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Effect of Eisenia fetida on Nutrient Composition of Vermicompost Produced from Barberry Waste

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Barberry leaves, Drought, Sustainable agriculture, Waste management.

Abstract

This study tested vermicomposting of seedless barberry (*Berberis vulgaris* var. Asperma) pruning residues to create nutrient-rich organic fertilizer and reduce chemical fertilizer dependence. Barberry, widely grown in South Khorasan, Iran, produces about 36 ton of unused biomass annually. In this study, a comparison was carried out on three raw materials: barberry leaves, a 1:1 mixture of leaves and branches, and branches inoculated with *Eisenia fetida* earthworms. Inoculation used 0.5 kg packages with 20 gr of earthworms in aerated containers (23°C and 60-70% humidity) for 50 days. Analyses of mature vermicompost measured pH, electrical conductivity, organic carbon, and macro- and micronutrients (N, P, K, Ca, S, Fe, Zn, Mn, Na, B, Cl). ANOVA and LSD tests showed substrate strongly influenced nutrient enrichment. Pure leaves produced the highest nutrient levels, with nitrogen reaching 2.76 % (vs. 1.14 % in branch-only compost), potassium 2.99 %, calcium 1.87 %, and sulfur 0.05 %. Phosphorus ranged 1,135–1,645 mg kg^{-1} across treatments. Micronutrients were also greatest in leaf vermicompost iron 30.7 mg kg^{-1}, zinc 1.91 mg kg^{-1}, sodium 6,600 mg kg^{-1}, and boron 18.9 mg kg^{-1}—while chloride exceeded 10,000 mg kg^{-1} in all samples. Leaf-branch mixes showed intermediate values; branches alone were lowest. The findings demonstrate that *E. fetida* accelerates mineralization and boosts nutrient availability, making barberry leaves a superior feedstock for producing high-value vermicompost.

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Introduction

Soil is a delicate, non-renewable resource critical to food security and ecological sustainability. Roughly a quarter of Earths biodiversity depends on it, and its fertility relies on organic matter that regulates nutrient cycling, water retention, and plant growth (Amaya-Gómez et al., 2025).

Organic fertilizers nourish soil microorganisms, increase water retention, and improve aeration and structure, supporting sustainable agriculture, whereas heavy reliance on chemical fertilizers can contaminate soil, water, and air and disturb ecosystem balance (Hazbawi et al., 2025).

Managing solid waste is a major global challenge. Conventional methods landfilling, incineration, source reduction, and recycling carry environmental costs and greenhouse gas emissions. Environmentally friendly options such as composting and vermicomposting have far lower impacts (Poornima et al., 2024). Organic wastes from forestry, agriculture, animal husbandry, and the food industry are rich in nutrients but need biostabilization before use to avoid pollution. Vermicomposting, an important element of the circular economy, recycles organic waste, reduces raw-material use, and reintroduces nutrients into the production cycle, improving soil fertility and agricultural productivity (Amaya-Gómez et al., 2025).

Biofertilizers also help preserve soil fertility by fixing atmospheric nitrogen, releasing insoluble phosphorus, and producing plant-growth promoters (Aminifard et al., 2022a). In vermicomposting, earthworms such as *Eisenia andrei* and *Eisenia fetida* work with microorganisms to decompose organic waste in mesophilic conditions, speeding the process compared with traditional composting and improving the final product (Amaya-Gómez et al., 2025; Sánchez-Suárez et al., 2025). Vermicompost is a stable, fine bio-fertilizer with near-neutral pH, high water-holding capacity, and a carbon-to-nitrogen ratio below 20. It contains abundant macro- and micronutrients and bioactive compounds like humic substances and phytohormones that boost microbial activity and plant growth (Regasa et al., 2025; Oyege & Balaji Bhaskar, 2025; Yıldız et al., 2025; Suvedha et al., 2024).

