The effect of different types of vermicompost on certain physicochemical properties of the soil in Al-Hasaka governorate and its reflection on the productivity of cumin crop

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Abstract

This study aimed to evaluate the effects of different types of vermicompost (sheep, cattle, and horse manure) and application rates (300, 600, 900, and 1200 kg/donum) on soil properties and cumin crop productivity in Al-Hasakah Governorate. Results demonstrated that horse-derived vermicompost was most effective in improving soil physical properties, significantly reducing bulk density while increasing porosity, thereby enhancing soil quality and facilitating water and air movement. Regarding chemical properties, sheep-derived vermicompost showed the greatest impact, improving pH and salinity levels while increasing essential nutrients (N, P, K), consequently boosting soil fertility and nutrient uptake. The 300 kg/donum application rate of sheep vermicompost achieved optimal economic returns, showing the most pronounced improvement in soil properties and cumin yield compared to other tested rates. Cattle vermicompost exhibited moderate improvements in both physical and chemical soil properties, though it proved less economically advantageous than sheep vermicompost.

Keywords: Cumin, Al-Hasakah soil, productivity, soil properties, vermicompost.

INTRODUCTION:

Hassakeh Governorate is one of the most prominent agricultural regions in Syria, significantly contributing to the local economy and providing a primary source of income for its residents through the cultivation of essential and commercial crops. Among these non-strategic crops, cumin holds an important economic position due to its extensive use in cooking, food industries, and pharmaceuticals, along with its high export value in local and international markets (Banerjee & Sarkar, 2003). Cumin is a major source of income for many farmers, who rely on cultivating high-economic-yield crops. Achieving good productivity from this crop is closely linked to soil fertility and the availability of essential nutrients, necessitating the adoption of sustainable agricultural practices that preserve soil quality and health under challenging climatic and environmental conditions (Hassanzadehdelouei et al., 2013).

In recent decades, concerns about the intensive use of chemical fertilizers and their negative impacts have increased. Excessive reliance on these fertilizers has led to soil health deterioration due to the loss of organic matter, reduced soil water retention capacity, and environmental problems caused by the accumulation of chemical residues. These potential damages from inorganic fertilizers have driven researchers and farmers to seek more sustainable and environmentally friendly agricultural solutions (Müller et al., 2015). Organic fertilizers, particularly vermicompost, have emerged as one of the promising alternatives. Vermicompost is produced through the decomposition of organic materials using earthworms and is rich in nutrients. It is uniquely effective in improving soil structure, increasing organic matter content, and enhancing biological activity, thereby improving crop quality and yield while maintaining soil health over the long term (Edwards & Arancon, 2004).

As part of efforts to improve cumin productivity in the Hassakeh region, this study aims to understand the effects of using different types of vermicompost derived from sheep, cow, and horse manure on the physical and chemical properties of the soil and their impact on cumin yield. This research is significant as it provides scientific data on the impact of organic fertilizers as a sustainable and environmentally friendly alternative to chemical fertilizers, identifying the optimal types of vermicompost for achieving the highest cumin productivity. The study also seeks to provide recommendations to farmers on the best practices for using these various types of vermicompost, thereby raising their awareness of more sustainable agricultural practices and enabling them to make informed decisions to improve their agricultural productivity. Furthermore, this research contributes to promoting the concept of sustainable agriculture, which has become a critical requirement in addressing climate change and challenges posed by limited water resources. Organic fertilizers, such as vermicompost, help improve soil structure and increase its water retention capacity, which is vital in an area suffering from a dry climate and scarce rainfall. Through this study, practical recommendations will be offered to enhance cumin productivity in Hassakeh while supporting local farmers with accurate information on the effectiveness of different types of vermicompost. Additionally, the research aims to advance agricultural sustainability by reducing dependence on chemical fertilizers that may weaken soil health in the long term, thus contributing to environmental conservation and agricultural productivity simultaneously. Beyond these benefits, the results of this study will expand scientific research and provide a foundational reference for future studies on the impact of organic fertilizers on other crops in similar agricultural environments.

Research Objectives:

1. study the effect of vermicompost derived from sheep, cow, and horse waste on selected physical and Chemical properties of the soil.
2. evaluate the impact of vermicompost on cumin yield, aiming to enhance agricultural efficiency and improve production quality.

MATERIALS AND METHODS:

Site and Time of the Study:

The research was conducted over two agricultural seasons (2023–2024) 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 a longitude of 40.83° E and a latitude of 36.58° N. The experimental field is positioned at coordinates 36°23'08.2608"N and 42°11'78.011"E, at an elevation of 452 meters above sea level. The area receives an average annual rainfall of approximately 350 mm and is considered an important agricultural region for the production 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. This composite sample was then analyzed to determine its physical and chemical characteristics, the results of which are presented in Table (1).

