Chapter

# Vermicomposting: An Effective Option for Recycling Organic Wastes

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## Abstract

Urbanization and industrialization resulted in rapid increase in volume of solid waste; its management has become one of the biggest problems today. Solid wastes can be disposed off by methods like land filling, incineration, conversion into biogas, recycling, and composting, but its overproduction has led to inappropriate disposal practices such as their indiscriminate and inappropriately timed application to agricultural fields that ultimately leads to water and soil pollution. However, if handled properly, these organic wastes can be used for vermicomposting; it is an effective recycling technology that improves the quality of the products which is disinfected, detoxified, and highly nutritive. It is a low cost, eco-biotechnological process of waste management in which earthworms are used to cooperate with microorganisms in order to convert biodegradable wastes into organic fertilizer. Earthworms excreta (vermicast) is a nutritive organic fertilizer rich in humus, NPK, micronutrients, beneficial soil microbes; nitrogen-fixing, phosphate solubilizing bacteria, actinomycets, and growth hormones auxins, gibberlins and cytokinins, is a suitable alternative to chemical fertilizers, being an excellent growth promoter and protector for crop plants. Thus, vermiculture not only results in management of soild waste but also produces excellent nutrient enriched vermicompost. Vermicompost is beneficial for sustainable organic agriculture and maintaining balanced ecosystem.


**Keywords:** organic waste, earthworms, vermicompost, nutrients, sustainable organic agriculture

## 1. Introduction

Increasing world population has resulted in higher consumption of goods and services that has driven a substantial increase of organic wastes originating from households, industry, and agriculture [1]. Much of the organic wastes are highly infectious as they contain a variety of pathogenic microorganisms. Dumping of organic wastes in open areas generates serious environmental issues such as the accumulation of heavy metals in soil, pollution of ground and surface waters due to leaching and run-off of nutrients. These organic wastes when applied directly to agricultural fields cause soil environment-related problems including phytotoxicity [2]. These wastes represent a valuable organic resource, which could be recycled and transformed into nutrient rich fertilizer and/or soil conditioner [3–5]. Moreover growing awareness about adverse effects of agricultural chemicals on human health has increased interest in organic agriculture [6]. Organic agriculture also promotes ecological conservation due to judicious use of natural resources [7–9]. In demand for safe and sustainable strategies to treat organic wastes includes best known practices of composting and vermicomposting for biological stabilization of solid organic wastes by transforming them into a safer and more stabilized material that can be used as a source of nutrients and soil conditioner in agricultural applications [10–12]. Vermicomposting is one of the most efficient means to mitigate and manage environmental pollution problems [13]. Recently, many studies are being done to establish vermicompost as one of the preferred organic substitutes to chemical fertilizers [14, 15]. Vermicompost is more rich in NPK, micronutrients and beneficial soil microbes (nitrogen fixing and phosphate solubilizing bacteria and actinomycetes), an excellent growth promoter and protector for crop plants [16, 17] than compost [18, 19].

