

Role of Vermicomposting in Sustainable Waste Management and Soil Fertility Enhancement through Organic Waste Recycling

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Abstract: The increasing demand for sustainable agricultural practices has highlighted the importance of vermicompost as a natural soil amendment and biofertilizer. This study investigates the effects of vermicompost prepared from different organic waste materials on soil fertility and plant growth performance. Various substrates, including kitchen waste, animal dung, agricultural residues, and garden waste, were processed through vermicomposting using selected earthworm species under controlled conditions. The resulting vermicompost samples were evaluated for nutrient composition, organic carbon, pH, and micronutrient content before application to soil. Pot experiments were conducted to assess seed germination, plant height, biomass production, leaf development, and chlorophyll content. The results demonstrated that vermicompost produced from animal manure significantly improved soil nitrogen and phosphorus levels, leading to enhanced vegetative growth. Kitchen waste vermicompost promoted potassium availability and improved plant vigor, while compost derived from agricultural and garden waste contributed to better soil structure and micronutrient enrichment. Plants treated with mixed-source vermicompost exhibited the highest growth performance and biomass accumulation. The study emphasizes that the source of organic waste directly affects vermicompost quality and its agricultural benefits. The findings support the use of tailored vermicompost formulations for improving soil health, enhancing crop productivity, and promoting sustainable waste recycling practices.

Keywords: Vermicomposting, Nutrient Composition, Organic Carbon, Micronutrient, Biomass Accumulation

1. Introduction

The management of organic waste has become one of the most critical environmental challenges in the modern world. Rapid urbanization, industrial expansion, changing lifestyles, and population growth have substantially increased the production of biodegradable waste materials. In India, municipal solid waste generation is increasing annually, with projections indicating enormous future accumulation if proper management systems are not implemented. Open dumping and improper disposal of organic waste lead to environmental pollution, emission of greenhouse gases, unpleasant odors, and the breeding of disease-causing organisms, posing serious risks to human and ecosystem health[1-8].

Organic wastes such as agricultural residues, kitchen waste, aquatic weeds, leaf litter, and animal dung contain substantial quantities of nutrients and organic matter that can be recycled into useful agricultural inputs. Biological waste conversion technologies therefore offer an environmentally sustainable alternative for waste management. Among these technologies, vermicomposting has emerged as one of the most promising and eco-friendly methods for converting organic waste into valuable biofertilizer[9].

Vermicomposting is the process by which earthworms and microorganisms jointly convert biodegradable waste into stabilized organic manure known as vermicompost. The



process accelerates decomposition and produces nutrient-rich humus-like material with enhanced biological activity. Compared with conventional composting, vermicomposting is faster, odor-free, and generates compost with superior nutrient availability and microbial richness. Vermicompost has been reported to improve soil texture, porosity, aeration, water-holding capacity, and microbial activity while supplying essential plant nutrients in readily available forms.

The growing demand for sustainable agricultural practices has further increased the significance of vermicomposting. Excessive dependence on chemical fertilizers and pesticides has led to declining soil fertility, destruction of beneficial soil organisms, contamination of water resources, and accumulation of toxic residues in ecosystems. Organic farming systems emphasize the use of biological soil amendments that maintain ecological balance while improving agricultural productivity. Vermicompost serves as an efficient biofertilizer capable of enhancing plant growth, crop yield, and soil health without causing environmental degradation.

The scientific importance of earthworms in soil fertility and organic matter decomposition was first highlighted by Charles Darwin in 1881. Since then, extensive research has established the role of earthworms as “ecosystem engineers” due to their ability to modify physical, chemical, and biological properties of soil. Earthworms ingest organic residues, fragment waste materials, stimulate microbial activity, and accelerate nutrient mineralization processes. The resulting vermicast is rich in nitrogen, phosphorus, potassium, micronutrients, enzymes, and beneficial microbes[10-12].

