Review Article

Effect of Vermicompost on Soil Properties, Plant Growth and Environmental Sustainability: A Review

Abstract

Vermicomposting, the process of converting organic waste into nutrient-rich compost through the activity of earthworms, has emerged as a promising solution to improve soil health, enhance agricultural productivity, and promote environmental sustainability. This review paper explores the effects of different doses of vermicompost on soil properties, plant growth and environmental sustainability. The application of vermicompost at varying dosages influences several soil characteristics, including nutrient availability, water retention, soil structure, and microbial activity, ultimately impacting plant growth and crop yields. Studies indicate that moderate doses of vermicompost often result in enhanced soil fertility and plant performance, while excessive application may lead to nutrient imbalances or phytotoxicity. Furthermore, vermicompost offers several environmental benefits, such as carbon sequestration, reduced dependence on synthetic fertilizers, and improved waste management. This review synthesizes findings from various studies to determine optimal dosages for specific soil types and crops, highlighting the need for region-specific guidelines. The review also identifies key research gaps and suggests directions for future studies, including long-term field trials and exploration of microbial interactions within vermicomposted soils. Ultimately, the findings emphasize the importance of balancing vermicompost doses to maximize both agricultural productivity and environmental sustainability.

Keywords: Vermicompost, phytotoxicity, crop yield, soil properties, plant growth and environmental sustainability.

1. Introduction

Soil fertility and health are fundamental to the success of agricultural systems, influencing crop yields, plant health, and ecosystem sustainability. As the global population continues to rise, the demand for food production intensifies, placing increasing pressure on agricultural lands. To meet these demands, farmers often rely on chemical fertilizers, which, while effective in enhancing crop yields, have been linked to environmental degradation, soil nutrient imbalances, and health risks. Between 2020 and 2021, global cereal production increased by 2.1%, driven by a 4.1% surge in maize production, with maize, wheat, and rice contributing to 90% of the total cereal output [Satyavathi *et al*., 2021].In response, sustainable agricultural practices are gaining importance, and organic amendments like vermicompost have emerged as a promising alternative.Vermicomposting is a biological process where organic matter is decomposed and transformed into nutrient-rich humus by earthworms and microorganisms. Vermicompost offers a natural solution enriched with crucial nutrients, humic acids, plant growth-regulating hormones, and enzymes, which positively influence plant nutrition, photosynthesis, and the nutrient content of various plant parts [Hagh *et al.,* 2013; Ozyazici and Turan, 2021].The resulting vermicompost is a high-quality, organic fertilizer that improves soil structure, nutrient content, microbial diversity, and moisture retention, contributing to healthier soils and more robust plant growth. Additionally, it offers an eco-friendly solution to the disposal of organic waste, reducing environmental pollution while simultaneously benefiting agricultural productivity.The benefits of vermicompost depend on several factors, including its quality, the dosage applied, and the specific needs of the soil and crops. Different doses of vermicompost can have varying effects on soil properties, plant growth, and overall crop performance. While moderate doses of vermicompost are generally beneficial, excessive application may lead to nutrient imbalances, toxicity, or soil salinization. As a result, understanding the optimal dosage of vermicompost for different crops and soil types is crucial for maximizing its positive effects. Zinc and iron deficiencies are prevalent in agricultural soils globally [Bezabeh*et al.,* 2022]. This review aims to synthesize existing research on the effects of various doses of vermicompost on soil properties, plant growth, and environmental sustainability. Vermicompost is vital in improving soil quality, sequestering organic carbon, and reducing excessive CO_2 emissions associated with intensive agricultural practices [Khalifa *et al.*, 2022; Shenoy and Siddaraju, 2020; Maurya*et al.,* 2015; Zaremanesh*et al.,* 2017].By examining studies that explore different application rates and their outcomes, this paper seeks to identify the ideal dosage for specific agricultural systems and highlight the broader implications of using vermicompost in sustainable farming.Vermicompost produced through the symbiotic interactions between microorganisms and earthworms, represents a cost-effective and environmentally friendly process that enhances soil quality and improves microbial biodiversity [Pathma, J.; Sakthivel, 2012; Vyas *et al.,* 2022; Brown, 1995; Souffront *et al.,* 2022; Lirikum*et al.,* 2022; Lazcano and Domínguez, 2011]. Furthermore, it will discuss the potential environmental benefits of vermicomposting, such as carbon sequestration and reduced dependence on chemical fertilizers, while also addressing the challenges and limitations associated with its use. Finally, the review will outline areas for future research, providing insights into how vermicomposting can be optimized to promote both agricultural productivity and environmental conservation.

