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Use of Earthworms for Sustainable Agriculture

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Abstract

Land degradation due to application of chemical fertilizers and pesticides is major impediment for sustainable agriculture. This can be prevented by the use of earthworm involving a technology called vermitechnology. Vermiculture, vermicompost, vermicast, vermibeds and vermiwash are the related terms of this technology. There is a long tradition of the awareness related to the beneficial effects of earthworms by the ancient naturalists. Earthworms have important roles in improving soil health and maintaining balance in soil ecosystem. The limitations of traditional chemical based agriculture can be overcome by the use of earthworm as a biotechnological tool. There are different ecotypes of earthworms and some are suitable for vermiculture. Method of vermicompost preparation involving vermitechnology has been described in brief and some precautionary measures needed in this case have also been mentioned. There are many experimental evidences which showed that vemicompost is highly beneficial for the soil health and growth of plants. The Problems and Prospects of vermitechnology in our country have also been discussed briefly.

Keywords: Earthworm; Vermitechnology; Vermicompost; Soil; Organic Fertilizer; Plant.

Introduction

Indiscriminate use of chemical fertilizers contributes largely to the deterioration of the environment through depletion of fossil fuels, generation of Carbon dioxide and contamination of water, air and land. Imbalanced use of chemical fertilizers leads to loss of soil fertility and produces adverse impact on agricultural productivity. In recent years, it has been realized that application of ecological and sustainable farming practices can only reverse the environmental degradation caused due to extensive use of chemical fertilizers (Aveyard 1998, Wani and Lee 1992, Wani et al. 1995). In normal condition, soil contains a number of micro and macro organisms that can convert organic waste into valuable resources containing plant nutrients which are critical for maintaining soil productivity. Earthworms present in the soil are very important biological organisms that maintain nutrient re-cycling in the soil and improve soil fertility. For this reason, Charles Darwin has rightly called earthworms as the "friend of farmers".

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Currently, a technology has been materialized using earthworm to increase soil fertility and to promote sustainable plant growth under Biotechnology Programme. This technology, involving earthworm for sustainable agriculture, is called vermitechnology.

What is Vermitechnology?

Vermitechnology is a biotechnological process in which certain species of earthworms are used to enhance the process of composting of organic wastes to produce a highly fertile, nutrient reach end product.

This process is faster than the normal composting process. The organic waste passes through the digestive canal of earthworm. During this passage, transformation of wastes into organic manures takes place. The organic manures are released in the form of earthworm castings. These are rich in microbes, plant growth regulators and also have paste repellence attributes.

What is Vermiculture?

Collection, breeding and successful rearing of earthworm for generations in an artificial media or laboratory is known as vermiculture.

What is Vermicomposting?

Composting is the process of bioconversion of organic matter by heterotrophic microorganisms (bacteria, fungi, actinomycetes, protozoa etc.) into humus like material. The process of composting using earthworms to create a heterogeneous mixture of decomposing vegetables or food wastes, bedding materials, and vermicast is called vermicomposting.

What is Vermicast?

It is the end product of the breakdown of organic matter by an earthworm in its digestive canal and is released through the anus as ball of mud. It is also known as worm castings, worm humus or worm manure. These castings have been shown to contain reduced levels of contaminants and a higher saturation of nutrients than what organic materials do contain before vermicomposting. It contains water soluble nutrients, nutrient rich organic fertilizer and soil conditioner. This vermicast is an excellent bio-organic manure.

What is Vermibed?

It is the actual layer of good moist loamy soil placed at the bottom, about 150 to 200 mm thick above and a thin layer (50mm) of broken bricks and coarse sand below. Earthworms are introduced into the loamy soil, which the worms will inhabit as their home. About 100 earthworms are introduced into a compost pit with a vermibed. The vermibed should always be kept moist, but should never be flooded.

What is Vermiwash?

The seepage drained from the worm bed is especially valued, and is used in diluted form as foliar spray. This is called vermiwash. A decoction is made of one part vermicompost to ten or twenty parts water. This concentrated liquid fertilizer contains valuable amino acids and silicic acids. This strengthens the epidermis of the leaves and reduces damage by aphids and penetrating fungal spores. It can also be used in drip irrigation.