Among the epigeic earthworm species commonly used for vermicomposting, *Eisenia fetida* and *Eudrilus eugeniae* are highly efficient waste converters. *Eisenia fetida* is preferred because of its adaptability, tolerance to environmental fluctuations, and rapid reproduction. *Eudrilus eugeniae*, widely known as the African nightcrawler, performs exceptionally well under tropical conditions due to its high feeding rate and rapid biomass production. Both species are capable of transforming a wide variety of organic wastes into nutrient-enriched vermicompost.

The present study aims to evaluate the role of vermicomposting in sustainable waste management and soil fertility enhancement through the recycling of different organic wastes. Special emphasis is given to the conversion of agricultural residues, weeds, leaf litter, and animal wastes into nutrient-rich compost using *Eisenia fetida* and *Eudrilus eugeniae*. The study also investigates the potential of vermitechnology as an eco-friendly strategy for improving soil productivity, promoting sustainable agriculture, and minimizing environmental pollution[13-17].

2. Literature Review

The increasing generation of biodegradable waste due to rapid urbanization, industrialization, and population growth has become a major environmental concern worldwide. Organic wastes originating from domestic, agricultural, industrial, and municipal sources contribute significantly to environmental pollution when improperly disposed of. Vermicomposting has emerged as an effective biological technology for converting these wastes into valuable organic manure while minimizing environmental hazards. According to Edwards and Burrows (1988), vermicomposting transforms organic residues into stable humus-like vermicompost under controlled environmental conditions using earthworms and microorganisms.

The role of vermicomposting in sustainable waste management has gained considerable attention because of its efficiency, low cost, and environmental safety. Arancon et al. (2003) reported that vermicomposting can process sewage sludge, agricultural residues, domestic waste,

and industrial organic waste into nutrient-rich biofertilizer. Compared to conventional composting, vermicomposting is faster, requires less space, and produces compost with higher microbial activity and nutrient availability. Furthermore, the process can be implemented at household, community, or industrial scales, making it highly adaptable for waste recycling programs.

Earthworms are the primary agents driving the vermicomposting process. During decomposition, earthworms ingest organic matter, soften it using calcium-rich secretions, grind it within the gizzard, and digest it through enzymatic and microbial action before excreting nutrient-rich castings. According to Edwards and Lofty (1972), this process accelerates organic matter stabilization and nutrient mineralization. Ndegwa and Thompson (2001) further demonstrated that nutrients such as nitrogen, phosphorus, potassium, and calcium become more soluble and readily available to plants during vermicomposting.

The success of vermicomposting depends on several abiotic and biotic factors. Moisture, temperature, pH, aeration, feed quality, and carbon-to-nitrogen ratio directly influence earthworm growth and microbial activity. Recommended a moisture content of 60–80%, while Ismail (1997) suggested an optimal temperature range of 12–28°C. Kaushik and Garg (2004) observed that vermicomposting proceeds effectively under near-neutral pH conditions. Feed quality and substrate particle size also affect earthworm consumption rates and decomposition efficiency.

Biotic interactions between earthworms and microorganisms are fundamental to vermicomposting. Earthworms stimulate microbial activity by fragmenting organic residues and increasing the surface area available for microbial colonization. Edwards and Fletcher (1988) reported that microbial communities present within wastes contribute significantly to organic matter decomposition and nutrient stabilization. Enzymes such as cellulases, proteases, lipases, and phosphatases released by earthworms and microbes accelerate biochemical transformation processes (Hand et al., 1988). According to Nannipieri and Bollag (1991), these enzymes also aid in the detoxification of pollutants present in organic wastes.

The ecological significance of earthworms has been acknowledged since ancient times. Aristotle described earthworms as the “intestines of the soil,” while Charles Darwin later emphasized their critical role in soil formation and fertility. Modern classifications categorize earthworms into epigeic, endogeic, and anecic groups based on ecological behavior. Epigeic species such as *Eisenia fetida* and *Eudriluseugeniae* are particularly suitable for vermicomposting because they efficiently convert organic residues into nutrient-rich castings and tolerate a wide range of environmental conditions.

