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Sustaining Soil Health through Vermicomposting-A Review

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Abstract

Organic wastes returned to the soil can maintain and enhance soil quality, fertility and productivity through favourable effect on soil properties and other processes. Vermicompost technology for composting of organic wastes is remarkably effective for reduction in the processing time of decomposition and produce food quality compost in terms of nutrients. It serves as an important component of integrated plant nutrient supply system for balanced fertilization along with maintaining health to sustain the productivity of soils. Organic wastes returned to soil as vermicompost contribute to reduce the fertilizer requirement of crop. Beneficial effects of vermicompost on yield and quality of crop are highlighted in the article.

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Introduction

India is a vast country covering 3.28 million km^{2}endowed with varied climate supporting rich biodiversity and highly diverse ecology. More than sixty percent of its population is dependent on climate sensitive activities such as agriculture. Currently, 43.7 m ha area (0.99% of total agricultural land) is under organic agricultural management worldwide (FiBL and IFOAM, 2016) and India is on first rank in terms of no. of organic producers *i.e.*, 585,000 (FIBL and IFOAM, 2017). The total area under organic certification in India is 5.71 million hectares during 2015-16. This includes 26% cultivable area with 1.49 million hectare and rest 74% (4.22 million hectare) forest and wild area for collection of minor forest produces. India produced around 1.35 million MT (2015-16) of certified organic products which includes all varieties of food products namely sugarcane, oil seeds, cereals and millets, cotton, pulses, medicinal plants, tea, fruits, spices, dry fruits, vegetables, coffee *etc*. Growing awareness regarding health benefits of organic food consumption, rising per capita spending on organic food products and increasing health concerns due to growing number of chemical poisoning cases are expected to drive global organic food market in the coming years. In India, the farmers have followed the path for organic food production, but the share of India in the world organic market is less than one percent (Ghosh, 2004). India can take advantage of the growing opportunities in organic agriculture by making use of organic production system through vermicomposting technology for soil and plant health management (Charyulu and Biswas, 2010).

Sustainable soil health

Sustainability is concerning ecosystem integrity, social well-being, economic resilience, and good governance. Organic management is associated with several positive impacts on land and water, including increase in soil fertility and thereby leads to enhanced productivity; better soil structure; better soil moisture retention and drainage, less water pollution and nitrate leaching in groundwater; reduced erosion (wind, water), and better soil carbon sequestration rates. However, organic farming is holistic production management system which promotes and enhances agro ecosystem health, including biodiversity, biological cycles, and soil biological activity. Ideally, the abundance, stability and diversity of soil microbes act as key pointers to soil health. These functions are able to sustain biological productivity of soil, maintain the quality of surrounding air and water environments, as well as promote plant, animal, and human health (Doran *et al.,* 1996).

Soil quality

Protection of soil quality under intensive land use and fast economic development is a major challenge for sustainable resource use in the developing world (Doran *et al.,* 1996). The basic assessment of soil health and soil quality is necessary to evaluate the degradation status and changing trends following different land use and smallholder management interventions (Lal and Stewart, 1995). In Asia, adverse effects on soil health and soil quality arise from nutrient imbalance in soil, excessive fertilization, soil pollution and soil loss processes (Hedlund *et al.,* 2003). Due to concerns with soil degradation and the need for sustainable soil management in agro- ecosystem, there has been much scientific attention to characterize soil quality.

Soil quality management

Enhance organic matter

Soil is naturally high or low in organic matter, while regular additions of organic matter improve soil structure, enhance water and nutrient holding capacity, protect soil from erosion and compaction, and support a healthy community of soil organisms. Practices that increase organic matter include: leaving crop residues in the field, choosing crop rotations that include high residue plants, using optimal nutrient and water management practices to grow healthy plants with large amounts of roots and residue.

Avoid excessive tillage

Reducing tillage minimizes the loss of organic matter and protects the soil surface with plant residue. Tillage is used to loosen surface soil, prepare the seedbed, and control weeds and pests.

Manage pests and nutrients efficiently

Pesticides and chemical fertilizers have valuable benefits, but they also can harm non-target organisms and pollute water and air, if they are mismanaged. Nutrients from organic sources also can pollute when misapplied or over-applied. Efficient pest and nutrient management means testing and monitoring soil and pests; applying only the necessary chemicals, at the right time and place to get the job done; and taking advantage of non-chemical approaches to pest and nutrient management such as crop rotations, cover crops, and manure management.

Prevent soil compaction

Compaction reduces the amount of air, water, and space available to roots and soil organisms. Compaction is caused by repeated traffic, heavy traffic, or travelling on wet soil. Subsoil tillage is only effective on soils with a clearly defined root-restricting plow pan.

