of 10.07%.

Regarding the effect of vermicompost type, horse vermicompost was superior in reducing bulk density compared to cow and sheep vermicomposts. Its overall average bulk density in the first season was 1.24 g/cm³, compared to 1.26 and 1.28 g/cm³ for cow and sheep vermicompost, respectively. This ranking repeated in the second season, with average bulk densities of 1.21, 1.25, and 1.26 g/cm³ for horse, cow, and sheep vermicompost, respectively.

This reduction can be attributed to the positive role of vermicompost in improving soil structure by increasing total porosity, enhancing root penetration, and improving the water–air balance, thereby increasing the soil's water-holding capacity. The modification of pore systems through organic matter also improves the dynamics of water and air movement within the soil layer, creating a more favorable physical environment for plant growth. Several studies have demonstrated that vermicompost promotes soil aggregate stability by stimulating aggregation processes. Organic compounds such as soluble carbohydrates and proteins, associated with glomalin, play a central role in binding fine particles, leading to the formation of more stable and less dense aggregates. These compounds also reduce aggregate disintegration mechanisms such as rapid slaking and microcracking, thereby improving soil physical properties, especially in silt-rich soils (Thiruneelakandan & Subbulakshmi, 2015; Widmer *et al.*, 2002; Amezketa *et al.*, 2015; Pant *et al.*, 2017).

It is noteworthy that the superior effect of horse vermicompost in reducing bulk density is not only due to its distinct physical properties, such as coarser texture and high fiber content (since horses are non-ruminants with hindgut fermentation in the cecum and colon), but also to complex chemical and biological mechanisms that yield both short- and long-term effects. Its high lignin content decomposes slowly under microbial activity, releasing humic substances including humic, fulvic, and humin acids which enhance soil stability and granular structure by strengthening particle cohesion within aggregates and increasing total porosity. These humic substances further contribute to the formation of stable humic–mineral complexes through their carboxyl and phenolic groups that bind with calcium (Ca^{2+}), magnesium (Mg^{2+}), and iron (Fe^{3+}) ions in the soil, creating coordination bonds that reinforce their stability.

In addition, the organic fibers provide a gradually decomposing carbon source that supports the activity of beneficial bacteria and fungi, particularly arbuscular mycorrhizal fungi of the genus Glomus spp., which produce glomalin-related soil proteins (GRSP). These proteins enclose clay and sand particles in a sticky organic coating that acts as a "natural glue," thereby enhancing the stability of humic–mineral complexes and improving soil aggregate stability. By comparison, cow and sheep vermicompost contain lower lignin levels, leading to faster decomposition and more short-term effects on bulk density. Conversely, horse vermicompost acts as a long-term structural amendment due to its high lignin and complex fiber content and its capacity to form stable humic–mineral complexes, making it the most effective in sustainably improving soil structure and reducing bulk density.

Effect of Different Types of Vermicompost on the Measured Particle Density of the Soil (g/cm³):

Particle density is one of the fundamental physical properties in soil characterization. It represents the density of the solid soil particles excluding the pore spaces and depends primarily on the mineral composition and organic matter content of the soil.

Table (3) illustrates the effect of applying different types of vermicompost at increasing rates on soil particle density during the two study seasons.

Table (3) Effect of Vermicompost Treatments on Soil Particle Density.

	2025-2024				2024-2023			
Average	Horse Manure Vermi-compost	Cow manure vermi-compost	Sheep Manure Vermi-compost	Average	Horse manure vermi-compost	Cow manure vermi-compost	Sheep Manure vermi-compost	Type / quantity kg/dunum
2.621 c	2.623 d	2•62 cd	2.62 cd	2.653 c	2.65 d	2.65 d	2.65 d	Control
2.612 bc	2.62 cd	2.603 abcd	2.613 bcd	2.641 bc	2.64 cd	2.63 bcd	2.65 d	300
2.603 b	2.613 bcd	2.593 abcd	2.603 abcd	2.628 b	2.63 bcd	2.62 abc	2.63 cd	600
2.602 b	2.61 abcd	2.593 abcd	2.603 abcd	2.603 a	2.61 abc	2.6 ab	2.6 ab	900
2.581 a	2.58 ab	2.586 abc	2.576 a	2.595 a	2.59 a	2.6 ab	2.596 ab	1200
	2.609 b	2.599 a	2.603 ab		2.624 a	2.620 a	2.628 a	Average
type=0.00776 Quantity=0.01002 type*Quantity=0.01735				**type=0.00729 Quantity=0.00942 type*Quantity=0.01631**				LSD 0.05
R 0.1				**R 0.1**				CV%

Note: In each column or row, values sharing the same letters are not significantly different at (P ≤ 0.05).

