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Biofortification of Vermicompost with Beneficial Microorganisms and Its Field Performance in Horticultural Crops

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Abstract:

Background of problem: *Traditional vermicompost may be unable to provide the ideal nutritional balance for certain horticultural crops. It might be challenging to predict how well crops will perform when vermicompost batches have varying nutritional amounts. Traditional vermicompost may not necessarily include a wide enough range of microorganisms to support strong plant growth and effectively ward soil-borne diseases. Crops used for horticulture have specific nutrient requirements and are more susceptible to pests and diseases. The existing field of vermicompost biofortification, emphasize the critical role Trichoderma and other beneficial microbes play in increasing the potency of this organic fertilizer. Vermicompost, a nutrient-rich byproduct of organic waste decomposition mediated by earthworms, contributes significantly to soil fertility and plant nutrition. However, it typically lacks the proper balance of nutrients. Trichoderma and other beneficial bacteria in vermicompost can enhance nutrient intake, promote robust plant development, and boost resistance to pests and diseases. Microbes enhance nutrient biofortification in crops, focusing on its effect on uptake in horticultural crops. This research discusses how Trichoderma stimulates growth and solubilizes minerals, increasing their availability for plants. The broader impacts of vermicompost biofortification with different microbes include impoved soil health, sustainable agriculture, and lowering dependency on synthetic fertilizers. The interaction between different microbes, vermicompost and the implications for nutrient-dense crops and sustainable food production are significant.*

Keywords: Beneficial microorganisms, biofortification, field performance, horticultural crops, vermicompost.

Introduction

Vermicompost can be biofortified with advantageous microorganisms to increase the effectiveness of the fertilizer. *Mycorrhizal* fungi, plant growth-promoting rhizobacteria (PGPR), and other helpful microbes can help to improve intake of nutrients, boost plant development, and improve plant resistance to pests and diseases (Fasusi *et al.,* 2021). Vermicompost is an organic fertilizer made when earthworms break down organic materials. It helps increase soil fertility and structure and is a great source of nutrients for plants (Thakur *et al.,* 2021). Vermicompost simply does not always offer the right balance of nutrients and helpful microbes for optimum plant growth. Vermicompost that has been biofortified increases crop yields and quality. Vermicompost that has been biofortified has been shown to increase plant height, improve fruit yield, size, and quality, and improve plant pathogen resistance in horticulture crops (Sharma *et al.,* 2022). Vermicompost biofortification with beneficial microorganisms is a promising approach for sustainable agriculture that can help to enhance soil health, boost production of crops, and decrease the usage of synthetic fertilizers and pesticides (Rehman *et al.,* 2023). Vermicompost is increasing in popularity as a soil amendment in horticultural crop production systems because it has a number of advantages over traditional fertilizers (Sindhu *et al.,* 2020).

Vermicompost can increase nutrient availability, water-holding capacity, and soil structure, which may contribute to better plant growth and production (Devi *et al.*, 2022). Additionally, the advantageous microorganisms in vermicompost may help in nutrient absorption and utilization by producing hormones and enzymes that reduce soil-borne plant diseases and promote plant growth. Vermicompost is improved to enhance soil health and promote the growth of plant cuttings (Tammam *et al.*, 2023). The effects of adding various beneficial microbes, such as nitrogen-fixing bacteria, *mycorrhizal* fungi, and *rhizobacteria* that promote plant growth, rooting and growth performance of plant cuttings. Studies have shown that vermicompost works as a soil amendment in horticulture (Bizos *et al.*, 2020). Biofortified vermicompost has been shown to improve the growth and survivability of pomegranate and peach cuttings (Tóthné *et al.*, 2021). Various studies have shown the positive effects of vermicompost supplemented with microbial consortia on shoot and root length, fresh and dry weight, leaf area and chlorophyll content of plant cuttings (Toubali *et al.*, 2020). These variations include the lack of the pathogen-reducing thermophilic phase in vermicomposting, different moisture content requirements that are higher for vermicomposting, and variations in end- product quality, with vermicomposting exhibiting more favorable effects on the physical characteristics of the soil as well as plant growth (Ozdemir *et al.,* 2023).

