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Vermicompost as a Catalyst for Enhancing Soil Physical Properties, Nutrient Availability, Crop Yield, and Sustainable Waste Management: A Comprehensive Review

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ABSTRACT

Vermicompost is increasingly recognized as a sustainable alternative to chemical fertilizers, offering a wide range of agronomic and ecological benefits. This review synthesizes current knowledge on vermicompost's role in enhancing soil fertility, improving crop yield and quality, suppressing plant diseases and pests, and contributing to organic waste recycling. Specifically, vermicompost improves soil structure, nutrient availability, and microbial activity, while acting as a biofertilizer and natural pest regulator through mechanisms such as induced systemic resistance and microbial antagonism. Field studies across various crops-including garlic, tomato, green gram, and maize demonstrate significant improvements in yield and nutritional content. Additionally, research conducted in Ethiopia highlights the potential of locally sourced vermicompost formulations and their integration with inorganic fertilizers for sustainable crop production. Overall, these findings affirm vermicompost's value in organic agriculture and its contribution to soil health, environmental protection, and long-term ecosystem balance.

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INTRODUCTION

Tropical agroecosystems are characteristically constrained by severe inherent nutrient deficiencies; paradoxically, substantial volumes of nutrient-dense domestic and agricultural organic residues remain underutilized within these regions (Gandhi et al., 1997). In developing economies, millions of metric tons of these organic waste streams are subjected to open burning or landfilling annually, exacerbating environmental degradation. Concurrently, the pervasive application of synthetic chemical fertilizers and anthropogenically derived pesticides induces widespread ecological degradation (Blouin et al., 2019; Eurostat, 2018; Van Groenigen et al., 2014). These conventional practices also present severe public health risks via the bioaccumulation of toxic residues within trophic food webs. Culminating ecological and human health concerns have catalyzed a paradigm shift toward sustainable alternative methodologies, driving the global expansion of certified organic agriculture.

As a holistic management framework, organic farming deliberately mitigates or entirely excludes the deployment of synthetic fertilizers, chemical pesticides, exogenous growth regulators, and intensive livestock feed additives. The foundational mechanism of this sustainable paradigm centers on the preservation and anthropogenic enhancement of the soil matrix's biochemical fertility. This is strategically executed through the systematic recycling of organic waste substrates—primarily via advanced composting technologies—thereby mitigating critical macro-nutritional imbalances arising from the accelerated depletion of essential nitrogen (N), phosphorus (P), and potassium (K) dynamics (Chhonkar, 2002).

Vermiculture, systematically known as earthworm husbandry, leverages specific macro-invertebrate species to bio-convert unstable organic substrates into highly humified, nutrient-dense excrement termed vermicasts. The resulting vermicompost functions as a macrobiotically diverse organic soil conditioner generated via the synchronous pathways of earthworm digestion and localized microbial stabilization; this process represents a self-sustaining paradigm for contemporary agroecosystems and municipal organic refuse processing (Alidadi et al., 2014; Przemieniecki et al., 2021).

Epigaeic earthworm species such as *Eisenia fetida* and *Eudrilus eugeniae* are considered optimal for vermiculture and vermicomposting due to their preference for surface organic matter and their efficiency in processing waste (Bansal and Kapoor, 2000; Dominguez and Edwards, 2004). These worms consume organic scraps like vegetable waste and compost, producing nutrient-rich castings. Capable of ingesting up to half their body weight daily, they effectively decompose organic residues and reduce waste volume by 40–60% (Dominguez, 2004).

An earthworm weighing approximately 0.5-0.6 g can consume organic waste equal to its body weight daily, producing casts equivalent to about 50% of the intake. Vermicast, the excreta of earthworms, is a nutrient-rich organic fertilizer containing humus, NPK, micronutrients, beneficial microbes (e.g., nitrogen-fixing and phosphate-solubilizing bacteria, actinomycetes), and plant growth hormones such as auxins, gibberellins, and cytokinins. Both vermicast and vermiwash have been scientifically validated as effective growth enhancers and protectants for crops (Rajiv et al., 2010).