Table (1): Some Physical and Chemical characteristics of the investigated Soil

Medium	pH	EC ($mS.cm^{-1}$)	C (%)	N (%)	P (%)	K (%)	Calcium carbonate %	Particle size distribution, %			Bulk Density (g/cm^3)	Real Density (g/cm^3)
								Sand (%)	Silt (%)	Clay (%)		
soil	7.7	0.43	0.557	0.08	0.0021	0.0331	23.5	14	47.5	38.5	1.32	2.6
								Texture class Silty Clay				

Geological Setting:

The region is covered by basaltic shields dating back to the Neogene–Quaternary period, in addition to ophiolitic rock masses and associated volcanic-sedimentary rocks belonging to the Ordovician and Silurian periods. These consist primarily of claystone with some interbedded sandstone layers. Paleozoic formations are exposed in only one area of the region—the core of Mount Abdulaziz—and date back to the Lower Carboniferous. Deeper rock layers, penetrated by drilling operations, mainly belong to the Miocene epoch.

Marine Neogene deposits are widely distributed across the area and primarily date back to the Miocene, while continental Neogene sediments appear in the basins of the Palmyrene Mountain range. Quaternary deposits are found in the form of fluvial terraces (such as in the Euphrates Basin), and in the Syrian Desert, they form a crust of carbonate and gypsum rocks (Techno export, 1964).

Fertilizer and Plant Material:

A. Preparation of Vermicompost:

Vermicompost was prepared in small plastic containers designated for experimental purposes, aiming to provide a suitable environment for the reproduction and activity of the red earthworm species *Eisenia fetida*. Initially, the bottom of each container was lined with a layer of dry organic materials, including fallen tree leaves, paper scraps, newspapers, shredded straw, dry plant residues, torn pieces of paper bags, and small pieces of dried palm fronds, filling about half of the container's volume. A small amount of pre-matured compost was also added to activate microorganisms and accelerate the decomposition process. Subsequently, two handfuls of a mixture of sand and soil were added to the organic layer to improve the physical structure and enhance aeration, then the mixture was moistened with water until the moisture level reached that of a wrung-out sponge, which is optimal for worm activity. Through careful proportioning of the components used, the carbon-to-nitrogen (C/N 25:1 -

30) ratio of the organic material was adjusted to an ideal range for worm activity, which helped speed up decomposition and improve the quality of the resulting vermicompost. Approximately 2000 worms (equivalent to about 5 kg) of *Eisenia fetida* were introduced, capable of consuming about 2.5 kg of food waste daily, based on data from the University of New Mexico. Afterward, plant-based food residues were evenly distributed over the surface of the container, while avoiding the addition of undesirable materials such as citrus peels, onions, garlic, and meat scraps, since these negatively affect the worm environment and may attract flies. It is preferable that the added residues are slightly warm to promote biological decomposition and reduce unpleasant odors. During the preparation period, moisture and aeration conditions were regularly monitored to ensure a stable and suitable environment, which contributed to producing mature, homogeneous vermicompost rich in beneficial organic matter. The vermicompost produced for use in the experiment was analyzed, and its results are presented in Table (2).

Table (2): Results of Analysis of Types of Vermicompost Fertilizers Used in the Experiment

Medium	pH	EC (ds/m)	C (%)	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Na (%)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)
Sheep Vermicompost	6.85	3	26	1.5	1.2	1,6	0.4	3	0.7	0.3	200	150	100	30
cow Vermicompost	7.8	2.8	29	1.7	1	1.3	0.3	3.5	0.8	0,2	250	100	90	20
horse Vermicompost	7.1	2.63	32	1.2	0,8	1,8	0,2	4	1	0.2	250	100	80	20

B. Preparation of Cumin Seeds:

Local Syrian cumin seeds were used at a quantity of 4 kg, selected from newly harvested, high-germination fruits that were free from diseases. The seeds were treated with fungicidal disinfectants at a rate of 4 g/kg using the dusting method, in preparation for their use in the experiment.

Field Experiment Methodology:

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 (300, 600, 900, or 1200 kg/dunum) 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.

On January 15th, sowing was performed mechanically using a seed drill, placing cumin seeds (*Cuminum cyminum* L.) at a depth of 2–3 cm along the planting rows. Surface irrigation (furrow irrigation) was used when rainfall amounts were insufficient to meet the crop's water requirements. Manual weeding was carried out two or three times during the growing season, depending on weed density.

Approximately two weeks before harvest, soil samples were collected from a depth of 0–20 cm within the root zone. Ten 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.

Cumin was harvested 120 days after sowing, once signs of maturity appeared on the plants. Three plants were randomly selected from each experimental plot to measure the morphological indicators of the plants. Plant height (cm) was measured at mid-growth when the plants were fully developed but before full maturity. The seed yield per plant (g) was measured immediately after harvest, once the seeds were collected and dried. Total yield (kg/dunum) was calculated from the weight of seeds harvested from the entire experimental plot after the harvest was completed.

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 (300, 600, 900, and 1200 kg/dunum) 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 m², with appropriate spacing maintained between treatments and between replications. The following is the layout of the experiment.