In horticulture crops, vermicompost biofortification utilizing beneficial microorganisms has shown remarkable results. The natural process of vermicomposting uses earthworms and their associated microbiome to transform organic wastes into this nutrient- and microorganism-rich substance. Vermicompost has been shown to increase the diversity and activity of antagonistic bacteria and nematodes, which promotes crop growth and production while assisting in the control of pests and diseases caused by soil-borne phytopathogens (Koskey *et al.,* 2020). Modern methods that are based on current research and the ecological processes of nature have emerged because of the endeavor to solve the urgent issues of hunger and sustainable agriculture. Modern breeding, transgenic developments, improved agronomic methods, and microbiological interventions are some of the methods used in biofortification to change the genetic makeup of crops, enhance micronutrient uptake, make sure they are distributed properly in edible tissues, and lower the levels of antinutrients in common foods. The goal is to improve the nutrient bioavailability. (Mishra *et al.*, 2023). Composting technique converts organic waste into vermicompost, a nutrient-rich byproduct, by utilizing the symbiotic relationship between earthworms and the microbiome that they inhabit. Because it not only improves soil quality but also serves as a source of nutrients and beneficial bacteria, this vermicompost is essential for modern agriculture (Koskey *et al.*,2020). This technique makes use of earthworms and the microbiome that goes with them. Because of its potential to enhance plant-microbe-soil interactions and increase crop production yield, liquid vermicompost extract (LVE), a byproduct of the vermicomposting process, has drawn interest (Dhaliwal *et al.*,2022). Vermicompost also contains significant amounts of group B vitamins, auxins, gibberellins, cytokinins, and other physiologically active metabolites, which can boost the yield and quality of a number of crops (Yatoo *et al.,* 2021). The short-term impacts of (LVE) on soil mycorrhizal inoculum potential (MIP) and plant-mycobiome interactions were examined in a field investigation carried out in Italy (Das *et al.,* 2018). Therefore, when beneficial microorganisms are fed to vermicompost, horticultural crops can perform better and plants can grow efficiently (Qurios *et al.*,2014). The use of beneficial microorganisms in vermicompost biofortification has the potential to improve the field performance of horticulture crops and provide a long-lasting, sustainable solution to nutrient deficits (Singh *et al.,* 2015).

Table 1 Effects of different microbes on sprouting and rooting in cuttings:

Microbes	Effect on sprouting	Effect on rooting
Trichoderma **fungi**	--------	-ve
Mycorrhizal **fungi**	+ve	+ve
Bacillus **bacteria**	--------	--------
Pseudomonas **bacteria**	--------	--------
Azotobacter **bacteria**	--------	+ve
Rhizobium **bacteria**	+ve	--------
Auxin**-producing bacteria**	+ve	+ve
Pythium **fungi**	-ve	-ve
Erwinia **bacteria**	-ve	-ve
Phytophthora **fungi**	-ve	-ve
Fusarium **fungi**	-ve	-ve

Different microbes have varying effect on sprouting and rooting of the plants (Table 1). Some microbes show positive effect, some show negative while few have on direct effect on plant growth parameters but may be involved in soil health improvement.
Positive Effects: Mycorrhizal fungi and helpful bacteria are linked to favorable effects on plant sprouting. Strong sprouting, improved root growth, and enhanced nutrient absorption are all facilitated by beneficial microorganisms. In turn, mycorrhizal relationships are facilitated by mycorrhizal fungi, which improve nutrient intake and overall growth (Spark *et al.*,2009).
Negative effects: Soil borne fungus and pathogenic bacteria both harm sprouting. A plant's entire health is compromised by pathogenic bacteria, which also prevent sprouting and produce the disease damping-off. The growth and germination of plants can be hampered by soilborne fungi that cause damping-off and root rot. No Significant Impact: Yeasts often don't have a big impact on how quickly plants sprout. Algae, protozoa, and several other non-beneficial microbes can have a variety of consequences based on their species and the surrounding environment (Dodus *et al.*,2014).