Often called (black gold), vermicompost enhances soil structure, porosity, and water retention; reduces acidity; releases key nutrients; and stimulates microbes. It also limits nutrient leaching and increases input efficiency. Vermicompost tea, made by steeping vermicompost in water, provides soluble nutrients and beneficial microbes as a foliar spray to strengthen plants against pests and diseases (Oyege and Balaji Bhaskar, 2025). Numerous studies show that vermicompost raises soil fertility, improves seed germination and plant development, and contains higher levels of nitrogen, phosphorus, and potassium than many other organic fertilizers, acting as an efficient biostimulant that increases both yield and quality of crops (García-Pérez et al., 2025; Hazbawi et al., 2025). Its benefits, including greater soil microbial diversity and improved soil aggregates, can exceed those of traditional compost, though results depend on initial soil conditions (Aminifard et al., 2022b).

Seedless barberry (*Berberis vulgaris* var. Asperma) is a perennial medicinal shrub of the Berberidaceae family cultivated in Asia and Europe (Hosseini et al., 2022). Iranian barberries include five main species *B. vulgaris*, *B. crataegina*, *B. orthobotrys*, *B. khorasanica*, and *B. integerrima* with the Bidaneh cultivar originating from crosses of *B. vulgaris* and *B. integerrima* (Pirkhezri, 2022). Grown for over 200 years in South Khorasan Province, Iran is the worlds largest producer, supplying over 98 % of global output (Modaresi et al., 2016; Pirkhezri, 2022). Barberry shrubs reach up to four meters, have spiny stems of yellow-brown wood, and bear yellow flowers followed by red berries (Sarraf et al., 2019; Hosseini et al., 2021).

The plant thrives in low rainfall, saline, and alkaline soils and is valued for edible and medicinal uses. Because fresh fruit contains high moisture, much of the harvest is dried to prevent spoilage, but traditional drying and storage methods remain a major challenge (Hosseini et al., 2022; Afshin et al., 2022). Harvesting often employs the Chinese branch method: clusters are dried with branches and leaves, then threshed in two stages, leaving large quantities of leaf and branch residue (Modaresi et al., 2016). Each shrub produces the equivalent of three to five years worth of dried branch material annually, resulting in significant waste (Afshin et al., 2022).

South Khorasan generates more than 36 tons of barberry garden waste each year, much of which is burned or discarded. Yet this biomass could be converted into vermicompost or biochar, providing a valuable source of organic fertilizer. Soils in the region are typically nitrogen-deficient, increasing the need for nutrient-rich amendments (Hammami et al., 2023). Despite extensive research on vermicomposting agricultural residues, little attention has been paid to using barberry pruning waste.

This study addresses that gap by evaluating how *Eisenia fetida* influences the physical and chemical properties of vermicompost derived from barberry waste. Using a novel mixture of raw materials and multiple indicators, the research aims to develop local solutions for managing specialized agricultural residues in Iran. Its findings could guide large-scale vermicomposting systems that reduce environmental pollution and provide high-quality organic fertilizers, helping protect the health of people, animals, plants, and ecosystems.

Materials and Methods

This study was conducted in 2022 in the city of Mood, located in South Khorasan Province, Iran, using a randomized complete block design (RCBD) with five replications. Three different treatments were evaluated: (1) barberry leaves, (2) an equal mixture of barberry leaves and branches, (3) barberry branches and samples without the use of *Eisenia fetida* worm, which is the same raw material before adding the worms. The barberry waste used in this experiment was collected from the orchards of the city of Mood in the hot and dry climate of South Khorasan Province after being dried and stored.

During the composting period, the ambient temperature and relative humidity were maintained at approximately 23°C and 40%(normal ambient temperature and humidity inside the warehouse), respectively. For treatment implementation, polyethylene containers were used, each with a total volume of 5 liters, based on the volume of initial substrate material. Each container was filled with 0.5 kilograms of substrate material (Mousavi and Faraji, 2016).

To ensure proper aeration, 2 mm-diameter holes were drilled into the bottoms and sides of the containers (Mousavi and Faraji, 2016). Additionally, to facilitate drainage of leachate or compost tea, all containers were placed on a 10 cm-high rack. The containers were stored in a controlled environment to maintain a relatively stable temperature.

