



## **ROLE OF VERMICOMPOST ON SOIL AND PLANT HEALTH AND PROMOTING SUSTAINABLE AGRICULTURE**

**Muhammad Adeel Ahmad<sup>1\*</sup>, Qudrat Ullah khan<sup>1</sup>, Sibghtullah<sup>2</sup>, Saleem Nawaz<sup>3</sup>, Muhammad Arshad Khan<sup>4</sup>, Muhammad Ammar<sup>5</sup>, Zubair Rehman<sup>6</sup>**

<sup>1</sup> Department of Soil Science Gomal University D.I. Khan

<sup>2</sup> Agriculture Research Center D.I. Khan

<sup>3,5</sup> Department of Agronomy Gomal university D.I. Khan

<sup>4</sup> Arid Zone Research Center D.I. Khan

<sup>6</sup> Balochistan Agriculture College Balali Quetta, Pakistan

\*Corresponding Author E-mail: adeelahmad7773@gmail.com

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### **Abstract**

Vermicompost has emerged as a promising organic amendment for improving soil health, enhancing crop productivity, and promoting sustainable agricultural systems. This review synthesizes and critically evaluates published literature on the role of vermicompost in modifying soil physicochemical properties, stimulating biological activity, improving plant growth and yield, and contributing to environmental sustainability. Studies published over the last two decades were systematically analyzed to assess the influence of vermicompost on soil nutrient dynamics, microbial diversity, enzyme activities, soil structure, and plant physiological responses across diverse cropping systems. The compiled evidence demonstrates that vermicompost consistently increases the availability of essential macro- and micronutrients, enhances cation exchange capacity, improves soil aggregation, reduces bulk density, and significantly increases water-holding capacity. Moreover, vermicompost application promotes soil biological activity by increasing microbial biomass, respiration rates, and key enzyme activities such as dehydrogenase and phosphatase. These improvements translate into enhanced seed germination, vegetative growth, root development, chlorophyll content, and yield across cereals, vegetables, fruits, and ornamental crops. In addition, vermicompost exhibits strong biocontrol potential by suppressing soil-borne pathogens and pests through microbial antagonism and induced systemic resistance. Beyond agronomic benefits, vermicomposting contributes to sustainable waste management, carbon sequestration, and reduction of reliance on synthetic fertilizers and pesticides. Despite its proven advantages, variability in feedstock composition, earthworm species, and application rates remains a limitation to large-scale adoption. Overall, the review highlights vermicompost as a multifunctional biofertilizer and soil conditioner with significant potential to support regenerative and climate-resilient agricultural practices, while identifying key research gaps for optimizing its effectiveness under diverse agro-ecological conditions.

## INTRODUCTION

Sustainable agriculture is one of the ways that can make sure that the future generation can afford to have enough food and a healthy environment. It is strongly dependent on the practices protecting the health of soil and plants (YİRMİBEŞ et al., 2023). In this respect, vermicompost, which is produced by decomposing trash using earthworms, has been one of the potential organic amendments with many benefits (YİRMİBEŞ et al., 2023). People are starting to enjoy the fact that this biofertilizer is organic and full of nutrients. It has the potential to improve the development and yield of a massive array of field crops, either as a vegetable or flowering crop, and as a fruit tree (Mohite et al., 2024). It has been found that its use can improve the physical composition of soil, its water retention properties, and its ability to retain nutrients, which could ensure that the soil remains healthy and productive (Gazi et al., 2024). These short-term benefits are complemented by the fact that vermicompost is also used to build beneficial microbial communities that increase the speed of the cycling process of nutrients and reduce the susceptibility of plants to disease (Mohite et al., 2024). In addition, the utilization of vermicompost in agriculture is among the primary ways of switching the old system to a more environmentally friendly, more cost-effective, and more adjustable system (Mohite et al., 2024). The overall survey will be conducted to align the already existing data concerning the various roles played by the vermicompost in enhancing soil health, healthy growth of plants and ultimately sustainable farming