Vermicomposting process and microbial inoculation:
Microorganisms can accelerate the degradation of organic materials, mineralization, and microbial enzyme activity during composting. To improve the efficiency of crops, such as those with a high germination index, microorganisms can be added. The advantages of microbial inoculation on composting agro-industrial waste can serve as a guide for selecting a suitable inoculum based on the kind of waste materials (Zanudin *et al.*,2022). Recently ammonia-oxidizing bacteria (AOBs) have been identified that enhance the humification and decomposition in cow dung compost. The inoculation of MT-AOB-2-4 increased bacterial activity in the composting process and had the highest influence on humic substance synthesis and the efficiency of organic matter breakdown (Xu *et al*.,2021). The biggest challenges to producing compost cheaply are those caused by microbial inoculation's influence on the procedure. Compost with a higher agronomic value is produced when the organic fraction of municipal solid waste (OFMSW) is inoculated. By using *Aspergillus niger* inoculation, the 18-day composting process was cut short, saving money (Heidarzadeh *et al.*,2019).
Different microbial inoculants inoculate goat dung in order to preserve carbon during composting. *Bacillus subtilis, Bacillus licheniformis, Trichoderma viride, Aspergillus niger,* and yeast were the microorganisms employed as inoculums. The B1 treatment had a much larger total organic carbon content than the other two treatments. The B1 treatment also had lower levels of moisture content, pH, EC, hemicellulose, and lignin as well as higher levels of GI value and humic acid carbon (Lu. *et al*., 2021). *Trichoderma and Bacillus* species are affected by the type of vermicompost used in its formulation. Biodiversity was increased with the aid of natural forest microorganisms, and the presence of Actinomyces sp. and *Azotobacter chrooccocum* assisted in reducing the level of heavy metals in the compost. Vermi composting has shown potential for the reuse of organic waste due to its expressive microbiological diversity, which can affect plant growth, suppress infections, and minimize the effects of biotic and abiotic stresses on plant output (Pereira *et al.*, 2022). The improvement of compost quality by the application of microbial inoculants and mineral additives. Dolomite, feldspar, rock phosphate, bentonite, and elemental sulfur were used as the mineral components, and *Trichoderma viride, T. harzianum, Serratia marcescens, Pseudomonas fluorescens,* and *Bacillus polymyxa* were used as the microbial inoculants. The microbial inoculants expedited composting and raised pile temperatures over the course of three days, with Pile 3 reaching the highest temperature of 63°C and the composting process improved the humification process (Gawad and Howeity, 2019). lignocellulosic waste

(LW) and the organic portion of municipal solid waste (OP-MSW) as starting materials for composting, with a focus on the effectiveness of microbial inoculation technology (MI). More important than the effect of MI may be variables like the initial C:N ratio, pH levels, moisture content, and aeration in order to boost composting efficiency. When compared to OP-MSW, MI frequently has a more pronounced positive impact on the composting of LW (Fan *et al.*,2017).

Microorganisms that are useful for biofortification:
Zn is biofortified in wheat by microorganisms that promote plant growth. The *Pseudomonas striata, Bacillus megaterium, and Trichoderma viride* had the highest colony diameter, clearing zone, halozone diameter, solubilization index, and solubilization efficiency. The potential for increasing the nutritional content of wheat crops by increasing zinc biofortification in wheat with the aid of these plant growth-promoting microorganisms as demonstrated in fig.1 (Bagmare and Iasmil,2023). Microbes have the power to promote Se uptake and accumulation in crops through a variety of mechanisms. Beneficial microorganisms can alter the redox chemistry of soil and affect soil properties, boosting Se's bioavailability. Microbes can form roots and encourage plant growth, which aids in Se absorption by plants. Microbes can increase the expression of several genes and proteins linked to Se metabolism in plants.