2. Vermicompost and Its Properties[Aslam *et al.,* 2019;Bianco *et al.,* 2022;Aechra *et al.,* 2022; Ghadimi et al., 2021; Hoque et al., 2022;Garai *et al.,* 2014]

- **Composition**: Nutrients (macro and micro) present in vermicompost, including nitrogen, phosphorus, potassium, trace elements, and humic substances.
- **Physicochemical properties**: pH, organic matter content, cation exchange capacity (CEC), moisture retention, etc.
- **Microbial activity**: Role of beneficial microorganisms in enhancing soil health and plant growth.

3. Effects of Different Doses of Vermicompost on Soil Properties

- **Soil structure**: The impact on soil aggregation, porosity, and aeration[Shen *et al.,* 2022].
- **Nutrient availability**: Effects on the availability of essential nutrients and their release rates (slow-release properties)[Bezabeh*et al.,* 2022].
- **Water retention**: Improvement in soil's water-holding capacity and its influence on drought tolerance[Dhanuja *et al.,* 2019].
- **Soil pH**: How vermicompost modifies soil acidity/alkalinity [Aslam *et al.,* 2019].
- **Cation Exchange Capacity (CEC)**: Influence of vermicompost on nutrient retention and soil fertility[Khalifa *et al.,* 2022].
- **Microbial communities**: How different doses affect soil microbiota and biodiversity[Pathma, J.; Sakthivel, 2012; Vyas *et al.,* 2022; Brown, 1995; Souffront *et al.,* 2022; Lirikum*et al.,* 2022; Lazcano and Domínguez, 2011].

4. Effects of Vermicompost on Plant Growth

- **Plant growth parameters**: Root and shoot growth, leaf area, plant height, and biomass[Karasahin, 2022].
- **Nutrient uptake**: Influence on the absorption of macronutrients (N, P, K) and micronutrients (Fe, Zn, Mn)[Singh and Misal, 2022;Haque and Biswas, 2021].
- **Crop yield**: Impact on the productivity of various crops (vegetables, fruits, grains, *etc.*)[Shukla *et al.*, 2013].
- **Disease resistance**: Role of vermicompost in enhancing plant immunity and reducing susceptibility to soil-borne diseases[Kovácik*et al.*, 2015].
- **Stress tolerance**: Influence on plant tolerance to environmental stresses like drought, salinity, and extreme temperatures [Karmakar *et al.*, 2021].

5. Optimal Vermicompost Dosage

- **Review of studies on dosage**: Overview of experimental studies assessing the effects of low, medium, and high doses of vermicompost [Sengupta *et al.*, 2021].
- **Recommended doses**: Summary of optimal doses for specific crops and soil types [Sengupta *et al.*, 2021].
- **Threshold effects**: Discussion on diminishing returns and potential negative effects of excessive vermicompost application (*e.g.*, nutrient imbalance, salt buildup, phytotoxicity).

6. Environmental and Economic Impact

- **Sustainability**: Vermicompost as a sustainable alternative to synthetic fertilizers [Ozyazici and Tura, 2021].
- **Carbon sequestration**: Role in reducing greenhouse gas emissions and improving soil carbon stocks[Khalifa e*t al.*, 2022; Shenoy and Siddaraju, 2020; Maurya*et al.*, 2015; Zaremanesh*et al.*, 2017].
- **Economic considerations**: Cost-effectiveness of vermicompost application in different agricultural systems [Kovácik*et al.*, 2015;Nayak*et al.*, 2019].
- **Waste management**: Potential for recycling organic waste into valuable soil amendments [Zahra, 2021].

7. Challenges and Limitations

- **Variability in vermicompost quality**: Differences in nutrient composition due to variations in feedstock and processing methods.

- **Lack of standardized recommendations**: Need for region-specific guidelines for vermicompost application.
- **Scale-up issues**: Practical challenges in large-scale production and application of vermicompost in commercial agriculture.
- **Regulatory concerns**: Issues related to the certification and quality control of vermicompost products.