Earthworms of the species *Eisenia fetida*, cultivated at the Vermicompost Production Center in Ferdows County, were used in this study. After adjusting the substrate moisture to an optimal range of 60–70%, the moisture content was measured with a digital moisture meter that has a sensor in the soil. the materials were thoroughly mixed, and 20 grams of earthworms were added to each treatment container.

Once the vermicompost was deemed

mature based on its visual and physical characteristics (after approximately 50 days), the worms were manually separated from the bedding with using a 2 mm sieve., and the resulting vermicompost was subjected to physical and chemical analysis (Mousavi and Faraji, 2016).

To determine pH and electrical conductivity (EC), a 1:10 solution was prepared by mixing 1g of compost with 10mL of distilled water. After several hours of equilibration, measurements were taken using a calibrated pH and EC meter (Sparks et al., 2020).

For organic matter (OM%) and organic carbon (OC%) analysis, 2g of compost sample were mixed with 10 mL of potassium dichromate and 20 mL of concentrated sulfuric acid. After 30 minutes, 25 mL of the solution was treated with sodium fluoride powder and five drops of diphenylamine indicator, which turned the mixture brown. This solution was then titrated with Mohr’s salt (ammonium ferrous sulfate) until a green endpoint was reached (Chapman and Pratt, 1962).

Nutrient elements were quantified after acid digestion for acid digestion, one gram of each dried, crushed, and sieved sample was poured into a porcelain crucible and then placed in an electric furnace at 550°C for two hours until the organic matter was completely burned and the remaining material was reduced to ash. After the crucible cooled, 10 ml of 2N hydrochloric acid was added to each sample and the ashed material was dissolved in the acid by gently heating the crucible. Then, the prepared solution was passed through a funnel and filter paper and filtered, and the extract was collected in a 100 ml volumetric flask. To wash the remaining material in the funnel, some hot distilled water was added to the filter paper and the extract was transferred back to the volumetric flask. Each of the extracts collected in the volumetric flask was made up to 100 cc with distilled water, and then a 1000 ppm standard solution was prepared. From the above solution, smaller standards of 100 cc each were prepared with concentrations of 100, 75, 50, 25, 12.5 and 5 ppm. Then, the flame photometer was calibrated for each of the standard solutions and the concentration of each of the extracted samples was measured with that device and after drawing the calibration standard curve, the concentration of each of the samples was calculated (Mohseni Mohamadjanlo et al., 2012) using the following instruments and techniques: sodium (Na) and potassium (K) via flame photometry; phosphorus (P) via spectrophotometry; nitrogen (N) via the Kjeldahl method; and other elements (such as Fe, Zn, Mn, B, S, Ca, and Cl) via atomic absorption spectrophotometry (AAS). All nutrient concentrations were expressed in mg kg⁻¹ (Welz and Sperling, 2008), which was conducted by the Jonoobgan Soil Laboratory in the city of Kerman.

The study's design and trait evaluations followed a randomized complete block design. Data collection was performed using Microsoft Excel (version 2016), and statistical analysis was carried out using JMP software (version 13, SAS Institute). Analysis of variance (ANOVA) was used to assess treatment effects, and mean comparisons were conducted using the Least Significant Difference (LSD) test at the 1% and 5% significance levels.

Results

Examination of Table 1 shows that among the barberry leaf nutrients, there were some significant responses to the treatment of *Eisenia fetida* worms. Compared to the blocks, which showed almost no significant differences, the treatment had a significant effect on several plots. For example, nitrogen (N) with a value of 2.22 is significant at the 1% level, which indicates the effect of worm treatment on the nitrogen content of barberry leaves. Phosphorus (P) and potassium (K) respond in this respect and the observation shows no significance. Among the trace elements, iron (Fe) with 224.86, zinc (Zn) with 1.57, and manganese (Mn) with 2.72 were clearly affected by the worm treatment. Boron (B) also showed a significant change at the 1% level with 40.28. Calcium (Ca) is significant at the 5% level, indicating that the treatment played a role in its distribution or absorption. Among the elements sodium (Na) and chlorine (Cl), sodium changed at the 1% level and chlorine at the 5% level. In general, the data results show that the experimental treatment affected micronutrients more than macronutrients such as phosphorus and potassium.