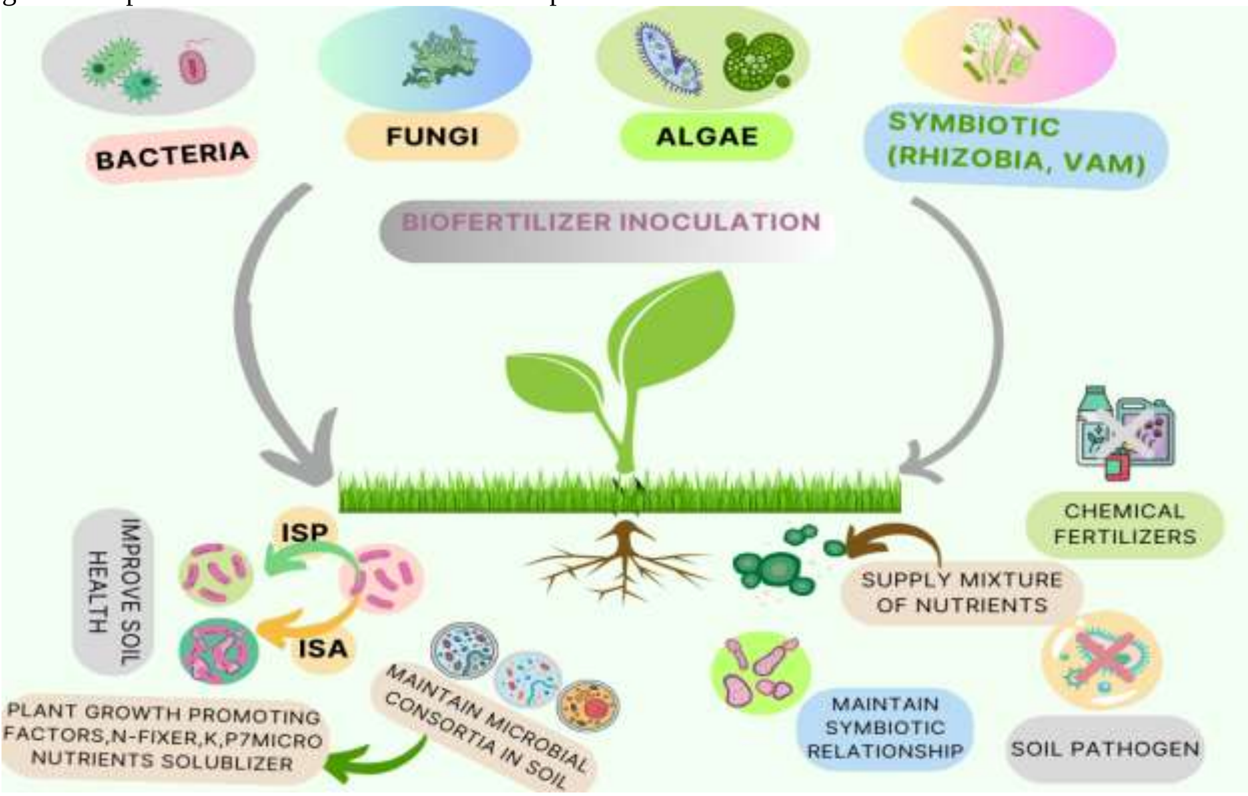

Fig. 1 Influence of biofertilizers on plant growth and soil health.

