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3. Vermicomposting: For Better Food and Nutritional Security

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Abstract:

The chapter "Vermicomposting: For Better Food and Nutritional Security" explores the transformative potential of vermicomposting in sustainable agriculture and food systems. Vermicomposting, the process of using earthworms to convert organic waste into nutrient-rich compost, offers a natural and effective solution for enhancing soil fertility and crop productivity. This chapter provides a comprehensive overview of vermicomposting techniques, including suitable worm species, optimal conditions for composting, and the types of organic waste that can be processed. It highlights the significant benefits of vermicompost, such as improved soil structure, increased microbial activity, and enhanced nutrient availability, which collectively contribute to higher crop yields and better-quality produce. The chapter also addresses the role of vermicomposting in waste management, reducing reliance on chemical fertilizers, and promoting environmental sustainability. Case studies and empirical data illustrate the successful application of vermicomposting in various agricultural contexts. By integrating vermicomposting into farming practices, this chapter underscores its critical role in achieving food and nutritional security, while fostering sustainable and resilient agricultural systems.

Keywords:

Vermicomposting, Sustainable Agriculture, Soil Fertility, Organic Waste, Crop Productivity, Nutrient-Rich Compost, Waste Management.

3.1 Introduction:

After green revolution, to meet the food demand of ever-increasing Indian population forced the farming community to accept the excess use of readily available form of plant nutrients in the packaged of chemical fertilizers that ultimately leads to degradation and deterioration of soil health. Unscientific application of chemical fertilizers causes lower factor productivity and disrupts soil and environmental health. Technology advancement and industrialization also supports to break the soil sustainability and planet health. Waste generation is a big trouble especially for future generation due to this rapid urbanization and industrial growth. Unavailability of scientific management techniques of this waste causing social, economic and environmental problems. Due to the era of green revolution, the soil becomes so unproductive due to a lack of sufficient organic amendments. Increase our dependency on artificial growth promoters' leads the product lack of essential mineral elements and full of heavy metals like elements that makes our daily life. If we think our next generation will be healthier and physically & mentally fit, now is the time to change our regular habit of applying such and such chemicals to the plant and get return a perfect attractive and sizable output that cannot fulfill our nutritional requirements, rather than they have to habitat this unhealthy life style. The regular increment the number of cancer patients in our planet proves that we are too unhealthy. Not only human beings, any other living things including plants cannot outside from this so-called healthy planet. So, if we want to get back our productive planet, we have to choose on which practices, we can depend. Vermicomposting is one of the eco-friendly approaches that reduce the amount of waste send to landfills, but it also produces a valuable compost that can be used to enrich soil in gardens and agriculture [1]. Since, the starting of cultivation of human beings, earthworms act as biological engineers. Vermicomposting is the process of using earthworms to turn organic waste into nutrient rich compost. 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 [2]. A wide range of raw materials (**Figure 3.1**) such as agricultural waste [3], animal waste [4], and municipality [5] waste is decomposed by earthworms and microorganisms for preparing vermicompost that act as a component of organic farming. Vermicompost not only supplies plant nutrients and growth promoting hormones but also improves soil physical property through soil aggregation [6]. Vermicompost has also been proven to be a miraculous plant growth stimulator [7]. The brief difference between chemical fertilizer and vermicompost is given in **Table 3.1**. Vermicast, a by-product of vermicomposting is also act as soil amendments makes sure the favorable growth of soil lifelines. Though residue burning is an easy way to manage agricultural waste, but on the behalf of greenhouse gas emission, this is a biggest issue now-a-days create several environmental hazards. By adaptation vermicomposting or vermicompost technique, this residue burning aspects can also be overcome. But, use of vermicompost or preparation of vermicompost is still not accepted in large scale due to lack of awareness and technology difficulties. So, there is a need of proper extension to explore the potentialities of vermicompost and its healthy issues on our planet.