Historical Perspectives

Although vermitechnology has developed recently, but the beneficial activities of earthworm was observed by ancient naturalists. Aristotle called the earthworms the "Intestines of the Earth". Besides its role as soil health indicator, it also helps to improve and enrich the soil as earthworm move through it. Earthworms make tunnels in the soil causing air and water to pass through. As they form tunnels, they bring up nutrients from below and carry organic matter from the surface, mixing it into the soil.

Earthworm can consume organic matter equal to their own weight in each day. Charles Darwin in his 39 years of studying earthworms, found that in a healthy environment, earthworms can create as much as 36000 pounds of nitrogen rich castings per acre. Darwin first pointed out in his book "Formation of Vegetable Moulds through the Action of Worms" that earthworm castings bring to the surface 7-18 tons of soil per acre annually.

Limitations of Traditional Agricultural System

The remarkable limitations of traditional agricultural practices are given below:

1. Nowadays, agriculture has become chemical manure based.
2. Soil is losing its microbial nutrient potentials.
3. Water level of soil is going down.
4. Rabi crop production is seen to be reduced.
5. Agricultural programme has become pesticide dependent.
6. Soil chemistry is being changed day by day by losing its organic fertility.

To check the above mentioned adversities, vermitechnology has been introduced which not only adds natural manuring potentialities to the soil, it also serves other beneficial attributes.

Role of Earthworm in Improving Soil Health

In Agro Eco System

Earthworms are natural burrowers. They move from upper surface to deep in the soil making burrows

there. They devour soil with organic materials and liberate faeces or castings with decomposed manure. The castings are distinct, small, rounded pallets or balls leading to the porosity in the soil which helps water holding capacity, aeration and microbial growth in the soil. Again, the movement and feeding behaviour of earthworm provide soil formation and mixing of soil with mineral nutrients. It has been observed that in natural tillage system, the soil is digged upto 30cm. while earthworm performs tillage upto 3meters depth. Hence, earthworms are called natural tillers. Earthworm burrows present macro pores that provide low resistance channels for plant root growth, water filtration and gas exchange.

In Humification

Humus is a type of soil vermicomposting with organic matters like humic acid, humin, cellulose and hemi cellulose. The posture soil with earthworms is provided with casts which contains 73 percent nitrogen found in the ingested litter. The organic wastes whenever pass through the elementary canal of earthworm, the decomposition of the said matter takes place yielding the nitrogenous manure.

In Rapid Biofertilizer Formation

It has been found that earthworms convert organic matter into a compost or vermicompost within a short period. In natural process one ton organic decompost manure is produced in six months while the same amount of compost manure may be obtained by employing thousand earthworms within a month. Thus earthworms appear as unique biofertilizer agent and referred to as mini fertilizer plant.

In Eradication of Fungus Outgrowth

In apple orchards scrab fungus grows on litters accumulated near the plant over the soil surface. The scrab fungus grows up along with the spreading of pores on the plant twigs and leaves leading to the ill health of the plant. Litter feeding earthworm, by consuming the said litter prevent the growth of harmful fungus and enabling good health of plants.

Pollution Indicator

Earthworms are being recognized as indicators of agro ecosystem health and as important tools for ensuring soil improvement and efficient nutrient cycling. They are linked with the accumulation of organic matter in the soil leading to soil fertility. The existence of less number of earthworms in any agro ecosystem denotes the incorporation of pollutants in the soil. It is evident that a good number of herbicides, pesticides and inorganic fertilizers transform soil chemistry and reduce the growth and viability of the earthworms. Thus, earthworm count indirectly helps to access the stress condition of the soil.

Vermibreeds used in Vermitechnology

In vermitechnology, earthworms are employed to produce manure. Not all earthworm species are used for this technology. There are suitable breeds and non-suitable breeds of earthworms found in nature.