### 1.1 Vermicomposting- a preferred approach in organic farming

Vermicomposting (vermis from the Latin for worm) is a mesophilic process [20] which involves a joint action of earthworms (active at 10–32°C) and mesophilic microbes [21] for the conversion of organic wastes into a valuable end product known as vermicompost. Whereas, composting involves the degradation of organic waste by microorganisms under controlled conditions, in which the organic material undergoes a characteristic thermophilic stage that allows sanitization of the waste by elimination of pathogenic microorganisms [22]. Composting is also used to treat manures, green wastes or municipal solid wastes [23]. However, vermicomposting gives a higher-quality end product than composting due to joint action of enzymatic and microbial activities that occur during the process [24]. This process is faster than traditional composting as the material passes through the earthworm gut, whereby the resulting earthworm castings are rich in microbial activity and plant growth regulators, and fortified with pest repellence attributes as well [25, 26]. Compared to traditional composting method, vermicomposting also results in mass reduction, shorter processing time, and high levels of humus with reduced phytotoxicity [27]. Thus, vermicompost is considered an ideal manure for organic agriculture as it is nutrient rich and contains high quality humus, plant growth hormones, enzymes, and substances that are able to protect crops against pests and diseases [28, 29]. Moreover, vermicompost has high porosity, aeration, drainage, and water-holding capacity [20]. In addition to increased N availability, C, P, K, Ca and Mg plant nutrient availability in the earthworm casts are also found [30]. Plant growth hormones namely cytokinins and auxins are found in organic wastes processed by earthworms [31]. They also release certain metabolites, such as vitamin B, vitamin D and similar substances into the compost [32]. Thus, earthworms accelerate the mineralization rate and convert the manures into casts with higher nutritional value and degree of humification than traditional method of composting [33]. The composition of commonly available nutrients in vermicompost is as follows: Organic carbon 9.5–17.98%, Nitrogen 0.5–1.50%, Phosphorous 0.1–0.30%, Potassium 0.15–0.56%, Sodium 0.06–0.30%, Calcium and Magnesium 22.67–47.60 meq/100 g, Copper 2–9.50 mg/kg, Iron 2–9.30 mg/kg, Zinc 5.70–11.50 mg/kg, Sulfur 128–548 mg/kg [34]. Hence, vermicomposting enables biological transformation of wastes into a valuable organic fertilizer [35, 36]. Vermicompost is popularly called as black gold and has become one of the major components of organic farming system [26].

## 2. Role of earthworm in vermicomposting

### 2.1 Biology of earthworm

Earthworms are invertebrates belonging to the phylum Annelida, class Oligochaeta and family Lumbricidae. The earthworms are long, elongated, cylindrical, soft bodied animals with uniform ring like structures consisting of segments along the length of their body outwardly highlighted by circular grooves called annuli. On the ventral surface of sides of the body each segment bears four pairs of short, stubby bristles, or setae used for its movement. Earthworms have an opening at the anterior end is mouth and the one at the posterior is anus. Earthworms possess both male and female gonads, so are called as hermaphrodites. They deposit their eggs in a cocoon without any larval stage. At the time of egg laying, the sexually mature worms contain a distinctive epidermal ring just beneath the anterior segments called, clitellum, which has gland cells to form a viscid, girdle like structure known as cocoon. The number of fertilized ova in each cocoon has 1–20 lumbricid worms.

### 2.2 Classification of earthworm

There are about 3320 species of earthworms all over the world [37], but hardly 8–10 species are suitable for vermicompost preparation. Earthworms have been extensively utilized for the recycling of a variety of organic wastes like municipal solid wastes [38] wheat straw [39], sewage sludge [40], forestry waste [41], vegetable waste [42], farmyard manure [43], sorghum stalk, wheat straw, paddy straw [44], coir pith [45]. Renowned scientists, Charles Darwin called earthworms as the 'unheralded soldiers of mankind', and Aristotle described them as the 'intestine of earth', as they could digest a wide range of organic materials [46, 47]. On the basis of morpho-ecological characteristics, earthworms have been classified into three categories [48]; Anecic (Greek word "out of the earth") – these are burrowing worms that only come to the surface at night to drag food down into their permanent burrows deep within the mineral layers of the soil. Endogeic (Greek word "within the earth") – these are also burrowing worms but their burrows are typically more shallow and they feed on the organic matter inside the soil, so they come to the surface only rarely. Epigeic (Greek word "upon the earth") – these worms live on the surface litter and feed on decaying organic matter. They do not have any permanent burrows. These "decomposers" are the type of worm used in vermicomposting. Two tropical species, African night crawler, *Eudrilus eugeniae* (Kinberg) and Oriental earthworm, *Perionyx excavates* (Perrier) and two temperate ones, red earthworm, *Eisenia andrei* (Bouche) and tiger earthworm, *Eisenia fetida* (Savigny) are extensively used in vermicomposting [49–51]. Most vermicomposting facilities and studies are using the worms *E. andrei* and *E. fetida* due to their high rate of consumption, digestion, and assimilation of organic matter, tolerance to a wide range of environmental factors, short life cycles, high reproductive rates and endurance and resistance during handling [52]. A few other species *Drawida nepalensis*, *Lampito mauritrr. Dichogaster* spp., *Polypheretima elongate, Amynthas* spp. *Dendrobaena octaedra, Eisenia hortensis* [53] have also been used for composting under specific conditions.