Consequently, vermicompost constitutes a highly nutritive, macrobiotically diverse bio-fertilizer characterized by dense, specialized microbial communities (Pathma and Sakthivel, 2013). The application of this technology yields an economically viable and ecologically sustainable strategy for the stabilization of biodegradable refuse streams, effectively converting municipal and agricultural waste into premium agronomic inputs (Garg et al., 2006). This comprehensive review synthesizes the multifaceted agricultural and ecological benefits of vermicomposting, with specific emphasis on its role in structural soil fertility remediation, organic solid waste optimization, and the suppression of phytopathogenic vectors and insect pests. Furthermore, this paper systematically explores the historical trajectories, current breakthroughs, and localized implementation of vermiculture research specifically contextualized within Ethiopian agroecosystems.

METHODOLOGY

A broad literature search using Google identified both Scopus-indexed and non-Scopus articles. Of over 130 papers screened, 93 were selected based on their relevance to the review’s objectives. Key concepts were extracted and synthesized for clarity. The search was guided by keywords including biofertilizer, earthworm, organic waste, vermicompost, waste management, and soil fertility improvement, ensuring a diverse and representative selection of studies.

SYNTHESIS AND DISCUSSION

The Vermicomposting Process

Vermicomposting is a mesophilic process (10–32°C) where earthworms and microbes convert organic waste into nutrient-rich compost (Edwards and Burrows, 1988; Benitez et al., 1999). It accommodates diverse waste sources-- agricultural, industrial, and domestic wastes through simple methods (Jeyabal and Kuppuswamy, 2001; Suthar et al., 2012; Yadav et al., 2011), combining physical (fragmentation, aeration) and biochemical (enzymatic digestion, nutrient release) actions to enhance nutrient availability (Ndegwa and Thompson, 2001; Jusselme et al., 2019).

To avoid heat stress, raw wastes undergo 10-20 days of pre-composting with daily turning for aeration (Derib et al., 2017). Earthworms are then introduced under controlled temperature, moisture, and ventilation (Glenn, 2009).

Red earthworms convert waste into compost within 45-50 days. Only 5-10% of ingested material is absorbed; the rest is excreted as nutrient-rich castings stabilized by gut mucus. The process yields humus-like fertilizer that improves soil and plant health (Theunissen et al., 2010; Lazcano et al., 2011; Lim et al., 2015).

Characteristics of Vermicompost and its nutrient composition

Vermicompost is a fine, pathogen-free organic manure made from earthworm castings enriched with beneficial microbes (Hemalatha, 2012). Its humic acid content makes it a sustainable biofertilizer, suitable for horticulture (Joshi et al., 2015). Moisture ranges from 32–66%, and polysaccharides improve soil aeration and drainage (Chaudhary et al., 2004).

Nutrient composition and pH vary by feedstock: sheep manure vermicompost has a pH of ~8.6, cattle ~6.0, and pig ~5.3 (Gutiérrez-Miceli et al., 2007; Chatterjee et al., 2021; Tognetti, 2005). Overall nutrient levels depend on the type of organic material used (Garg and Gupta, 2009).

Vermicompost is rich in organic carbon (9.15–17.98%) and contains essential macronutrients such as nitrogen (0.5–0.9%), phosphorus (0.1–0.26%), and potassium (0.15–0.256%). It also includes sodium (0.055–0.3%) and significant levels of calcium and magnesium (22.67–47.60 meq/100g). Micronutrients like copper (2.0–9.5 mg/kg), iron (2.0–9.3 mg/kg), zinc (5.7–9.3 mg/kg), and sulphur (128–548 mg/kg) further enhance its value as a soil amendment.

Table 1. Chemical composition of vermicompost

Nutrient	Content
Organic carbon %	9.15 -17.98
Total nitrogen %	0.5 -0.9
Phosphorous %	0. 1 – 0.26
Potassium %	0.15 - 0.256
Sodium %	0.055 – 0.3
Ca and Mg (meq/100g)	22.67 - 47.60
Copper (mg kg^{-1})	2.0 - 9.5
Iron (mg kg^{-1})	2.0 - 9.3
Zinc (mg kg^{-1})	5.7 – 9.3
Sulphur (mg kg^{-1})	128.0 - 548.0

Source: Garg, Gupta, 2009

Comparative Advantages of Vermicompost

Vermicompost is widely recognized as a superior plant growth promoter compared to conventional compost and chemical fertilizers (Sinha and Bharambe, 2007; Sinha et al., 2009). It is reported to be at least four times more nutritive than cattle dung compost (Suhane, 2007). Unlike conventional compost, which is rich in ammonium, vermicompost contains higher levels of nitrates-an immediately available form of nitrogen-enhancing plant growth and yield (Atiyeh et al., 2000). It also offers greater nitrogen availability per unit weight and significantly boosts essential nutrients like phosphorus, potassium, sulfur, and magnesium in soil (Subler et al., 1998). Vermicompost retains nutrients longer and delivers macro- and micronutrients more effectively than conventional compost.