Keep the ground covered

Residue management in bare soil is susceptible to wind and water erosion, and to drying and crusting. Ground cover protects soil, provides habitats for larger soil organisms, such as insects and earthworms, and can improve water availability. Ground can be covered by leaving crop residue on the surface or by planting cover crops.

Diversify cropping systems

Diversity is beneficial for several reasons that each plant contributes a unique root structure and type of residue to the soil. A diversity of soil organisms can help control pest populations, and a diversity of cultural practices can reduce weed and disease pressures. Organic wastes returned to the soil can maintain, enhance soil quality, fertility and productivity through favourable effect on soil properties and other processes.

Vermicompost technology for composting of organic wastes is remarkably effective for reduction in the processing time of decomposition and produce good quality compost in terms of nutrients.

Vermicompost

Vermicompost as organic manure is being popularized for producing high quality organic fertilizers in organically grown products due to health awareness. Earthworms are popularly known as the "farmer's friend" or "nature's plowman". Vermiculture technology, is one of the sustainable way to deal with the decomposition of organic waste by certain species of earthworms into nutrient rich liquid substance called vermicasts (Nagavallemma *et al.,* 2004, Manyuchi *et al.,* 2012, Quaik *et al.,* 2012). Earthworms feed on the organic waste and their gut act as the bioreactor where the vermicasts are produced (Nath *et al.,* 2009, Manyuchi *et al.,* 2013). Wastes of animal and plant origin are one of the major under-utilized resources that could not be fully exploited due to the non-availability of a viable technology for their economic recycling. Vermicomposting has been recognized as an eco-friendly technology for converting organic wastes into high value organic manure (Kale *et al.,* 1982; Senapathi, 1993).

Earthworms are burrowing animals and their gut and the intestine act as a bioreactor where worms secrete enzymes like proteases, lipases, amylases, cellulases and chitinases for biochemical conversion of the cellulosic and the proteinaceous materials in the organic wastes and various species of earthworms like *Megascolex mauritii, Eisenia foetida, Eudrilus eugeniae, Perionnyxex cavatus, Lampito mauritii, Eisenia andrei, Lampito rubellus* and *Drawidawillis* are used by degradation of waste products (Gomez-Brandon *et al.,* 2012, Manyuchi *et al.,* 2012, Manyuchi *et al.,* 2013). However, *Eisenia foetida* has been reported as most appropriate earthworm for vermicomposting (Suthar, 2010).

The physical properties of earthworms such as weight, length, and reproduction rate and population density play an important key role in vermicomposting (Palsania *et al.,* 2008, Shweta 2011).

Strategies for improving soil health

Assessment of soil health: The use of bio-indicators is becoming an increasingly important way to assess soil health. Pankhurst et.al (1997) reviews how soil organisms and biotic processes can be used as indicators of soil health. A range of techniques include measurements of soil microbial activity based on the soil's CO_2 respiration; DNA testing and an 'in-situ' techniques.

Increasing biological activity

Organic conversion begins with a process that encourages increased microbial and arthropod activity within the soil. Biological activity begins with the breakdown of soil organic matter. Organic farmers supply organic matter through incorporation of FYM, vermicompost, green manure crops, crop waste and compost. Earthworms act as a major soil biota with respect to soil formation. When earthworms feed, they trigger and highly support microbial actions by the breaking down and stabilization rates of organic matter.

Compost: The use of compost in India is not widely practiced, due to practical problems of preparation and cost effectiveness. Animal manures and crop wastes form the major ingredients of compost. Composted manure is easier to spread, and losses to the environment are minimised. Rock minerals and clay added to compost in small quantities, may help to reduce nitrogen losses from the heap by absorbing ammonia (Lampkin, 1990).

Compost enrichment: Compost enrichment through re-mineralisation by the addition of various fertilisers of mineral origin like rock phosphate, dolomite, limestone and rock dusts (from silicate rocks, including basalt and bentonite and some commercial organic blends).

Green manuring: Green manure crops help to build up soil organic matter and nutrients to stimulate biological activity. Green manure crops are an essential component in intensive organic annual cropping rotations. Early establishment of a cereal crop immediately following incorporation of the green manure has been shown to be the simplest and one of the most effective methods of reducing nitrate leaching.

Correcting deficiencies organically: Unseasonal weather conditions may result in a deficiency during a critical crop growth period that may lead to plant health decline, predisposing crops to pest and disease attack and a permanent yield depression. Organic growers may use of foliar sprays such as Panchgavya, Amrit solution, Vermiwash, seaweed extracts, molasses and trace elements to correct temporary deficiencies.