Suitable Breeds for Vermiculture

Among the earthworms which live on the soil surface and thrive on organic wastes are called suitable breeds for vermiculture. Such worms possess the following features-

i. They have wide range tolerance to environmental factors.
ii. They are very much efficient to consume a greater biomass and convert them to an organic decompost matter.
iii. They have rapid population growth.
iv. They need less duration to complete life cycle.
v. They are disease resistant.

Names of suitable vermibreeds are given below:

Sl. No.	Common name	Scientific Name
1.	Red wiggler	*Eisenia foetida*
2.	European Crawler	*Eisenia hortensis*
3.	Red earthworm	*Lumbricus rubellus*
4.	Blue worm	*Perionyx excavator*
5.	African night craw	*Eudrilus engeniae*

Non-Suitable Breeds for Vermiculture

The earthworm species which are deep soil dwellers are not recommended for vermiculture and are called non-suitable breeds for vermiculture. It includes the following species

Sl. No.	Common Name	Scientific Name
1.	Night crawler	*Lumbricus terrestris*
2.	White earthworm	*Enchytraeus albidus*

Ecotypes of Earthworms

Earthworms are divided into three groups called ecotypes. These three groups are Epigeic, Endogeic and Anecic. Comparative accounts of these three groups are given below.

Sl. No.	Epigeic	Endogeic	Anecic
1.	Surface dweller	Soil dweller(10 to 50 cm deep)	Deep soil burrower (down to 2 meters)
2.	Ingests large non-decompost litter. (Litter feeder	Ingests large quantities of organic rich soil. (Soil feeder)	Ingests partially decomposed litter, manure and other organic matter. (Litter and soil feeder)
3.	Pigmented body.	Non pigmented body.	Dorsally pigmented body.
4.	Structurally small. (Adult 1 to 7 cm long)	Structurally optimum in length. (Adult 2 to 12 cm long)	Structurally large. (Adult 8 to 15 cm long)
5.	They do not make burrows	They make horizontal burrows	They make extensive vertical burrows
6.	Tolerant to resistance	Less tolerant	Less tolerant.
7.	Reproductive rate high.	Optimum.	Less
8.	Used in vermicomposting	Used in soil formation and aeration	Used in decomposition and nutrient cycling
9.	Colour red brown	Gray, blue and pink	Reddish-brown
10.	Major species take part in composting.	Do not take part in composting.	Limited species take part in composting.
11.	Example: *Eisenia foetida.*	Example: *Allolobophora chlorotica.*	Example: *Lumbricus terrestris.*

Methods of Vermicompost Preparation Involving Vermitechnology

A thatched roof shed preferably open from all sides with unpaved floor can be erected in east-west direction to protect the side from direct sunlight. A shed area of 12′x12′ is sufficient to accommodate three vermibeds of 10′x3′each having 1′ space in between for treatment of 9 to 12 quintals of waste in a cycle of 40 to 45 days. The length of the shed can be increased or decreased depending upon the quantity of waste to be treated and availability of space. The height of thatched roof is kept at 8′ from the centre and 6′ from the sides. The base of the site is raised atleast 6′′ above ground to protect it from flooding during the rains. The vermibeds are laid over the raised ground as per the procedure given below. The site marked for vermibeds on the raised ground is watered and a 4" to 6" layer of any slowly biodegradable agricultural residue such as dried leaves, straw, sugar cane trash etc. may be laid over it after soaking with water. This is followed by 1" layer of vermicompostor farm yard manure.

Earthworms are released on each vermibed at the rate of 1.5 kg per vermibed for treatment of cowdung or agriwaste or household garbage. The loaded waste is finally covered with a jute mat or banana leaves to protect earthworms from birds and insects. Water is sprinkled on the vermibeds daily according to requirement and season to keep them moist. They waste is turned upside down fortnightly without disturbing the basal layer. The appearance of black granular crumbly powder on the top of vermibeds indicates harvest stage of the compost. Watering is stopped for at least five days at this stage. The earthworms go down and the compost is collected from the top without disturbing the lower layers. The first lot of vermicompost is ready for harvesting after two months and the subsequent lots can be harvested after every six weeks of loading. The vermibed is loaded for the next treatment cycle.