It is believed that adding microbial supplementation to Se biofortification is both economically and environmentally safe (Yang *et al*.,2021). Microorganisms can be used to increase iron (Fe) and zinc (Zn) availability in edible crops more sustainable than conventional biofortification techniques. Through a variety of mechanisms, including the manufacture of acids, chelators, and phytohormones, the control of micronutrient transporters, and the De-complexing of micronutrients from substances like phytate during postharvest processing, microorganisms can increase the availability of minerals (Verma *et al.*, 2021).
The use of plant growth-promoting microorganisms (PGPM) to improve crop biofortification and increase nutrient uptake in micronutrients. Plant growth-promoting rhizobacteria (PGPR) and plant growth-promoting fungus (PGPF) are two significant classes of PGPM. PGPM will encourage micronutrient uptake in food crops in order to increase the productivity of farmed land, improve food fortification, and solve the problem of hidden hunger (Aadhikari *et al.,*2021). Crop selenium uptake has been increased by selenium biofortification employing helpful microorganisms such mycorrhizal fungi and plant growth-promoting rhizobacteria (PGPRs). It has been discovered that these bacteria boost plant nutrient intake, growth, and yield in addition to increasing tolerance to abiotic challenges including drought and salt stress. PGPRs and mycorrhizal fungi can be used to supplement the soil with selenium, which can improve crop development and yield while preventing

selenium deficiency and protecting human health (Ye *et al.*, 2020). Plant growth, nutritional status, and pathogen assault are all significantly enhanced by biofertilizer fertilization. Biocontrol chemicals efficiently halt the growth of pathogens. Genetic engineering techniques can be used to produce biofortified crops with improved nutritional quality, such as golden rice and soybean crops with increased levels of beta-carotene and stearidonic acid (Khan *et al.*, 2019). Selenium biofortification in crops aims to increase selenium accumulation in edible plants or to increase their bioavailability in order to meet a hidden requirement for essential micronutrients. Rhizobacteria called *Selena Rhizobacteria* can be used as biotechnological tools to enhance plant nutrition and quality and to increase plant development. Due to its critical function in preserving human health, selenium must be moved across soil, crop, and environmental interfaces if human selenium status is to be improved. Selenium can defend plants against abiotic stresses (Patel *et al.*, 2018).

Microbial enrichment of vermicompost:

Vermicomposting is a low-cost, environmentally friendly method for turning organic waste into fertilizer, which is nutrient- and microorganism-rich. *Azospirillum brasilense* and *Rhizobium leguminosarum* are two microbial inoculants were added to vermicompost in order to increase the inoculum amount and adjust time during vermicomposting. In the initial stages of storage, the total microbial population in the vermicompost injected with *A. brasilense* and *R. leguminosarum* was high (Rajashekar *et al.*, 2012).In fig.2 the flow chart of different biofertilizers and green manures is revealed. Vermicomposts made from various plant biomasses were enhanced with microbial inoculants before being assessed for their effects on the soil microbial population, rice yield, and nutrient availability. The nitrogen content and microbial population of vermicomposts were dramatically boosted by the addition of *Azotobacter chroococcum*, *Azospirillum brasilense*, and *Pseudomonas fluorescens*, either alone or in consortia (Mahanta *et al.*, 2012). Vermicompost's microbial populations have potentital make it more suitable for use in the creation of organic fertilizers. Pseudomonas and

