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Use of vermicomposting biotechnology for recycling organic wastes in agriculture

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Abstract

Recent trend of declining sustainability in agricultural production is appearing as a major threat to most of the Asian countries. To combat the situation, increasing importance is now being paid on incorporation of organic materials for rejuvenating the health condition and, hence, the productivity of these soils. Large scale availability of conventional organic manures being a big problem nowadays, major attention is being paid on recycling of different kinds of organic wastes for this purpose. Apart from abatement of environmental pollution, such reuse of organic wastes in agriculture helps in the improvement of various physical, chemical and biological properties of the soils and, thus, helps in sustaining the soil health. While recycling different organic wastes in agriculture, it is essential to process the materials through an adequate period of composting for improving their usability in the soils. However, due to some short comings of traditional composting systems, the technology of recycling of organic wastes has not been widely accepted so far. Under this situation, vermicomposting has recently emerged as a simple but efficient biotechnology for recycling wide ranges of organic wastes with the help of some specific groups of earthworms. In view of the growing popularity of this biotechnology, various aspects of waste recycling in agriculture through vermicomposting have been dealt in this communication.

Keywords: Organic wastes, Recycling, Vermicomposting biotechnology, Agricultural uses

Review

Introduction

With the rapidly increasing population in most of the Asian countries, the major challenge facing the mankind during the beginning of the new millennium is to provide food sustenance for all the people of this continent. With per capita land area decreasing consistently, various measures are being adopted to increase the agricultural production from these shrinking resources to meet the emergent demand of escalating population. However, sustaining the food production from these decreasing land areas depends largely on one factor, maintenance of soil health at high levels for encouraging good growth of plants. The recent trend of consistently reducing use efficiency of mineral fertilizers under high productive systems associated with the problems of gradual deterioration of soil health due to indiscriminate use of fertilizers is raising frequent questions about over dependence on mineral fertilizers in sustaining the health and, consequently, the productivity of the arable soils of this continent. It has been appreciated that mineral fertilizers can only supply plant nutrients to the soils but they cannot take care of other physical, chemical and biological attributes of soil health. On the other hand, organic materials play a much more positive role in this respect. Under this context, the concept of integrated plant nutrition system involving both inorganic and organic sources of nutrients has been conceived and gaining momentum (Chattopadhyay 2005). Such integration of mineral fertilizers and organic manures has special significance for many of the Asian countries because the arable soils of most tropical and subtropical countries are poor in organic matter due to high temperature and more intense microbial activity (Gaur 2006). Hence, a regular and sizeable addition of organic material to soil is essential for maintaining optimum organic matter status and, thereby, sustaining the health of the soil (Manna et al. 2005).

The beneficial roles of organic matter in the sustenance of soil health and productivity are well documented (Kumazawa 1984). Allison (1973) summarized

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the important contributions of organic matter in sustaining the productivity levels of soils to be as follows:

1. It is a natural resource of plant nutrients and microbial energy.
2. It serves as cation exchange site and chelating agent.
3. It improves physical condition of soils.

However, in spite of such significant importance of using organic matter in tropical soils, large-scale availability of organic materials from traditional sources has remained a big problem. It is, therefore, necessary to utilize effectively all the organic resources available on and off the farm. Under this context, the potentials of reusing various kinds of organic wastes have been emphasized by many workers (Gallardo-Lara and Nogales 1987; Howe and Coker 1992). Gupta et al. (1998) calculated that, on an average, around 4 to 5 kg of organic wastes are generated per person per day in India. This calculation is likely to be by and large applicable to most of the Asian countries also. Thus, with escalation of human population, huge amount of varying natures of organic wastes are being generated in these countries every year. Bisoyi (2003) made a systematic assessment of the quality of some common organic wastes in India and has shown these wastes to be the source of large amount of nutrient elements in addition to organic matter. Successful recycling of these wastes in different Asian countries will not only add substantial amount of all the plant nutrients but will also bring in the much-needed organic matter to the soils, leading to betterment of soil health (Table 1).

Table 1 Potentials of NPK from different organic wastes in India

Source	Plant nutrients (million ton)			
	N	P_2O_5	K_2O	Total
Cattle	2.997	0.793	1.332	5.102
Buffalo	0.745	0.276	0.487	1.508
Goat and sheep	0.214	0.063	0.020	0.297
Pig	0.044	0.027	0.029	0.100
Poultry	0.027	0.020	0.010	0.057
Other livestock	0.079	0.018	0.069	0.166
Human beings	3.228	0.776	0.715	4.719
Farm crop wastes	5.600	2.300	10.700	18.600
Forest litter	0.075	0.030	0.075	0.180
Water hyacinth compost	0.060	0.033	0.075	0.168
Rural compost	1.130	0.678	1.130	2.938
Urban compost	0.024	0.015	0.030	0.069
Sewage sludge	0.012	0.009	0.003	0.024
Total	*14.215*	*5.038*	*14.675*	*39.928*

Adapted from Bisoyi (2003).