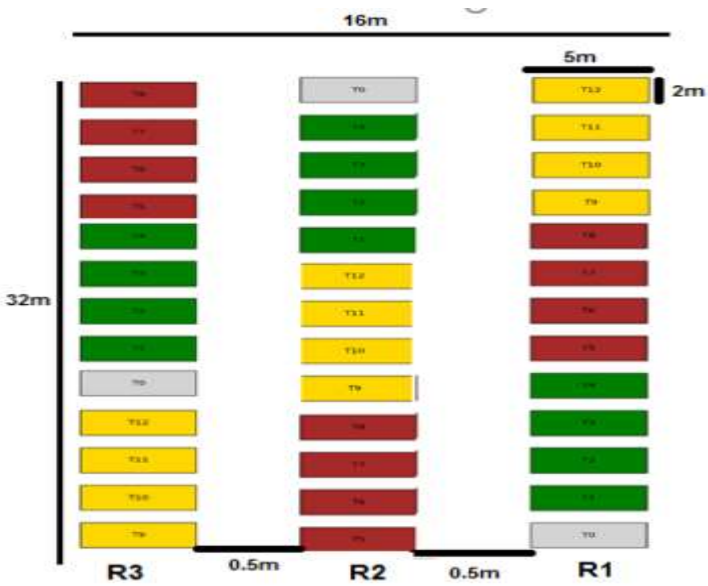

Figure (1): Layout of the Field Experiment

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: Measured using the paraffin wax method.

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

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

$$100\times (Ps / PB-1) = \text{Porosity}$$

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

% Solid space = $(\rho B/\rho b)\times 100$

% Field Capacity = $(W_W - W_d) / W_d \times 100$

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

Exchangeable sodium and potassium: Using the flame photometer.

Exchangeable calcium and magnesium: Determined by titration with versenate solution using murexide indicator for calcium determination, and Eriochrome Black T indicator for the combined determination of calcium and magnesium.

Total Sulfur: Total sulfur was determined by the wet digestion method using a mixture of nitric and perchloric acids, followed by the turbidimetric measurement of the barium sulfate ($BaSO_4$) precipitate formed after adding barium chloride ($BaCl_2$), according to standard procedures. The turbidity of the $BaSO_4$ precipitate was measured using a spectrophotometer at a wavelength of 420 nm to estimate the sulfur content in the samples.

The micronutrients (iron (Fe), zinc (Zn), manganese (Mn), and copper (Cu)): are extracted from the soil using DTPA (Diethylene Tri amine Penta acetic Acid) solution, and their concentrations are determined using an Atomic Absorption Spectrophotometer (AAS)

Studied Morphological Indicators of the Plant:

Three plants were randomly selected from each experimental unit, and the following morphological indicators were measured:

- Plant height (cm).

- Seed yield per plant (g).

-Total yield (kg/dunum).

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

1. Impact of Vermicompost Treatments in Soil Physical Properties:

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.

a) Effect of Vermicompost Treatments in Soil Bulk Density

Soil bulk density is an important physical property that affects soil permeability, aeration, and root distribution. The study results showed that the addition of vermicompost led to a decrease in bulk density values compared to the control treatment, with the effect being more pronounced as the application rate increased. It was also observed that the type of vermicompost used had a different impact on bulk density, reflecting the variations in the organic composition of each type and its effect on soil structure.

Table (3): Effect of Different Types and Quantities of Vermicompost on Bulk Density (g/cm³)

Treatment (kg/donum)	0 kg/donum	300 kg/donum	600 kg/donum	900 kg/donum	1200 kg/donum	Average
Sheep Vermicompost	1.340^{l}	1.280^{k}	1.250^{i}	1.210^{f}	1.170^{c}	1.250^{c}
Cow Vermicompost		1.260^{j}	1.230^{h}	1.200^{e}	1.150^{b}	1.236^{b}
Horse Vermicompost		1.220^{g}	1.190^{d}	1.150^{b}	1.110^{a}	1.202^{a}
Average	1.340^{e}	1.253^{d}	1.223^{c}	1.187^{b}	1.143^{a}	
LSD(0.05)	types	0,0033				
	concentrations	0,0043				
	interactions	0,0075				
CV%	0.4					

In each column means with similar letters do not significantly differ (P *0.05*)

The results presented in Table 3 show that the Treatment of vermicompost significantly reduced soil bulk density compared to the control treatment (1.340 g/cm³). The lowest bulk density (1.143 g/cm³) was recorded at the highest application rate (1200 kg/donum), indicating a clear inverse relationship between increasing vermicompost quantities and decreasing bulk density.

Among the vermicompost types, horse vermicompost was the most effective, achieving the lowest bulk density (1.110 g/cm³ at 1200 kg/donum), followed by cow vermicompost. Sheep vermicompost showed the least reduction in bulk density. This variation can be attributed to differences in the organic matter content and physical properties of the vermicompost types, with horse vermicompost exhibiting a higher capacity to improve soil aggregation and porosity.

The interaction between vermicompost type and application rate was statistically significant at ($P \leq 0.05$), highlighting the importance of selecting the appropriate vermicompost type and optimal rate for achieving the desired improvement in soil structure.

These findings align with those of Singh et al. (2017) and Maheshwarappa et al. (1999), who reported that particle density is less responsive to organic amendments than bulk density. However, some treatments did show significant differences compared to the control (T0), supported by Aechra et al. (2022), Azarmi et al. (2008) and Sheikh and Dwivedi (2018), who explained that organic matter contributes to releasing some adsorbed elements from the surfaces of solid particles through chemical reactions in the soil solution, leading to their uptake by plants and a reduction in the weight of solid particles interacting with the organic matter.