Table 1. Analysis of variance for nutrient elements in the barberry leaf treatment.

S.O.V	D.F	N	P	K	Ca	S	Fe	Zn	Mn	B	Na	Cl
Block	4	0/0013^{ns}	276264^{ns}	1484375^{ns}	775000^{ns}	0/0008^{ns}	16.68^{ns}	0.0022^{ns}	3.37^{ns}	0.135^{ns}	1146875^{ns}	2009375^{ns}
Treatment	1	0.329**	224946^{ns}	3906250^{ns}	21025000**	0.016**	179.43*	0.16**	1.98^{ns}	1.15*	13225000**	640000^{ns}
Error	4	0/0013	276264	1484375	775000	0.0008	16.68	0.002	3.37	0.13	1146875	2009375

Note: **, * and N.S indicate significance at the 1% level, at the 5% level, and non-significance, respectively

Examination of Table 2 shows that the experimental treatment had a small effect on several nutritional elements of barberry leaves and branches. Nitrogen with a value of 0.329 is significant at the one percent level; that is, the treatment was able to create a significant change in the amount of nitrogen. Calcium also showed a similar reaction and had a significant difference at the one percent level, which indicates the sensitivity of this element to the conditions and treatment applied. Sulfur is also significant with a value of 0.016 at the one percent level. Among the micronutrients, iron with a value of 179.43 showed a significant change at the 5 percent level, and zinc (0.16) is also significant at the one percent level. Boron with a value of 1.15 has a significant difference at the five percent level, and sodium with a value of 13,225,000 has also been reported to be significant at the one percent level. In contrast, phosphorus, potassium, manganese, and chlorine did not show a specific response to the treatment. This pattern indicates that treatment conditions particularly affected elements related to cell structure and ionic balance, such as nitrogen, calcium, and sodium, while essential elements such as potassium or phosphorus were more resistant to these changes.

Table 2. Analysis of variance for nutrient elements in the barberry leaves and branches treatment.

S.O.V	D.F	N	P	K	Ca	S	Fe	Zn	Mn	B	Na	Cl
Block	4	0.00008^{ns}	6265537^{ns}	28132750^{ns}	9062500^{ns}	0.00012^{ns}	0.50^{ns}	0.003^{ns}	0.80^{ns}	0.005^{ns}	146875^{na}	4281250^{ns}
Treatment	1	0.0083^{**}	317185.4^{ns}	2070250^{ns}	7656250^{ns}	0.004^{**}	289.98^{**}	0.012^{ns}	3.24^{ns}	3.22^{**}	1225000^{*}	7656250^{ns}
Error	4	0.00008	626537	28132750	9062500	0.00012	0.50	0.003	0.80	0.005	146875	4281250

Note: **, * and N.S indicate significance at the 1% level, at the 5% level, and non-significance, respectively.

Table 3 shows that the treatment of Eisenia fuscata on barberry branches had the greatest effect on nitrogen, iron, and sulfur boron. Nitrogen content was 0.00008 and was significant at the one percent level; iron also reacted very significantly with a value of 289.98. Boron also showed a significant difference with a value of 3.22, and sodium with 1,225,000 was significant at the five percent level. In contrast, phosphorus, potassium, calcium, zinc, manganese, and chlorine did not react significantly to the treatment.

Table 3. Analysis of variance for nutrient elements in the barberry branches treatment.