Numerous studies have demonstrated the positive effects of vermicompost on plant growth and soil fertility. reported hormone-like effects of vermicompost that stimulate root growth, flowering, and biomass production. Vermicompost applications have improved crop growth parameters including plant height, leaf area, root development, flowering, and yield in several crops such as rice, wheat, sugarcane, cowpea, banana, strawberries, peanuts, and grapes .observed enhanced seedling growth and flower bud production following vermicompost application. Humic substances present in vermicompost further contribute to improved nutrient uptake and plant productivity.

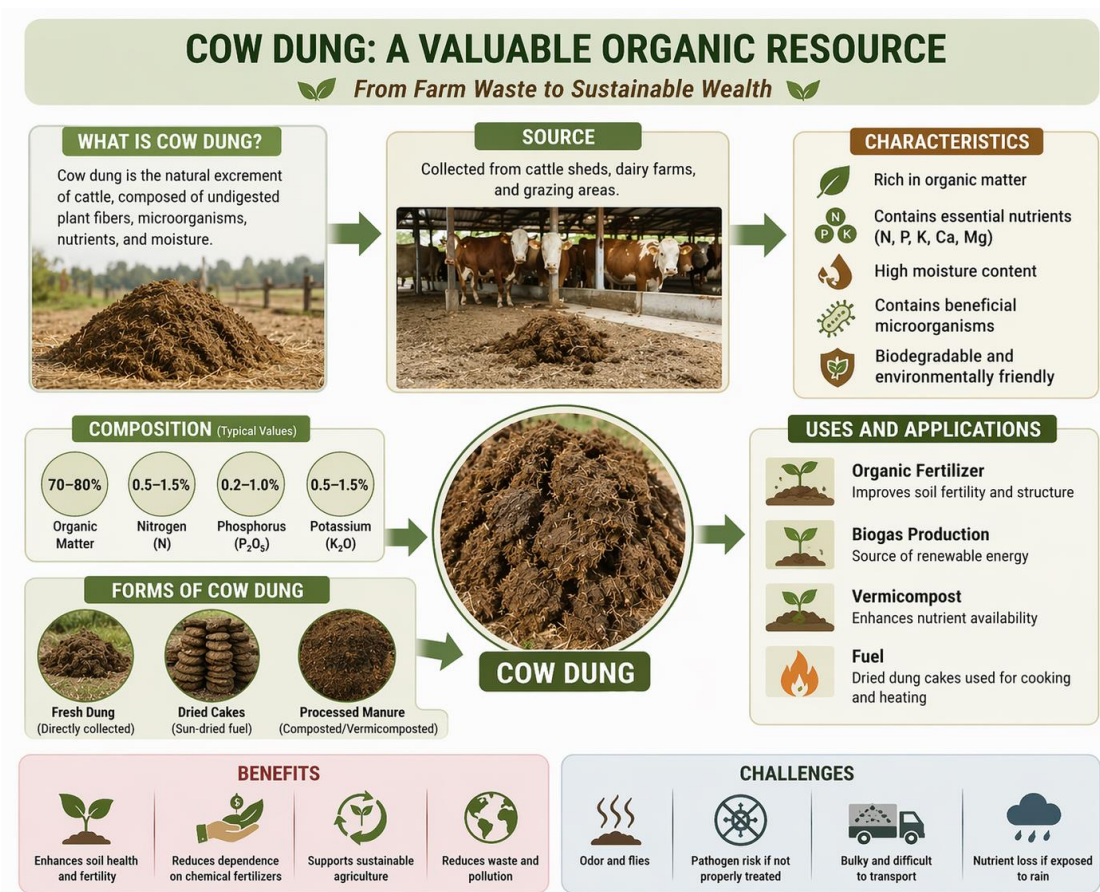


Figure 1: Cow Dung

Organic industrial residues such as Solid Waste Generated from the Sago Industry (SISW) have also been investigated as vermicomposting substrates. Mba (1996) and Christy and Ramaligam (2005) reported that sago industry waste possesses high organic matter and nutrient content suitable for vermicomposting. *Eudriluseugeniae* efficiently converted cassava and sago residues into nutrient-rich manure while reducing waste accumulation and environmental pollution. Subramanian et al. (2010) noted that vermicomposting significantly shortens decomposition time compared with natural decomposition processes.