Additionally, organic matter acts as a binding agent for soil particles, forming larger and less dense aggregates, increasing the proportion of macropores, or due to the lower density of organic materials compared to primary and secondary minerals, ultimately resulting in a decrease in soil particle density. These results are consistent with findings by Baladiya (2014) and Jabbar (2013).

b) The effect of type and quantity of vermicompost in porosity (%):

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): Effect of Different Types and Quantities of Vermicompost in porosity%

Treatment (kg/donum)	0 kg/donum	300 kg/donum	600 kg/donum	900 kg/donum	1200 kg/donum	Average
Sheep Vermicompost	48.46^{l}	50.77^{k}	51.92^{i}	53.46^{f}	55.00^{c}	52.79^{c}
Cow Vermicompost		51.54^{j}	52.69^{h}	53.85^{e}	55.77^{b}	53.46^{b}
Horse Vermicompost		53.08^{g}	54.23^{d}	55.77^{b}	57.31^{a}	55.09^{a}
Average	48.46^{e}	51.79^{d}	52.94^{c}	54. 36^{b}	56.02^{a}	
LSD(0.05)	types		0,128			
	concentrations		0,166			
	interactions		0,287			
CV%	0,3					

In each column means with similar letters do not significantly differ (P *0.05*)

Table (4) illustrates that the addition of vermicompost significantly improved soil porosity with increasing amounts from 300 kg/donum to 1200 kg/donum, with values rising from 48.46% in the control treatment to 56.02% at the highest level of application.

- Horse vermicompost showed the highest porosity values at all levels, reaching 57.31% at 1200 kg/donum. This is attributed to its high organic content, which enhances soil structure by increasing medium-sized pores.
- Cow vermicompost ranked second, with values ranging from 51.54% - 55.77%, reflecting its gradual improvement in soil porosity.
- Sheep vermicompost had the least effect, with values ranging from 50.77% - 55.00%, likely due to its lower degree of decomposition and higher inorganic content.

The interaction between types and quantities was significant at a 0.05 level, with a low coefficient of variation (0.3%), indicating the reliability of the results.

These differences are attributed to the ability of vermicompost to improve soil structure by increasing the proportion of medium-sized pores (30–50 µm and 50–500 µm) while reducing large pores (>500 µm), which enhances water and air dynamics within the soil.These interpretations align with findings by Maheshwarappa et al. (1999) and Sharma et al. (2002), who noted that organic fertilizers improve soil structural and pore characteristics. Similarly, Sheikh and Dwivedi (2018) and AECHRA et al. (2022) reported that the gradual accumulation of organic matter induces structural changes in pore distribution, enhancing soil agricultural efficiency. These results also correspond with Singh et al. (2017) and Marinari et al. (2000), who showed that increased porosity is associated with a rise in the proportion of medium-sized rounded pores (30–50 and 50–500 micrometers) and a decrease in very large pores (>500 micrometers). Pores with diameters between 50 and 500 micrometers are considered most important for soil-water-plant relations because of their role in improving aeration, drainage, and moisture retention. Plant roots require pores between 100 and 200 micrometers to grow freely (Hamblin, A.P., and D.J. Greenland, 1977). Thus, the porosity improvement resulting from vermicompost application significantly enhances soil physical properties by increasing aeration and balancing air and water within pores, positively impacting root growth and activity. Soil water holding capacity also rises, reducing water loss and providing stable moisture for plants. Moreover, this improved structure creates a suitable environment for beneficial microbial proliferation and activity, which enhances biological interactions in the soil. Together, these factors contribute to improved soil fertility, productivity, and long-term sustainability, making vermicompost an effective option for sustainable agriculture. These conclusions are supported by studies from Baladiya (2014) and Jabbar (2013), which emphasized that increased porosity is a key indicator of improved soil physical quality.

2. Impact of Vermicompost Addition on Soil chemical Properties:

Vermicompost is considered one of the most important organic fertilizers that play a key role in improving the chemical properties of the soil, which positively reflects on soil fertility and crop productivity. Therefore, studying its impact on the soil is essential for achieving sustainable agriculture and increasing the efficiency of natural resource use

a) Impact of Vermicompost Addition on Soil pH:

Table (5): Effect of Different Types and Quantities of Vermicompost on Soil pH

Treatment (kg/donum)	0 kg/donum	300 kg/donum	600 kg/donum	900 kg/donum	1200 kg/donum	Average
Sheep Vermicompost	7.75^{j}	7.67^{i}	7.30^{e}	7.03^{b}	6.87^{a}	7.22^{a}
Cow Vermicompost		7.57^{h}	7.59^{h}	7.37^{f}	$7,12^{c}$	7.41^{b}
Horse Vermicompost		$7,71^{ij}$	$7,48^{g}$	$7,32^{e}$	$7,25^{d}$	7.44^{b}
Average	7.75^{e}	7.65^{d}	7.45^{c}	7.24^{b}	$7,08^{a}$	
LSD(0.05)	types	0,020				
	concentrations	0,026				
	interactions	0,045				
CV%	0,4					

In each column means with similar letters do not significantly differ (P *0.05*)

The table presents the impact of different types and quantities of vermicompost on soil pH. The results showed that soil pH decreases gradually with increasing amounts of vermicompost, with sheep vermicompost showing the lowest pH, while cow and horse vermicompost have higher pH levels. The statistical results indicate significant differences between the types of vermicompost, with values varying significantly (LSD = 0.020). Additionally, the interaction between types and quantities showed significant effects on pH (LSD = 0.045). The coefficient of variation (CV%) was low at 0.4%, indicating minimal variability in the data and enhancing the accuracy of the results. Overall, the findings suggest that the use of vermicompost contributes to adjusting soil pH positively and improving soil chemical properties.

