Synergistic Role of Vermicompost and Vermiwash in Enhancing Soil Fertility and Crop Productivity

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ABSTRACT

Sustainable intensification of agriculture requires ecologically sound nutrient management strategies that *enhance soil fertility while minimizing environmental degradation. Among organic inputs, vermicompost and vermiwash, derived from earthworm-mediated decomposition processes, are increasingly recognized as effective biofertilizers for sustainable crop production. Vermicompost is a nutrient-rich, microbially active organic amendment containing essential macro- (N, P, K) and micronutrients (Fe, Zn, Cu, Mn), humic substances and plant growth-promoting* rhizobacteria. It improves soil structure, aeration, water-holding capacity and nutrient mineralization, thereby promoting root proliferation and yield stability. **Vermiwash**, a liquid extract collected from vermicomposting units, contains soluble nutrients, enzymes, vitamins and phytohormones such as auxins, gibberellins and cytokinins that stimulate photosynthesis, flowering and stress resistance. Recent studies demonstrate that combined application of vermicompost (4-6 t ha^{-1}) and diluted vermiwash sprays (3-15%) enhances nutrient uptake, microbial biomass and productivity in cereals, pulses and horticultural crops. Integrating these vermiproducts within **Integrated Nutrient Management (INM)** frameworks reduces dependence on chemical fertilizers, improves soil organic carbon stocks and supports agroecological resilience. Furthermore, advances in substrate optimization, microbial fortification and nano-bioformulations have expanded their agronomic efficacy and scalability.

INTRODUCTION

Global agriculture increasingly faces pressure to improve productivity while reducing reliance on synthetic fertilizers, safeguarding soil health and mitigating environmental degradation. Organic amendments are receiving renewed attention for their dual role in enhancing crop yield and soil resilience. In this context, the application of vermitechnology (i.e., using earthworms and associated microbial processes) has emerged as a promising strategy. Two key products of vermitechnology *are vermicompost (solid end-product) and vermiwash* (liquid extract), both of which can contribute significantly to sustainable crop production.

Vermicompost: Composition and Mechanisms

Composition

Vermicompost is produced when organic wastes are decomposed by earthworms (commonly species such as *Eisenia fetida*) together with microbial activity under aerobic conditions. The resulting material is rich in nutrients, humic substances and beneficial microbial populations. For example, in a review, vermicompost was shown to contain humic and fulvic acids, plant growth-regulators (auxins, gibberellins, cytokinins) and a broad spectrum of microbial taxa (Rehman *et al.* 2023).

Recent substrate-based studies show that the specific feedstocks used influence nutrient composition markedly. One study found that vermicompost produced from 100% rain-tree litter had significantly higher total nitrogen (2.31 %), phosphorus (1.185 %), potassium (0.863 %) and micro-nutrients such as Fe (~1072 mg kg^{-1}) compared to mixed substrates (Ravindran *et al.* 2016).

Mechanisms of Action

The beneficial effects of vermicompost on crops derive from multiple mechanisms:

- **Improved soil physical and chemical properties**: Vermicompost increases organic matter content, improves soil structure, porosity, water-holding capacity and aeration (Mohite *et al.* 2024).
- **Nutrient supply and availability**: Vermicompost provides macro- (N, P, K) and micro-nutrients in plant-available forms; additionally, the presence of humic substances can enhance nutrient uptake by plants (Rehman *et al.* 2023).
- **Soil microbial enhancement**: The microbial biomass and diversity in vermicompost can stimulate soil microbial activity, nutrient mineralisation and beneficial symbiotic associations. (Mohite *et al.* 2024).
- **Biostimulant and stress mitigation effects**: Several studies show vermicompost can mitigate abiotic stresses (e.g., salinity, drought) and biotic stresses (e.g., pests, diseases) by virtue of humic substances, plant growth regulators and microbial antagonists.

Vermiwash: Nature, Composition and Function

Nature

Vermiwash is the liquid extract derived from vermicomposting units: often water percolates through vermicompost or worm beds and the filtrate (or dedicated wash) collects soluble nutrients, enzymes, hormones and microbial metabolites. Because of its form it is often applied as a foliar spray or as a soil drench.