### 2.3 How does earthworm facilitate vermicomposting?

Earthworms promote the growth of "beneficial decomposer aerobic bacteria" in organic waste material and also act as a grinder, crusher, chemical degrader and a biological stimulator of waste material [54, 55]. Earthworm hosts millions of decomposer (biodegrader) microbes [56], hydrolytic enzymes and hormones that helps in rapid decomposition of complex organic matter into vermicompost in a relatively smaller duration of 1–2 months [57] as compared to traditional composting method which takes nearly 5 months [58]. The mechanism of formation of vermicompost by earthworms occurs in following steps; organic material consumed by earthworm is softened by the saliva in the mouth of the earthworms. Food in esophagus is further softening and neutralization by calcium and physical breakdown in muscular gizzard results in particles of size <2 μ, thereby giving an enhanced surface area for microbial processing. This finally ground material is exposed to various enzymes such as protease, amylase, lipase, cellulase and chitinase secreted in lumen by stomach and small intestine [12]. Moreover, microbes associated with intestine facilitate breaking down of complex biomolecules into simple compounds. Only 5–10% of the ingested material is absorbed into the tissues of worms for its growth and the rest is excreted as vermicast. The vermicast is a good organic fertilizer and soil conditioner. High-quality vermicast can be produced by worms such as the red wrigglers (*E. fetida*) as it contains humus with high levels of nutrients that has good potential for the production of organic fertilizer. Vermiwash is a liquid fertilizer and used as a foliar spray produced by passing water through columns of vermiculture beds [59].

### 2.4 Suitable environmental conditions for earthworms

Optimum conditions of temperature 15–20°C (limits 4–30°C), Moisture content 80–90% (limits 60–90%), Oxygen – Aerobicity, Ammonia content of the waste Low: <1 $mg \cdot g^{-1}$ (0.016 oz.1b–1), Salt content Low < 0.5% and pH of 5–9 are preferred for stable life cycle of earthworm.

### 2.5 Starter food for multiplication of earthworms

To attain the desired earthworm population their starter food includes 1:1 mixture of cow dung and decaying leaves in a cement tank/wooden box/plastic bucket with proper drainage facilities and on attaining sufficient number of earthworms, subsequently other sources of organic wastes can be provided. Compost worms being voracious feeders, consume in excess of their body weight each day but they prefer some foods to others. Manures are the most commonly used worm feedstock, with dairy and beef manures generally considered the best natural food for *E. fetida* [60]. The unit should be kept in shade. Sufficient moisture level should be maintained by occasional sprinkling of water. Within 1–2 months, the worms multiply 300 times, which can be used for large scale vermicomposting.

## 3. Methods of vermicomposting

Earthworms are used to convert organic waste material into dark brown nutrient rich humus that is a good source of manure for plants. Worms can also degrade specific pollutants and might allow community formation of useful microorganisms. Three commonly used methods for vermicomposting are discussed below:

1. Bin composting: The most common method for small scale composting is bin composting method. The bin can be constructed of several materials such as wooden/plastic/recycled containers like bathtubs and barrels. A vermicompost bin may be in different sizes and shapes, but its average dimensions are 45 × 30 × 45 cm. Around 10 holes with 1–1.5 cm in diameter holes in bottom, sides and cap of bin is useful for aeration and drainage.

2. Pit composting: For large scale composting, pits of sizes 2.5 m × 1 m × 0.3 m under thatched sheds with sides left open are advisable. The bottom and sides of the pit should be made hard with a wooden mallet.

