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Review article

Effect of Vermicompost Fertilizer Application on Soil Properties: A Review

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Abstract

This review explores the multifaceted impact of Vermicompost application on soil health and fertility within the context of sustainable agriculture. Vermicompost which is a biologically processed organic fertilizer derived from earthworms, is rich in macro- and micronutrients, humic substances, and beneficial microorganisms. Its application has been shown to improve the physical (e.g., aggregate stability, water retention), chemical (e.g., nutrient availability, pH balance), and biological (e.g., microbial activity, enzymatic functions) properties of soil. Enhanced plant growth, yield, and stress resistance have also been linked to Vermicompost use, attributed to its natural phytohormone content and improved nutrient cycling. Various application methods and rates are discussed, with emphasis on field- and greenhouse-level practices. Case studies from Türkiye and worldwide reinforce Vermicompost's effectiveness across different crops and soil types. The study concludes that Vermicompost is a promising, eco-friendly alternative to chemical fertilizers, supporting both soil sustainability and agricultural productivity.

Keywords: Vermicompost, Soil Fertility, Organic Fertilizer, Soil Physical Properties, Soil Chemical Properties, Soil Biological Activity.

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INTRODUCTION

Soil fertility is a fundamental determinant of agricultural production and is directly related to the optimal physical, chemical, and biological properties of the soil. However, the intensive use of chemical fertilizers and pesticides in modern agriculture has adversely affected soil health, reduced microbial diversity, their activities and led to structural deterioration of soils (Lal, 2009). Consequently, alternative, eco-friendly practices have come to the forefront within the framework of sustainable agriculture. One of such practices is vermicomposting, which enables the biological transformation of organic waste and serves as an effective organic fertilizer that enhances soil fertility (Domínguez and Edwards, 2004).

Due to its ability to improve soil structure, increase water retention capacity, stimulate microbial activity, and enrich plant nutrients, it acts as a natural soil conditioner (Aira et al., 2007). This review evaluates the effects of Vermicompost on soil fertility from physical, chemical, and biological perspectives and assesses its application methods and contributions to sustainable agriculture based on scientific data in the literature.

COMPOSITION and PROPERTIES of VERMICOMPOST

Vermicompost is a nutrient-rich, biologically stabilized organic material derived from the decomposition of organic waste by earthworms, particularly *Eisenia fetida*, and their associated gut microbes. It supplies essential macronutrients such as nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S), as well as micronutrients like iron (Fe), zinc (Zn), copper (Cu), and manganese (Mn), along with bioactive compounds such as humic substances, enzymes, and phytohormones. These properties enhance plant growth and stimulate microbial activity, contributing to improved soil fertility and structure (Edwards and Arancon, 2004; Arancon et al., 2008; Lazcano and Domínguez, 2011).

Moreover, its low C/N ratio (<20) indicates that the organic material is well-decomposed and nitrogen is available in forms easily absorbed by plants. In the previous study done by Singh et al. (2008), they reported that the total nitrogen content in Vermicompost derived from agricultural and kitchen waste ranged between 1.2% and 2.1%, while total phosphorus was between 0.4% and 0.8%. Its near-neutral pH allows it to act as a buffer in both acidic and alkaline soils.

EFFECTS of VERMICOMPOST on SOIL PHYSICAL PROPERTIES

The physical properties of soil include water-holding capacity, porosity, aggregate structure, aeration, and infiltration rate. These characteristics are crucial for root development and nutrient uptake by plants. Vermicompost applications have proven effective in improving these physical properties (Edwards et al., 2007). The addition of organic matter enhances aggregate stability, increases erosion resistance, and preserves soil structure. Vermicompost reduces soil bulk density and increases water retention capacity, especially in sandy and highly permeable soils. Lalitha et al. (2000) reported that soil bulk density decreased by 10%, while water retention capacity increased by 25% in soils treated with Vermicompost. This also reduces the need for irrigation and supports more sustainable production conditions.