Compost is harvested from the vermiculture operation when scraps of uneaten food are no longer visible. The harvesting process should ensure that adult worms are not lost in the process of harvesting the compost. The small lemon shaped cocoons of earthworm should also be returned to the system. One process for harvesting involves stopping the addition of food items on one side of the worm bin while continuing to add them to the other side of the bin. The worms will naturally migrate to the side of the bin where food is being added and allow the easy harvesting of the other side of the bin.

Precautionary Measures for Compost Making

1. Temperature of the vermibed should be within the range of 20 to 30^{0}C.
2. Moisture level in the bed should not exceed 40to 50 percent. Water logging hampers normal activities of worms leading to weight loss and decline in worm biomass.
3. Earthworms should not be injured during handling.

4. Vermibed should be protected from predators like red ants, white ants, centipedes and others like todes, rats, cats, poultry birds etc.
5. Frequent observation of culture bed is essential as accumulated casts may cause retardation of growth of the worms.
6. Space is the criterion for growth and establishment of culture.
7. Minimum space required is 2 m^2 per 2000 worms with 30 to 45 cm thick bed.
8. Mixture of cattle, sheep and horse dung with vegetable wastes forms ideal feed for worms. Addition of neem cake in small quantity enhances growth of worms.

Benefits of Vermicompost

Soil Quality

- Improves soil physical structure
- Enriches soil by addition of enzymes such as phosphatase and cellulose.
- Microbial activity in worm castings is 10 to 20 times higher.
- Attracts deep burrowing earthworms already present in the soil.
- Improves water holding capacity of the soil.

Plant Growth

- Enhances germination, plant growth and crop yield.
- Improves root growth and structure.
- Enriches soil with microorganisms and adds plant hormones such as auxins and gibberellic acid.

Economic Benefit

- Low capital investment and relatively simple technologies make vermicompost useful in less developed countries.
- Creates low-skilled jobs at local level.
- Bio-waste conversion reduces waste flow to landfills.

Environmental Benefit

- Elimination of bio-wastes from the waste stream reduces contamination of other recyclables collected in a single bin.
- Vermicompost production reduces greenhouse gas emissions such as Methane and Nitric oxide produced in landfills or incinerators.

Use as Fertilizers

- Vermicompost is an eco-friendly natural fertilizer prepared from biodegradable organic wastes and is free from chemical inputs.
- This fertilizer does not have any adverse effect on soil or plants.
- It promotes better root growth and nutrient absorption.

Some Experimental Observations about the Importance of Vermicompost

1. Sreenivas et al. (2000) studied the integrated effect of application of fertilizer and vermicompost on soil available nitrogen (N) and uptake of Ridge Gourd (*Luffa acutangula*) at Rajendranagar, Andhra Pradesh , India. Soil available nitrogen increased significantly with increasing levels of vermicompost and highest N uptake was obtained at 50% of the recommended fertilizer rate plus 10 ton/hectare vermicompost. Similarly the uptake of N, P,K and Mg by rice (*Oryza sativa*) plant was highest when fertilizer was applied in combination with vermicompost (Jadhav et al. 1997).
2. Growth promoting activity of vermicompost was tested using a plant bioassay method. The Plumule length of maize (*Zea mays*) seedling was measured 48 hours after soaking in vermicompost water and in normal water. The marked difference in plumule length of maize seedlings indicated that plant growth promoting hormones are present in vermicompost (Nagavallemma K. P. et al. ,2004)
3. The application of vermicompost gave higher germination (92%) of mung bean (*Vigna radiata*) compared to the control (84%). Further, the growth and yield of mung bean was also significantly higher with vermicompost application. In another experiment, it has been found that the fresh and dry matter yields of cowpea (*Vigna unguiculata*), were higher when soil was amended with vermicompost than with biodigested slurry (Karmegam et al. 1999, Karmegam and Daniel, 2000).
4. The efficiency of vermicompost was evaluated in a field study by Desai et al. (1999). They started that the application of vermicompost along with fertilizer N gave higher dry matter (16.2 g/plant)

and grain yield (.6 ton/hectare) of Wheat (*Triticum aestivum*) and higher dry matter yield (0.66g/ Plant) of the following Coriander (*Coriandrum sativum*) crop in sequential cropping system. Similarly, a positive response was obtained with the application of vermicompost to other field crops such as sorghum (*Sorghum bicolor*) (Patil and Sheelavantar, 2000) and Sunflower (*Helianthus annuus*) (Devi and Agarwal 1998, Devi et al. 1998).