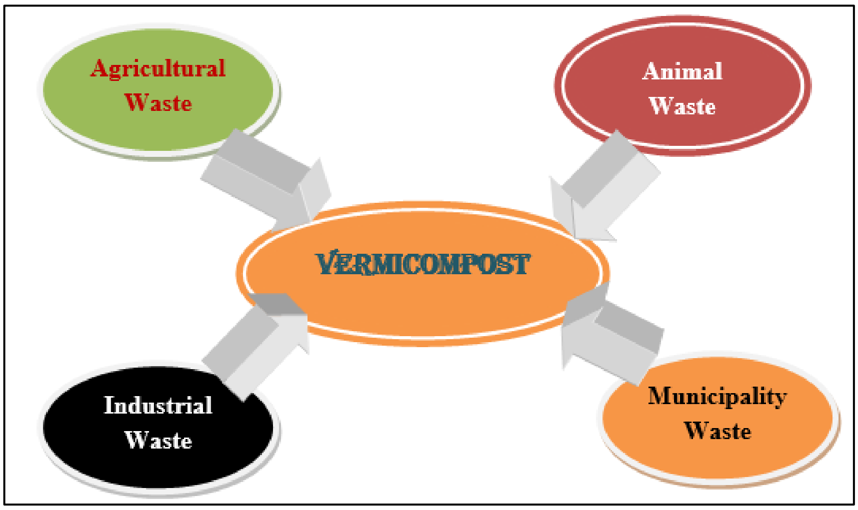


Figure 3.1: Input material in Vermicompost

3.2 Vermicompost:

Vermicompost (vermi-compost) is an organic manure produce from the vermicast by earthworm feeding on biological waste materials, plant residues etc.

It is odorless, clean organic material enriched with all beneficial soil microbes containing adequate quantity of water-soluble nutrients and soil conditioners (**Figure 3.2**).

Eco-friendly, non-toxic bio-fertilizer that is helpful for sustaining soil health and useful for recycling agricultural waste. Vermicompost, with its balanced nutrient content and enriched micronutrients is a potent organic fertilizer that can greatly enhance soil health and plant growth.

The nitrogen, phosphorus and potassium content in vermicompost provide essential nutrients for plant growth and development.

Additionally, micronutrients like magnesium, iron, zinc, manganese, boron and copper contribute to overall plant health aiding in various metabolic processes and enzyme functions.

3.2.1 Vermicomposting:

Vermicomposting is generally defined as the solid phase decomposition of organic residues in the aerobic environment by exploiting the optimum biological activity of earth worms and microorganisms [25].

Vermicomposting is described as "Bio-oxidation and stabilization of organic material involved by the joint action of earthworms and mesophilic microorganisms".

Vermicomposting involves the process of creating a mixture of decomposing organic waste materials such as vegetable scrapes, food wastes and bedding materials like shredded paper or cardboard, along with vermicast, which is the nutrient rich excrement produced by earthworms during the digestion of organic matter.

3.3 Earthworm: A Biological Agent of Healthy Planet:

Among the soil biota, earth worm is one of the major kinds and a key component of tropical and subtropical ecosystems [8], helps in soil aggregation, nutrient recycling, litter decomposition *etc.* by producing casts, pellets and galleries.

Earthworm creates a favorable place by secretion of mucus for maintaining or improving the activity of microorganisms. Around 3000 species of earthworms documented so far [9].

The earthworms are of three types that have been described below.