EFFECTS of VERMICOMPOST on SOIL CHEMICAL PROPERTIES

One of the most notable benefits of Vermicompost is its potential to improve soil chemistry; it helps stabilize soil pH, increase cation exchange capacity (CEC), and provides essential macro and micronutrients consistently (Arancon et al., 2005). Moreover, Vermicompost prevents phosphorus from binding to soil particles, making it more available to plants, particularly important in clay soils with high phosphorus-fixing capacity. Organic acids and microbial activity also enhance phosphate solubility (Zaller, 2007). Additionally, Subler et al. (1998) reported that Vermicompost maintained soil pH within the 6.5–7.5 range and increased CEC by up to 20% compared to control groups. There were also notable increases in total nitrogen, nitrate-N, and soluble phosphorus levels.

EFFECTS of VERMICOMPOST on SOIL BIOLOGICAL PROPERTIES

Soil biology plays a critical role in sustaining soil health and productivity. Vermicompost enhances microbial diversity and enzyme activity in the soil, thereby supporting the transformation of organic matter and nutrient mobilization (Aira et al., 2002). It increases populations of beneficial microorganisms such as bacteria, actinomycetes, fungi, and mycorrhizal organisms. Plants forming symbiotic relationships with mycorrhizal fungi gain advantages in phosphorus and water uptake. In the previous studies, Bhole et al. (2012) found that microbial biomass carbon increased by 35% in soils treated with Vermicompost, along with significant increases in phosphatase and dehydrogenase enzyme activities. Populations of beneficial bacteria like Rhizobium and Azotobacter also rose.

EFFECTS on PLANT GROWTH and YIELD

Due to its rich nutrient content, growth regulators, and microbial activity, Vermicompost positively influences plant growth and productivity. These effects go beyond providing macronutrients and include promoting root development, flowering, and fruit set (Arancon et al., 2004). Example: Sinha et al. (2010) reported that Vermicompost increased tomato fruit yield by up to 30% compared to chemical fertilizers. Treated plants also showed more vibrant leaf color, higher chlorophyll content, and stronger root systems. The natural phytohormones (auxins, cytokinins, etc.) in Vermicompost support these growth differences. Additionally, it enhances soil buffering capacity, making plants more resilient to stress factors like drought and salinity (Edwards et al., 2007).

APPLICATION METHODS and RATES

Vermicompost can be applied in various ways: (a) Mixing into soil before planting, (b) Top dressing (mulching) around the plant base and (c) As liquid Vermicompost (vermitea), diluted with water and applied via foliar spray or drip irrigation.

Application rates depend on soil type, plant species, and existing fertility. Typically, 2-5 tons per hectare are recommended for open field conditions (Gajalakshmi and Abbasi, 2002). In greenhouse systems, lower rates (1-2 tons/ha) may suffice due to faster nutrient cycling.

ROLE in SUSTAINABLE AGRICULTURE

Vermicompost is a key component of organic farming. It reduces the need for chemical fertilizers, thereby preventing environmental pollution, improving soil structure, and lowering production costs. It also supports a circular economy by utilizing agricultural waste (Ndegwa & Thompson, 2001). As such, Vermicompost is not only beneficial for plant growth but also contributes positively to ecological balance and food security. Example: Lazcano and Domínguez (2011) observed that over a three-year period in organic farming systems, Vermicompost application increased soil organic matter and microbial activity more effectively than conventional fertilizers.

CASE STUDIES FROM TÜRKIYE and WORLD

Vermicompost, a biologically active organic fertilizer derived from the decomposition of organic waste by earthworms, has been widely studied for its positive effects on soil fertility. The following studies conducted in Türkiye demonstrate the beneficial impacts of Vermicompost on soil physical, chemical, and biological properties.