This variation between types of vermicompost can be attributed to differences in their chemical composition and organic content, which enhance their ability to improve alkaline soil properties and increase crop productivity. These findings align with those of (Atiyeh et al., 2001), who reported that increasing vermicompost application rates leads to a gradual reduction in soil pH. Similarly, Maheshwarapa et al., (1999) indicated that vermicompost application stabilizes soil pH and brings it closer to neutral, thus enhancing optimal plant growth conditions.

This effect is linked to the neutral pH of vermicompost produced by worms, which helps adjust soil acidity upon application. Furthermore, the production of ions such as NH4+, CO2, and organic acids during microbial metabolism in vermicompost likely contributes directly to reducing soil pH, as noted by (Albanell et al., 1988).

b) Impact of Vermicompost Addition on Soil EC:

Electrical conductivity (EC) reflects the concentration of dissolved inorganic salts in the soil. By measuring the EC of a solution, the total quantity of dissolved salts can be determined. EC measurement is one of the methods used to estimate the total dissolved salts in the soil, as the salt concentration in the aqueous extract is proportional to electrical conductivity.

The EC value is a critical indicator because it reflects the salinity level of the fertilizer and the concentration of ions, which may suggest potential phytotoxicity (plant toxicity) affecting plant growth (Gao et al., 2010). Additionally, the EC value depends on the rate of organic matter decomposition, which leads to ion accumulation (Chan et al., 2016).

Table (6): Effect of Different Types and Quantities of Vermicompost on Electrical Conductivity of Soil

Treatment (kg/donum)	0 kg/donum	300 kg/donum	600 kg/donum	900 kg/donum	1200 kg/donum	Average
Sheep Vermicompost	0.411^{a}	0.455^{c}	0.492^{f}	0.542^{h}	0.600^{j}	0.522^{c}
Cow Vermicompost		0.430^{b}	0.475^{e}	0.520^{g}	0.562^{i}	0.496^{b}
Horse Vermicompost		0.432^{b}	0.462^{d}	0.517^{g}	0.560^{i}	0.493^{a}
Average	0.411^{a}	0.439^{b}	0.476^{c}	0.526d	0.574^{e}	
LSD(0.05)	Types		0.0025			
	concentrations		0.0032			
	interactions		0.0055			
CV%	0.7					

In each column means with similar letters do not significantly differ (P *0.05*)

The table displays Effect of the applied treatments on the electrical conductivity (EC). It Obtained data shows a gradual increase in EC with increasing amounts of vermicompost. Sheep vermicompost resulted in the lowest EC, while cow and horse vermicompost had higher EC levels. The statistical analysis reveals significant differences between the types of vermicompost (LSD = 0.0025) and between concentrations (LSD = 0.0032). Additionally, the interaction between types and concentrations was significant (LSD = 0.0055). The coefficient of variation (CV%) was 0.7%, indicating minimal variability in the data.

These differences highlight the variation in soluble salt concentrations between different types of vermicompost. The significant increase in EC in soils treated with vermicompost compared to untreated soils ($P \leq 0.05$) reflects the impact of organic matter decomposition and nutrient release, which contribute to higher salt levels in the soil. These findings are consistent with previous research, such as (Atiyeh et al, 2001), which reported that the EC of vermicompost depends on the raw materials and ion concentration present during the composting process (Atiyeh et al, 2002b).

The increase in EC underscores the need for careful management of vermicompost application rates to mitigate potential negative effects on plant growth due to high salt accumulation. In summary, while vermicompost improves soil properties, its use should be monitored to balance the benefits and prevent the adverse effects of increased salinity.

c) Impact of Vermicompost Addition on Soil OM%:

The addition of vermicompost (worm compost) is considered one of the sustainable agricultural practices for improving soil fertility, as it contributes to increasing organic carbon content - a key indicator of soil quality. The effectiveness of vermicompost varies depending on its source (such as sheep, cow, or horse manure) and application rate.

Table (7): Effect of Different Types and Quantities of Vermicompost on Soil OM%

Treatment (kg/donum)	0 kg/donum	300 kg/donum	600 kg/donum	900 kg/donum	1200 kg/donum	Average
Sheep Vermicompost	1.070^{l}	1.722^{i}	2.322^{d}	2.494^{b}	2.665^{a}	2.301^{a}
Cow Vermicompost	1.070^{l}	1.487^{k}	2.127^{h}	2.217^{f}	2.338^{c}	2.042^{c}
Horse Vermicompost	1.070^{l}	1.547j	2.182^{g}	2.270^{e}	2.494^{b}	2.123^{b}
Average	1.070^{e}	1.585^{d}	2.210^{c}	2.327^{b}	2.499^{a}	
LSD(0.05)	types	0.0027				
	concentrations	0.0035				
	interactions	0.0061				
CV%	0.2					

In each column means with similar letters do not significantly differ (P *0.05*)

The table shows the effect of different types and quantities of vermicompost on the percentage of organic matter (OM%) in soil. The results indicate a significant increase in OM% with higher amounts of vermicompost. Sheep vermicompost recorded the highest organic matter percentage, followed by horse and cow vermicompost. The statistical analysis revealed significant differences between types of vermicompost (LSD = 0.0027) and between concentrations (LSD = 0.0035). Additionally, the interaction between types and concentrations was significant (LSD = 0.0061). The coefficient of variation (CV%) was low at 0.2%, indicating minimal variability in the data.