The results showed that the different types of vermicompost did not cause significant differences in particle density, and the lower application rates (0.3and 0.6) tons /ha had no significant effect. However, at the higher rates (0.9 and 1.2) tons /ha, a slight but statistically

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significant reduction ($P \leq 0.05$) was observed, reflecting the cumulative effect of vermicompost application on the physical structure of the soil.

In the season (2023–2024), the highest particle density was recorded in the control treatment (2.65 g/cm³), with no significant difference in treatments with low additions (0.3 and 0.6 t/ha), where values ranged between 2.63 and 2.64 g/cm³. A relative decrease was noted in the higher application treatments (0.9 and 1.2 t/ha), with particle density around 2.60 g/cm³, particularly for horse vermicompost. Statistical analysis (LSD test) indicated significant differences among some treatments, suggesting that increased organic matter input began to affect this physical property.

In the season (2024–2025), similar trends persisted, with the control treatment maintaining the highest particle density (2.62 g/cm³), while the lowest values were recorded in the 1200 kg/donum treatments of sheep and horse vermicompost (2.58 g/cm³), showing clear significant differences compared to the control. This reflects the cumulative and sustained effect of organic materials at higher rates, which gradually impacts soil physical properties.

Regarding the effect of vermicompost type, the results revealed close values among the three types without significant differences during both seasons. This is attributed to the fact that particle density reflects the density of solid soil constituents (organic and mineral), which is a relatively stable property not easily affected by short-term organic additions, except in cases of large amounts or distinctive compositions.

These results are consistent with previous studies indicating that particle density decreases, but is less responsive to organic amendments compared to bulk density. This is due to the role of organic matter in releasing some adsorbed elements from particle surfaces through chemical reactions in the soil solution, which facilitates their uptake and reduces the weight of reactive particles (Singh *et al.*, 2017; Maheshwarappa *et al.*, 1999; Azarmi *et al.,* 2008; Sheikh & Dwivedi, 2018; Aechra *et al.*, 2022). Organic matter also contributes to the formation of larger and less dense soil aggregates and increased porosity. In addition, the lower density of organic materials compared to primary and secondary minerals further reduces soil particle density, which is in agreement with the findings of (Baldiya, 2014) and (Jabbar *et al.* 2013).

Even a slight reduction in particle density is considered an important indicator of improved soil physical properties, as it enhances pore distribution, increases water-holding capacity, improves aeration and microbial activity, and creates a favorable environment for organic matter decomposition and long-term soil improvement. This is related to the role of vermicompost in increasing soil organic matter content, improving its structure and porosity, thereby contributing to the reduction of particle density, as also confirmed by (Sharma et al., 2002).

Effect of different types of vermicompost on the total porosity (%) of the studied soil:

Total porosity is one of the most important physical properties of soil, as it is closely linked to its ability to aerate roots and retain water, which directly impacts plant growth and productivity. The addition of organic matter to the soil, particularly vermicompost, plays a significant role in improving soil structure and breaking down soil aggregates, thereby .contributing to an increase in the soil's porosity Table (4) illustrates the effect of applying different types of vermicompost (sheep, cow, horse) at increasing rates (0.3, 0.6, 0.9, and 1.2) t/ha on the total soil porosity during two agricultural seasons.