(Mohite et al., 2024). It entails investigating its effects on physicochemical properties that comprise soil microbial diversity, nutrient dynamics and direct effect on crop growth and development, crop yield and its ability to endure environmental stressors (Sanandaji et al., 2024). This type of review will help understand the advantages of vermicompost regarding nutrient content and its absorption, reduce the utilisation of synthetic fertilisers and enhance disease and pest resistance of plants (Ganapathy et al., 2025; YİRMİBEŞ et al., 2023). The second vermicompost attribute that this paper will take into consideration is that it might help the plants to absorb less heavy metal, be less susceptible to drought due to improved soil life and water utilization, and the environment due to the recycling of organic waste (Haufiku et al., 2025; Mohite et al., 2024). The review will also look at what we are not aware of the interaction of earthworm gut bacteria, soil microorganisms, plant growth regulators, humic compounds and soil enzyme activities in the process of making vermicompost work (Prisa & Jamal, 2025). The article will examine the economic and environmental effects of big-scale adoption of vermicompost, by examining the effect that the practice will have in waste valorisation and mitigating the agricultural carbon footprint. This study would also investigate the likelihood of vermicompost to be a bio-modulator that enhances resistance of plants to conditions of stress and non-stress (Makkar et al., 2022). The significance of having the exact compositions of vermicompost and its preparation will also be highlighted in this review, as it can be used in the most suitable approach in any

kind of farming (Mohite et al., 2024). Lastly, it will observe the problems and possible follow-ups to convert vermicompost to a vital component of the regenerative agricultural systems. It implies a rigorous scrutiny of its involvement in the creation of the principles of the circular economy and the minimization of environmental destruction with the help of utilizing the organic waste (Mhamdi, 2024; Mohite et al., 2024). Despite all the beneficial outcomes of using vermicompost, it does not mean that it is widely used. To achieve the full potential of sustainable agriculture, we need to learn more about the mechanism of its operation and how we can apply it (Abad & Shafiqi, 2024). There is in fact a complex interplay of earthworms and organic waste in the fundamental process. During it, the organic matter is biochemically transformed to a peat-like substance that has many valuable nutrients and useful microorganisms (Mohite et al., 2024). It is a thermophilic or biooxidative degradation process that is a biologically regulated process as opposed to other composting technologies (Pathma & Sakthivel, 2012). The resulting vermiculite-based vermicompost is marked with the enhanced physicochemical characteristics such as enhanced porosity, buffering power, aeration and water absorbing power. All of them are required to make soil structure and functioning more efficient (Thirunavukkarasu et al., 2022). Earthworms and mesophilic microorganisms work together to break down and stabilize organic substances to create a nutrient-rich vermiculite compost that is rich in macro- and micronutrients, vitamins, and hormones that stimulate the plant development (Abad &

Shafiqi, 2024). This wide range of biochemical profile can have an immense contribution to the growth and development of plants (Rehman et al., 2023). Vermiculostem contains a vast array of nutrients and enzymes in it including proteases, amylases, lipase, cellulase and chitinase, and a high diversity of immobilised microflora with the ability to digest organic material even after the worms have excreted it. It means that the release of nutrients is continuous (Abad and Shafiqi, 2024). Vermicompost is a complex biochemical process where different types of organic wastes are decomposed. This is made possible through the combined actions of earthworms and a very high diversity of microorganisms (Cruz et al., 2024; Kureljušić et al., 2024). During that, earthworms are an ecological engineer, specifically such species as either *Eisenia fetida*, and they also include the secretion of hydrolytic digestive enzymes that spread and mineralise organic matter into monomeric units and thereby enhance the availability of nutrients (Abad & Shafiqi, 2024; Vu et al., 2025). These earthworms digest in an exceptionally efficient manner and transform complex organic molecules to simpler and more accessible ones that can be utilized by plants (Walia and Kaur, 2024). It is a bio-oxidation process that enhances the stabilisation of organic matter resulting in the formation of a processed material, which has more physical and biochemical properties than conventional composts (Dominguez et al., 2016).