While recycling different organic wastes in agriculture, it is essential to process them through an adequate period of composting. Composting has been described as a biological process for converting solid waste into a stable, humus-like product, which is used as a soil conditioner (Talashilkar 1989). Apart from providing substantial plant nutrition, these composts promote soil aggregation, improve air-water relationship, enhance cation exchange capacity, increase water retentivity, provide energy and improve several other physico-chemical properties of soils (Webber 1978; Epstein 1997). In addition, importance of composts in taking care of most of the pathogens present in the substrates has been emphasized by Tandon (1995). Chen and Wu (2005) discussed wide ranges of benefits from use of composts in different agricultural systems. However, the major constraints related to large scale adoption of composting technology have been described to be their bulk volume, long time required for composting, incomplete decomposition of resistant components, lower nutrient values as compared to mineral fertilizers and, above all, the complicated processes of composting (Chattopadhyay 2005). Good amount of studies have been and are being carried out at different levels to overcome these problems. In the course of these studies, in recent years, vermicomposting has emerged as an effective biotechnology for decomposing wide ranges of organic wastes with the help of intestinal microorganisms of some specific kinds of earthworms (Edwards and Lofty 1972; Kale 1993). Composts produced with such biotechnology have been found to be superior in nutrient status than the traditionally prepared compost and to contain various vitamins, plant growth regulators, antibiotics, etc., (Tilak et al. 2010) resulting in better performance after their field application. In the present communication, the possibility of recycling different organic wastes in agriculture through vermicomposting biotechnology has been discussed.

Vermicomposting biotechnology

Beneficial effects of earthworms in improving structure, aeration, nutrient status and some other properties of the soils and, thereby, the growth of the crops have been known since long (Darwin 1837). However, the knowledge about the efficiency of some groups of the earthworms in decomposing various organic materials was gathered later on, and the concept of utilizing this behavior for composting wide ranges of organic wastes was conceived during mid-twentieth century (Senapati 1993). Based on ecological niches, earthworms may be broadly grouped into three categories *viz.* endogeics, anecics and epigeics (Bouche 1977). Endogeic earthworms are geophagous in nature, which live deep inside the soil. Anecics reside just below the soil surface and feed on the organic materials mixed with the soils. The third group is known as epigeics which live on upper surface of soils feeding mainly on plant litter and other organic debris available on the soil surface. As these earthworms can consume a variety of organic matters, they are most suitable for converting organic wastes into useful organic manures. However, uses of anecic and endogeic earthworms in such composting process have also been reported by Lavelle and Martin (1992). A list of common earthworm species suitable for vermicomposting has been presented in Table 2.

These epigeic earthworms being voracious feeders can consume large quantities of different organic materials. In spite of their high rate of consumption, they utilize only a very small part of the consumed food for their body synthesis and excrete about 90% to 95% of the ingested materials as vermicast. Since the intestines of the earthworms harbor high concentrations of various kinds of microorganisms (Wallwork 1984), these vermicasts exhibit rich population of these organisms also (Atlavinyte and Vanagas 1982). Analysis of gut content of the earthworms has revealed the occurrence of different kinds of symbionts like microfungi, bacteria, protozoans, actinomycetes, etc. (Dash and Senapati 1986). Earthworm guts provide congenial environmental condition for their proliferation, and hence, the total numbers of such microorganisms in earthworm intestines generally increase many folds as compared to their habitats (Ponomarera 1962). The food materials ingested by the earthworms are, thus, subjected to more intense microbial activity in the alimentary canal not only due to these higher concentrations of different microorganisms but also owing to increased surface area of the food particles meshed to very fine sizes while passing through the gizzard. In addition to the activities of the microbes, occurrence of various enzymes in earthworm guts also helps such processes. These enzymes operate in near neutral to slightly alkaline pH range in the intestinal fluid of the worms (Senapati 1993). In addition, existence of various hormones, antibiotics, etc. has also been reported in earthworm gut (Edwards and Lofty 1972). All these components mix thoroughly with the food materials in the intestines of the earthworms and are released with their excreta to be known as vermicast. These vermicasts undergo rapid aerobic decomposition in presence of different microbes, which activity is accelerated by various enzymes and encouraged by occurrence of numbers of growth promoting substances. Aerobic microorganisms, being more active decomposers than the anaerobes, degrade vermicasts more rapidly than the traditional 'pit composting' methods, and a nutrient rich well-humified organic manure is obtained in shorter period of time which is termed as 'vermicompost' (Chattopadhyay 2005).

