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Vermicomposting: A potential technology for Sustainable Agriculture and Waste Management

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Abstract
Potentialities of exploiting earthworm activities for our economic interest are multiple. These simple creatures can turn waste into gold by converting decomposable organic waste into valuable compost through vermicomposting. Vermicompost is cheap and sustains crop yield without deleterious effect on the environment, thus having promise to marginal and resource poor farmers. It will not only eliminate or minimize the requirement of chemical fertilizer and growth regulator but also improves the qualities of the soil and give better crops. Low capital investment and relatively simple technologies make vermicomposting practical for less-developed agricultural areas and provides employment opportunities. This may be a good asset for sustainable agriculture and waste management in years to come.
Key Words: Vermicompost, Organic waste, Earthworms, Vermicast, Chemical fertilizers.

1. Introduction

Continuous use of chemical fertilizers will lead to decline in the soil fertility and productivity besides causing deficiency and imbalance of micronutrients. The use of chemical fertilizers and pesticide has posed a serious threat to the environment and resulted in repercussions on the ecosystem. There is a great need for maintaining a viable equilibrium between growth in agricultural output, environment and ecosystem in view of ever increasing population. More than 60 percent portion of solid waste is constituted by decomposable material. Degradation of organic waste using earthworms to produce vermicompost is one of the recent developments in biological sciences. Vermicompost is a heterogeneous mixture of decomposed organic waste produced with the help of earthworms. Since long, earthworms have been known as farmer's friends, nature's best fertilizer, natural ploughmen and intestines of the earth. Earthworms act in the soil as aerators, grinders, crushers, chemical degraders and biological stimulators. Their utilization and importance have been stressed by renowned scientists like Muller (1878), Charles Darwin (1881), M. Fukoka (1978) and M.S. Swaminathan (1973). Earthworms, minimizing any need for expensive engineering to convert waste, have been called as ecological engineers. The worms ensure bio-conversion of vegetable/garden waste into NPK rich manure called Vermicompost within 40-45 days under complete aerobic conditions. Organic waste used for making vermicompost primarily includes vegetable waste, food waste, agriculture waste and sewage sludge. Vermicompost contains reduced levels of toxic contaminants and high proportion of minerals as well as water soluble nutrients, thus, proved to be an excellent organic fertilizer [1,2]. The use of vermicompost is hence, one of the working principles for organic farming. Ecosystem services like solid waste management, treatment of sewage sludge and detoxification of soil are ecological benefits of vermicomposting [3].

2. Suitable worm species

Most commonly used exotic species are Red wiggler or tiger worm (*Eisenia foetida or Eisenia andrei*), European night crawlers (*Eisenia hortensis*), African night crawlers (*Eudrilus eugeniae*) and Red Earthworm (*Lumbricus rubellus*). The indigenous species being used are Blue worms (*Perionyx excavatus* and *P. sansibaricus*).These species are well adapted to shallow compost bins. These shallow dwelling species are commonly found in the organic-rich soils of Europe and North America. These species can be easily procured from nurseries and commercial or can be easily collected from compost and manure piles. However, some species like Canadian night crawlers (*Lumbricus terrestris*) and common earthworm (*Pheretima posthuma*) are not recommended, as they burrow deeper than most compost bins can accommodate [4].