Figure 3.2: Conversion of organic waste into compost and vermicompost

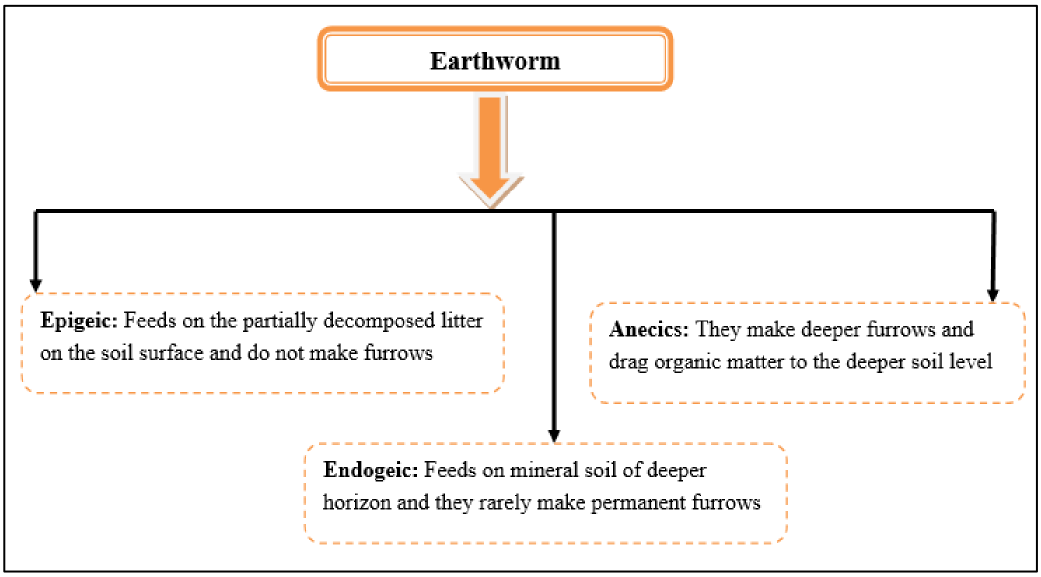


Figure 3.3: Earthworm

Table 3.1: Comparisons between Chemical fertilizers and Vermicompost

Indices	Chemical Fertilizers	Vermicompost
Synthesis process	Factory based manufactured	Natural decomposition of organic waste with the help of earthworms
Macro-nutrients	Mostly used Straight fertilizers	Secondary minerals (Ca, Mg & S) also present with all the primary minerals [10]
Micro-nutrients	Not incorporated	Significant number of micronutrients (Zn, B, Mn, Cu & Fe) also present [11]
Soil structure	Degradation happens due to excess use of chemical fertilizers	Improves soil physicochemical properties
Biological activity of soil	Reduces biological activity	Encourage the activity of soil microbes [12]
Environmental impact	Excess use of chemical fertilizers causes environmental pollution	Eco-friendly approach
Saving cost of cultivation	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 [13].

The most common earthworms [14] have successfully used in India for vermicompost preparation are:

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

Figure 3.4: Asian worms (*Perionyx excavates*)

Figure 3.5: Tiger worms (*Eisenia fetida*)

Figure 3.6: African earthworm (*Eudrilus eugeniae)*

3.4 General Properties of Vermicompost:

After the genuine realization regarding the significant impact of organic inputs among crop field, the acceptability of vermicompost has been rising rapidly. The excreta of earthworm have several characteristics. These are:

A. Physical Characteristics:

- Vermicompost is always non-toxic and eco-friendly in nature which is highly decomposed.
- Municipal waste, agricultural waste, sewage sludge, industrial waste, and human feces can be used for vermicompost preparation.
- Aerobic decomposition produces normal odor, porous texture and brown color that indicate the vermicompost is ready to use.
- Vermicompost plays the role of a "soil conditioner" by improving the soil porosity, drainage, and water holding capacity [15].

B. Chemical Properties:

- Vermicompost is rich in all macro and micro plant nutrients compared to other composts.
- In contrast with other conventional compost, vermicompost contains worm mucus which facilitates in preventing washing away of nutrients present there [16].
- Earthworms accumulated heavy metals present in feeding material in their body tissue. This property makes vermicompost lesser contaminant than any other compost and becomes it environmentally sustainable.
- Comparison study in chemical properties between farm yard compost and vermicompost followed in **Table 3.2** [17]

Table 3.2: Chemical Properties of Farm Yard Compost and Vermicompost

Properties	Compost	Vermicompost
pH	7.16	7.72
EC (dS m^{-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

C. Biological Properties:

- Vermicompost is an inhabitant of several microorganisms' *viz.* bacteria, fungi and actinomycetes, which can release several enzymatic substances that actually stabilize plant growth [18].
- Nitrogen fixing bacteria and other symbiotic associative bacteria are also present in good numbers.
- In addition to these, vermicompost harbor a large number of vesicular-arbuscular mycorrhiza (VAM) propagules that's helps to increase availability of nitrogen and phosphorus to plants.

3.4.1 Materials for Preparation of Vermicompost:

- **Crop residue:** Stems, leaves and other plant parts left in the field after harvesting of crops.
- **Weed biomass:** Unwanted plant materials such as invasive weeds or overgrown vegetation that is removed from agricultural fields or gardens.