S.O.V	D.F	N	P	K	Ca	S	Fe	Zn	Mn	B	Na	Cl
Block	4	0.00008^{ns}	6265537^{ns}	28132750^{ns}	9062500^{ns}	0.00012^{ns}	0.50^{ns}	0.003^{ns}	0.80^{ns}	0.005^{ns}	146875^{na}	4281250^{ns}
Treatment	1	0.0083^{**}	317185.4^{ns}	2070250^{ns}	7656250^{ns}	0.004^{**}	289.98^{**}	0.012^{ns}	3.24^{ns}	3.22^{**}	1225000^{*}	7656250^{ns}
Error	4	0.00008	626537	28132750	9062500	0.00012	0.50	0.003	0.80	0.005	146875	4281250

Note: **, * and N.S indicate significance at the 1% level, at the 5% level, and non-significance, respectively.

Macronutrient Elements

Based on the data in Table 4, each treatment compared to its control treatment, the different barberry compositions and the control treatments without the use of worms have significant differences in terms of the concentration of macronutrients, which can be a reflection of the characteristics of the raw material and the effect of the *Eisenia fetida* worm process. The highest nitrogen content is seen in the barberry leaf treatment, 27600 (mg kg^{-1}), while the control treatments generally have lower values. This difference indicates that the presence of earthworms and related microbial activity has increased the availability and fixation of nitrogen. Barberry branches alone have the lowest amount. Phosphorus is in the range of 1135 to 1645 (mg kg^{-1}) and the differences between the treatments are not statistically different. Barberry leaves also have the highest potassium content, 29900 (mg kg^{-1}). However, there is no significant difference compared to the control treatment. Calcium also shows no statistical difference in the barberry wood treatment and the barberry wood control. However, sulfur in the barberry wood treatment is different from the other elements and shows a significant decrease in sulfur compared to the control.

Table 4. Nutrient contents (N, P, K, Ca, S) of different materials as vermicompost

Treatments	**N**	**P**	**K**	**Ca**	÷
		mg kg^{-1}			
Barberry leaves	27600a	1644.82a	29900.0a	18700.0a	5040a
Barberry leaves control	18200b	1317.88a	20000.0a	12000.0b	3200b
barberry leaves and branches	18700a	1525.34a	17500.0a	10900.0a	1800a
barberry leaves and branches control	15100b	1225.38a	16250.0a	8000.0b	1000b
barberry branches	11900a	1491.19a	11910.0a	7750.0a	700b
Barberry branches control	11400b	1135.0a	11000.0a	6000.0a	1100a

Mean values in each column followed by the same letter are not significantly different by the LSD ($P < 0.05$).

Micronutrient Elements

Table 5. Nutrient contents (Fe, Zn, Mn, Na, B and Cl) of different materials as vermicompost

Treatments	Fe	Zn	Mn	Na	B	÷
	mg kg^{-1}					
Barberry leaves	30.71a	1.91a	7.59a	6600.0a	18.94a	15850.0a
Barberry leaves control	21.23b	1.12b	6.55b	2500.0b	14.93b	10000.0b
barberry leaves and branches	21.74b	0.78b	7.13a	4050.0a	8.81b	15600.0a
barberry leaves and branches control	30.22a	1.04a	8.02a	1750.0b	9.49	14000.0a
barberry branches	11.74b	0.73a	6.15a	1950.0a	1.74b	12750.0a
barberry branches control	22.51a	0.80a	7.29a	1250.0b	2.88a	11000.0a

Mean values in each column followed by the same letter are not significantly different by the LSD ($P < 0.05$).

Table 5 presents the micronutrient (Fe, Zn, Mn, Na, B, and Cl) of vermicomposts derived from different barberry residues. Distinct variations emerge among treatments, highlighting the strong influence of feedstock type (leaves, branches, or their combination) and the vermicomposting process itself. Overall, vermicomposted barberry leaves provide the richest profile of micronutrients and sodium, whereas barberry branches and their controls consistently contain the lowest levels.

Iron (Fe) content was highest in vermicomposted barberry leaves (30.71 mg kg^{-1}) and statistically similar in mixed leaf–branch compost (30.22 mg kg^{-1}), both significantly exceeding their controls (21.23 and 21.74 mg kg^{-1}, respectively). Zinc (Zn) followed a comparable trend, reaching 1.91 mg kg^{-1} in leaf vermicompost compared with only 0.73–1.12 mg kg^{-1} in the controls and branch treatments. The presence of distinct superscript letters confirms that vermicomposting substantially increases Fe and Zn availability, elements critical for plant enzymatic activity and chlorophyll synthesis.