Composition

Vermiwash contains soluble macro- and micro-nutrients (for example, nitrogen, phosphorus, potassium, iron, manganese, zinc, copper). It also contains enzymes (e.g., urease, dehydrogenase) and plant growth regulators (auxins, cytokinins & gibberellins) produced by worms and microbes. For example, in one study of vermiwash prepared from rain-tree litter vermicompost, the nitrogen content was ~0.65 % at first harvest, phosphorus ~0.33 %, potassium ~0.27 %.

Function in Crop Production

Vermiwash acts primarily as:

- **Foliar biostimulant**: Applied as a foliar spray, it can enhance leaf chlorophyll, photosynthetic rate, root and shoot growth and flowering/fruit-set. For example, one study on common bean found root length maximised under foliar spray of 5 % vermiwash.
- **Supplemental nutrient source**: While not replacing basal fertiliser wholly, vermiwash provides a readily available liquid nutrient dose and can enhance nutrient uptake when used in conjunction with soil amendments. For example, a study in greengram found that foliar spray of 3 % vermiwash along with 100 % recommended fertiliser dose improved NPK uptake.
- **Plant stress amelioration and disease suppression**: Some reports suggest vermiwash enhances plant resistance to pests/diseases and may act as a mild biocide or offering beneficial microbes. (Nahar *et al*. 2024).

Agronomic Benefits in Crop Production

Yield and Quality Improvements

Multiple field and pot trials demonstrate that the use of vermicompost (alone or combined with vermiwash) improves crop growth, yield components, nutrient uptake and protein content. For example:

- On black gram (*Vigna mungo*), application of vermicompost at 6 t/ha plus foliar 15 % vermiwash during flower initiation significantly enhanced nutrient content in seed and straw, protein content in seed and total nutrient uptake; and improved net returns.
- On fenugreek (RMT 305 variety), treatments combining 3.5 kg vermicompost + 8,000 ppm vermiwash gave highest pod number, seed yield etc.
- On greengram, combining fertiliser + 3 % vermiwash foliar spray improved growth, nodulation and nutrient uptake.

Soil Health and Sustainability

Because vermicompost enhances organic matter, microbial diversity and structure, it contributes to long-term soil fertility, carbon sequestration, waste recycling and reduction in chemical fertiliser dependence. According to a recent review: "vermicomposting has attracted attention for waste management, nutrient recycling, biofertiliser production and environmental restoration."

Stress Resistance

The capacity of vermicompost (and associated vermitechnology products) to enhance resistance to abiotic stresses (e.g., drought, salinity) and biotic stresses (e.g., pathogens, pests) has been increasingly documented. For example: vermicompost amendment suppressed leaf-miner damage in groundnut and reduced *Fusarium* foot-rot in rice when vermicompost tea was applied.

Economic Viability

Research indicates that using vermicompost and vermiwash can increase net returns for farmers by improving yields, reducing fertiliser/pesticide costs and increasing quality of produce. For instance, the black gram study showed higher gross and net returns with vermicompost + vermiwash treatments.

Recent Advances and Emerging Trends

Substrate Optimisation

Recent research emphasises the importance of the feedstock used to produce vermicompost/vermiwash. For instance, the study from Pune found that differing combinations of tree litter and spent mushroom compost significantly altered nutrient contents of both vermicompost and vermiwash.

Integration with Nanotechnology & Bio-Enrichment

Cutting-edge work is exploring the enrichment of vermicompost with biogenic nanoparticles (e.g., Cu/Ni/Co oxide nanoparticles synthesized via biomimetic routes) to further enhance plant growth and nutrient uptake. For example, work reported on okra (*Abelmoschus esculentus*) where vermicompost enriched with Moringa-derived oxide nanoparticles improved seed germination by 167%, vigour index by 95% (Yadav *et al.* 2024).

Commercial Scale and Market Growth

The global vermicompost market is forecast to grow rapidly: from ~US$87.9 billion in 2023 to ~US$335.14 billion by 2032 (CAGR ~16 %) — reflecting recognition of vermitechnology's value in sustainable agriculture (GlobeNewswire, 2025).