8. Future Directions and Research Gaps

- **Need for long-term studies**: The importance of conducting long-term field trials to assess the lasting effects of vermicompost on soil health and crop yield.
- **Research on application techniques**: Investigating the best methods for vermicompost application (incorporation, top dressing, etc.) and their impact on crop performance.
- **Microbial interactions**: Understanding the role of vermicompost in promoting beneficial soil microbes and their effects on plant health.
- **Interdisciplinary approaches**: Encouraging collaboration between agronomists, environmental scientists, and policymakers to create more effective soil management practices.

9. Conclusion

The application of vermicompost in varying doses plays a pivotal role in enhancing soil properties, improving plant growth, and promoting environmental sustainability. Moderate doses of vermicompost generally result in significant improvements in soil fertility, structure, and microbial health, contributing to increased crop yields and more resilient agricultural systems. Vermicompost enhances nutrient availability, water retention, and soil aeration, which are essential for supporting plant growth and maintaining healthy soils. Additionally, its ability to enrich soil microbial communities helps to suppress soil-borne diseases and improve plant resistance to environmental stresses, such as drought and salinity. However, the effects of vermicompost are dose-dependent, with excessive application potentially leading to nutrient imbalances, phytotoxicity, and other adverse effects. The optimal dosage varies depending on soil type, crop species, and local environmental conditions. Therefore, careful management and region-specific guidelines are necessary to maximize the benefits of vermicompost while avoiding negative consequences. From an environmental perspective, vermicompost offers substantial benefits, including carbon sequestration, reduced greenhouse gas emissions, and a decrease in the reliance on chemical fertilizers. Its use in organic waste recycling also addresses waste management issues, reducing landfill burdens and promoting a circular economy. Furthermore, vermicomposting aligns with sustainable farming practices by promoting ecological balance and minimizing the environmental footprint of agricultural activities. Despite its potential, several challenges remain, including variability in the quality of vermicompost, the need for standardized application recommendations, and the practical difficulties of large-scale vermicompost production and distribution. Future research should focus on optimizing application techniques, conducting long-term field trials, and exploring the complex microbial interactions within vermicomposted soils. Vermicomposting is a promising practice that can enhance soil health, increase crop productivity, and contribute to sustainable agricultural systems. To fully realize its potential, further studies are required to develop more precise guidelines for its application, ensuring that both agricultural productivity and environmental sustainability are achieved.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

Option 2:

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc. have been used during the writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

1.NO

2. NO

3. NO

References

1. Aechra, S.; Meena, R.H.; Meena, S.C.; Mundra, S.L.; Lakhawat, S.S.; Mordia, A.; Jat, G. Soil microbial dynamics and enzyme activities as influenced by biofertilizers and split application of vermicompost in rhizosphere of wheat (*Triticum aestivum* L.). J. Environ. Biol. 2021, 42, 1370–1378.
2. Aslam, Z.; Bashir, S.; Hassan, W.; Bellitürk, K.; Ahmad, N.; Niazi, N.K.; Khan, A.; Khan, M.I.; Chen, Z.; Maitah, M. Unveiling the Efficiency of Vermicompost Derived from Different Biowastes on Wheat (*Triticum aestivum* L.) Plant Growth and Soil Health. Agronomy 2019, 9, 791.
3. Aslam, Z.; Bashir, S.; Hassan, W.; Bellitürk, K.; Ahmad, N.; Niazi, N.K.; Khan, A.; Khan, M.I.; Chen, Z.; Maitah, M. Unveiling the Efficiency of Vermicompost Derived from Different Biowastes on Wheat (*Triticum aestivum* L.) Plant Growth and Soil Health. Agronomy 2019, 9, 791.
4. Bezabeh, M.W.; Hailemariam, M.H.; Sogn, T.A.; Eich-Greatorex, S. Wheat (Triticum aestivum) production and grain quality resulting from compost application and rotation with faba bean. J. Agric. Food Res. 2022, 10, 100425.
5. Bezabeh, M.W.; Hailemariam, M.H.; Sogn, T.A.; Eich-Greatorex, S. Wheat (*Triticum aestivum*) production and grain quality resulting from compost application and rotation with faba bean. J. Agric. Food Res. 2022, 10, 100425.
6. Bianco, A.; Fancello, F.; Garau, M.; Deroma, M.; Atzori, A.S.; Castaldi, P.; Zara, G.; Budroni, M. Microbial and chemical dynamics of brewers' spent grain during a low-input pre-vermicomposting treatment. Sci. Total Environ. 2022, 802, 149792.
7. Brown, G.G. How do earthworms affect microfloral and faunal community diversity? Plant Soil 1995, 170, 209–231.
8. Dhanuja, C.; Saxena, D.K.; Abbasi, T.; Abbasi, S.A. Effect of application of vermicompost on methane emission and grain yield of Chinna Ponni paddy crop. Paddy Water Environ. 2019, 17, 797–802.
9. Garai, T.K.; Datta, J.K.; Mondal, N.K. Evaluation of integrated nutrient management on boro rice in alluvial soil and its impacts upon growth, yield attributes, yield and soil nutrient status. Arch. Agron. Soil Sci. 2014, 60, 1–14.

