Chapter

Vermicomposting: A Step towards Sustainability

Priyanka Saha, Anamika Barman and Anurag Bera

Abstract

Agricultural production depends on so many things. Proper nutrient management is one of them. It becomes a trend to apply excess amount of fertilizer for enhancing productivity without considering its effect on soil health. Vermicomposting is a process of scientifically decomposing agricultural, municipality, and industrial wastes into nutrient enriched compost by earthworms. Vermicompost not only balance underground soil environment and makes is a suitable habitat for soil micro biota but also improves above ground environment. Microbes are the fundamental element of ecosystem. Use of vermicompost increases growth and proliferation of microbes that amplify environment's betterment. Vermicomposting is also affordable for resource poor small and marginal farmers. Therefore, vermicompost use is more economical than synthetic organic fertilizer. So, economic viability, environmental stability, and enhancing livelihood quality are the major causes for its worldwide adoption in food production.

Keywords: vermicompost, soil fertility, sustainability, earthworm, soil health

1. Introduction

Increasing population and food demand has forced the farming community to apply excess amount of chemical fertilizer that leads to degradation of soil health and causing environmental pollution. Factor productivity of the soil is also decreasing due to injudicious fertilization. The technology advancement and industrialization has created many challenges associated with sustainability. Sustainability is a concept of utilizing the natural resources without compromising the ability of future generation to meet their own needs. Rapid urbanization and industrial growth is worrisome with respect to huge amount of waste generation. Unscientific management of these wastes causing social, economic, and environmental problems. After consuming so much chemicals during the green revolution era, the soil eventually became unproductive due to a lack of sufficient organic matter amendments. Vermicomposting is one of the many potential approaches that have gained significant attention over decades. It is an eco-friendly concept of waste management where decomposition process is aided by microorganisms [1–3]. Earthworms are the biological engineers since the beginning of humankind. The technique of culturing earthworm for managing wastes and preparing compost is known as vermicomposting. Vermicomposting is defined as a bio-oxidative process where earthworms and decomposer microorganisms (bacteria, fungi, and actinomycetes) act synergistically to manage organic waste in a scientific way that also aids in improvement of soil physical, chemical, and biological properties [4]. A wide range of raw materials (**Figure 1**) such as agricultural waste [5], animal waste [6], and municipality [7] waste are decomposed by earthworms and microorganisms for preparing vermicompost. This bio-technique increases mineralization of waste material led to enhancement in bioavailability of essential plant nutrients. Vermicompost not only supplies plant nutrients and growth promoting hormones but also improves soil physical property through soil aggregation [8]. Hence it is used as a component of organic farming. Vermicompost has also been proven to be a miraculous plant growth stimulator [9]. Vermicast, the end product is also rich in hormones and enzymes which make the soil environment favorable for soil biota. Residue burning is a common issue nowadays that causing severe environmental hazards. This issue can also be overcome by adopting vermicomposting technique.

In spite of having so many benefits, use of vermicompost is still not accepted widely due to lack of awareness and technology barriers. There is a need for proper extension to explore the potentialities of vermicompost. So, this study was conducted with the objectives for getting a precise idea about general properties, preparation methods, benefits and its limitations, and most importantly understanding the significance of vermicompost in crop production.