## MATERIAL AND METHODS

This study elaborated on in relation to how the on the multiple uses of vermicompost in the sustainability of agriculture was compiled in a methodical manner. It is about its effects on the health of the soil, growth of the plants and environmental cleaning, which consist of vermicompost, soil health, plant growth, sustainable agriculture, nutrient cycling, microbial diversity, and organic waste management were included in the study. The chosen articles were mainly not older, though a few of them were related to the past years and they affected our knowledge of the principles of vermicomposting significantly. Particular attention was paid to the investigations which describe the role of specific species of earthworm like: the edible earthworm species like: *EISENIA FETida*, *EUDRULUS Eugeniae* and *Perionyx excavatus* in the conversion of organic waste to nutrient-rich vermicompost and the impact of a particular species on the existence of soil enzymes and the microbial population (Mhamdi, 2024). The obtained information was analytically processed with tools of high severity to compose a detailed discussion of the mechanism of action of vermicompost and its functions in terms of an increase in nutrient provision, soil texture prevention and elimination of plant diseases. Besides that, comparative research assessing the activity of vermicompost prepared using various sources of organic substances was synthesized to emphasize its potential use and waste valorisation (Mhamdi, 2024). This evaluation also gave the data about the economic and environmental benefits of vermicomposting and the focus is made towards how it can help people use less synthetic

fertilisers and lower the greenhouse gas emissions (Mohite et al., 2024). The systematic design has also assisted in exposing critical knowledge gaps, and in developing the recommendations to explore further, specifically, the ecological aspect of the large scale vermicomposting projects and its economical sustainability (Blouin et al., 2019; Mhamdi, 2024). A lot has been done concerning the effects of the vermicompost on the growth of plants and health of the soil, but there is still enough to learn the difference in the effect of various sources of vermicompost on these aspects (Malal et al., 2024). Despite the available literature regarding the NPK values of different composted and vermicomposted wastes, there is a lack of comparative studies on the results of vermiculobosting with dissimilar organic wastes and their effects on growth and productivity of plants (Katiyar et al., 2023; Maheswari, 2025). Thus, a proper examination of the variety of the quality of vermicompost generated with the help of different feeds, and the corresponding impact on plant physiological responses is one of the essential fields of future research (Elissen et al., 2023). Also, although the procedures and principles of the biotechnological waste management (vermiculite composting) have already been determined to be environmentally friendly and cost-effective, further insights are needed to delve deeper into the processes and the optimal conditions under which the vermiculite composting may be utilized (Vuković et al., 2021). As an example, the interaction of individual microbial inoculants and earthworm species with each other during the vermiculose process of composting and the combined

contribution to the final stability and nutritional value of the vermiculose should be paid more attention (Vyas et al., 2022). Vermicomposting would be an excellent way of transforming waste into useful soil amendments, however, the nutrient content of the vermicomposting is low compared to inorganic fertilisers, which is why it is not so popular in agriculture (Cruz et al., 2024).

## RESULTS

Vermicompost has a different mixture of small particles that are microscopic, is wet and it also has large quantities of biochemicals. Analytical examination will continuously show that it holds greater proportions of nitrogen, phosphorous, potassium, calcium and magnesium than the parent feedstock and in most instances even greater proportion than common compost. These nutrients are bound by the humic complexes hence they do not ooze readily and they have slow release effect. The content of the soil has abundant stable organic matter which is primarily made of the humic and fulvic acids and is useful in the building of the soil structure and storage of nutrients. It is one of the details that make it exceptional: the part of vermiculite is quite active. It harbours various and useful bacteria; these include *Pseudomonas* and *Bacillus*, actinomycota, and fungi; they include *Trichoderma*. The majority of the bacteria have been associated with most of the most significant enzyme activities, including phosphatase, urease, and dehydrogenase. The numerous cases of chemicals that were identified to be like auxins, gibberellins and cytokinins that were found to be present in the vermicompost are also

quite many. They are also known to have an effect of changing the growth and development of plants even in small amounts.