3. Pile composting: Pile method is mostly used for vermicomposting in larger scale. The piles can be made in porch place like greenhouse or in a floor with some facilities for drainage in warm climate. The pile size may vary in length and width, however, its height is average height of bin used for bin composting.

## 4. Conventional steps involved in vermicomposting

Prior to the vermicomposting process, it is preferred to assign pre-composting of organic waste (thermophilic composting), which comprises a short period of high temperature for facilitating mass reduction, waste stabilization, and pathogen reduction [61, 62]. Thermophilic composting results in sanitization of organic wastes and elimination of toxic compounds [63]. Although pathogen removal occurs during transit in the worm gut [64] but thermophilic composting prior to vermicomposting is advisable to avoid the earthworm mortality. Then, after some days of high temperature, pre-mature compost is cooled by spreading it as thin layers on vermicomposting beds. Vermicomposting can be done either in containers, pits or piles.

1. **Materials required for vermicomposting:** Carbon and nitrogen-rich organic materials, spade, ground space, stakes, hollow blocks, plastic sheets or used sacks, water (according to the season) and water sprinklers, shading materials, nylon net or any substitute to cover the beds, and composting earthworms.

2. **Site Selection:** Vermicompost production can be done at any place which is having shades, cool and has high humidity. For instance, abandoned cattle shed, or poultry shed or unused buildings or artificial shading could also be provided.

3. **Shredding of organic waste material:** The collected organic waste material should be processed for shredding along with mechanical separation of the metal, glass and ceramics that should be kept aside.

4. **Pre-digestion of organic waste material:** Pre-digestion of organic waste should be done for at least 20–25 days prior by mixing the waste material along with raw material (e.g., cattle dung slurry). Regular watering is required for partially digesting it and making it fit for earthworm consumption. Raw material to be used includes for composting – cow dung, crop residues, farm wastes, vegetable market wastes and fruit wastes. Cow dung should be at least 20–25 days old to avoid excess heat generation during the composting process. Moreover addition of higher quantities of acid-rich substances such as citrus wastes should be avoided. It is important to mix carbonaceous with nitrogenous organic materials at the right proportions to obtain a C: N ratio of about 30:1, as it results in product of highest stability, the best fertilizer-value and with lowest potential for environmental pollution. For example, rice straw and fresh manure are mixed at about 25:75 ratio by weight. When the material with higher carbon content is used with C:N ratio exceeding 40:1, it is advisable to add nitrogen supplements to ensure its effective decomposition.

5. **Earthworm bed preparation:** An hospitable living environment for worms called bedding is prepared. Bedding is a material that provides the worms with a relatively stable habitat with following characteristics:

    i. **High absorbency**: As earthworms breathes through their skins and therefore bedding must be able to absorb and retain water fairly well. Worms dies if its skin dries out.

    ii. **Good bulking potential**: Worms respire aerobically and different bedding materials affect the overall porosity of the bedding, including the range of particle size and shape, the texture, and the strength and rigidity of its structure. If bedding material is too dense or packs too tightly, then the flow of air is reduced or eliminated. This overall effect is referred as the material's bulking potential.

    iii. **Low protein and/or nitrogen content/high Carbon:** Earthworms consume their bedding as it breaks down and it is very important for this process to be slow. High protein/nitrogen levels can result in rapid degradation of bedding and its associated heating, creating inhospitable or fatal conditions. High carbon content is required as earthworms and microbes in the feed mixtures activate microbial respiration and degradation of organic wastes, thereby increasing the loss of organic carbon during the vermicomposting process [65, 66]. Various bedding material according to absorbency, bulking potential and C:N are enlisted in **Table 1**.