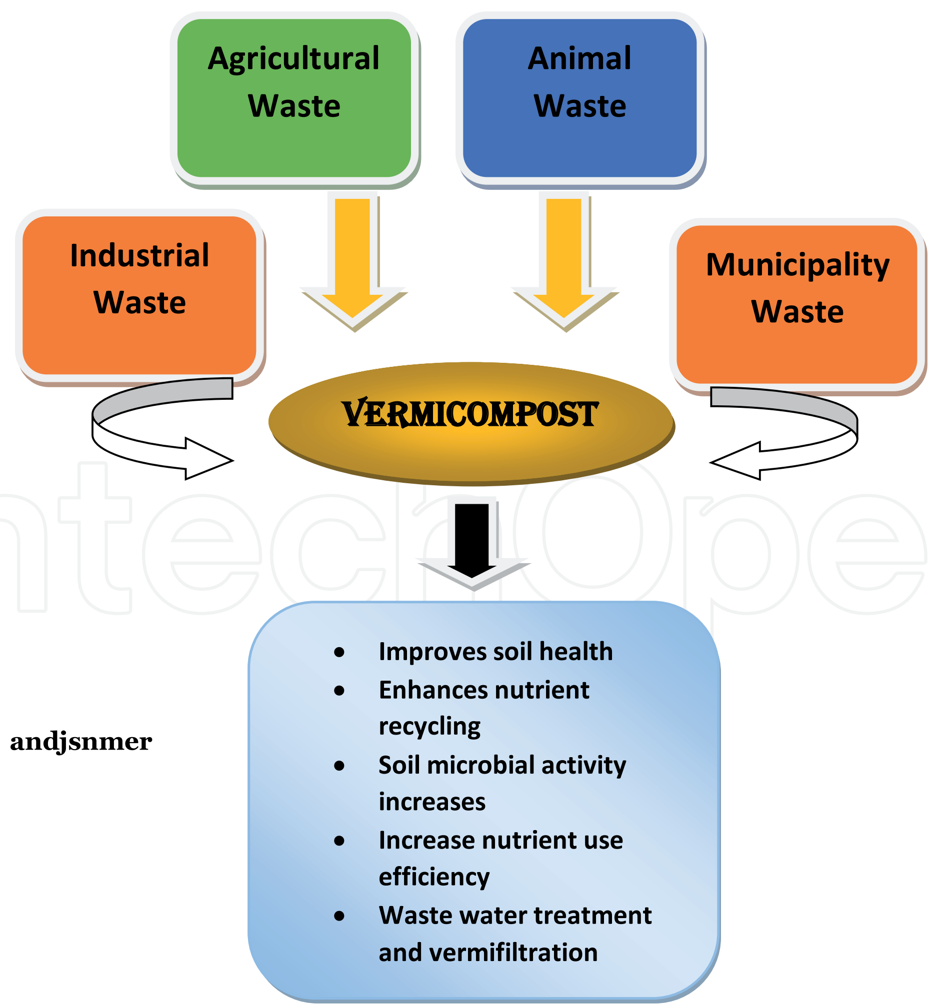


Figure 1.
Vermicompost and its role in agriculture.

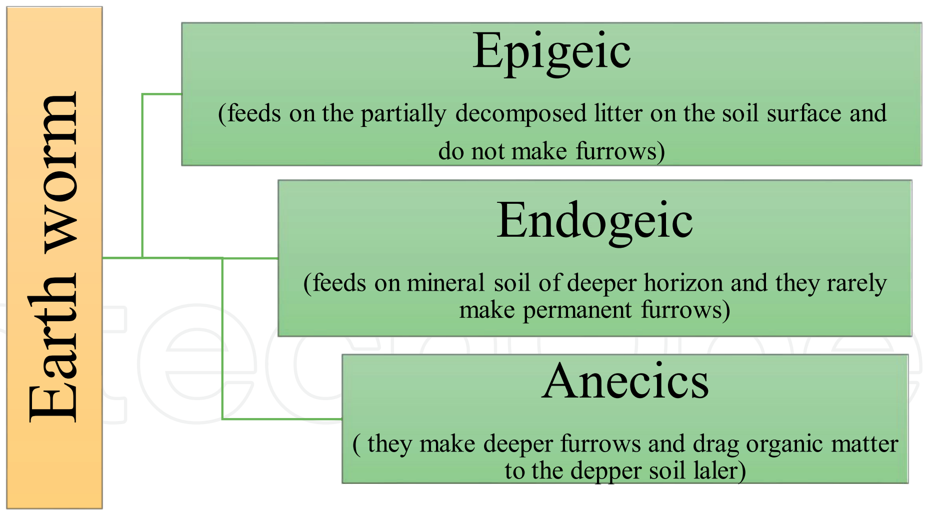


Figure 2.
Earth warm classification.