5. Application of vermicompost at 5 ton/hectare significantly increased the yield of tomato (*Lycopersicon esculentum*) at the rate of 5.8 ton/ hectare compared to control of 3.5 ton/hectare as observed in farmers' field in Adarsha watershed, Kothapally, Andhra Pradesh.
6. The fresh weight of flowers such as *Chrysanthemum chinensis* increased with the application of different levels of vermicompost. Also, the number of flowers per plant (26), flower diameter (6 cm) and yield (0.5 ton/hectare) were maximum with the application of 10 ton/hectare of vermicompost along with 50% of recommended dose of NPK fertilizer (Nethra et al. 1999).
7. Studies on vermicompost indicate that it increases macropore space ranging from 50 to 500µm in the soil, resulting in improved air-water relationship in the soil which favourably affects plant growth (Marinari et al. 2000). The application of organic matter including vermicompost favourably affects soil pH, microbial population and soil enzyme activities (Maheswarappa et al. 1999). It also reduces the proportion of water soluble chemical species which cause possible environmental contamination (Mitchell and Edwards, 1997).

Problems Associated with Vermitechnology

Maintenance of Moisture

Vermicompost always necessitates high moisture content in the vermibed which becomes a problematic task during summer season for the farmers associated with vermiculture.

Transport of Earthworms for Inoculation

For vermiculture seed earthworms should be carried to the site of culture. In winter season, it can be done safely. But in other seasons, transport of earthworms needs air-conditioned cars. If weather temperature is more than 15^0C, the worms come out of the pack and on exposure to high temperature they die.

Escaping Tendency of Earthworms

Earthworms usually stay in the vermipit. During inoculation, the worms try to come out of the pit and to check such problem light is put over the pit so that they are further inserted in the pit. Such inconvenience may also develop during rainy season when external humidity is higher than the pit.

Prevalence of Bad Odour

Vermicompost site may lead to bad smell due to decomposition of excess feed stock of vermibed. The bad smell is due to release of ammonia gas.

Increased Fly and Rodent Population

As the vermibed is associated with kitchen wastes, several flies and rodents are attracted to the site. Such pest population is seen to be increased with vermiculture attached to domestic sites.

Prospects of Vermitechnology in India

In the late 1980s and 1990s agricultural scientists in the world realized the limitations of the chemical fertilizer used in agriculture. While on one hand research was initiated to improve the use and efficiency of chemical fertilizers, on the other hand alternative input were also considered.

Organic matter recycling has been in use in India for centuries. In 19th and 20th century, scientific methods for converting low valued organic matter into high valued organic compost were developed. The activities of earthworms for recycling of organic matter became the focus of attention of scientific community during 1990s. Initially vermiculture i.e., use of surface living earthworms was carried out at a very small scale mainly for management of kitchen wastes. In 1995 Morarka Foundation began with 100 earthworms of Eiseniafoetida to develop a commercial process of vermiculture. This pioneering effort enabled Morarka Foundation to become the single largest producer of vermicompost in 1998, a position which it is still enjoying.

From 1997-98 onwards, many government agencies in India such as Directorate of Agriculture, Watershed department, DPIP, Department of Biotechnology financially supported vermiculture programme. Subsequently, beginning in the year 2000, entrepreneurs came forward to set up large scale commercial units for the production of vermicompost. During these periods many cattle relief organizations, Gaushalas had also started vermiculture. In the last few years, vermiculture production units have also

been set up as "Common Facility Centres" by group of farmers in villages. Vermiculture production units have now become a major component of agri-business models across the country.

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