Benefits of vermicomposting

As discussed earlier, vermicomposting biotechnology helps in recycling different organic wastes with the help of large numbers of aerobic microorganisms. This results, in general, better nutrient status of the produced materials, as compared to those prepared by traditional composting systems. Scot (1998), while assessing the nature and properties of cattle wastes, digested with and without earthworms, observed availability of nitrogen to be higher in vermicomposted materials. While working on nature and magnitudes of transformation of phosphorus during the course of vermicomposting of different wastes, Ghosh et al. (1999b) observed that vermicomposting process tends to reduce the quantum of fixation of P as insoluble Fe, Al and Ca phosphate, and also helped mineralize P from organic to inorganic forms. Among the effects of different microorganisms and enzymes contributing to such increased availability of phosphorus, major emphasis may be given to the presence of very high concentration of phosphate-solubilizing bacteria in the vermicast. Bhattacharya and Chattopadhyay (2002) reported vermicasts prepared from mixtures of cattle wastes and fly ash to exhibit high occurrence of such microorganism. Such rich occurrence of phosphorus-solubilizing bacteria is likely to solubilize good amount of phosphorus from insoluble form in any organic waste material, and also to qualify vermicompost as a potential phosphatic biofertilizer. Increased nutrient availability and microbial activity due to vermicomposting, as reported by Jambhekar (1992), has been presented in Table 3. Ghosh et al. (1999a) also reported the results of a study on effect of inclusion of epigeic earthworm *Eisenia foetida* on several organic wastes *viz.* cow dung, poultry droppings, kitchen wastes, municipal wastes and

Table 2 List of some earthworm species suitable for vermicomposting

Lumbricidae	Megascolecidae	Ocnerodrilidae	Octaochaetidae	Eudrilidae	Moniligastridae
Bimasto parvus	*Lampito mauritii*	*Ocnerodrulus occidenalis*	*Dichogaster bolaui*	*Eudrilus euginae*	*Moniligaster perrieri*
Eisenia foetida	*Perionyx excavatus*		*Dichogaster saliens*		
Eisenia hortensis	*Metaphire anomala*		*Romiella bishambari*		
	Polypheretima elongate				

Screened from Julka 1988.

Table 3 Status of major nutrients and microbial population in some organic wastes treated with and without earthworms

Substrate	Parameters				
	C:N ratio	N (%)	Available P_2O_5 (%)	Available K_2O (%)	Microbial count
Cow dung					
Original	49.1	0.53	0.003	0.104	-
Vermicomposted	16.8	1.20	0.004	0.396	24×10^6
Untreated	24.0	1.00	0.003	0.192	18×10^5
Sugarcane trash					
Original	38.17	0.66	0.080	0.020	-
Vermicomposted	16.07	1.40	0.100	0.010	24×10^6
Untreated	30.72	0.80	0.090	0.060	20×10^5
Horse manure					
Original	55.3	0.68	0.010	0.060	-
Vermicomposted	15.3	1.80	0.030	0.020	30×10^6
Untreated	29.6	1.29	0.020	0.010	28×10^5

Adapted from Jambhekar (1992).

dry leaves, and observed that the availability of three major nutrient elements *viz.* N, P and K, and four micronutrients *viz.* Fe, Cu, Mn and Zn was considerably higher in the vermicomposted treatments for all the wastes as compared to those without earthworms. Similarly, adoption of vermicomposting technology has shown to increase the concentration of beneficial bacteria like nitrogen-fixing ones too (Bhattacharya and Chattopadhyay 2004). This helps in accumulation of atmospheric N_2 into the vermicomposted waste materials, thus, increasing their nitrogen status. The behavior is likely to facilitate the composting of different slowly degradable waste materials like saw dust, coir waste, sugarcane trash, etc. which exhibit high lignocellulose content, wide C:N ratio and low moisture.

Such high nutrient content and other beneficial properties of vermicompost help in increased production of healthier crops. As shown in Table 4, substantial yield increments in different crops on integration of chemical fertilizers with vermicompost prepared from organic wastes have been reported by Ghosh et al. (1999a). Similar results on different vegetables have also been observed under an ongoing research program at this center. All these studies have shown use of vermicompost to be able to reduce the application of mineral fertilizers substantially without affecting the crop yield.

Occurrences of different diseases in the crops have also been found to come down due to use of vermicompost, thus, reducing the need of pesticide application to the plants. While working on use of vermicomposted fly ash in agriculture, Iftikar et al. (2011) reported incidence of different diseases to be reduced substantially on use of vermicompost in tomato cultivation (Table 5). Similar reports are available for other crops also.