2. Earth worm and its kind

Among the soil biota, earth worm is one of the major kinds and a key component of tropical and subtropical ecosystems [10, 11]. It helps is soil aggregation, nutrient recycling, litter decomposition, etc. Earthworm improves the soil environment by producing cast, pellets, and galleries. Mucus secretion from the gut of earth worm enhances microbial activity. Around 3000 species of earthworms documented so far [12]. The earthworms are of three types that have been described in **Figure 2**.

The most common earthworms [13] have successfully used in India for vermicompost preparation are:

Indices	Chemical fertilizers	Vermicompost
Synthesis process	They are synthesized and manufactured in factories.	They are the product of natural decomposition of organic matter with the help of earth worms.
Macronutrients	Major chemical fertilizer contains only one macronutrient (either nitrogen or phosphorus or potassium).	Vermicompost contains almost all the primary minerals along with some quantities of secondary minerals (Ca, Mg, and S) [14].
Micronutrients	Not present.	Significant amount of micronutrients: Zn, B, Mn, Fe, Cu, etc. also present [15].
Soil structure	Over use of chemical fertilizer degrades soil structure.	It improves soil aggregation, water holding capacity, soil aeration, etc.
Biological activity of soil	It reduces biological activity of soil.	It improves activity of soil microbes thus enhances soil fertility [16].
Environmental impact	Excessive use of chemical fertilizers causes environmental pollution.	Vermicompost is an eco-friendly approach [17].
Saving cost of cultivation	Use of chemical fertilizers increases the cost of cultivation.	The farmer/consumer can expect approximately $110–$350 in additional income from applying one ton of vermicompost due to offset costs of traditional fertilizer and pesticides [18].

Table 1.
Difference between chemical fertilizer and vermicompost.

Figure 3.
*African earthworm (*Eudrilus eugeniae*).*

Figure 4.
*Tiger worm (*Eisenia fetida*).*

Figure 5.
*Asian worms (*Perionyx excavatus*).*

- *Perionyx excavates* (a native species)
- *Eisenia fetida* (exotic species that have colonized many ecosystems)
- *Eudrilus eugeniae* (exotic species largely confines to experimental setup)

Apart from being ecological engineer, earth worm is a rich source of protein thus it can be used as high quality feed to farm animals. Das et al. [13] reported that earthworm cast increases mushroom production. The brief difference between chemical fertilizer and vermicompost is given in **Table 1**.

Most commonly used earthworm species are: African earthworm (*E. eugeniae*), that is, **Figure** 3, Tiger worm (*E. fetida*), that is, **Figure** 4, and Asian worms (*Perionyx excavatus*), that is, **Figure** 5.

3. General properties of vermicompost

In terms of sustainable crop production, the acceptability of vermicompost has been rising rapidly as soon as the human realizes the significance of organic inputs in crop field. The excreta of earthworms, which is considered as the main product, that is, vermicompost has several characteristics. These are:

3.1 Physical properties

- A good vermicompost is always non-toxic, well-decomposed, ecologically compatible, and environment friendly.

- Any type of green waste viz. municipal waste, agricultural waste, sewage sludge, industrial waste, and human feces can be used for the conversion by earthworm.

- When turning of soil is occurred in proper manner, it is symptomatic to aerobic decomposition which will produce normal odor after preparation. If there is improper aeration, foul odor can be formed.

- The final outcome of vermicomposting would be comprising of fine particulate structure, granular form.

- Vermicompost plays the role of a "soil conditioner" by improving the soil porosity, drainage, and water holding capacity [19].