Manganese (Mn) concentrations ranged from 6.15 to 8.02 mg kg^{-1}, with no significant difference between vermicomposted materials and their controls as indicated by similar superscripts. In contrast, sodium (Na) exhibited dramatic increases in vermicomposted leaves (6600 mg kg^{-1}) compared to their control (2500 mg kg^{-1}), underscoring the capacity of earthworm-mediated decomposition to enhance soluble sodium levels. The mixed leaves and branches also maintained moderately high Na (4050 mg kg^{-1}), suggesting that leafy biomass strongly influences sodium mobilization.

Boron (B) concentrations were highest in leaf vermicompost (18.94 mg kg^{-1}), dropping sharply to 1.74 mg kg^{-1} in branch vermicompost. These results illustrate the leaf material's superior ability to release boron, an essential micronutrient for cell wall structure and reproductive growth. Chloride (Cl) levels were consistently high across all treatments, peaking at 15850 mg kg^{-1} in leaf vermicompost and remaining above 10000 mg kg^{-1} in all samples. Elevated Cl levels can be beneficial for certain crops but warrant careful management to avoid salinity issues.

Physicochemical Properties

Table 6. Comparison of the average chemical and physical properties in the studied treatments, including organic carbon, EC, and pH of various materials as vermicompost.

Treatments	SP (%)	Ec (dS/m)	pH	O.C (%)	O.M (%)	Bulk Density (g cm^{-3})	Particle Density (g cm^{-3})	C/N%
Barberry leaves	122a	8.54a	9.68a	7.30a	9.20a	0.47a	1.64a	2.644a
Barberry leaves control	100a	9.20a	4.10b	2.70b	4.70a	0.37a	0.87a	1.483b
barberry leaves and branches	125.20a	5.70a	9.58a	5.74a	6.28a	0.46a	1.64a	3.069a
barberry leaves and branches control	109.00a	6.40a	4.30b	0.67a	1.17a	0.37a	0.87a	0.443b
barberry branches	101.00a	4.66a	8.68a	4.78a	5.00a	0.47a	1.66a	4.016a
barberry branches control	102.00a	4.10a	4.80b	2.30a	4.10a	0.36a	0.86a	2.017b

Mean values in each column followed by the same letter are not significantly different by the LSD ($P < 0.05$). The abbreviations employed in the table are defined as follows: SP, Saturation Percentage; EC, Electrical Conductivity; pH, Potential of Hydrogen; OC, Organic Carbon; and OM, Organic Matter.

The table compares key soil chemical and physical properties under different organic amendment treatments derived from barberry (Berberis spp.). Six treatments are reported: (1) barberry leaves, (2) barberry leaves control, (3) barberry leaves and branches, (4) barberry leaves and branches control, (5) barberry branches, and (6) barberry branches control. Measured soil parameters include Saturation Percentage (SP%), electrical conductivity (Ec), pH, organic carbon (O.C%), organic matter (O.M%), bulk density, and particle density. Letters following each value indicate statistical grouping, with shared letters signifying no significant difference at the chosen confidence level.

Saturation Percentage (SP%), an indicator of microbial activity, was highest in the "barberry leaves and branches" treatment (125.20%) and "barberry leaves" alone (122%), clearly exceeding their respective controls. This suggests that adding leaf material, especially when combined with branches, stimulates microbial metabolism. Electrical conductivity (Ec) showed a different pattern: the highest Ec occurred in the barberry leaves control (9.20dS/m) and the leaves-only treatment (8.54dS/m), indicating increased soluble salts in soils with leaf residues, whereas treatments with branches, alone or combined, exhibited lower EC values (as low as 4.10 a in the branches control). Lower EC in branch treatments may reflect slower mineralization or less release of soluble ions.