As reported by Sujit Adhikary (2012), a comparative analysis of chemical and microbiological properties among agricultural soil, vermicompost, and manure reveals notable differences in nutrient profiles and soil-enhancing characteristics. Vermicompost shows a balanced pH (8.09) and lower electrical conductivity than manure, indicating reduced salinity. It offers moderate moisture (535 g/kg) and superior water holding capacity (1103 g/kg), enhancing soil structure. Though manure contains higher total carbon and nitrogen, vermicompost provides a more stable C:N ratio (20.9) and improved calcium levels (26.3 mg/g), beneficial for plant growth. Unlike manure, vermicompost has lower dissolved organic carbon and nitrogen but avoids excess ammonium and phosphorus, reducing nutrient leaching risks. Both vermicompost and manure are free from *E. coli* O157:H7, but vermicompost maintains a favorable microbial balance with fewer pathogens and strong heterotrophic bacterial presence.

Table 2. A comparison of the chemical, microbiological properties of agricultural soil, vermicompost and manure

Parameters	Nutrient available from		
	Soil	Vermicompost	Manure
pH	5.96 ± 0.11	8.09 ± 0.09	8.59 ± 0.14
Electrical conductivity (mS cm^{-1})	0.33 ± 0.04	0.18 ± 0.02	3.05 ± 0.08
Moisture content (g kg^{-1})	249 ± 4	535 ± 3	864 ± 5
Water holding capacity (g kg^{-1})	361 ± 4	1103 ± 13	ND
DOC (mg g^{-1} dry matter)	0.13 ± 0.03	0.60 ± 0.24	15.4 ± 7.91
DN (mg g^{-1} dry matter)	0.04 ± 0.01	0.07 ± 0.03	1.89 ± 1.07
Total C (g kg^{-1})	31 ± 1	181 ± 3	299 ± 6
Total N (g kg^{-1})	3.0 ± 0.3	8.7 ± 0.7	14.2 ± 1.5
C:N ratio	10.2	20.9	21.1
NO_3^- (mg g^{-1} dry matter)	<0.1	<0.1	<0.1
NH_4^- (mg g^{-1} dry matter)	<0.1	<0.1	1.0 ± 0.7
P (mg g^{-1} dry matter)	<0.1	<0.1	2.2 ± 1.6
K (mg g^{-1} dry matter)	0.9 ± 0.2	1.3 ± 0.1	2.1 ± 0.1
Ca (mg g^{-1} dry matter)	10.5 ± 3.4	26.3 ± 2.2	0.3 ± 0.1
Na (mg g^{-1} dry matter)	0.05 ± 0.05	0.05 ± 0.05	0.42 ± 0.02
Background heterotrophic bacteria log $_{10}$ CFU g^{-1})	7.85	8.41	8.93
Escherichia coli O157:H7 log $_{10}$ CFU g^{-1})	0.00	0.00	0.00

ND – not determined
Source: Sujit Adhikary, 2012.

As reported by Afroja N., Sayma K., and Shahid A. H. (2019), a comparative assessment of vermicompost and conventional compost reveals notable differences in physical and chemical properties. Vermicompost is darker in color, odor-free, and slightly more alkaline (pH 8.50) than compost (pH 8.16). It shows higher electrical conductivity and contains greater levels of organic carbon (24.54%), total nitrogen (2.40%), phosphorus, potassium, sulfur, calcium, magnesium, and micronutrients such as zinc (110 mg/kg) and manganese (220 mg/kg). These enhanced properties underscore vermicompost's superior value as a soil amendment and nutrient source.