3.2 Chemical properties

- Vermicompost is rich in almost all essential macro and micro plant nutrients. Several experiment states that average nutrient content of vermicompost is greater than other conventional compost, produced from other procedures.

- Among all the secondary nutrients, calcium content in vermicompost is higher than other compost.

- In contrast with other conventional compost, vermicompost contains worm mucus which facilitates in preventing washing away of nutrients present there [20].

- Due to vermi-conversion, heavy metal present in feeding material is found to be reduced in earthworm cast owing to its accumulation in worm tissue. According to the feed used, the rate of removal of heavy metal depends in vermicomposting techniques. This property makes vermicompost lesser contaminant than any other compost. Thus, it becomes more environmentally sustainable [21].

- There are certain differences found in chemical properties between simple farm yard compost and vermicompost. Vermicompost ranges higher in macro and micro-nutrients as well as soil organic carbon status that can be observed from the **Table 2** [22].

3.3 Biological properties

- The by-product of earth casting is an inhabitant of several microorganism, viz. bacteria, fungi, and actinomycetes. These micro-organisms release several enzyme and phytohormones which helps in improving plant growth. Thus, vermicompost facilitates both microbial and enzymatic activity [22, 23].

- The microbial population of nitrogen fixer bacteria and other symbiotic associative bacteria are supposed to be in a good range of numbers in the excreta of earthworm.

- In addition, earthworm casts harbor a large number of vesicular-arbuscular mycorrhiza (VAM) propagules. These propagules survive up to 11 months on the

Properties	Compost	Vermicompost
pH	7.16	7.72
EC (dSm^{-1})	3.65	6.88
OC	20.5	17.3
Total N (%)	2.42	3.5
Total P (%)	0.88	0.71
Total K ($mg.kg^{-1}$)	653.5	950.5
Total Ca (%)	2.9	3.5
Total Mg (%)	1.5	2.8
Total Fe ($mg.kg^{-1}$)	4467	6045
Total Zn ($mg.kg^{-1}$)	115.5	189.5
Total Cu ($mg.kg^{-1}$)	59	38
Total Mn ($mg.kg^{-1}$)	221.45	344.15
C:N	8.47	5.51

Table 2.
Chemical properties of compost and vermicompost.

Properties	Impact	References
Soil physical properties	Soil aggregation, soil structure, and water holding capacity, infiltration rate improves after vermicompost application.	Edwards and Burrow [19]
Soil chemical properties	Vermicompost also offers a greater chance for reducing salinity, alkalinity, and reduction of heavy metal contamination.	Nancarrow et al. [20]
Soil microbial properties	Microbial biomass is also increases with the use of vermicompost.	Blouin et al. [12]

Table 3.
Effect of vermicompost on different soil properties.

cast, and helps in increasing microbial activity to produce nitrogen and phosphorus in readily available form to the plant (**Table 3**) [24].

4. Preparation methods

Earthworms are often termed as "Bio-engineers" because of their unique ability to convert organic wastes into dark brown nutrient rich compost materials. We use these worms along with some easy-available inputs to produce the vermicompost. In South-Asian countries like India, we often see market price of the vermicompost is very low, which is attributed to the low-cost inputs of this compost. This vermicompost can be prepared in various techniques, among all those two most common methods are: bed and pit methods.

Bed method is easy to prepare and maintain throughout the process as here composting is done on pucca or kachcha floor by making the bed with organic materials like hay, straw, corn silage, etc.

Figure 6.
Bed method.

Figure 7.
Pit method.