Soil pH varied widely across treatments, from acidic (4.10 b in the barberry leaves control) to moderately alkaline (9.68 a in the barberry leaves treatment). The addition of leaves alone or combined with branches generally maintained higher pH values (around 9.5), while control soils without fresh organic inputs tended to be more acidic. These findings suggest that decomposing barberry biomass—particularly leaves—has a liming effect, likely due to the release of basic cations during decomposition.

Organic carbon (O.C%) and organic matter (O.M%) percentages were consistently elevated in treatments receiving barberry biomass compared to controls. For example, barberry leaves increased O.C to 7.30% and O.M to 9.20%, while the corresponding control recorded only 2.70 b and 4.70 a, respectively. Similarly, the leaves-and-branches treatment maintained high O.C (5.74 %) and O.M (6.28%), again well above the 0.67 % and 1.17 % seen in its control. This confirms that incorporating barberry residues enriches soil organic matter, which is essential for nutrient cycling and improved soil fertility.

Bulk density, an indicator of soil compaction, was slightly lower in most amended soils (0.46–0.47 g cm^{-3}) compared to controls (0.36–0.37 g cm^{-3} in some cases), reflecting modest improvements in soil structure due to organic additions. Particle density remained relatively stable across treatments, hovering around 1.64–1.66 (g cm^{-3}) for amended soils and dropping to about 0.86–0.87 (g cm^{-3}) in controls. Overall, the incorporation of barberry leaves and branches not only enhanced soil chemical properties but also slightly improved physical characteristics, supporting their use as valuable organic amendments to promote soil health.

Table 7. Results of Pearson correlation analysis among different nutrients

	N	P	K	Ca	S	Fe	B	Zn	Mn	Na
N										
P	P= 0.009^{**} R= 0.59									
K	P= 0.000^{**} R= 0.85	P= 0.000^{**} R= 0.72								
Ca	P= 0.000^{**} R= 0.87	P= 0.006^{**} R= 0.61	P= 0.000^{**} R= 0.88							
S	P= 0.000^{**} R= 0.95	P= 0.012^{*} R= 0.57	P= 0.000^{**} R= 0.84	P= 0.000^{**} R= 0.83						
Fe	P= 0.000^{**} R= 0.79	P= 0.006^{**} R= 0.61	P= 0.000^{**} R= 0.79	P= 0.001^{**} R= 0.68	P= 0.000^{**} R= 0.72					
B	P= 0.000^{**} R= 0.96	P= 0.008^{**} R= 0.60	P= 0.000^{**} R= 0.86	P= 0.000^{**} R= 0.85	P= 0.000^{**} R= 0.95	P= 0.000^{**} R= 0.82				
Zn	P= 0.000^{**} R= 0.89	P= 0.018^{*} R= 0.54	P= 0.000^{**} R= 0.81	P= 0.000^{**} R= 0.82	P= 0.000^{**} R= 0.93	P= 0.000^{**} R= 0.72	P= 0.000^{**} R= 0.89			
Mn	P= 0.000^{**} R= 0.92	P= 0.009^{**} R= 0.59	P= 0.000^{**} R= 0.85	P= 0.000^{**} R= 0.85	P= 0.000^{**} R= 0.96	P= 0.000^{**} R= 0.80	P= 0.000^{**} R= 0.98	P= 0.000^{**} R= 0.92		
Na	P= 0.000^{**} R= 0.76	P= 0.000^{**} R= 0.71	P= 0.000^{**} R= 0.88	P= 0.000^{**} R= 0.71	P= 0.000^{**} R= 0.75	P= 0.005^{**} R= 0.62	P= 0.001^{**} R= 0.69	P= 0.001^{**} R= 0.70	P= 0.001^{**} R= 0.68	
Cl	P= $0.081^{N.S}$ R= 0.42	P= $0.955^{N.S}$ R= - 0.01	P= $0.158^{N.S}$ R= 0.34	P= $0.089^{N.S}$ R= 0.41	P= 0.014^{*} R= 0.35	P= $0.308^{N.S}$ R= 0.25	P= $0.194^{N.S}$ R= 0.32	P= $0.304^{N.S}$ R= 0.25	P= $0.222^{N.S}$ R= 0.30	P= $0.161^{N.S}$ R= 0.34

Note: **, * and N.S indicate significance at the 1% level, at the 5% level, and non-significance, respectively.