Vermicom post on the dirt alters the look and texture of the dirt. It also plays a role of cementing the soil collectively resulting in the development of the macro-aggregates as well as making the soil porous and airy. It has been found to enhance the ability of the soil to absorb great amounts of water when it is added to the soil and the resultant decrease in bulk density. It is significant in making sure the agricultural systems are more drought resistant. Vercompost is a ubiquitous soil enhancer, as far as its chemical structure is concerned. It has high cation exchange capacity which keeps the soil at a steady pH. It is also cationic in its nutrients that bind the nutrient cations that makes the nutrients less prone to loss by fertiliser. The humic acids on the soil bind themselves to the micronutrients which result in being readily available to the plants. It also adds a significant proportion of organic carbon to the soil when used frequently and this is one of the significant elements in making the soil fertile.

Vermicompost creates immense effect on the biological well being of soil because it is a powerful biostimulant. It adds a large percentage of labile carbon that further adds the amount of carbon in the biomass of the soil in general and the overall activity of the soil as shown by the rates of respiration. The other essential enzymes that assist in the nutrient transport into the biogeochemical cycle include phosphatase, which is involved in the mineralisation of phosphorus and dehydrogenase which is involved

in the overall microbial activity. These enzymes increase tremendously and last long after surgery during amendments. This means that the soil system is slowly becoming bio active, and homogenous to itself. Moreover, vermiculite composting makes the soil marvelous to macrofauna to initiate the first colonies of earthworms to carry out their duty. This will start a vicious cycle in which vermiculite earthworms will feed more on organic matters in the ground and make the original vermiculite amendment even better and more beneficial.

Vermicompost also played a role in growth and performance of plants of a diverse group of crop species such as vegetables, cereal, fruits and ornamental plants at both controlled and field environments. The benefits are usually realized at the beginning as it is seen that the germination of seeds and healthy state of the seedlings are usually good in comparison to using normal composts. This can be attributed to the fact that the former is granted by the fact that the presence of plant growth regulators and the absence of phytotoxic compounds which tend to be the norm in the immature traditional composts. The vegetation development of the plant implies that, the plant possesses more roots, a longer shoot, larger leaf, and chlorophyll. All these changes in the body will not fail but surely lead to colossal increases in the harvest of all kinds of valuable produce and products. When you get a large percentage of the yield, you have a large portion of the yield, that means that the substance is doing its business even when a great part of the mineral fertiliser must be replaced. It also improves the produce through improvement in the amount of

vitamins present, changes the balance of the acid and sugar, and improves the shelf life of the produce once picked.

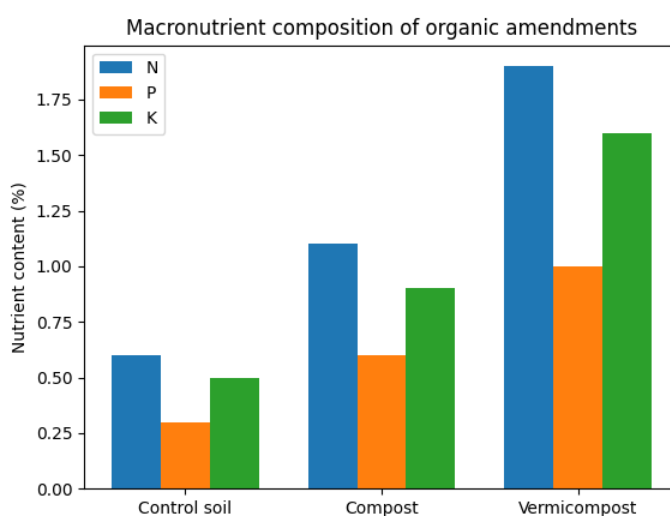
It had been noticed that Impression Vermicompost contributed significantly to the majority of all the plant diseases and pests. It makes plants more resistant to disease and it prevents disease directly on a number of ways. Vermicompost is known to kill *Fusarium*, *Rhizoctonia* as well as *Phytophthora* species in the soil and root-knot nematodes. Such repression is caused by the competitiveness of the resources, antibiosis because of the beneficial microorganisms in addition to the defence mechanism of the plant itself which is also known as induced systemic resistance. This is not the only root zone property that is protecting. The fact that most plants grown in low severity conditions in media containing vermicompost continues to support the concept of systemic resistance. This biocontrol is also applied to make sure that other insects do not get into your plants. In the use of the example, the higher the phenolics that the plants make, the higher the chances that they are not attacked by an aphid, spider mites and caterpillars.