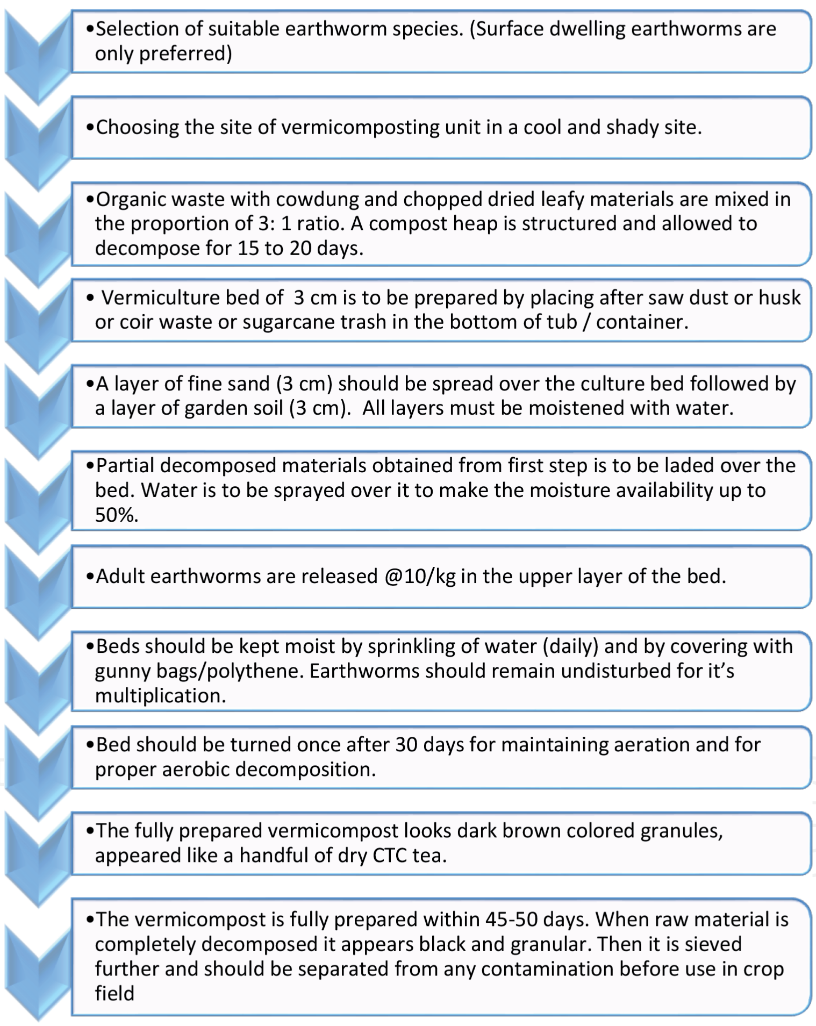
Figure 8.
Spraying of water in bed.

Figure 9.
Adult worms in compost.

Pit method is comparatively strenuous process where composting is done on cemented pits of approx. The unit is covered with grass or any other organic mixtures (**Figures 6-10**).

Figure 10.
Fully prepared vermicompost.