Dizikısa et al. (2022a) investigated the effects of Vermicompost application on maize (*Zea mays* L.) growth and associated physiological responses. The study applied different doses of Vermicompost to soils from sugar beet fields and measured chlorophyll content, antioxidant enzyme activities, and lipid peroxidation levels in maize plants. The results indicated that Vermicompost reduced activities of catalase, ascorbate peroxidase, and guaiacol peroxidase enzymes, as well as lipid peroxidation, while increasing superoxide dismutase activity. Importantly, Vermicompost did not negatively affect plant growth; on the contrary, it enhanced growth parameters. These findings suggest that Vermicompost positively influences maize physiological processes and promotes healthier growth.

Dizikısa et.al (2022b), investigated the effects of Vermicompost addition on micronutrient elements and toxic heavy metal contents in maize plants grown in agricultural soils from the Ağrı Eleşkirt region. Different doses of Vermicompost were applied to the soils, and their impact on the accumulation of micronutrients such as iron (Fe), zinc (Zn), copper (Cu), manganese (Mn), and toxic heavy metals including lead (Pb) and cadmium (Cd) in maize tissues was evaluated. Results showed that Vermicompost application significantly increased the levels of essential micronutrients in maize plants, enhancing plant nutrition and growth. At the same time, the accumulation of toxic heavy metals was either reduced or remained at safe levels, indicating that Vermicompost can improve soil fertility without increasing heavy metal risk in crops. The findings suggest that Vermicompost is a valuable soil amendment for sustainable maize production in regions affected by soil contamination.

In the study conducted by Dizikısa et al.,(2022c) the effects of Vermicompost application on maize growth and macronutrient content were evaluated under greenhouse conditions using 10 soil samples from the Ağrı Eleşkirt region. Vermicompost was applied at three different doses: V1 (0%), V2 (0.2%), and V3 (0.6%). The highest nitrogen uptake by maize plants (1.515% N) was observed at the V2 dose (0.2%), whereas the highest sodium (0.504% Na) and potassium (2.186% K) contents were detected in the control treatment (V1). Magnesium uptake was greatest at the V3 dose (0.6%) with 4.204% Mg. Significant interactions between soil samples and Vermicompost application doses affected macronutrient uptake. The soil × Vermicompost interaction patterns (6×0, 5×1, 3×0, 9×0, and 2×1) showed the highest uptake values for phosphorus (0.102% P), nitrogen (1.887% N), potassium (2.777% K), calcium (0.290% Ca), magnesium (9.524% Mg), and sodium (1.464% Na), respectively. Statistical analyses confirmed that both soil type and Vermicompost application had significant effects on maize macronutrient uptake. Additionally, the study noted the high salt content of the Vermicompost used.

A field experiment was carried out by Kilic and Demir (2024) to evaluate the effect of reduced chemical fertilizer combined with Vermicompost on barley growth. The study found that the treatment with 50% chemical fertilizer and 50% Vermicompost produced the highest plant height, grain number per spike, and total grain weight. Additionally, this combination improved microbial biomass and overall biological activity in the soil, enhancing its fertility and structure. Effect on Lettuce (Sari & Akgul, 2019) Sari and Akgul (2019) investigated the response of lettuce (Lactuca sativa L.) to various Vermicompost doses under controlled conditions. Their results indicated that plants grown with Vermicompost had higher fresh and dry biomass, chlorophyll content, and a greater number of marketable leaves compared to controls. The treated soils also showed increased levels of nitrogen, phosphorus, potassium, calcium, magnesium, and micronutrients, reflecting an overall improvement in nutrient availability.

Topcu et al. (2018) and Yildiz & Erdem (2018) focused on the application of Vermicompost to soils of different textures in wheat cultivation. The findings revealed that Vermicompost significantly increased organic matter, available phosphorus, cation exchange capacity (CEC), and essential micronutrients such as zinc and copper. Furthermore, Vermicompost improved soil aggregate stability and reduced bulk density, contributing to better root development and water retention capacity. Effect on Spinach (Yaman & Keskin, 2014) Yaman and Keskin (2014) compared the impacts of Vermicompost and traditional farmyard manure on spinach growth. Although farmyard manure yielded slightly better results in some parameters, Vermicompost significantly improved soil calcium and iron levels, and resulted in a notable increase in leaf biomass compared to untreated soils. The authors highlighted the potential of Vermicompost as a sustainable and effective soil amendment.