Table 3. Properties of vermicompost and Compost

Properties	Vermicompost	Compost
Colour	Dark grey to black	Dark grey
Physical condition	Non-granular form	Non-granular form
Odour	Absence of foul odour	Presence of foul odour
pH	8.50	8.16
EC (dSm^{-1})	5.63	3.47
OC (%)	24.54	19.40
Total N (%)	2.40	1.69
Total P (%)	0.93	0.81
Total K (%)	0.54	0.34
Total S (%)	0.25	0.12
Total Ca (%)	1.90	1.45
Total Mg (%)	0.92	0.79
Total Na (%)	1.15	1.06
Total Fe ($mgkg^{-1}$)	0.16	0.12
Total Zn ($mgkg^{-1}$)	110	90
Total Mn ($mgkg^{-1}$)	220	140

Source: Adapted from Afroja N., Sayma K. and Shahid A. H., 2019.

Rekha et al. (2018) reported that vermicompost contains high levels of humus and functions as a nutrient-rich organic fertilizer, with nitrogen (2–3%), phosphorus (1.55–2.25%), and potassium (1.85–2.25%). It also harbors beneficial microbes such as nitrogen-fixing bacteria and mycorrhizal fungi, along with plant growth hormones. Worm castings were found to contain nearly twice the concentration of macro- and micronutrients compared to garden compost.

Manifold Advantages of Vermicompost

Vermicompost is gaining attention as a plant growth medium and soil enhancer (Chamani et al., 2008). It acts as a biofertilizer, restores nutrients, improves soil fertility, and supports long-term soil health. Vermicomposting also offers an economical solution for organic waste management, reducing environmental impact (Peyvast et al., 2008). Overall, vermiculture promotes sustainable agriculture and helps maintain ecological balance.

Vermicomposting as a Waste Management Strategy

Urbanization and industrialization have intensified solid waste issues, contributing to greenhouse gas emissions and environmental degradation (Elkington and Hartigan, 2008; Rahman and Khondaker, 2012). Open dumping of organic waste leads to heavy metal buildup, water pollution, and soil toxicity (Hsu and Lo, 1999). Yet, organic waste holds potential as a recyclable resource for producing nutrient-rich fertilizers (Marshall and Farahbakhsh, 2013; Bernstad et al., 2016; Calabi-Floody, 2018).

Vermicomposting uses earthworms and microbes to transform waste into odor-free, humus-rich compost (Monroy et al., 2009). Unlike landfilling or burning, it recycles waste efficiently, reduces pollution, and supports a circular bioeconomy by converting waste into valuable agricultural inputs.

Vermicompost as soil conditioner and soil fertility ameliorant

Vermicompost enhances sustainable agriculture by improving soil structure, aeration, moisture retention, and nutrient availability (Marinari et al., 2000; Orozco et al., 1996). It supports microbial activity, enzyme functions, and pH balance (Maheswarappa et al., 1999), while earthworm secretions contribute growth-promoting compounds and aid organic matter decomposition (Edwards and Arancon, 2004).

As a slow-release fertilizer, vermicompost boosts cation exchange capacity and plant growth (Atiyeh et al., 2001; Chaoui et al., 2002). In acidic soils, its combination with lime and phosphorus fertilizer helps mitigate acidity and aluminum toxicity (Abdissa Bekele et al., 2018). Application rates typically range from 1–5 t ha^{-1} yr^{-1}, with higher doses recommended for degraded soils (Edwards et al., 2010).

Vermicompost for Crop Growth and Yield Enhancement

Vermicompost is highly valued in organic farming for its rich nutrient profile, humus content, growth hormones, and natural pest resistance (Sinha et al., 2010). Its application improves seed germination, plant vigor, and overall yield across a wide range of crops including vegetables, cereals, and herbs (Levinsh, 2011; Arancon et al., 2006; Rekha et al., 2018).

Quality improvements-such as elevated vitamin C, calcium, essential oils, and protein-have been observed in crops like mint, tomato, cabbage, and potato (Verma et al., 2014; Rivera and Wright, 2009). These effects are attributed to bioactive compounds and plant growth regulators present in vermicompost (Atiyeh et al., 2000).