3. Vermicomposting Modes and Production Methodology

There are two different modes for vermicomposting which are generally adopted- bulk mode and small scale mode. Vermicomposting in the bulk /commercial mode is commonly practiced in United States, Canada, Italy, Japan, Malaysia, Philippines. There are two methodologies for large scale vermiculture-windrow method and raised bed or flow-through system. In windrow method, large bins having bedding materials for the earthworms along with the organic wastes are used. It proved to be a sustainable, cost-efficient way for management of dairy waste [6].In the raised bed or flow-through system, the worms are fed an inch of "worm chow" across the top of the bed, and an inch of castings are harvested from below by pulling a breaker bar across the large mesh screen which forms the base of the bed. The flow-through system eliminates the need to separate worms from the castings before packaging as it utilizes surface dwellers red worms. The worm food in commercial vermicomposting includes dairy cow or pig manure, sewage, brewery waste, cotton mill waste, agricultural waste, food processing and grocery waste and cafeteria waste. Other organic wastes like garbage from the residences, paper waste from the offices, fallen leaves or litter from the plants, laboratory wastes, agricultural waste from the fields etc. can also be utilized as raw material to produce vermicompost at large scale. On small scale level/home systems, non biodegradable containers having drain holes like old plastic containers, wood or metal containers may be used for vermicomposting. But the metallic bins pose the risk of liberation of toxic heavy metal ions into the vermicompost, therefore, they are not generally recommended for vermicomposting [7]. Worm compost bins made from plastic are ideal, but require more drainage than wooden ones because they are non-absorbent. However, wooden bins will eventually decay and need to be replaced. Perforations are manually added to the worm bins for aeration and drainage of excess liquid material [8]. A base is prepared as 1” layer of brick bats/pebbles, 1” layer of course sand, 2” garden soil and 1” layer of FYM/Vermicompost in these non biodegradable containers. Approximately 400gms of earthworms are released on this bed followed by Sprinkling of water and loading of 1” layer of cow dung. It is left for 20 days with regular sprinkling of water and turning after every 10 days is required. It is followed by loading of approx. 300-500 gms (2-3 inch) of kitchen/garden waste on alternate days by mixing with upper 4” layer till tub is filled. Earthworms act as bioreactors in the pile. They have a specific body organ called gizzard that acts as a mill and grinds the waste. Gut of the worm provides optimum pH; enzymes and other favorable conditions for biodegradation. After 30 days, the entire waste would be converted into vermicompost which looks granular in appearance and ready for harvesting. Stop sprinkling water, take out harvest from the top, and start reloading the waste in the tub without disturbing the base. Small scale vermicomposting is the best mode for conversion of kitchen and garden waste into manure. Except for dairy products, fats, meat, citrus fruits, faeces etc. worms can be fed on anything ranging from bread to leaves and to hospital wastes. Domestic waste used for vermicomposting includes fruits and vegetables peels and ends (excluding citrus and other "high acid" foods), tea bags (even those with high tannin levels), grains such as bread, cracker and cereal (including moldy and stale), eggshells, leaves and grass clippings (not sprayed with pesticides) [9], newspapers (most inks used in newspapers are not toxic) [10]. The worm species like *Eisenia foetida*, *Eisenia andrei*, and *Lumbricus rubellus* are best suited for small scale vermicomposting. If decomposition has become anaerobic, to restore healthy conditions and to prevent the worms from dying, excess waste water must be removed periodically as well as addition of food scraps with high moisture content must be avoided.

4. Harvesting and collection of vermicompost

When there is no decomposable material left in the vermibed, vermicompost is ready for harvest. For this purpose, pyramid method of harvesting is most commonly employed due to its simplicity and efficacy [11].in this method, compost is first segregated into large clumps and later on these are shifted back into composting bins for further breakdown until the formation of lighter compost. Finally this lighter compost is organized into piles in the exposure of sun rays. Since worms are negatively phototactic, they start shifting from top layers of compost towards bottom of the vermicompost pile. After a few minutes, the top of the pyramid is removed repeatedly, until the worms are again visible. This repeats until the mound is composed mostly of worms. It is generally advised to separate the eggs/cocoons of worms as many as possible while harvesting. They can be easily identified in the vermicompost pile due to their lemon shape and yellow color.

5. Factors affecting vermicomposting

Worm activity is generally depends upon climate and temperature. Temperature is the key factor in determining success of vermicomposting. The optimum temperature for commonly used worm species is 15–25°C. Due to the rise in the temperature worm activity declines, even death of worms may be noticed at elevated temperature. Hence, there must be a strict control over the temperature of large scale bins. Earthworms should be protected from direct light. Shade is required for maintaining moisture temperature and faster rate of degradation. Worm bins can be placed in the shady places in order to have ideal temperature for their maximum activity. Watering is essential to maintain the temperature of the pile. Moisture level should fall between 40-50%. A pile should have 60-100% relative humidity. The rate of vermicomposting also depends upon particle size. Smaller the particle size, faster will be the rate of degradation. So always chop the larger organic matter to small size before feeding it to the worms. A chemical factor like Carbon and Nitrogen ratio is very important for faster and complete microbial digestion of the waste. Calcium is essential for cocoons of the worms. For this broken egg shells and ground bones or lime can be added to the pile. Initial pH may be acidic or basic depending on the type of food waste but final pH of the pile is generally neutral (4.5-7.6). Rate of worm activity may be affected by presence of microflora in the vermibins. Mainly bacteria, actinomycetes and fungi are the workhorses, they breakdown the waste to humus, CO_2 and H_2O. Earthworms in turn feed on this degraded matter.