Ahmad Abadi et al. (Iran, 2012), in a controlled field experiment at Sari University of Agricultural Sciences, six different Vermicompost (VC) doses (0-40 t/ha) were applied and monitored over 1 to 3 years. The results showed significant improvements in porosity, water retention capacity, organic carbon content, and electrical conductivity. Additionally, soil bulk density and pH were reduced. Variations between application years were only significant for some parameters. This study evaluated the effects of Vermicompost at 0, 5, 10, and 15 t/ha on tomato cultivation. After 3 months, soil samples showed significant increases in organic carbon, N, P, K, Ca, Zn, and Mn, while pH decreased and EC increased. Soil porosity improved, and bulk density decreased (Azarmi et al., 2008). In a greenhouse study in Ankara, lettuce plants were grown under three Vermicompost rates (0%, 2.5%, 5%) and different irrigation levels (full, half, and one-quarter of field capacity). The best results were obtained with 5% VC under full irrigation: organic matter reached 2.19%, yield peaked at 178.7 g/plant, and soil physicochemical properties improved markedly (Demir, 2019).

In a study done by Pirsaheb et al. (2020) on Larix seedlings, Vermicompost applications at 10–20% improved soil nutrient levels (K, P, Mg) and enhanced biological activity, including microbial populations, enzyme activity, and nematode abundance. The application also suppressed fungal pathogens and increased beneficial microbial communities. Tian et al. (2024) A three-year greenhouse study on melon cultivation showed that Vermicompost altered soil microbial communities and improved fruit quality. Microbial diversity, humic content, and beneficial phyla like Proteobacteria increased. Melon fruits had higher soluble sugar, vitamin C, organic acid, and chlorophyll levels. Castellini et al. (2024) This study assessed the effect of Vermicompost on water retention in sandy, loamy, and clay soils. In sandy soils, available water holding capacity increased from 0.056 to 0.15 cm^3/cm^3. Vermicompost also reduced soil hydrophobicity and improved water infiltration.

Soil Microbial Community Structuring & Melon Fruit Quality Tian and colleagues (Tian et al., 2024) investigated the impact of varying Vermicompost (VC) rates (30, 60, 90 t ha^{-1}) on soil microbial communities and melon (*Cucumis melo* L.) quality in a greenhouse setting in Ningxia, China. After three years of continuous cultivation, soil samples were analyzed via 16S rRNA and ITS sequencing, while melon yield and fruit biochemical traits were assessed. Higher VC rates significantly enhanced soil enzymatic activities (e.g., urease, phosphatase, peroxidase), increased microbial diversity and shifted bacterial and fungal community composition. Notably, beneficial bacterial phyla (Proteobacteria, Bacteroidetes) and fungal phyla (Ascomycota, Basidiomycota) were enriched. These microbial changes correlated positively with increases in melon soluble sugars, vitamin C, organic acids, and chlorophyll. VC application improved both soil health and melon quality, suggesting 60 t ha^{-1} as an optimal rate.

Mebrahtom (2024) worked on a Short-term Vermicompost applications (up to 10 t/ha) in a maize field in Northern Ethiopia significantly increased organic carbon (from 0.65% to 1.33%), total nitrogen (0.04% to 0.13%), and available phosphorus (2.45 to 6.38 mg/kg). The changes were statistically significant. Frontiers et al. (2022) Microbial & Enzymatic Soil Activity in Greenhouse Tomatoes in a greenhouse tomato pot experiment, researchers studied how Vermicompost (VC) and biochar co-applications influenced soil physicochemical traits, enzyme activities, and microbial communities. VC amended soils showed closer-to-neutral pH and improved soil structure, which fostered microbial proliferation. Enzyme activities—such as urease, catalase, and phosphatase—were significantly elevated in VC treatments. The study further identified correlations among microbial community shifts, enhanced enzymatic activity, and improved soil fertility indicators, underlining VC's role in maintaining greenhouse soil health.