10. Ghadimi, M.; Sirousmehr, A.; Ansari, M.H.; Ghanbari, A. Organic soil amendments using vermicomposts under inoculation of N2-fixing bacteria for sustainable rice production. PeerJ 2021, 9, 10833.
11. Hagh, E.D.; Mirshekari, B.; Ardakani, M.R.; Farahvash, F.; Rejali, F. Maize biofortification and yield improvement through organic biochemical nutrient management. Idesia 2016, 34, 37–46.
12. Haque, M.M.; Biswas, J.C. Emission factors and global warming potential as influenced by fertilizer management for the cultivation of rice under varied growing seasons. Environ. Res. 2021, 197, 111156.
13. Hoque, T.S.; Hasan, A.K.; Hasan, M.A.; Nahar, N.; Dey, D.K.; Mia, S.; Solaiman, Z.M.; Kader, M.A. Nutrient Release from Vermicompost under Anaerobic Conditions in Two Contrasting Soils of Bangladesh and Its Effect on Wetland Rice Crop. Agriculture 2022, 12, 376.
14. Karasahin, M. Effects of vermicompost and inorganic fertilizer applications in different forms and doses on grain corn. J. Plant Nutr. 2022, 46, 3002–3017.
15. Karmakar, S.; Prakash, P.; Chattopadhyay, A.; Dutta, D. Zinc Sulphate and Vermicompost Mitigate Phytotoxic Effects of Arsenic by Altering Arsenic Uptake, Biochemical and Antioxidant Enzyme Activities in Wheat (*Triticum aestivum* L.). Russ. J. Plant Physiol. 2021, 68, S72–S81.
16. Khalifa, T.H.; Mariey, S.A.; Ghareeb, Z.E.; Khatab, I.A.; Alyamani, A. Effect of Organic Amendments and Nano-Zinc Foliar Application on Alleviation of Water Stress in Some Soil Properties and Water Productivity of Barley Yield. Agronomy 2022, 12, 585.
17. Khalifa, T.H.; Mariey, S.A.; Ghareeb, Z.E.; Khatab, I.A.; Alyamani, A. Effect of Organic Amendments and Nano-Zinc Foliar Application on Alleviation of Water Stress in Some Soil Properties and Water Productivity of Barley Yield. Agronomy 2022, 12, 585.
18. Khalifa, T.H.; Mariey, S.A.; Ghareeb, Z.E.; Khatab, I.A.; Alyamani, A. Effect of Organic Amendments and Nano-Zinc Foliar Application on Alleviation of Water Stress in Some Soil Properties and Water Productivity of Barley Yield. Agronomy 2022, 12, 585.
19. Kovácik, P.; Renco, M.; Šimanskỳ, V.; Hanácková, E.; Wisniowska-Kielian, B. Impact of vermicompost extract application into soil and on plant leaves on maize phytomass formation. J. Ecol. Eng. 2015, 16, 143–153.