These increases in organic matter contribute to better soil aeration and drainage, which improves crop growth and overall productivity. The statistical significance and differences between treatments were evident, as shown by the LSD (0.05) values and the coefficient of variation (CV%).

In summary, vermicompost, especially from sheep and horse sources, significantly enhances soil organic matter, improving soil structure, nutrient retention, and overall agricultural productivity. "These results are consistent with the findings of Aira et al. (2007) who showed that the use of vermicompost enhances the accumulation of organic carbon by stimulating microbial activity and the decomposition of complex organic compounds. Meanwhile, Lal (2004) confirmed that a high level of organic carbon is a vital indicator of improved soil fertility and biological activity.

3. Impact of Vermicompost Addition on Macronutrients:

a) Impact of Vermicompost Addition on Nitrogen:

Nitrogen is one of the essential nutrients for plant growth, and the addition of vermicompost plays a critical role in improving soil total nitrogen content.

Table (8): Effect of Different Types and Quantities of Vermicompost on Total Nitrogen

Treatment (kg/donum)	0 kg/donum	300 kg/donum	600 kg/donum	900 kg/donum	1200 kg/donum	Average
Sheep Vermicompost	0.075^{j}	0.106^{g}	0.128^{e}	0.146^{b}	0.168^{a}	0.137^{a}
Cow Vermicompost		0.095^{i}	0.109^{g}	0.135^{d}	0.166^{a}	0.126^{c}
Horse Vermicompost		0.100^{h}	0.119^{f}	0.141^{c}	0.167^{a}	0.131^{b}
Average	0.075^{e}	0.100^{d}	0.118^{c}	0.140^{b}	0.167^{a}	
LSD(0.05)	types	0.0012				
	concentrations	0.0015				
	interactions	0.0027				
CV%	1.4					

In each column means with similar letters do not significantly differ (P 0.05)

The results from Table 8 showed that The application of sheep vermicompost at rate of 900 kg/dounm achieved the highest total nitrogen content with an increase of 6.1%, followed by horse vermicompost with a 6.0% increase. Cattle vermicompost recorded a comparatively lower increase of **5.5%**. Although the differences between sheep and horse vermicompost were not statistically significant at the level of ($P < 0.05$), the difference between these two and cattle vermicompost was significant, indicating a higher effectiveness of sheep and horse vermicompost in enhancing total nitrogen compared to cattle.

At a rate of 1200 kg/donum, there were no significant differences between the three types of vermicompost (sheep, horses, and cattle), with values ranging from **0.167** to **0.168**. These results reflect a low coefficient of variation (CV = 1.4%), highlighting the accuracy and reliability of the experimental data.

This superiority of sheep and horse vermicompost is attributed to their faster decomposition rates and higher nutrient availability, which enhance microbial activity and increase nitrogen availability for plants. Studies such as Arancon et al. (2006) and Nethra et al. (1999) support these findings, demonstrating that vermicompost significantly improves soil fertility and nitrogen content, thereby promoting better plant growth.

b) Impact of Vermicompost Addition on Phosphorus:

Phosphorus is a vital element for plant growth, playing a pivotal role in metabolic processes and energy transfer.

Table (9): Effect of Different Types and Quantities of Vermicompost on Exchangeable Phosphorus

Treatment (kg/donum)	0 kg/donum	300 kg/donum	600 kg/donum	900 kg/donum	1200 kg/donum	Average
Sheep Vermicompost	13,75^{m}	18.73^{i}	20.23^{g}	23.44^{d}	24.96a	21.84^{a}
Cow Vermicompost		16.18l	18.68^{j}	21.68^{f}	23.93^{c}	20.12^{c}
Horse Vermicompost		17.84^{k}	19.82^{h}	22.42^{e}	24. 54^{b}	21.15^{b}
Average	13,75^{e}	17.58^{d}	19.58^{c}	22.51^{b}	24.48^{a}	-
LSD(0.05)	types	0.0094				
	concentrations	0.0121				
	interactions	0.0210				
CV%	0.1					

In each column means with similar letters do not significantly differ (P *0.05*)

Table 9 presents the effects of different types and quantities of vermicompost on exchangeable phosphorus content in the soil. The results indicate that sheep vermicompost was the most effective in enhancing phosphorus levels, followed by horse vermicompost and cow vermicompost. Gradual increases in phosphorus content were observed with the addition of higher quantities of vermicompost.

- Sheep Vermicompost showed the highest phosphorus content, reaching 24.96 mg/kg at a rate of 1200 kg/donum, which was statistically significant.
- Horse Vermicompost recorded an average phosphorus content of 21.15 mg/kg, while cow vermicompost had an average of 20.12 mg/kg.