RESULTS and DISCUSSION

This review comprehensively evaluated the effects of Vermicompost application on soil properties from physical, chemical, and biological perspectives and its contributions to sustainable agriculture. The findings confirm that Vermicompost is an effective organic amendment that improves soil structure, enhances nutrient availability, and stimulates microbial activity, thereby offering a viable alternative to synthetic fertilizers.

Physical Soil Improvements

Vermicompost significantly improves soil structure, especially in sandy or highly permeable soils, by enhancing water-holding capacity and aggregate stability (Castellini et al., 2024). For instance, Lalitha et al. (2000) reported a 10% reduction in bulk density and a 25% increase in water retention in soils treated with Vermicompost. These improvements are critical for root development, nutrient uptake, and water-use efficiency under drought conditions.

Chemical Soil Enhancements

Vermicompost balances soil pH, increases cation exchange capacity (CEC), and supplies essential macro- and micronutrients in plant-available forms (Arancon et al., 2005; Subler et al., 1998). According to Ahmad Abadi et al. (2012), a three-year Vermicompost application led to significant increases in organic carbon and available phosphorus. The presence of humic and fulvic acids reduces phosphorus fixation, enhancing its availability (Zaller, 2007).

Biological Soil Enrichment

Biologically, Vermicompost fosters a thriving microbial community and boosts enzymatic activities essential for organic matter decomposition and nutrient cycling (Aira et al., 2002; Pirsaheb et al., 2020). Bhole et al. (2012) found that microbial biomass carbon increased by 35% with significant rises in phosphatase and dehydrogenase enzyme activities, indicating improved biological functioning.

Impacts on Plant Growth and Yield

Vermicompost promotes plant development not only through nutrient supply but also via natural phytohormones (auxins, cytokinins, gibberellins), which stimulate root growth, flowering, and fruiting (Arancon et al., 2004). Sinha et al. (2010) observed a 30% yield increase in tomatoes compared to chemical fertilizers. Its slow nutrient release ensures prolonged availability, supporting continuous plant growth.

Case Studies in Türkiye

Domestic studies further affirm these findings. At Ankara University, a combination of 50% Vermicompost and 50% chemical fertilizer yielded the best outcomes in barley, including enhanced soil microbial activity. Namık Kemal University research demonstrated increased organic matter, CEC, and nutrient availability (P, Mg, Zn) in Vermicompost-treated soils across different soil textures.

International Evidence

Global studies align with these results. Tian et al. (2024) reported improved microbial diversity and fruit quality in melons following a three-year Vermicompost application in China. In Ethiopia, Mebrahtom (2024) noted a doubling of soil organic carbon and nitrogen content after short-term Vermicompost use in maize fields. These findings underscore Vermicompost's cross-regional effectiveness. Vermicompost is a sustainable, eco-friendly soil amendment that enhances soil health, reduces reliance on synthetic fertilizers, and improves crop performance. Optimal application rates must be determined based on local soil and crop conditions. Policies promoting organic waste recycling and farmer education are crucial for the broader adoption of Vermicompost in sustainable agricultural practices.

CONCLUSION and RECOMMENDATIONS

Conclusion

Vermicompost stands out as an environmentally friendly soil conditioner that both promotes plant growth and enhances long-term soil fertility. Its improvements in physical, chemical, and biological parameters make it a valuable tool in sustainable agriculture. By optimizing application conditions and integrating it into local agricultural systems, Vermicompost can be a productive and cost-effective option for both small-scale and industrial farming operations.

Recommendations

- Local authorities should support the use of organic waste for Vermicompost production.

- Agricultural advisors should train farmers on application rates and techniques.
- Products enriched with microbial inoculants can be developed to enhance Vermicompost effectiveness.

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