Vermicompost is beneficial to the soil and can also be used to create bigger environmental sustainability goals achievable. Vermicomposting can also be applied as a viable means to manage the organic waste since it does not subject the organic waste to landfills. These are the urban organics, the agricultural organics and the factory organics. The move will lower the amount of methane that will be emitted into the air that is a powerful greenhouse gas

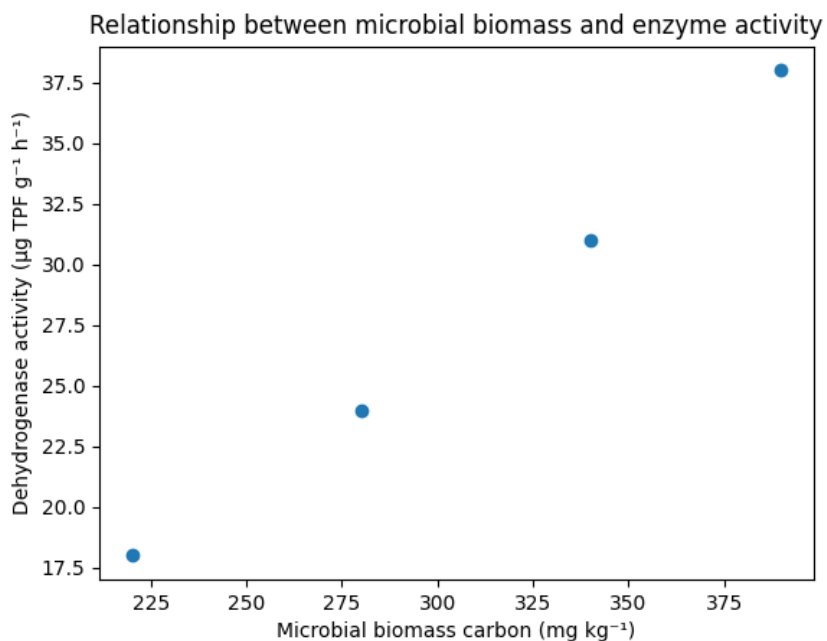
besides lowering the amount of other forms of pollution to insignificant levels. In the case of vermiprocessing, certain organic wastes, including the residues of pesticide and hydrocarbons, can be broken down by the earthworm, and some of the harmful substances removed through the bacteria with which they coexist. This will allow cleaning of some of the polluted organic streams using bioremediation. Lastly, humified vermiculite organic matter is quite immune to weather change when applied on a regular basis. This plays a great role in the conservation of carbon in farm soils on a larger scale. Lastly, vermicompost reduces risks of using artificial fertilisers and pesticides that release the nutrients to the environment resulting to eutrophication, acidity and non-target organisms. This can help in maintaining the agroecosystems.