Table 7 shows that most nutrients have a positive and relatively strong correlation with each other. The existence of such a link indicates that an increase in one element is likely to occur simultaneously with an increase in these elements. Potassium has significant coefficients along with calcium and nitrogen. This coordination can be related to their function in regulating osmotic pressure and transporting sugars. Also, the high correlation of potassium with boron indicates that the balance of these two elements may be important for the health of the plant cell wall. Boron shows a strong correlation with many micronutrients, including manganese and zinc. Such a pattern is probably due to their common role in enzymatic processes and cell division. The close relationship between boron and manganese is also of interest and may play a role in improving the quality of young tissues. Chlorine behaves differently compared to other elements. Its correlation coefficients with most elements are low and often insignificant. It can be said that chlorine has specific absorption or transport pathways and is less affected by changes in other elements.

Discussion

Barberry-leaf vermicompost proved

exceptionally nutrient-rich compared with many reported feedstocks. It contained 2.76 % nitrogen and 2.99 % potassium, with 0.16 % phosphorus, 1.87 % calcium, and 0.05 % sulfur, plus high sodium (6600mg kg^{-1}). Even barberry branches maintained about 1.1% nitrogen, confirming that barberry residues especially leaves are an outstanding feedstock for vermicomposting in arid soils.

Relative to other composts, barberry vermicompost consistently showed higher nitrogen and potassium but lower phosphorus and organic carbon, and it had a strongly alkaline, saline profile (pH = 9.7; EC = 8.5 mS cm^{-1}): Pineapple–vegetable compost: richer in phosphorus (1.2 %), slightly higher potassium (3.7 %), and far more organic carbon (18-19 % C, 31-33 % OM) with near-neutral pH (Castillo-González et al., 2019). Grape-pomace vermicompost: more organic matter (30-40 %), higher micronutrients such as Fe and Zn, and milder pH (5.6-7.6) (Gabur et al., 2024). Indonesian market-waste vermicompost: greater phosphorus (0.29-0.43 %) and organic carbon (19-27 %) with balanced pH (7.1-7.6) (Syarifinnur et al., 2023). PRAN mango-seed vermicompost: more phosphorus (0.51%) and calcium (5.34 %) but less nitrogen (1.68%) and potassium (1.49 %) (Ibrahim et al., 2024). Mango-wood vermicompost: lower nitrogen (1.1–2.0 %) and potassium (0.7-1.6 %), slower C/N reduction (5.6-11.4) (Keniya et al., 2023). Eucalyptus-leaf vermicompost: slower mineralization (C/N=21) and lower N and K (Bhagat et al., 2022). Wood-chip sewage sludge compost; required microbial inoculation to reduce heavy metal toxicity and had lower N, K, and Ca (Maboeta & Van Rensburg, 2003). Mango-leaf vermicompost: lower N and K and a higher C/N ratio (Gajalakshmi et al., 2005). Typical garden, kitchen, or cow-dung vermicompost: only 1.02-1.97 % N, 0.37- 0.62 % P, and 0.60-1.01 % K (Wani et al., 2013).

Conclusion

Barberry leaves are identified as the superior feedstock for vermicomposting, producing compost with significantly higher macro- (N, K, Ca, S) and micro-nutrient (Fe, Zn, Na, B) levels than branches or mixed residues. Compared with untreated residues, vermicomposting greatly enhances nutrient availability especially nitrogen, calcium, and trace elements and improves soil chemical and physical properties by increasing microbial activity, Saturation Percentage, pH, and organic carbon while slightly lowering bulk density. Because leaf-derived vermicompost carries consistently high chloride (salinity), application rates must be carefully managed. Practical recommendation: use a higher proportion of barberry leaves in the feedstock to maximize nutrient enrichment while monitoring and adjusting application to prevent salt build-up, ensuring long term soil fertility and plant health.

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