4.1 Step by step of preparation methods



5. Beneficial effects of vermicompost

5.1 Effect of vermicompost on the soil physiochemical properties

Addition of vermicompost improves soil physico-chemical properties viz. soil structure, soil water holding capacity, penetration resistance, bulk density, soil organic carbon, aggregation, nutrient content, etc. According to the findings of various long term research addition of vermicompost reduces the bulk density of the soil and increases the water holding capacity of soil [25]. Aksakal et al. [26] found that when vermicompost was added in the soil, the mean bulk density, and mean total porosity were the least. Air permeability rose and penetration resistance reduced dramatically as wet aggregate stability improved and bulk density reduced. Increased microbial population and activity led in the development of aggregates and increased soil porosity, resulting in decreased particle and bulk densities. Physicochemical characteristics such as pH, electrical conductivity (EC), porosity, moisture content, water holding capacity, and chemical properties like nitrogen, phosphorous, potassium, calcium, and magnesium were all found to be significantly improved in vermicompost treated soil, while the corresponding physicochemical values in control soil were minimal in rice crop [27]. Vermicompost has indeed been found to have significant concentration of total and bioavailable nitrogen, phosphorus, potassium (NPK), and micronutrients, as well as microbial and enzyme activity and growth regulators [28]. Polysaccharides appeared to be abundant in vermicompost [29]. Polysaccharide worked as a cementing ingredient in the soil, causing aggregate stability, which helped to establish and maintain the soil structure for improved aeration, water retention, drainage, and aerobic conditions. The preservation of soil structure is essential for root elongation and nutrient uptake. The inclusion of mucus secretion and microorganisms from the earthworm's gut improves the soil's aggregate stability. The absorbent organic matter in vermicomposts increases the soil's water retention capacity by holding only the quantity of water required by the plant roots [30]. Vermicomposts have been found to have a higher base exchange capacity and a higher oxidation potential rise [31]. The C/N ratio of vermicompost is usually lower, indicating that it is more suited for use as a soil amendment. By altering the physiochemical parameters of the soil, vermicompost was able to limit the loss of nutrients through leaching [32]. Humic acid and biologically active compounds like plant growth regulators are abundant in vermicompost [33]. Humic acid has been proven to improve nutrient accretion in situations where nutrients are scarce or when additional nutrients are provided. Humic acids may have a hormone-like effect on plant growth and productivity as a result of their involvement in cell respiration, photosynthesis, oxidative phosphorylation, biogenesis, and a variety of other enzymatic functions.

5.2 Effect of vermicompost on the soil biological properties

Biological properties of soil can be enhanced through application of vermicompost. Recent studies founded that soil biological characteristics viz. soil organic carbon as well as soil microbial biomass, enzymatic activity, population of different beneficial microorganism, hormones, etc. significantly enhanced with application of vermicompost [34]. The activity of the dehydrogenase enzyme, which is commonly employed to quantify the respiratory activity of microbial communities, was shown to be higher in vermicompost than in commercial medium [35]. Application of vermicompost improved the nitrogen status of soil by introducing the beneficial microorganism in the rhizosphere of the plant which ultimately enhances the nitrogenase activity in soil, which is the enzyme responsible for nitrogen fixation (**Tables 4** and 5).

5.3 Effect of vermicompost on the soil fertility

Vermicompost has a great importance to increase the soil fertility level. In recent years organic amendments are getting more importance for nutrient management

Crop	Treatments	Physiochemical effects				References
		pH	EC (dSm^{-1})	BD ($g\ cm^{-3}$)	Porosity (%)	
Rice	Control	7.4 ± 2.01	2.0 ± 1.0	—	39 ± 2.0	Tharmaraj et al. [27]
	Vermicompost	7.1 ± 0.01	1.01 ± 1.0	—	41 ± 1.0	
	Vermi-wash	7.2 ± 1.02	2.0 ± 1.1	—	40 ± 1.1	
	Vermicompost+ Vermi-wash	7.0 + 0.03	0.02 ± 0.01	—	44 ± 1.0	
Wheat	Soil sample	8.56	25.82	1.52	25.38	Mahmoud et al. [36]
	Vermicompost @5 g kg^{-1} soil	7.6	4.65	1.42	26.85	

Table 4.
Effect of vermicompost on physiochemical properties of soil on different crops.

Parameters	Compost ($g\ m^{-2}$)			
	Vermicompost		Conventional compost	
	100	150	100	150
Nitrogen (%)	0.61	0.72	0.54	0.62
Phosphorus (%)	0.0057	0.0077	0.0039	0.0047
Potassium (%)	11.11	11.17	10.41	10.48
Calcium (%)	1.443	1.683	0.561	0.641

Source: Islam et al. [37].