Statistical analysis revealed significant differences among the types of vermicompost at all levels, with LSD (0.05) values indicating high precision in the results. The lowest coefficient of variation (CV = 0.1%) reflects the reliability of these findings.

These results demonstrate that sheep and horse vermicompost were superior in increasing phosphorus availability compared to cow vermicompost. This improvement in phosphorus content significantly contributed to enhanced nutrient uptake by plants, promoting better root development and overall plant growth. Additionally, the distinct nutrient compositions among different vermicompost types suggest varying impacts on soil fertility, with sheep vermicompost showing higher concentrations of phosphorus and potassium, whereas cow vermicompost exhibited higher carbon and nitrogen levels alongside a different pH level. This increase is attributed to the slow decomposition of phosphorus in vermicompost and the microbial activity in the soil, which plays a crucial role in long-term phosphorus supply, as highlighted by Arancon et al., 2006. Similar studies have shown comparable increases in phosphorus content following the addition of organic fertilizers, with this attributed to phosphatase enzyme activity and organic matter decomposition, enhancing mineralization and increasing phosphorus availability for plants (Sharpley and Syres, 1977).

c) Impact of Vermicompost Addition on Potassium:

Available potassium (K^+) is a vital element for enhancing environmental stress tolerance and improving crop quality.

Table (10): Effect of Different Types and Quantities of Vermicompost Exchangeable Potassium

Treatment (kg/donum)	0 kg/donum	300 kg/donum	600 kg/donum	900 kg/donum	1200 kg/donum	Average
Sheep Vermicompost	331ᵐ	453.85^{j}	506.75^{f}	537.75^{b}	564.71^{a}	515.76^{a}
Cow Vermicompost		447.66^{k}	483.23^{i}	501.19^{g}	515.20^{d}	486.82^{c}
Horse Vermicompost		446.51^{l}	490.41^{h}	514.31^{e}	536.80^{c}	497.01^{b}
Average	331^{e}	449.34^{d}	493.46^{c}	517.75^{b}	538.90^{a}	-
LSD(0.05)	types	0.296				
	concentrations	0.382				
	interactions	0.661				
CV%	0.1					

In each column means with similar letters do not significantly differ (P *0.05*)

The results presented in Table 10 indicate that the application of different types and rates of vermicompost led to a significant increase in exchangeable potassium content in the soil. The application of 1200 kg/donum of sheep vermicompost recorded the highest average potassium content at 564.71 mg/kg, followed by horse vermicompost with an average of 536.80 mg/kg, while cow vermicompost recorded an average of 515.20 mg/kg.

Statistical analysis revealed significant differences between the different types at all concentrations, with a coefficient of variation (CV = 0.1%), reflecting the accuracy and reliability of the data. These results align with previous studies indicating that vermicompost enhances enzymatic activity and reduces potassium fixation in the soil, thereby increasing its availability to plants (Olk & Cassman, 1993). Furthermore, research shows that vermicompost improves the stability of organic compounds and enhances microbial activity, contributing to more efficient nutrient supply, including potassium (Rao et al., 1996).

These results highlight the importance of using vermicompost to improve soil fertility and increase the availability of essential nutrients such as potassium, thereby promoting healthy plant growth and increased productivity.

4. Impact of Vermicompost Addition on productivity:

Total seed production per unit area is a critical indicator for evaluating the feasibility of agricultural practices and the efficiency of organic fertilization in achieving sustainable economic yields. The importance of using vermicompost lies in its ability to improve the physical, chemical, and biological properties of the soil, which positively impacts crop productivity by providing a suitable growth environment and enhancing nutrient uptake efficiency.

The cumin crop’s response in terms of yield varies according to the type of vermicompost used and the application rate, as differences in nutrient content and organic matter among sheep, cattle, and horse manure result in variability in their effects on the final yield.

The following table demonstrates the effect of adding vermicompost from different sources (sheep, cow, and horse) in varying quantities (0, 300, 600, 900, and 1200 kg/donum) on crop productivity. The results showed significant differences between the types and quantities of vermicompost, as well as their interactions. Sheep vermicompost outperformed others in enhancing productivity (72.25 kg) compared to cow (68.25 kg) and horse vermicompost (66.08 kg), with the highest productivity recorded at 1200 kg/donum of sheep vermicompost (81 kg).

Table (11): Effect of Different Types and Quantities of Vermicompost on productivity

Treatment (kg/donum)	0 kg/donum	300 kg/donum	600 kg/donum	900 kg/donum	1200 kg/donum	Average
Sheep Vermicompost	40^{g}	63^{e}	70^{cd}	76^{b}	81^{a}	72.25^{a}
Cow Vermicompost		60^{ef}	67^{d}	71^{c}	75^{b}	68.25^{b}
Horse Vermicompost		58^{f}	65^{e}	70^{cd}	73^{bc}	66.08^{c}
Average	40^{e}	60.33^{d}	66.77^{c}	72.33^{b}	76^{a}	
LSD(0.05)	types	1.496				
	concentrations	1.931				
	interactions	3.344				
CV%	3.2					

In each column means with similar letters do not significantly differ (P *0.05*)

A clear upward trend in productivity was observed with increasing vermicompost quantities, reflecting the role of organic matter in improving soil properties and promoting crop growth. The coefficient of variation (CV%) was 3.2%, indicating high data stability and precision. These findings align with studies highlighting the positive impact of vermicompost on productivity by improving soil physical and chemical properties. Accordingly, it is recommended to use sheep vermicompost at rates up to 1200 kg/donum in similar regions, this increase aligns with the study by (Safi et al. 2017), which demonstrated that vermicompost significantly enhances agricultural productivity by improving the physical and chemical properties of the soil. while considering conducting an economic feasibility study to assess application costs.