- **Vegetable waste:** Discarded parts of vegetables, including peels, stems, and leaves, generated from households, markets or food processing facilities.
- **Leaf litter:** Fallen leaves from trees and shrubs, commonly found in forests, parks and gardens.
- **Hotel refuse:** Organic waste produced by hotels and restaurants, including leftover food, fruit and vegetable scraps and biodegradable packaging materials.
- **Waste from agro-industries:** Byproducts generated during agricultural processing operations such as fruit pomace, husks and shells.
- **Biodegradable portion of urban and rural waste:** Organic waste generated by households, communities and agricultural activities, including kitchen scraps, yard trimmings, and animal manure.

But it should be in mind that waste containing salt, pickle, oil, and vinegar, meat, and milk products cannot be used as food for the earthworms in a vermicomposting pit because these items can lead to the growth of disease-causing small organisms. These small organisms may harm the earthworms and hinder the preparation of compost.

3.5 Phase of Vermicomposting:

A. Phase 1: Collection of waste; shredding; mechanical separation of the metal, glass and ceramics and storage of organic wastes.

B. Phase 2: Heaping the material along with cow dung slurry for pre-digestion for near about fifteen to twenty days. This process makes the materials ready for earthworm consumption.

C. Phase 3: Put the pre-digested materials into vermicompost bed either concrete or earthen. Continuous watering and loose soil make it suitable for earthworms to put into the materials.

D. Phase 4: Collection of earthworms by sieving the composted material to separate fully composted material. The partially composted material will be again put into vermicompost bed.

E. Phase 5: Storing the vermicompost in proper place to maintain moisture and allow the beneficial microorganisms to grow.

• Essential Precaution Needed for Proper Vermicompost Preparation

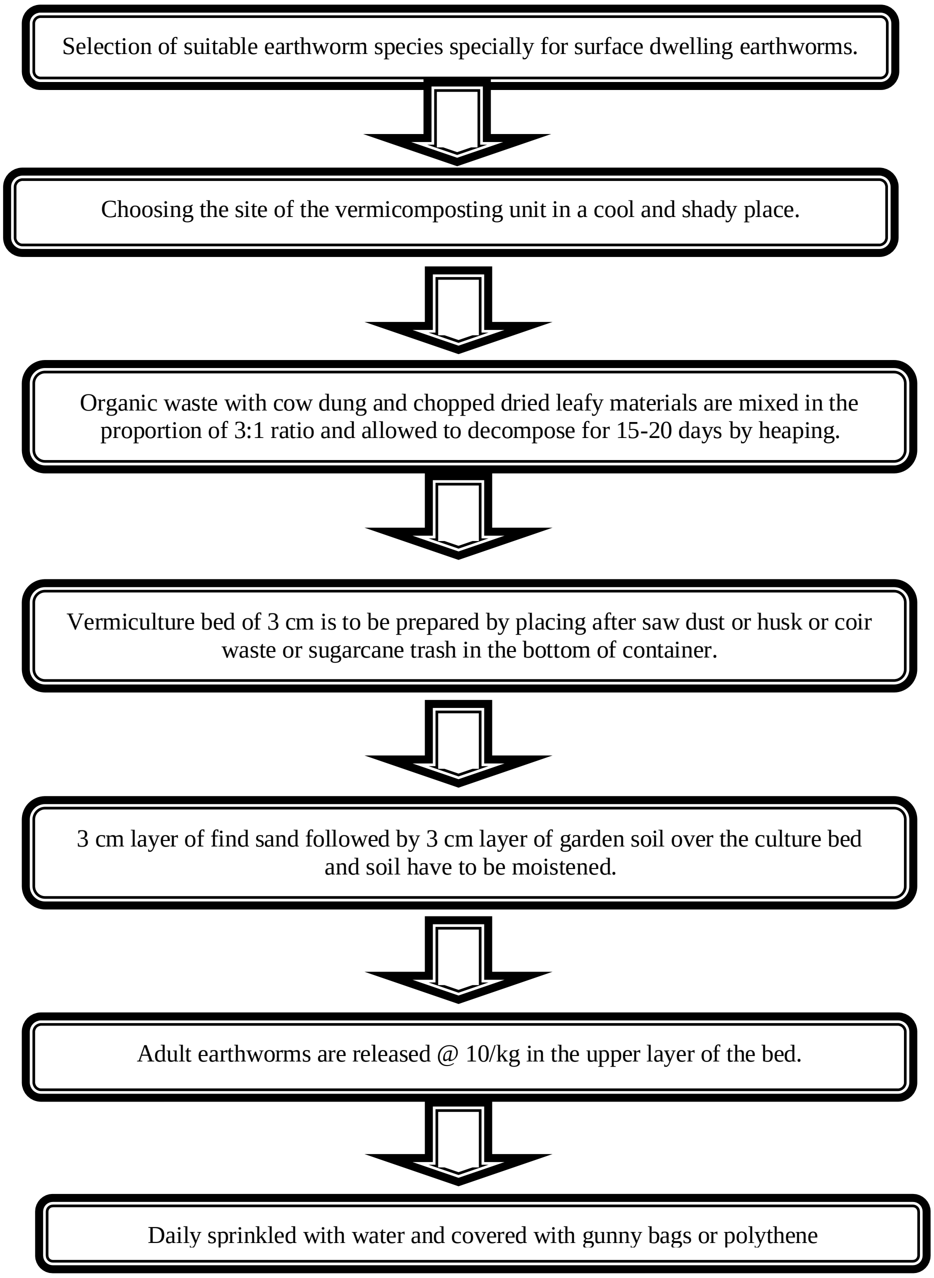
a. Always maintaining a hospitable living environment for earthworms.
b. An efficient food source without any poisonous chemicals or hazardous materials.
c. During vermicompost preparation, bed should be watered everyday as per needed.
d. Maintaining a proper aeration by turning the material once in two days.
e. Vermi beds or pits always protect from extreme temperature.