Despite extensive research on vermicomposting, further investigations are required to optimize substrate combinations, improve nutrient enrichment, and evaluate the comparative performance of earthworm species under different waste conditions. The present study therefore focuses on the role of vermicomposting in sustainable waste management and soil fertility enhancement through the recycling of diverse organic wastes using *Eiseniafetida* and *Eudriluseugeniae*.

3.Results and Discussion

The results revealed that vermicompost application significantly influenced carbohydrate metabolism in black gram plants. Plants treated with 20% vermicompost recorded the highest levels of reducing sugars, non-reducing sugars, total sugars, starch, and carbohydrates compared to other treatments and the control. The accumulation of soluble sugars reflects enhanced physiological and metabolic activity within the plants. Maximum sugar concentration was observed at 60 DAS (Days After Sowing), indicating active photosynthesis and translocation of

metabolites during the growth period.

The improvement in sugar content may be attributed to the nutrient-rich nature of vermicompost, which supplies essential macro- and micronutrients and improves soil microbial activity. Enhanced nutrient uptake increases chlorophyll synthesis and photosynthetic efficiency, leading to greater carbohydrate production. Similar findings were reported in several plant species including Albizia lebbek, groundnut, Pisum sativum, maize, green ash and tree species such as Cassia siamea, Delonix regia, Erythrina variegata, Samanea saman, and Sterculia foetida.

Higher starch and carbohydrate content in vermicompost-treated plants indicates improved energy storage and metabolic efficiency. Carbohydrates serve as precursors for several biochemical processes and contribute directly to plant growth and biomass accumulation. The increase in carbohydrate concentration may also be linked to enhanced translocation of mineral ions facilitated by microbial associations and improved root activity. Cooper (1984) reported that mycorrhizal infection promotes movement of essential ions and accelerates metabolic synthesis through enhanced carbohydrate translocation.

The present findings agree with Borages and Chaney (1993), who observed higher root soluble sugars and starch levels in mycorrhizal seedlings than in non-mycorrhizal plants. Kameli (1990) further emphasized the role of sugar accumulation and organic solutes in regulating carbohydrate metabolism and plant stress tolerance.

Overall, the study demonstrates that vermicompost application, particularly at 20% concentration, significantly improves carbohydrate metabolism and energy reserve compounds in black gram. This enhancement contributes to better plant growth, vigor, and productivity, highlighting the importance of vermicompost in sustainable crop production systems.

4. Conclusion

The present investigation confirmed that sago industrial solid waste (SISW), when combined with cow dung and leaf litter, can be effectively converted into high-quality vermicompost through earthworm-mediated bioconversion. The vermicomposting process successfully transformed hazardous and underutilized industrial waste into a stable, nutrient-rich, and environmentally beneficial biofertilizer.

The study showed that vermicompost prepared from the mixture of 70% cow dung, 20% SISW, and 10% leaf litter exhibited superior physicochemical and nutritional properties compared to other treatments. Significant reductions in pH, total organic carbon, and C:N ratio indicated effective decomposition and stabilization of the waste materials, while increases in total nitrogen, phosphorus, and potassium reflected enhanced nutrient enrichment during vermicomposting.

Application of SISW-based vermicompost had a remarkable positive effect on the growth, biochemical characteristics, and yield of Vigna mungo. Plants treated with 20% vermicompost showed enhanced seed germination, root and shoot growth, leaf development, biomass accumulation, chlorophyll and carotenoid content, protein synthesis, antioxidant activity, and enzyme production. Yield parameters including pod number, seed weight, root nodules, and total productivity were also significantly improved.

The study further demonstrated that lower concentrations of SISW in the vermibed favored better earthworm survival, biomass accumulation, and reproductive performance, confirming the suitability of blended substrates for efficient vermicomposting. The findings emphasize that industrial organic wastes such as SISW can be sustainably managed through vermitechnology instead of being disposed of as pollutants.