When integrated with chemical fertilizers, vermicompost further enhances crop performance. In green gram, application rates of 7.5–10 t ha^{-1} significantly increased pod number, grain count, and biological yield compared to control and FYM treatments (Tak, 2003). For example, 10 t ha^{-1} of vermicompost resulted in the highest grain yield (7.78 q/ha) and biological yield (22.43 q/ha), along with improved harvest index.

These findings affirm vermicompost's role in boosting both yield and quality, while offering a sustainable alternative to synthetic inputs.

Table 4. Effect of Vermicompost on Yield and Yield Attributes of Green Gram

Treatment	No. of pods/plant	Length of pods (cm)	No of grains/ pod	T.W. (g)	Grain yield (q/ha)	Straw yield (q/ha)	Biological yield (q/ha)	HI (%)
Control	14.00	4.90	4.18	30.01	4.00	12.03	16.03	24.95
FYM@ 10t/ha	18.56	7.03	6.32	33.12	6.96	13.35	20.31	34.27
Vermicompost@5 t/ha	18.96	7.48	6.48	33.34	7.10	13.55	20.65	34.52
Vermicompost@7.5 t/ha	20.51	7.86	7.17	33.58	7.67	14.55	22.22	35.52
Vermicompost@ 10 t/ha	20.87	7.98	7.25	33.95	7.78	14.65	22.43	34.86
Sem ±	0.34	0.19	0.14	0.66	0.16	0.34	0.51	0.81
CD(p=0.05)	0.99	0.55	0.40	1.91	0.47	0.97	1.47	2.33

Source: Tak, (2003).

Other studies show that vermicompost significantly enhances both yield and quality parameters in garlic and tomato crops. In garlic, application of 5 t ha^{-1} resulted in the highest marketable bulb yield (6.99 t ha^{-1}) and lowest unmarketable yield (0.72 t ha^{-1}), along with improvements in dry matter, total soluble solids, biomass, and harvest index (Alemu, 2016).

Similarly, tomato yield increased linearly with vermicompost rates. At 2 t ha^{-1}, fruit yield peaked at 140.7 t ha^{-1}, accompanied by higher dry weight, fruit count, and nutrient content in both fruits and plant tissues (Hyder et al., 2015). These effects are attributed to vermicompost's rich microbial activity, including fungi, bacteria, and actinomycetes, which promote plant growth and nutrient uptake.

Overall, increasing vermicompost rates not only boosts crop productivity but also improves nutritional quality, making it a valuable input for sustainable agriculture.

Table 5. The effect of vermicompost on different growth and yield related parameters of garlic

Treatment (t ha^{-1})	DM (%)	TSS (Brix)	HI (%)	FBY (g/plant)	TBY (t ha^{-1})	MBY (t ha^{-1})	UMBY (t ha^{-1})
0	47.21c	5.13c	61.54c	32.91b	7.10c	6.36c	0.81a
2.5	48.46b	5.27b	66.16b	33.30b	7.33b	6.60b	0.74b
5	51.05a	5.69a	68.36a	34.45a	7.78a	6.99a	0.72b
LSD	1.152	1.37	3.71	0.63	0.18	0.21	0.06

DM- dry matter TSS-total soluble solid, HI-harvest index, TBY-total bulb yield, FBY- fresh biomass yield, MBY-marketable bulb yield, UMBY- un marketable bulb yield, LSD - least significant difference.
Source: Alemu,2016.

Table 6. Effect of vermicompost on different parameters of tomato plants

Treatment (t ha^{-1})	Fruits/ plant	Dry weight (g)		Yield (t ha^{-1})	Fruit Nutrient content (%)			Plant Nutrient content (%)		
		Root	Shoot		N	P	K	N	P	K
0	11.7	3.3	37.3	1.85	2.1	0.49	3.97	1.94	0.14	1.8
0.5	17.0	6.8	99.3	2.307	2.6	0.52	4.23	2.59	0.20	2.1
1	21.3	8	112.7	2.884	3.1	0.56	4.60	2.64	0.27	2.3
1.5	26.7	9	125.0	3.326	3.6	0.62	4.90	2.67	0.31	2.9
2	32.3	10.2	140.7	4.383	3.7	0.67	5.17	3.4	0.32	3.2

Source: Adapted from Hyder et al., 2015

Vermicompost as Plant Disease and Pest Regulator

Disease Control with Vermicompost

Vermicompost plays a vital role in suppressing plant diseases and pests through its rich microbial activity and bioactive compounds. Earthworm casts contain oxidative enzymes that stimulate lignin formation via PAL enzyme activity, reinforcing plant cell walls (Amooaghaie and Golmohammadi, 2017). Beneficial microbes, especially actinomycetes, produce chitinase and other metabolites (e.g., HCN, siderophores, IAA, cellulase, protease) that inhibit pathogens and enhance plant resistance (Adhikary, 2012; Gopalakrishnan et al., 2011).