6. **Vermiculture bed:** Vermiculture bed can be prepared by placing a first layer of saw dust, newspaper, straw, coir waste, sugarcane trash etc. at the bottom of tub/container. Newspaper is one of bedding material that high in absorbency whereas for the sawdust the level of absorbency is poor to medium. A second layer of moistened fine sand of 3 cm thick should be spread over the culture bed followed by a layer of garden soil (3 cm). The floor of the unit should be compacted to prevent earthworm's migration into the soil.

7. **Loading of organic waste mixture in bed:** Third layer of the pre-digested organic waste prepared is added. Thereafter a thin layer of cow dung mixture is placed on the surface of waste material as starter food for compost worms. Then compost worms are to be added without spreading them out. Earthworms consume various organic wastes and reduce the volume by 40–60%. Earthworm eats waste equivalent to its body weight, and produce cast about 50% of the wastes, it consumes in a day.

8. **Composting process:** After addition of compost worms wait for at least 15 days for the thermophillic process to end. During this process there is a rapid increase in temperature followed by a gradual decrease. During this period turning to the material 2–3 times at 4–5 days interval is required. Its temperature should be maintained at 30°C, when temperature approaches ambient temperature (<35°C) covering is to be removed and for temperature maintenance, upturning and regular sprinkling of water is advisable. Prominent precautionary measures include; Composting pit should be covered with nylon net or any substitute material to serve as barrier against predators like ants, birds, lizards as it may disturb the activity of earthworm, Blockage of side air vents should be avoided as it can quickly lead to putrefaction and extreme

weather conditions such as frost, heavy rainfall, drought and overheating should be avoided. No smell comes out of composting site if the right products or bedding and feed are used. The vermicompost once formed completely will give the smell of moist soil. Maturity could be judged visually also by observing the formation of granular structure of the compost at the surface of the tank. Next step is to make a heap in sunlight on a plastic sheet and keep it for 1-2 hours. The worms will gather at the bottom of heap. After removing vermicompost on top, the worms settled down at the bottom can be carefully collected for use in the next batch of vermicomposting.

| Bedding Material | Absorbency | Bulking Pot. | C:N Ratio |
|---|---|---|---|
| Horse manure | Medium-good | Good | 22–56 |
| Peat moss | Good | Medium | 58 |
| Corn silage | Medium-Good | Medium | 38–43 |
| Hay–general | Poor | Medium | 15–32 |
| Straw–general | Poor | Medium-Good | 48–150 |
| Straw–oat | Poor | Medium | 48–98 |
| Straw–wheat | Poor | Medium-Good | 100–150 |
| Paper from municipal waste stream | Medium-Good | Medium | 127–178 |
| Newspaper | Good | Medium | 170 |
| Bark–hardwoods | Poor | Good | 116–436 |
| Bark–softwoods | Poor | Good | 131–1285 |
| Corrugated cardboard | Good | Medium | 563 |
| Lumber mill waste–chipped | Poor | Good | 170 |
| Paper fibre sludge | Medium-Good | Medium | 250 |
| Paper mill sludge | Good | Medium | 54 |
| Sawdust | Poor-Medium | Poor-Medium | 142–750 |
| Shrub trimmings | Poor | Good | 53 |
| Hardwood chips, shavings | Poor | Good | 451–819 |
| Softwood chips, shavings | Poor | Good | 212–1313 |
| Leaves (dry, loose) | Poor-Medium | Poor-Medium | 40–80 |
| Corn stalks | Poor | Good | 60–73 |
| Corn cobs | Poor-Medium | Good | 56–123 |
| Paper mill sludge | Good | Medium | 54 |
| Sawdust | Poor-Medium | Poor-Medium | 142–750 |
| Shrub trimmings | Poor | Good | 53 |
| Hardwood chips, shavings | Poor | Good | 451–819 |
| Softwood chips, shavings | Poor | Good | 212–1313 |
| Leaves (dry, loose) | Poor-Medium | Poor-Medium | 40–80 |
| Corn stalks | Poor | Good | 60–73 |
| Corn cobs | Poor-Medium | Good | 56–123 |

**Table 1.**
*List of some of the commonly used earthworm bedding material.*

## 5. Effect of abiotic factors on vermicomposting

The most important abiotic factors which affect vermicomposting process include moisture, pH, temperature, aeration, pH value, ammonia and salt content.