20. Kovácik, P.; Renco, M.; Šimanskỳ, V.; Hanácková, E.; Wisniowska-Kielian, B. Impact of vermicompost extract application into soil and on plant leaves on maize phytomass formation. J. Ecol. Eng. 2015, 16, 143–153.
21. Lazcano, C.; Domínguez, J. The use of vermicompost in sustainable agriculture: Impact on plant growth and soil fertility. Soil Nutr. 2011, 10, 187.
22. Lirikum; Kakati, L.N.; Thyug, L.; Mozhui, L. Vermicomposting: An eco-friendly approach for waste management and nutrient enhancement. Trop. Ecol. 2022, 63, 325–337.
23. Maurya, S.K.; Meena, R.; Meena, R.N.; Meena, R.K.; Ram, B.; Verma, M.K.; Rai, A. Effect of mulching and organic sources on growth parameters and yield of pearl millet (*Pennisetum glaucum* L.) crop under rainfed area of Vindhyan region, India. J. Pure Appl. Microbiol. 2015, 9, 351–355.
24. Maurya, S.K.; Meena, R.; Meena, R.N.; Meena, R.K.; Ram, B.; Verma, M.K.; Rai, A. Effect of mulching and organic sources on growth parameters and yield of pearl millet (*Pennisetum glaucum* L.) crop under rainfed area of Vindhyan region, India. J. Pure Appl. Microbiol. 2015, 9, 351–355.
25. Nayak, M.; Swain, D.K.; Sen, R. Strategic valorization of de-oiled microalgal biomass waste as biofertilizer for sustainable and improved agriculture of rice (Oryza sativa L.) crop. Sci. Total Environ. 2019, 682, 475–484.
26. Ozyazici, G.; Turan, N. Effect of vermicompost application on mineral nutrient composition of grains of buckwheat (Fagopyrum esculentum m.). Sustainability 2021, 13, 6004.
27. Ozyazici, G.; Turan, N. Effect of vermicompost application on mineral nutrient composition of grains of buckwheat (Fagopyrum esculentum m.). Sustainability 2021, 13, 6004.
28. Pathma, J.; Sakthivel, N. Microbial diversity of vermicompost bacteria that exhibit useful agricultural traits and waste management potential. SpringerPlus 2012, 1, 26.
29. Satyavathi, C.T.; Ambawat, S.; Khandelwal, V.; Srivastava, R.K. Pearl Millet: A Climate-Resilient Nutricereal for Mitigating Hidden Hunger and Provide Nutritional Security. Front. Plant Sci. 2021, 12, 659938.

30. Sengupta, S.; Bhattacharyya, K.; Mandal, J.; Bhattacharya, P.; Halder, S.; Pari, A. Deficit irrigation and organic amendments can reduce dietary arsenic risk from rice: Introducing machine learning-based prediction models from field data. Agric. Ecosyst. Environ. 2021, 319, 107516.
31. Shen, Z.; Yu, Z.; Xu, L.; Zhao, Y.; Yi, S.; Shen, C.; Wang, Y.; Li, Y.; Zuo, W.; Gu, C.; et al. Effects of Vermicompost Application on Growth and Heavy Metal Uptake of Barley Grown in Mudflat Salt-Affected Soils. Agronomy 2022, 12, 1007.
32. Shenoy, H.; Siddaraju, M.N. Effect of integrated nitrogen management through organic and inorganic sources on the yield of rice (*Oryza sativa* L.) and status of soil fertility at harvest. J. Appl. Nat. Sci. 2020, 12, 721–727.
33. Shenoy, H.; Siddaraju, M.N. Effect of integrated nitrogen management through organic and inorganic sources on the yield of rice (*Oryza sativa* L.) and status of soil fertility at harvest. J. Appl. Nat. Sci. 2020, 12, 721–727.
34. Shukla, L.; Tyagi, S.P.; Manjunath, R.; Kumar, J.; Saxena, A.K. Effect of vermicompost and microbial inoculants on soil health, growth and yield of HD 2687 wheat (*Triticum aestivum*). Indian J. Agric. Sci. 2013, 83, 340–343.
35. Singh, S.; Misal, N.B. Effect of Different Levels of Organic and Inorganic Fertilizers on Maize (Zea mays L.). Indian J. Agric. Res. 2022, 56, 562–566.
36. Souffront, D.K.S.; Salazar-Amoretti, D.; Jayachandran, K. Influence of vermicompost tea on secondary metabolite production in tomato crop. Sci. Hortic. 2022, 301, 111135.
37. Vyas, P.; Sharma, S.; Gupta, J. Vermicomposting with microbial amendment: Implications for bioremediation of industrial and agricultural waste. BioTechnologia 2022, 103, 203–215.
38. Zahra, A. Benefits of Vermicomposting and Why It's The Future. 2021. Available online: https://blog.mywastesolution.com/ benefits-of-vermicomposting-and-why-its-the-future/ (accessed on 17 October 2023).
39. Zaremanesh, H.; Nasiri, B.; Amiri, A. The effect of vermicompost biological fertilizer on corn yield. J. Mater. Environ. Sci. 2017, 8, 154–159.
40. Zaremanesh, H.; Nasiri, B.; Amiri, A. The effect of vermicompost biological fertilizer on corn yield. J. Mater. Environ. Sci. 2017, 8, 154–159.