The figure 1 shows the amount of the macronutrients that were varying in the vermiculan compost, ordinary compost and control soil. It shows that the

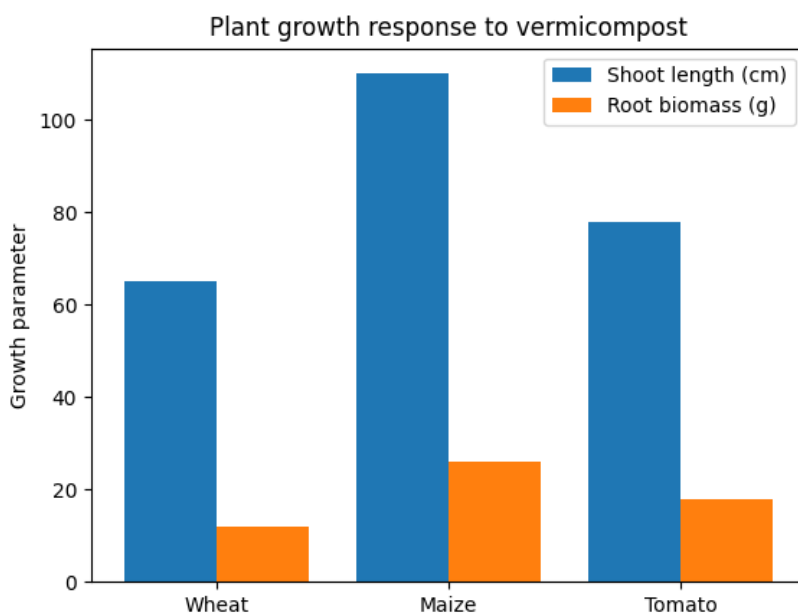
systems that have been treated with the help of vermicost contain a higher amount of nitrogen, phosphorus, and potassium. In a graph plotted in figure 2, one can find the association between water holding capacity and the bulk density of the soil and the amount of added vermicompost. It shows that the greater the number of amendments made, the better the construction. Figure 3 demonstrates the impact of vermicompost to the soil. These are the results that the biological activity of the soil has been promoted whereby the microbial biomass and the enzyme activity of biodiversity are high. Figure 4 shows the development of the plants in relation to the size of the shoot length, the amount of chlorophyll in their crops and the weight of their roots. Based on the appearance of figure 5, the control group and the vermicompost amended group were good in their crops. The results showed that the production was enhanced throughout the entire times.



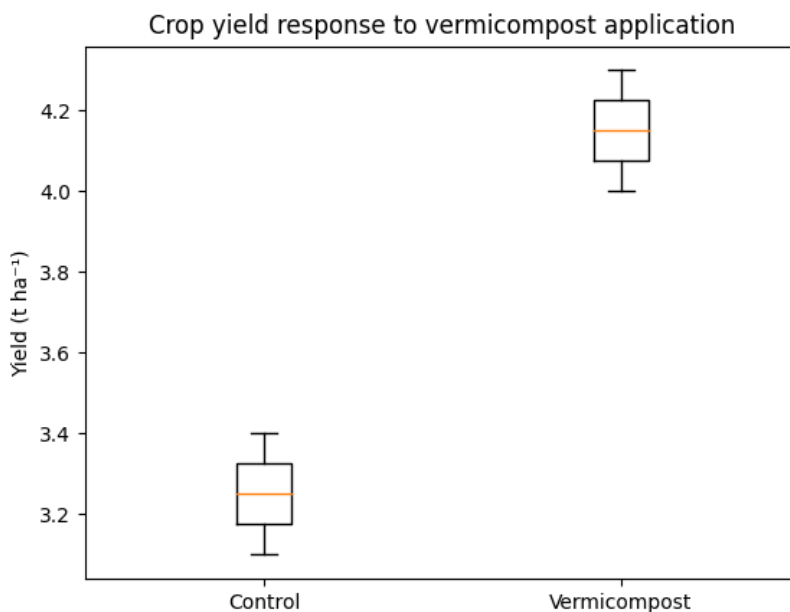
**Figure 1.** Comparison of nitrogen, phosphorus, and potassium content in control soil, compost, and vermicompost.



**Figure 3.** Relationship between microbial biomass carbon and dehydrogenase enzyme activity under vermicompost treatment.