Table 5.
Comparison between the effect of vermicompost and conventional compost on different nutrient content of the Amaranthus viridis production.

and sustainable crop production since the long-term use of inorganic fertilizer lacking organic additives has the ability to ruin soil qualities [34]. Long-term treatment of balanced inorganic fertilizers led to reduced soil bulk density, improved total porosity, and higher water-holding capacity. Inorganic fertilizers also promoted soil aggregation in deeper soil layers and raised maize and wheat grain and straw yields [38]. In their research, using farmyard manure (organic fertilizer) instead of inorganic fertilizer improved soil qualities in a similar way. Furthermore, compost provides substantially higher boosts in soil organic carbon as well as some plant nutrients when compared to mineral fertilizers [39, 40]. Thus, using vermicompost improves overall soil fertility by improving numerous soil physical, chemical, and biological qualities.

5.4 Effect of vermicompost on plant growth and development

Vermicompost promotes the growth and development of a variety of plant species, especially various horticulture crops, that is, sweet corn, tomato, strawberry [41], cereals crop rice [27], wheat, sorghum [32], fruit crops papaya [42], and pineapple [43]. Several growth and yield metrics viz. stem diameter, plant height, marketable yield per plant, mean leaf number, and total plant biomass of tomato plant were recorded significantly higher with the application of vermicompost (**Figure 11**).

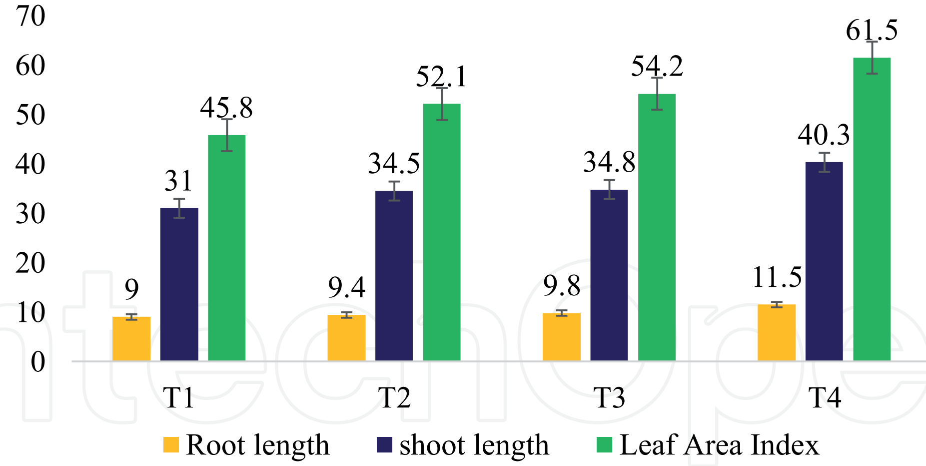


Figure 11.
Effect of vermicompost on growth parameters of Phaseolus vulgaris (20 DAS). Source: Ref. [34]. T1: Control (without application of inorganic NPK or vermicompost), T2: 100% recommended dose of NPK (20:80:40 kg ha^{-1}), T3: 100% recommended dose of vermicompost (5 t ha^{-1}), and T4: 50% vermicompost supplemented with 50% NPK (W/W).

The increase in growth and development of plant is due to the improving action of vermicompost application on soil physical, chemical, and biological properties which ultimately improves the overall soil fertility, which enhances the plant growth and development. Vermicompost has been demonstrated to improve plant dry weight [44] and uptake of plant N [45] serve as a naturally available, slow released sources of plant nutrients.