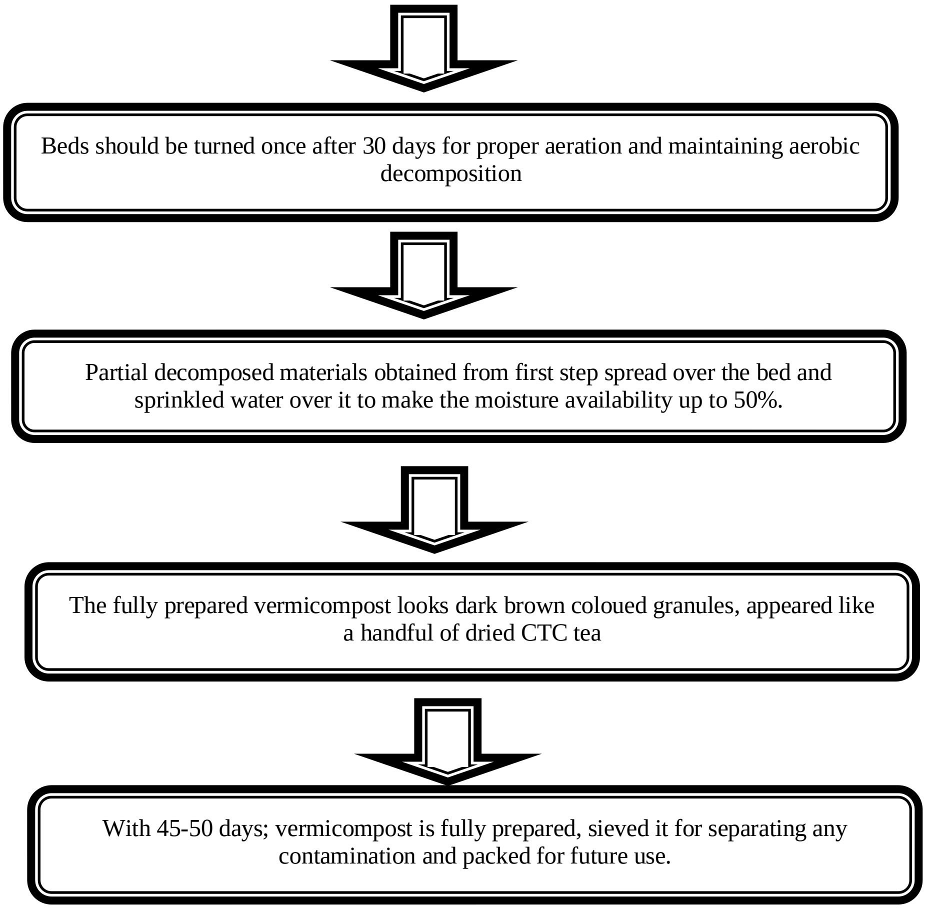
• Preparation Methods

Vermicomposting is the conversion of organic waste viz. municipal waste, agricultural waste, and sewage sludge, industrial waste and human feces into dark brown nutrient rich compost material with the help of “Bio-engineers”.

Along with these materials, we can also use some easily available inputs just to accelerate the decomposition process and enhance nutrient content. In Indian condition, among various techniques of vermicomposting, two most common methods are seen viz. bed method and pit method. In bed method of vermicomposting, layering of organic materials likes' hay, straw, corn silage etc. on a solid or earthen floor with cow dung is maintained to facilitate a conducive environment. But, in case of pit method, the process is somehow difficult than bed method. Here, composting is done on cemented pits, units covered with grass or any other organic mixtures just to conserve moisture.

Step By Step of Preparation Method:





3.6 Advantages of Vermicompost:

- Vermicompost offers the combination of a greater number of nutrients to the plant than other composts.
- Vermicompost does not allow the nutrients to leaching; it can easily hold the nutrients and avail to the plant.
- Vermicompost cannot leave its residual effect on soil health like chemical fertilizers. It can always sustain soil health and maintain the plant healthier.
- Vermicompost have the potentiality to improve soil water holding capacity, soil aggregation, and soil buffering capacity and soil microbial population that ultimately helps to produce economic and healthy output.

3.7 Effect of Vermicompost on The Soil Physiochemical Properties:

Soil physic-chemical properties like soil structure, soil water holding capacity, soil bulk density, soil aggregation, soil nutrient content *etc.* can be improved or sustained by applying recommended dose of vermicompost in long term basis [**Table 3.3**]. 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 [19]. Aksakal et al. [20] 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. Vermicompost has indeed been found to have significant concentration of total and bio-available nitrogen, phosphorus, potassium (NPK), and micronutrients, as well as microbial and enzyme activity and growth regulators [21].