Table No. (4): Effect of vermicompost treatments on soil porosity

Average	2025-2024			Average	2024-2023			
	Horse manure vermi-compost	Cow manure vermi-compost	Sheep manure vermi-compost		Horse manure vermi-compost	Cow manure vermi-compost	Sheep manure vermi-compost	Type / quantity kg/dunum
50.70^{d}	50.70^{h}	50.70^{h}	50.70^{h}	50.63^{e}	50.63^{g}	50.63^{g}	50.63^{g}	Control
51.96^{c}	52.87^{cd}	51.54^{g}	51.46^{g}	51.54^{d}	52.65^{bc}	50.95^{g}	51.01^{g}	300
52.59^{b}	53.85^{b}	52.12^{ef}	51.79^{fg}	51.94^{c}	52.85^{b}	51.91^{de}	51.07^{fg}	600
52.87^{b}	54.23^{b}	52.51^{de}	51.86^{fg}	52.50^{b}	53.64^{a}	52.31^{cd}	51.54^{ef}	900
53.57^{a}	55.04^{a}	53.28^{c}	52.39^{de}	52.91^{a}	54.05^{a}	53.08^{b}	51.60^{e}	1200
	53.34^{a}	52.03^{b}	51.64^{c}		52.76^{a}	51.78^{b}	51.17^{c}	Average
type= 0.2054 Quantity= 0.2652 type × Quantity =0.4593				type= 0.2346 Quantity= 0.3029 type × Quantity =0.5246				LSD 0.05
R 1.1				R 1.2				CV%

Note: In each column or row, values sharing the same letters are not significantly different at ($P \leq 0.05$).

The results showed that all vermicompost treatments significantly improved total soil porosity compared to the control, and these improvements increased progressively with higher application rates, particularly with horse vermicompost.

In the season (2023–2024), the lowest porosity value was recorded in the control treatment (50.63%), which gradually increased to 52.91% at the 1.2 t/ha rate, representing an overall increase of 4.50%. The highest porosity (54.05%) was observed in the 1.2 t/ha horse vermicompost treatment, showing an increase of 6.77% over the control. In the season (2024–2025), porosity in the control was 50.70%, rising gradually to 53.57% at the highest application rate, an overall increase of 5.66%. The highest porosity in this season (55.04%) was also recorded in the 1.2 t/ha horse vermicompost treatment, representing an 8.57% increase.

Comparing the types of vermicompost, horse vermicompost outperformed the others in increasing porosity, with average porosities of 52.76% and 53.34% in the first and second seasons, respectively, followed by cow and then sheep vermicompost. This improvement is attributed to the fibrous structural composition of horse vermicompost, which enhances soil structure and increases pore space. The increase in total soil porosity can be explained by several interrelated factors: the addition of organic matter reduces bulk density through the disintegration of fine particles and the increase of air-filled voids; it also facilitates the formation of larger, more stable and less compact aggregates due to organic binding agents and colloidal substances, thereby improving soil structure. Additionally, the lower density of organic matter compared to minerals increases void spaces in the soil matrix. Moreover, biological and microbial activity contributes to organic matter decomposition and the creation of micropores through the movement of microorganisms and earthworms, further enhancing total porosity and improving soil physical properties. These explanations are consistent with (Maheshwarappa *et al.* 1999) and (Sharma *et al.* 2002), who reported that organic fertilizers improve soil aggregation and porosity. Similarly, (Sheikh and Dwivedi, 2018) and (Aechra *et al.*, 2022) highlighted that the gradual accumulation of organic matter induces structural changes in pore distribution, enhancing the agricultural efficiency of soils. These findings are also in agreement with (Singh *et al.,*2017) and (Marinari *et al.,*2000), who demonstrated that increased porosity is linked to a higher proportion of medium-sized rounded pores (30–50 and 50–500 μm) and a reduction in very large pores (>500 μm).

Pores with diameters between 50–500 μm are considered the most important in soil–water–plant relations due to their role in improving aeration, drainage, and moisture retention. Moreover, plant roots require pores of 100–200 μm diameters to grow freely (Hamblin, A.P., and D.J. Greenland, 1977). Thus, the improvement in porosity resulting from vermicompost application enhances soil physical properties by increasing aeration and achieving a balance of air and water in the pores, which positively reflects on root growth and activity. It also increases soil field capacity, reduces water loss, and provides stable moisture for plants. Furthermore, this improved structure creates a favorable environment for the proliferation and activity of beneficial microorganisms, thereby enhancing soil biological interactions.