Vermicompost

Vermicompost- an odourless, dark brown biofertilizer i.e. rich in potential microbes and micro macronutrients obtained from the process of vermiculture technology. It is a stabilized, finely divided peat-like material with a low C:N ratio, high porosity and high water-holding capacity, in which most nutrients are present in forms that are readily taken up by plants.

Physical conditions required for vermicomposting

The organic waste is degraded to a bio-fertilizer in a vermin reactor by continues action of earthworms over a particular time period ranging from 28-120 days (Borah *et al.*, 2007, Manyuchi *et al.*, 2013). The optimum temperature for effective vermicompost process ranged from 18-67°C, pH 5.9-8.3, moisture content 10.6-80% and electrical conductivity ranged from 0.70-80 µscm-1 (Suthar 2009, Garg and Gupta 2011, Indrajeet *et al.*, 2010, Lim *et al.*, 2012).

Vermicomposting process

Vermicomposting materials: Generally, animal excreta, kitchen waste, farm residues and forest litter are commonly used as composting materials. Mostly cow dung and dried chopped crop residues are the key raw material.

Selection of suitable earthworm: For better vermicompost production, surface earthworm alone should be used. Red earthworm (*Eiseniafoetida*) is found to be commonly used worm in India (Table 1) because of its high multiplication rate and thereby converts the organic matter into vermicompost within 45-50 days.

Site for vermicompost: Any place with shade, high humidity and cooling like abandoned cattle shed or poultry shed or unused buildings can be used. A thatched roof may be provided to protect the process from direct sunlight and rain. The waste heaped for vermicompost production should be covered with moist gunny bags.

Vermicomposting Method

Bed Method: Composting is done on the pucca/kachcha floor by making bed (6’x2’x2’ feet size) of organic mixture, easy to maintain and to practice.

Pit method: Composting is done in the cemented pits of size 5x5x3 feet. The unit is covered with thatch grass or any other locally available materials. This method is not preferred due to poor aeration, water logging at bottom, and more cost of production.

Farm wastes vermicomposting

Pits of sizes 2.5 m × 1 m × 0.3 m (length, breadth and depth) are taken in thatched sheds with sides left open. The bottom and sides of the pit are made hard by compacting with a wooden mallet. At the bottom of the pit a layer of husk is spread with the concave side upward to ensure drainage of excess water and for proper aeration. The husk is moistened and above this, bio-waste mixed with cow dung in the ratio of 8:1 is spread up to a height of 30 cm above the ground level and water is sprinkled daily. After the partial decomposition of wastes for 7 to 10 days, the worms are introduced @ 500 to 1000 in numbers per pit.

The pit is covered with jute bags. Moisture is maintained at 40 to 50 per cent to maintain population density and a temperature of 20-30°C by sprinkling water over the bed. At higher temperature the worms are found to aestivate and at lower temperature, they will hibernate. When the compost is ready, it is removed from the pit along with the worms and heaped in shade with ample light. The worms will move to bottom of the heap. After one or two days, the compost from the top of the heap is removed. The undecomposed residues are put back to the pit with worms for further composting.

Vermicompost harvesting

Harvesting the compost means removing finished castings from the beds. The finished product is black or dark brown and is called crumbly worm compost. Harvesting the compost and adding fresh bedding, at least twice a year is necessary to keep the worms healthy.

The compost can be harvested by spreading a sheet of plastic under a bright light or in the sun. The contents of the bed leaving the bedding materials are divided into a number of heaps on the sheet.

The worms will crawl away from the light into the centre of each heap and the worm compost can be brushed away on the outside by hand. The crawling worms will be collected for re-use. The figure 1 to 5 shows the vermicomposting products, earthworm culture, vermicomposting beds and vermiculture harvester.

Vermicompost nutrients

Vermicompost is an excellent soil additive made up of digested compost. Worm castings are much higher in nutrients and microbial life and therefore, are considered as a higher value product. Vermicompost contains an average of nutrient contents as given below in the Table 2.