5. Economic Feasibility of Fertilizer Application:

Economic analysis is a fundamental step in evaluating the effectiveness of any fertilization treatment and determining its feasibility for farmers. This evaluation goes beyond merely increasing production to achieving the highest net profit. In this study, the gross income from cumin production per donum was calculated based on the average cumin yield (kg/donum) and the selling price per kilogram. The cost of adding vermicompost was then calculated according to the quantities used and the price per kilogram of vermicompost.

Net profit is defined as the difference between the revenue generated from selling cumin (USD/donum) and the cost of the added vermicompost (USD/donum), according to the following equations:

Cumin revenue ($/donum) = Cumin yield (kg/donum) × Price per kilogram (6USD).

Vermicompost cost ($/donum) = Quantity of vermicompost applied (kg/donum) × Price per kilogram of vermicompost (0.25 USD).

Net profit ($/donum) = Cumin revenue − Vermicompost cost.

These calculations demonstrate how the addition of vermicompost influences the profitability of cumin production, with varying levels of profitability depending on the quantity and type of vermicompost applied.

Table (12): Effect of Different Types and Quantities of Vermicompost on Profit

Type of Vermicompost	Quantity Added (kg/donum)	Cumin Production (kg/donum)	Revenue ($/donum)	Cost of Compost ($/donum)	Profit ($/donum)
Without Addition	0	40	0	0	0
Sheep Vermicompost	300	63	138	75	63
	600	70	180	150	30
	900	76	216	225	-9
	1200	81	246	300	-54
Cow Vermicompost	300	60	120	75	45
	600	67	162	150	12
	900	71	192	225	-33
	1200	75	210	300	-90
Horse Vermicompost	300	58	108	75	33
	600	65	150	150	0
	900	70	180	225	-45
	1200	73	198	300	-102

Conclusions:

Soil Improvement: Vermicompost has significantly improved the physical and chemical properties of the soil, increasing the content of macronutrients. Horse vermicompost was the most effective in enhancing physical properties, while sheep vermicompost was the most effective for improving the studied chemical properties.

Increased Cumin Productivity: The highest productivity was recorded with 1200 kg/donum of sheep vermicompost, outperforming other types. However, the most economically viable option is 300 kg/donum of sheep vermicompost.

Sustainability in Agriculture: Vermicompost supports sustainability by reducing dependency on chemical fertilizers and enhancing organic matter content in the soil.

Recommendations:

- Encourage the use of vermicompost as a sustainable alternative to chemical fertilizers, with a focus on sheep vermicompost.
- Adopt suitable application rates: 300 kg/donum is recommended for optimal results.
- Educate farmers: Provide training on the benefits, production, and use of vermicompost.
- Expand local vermicompost production: To support sustainable agriculture and reduce costs.

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تأثير أنواع مختلفة من الفيرمي كومبوست على بعض الخصائص الفيزيائية والكيميائية في تربة محافظة الحسكة وانعكاسها على إنتاجية محصول الكمون

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الملخص

تهدف هذه الدراسة إلى تقييم تأثير أنواع مختلفة من الفيرمي كمبوست (الأغنام، الأبقار، والخيول) وكميات تطبيقها (300، 600، 900، و1200 كغ/دونم) على خصائص التربة في محافظة الحسكة وإنتاجية محصول الكمون. أظهرت النتائج أن فيرمي كمبوست الخيول كان الأكثر فعالية في تحسين الخصائص الفيزيائية للتربة، حيث أدى إلى تقليل الكثافة الظاهرية بشكل كبير وزيادة المسامية، مما يحسن جودة التربة ويسهل حركة الماء والهواء داخلها. أما بالنسبة للخصائص الكيميائية، فقد كان لفيرمي كمبوست الأغنام التأثير الأكبر، حيث حسّن درجة الحموضة والملوحة وزاد من مستويات العناصر الغذائية الأساسية مثل النيتروجين (N) والفوسفور (P)والبوتاسيوم (K)، مما عزز خصوبة التربة وامتصاص العناصر الغذائية من قبل النباتات. وقد حقق فيرمي كمبوست الأغنام بكمية 300 كغ/دونم أفضل العوائد الاقتصادية، حيث كان له التأثير الأكثر وضوحًا في تحسين خصائص التربة وزيادة إنتاجية الكمون مقارنةً بالكميات الأخرى التي تمت دراستها. من ناحية أخرى، أظهر فيرمي كمبوست الأبقار تحسينات جيدة في الخصائص الفيزيائية والكيميائية للتربة، لكنه لم يتفوق على فيرمي كمبوست الأغنام من حيث العوائد الاقتصادية.

الكلمات المفتاحية: الكمون، تربة الحسكة، الإنتاجية، خصائص التربة، الفيرمي كمبوست.