Consequently, these combined factors improve soil fertility, productivity, and sustainability in the long term, making vermicompost an effective option for sustainable agriculture. These conclusions are supported by the findings of (Baladiya, 2014) and (Jabbar, 2013), which confirmed that increased porosity is a key indicator of improved soil physical quality.

The primary reason for the increase in porosity is its inverse relationship with bulk density; as bulk density decreases, porosity increases. This increase is positive, as it reflects a higher proportion of large and medium pores capable of retaining plant-available water and air, compared to small pores that hold unavailable water. This is further evidenced by the strong negative correlation between bulk density and total porosity found in this study, with correlation coefficients of r = -0.969 and r = -0.986 for the two seasons, respectively, supporting the hypothesis that organic amendments significantly influence soil structure, porosity, and aggregate stability (Marinari *et al.*, 2000).

Effect of different types of vermicompost on the solid space (%) of the studied soil:

Soil solid volume represents the non-porous fraction of the total soil volume and indicates the extent of accumulation of mineral and organic particles within the soil. This physical property is an important indicator of soil cohesion and compressibility and is inversely related to porosity. It is well established that the addition of organic materials, particularly vermicompost, reduces the proportion of solid volume by improving soil structure and enhancing soil aggregate dispersion, thereby contributing to increased water use efficiency and improved root environment. Table (5) illustrates the effect of applying different types of vermicompost (sheep, cow, horse) at increasing rates (0.3, 0.6, 0.9, and 1.2) t/ha on the soil's solid phase mass during the two study seasons.

Table No. (5): Effect of vermicompost treatments on solid space in the soil.

Average	2025-2024			Average	2024-2023			Type / quantity kg/dunum
	Horse manure vermi-compost	Cow manure vermi-compost	Sheep manure vermi-compost		Horse manure vermi-compost	Cow manure vermi-compost	Sheep manure vermi-compost	
49.21^{d}	49.23^{i}	49.23^{i}	49.17^{i}	49.37^{c}	49.37^{g}	49.37^{g}	49.37^{g}	Control
47.98^{c}	47.06^{de}	48.4^{ghi}	48.47^{hi}	48.47^{b}	47.35^{bcd}	49.05^{fg}	48.99^{fg}	300
47.37^{b}	46.09^{bc}	47.81^{efgh}	48.21^{fgh}	48.06^{b}	47.15^{bcd}	48.09^{def}	48.92^{fg}	600
47.05^{b}	45.71^{ab}	47.43^{def}	48.02^{fgh}	47.50^{a}	46.36^{ab}	47.69^{cde}	48.46^{efg}	900
46.44^{a}	45.01^{a}	46.78^{cd}	47.54^{defg}	47.09^{a}	45.94^{a}	46.92^{abc}	48.39^{efg}	1200
	46.62^{a}	47.93^{b}	48.28^{c}		47.23^{a}	48.22^{b}	$^{c}48.83$	Average
type= 0.2054 Quantity= 0.2652 type × Quantity =0.4593				type= 0.2346 Quantity= 0.3029 type × Quantity =0.5246				LSD 0.05
R 1.2				R 1.3				CV%

Note: In each column or row, values sharing the same letters are not significantly different at ($P \leq 0.05$).

The results show that the solid phase mass gradually decreased with increasing amounts of added vermicompost, particularly evident in the 900 and 1200 kg/donum treatments, reflecting an improvement in the soil's physical structure and an increase in its organic matter content.

In the season (2023–2024), the control treatment recorded the highest solid mass value at 49.37 g, while values progressively declined with higher vermicompost application rates. Notably, horse vermicompost treatments recorded the lowest solid mass (45.94 g) at the highest application rate of 1.2 t/ha. These results indicate the efficiency of this type of vermicompost in modifying the soil's physical properties, attributed to its content of organic materials with characteristics that help reduce the density of the solid components.