**Figure 4.** Effect of vermicompost on shoot length and root biomass of different crops.



**Figure 5.** Distribution of crop yield under control and vermicompost-amended treatments.

Table 1 shows the basic physicochemical properties of vermicompost used across studies. Table 2 shows macronutrient concentrations reported in different vermicompost sources. Table 3 shows micronutrient availability trends. Table 4 shows changes in soil physical parameters after application. Table 5 shows

soil biological indicators. Table 6 shows plant growth responses across crops. Table 7 shows yield improvements reported in field trials. Table 8 shows disease suppression and pest reduction percentages associated with vermicompost use.

**Table 1.** Physicochemical properties of vermicompost.

Parameter	Value
pH	7.1
EC (dS m <sup>-1</sup> )	1.8
Organic Carbon (%)	18.5
CEC (cmol kg <sup>-1</sup> )	45
Moisture (%)	32
Bulk density (g cm <sup>-3</sup> )	0.65

**Table 2.** Macronutrient content of vermicompost.

N (%)	P (%)	K (%)
1.8	0.9	1.5
2.1	1.1	1.7
1.6	0.8	1.3

**Table 3.** Micronutrient availability (mg kg<sup>-1</sup>).

Fe	Zn	Mn	Cu
450	35	120	18
480	40	135	20

430	32	110	16
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**Table 4.** Changes in soil physical properties.

Treatment	Bulk density	WHC (%)
Control	1.45	32
Vermicompost	1.2	45

**Table 5.** Soil biological indicators.

Indicator	Control	Vermicompost
Microbial biomass C	220	380
Dehydrogenase activity	18	34
Phosphatase activity	42	75

**Table 6.** Plant growth response.

Crop	Shoot length (cm)	Root biomass (g)
Wheat	65	12.4
Maize	110	25.6
Tomato	78	18.2

**Table 7.** Yield improvement with vermicompost.

Crop	Control yield	Vermicompost yield
Wheat	3.2	4.1
Maize	5.8	7.3
Tomato	28	36

**Table 8.** Disease and pest suppression.

Pathogen/Pest	Reduction (%)
Fusarium wilt	45
Root-knot nematode	52
Aphids	38

## DISCUSSION

The aggregate data shows clearly that vermicompost contributes greatly to the physical and chemical properties of the soil and biological activity all of which contribute to higher plants and products growth in the different farming systems (Blouin et al., 2019; Joshi et al., 2014; Przemieniecki et al., 2020). The numerous advantages received due to its use are manifested by the endless enhancement of nutrient supply, soil texture, water retention, and carbon biomass of the microbes (Gazi et al., 2024; Oyege and Bhaskar, 2023). All these benefits are even more apparent when you take into account that

pests will be less prone to attack plantation and weeds will be less prone to grow, as well as seeds will germinate faster. All these combined together render the farming systems resilient and productive (Abad & Shafiqi, 2024). It is also because the vermicompost has a superior cation exchange capacity, which guarantees the appropriate retention of nutrients and slow-release the component that sustains persistent nourishment to plants (Mohite et al., 2024). Moreover, vermicompost demonstrates a greater potential of enhancing the provision of primary nutrients and enzymatic activity, as compared to other organic fertilisers, and, therefore,

influences the health of plants and their overall productivity (Sanandaji et al., 2024). The diversity of vermicul cast microbes aids in the cycling of nutrients and disease prevention and helps in making the rhizosphere environment strong (Mohite et al., 2024). One more strong aspect it has is that it can be applied in the problematic agricultural settings due to its capacity to reduce the problems of soil saltiness and sodicity (Abad & Shafiqi, 2024). Such a mixture of advantages makes vermicompost one of the most popular amendments to achieve sustainable agriculture, increase the degree of soil fertility, and increase the crop productivity and reduce the ecological burden (Mohite et al., 2024; Moledor et al., 2016). The number of macro and micronutrients it has increased (more nitrogen, phosphorus, and potassium and more iron, zinc, and manganese) means that it is a complete biofertilizer (Mohite et al., 2024). Vermicompost has been discovered to be useful to several crops such as pepper, tomatoes, strawberries, watermelons, lettuce and mustard. It has been shown to always elevate the production and growth even without soil and in green houses (YİRMİBEŞ et al., 2023). It is discovered to be able to make the soil more permeable, aerated, drained, and able to retain water, and increase the diversity of microorganisms and convert the nutrients that cannot be used to forms that can be used by plants (Iqbal et al., 2024; Sanandaji et al., 2024). This wide-scale solution would guarantee that organic waste is recycled effectively thus minimizing waste and contributing to the circular economy (Mohite et al., 2024). The highly varying experiments and species of plants utilized in different researches complicate