Polysaccharide acts as a cementing agent to establish a healthy soil structure for maintaining soil aeration, water retention, and drainage. The lower C: N ratio of vermicompost indicates more suitability as soil amendments and also able to limit the loss of nutrients through leaching. Humic acid and biologically active compounds like plant growth regulators are abundant in vermicompost [22]. 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.

Table 3.3: Effect Of Vermicompost on Physiochemical Properties of Soil on Different Crops

Crop	Treatments	Physiochemical effects				References
		pH	EC (dS m^{-1})	BD (g cm^{-3})	Porosity (%)	
Rice	Control	7.4 ± 2.01	2.0 ± 1.0	-	39 ± 2.0	Tharmaraj *et al.*[19]
	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.* [27]
	Vermicompost @ 5 g kg^{-1} soil	7.6	4.65	1.42	26.85	

3.8 Effect of Vermicompost on The Soil Biological Properties:

Biological properties of soil can be eventually improved by application of vermicompost. These vermicompost act as a media or agent to improve soil biological condition like soil microbial biomass, enzymatic activity, population of different beneficial microorganisms etc. and sustain the nutrient availability status to the plant [**Table 3.4**].

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 [23].

Table 3.4: Comparison between the effect of vermicompost and conventional compost on different nutrient content of the *Amaranthus viridis* production

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: [27]

3.9 Effect of Vermicompost on Soil Fertility:

Vermicompost has a positive significance effect on sustaining soil fertility status. Long term use of inorganic fertilizers results in lacking of organic additives that also promote or give more attentive on using of vermicompost as organic amendments for improving soil inherent fertility status. Using vermicompost improves overall soil physical, chemical and biological qualities compared to other farm yard composts.

3.10 Effect of Vermicompost on Plant Diseases:

Vermicompost is useful for remedies of plant diseases due to soil-borne and foliar plant pathogens and pests that may prove the vermicompost is an organic fertilizer as well as bio-control agent.