In the season (2024–2025), the same trends continued, with the control maintaining the highest value at 49.17 g, whereas the 1.2 t/ha treatments of horse vermicompost again recorded the lowest values (45.01 g), followed by cow and sheep vermicompost treatments, with statistically significant differences. This indicates the cumulative effect of vermicompost use, especially horse vermicompost, in reducing the soil's solid mass.

Analyzing the effect of vermicompost type, horse vermicompost was the most effective in reducing solid phase mass during both seasons, with averages of 47.23 g in the first season and 46.62 g in the second, compared to higher averages for the other treatments. These findings suggest that horse vermicompost possesses physical and compositional properties that promote soil disaggregation and structural improvement by increasing light organic matter and enhancing aeration and porosity.

Regarding the effect of vermicompost type, horse vermicompost was superior in increasing porosity, followed by cow vermicompost, and then sheep vermicompost. This improvement is attributed to the fibrous structure of horse vermicompost, which contributes to enhancing soil structure and increasing its porosity.

These results are consistent with findings by (Singh et al., 2017) and (Sharma & Chauhan, 2002), which indicated that the addition of organic materials contributes to reducing the solid phase mass by promoting soil aggregation and increasing porosity.

This reduction is associated with the redistribution of solid particles and improved structural stability due to organic amendments, which reduce cohesion and increase the number of pores. Moreover, an inverse relationship was observed between total porosity and solid phase mass, where increases in porosity corresponded with decreases in solid mass. Additionally, the low coefficient of variation enhances the accuracy and reliability of the results, indicating consistent effects across experimental replicates.

Effect of different types of vermicompost on the maximum water holding capacity (MWHC%) of the soil:

Field capacity is one of the most important soil hydraulic properties, representing the amount of water that soil can retain after being saturated and after excess water has drained due to gravity, thus indicating the maximum water available to plants. Field capacity is influenced by various factors, notably the organic matter content and total porosity. The addition of vermicompost enhances the soil's water retention capacity by improving soil structure and increasing the proportion of fine pores, which positively impacts plant nutrition and water use efficiency.

Table (6) presents the results of soil field capacity (FC) under the influence of adding different types of vermicompost (sheep, cow, horse) at increasing application rates (0.3, 0.6, 0.9, and 1.2) t/h over two consecutive growing seasons (2023–2024 and 2024–2025).

Table No. (6): Effect of vermicompost treatments on the maximum water holding capacity (MWHC) of the soil.

Average	2025-2024			Average	2024-2023			Type / quantity kg/dunum
	Horse manure vermi-compost	Cow manure vermi-compost	Sheep manure vermi-compost		Horse manure vermi-compost	Cow manure vermi-compost	Sheep manure vermi-compost	
33.51^e	33.46^h	33.46^h	33.46^h	33.41^e	33.41^g	33.41^g	33.41^g	Control
34.33^d	34.90^cd	34.02^g	33.9^g	34.01^d	34.75^bc	33.63^g	33.66^g	300
34.73^c	35.54^b	34.40^ef	34.18^fg	34.28^c	34.88^b	34.26^de	33.71^fg	600
34.94^b	35.79^b	34.66^de	34.23^fg	34.65^b	35.40^a	34.52^cd	34.02^ef	900
35.34^a	36.33^a	35.17^c	34.58^e	34.92^a	35.68^a	35.03^b	34.06^e	1200
	35.22^a	34.36^b	34.13^c		34.82^a	34.17^b	33.77^c	Average
type= 0.1353 Quantity= 0.1747 type × Quantity =0.3026				type= 0.1545 Quantity= 0.1995 type × Quantity =0.3455				LSD 0.05
R 1.1				R 1.2				CV%

Note: In each column or row, values sharing the same letters are not significantly different at (P ≤ 0.05).

The results showed significant differences between treatments based on the type and amount of added organic fertilizer, where all treatments contributed to increasing field capacity compared to the control treatment, which recorded the lowest values in both seasons.