5.5 Effect of vermicompost on plant diseases

Various studies had showed that vermicompost is useful for remedies of different plant diseases. Many plant diseases caused by soil-borne, foliar plant pathogens, and pests have been suppressed by vermicompost products, which have been proven to be effective as organic fertilizers and biological control agents. In conventional agriculture, excessive and repeated use of chemical pesticides resulted in "biological resistance" in crop diseases and pests. As a result, significantly higher doses are now needed to inhibit them for the growth of high-yielding crops that are more sensitive to pests and diseases [46]. A study was conducted to compared the inhibition performance of two different methods, in which two nonconventional chemicals $ZnSO_4$ and oxalic acid, as well as the bio-control agent *Pseudomonas syringae*, were practiced as foliar sprays and seed coatings, respectively, against collar rot of chickpea caused by *Sclerotium rolfsii*, with the combination of vermicompost substitution. When compared to controls, vermicompost substitutes reduced chickpea mortality significantly, but inhibition was much more efficient for treatments that included pre inoculation with nonconventional pesticides as foliar sprays against pathogen [47]. Vermicompost applications suppressed the tomato late blight caused by *Phytophthora brassicae*, *Phytophthora nicotianae*, and tomato Fusarium wilt produced by *Fusarium lycopersici*, as described by. Earthworm has stimulatory effect on soil microbial activities thus it suppressed the plant diseases more potentially than aerobic compost. There is a lot of research on the suppression effect of organic matter amendments in soils, with gratifying levels of reduction in plant parasitic nematode infestations. There are few scholarly publications on the suppressing effect of solid vermicomposts on numbers and outbreaks of plant parasitic nematodes relative to OM and thermophilic compost

Industry sludge type	Earthworm species used	Physico-chemical properties and heavy metals reduction	References
Sewage sludge derived biochar	*Eisenia fetida*	Biochar injected before composting lowered *E. fetida*'s bioavailability of Cd and Zn. Except for higher Cr concentrations, the biochar-added vermicomposts had good fertilizing capabilities.	Malińska et al. [50]
Municipal sludge mixed with cow dung	*E. fetida*	Cr, Cu, Ni, and Pb all the metal compounds were reduced after vermicomposting.	Srivastava et al. [51]

Table 6.
Effect of different types of earthworm species on heavy metal reductions of industrial sludge.

additives. Solid vermicompost applications for control of plant parasitic nematode populations have been studied [48]. Solid vermicomposts ranging from 2 to 8 kg ha^{-1} were applied to tomatoes, peppers, strawberries, and grapes in field treatments. They were able to suppress plant parasitic nematodes with great success. These researchers investigated the suppression capacity of plant parasitic nematodes in vermicomposts made from paper waste, food waste, and cattle manure under field circumstances and found considerable suppression.

5.6 Effect of vermicompost on bioremediation and detoxification of industrial wastes

Vermicompost has a greater importance in bioremediation and detoxification of industrial waste. Because of their robust metabolic system and the participation of earthworm gut bacteria and chloragocyte cells, earthworms have the potential to valorize and detoxification of heavy metals in industrial by-products. The majority of research found that vermicompost made from organic waste comprises greater concentrations of humic chemicals, which are important for plant growth [49]. Earthworm has a vast role in bioconversion of waste materials. Because of their robust metabolic system and participation of varied intestinal micro biota, enzymes, and chloragocyte cells that decrease hazardous forms to benign forms, earthworms have the ability to bio-convert and detoxify most heavy metals in industrial sludges (**Table 6**) [51].

6. Limitations of vermicompost

1. Vermicomposting is a time taking process. It requires almost 6-month for decomposing the organic wastes to prepare vermicompost.

2. In comparison to the traditional composting process, vermicompost requires higher maintenance.

3. Vermicompost may harbor pest and diseases as the temperature of vermicomposting pit have to be cool enough to support earthworm life.

7. Conclusion

Since vermicompost is organic in nature, it is not harmful for the environment. Vermicomposting process is also easy to operate and can be successfully prepared by unskilled small and marginal farmers. Amidst the environmental degradation and increasing food demand, vermicompost can be a solution. Although, its use alone in agriculture would not be able to meet the food demand but its use with chemical fertilizer through integrated manner can achieve sustainability in food production. The adoption rate of vermicompost is low and there is tendency of adopting vermicompost by female famers only. The potentiality of vermicompost is still not fully exploited yet. Hence, there is a need to appoint more extension worker to educate the farmers about vermicomposting and its benefits for achieving sustainability.

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