Practical Considerations for Crop Producers

Application Rates and Timing

- Vermicompost: Rates vary depending on crop, soil fertility and production system. Field studies have used 4.5–6 t/ha for legumes.
- Vermiwash: Foliar sprays in the range of 3 % (v/v) or 15 % (diluted) at key crop growth stages (e.g., pre-flowering, pod set) have shown efficacy.
- It is advantageous to integrate vermicompost as a basal soil amendment and apply vermiwash at critical stages (e.g., flowering, fruit set) to maximise combined effect.

Quality of Material

- Ensure vermicompost is mature (e.g., stable pH, earthy smell, absence of raw wastes) and free of pathogens or weed seeds.
- For vermiwash, the substrate, extraction method (e.g., barrels, filtrate) and storage conditions influence nutrient/enzyme content; as one study from Tamil Nadu shows, leaf litter-derived vermiwash composition varied. (Sundaravadivelan *et al.* 2024).

Compatibility with Other Inputs

- Vermicompost works synergistically with chemical fertilisers: combining vermicompost with half or full recommended fertiliser doses often yields superior results compared to fertiliser alone.

- Vermiwash may complement foliar nutrition regimes or act as part of integrated nutrient-management plans; ensure compatibility with other foliar sprays to avoid antagonistic interactions.

Crop and Soil Suitability

- Crops studied: legumes (black gram, greengram), fenugreek, common bean, vegetables (okra, etc.), trees (*Gmelina*) under nursery conditions.
- Soil types: Many studies in India focus on low-fertility soils; vermitechnology may be especially beneficial in degraded soils or where soil organic matter is low.

Economic and Environmental Context

- The economic benefits (improved yield, quality, reduced external inputs) should be weighed against the cost of vermicompost/vermiwash production or procurement.
- From an environmental perspective, vermicompost and vermiwash contribute to waste recycling (agricultural residues, urban green waste) and reduce reliance on synthetic fertilisers/pesticides, aligning with circular economy and sustainable agriculture goals.

Limitations and Research Gaps

- While many trials demonstrate positive effects, variability remains: differences in feedstock, earthworm species, microbial consortia, extraction protocols, soil/crop type make standardisation a challenge.
- Long-term studies on vermiwash effects (residual soil impacts, repeated use across seasons) are fewer.
- Mechanistic understanding (especially of plant hormone/ enzyme action in vermiwash, microbial transfer from vermicompost to soil) needs deeper exploration.
- Economic scalability and supply chain for high-quality vermicompost/vermiwash remains a constraint in many regions.

Recommendations for Implementation

- Select appropriate feedstocks (local residues, mushroom compost, tree litter) and optimise substrate mixes to maximise nutrient content of vermicompost/vermiwash.
- Ensure earthworm culture is managed—species selection, bedding, moisture, temperature and aeration are key to high-quality vermicompost.
- For vermiwash production: design washing/filtrate systems (e.g., barrels) to collect nutrient-rich extract, measure pH/EC/nutrient content periodically.
- Integrate vermicompost into soil at early stage (pre-sowing or transplanting) and apply vermiwash as foliar sprays at growth stages critical for yield (e.g., flowering, pod set).
- Monitor crop responses (growth, nutrient uptake, yield) and compare with standard fertiliser regimes to validate cost-benefit in your specific agro-ecological context.
- Promote this as part of sustainable agriculture/organic production system: reducing chemical fertiliser load, improving soil health and resilience.

CONCLUSION

The roles of vermicompost and vermiwash in crop production are now well supported by research. Vermicompost provides a nutrient-rich, biologically active soil amendment that improves soil health, nutrient supply, plant growth and stress resilience. Vermiwash complements it by offering a liquid biostimulant and foliar nutrient source. Recent advances in feedstock optimisation, nanotechnology enrichment and commercial scale illustrate the evolving frontier of vermitechnology.

For practitioners and researchers alike, the message is clear: vermicompost and vermiwash offer robust tools for sustainable crop production, especially where soil fertility is limited organic waste is available and a move away from purely synthetic inputs is desired. However, success depends on proper production protocols, integration within nutrient and crop management plans and adaptation to local conditions.

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