In the season (2023–2024), the water holding capacity was lowest in the control treatment (33.41%), while it gradually increased with higher vermicompost rates, reaching the highest value (35.68%) in the treatment with 1.2 t/ha of horse vermicompost, representing an increase of 6.79%. A similar trend was observed in the season (2024–2025), where the control treatment recorded 33.46%, and the highest value (36.33%) was also observed in the 1.2 t/ha horse vermicompost treatment, with an increase of 8.58%.

Regarding the effect of vermicompost type, horse vermicompost clearly outperformed the others in raising water holding capacity, with an overall average of 34.82% in the first season, compared to 34.17% and 33.77% for cow and sheep vermicompost, respectively. The same ranking persisted in the second season, with values of 35.20%, 34.34%, and 34.08%, respectively. This increase in field capacity can be explained by the improvement of soil structure due to the increased organic matter content, leading to better pore distribution and higher water retention efficiency. Turner et al. (1994) indicated that increasing organic matter content contributes to improving soil water retention; however, this does not necessarily mean an improvement in the soil's efficiency in supplying water to plants, which calls for further studies to evaluate the actual plant-available water under these amendments. Soil water-holding capacity (WHC) is determined by several factors, including pore number, pore size distribution, and specific surface area. The increased aggregation resulting from vermicompost addition enlarges the total volume of micropores, thereby improving field capacity. Studies by (Kladivko & Nelson,1979) and (Tiarks et al. 1974) confirmed these effects, indicating that increased organic matter improves soil pore structure. These results are consistent with (Singh et al.,2017) and (Sheikh & Dwivedi, 2018), who noted that organic fertilization significantly enhances field capacity, especially in light-textured soils. Statistically, although significant differences were observed among some treatments, the closeness of values between certain concentrations or types reflects a gradual and cumulative effect that increases with higher application rates. Additionally, the low coefficient of variation (CV) indicates data homogeneity and stability of results, supporting their reliability and accuracy. For the studied soil properties, classified as relatively non-aggregated, the greatest treatment effect is likely due to the physical and chemical characteristics of the added organic matter, such as degree of decomposition, particle size, and moisture content. The effect of these organic amendments is expected to change over time due to the ongoing decomposition of organic matter in the soil, highlighting the importance of long-term studies to assess the sustainability of these effects. Based on the above, it can be concluded that vermicompost, particularly derived from horse manure, is an effective means to improve soil field capacity, with positive implications for water-use efficiency and plant tolerance to periods of water stress. However, further studies are needed, including different soil types and crops, to determine the optimal conditions that maximize the benefits of organic amendments in improving soil water properties.

Effect of Vermicompost Treatments on Some Physical and Chemical Properties of the Soil:

Soil physical properties are fundamental factors that significantly influence soil health and agricultural productivity. These properties include a set of factors such as bulk density, particle density, porosity, field water capacity, soil structure, and water retention. Studying these properties is crucial to understanding how the soil interacts with its surrounding environment, especially regarding their effects on plant growth and productivity.

Table (7): Physical and Chemical Properties of the Soil at the Study Site (0–30 cm Depth) During the Two Growing Seasons.

2025-2024			2024-2023			
Clay %	Silt %	Sand %	Clay %	Silt %	Sand %	**The physical and chemical properties**
37.55	**33.25**	**29.2**	**41.6**	**29.25**	**29.15**	
Silty Clay			**Silty Clay**			**Mechanical composition**
1.29			**1.32**			Bulk density ($g.cm^{-1}$)
2.62			**2.67**			Particle density ($g.cm^{-1}$)
50.76			**50.56**			Total porosity (%)
7.7			**7.8**			pH
0.84			**1.06**			EC (dS/m)
0.046			**0.0425**			Total nitrogen (N) %
18.4			**17.85**			Available phosphorus (P) ppm
221			**205**			Available potassium (K) ppm
0.551			**0.437**			Organic carbon (C)**%**
21			**23.5**			Calcium carbonate **%**
11.97:1			**10.28:1**			**C:N**
2.64			**2.46**			Zn ppm
6.2			**5.91**			Fe ppm
2.96			**2.32**			Mn ppm

These data indicate that the soil maintained its mechanical texture, classified as silty clay, with a slight decrease in sand content and a minor increase in silt content. Bulk density decreased from 1.32 to 1.29 g/cm³, while total porosity increased from 50.56% to 50.76%. In addition, particle density declined from 2.67 to 2.62 g/cm³. A reduction in electrical conductivity (EC) was also observed, from 1.06 to 0.84 dS/m, along with an increase in the concentrations of essential nutrients such as nitrogen, phosphorus, and potassium. Moreover, both organic carbon content and the C: N ratio increased, accompanied by higher concentrations of some micronutrients (Zn, Fe, Mn), and a slight decrease in calcium carbonate content.