Numerous studies confirm vermicompost's effectiveness against a wide range of pests and diseases-including damping off, Fusarium wilt, aphids, collar rot, nematodes, and late blight-across crops such as tomato, cucumber, chickpea, groundnut, and cabbage (Rao et al., 2001; Arancon et al., 2007b; Zhang et al., 2020). Vermicast treatments have also suppressed *Phytophthora* spp. and *Rhizoctonia solani* (Simsek-Ersahin et al., 2009).

Mechanisms of Disease Suppression

Vermicompost suppresses plant pathogens through two main mechanisms:

- **General suppression**: Involves microbial competition, antibiosis, hyperparasitism, and induced systemic resistance (ISR), where beneficial microbes occupy root zones and block pathogen access (Hoitink and Grebus, 1994).
- **Specific suppression**: Relies on targeted action by select microbes or introduced biocontrol agents against specific pathogens (Hoitink et al., 1997).

These mechanisms are rooted in the "soil food web" concept, where beneficial organisms dominate the rhizosphere, limiting pathogen establishment and activity.

Evidence from Field Studies

Table 7 summarizes key findings from various studies demonstrating vermicompost's role in controlling pests and diseases across diverse crops. From aphids in groundnut to Fusarium wilt in cucumber, vermicompost has shown consistent bio-control potential (Ali Mohd Yatoo, 2021).

Table 7. Disease and pest control by vermicompost

S. No	Disease/pest	Crop	Treatment	Reference
1	Jassid (Empoasca verri), aphid (Aphis craccivora)	Groundnut	Vermicompost	Rao et al., (2001)
2	Damping off and root rot	Cucumbers and Radishes	Vermicompost	Chaoui et al., (2002)
3	Damping off	Tomatoes	Vermicompost	Rivera et al., (2004)
4	Damping off	Patience plant (Impatiens walleriana)	Vermicompost	Asciutto et al., (20060
5	Tetranychus urticae, pseudococcus sp. *Myzus persicae*	Bush beans, Eggplant, Tomato, Cucumber, and Cabbage	Vermicompost	Arancon et al., (2007b)
6	Collar rot	Chickpea	Vermicompost	Sahni et al., (2008a)
7	Fusarium wilt	chickpea	Vermicompost	Gopalakrishnan et al., (2011)
8	Helicoverpa zea and pieris rapae	cabbage	Vermicompost	Little and Cardoza (2011)
9	Meloidogyne incognita	Brinjal	Vermicompost	Nath et al., (2011)
10	Earworm (Helicoverpa zea)	Corn plant	Vermicompost	Cardoza and Buhler (2012)
11	Aphid (Lipaphis Crysimi)	Mustard	Vermicompost	Nath and Singh (2012)
12	Fusarium wilt	Tomato	Vermicompost	Basco et al., (2017)
13	Damping off	Cucumber	Vermicompost	You et al., (2019)
14	Polyphagotarsonemus latus	Chili	Vermicompost	Jangra et al., (2019)
15	Late blight disease	potato	Vermicompost	Peerzada et al., (2020)
16	Fusarium wilt	Cucumber	Vermicompost	Zhang et al., (2020)

Source: Ali Mohd Yatoo,2021.

Pest Control with Vermicompost

Vermicompost has proven effective in managing a wide range of arthropod pests, including caterpillars (e.g., tomato hornworms, cabbage loopers), beetles, aphids, spider mites, and mealy bugs (Arancon et al., 2005). Early studies by Arancon and Edwards (2004) demonstrated that low application rates of food waste vermicompost significantly reduced pest infestations in crops like cucumber, tomato, bush beans, eggplant, and cabbage.