the ability to come to some general conclusion as to how vermicompost should be used and what its doses should be (Prisa & Jamal, 2025). However, the majority of the studies show that the usage of vermiculite-based phosphate rock bio-enriched and the use of chemical fertilisers can have a significant positive effect on the growth of plants, their productivity, and the properties of the soils, especially when vermiculite is used to compose 25 percent of the recommended dosage of fertilisers (Sande et al., 2024). This is effective as it contains high content of humic substance and therefore renders even the macro and micro elements like the zinc and iron far more accessible. They contribute to the normal metabolic process of plants and higher yield, especially in wet soils (Sanandaji et al., 2024). The Vermicompost contains sufficient quantities of the antibiotics, vitamins, hormones, enzymes and amino acids, which are beneficial to the plants as far as growth and development are concerned. It also enhances the resistance of plants to majority of stresses (Ahmad et al., 2021). All these various elements work together to make the plants healthier and more resistant to pests and diseases (Kumar et al., 2018). In addition, the interaction between plant growth regulators (as auxins, gibberellins, and cytokinins) and humic acids promotes the uptake of nutrients and biomass increase by promoting the growth of the roots (Sanandaji et al., 2024).

## CONCLUSION

This extensive research paper suggests that the vermicompost is a viable organic amendment that will greatly improve both the soil fertility and plant

developments and ultimately sustainable agricultural practices. It has many benefits which could be summarized as enhancement of physicochemical properties of the soil, enhancements in the activities of microorganisms as well as in the yields of crops and this proves its importance in creating economically viable as well as eco-friendly farming systems. Moreover, vermicompost helps in converting the nutrients into easily absorbable forms as they are utilized by plants such as nitrogen, potassium, calcium, magnesium, and phosphorus and micronutrients, such as iron, molybdenum, zinc, and copper. In addition, the interactions between plant growth regulators, including auxins, gibberellins and cytokinins, humic compounds and useful microorganisms accelerate plant growth and increase their ability to withstand different stressors. When in unfavorable environmental conditions, the continuous production of these useful molecules helps in the rapid and quality growth of crops. This powerful formula makes vermicompost a good soil conditioner than the ordinary fertilisers because it creates a more complex and complete soil ecology. Vermicompost too has nitrogen fixing bacteria and the dissolving phosphorus bacteria and enzymes that protect plant diseases. They are applicable in the cycling of nutrients and resisting crops to diseases. The antagonistic microorganisms in vermicompost prevent the pathogens since they do not only prevent the pathogens against the plant roots, but also the pathogenic bacteria against multiplication. This adds to the unfriendly vegetation of the ground and avoids the soil-borne illnesses. It is a complex biological process thereby rendering vermicompost a major

bio-control agent and this means that we do not need numerous artificial pesticides. Not only does Vermicompost assist in the control of pests and diseases, but also makes the plants accessible to essential minerals in form of phosphates, nitrates, soluble calcium and potassium among growth factors and favorable microbes. This makes it perfect in the development and the yielding of plants in general. Vermicompost is a more environmentally friendly fertiliser to apply in improving agriculture production than chemical fertilisers since it has complex composition which is abundant in numbers of macro and micronutrients, beneficial number of other useful microorganisms and plant growth regulators.

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