Conclusions

All types of vermicompost (sheep, cow, and horse) significantly improved the physical properties of the soil compared to the control. Horse manure vermicompost was the most effective, showing the highest improvement in reducing soil bulk density (up to 9.61) %, soil particle density (up to 1.85%), and solid space (up to 7.73) %, as well as increasing total porosity (up to 7.67%) and maximum water-holding capacity (up to 7.68) %. The improvements were more pronounced at higher application rates (0.9 and 1.2) tons/ha, indicating a clear dose-dependent effect, while even the lower rates (0.3–0.6) tons/ha produced measurable, albeit smaller, benefits.

Based on the above, vermicompost can be considered a promising and effective amendment for improving soil physical properties, providing a more favorable environment for root growth, and increasing water and nutrient uptake efficiency. However, the impact may vary depending on soil type and the nature of the organic material used, necessitating further studies to evaluate the long-term sustainability of these improvements.

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المجلة الليبية للعلوم الزراعية
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تأثير أنواع مختلفة من سماد الفيرمي كمبوست في بعض الخصائص الفيزيائية للتربة في محافظة الحسكة

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المستخلص

يمثل الفيرمي كمبوست أحد أهم الأسمدة العضوية الصديقة للبيئة لما له من دور فعّال في تحسين الخصائص الفيزيائية والكيميائية والبيولوجية للتربة، إضافةً إلى دوره في تعزيز الإنتاج الزراعي بشكل مستدام، خاصةً في المناطق التي تعاني من تدهور خصوبة التربة. ويُعد الكمون من المحاصيل الاقتصادية الرئيسة في محافظة الحسكة، إذ يتطلب ظروفاً غذائية وبيئية مناسبة لتحقيق إنتاجية عالية وجودة متفوقة.

أُجريت هذه الدراسة خلال موسمين زراعيين (2023–2024) و(2024–2025) في محافظة الحسكة بسوريا، بهدف تقييم تأثير أنواع مختلفة من الفيرمي كمبوست المستخرج من (روث الأغنام والأبقار والخيول) والمضاف بمستويات متدرجة (0.3، 0.6، 0.9، و1.2 طن/هكتار) على بعض الخصائص الفيزيائية للتربة. نُفذت التجربة وفق تصميم عاملي معتمد على تصميم القطاعات العشوائية الكاملة (RCBD) وبثلاثة مكررات. وشملت القياسات الحقلية: الكثافة الظاهرية، الكثافة الحقيقية، المسامية الكلية، نسبة الجزء الصلب، والسعة الحقلية.

أظهرت النتائج أن إضافة الفيرمي كمبوست من مصادر مختلفة أدت إلى تحسينات معنوية في الخصائص الفيزيائية للتربة، تمثلت في انخفاض الكثافة الظاهرية والكثافة الحقيقية ونسبة الحيز الصلب، وارتفاع المسامية الكلية والسعة الحقلية العظمى. وقد بلغت معدلات التحسن عند أعلى مستوى إضافة من فيرمي كمبوست روث الخيول (1.2 طن/هكتار) (9.62، 1.85، 7.65، 7.73، و7.68) % على التوالي مقارنةً بمعاملة الشاهد (دون إضافة). كما تبيّن تفوّق فيرمي كمبوست روث الخيول في تحسين الخصائص الفيزيائية للتربة، تلاه فيرمي كمبوست روث الأبقار، ثم فيرمي كمبوست روث الأغنام.

الكلمات المفتاحية: الفيرمي كمبوست، الخصائص الفيزيائية للتربة، الكثافة الظاهرية، المسامية، السعة الحقلية..

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