6. Precautions during vermicomposting

Vermicompost bins should have holes for passage of oxygen as the worms do the aerobic breakdown of detritus under normal conditions. Lack of proper supply of oxygen in the vermibins or addition of excess wet feedstock may initiate anaerobic breakdown by the worms producing ammoniating smell [12]. Pest such as rodents and flies can be prevented by avoiding the use of meat or dairy product in a worm bins. In African countries, Predatory ants are the common pest of worm bins. If fruit and vegetable waste is not thoroughly covered with bedding fruit and vinegar flies may breed in the bins in warm weather. This problem may be avoided by thoroughly covering the waste by at least 5 cm. of bedding material as well as by maintaining the correct pH (almost neutral) and water content of the bin. Avoid overwatering, overloading and addition of citric, acidic and cooked food. When humidity or water content is high, worms try to escape out of the bins. Worms escaping can be prevented by maintaining proper humidity and water level in the bins. Since worms show negative phototaxis, light exposure to bins may avoid worm escaping.

7. Advantages of vermicompost

Vermicompost is found to be enriched with nutrients and contains high percentage of essential minerals particularly NPK in contrast to ordinary compost produced by other methods. In addition to this worm mucus holds the nutrients and prevents their seepage into the water or deep soil layers ensuring their availability for the plants. The nutrients content in vermicompost vary depending on the waste materials that are being used for compost preparation. If the waste materials are heterogeneous one, there will be wide range of nutrients available in the compost. If the waste materials are homogenous one, there will be only certain nutrients are available. The worm castings are very important to the fertility of the soil. The castings contain high amounts of nitrogen, potassium, phosphorus, calcium, and magnesium. Castings contain 5 times the available nitrogen, 7 times the available potash, and 1½ times more calcium than found in good topsoil [Table 1].

Table 1: Percentage of Nutrients in Vermicompost

Mineral Nutrient	% age in Vermicompost
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 to 47.60 meq/100g
Copper	2 – 9.50 mg/ kg
Iron	2 – 9.30 mg/ kg
Zinc	5.70 – 11.50 mg/ kg
Sulphur	128 – 548 mg /kg

It also decreases the bioavailability of toxic heavy metals in the soil [13-15], increase the soil microflora, aeration and water holding capacity. Several researchers have demonstrated that earthworm castings have excellent aeration, porosity, structure, drainage, and moisture-holding capacity. Microbial activity in worm castings is 10 to 20 times higher than in the soil and organic matter that the worm ingests. Vermicompost application in the fields promotes seed germination, plant growth, and crop yield, improves root growth and structure and enriches soil with plant hormones such as Auxins and Gibberellic acid. The content of the earthworm castings, along with the natural tillage by the worms burrowing action, enhances the permeability of water in the soil. Worm castings can hold close to nine times their weight in water. Use of vermitechnology for recycling organic waste reduces greenhouse gas emissions such as methane and nitric oxide which may be otherwise produced in landfills or incinerators when not composted or through methane harvest Vermicompost can be mixed directly into the soil, or first solubilised in water and made into a worm tea. The resulting liquid is used as a fertilizer or sprayed on the plants. Vermicompost is free flowing, easy to apply, handle and store and does not have bad odor. The vermicompost may be used for farming, landscaping, to create compost tea, or for sale. It is cheap with good keeping qualities.

8. Conclusion

Vermicomposting is an essential tool of organic farming, may be more helpful in increasing crop productivity in sustainable manner, quality produce, reducing cost of agricultural inputs in addition to improving inherent capacity of soil without deleterious effect on the environment. It is the best ecological production management system that promotes and enhances biodiversity, biological cycles and soil biological activity. Low capital investment and relatively simple technologies make vermicomposting practical for less-developed agricultural areas and provides employment opportunities.

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