1. **Moisture:** A strong relationship exists between the moisture content of organic wastes and the growth rate of earthworms. In a comparative study on vermicomposting process and earthworm's growth at different temperature and moisture ranges showed that 65–75% is most suitable range of moisture at all ranges of vermicomposting temperature [67]. The bedding used for vermicomposting must be able to hold sufficient moisture as earthworms respire through their skins and moisture content in the bedding of less than of 45% can be fatal to the worms. Although epigenic species, *E. fetida* and *E. andrei* can survive moisture ranges between 50% and 90%, but they grow more rapidly between 80% and 90% [20, 68]. The bacteria also plays vital role in vermicomposting. Its activity decreases in moisture content lower than 40% and it almost stops in lower than 10% [69].

2. **Temperature:** Earthworm's activity, metabolism, growth, respiration and reproduction are greatly influenced by temperature [70]. The temperature for the stable development of earthworm population should not exceed 25°C [71]. Although *E. fetida* cocoons survive extended periods of deep freezing and remain viable [72] but they do not reproduce and do not consume sufficient food at single digit temperatures. It is generally considered necessary to keep the temperatures preferably 15°C for vermicomposting efficiency and 20°C for effective reproductive vermiculture operations. Temperatures above 35°C will cause the worms to leave the area or if they cannot leave, they will quickly die. Bacterial activity is also greatly depended on temperature as it multiplies by two per each 10°C increase in temperature and is quite active around 15–30°C.

3. **Aeration:** Earthworms are oxygen breathers and cannot survive in anaerobic conditions. They operate best when compost material is porous and well aerated. Earthworms also help themselves by aerating their bedding by their movement through it. *E. fetida* have been reported to migrate in high numbers from oxygen depleted water saturated substrate, or in which carbon dioxide or hydrogen sulfide has accumulated.

4. **pH value:** The pH value is also one of the important factors affecting the vermicomposting process [73]. Epigenic worms can survive in a pH range of 5–9 [74]. The pH of worm beds tends to drop over time. If the food source/bedding is alkaline, than pH of bed drop to neutral or slightly alkaline and if the food source is acidic than the pH of the beds can drop well below 7. The pH can be adjusted upwards by adding calcium carbonate or peat moss for adjusting pH downward can be introduced into the mix. Although microorganisms which are active in vermicomposting which can maintain their activity even in lower pH of around 4 but recommended pH range for compost is around 6.5–7.5.

5. **Ammonia and salt content:** Earthworms cannot survive in organic wastes containing high levels of ammonia. Worms are also very sensitive to salts and they prefer salt contents less than 0.5% [75]. However, many types of manures

have high salt contents and if they are to be used as bedding, they should be leached first to reduce the salt content, it is done by simply running water through the material for a period of time [60].

## 6. Common methods of vermicompost harvesting

The vermicompost is ready within 60–90 days and ultimately the material becomes black, granular, lightweight, moderately loose, crumbly and humus-rich. Watering must be avoided two to three days before emptying the beds to facilitate the separation of worms from the compost. Common procedures for harvesting the vermicompost are briefly described below. Any method may be adopted exclusively by preference. Moreover, two or more methods may be applied on the same pile. Except for the first method, the rest are intended for bulk harvesting.

### 6.1 Manual harvesting of Vermicompost

This method is practiced if one wants to collect small amounts of vermicast just a few days after the compost pile is stocked with composting worms. In this case only top layer is covered with a thin layer of vermicast and rest of pile has not fully decomposed. The vermicast on top of the pile are simply gathered by hand/trowel and transferred directly into a container. This method is recommended if there is need of organic soil amendment in preparing a fertile potting mix. With time, as vermicompost is collected at the bottom of the pile it is further collected by hand.