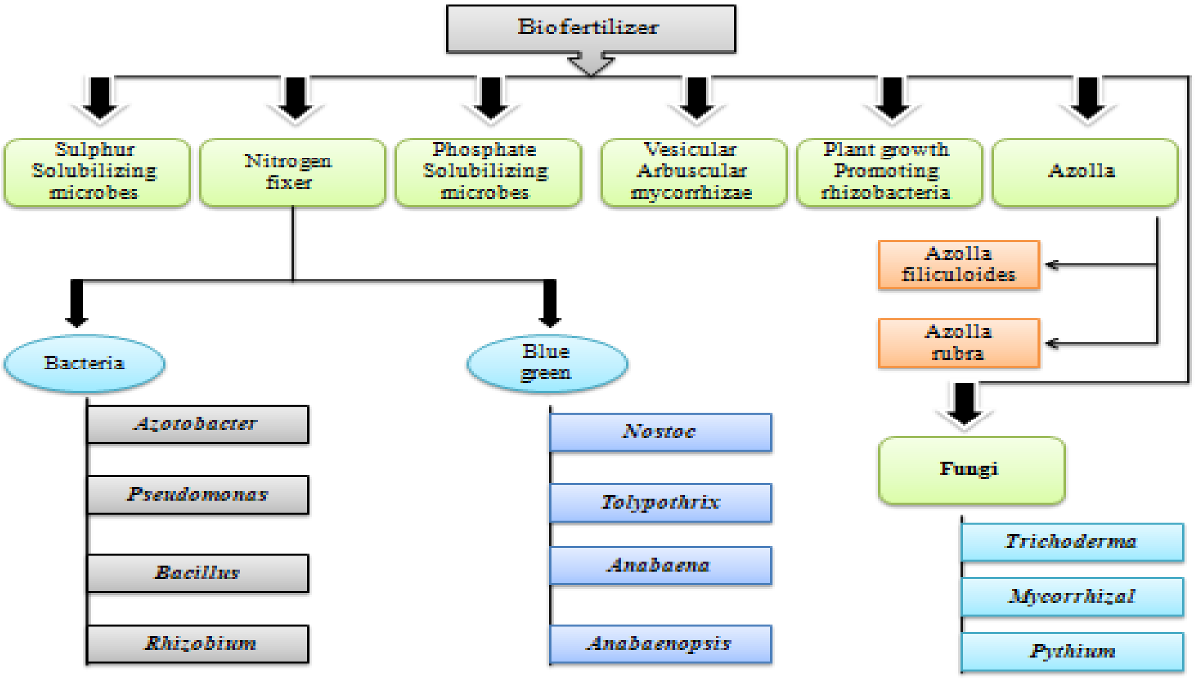

Fig 2 Types of biofertilizers and green manures.

Azotobacter bacteria were used as inoculums and injected for 60 days onto vermicompost beds. Longer incubation periods resulted in lower population of organic carbon, EC, and pH as well as higher levels of bacteria, nitrogen, bioavailable phosphorus, ash, and humic acid (Hemati *et al.*, 2013). The effect of bacterial and fertilizer treatments on enriching vermicompost on humification indices and physico-chemical analysis of extracted humic acid. Throughout a 60-day incubation period at 28°C, the treatments were evaluated for humic acid elemental composition, functional group identification, and spectroscopic tests. The VC+NSP and VCC treatments had the highest and lowest humification indices during enrichment, respectively (Alkani and Hemati,2013). Vermicompost is produced by earthworms and bacteria and is a rich source of nutrients for plant growth, including calcium, nitrates, phosphorus, and soluble potassium. Beside this, auxins, cytokinins, and gibberellins, among other plant growth hormones, are found in vermicompost.

Conclusion:

Vermicompost biofortification using advantageous microorganisms shows great promise for overcoming the difficulties involved in various crops. Research has shown that mycorrhizal fungi, plant growth-promoting rhizobacteria (PGPR), and other helpful microorganisms can be added to vermicompost to increase its microbial diversity and nutritional balance. Potential to compensate for nutrient shortages, ultimately leading to improved plant growth, higher yields, and increased resistance against pests and diseases. The value of tailoring biofortified vermicompost formulations to each crop's particular needs in order to maximize performance.

Research gap: To better meet the vast global food demand, we use chemical fertilizer frequently. To protect the "production source," variety of chemical insecticides are used , some of which may be lethal or harmful to the environment. Currently, there isn't an organic fertilizer available that can meet all of the plant's nutritional requirements, including N, P, and K. They do not have enough nutrients. One possible solution to this problem is the addition of various plant components to *Trichoderma* species. However, the procedure for making vermicompost will remain the same.

Future scope and prospective:
Finding and improving certain microbial consortia that are most suited for different horticulture crops can be the focus of further research. Vermicompost that has been biofortified may improve resource use in precision agriculture techniques like sensor-based nutrient management and smart irrigation, as well as boost crop yields and decrease waste. The benefits of using biofortified vermicompost for the environment, such as its potential reduce greenhouse gas emissions and soil erosion as well as to enhance the health of the entire ecosystem.

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