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References

- [1] S. H. Kalantari, M. M. Ardalan, H. A. Alikhani and M. Shorafa, M. "Effect of compost and vermicompost on corn growth," *African Journal of Agricultural Research*, vol. 5, pp.1317–1323, 2010.
- [2] B. Kalaiarasan, T. Senthilkumar, S. Kumar and V. Swaminathan, "Effect of biofertilizers and vermicompost on growth of *Acoruscalamus*," *Advances in Plant Sciences*, vol.21, pp.323–326, 2008.
- [3] P. Karuppaiah and J. Kathiravan, "Influence of tillage, organic manure, and biofertilizers on cucumber performance," *Plant Archives*, vol. 6, pp. 216–221, 2006.
- [4] P. Kaushik and V. K. Garg, "Changes in biological and chemical parameters during vermicomposting," *Bioresource Technology*, vol. 94, pp. 203–209, 2004.
- [5] M. F. Khatun, M.A. H. Chowdhury, M. S. Islam, S. M. S. Haider and M. Z. A. Talukder, "Effect of leaf litter on growth of okra," *International Journal of Experimental Agriculture*, vol. 1, pp.5–11, 2010.
- [6] M. Khwairakpam and R. Bhargava, "Vermicomposting of filter mud using different earthworm species," *Bioresource Technology*, vol. 100, pp. 5846–5852, 2009.
- [7] P. Kumudha and M. Gnanathinayagam, "Effect of biofertilizers on seed germination of *Albizialebeck*," *Advances in Plant Sciences*, vol. 20, pp. 417–421, 2007.
- [8] F. F. Luqueno, V. Reyes-Varela, C. Martinez-Suarez, G. Salmon-Hernandez, J. Yanez-Meneses, J. M. Caballous-Ramirez and L. Dendooven, "Effect of nitrogen sources on common bean yield," *Bioresource Technology*, vol. 101, pp. 396–403, 2010.
- [9] H. M. Maheshbabu, N. K. Ravihunje, K. B. Patil and H. B. Babalad, "Effect of organic manures on soybean growth and yield," *Karnataka Journal of Agricultural Sciences*, vol. 21, pp. 219–221, 2008.
- [10] P. Malairajan, G. Gopalakrishnan, S. Narasimhan and K. J. K. Veni, "Pharmacological studies," *Indian Journal of Pharmacology*, vol. 40, no.126, 2008.
- [11] B. Malgorzata and K. Georgies, "Response of pepper plants to organic fertilization," *Journal of Central European Agriculture*, vol. 9, pp. 715–722, 2008.
- [12] Mamta, K. A. Wani and R. J. Rao, "Effect of vermicompost on brinjal growth under field conditions," *Journal of New Biological Reports*, vol. 1, pp. 25–28, 2012.
- [13] P. T. Manoharan, M. Pandi, V. Shanmugaiah, S. Gomathinayagam and N. Balasubramanian, "Effect of mycorrhizal fungi on tree seedlings," *African Journal of Biotechnology*, vol. 7, pp. 3431–3436, 2008.
- [14] R. Melgar, E. Benitez and R. Nogales, "Vermicomposting of olive oil industry waste using *Eisenia Andrei*," *Journal of Environmental Science and Health*, vol. 44, pp. 488–495, 2009.
- [15] A. Miceli, R. Thierry, A. Flisch, U. Sennhauser, F. Casali and M. Simon, "Monte Carlo simulation of high-resolution X-ray CT systems," *Nuclear Instruments and Methods in Physics Research A*, vol. 583, pp. 313–323, 2007.
- [16] F. Monroy, M. Aira, J. A. Gago and J. Dominguez, "Life cycle of *Octodrilus complanatus*," *Comptes Rendus Biologies*, vol. 330, pp. 389–391, 2007.
- [17] R. K. Nagar, R. C. Dadheech and Y. Kanojiya, "Effect of nitrogen and *Bradyrhizobium* on soybean yield," *International Journal of Crop Science*, vol. 20, pp. 79–82, 2002.