In controlled experiments, incorporating 20–40% vermicompost into commercial growth media (MetroMix 360) led to marked reductions in damage caused by aphids (*Myzus persicae*), mealy bugs (*Pseudococcus*), and cabbage caterpillars (*Pieris brassicae*) compared to untreated controls (Arancon et al., 2003; Edwards and Arancon, 2004).

Field trials further confirmed vermicompost's efficacy in suppressing plant-parasitic nematodes across crops such as tomato, pepper, strawberry, and grape, with application rates ranging from 2 to 8 kg ha^{-1} (Arancon et al., 2005; 2007).

These findings highlight vermicompost's potential as a natural pest management tool, reducing reliance on chemical pesticides and supporting integrated pest control strategies.

Mechanisms of Plant Pest Control by Vermicompost Products

While the exact mechanisms by which vermicompost suppresses pest attacks remain under investigation (Edwards et al., 2004), researchers suggest that changes in nutrient availability and balance may influence plant physiology, making crops less vulnerable to pests (Patriquin et al., 1995). Slow-release organic nitrogen from vermicompost, along with increased phenol content in leaves, may reduce susceptibility to arthropod damage.

Vermicompost has proven effective at low application rates (Arancon et al., 2002; Yardim et al., 2006), offering a cost-efficient alternative to chemical pesticides. Beyond pest control, it enriches soil with nutrients and growth regulators while minimizing environmental contamination. Its use holds strong promise for organic horticulture and sustainable agriculture.

Progress and Prospects of Vermicompost Research in Ethiopia

Vermicompost research in Ethiopia has shown promising beginnings, with contributions from federal and regional agricultural research centers, though efforts remain fragmented. Several field experiments have demonstrated its agronomic and economic potential when integrated with conventional fertilizers.

At Chelia highlands in Oromia, Tolera et al. (2018) reported significantly higher barley yields from a 50:50 integration of vermicompost and conventional compost, based on nitrogen equivalence, combined with recommended NP fertilizer. Economic analysis confirmed the profitability of this approach. Further research by the same author recommended 92/69/30 kg NPS ha^{-1} and a 50:50 blend of NPS and vermicompost for highland maize production in Vertisols of Ambo and similar agro-ecologies (Tolera et al., 2019).

In Welmera and Dendi districts, Girma Chala and Gebreyes Gurmu (2014, 2017) evaluated the effects of organic and inorganic fertilizers on wheat and teff. The highest grain and biomass yield for both crops were achieved using a 50:50 combination of vermicompost and recommended N and P rates. Organic amendments also improved soil chemical properties, including organic matter, total nitrogen, available phosphorus, and pH.

At Mechara Agricultural Research Center, Tadele et al. (2020) assessed the nutrient content of vermicompost prepared from various locally available straw substrates-haricot bean, grass, teff, maize, sorghum, and mixed straw. All materials produced nutrient-rich compost capable of correcting soil nutrient imbalances. However, the study emphasized the need for further research on optimal application rates and field-level impacts on crop yield and soil properties.

Table 8. Chemical properties of vermicompost prepared from different materials

	Digested substrates					
Parameters	Haricot bean	Grass	Mixed straw	Teff	Maize	Sorghum
pH (H_2O) (1:2.5)	8.4	7.5	8.1	8.1	8.4	8.4
EC(mS/cm)(1:2.5)	4.1	5.3	3.7	4.2	4.5	3.3
CEC (meq/100g)	57.4	58.3	63.0	68.7	66.1	63.0
Organic carbon (%)	21.2	34.7	27.1	27.0	28.2	23.3
C:N Ratio	7.0	8.1	7.3	7.2	9.1	7.4
Total nitrogen (%)	3.0	4.3	3.7	3.8	3.1	3.2
Available P (mg P_2O_5/kg)	775.4	1277.6	829.9	1023.8	987.4	905.9
Available K (mg K_2O/kg)	6963.6	4987.0	4571.5	7327.7	4545.5	3740.4
Exchangeable K (meq/100g)	11.6	10.0	20.7	20.9	19.9	18.9
Exchangeable Ca (meq/100g)	26.8	31.2	32.0	35.2	34.0	34.0
Exchangeable Mg (meq/100g)	13.2	12.8	10.0	12.0	12.0	12.0
Fe (mg/kg)	29.6	29.0	38.2	54.2	46.0	46.0
Mn (mg/kg)	354.3	101.8	120.9	117.7	105.1	112.0
Cu (mg/kg)	4.2	1.3	2.7	0.9	4.2	6.7
Zn (mg/kg)	32.3	35.8	41.3	45.7	41.0	58.7

Source: Tadele et al., 2020.