Organic crop production through vermicomposting

There have been several reports that earthworms and its vermicompost can induce excellent plant growth and enhance crop production. Ramasamy *et al.*, (2011) at Tamil Nadu concluded in an experiment on maize that the maximum kernel number of 598.55/cob and the highest length of 1.71kernel/cm were noticed in the plants cultivated on 75% vermicompost concentration whereas the maximum kernel breadth of 1.40kernel/cm, circumference of 3.07cm/kernel, weight of 0.41 g/kernel and total weight of all kernels (232.43 g/cob) were noticed in the plants grown with 50% vermicompost concentration. Prajapati *et al.*, (2018) in an experiment at Allahabad revealed that NPK@ 100% + Vermicompost@ 100% showed the highest plant height 158.22 cm, number of leaves per plant 11.00, cob length 17.50 cm leaf length per plant 48.50 cm, and dry weight 163.46 g, and highest yield, 42.77 q ha^{-1}, the application of NPK with vermicompost were excellent source for fertilization than fertilizers.

Table.1 Important characteristics of red earthworm

Characters	Red earthworm *(Eisenia foetida)*
Body length	3-10 cm
Body weight	0.6-1.0 gm
Maturity	50-55 days
Conversion rate	2.0 q/1500 worms/2 months
Cocoon production	1 in every 3 days
Incubation of cocoon& Temperature	20-23 Ays & 22-250C

Table 2. Average nutrient contents in vermicompost

Parameters	Vermicompost (%)	FYM (%)
Organic carbon	25-27	12.2
Organic matter	20-21	-
C/N ratio	34.7	34.7
Nitrogen	2.5-3.0	0.50
Phosphorus	1.50-2.0	0.25
Potassium	1.5-2.0	0.50

Figure.1 Products obtained from vermiculture technology

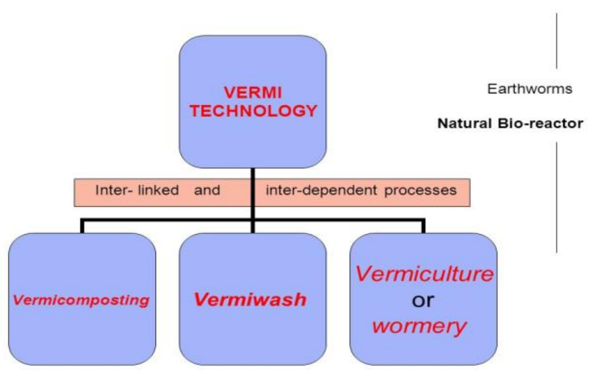

Figure.2 Earthworm culture for vermicomposting

Figure.3 Vermicomposting beds under thatches shade

Figure.4 Cemented and shed net house vermicomposting beds

Figure.5 Vermicompost harvester (manure siever)

Jeyabal and Kuppuswamy (2001) studieddifferent combinations of coirpith/weeds and cow dung/sugarcane pressmud/biodigested slurry for vermicomposting and found that biodigested slurry and weeds was found to be an ideal combination for vermicomposting considering the nutrient content and compost maturity period. Jeyabal and Kuppuswamy (2001) showed that the integrated application of vermicompost, fertilizer N and biofertilizers viz., *Azospirillum* and phosphobacteria increased rice yield by 15.9% over application of fertilizer N alone.

Hadis *et al.*, (2018) conducted an experiment at Ethiopia to determine effects of vermicompost, inorganic fertilizers and their combinations on nutrient uptake, yield and yield components of wheat. Results indicated that both vermicompost and NPK fertilizers significantly increased yield components, yield and nutrient uptake of wheat. Vermicompost applied at 2, 4 and 6 tha^{-1} increased grains yield of wheat by 11, 17 and 26% over control, respectively whereas 33.33, 66.67 and 100% NPK fertilizers increased the grain yield by 10, 24 and 30%, respectively over the control. Vermicompost applied at 6 tha^{-1} resulted in the highest nutrient uptake and it increased grain uptake of N, P and K by 51, 110 and 89% over control, respectively whereas among fertilizer rates, the highest uptake was produced by 100% NPK treatment and it increased the N, P and K uptake in the grain by were 79, 100 and 96% over control, respectively.

In conclusion, this study indicated the importance of earthworms as engineers of soil and human health. Vermicompost can be described as a complex mixture of earthworm faeces, humified organic matter and microorganisms, which when added to the soil or plant growing media, increases germination, growth, flowering, fruit production and accelerates the development of a wide range of plant species. Vermiculture technology is a modern concept of harnessing an ecosystem for effective utilization of organic waste with the help of earthworms. Stimulation of plant growth may depend mainly on the biological characteristics of vermicompost, the plant species used, and the cultivation conditions. This technology undergoes with multiple objectives like waste management of community, highly economical and sustainable way of increasing crop production with improvement of soil health and thereby promotes the survival and dispersal of the useful microbes such as bacteria, fungi and actinomycetes within such systems.The most effective uses of earthworms are organic waste management and supplement of readily available plant nutrients and vermicompost to improves soil health.

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