### 6.2 Vermicompost harvesting by pyramidal heap

The vermicompost is first gathered to form a pyramid like heap within the composting enclosure provided that the heap is exposed to light or it is transferred on to a flat surface elsewhere in open sun on a plastic sheet or a sack. This method of harvesting vermicompost takes the advantage of the earthworm's sensitivity towards light as they will tend to move deep into the pyramid. Vermicompost from the bottom, sides, and top surface of the heap is then collected by hand or with a trowel. After the first cycle of vermicompost collection, a few minutes are passed to provide sufficient time for the earthworms to move deeper and another cycle is commenced. For faster rate of harvesting vermicompost, the original heap is divided into several smaller heaps.

### 6.3 Screening or sieving of vermicompost

This method of vermicompost harvesting is done manually with tool consists of mesh wire nailed on wood called sieve. A small portion from vermicompost pile spread on flat floor is transferred into a sieve and it is shaken so that fine vermicompost falls on the ground. Any undecomposed subtrates and earthworms are retained in the screener and the worms are separated manually.

### 6.4 Vermicompost harvesting by inducing the migration of earthworms

This method of harvesting vermicompost is based on earthworms' ability to detect sources of food. Earthworms have the habit of abandoning the pile exhausted of food and moving towards fresher palatable source. Despite many modifications in this technique, but the basic principle is the same to provide fresh or more palatable food to cause the migration of earthworms from the exhausted pile to the new food source.

## 7. Storing and packing of vermicompost

The harvested vermicompost should be stored in dark and cool place as sunlight will lead to loss of moisture and nutrient content. Moreover, harvested vermicompost material should be stored in open rather than packed in sacs. Packing should be done at the time of selling and laminated sac is always advisable. During compost storage in open place, periodical sprinkling of water should be done to maintain moisture level and beneficial microbial population. Vermicompost can be stored for longer periods of one year without loss of its quality, if its moisture is maintained at 40% level.

## 8. Role of vermicompost on soil fertility

The key role of vermicompost is change in physical, chemical and biological properties of soil by earthworm activities and they thus called as soil managers [59]. It substantially improves soil structure, texture, aeration and prevents soil erosion. It increases the macropore space ranging from 50 to 500 μm, resulting in improved air-water relationship in the soil thereby favorably affecting plant growth [76]. It also favorably affects soil pH, its microbial population and soil enzyme activities [77]. Moreover, vermicompost is rich source of nutrients such as nitrates, phosphates and exchangeable calcium and soluble potassium [30]. Apart from adding mineralogical nutrients, vermicompost is also rich in beneficial micro flora such as N-fixers, P-solubilizers, cellulose decomposing micro-flora, etc. It also reduces the proportion of water soluble chemical, which causes possible environmental contamination [78]. Mucus excreted by earthworm's digestive canal produces some antibiotics and hormone-like biochemicals thereby boosting plant growth [70] and enhancing the decomposition of organic matter in soil [79]. Vermicompost has been reported to have favorable influence on the growth and yield parameters of several crops like paddy, sugarcane, brinjal, tomato, and okra [59]. Thus, vermicompost acts a soil conditioner [80] and a slow-release fertilizer [81] that ultimately improves soil structure, soil fertility, plant growth and suppresses diseases caused by soil-borne plant pathogens, increases crop yield [82–84].

## 9. Conclusion

Chemical fertilizers are produced from "vanishing resources" of earth and crops grown on chemical fertilizers have low and contaminated nutrient value in comparison to grown naturally or organic way. To preserve the agro-ecosystem and protect human health from the harmful chemical fertilizers 'Ecological Agriculture and Organic Farming' has to be promoted as the new emerging concept of "Organic Farming" focuses mainly on production of chemical free foods. Organic farming with use of organic fertilizers like "vermicompost" could substitute the chemical fertilizers and can reduce the economic cost and may also lead to organic products which fetches higher price in the market.

## Conflict of interest

No conflict of interest is indulged.

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