Similar work was done at Bako Agricultural Research Centre (BARC), to evaluate the nutrient composition of vermicompost prepared from locally available crop residues and animal wastes. The objective was to identify combinations that yield high-quality vermicompost for improving soil fertility and crop productivity (Derib et al., 2017).

Among the tested mixtures, vermicompost derived from soybean straw and cattle manure exhibited superior nutrient content-particularly in total nitrogen (1.98%), total potassium (3.94%), calcium (7.91%), and magnesium (8.7%)- making it the most promising for soil enrichment. This enhanced profile is likely due to the higher nitrogen content in soybean straw compared to maize and niger residues.

Other combinations, such as soybean + niger straw with sheep manure, and mixed crop residues with farmyard manure, also showed favorable nutrient balances. In contrast, conventional compost had lower organic carbon (19.32%) and total nutrient values, reinforcing the advantage of vermicompost blends.

These findings suggest that strategic selection of feed materials -especially leguminous residues like soybean-can significantly influence the quality of vermicompost and its potential for sustainable soil management.

Table 9. Nutrient content of vermicomposts prepared from different crop residues and animal wastes

Feed material Combinations	Nutrient contents								
	pH (H2O)	OC %	OM %	TN %	C:N ratio	T.P %	T.K %	T. Ca %	T. Mg %
Maize St. + Cattle Manure	8.29	32.11	55.3	1.53	20.99	1.22	2.42	5.32	2.1
Soybean Str. + Cattle Manure	8.20	32.22	55.5	1.98	16.27	1.39	3.94	7.91	8.7
Niger Str. + Cattle Manure	8.51	35.21	60.7	1.98	17.78	0.69	2.29	3.08	1.85
Maize St.+ Soybean st.+ Cattle Manure	8.4	35.38	61.0	1.37	25.82	0.68	1.8	5.27	3.8
Maize St.+ Niger Str. + Cattle Manure	8.12	34.43	59.3	1.75	19.67	0.69	1.75	8.39	3.78
Maize St.+ Soybean St + Str.+ Sheep Manure	8.74	33.00	56.8	2.17	15.21	0.80	2.7	6.26	6.89
Maize St.+ Niger Str. + Sheep manure	8.88	35.09	60.5	2.42	14.50	0.90	2.32	3.08	3.33
Soy bean Str.+ Niger str.+Cattle Manure	8.12	37.24	64.2	1.98	18.81	0.72	1.92	5.29	3.18
Soybean Str.+ Niger Str.+ Sheep Manure	8.56	36.02	62.1	2.42	14.88	0.83	2.53	5.29	5.71
Crop Residue (Ms. Sbs. Ns) + FYM (cattle + sheep Manure)	8.05	35.50	61.2	1.98	17.93	0.83	2.22	3.17	8.24
Cattle Manure only	8.16	42.87	73.9	2.1	20.41	0.69	1.7	5.31	1.91
Conven. Compost	9.25	19.32	33.3	0.87	22.21	0.47	1.53	8.39	4.40

The values recorded are means of triplicates
Source: Derib et al., 2017

CONCLUSION

The Role of Vermicompost in Sustainable Agriculture

Vermicompost offers a wide array of agronomic and ecological benefits, making it an increasingly attractive option for use as a plant growth medium and soil amendment. It functions as a biofertilizer, replenishing essential nutrients, improving soil structure, and enhancing long-term soil fertility. Rich in humus, plant growth hormones, enzymes, and beneficial microorganisms, vermicompost not only supports crop productivity but also provides natural protection against pests and diseases. Furthermore, its role in organic waste recycling positions it as a sustainable alternative to chemical fertilizers and conventional waste management practices. Overall, vermicompost contributes significantly to the advancement of organic agriculture and the preservation of a balanced ecosystem.

Declaration of Competing Interest

The authors declare that they have no conflict of interest.

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