Conventional agriculture encourages use of high dose of chemical pesticides leads to the development of biological resistance in crop diseases and pests. That’s why, need more & more and diversified formulations of these chemicals just to sustain the high number of yields.

3.11 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 [24].

3.12 Knowledge Gaps:

Extreme number of papers contributed to understand the role of vermicompost in planet health, but still there have meaning and knowledgeable gaps regarding the use of vermicompost [**Figure 3.6**].

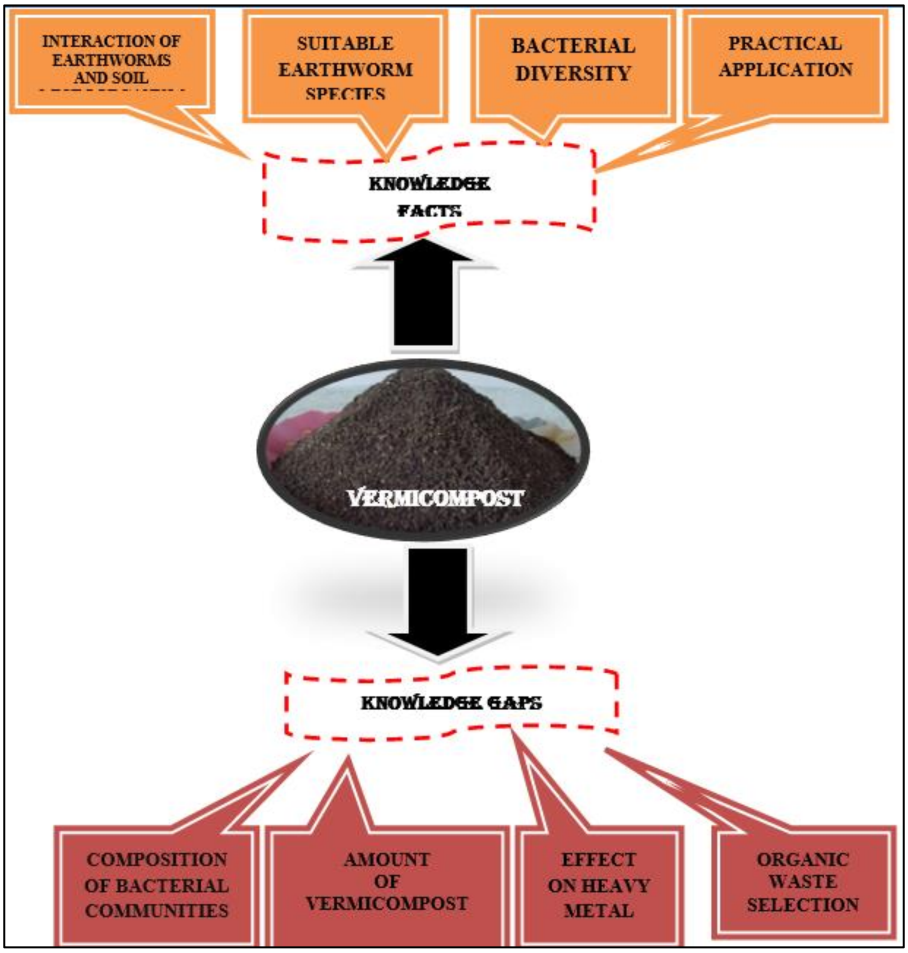


Figure 3.6: ***Even though many facts about vermicompost are known, there are still knowledge gaps that need to be additionally explored to maximize the potential of vermicompost***

3.13 Limitation of Vermicompost:

- To decompose the organic wastes into vermicompost requires minimum 6 months. So, vermicomposting is a time taking process.
- For preparation of vermicompost requires extra maintenance compared to other composting.
- Vermicompost may harbor pest and diseases as the temperature of vermicomposting pit have to be cool enough to support earthworm life.

3.14 Conclusion:

Vermicompost is organic in nature, so it is not harmful or unhealthy for the environment. If we move our focus from the "quantity of food" to the "quality of food", then our only way to accommodate organic practice in farming system. It's also true that only organic practice cannot meet our food demand but use of vermicompost like organic inputs along with chemical inputs as integrated way, makes our surroundings lively.

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