Protocol for vermicomposting

By following the conventional system of composting, vermicomposting is generally undertaken in small pits. However, recent studies carried out at Institute of Agriculture, Visva-Bharati University have shown vermicomposting should preferably be carried out above ground level, in a place without possibility of water stagnation (Chattopadhyay 2005). This will ensure occurrence of aerobic condition. The bed may be enclosed with brick-made structures with good numbers of holes or the wastes be kept as heaps without any enclosure. A shed is

Table 4 Effect of vermicompost on crop yields (t/ha)

Treatments	Potato	Mustard	Mulberry	Marigold
FYM + NPK_{100}	36.8	1.6	8.1	9.6
VC + NPK_{100}	44.3	1.9	10.5	11.6
VC + NPK_{75}	43.5	1.87	9.7	13.4
VC + NPK_{50}	43.0	1.89	9.7	16.3
Control	12.3	0.40	2.7	4.2

FYM, farm yard manure; VC, vermicompost; $NPK_{100,75,50}$, percent of recommended NPK fertilization (Ghosh et al. 1999a).

Table 5 Disease infestation of tomato under different treatments

Treatments	Bacterial wilt	Leaf curl	Bacterial blight
FYM 10 tha-1 + NPK 100%	2	4	6
VC 10 tha-1 + NPK 100%	1	1	2
VF 10 tha-1 + NPK 100%	1	2	2
NPK 100%	6	11	14

FYM, farm yard manure; VC, vermicompost; VF, vermicomposted fly ash; NPK_{100}, percent of recommended NPK fertilization.

to be provided above the bed to prevent entry of rainwater or sunshine.

Wide ranges of organic wastes may be used for vermicomposting. However, they should preferably be mixed with at least 20% to 25% cow dung or sprinkled with cow dung slurry. Large sized wastes like straws, plant twigs, etc. may be shredded to smaller sizes to facilitate composting. The mixture should be kept under moist condition for 10 to 15 days. This will allow the initial thermophilic condition of organic materials to subside to a tolerable level for the earthworms. This rise in temperature in the organic materials during primary period of decomposition helps kill most of the mesophilic pathogens in the waste materials, making the resultant compost more safe for field application.

After 10 to 15 days of primary decomposition, epigeic earthworms are to be incorporated in the organic materials at 8 to 10 worms kg^{-1} of waste. Selection of the species of earthworms for vermicomposting should primarily be based on their capacity for consumption of organic wastes, rate of multiplication and adaptability to local condition. Special care should be exercised to keep the wastes under moist condition through periodic addition of water during the entire course of composting. This will not only help the earthworms to get a favorable environment but will also permit more intensive activities of the microorganisms in degrading the wastes. Periodic bottom-up turning of the waste materials will be particularly useful for the composting process by exposing the lower layer of the waste materials to the aerobic zones. This will accelerate the rate of decomposition of the organic materials and also encourage multiplication of the earthworms. Temperature is also an important factor. Optimum temperature range for vermicomposting is around 25°C to 35°C. Rate of composting becomes slower under low temperature levels.

At maturation, the compost material assumes dark to brown coloration, becomes nonsticky and odorless. At this stage, the moisture content of the composted materials is brought down by stopping the application of water. The compost materials are then sieved, and the worms remaining above the sieve are transferred to another vermicompost bed which is kept ready with partially decomposed mixture of organic waste. Since the numbers of earthworms increase considerably during the period of vermicomposting, the amount of organic waste can be increased accordingly under successive compostings. In case of larger production of composts, sometimes high intensities of light are provided from the top of the compost heap. Since most earthworms do not like high intensity of light, they tend to migrate from upper surface to lower depth of the heap. Vermicompost may then be harvested from the top of the heap. However, sieving will ensure availability of uniform-sized granular particles. This will also reduce the possibility of less matured materials to be mixed with the compost.

Conclusion

In recent years, vermicomposting is emerging as a simple, easily adoptable and effective biotechnology for recycling wide ranges of organic wastes for agricultural production. This can be taken up in small scales at household levels or at large levels as business propositions. The former practice helps an agriculturist or gardener to produce vermicompost from his homestead garbage for the purpose of utilizing the generated vermicompost for own consumption. On the other hand, vermicomposting can also be taken up at commercial level using municipal and/or other sources of wastes and the product be marketed as good quality organic manure. The gradually expanding market of organic foods for sustaining human health presents significant opportunities for undertaking such activity on commercial basis. In this communication, a brief account of the concept, benefits and method of vermicomposting has been presented with relation to its agricultural use. Various processes of improvements of quality of vermicompost as well as pace of such composting are being suggested now by different workers. They include microbiological inoculation, enrichment of quality, improved management procedures, etc. (Bhattacharyya and Kumar 2009; Saha 2009; Mal 2010). The vermicomposting technology may be modified suitably based on the demands of specific situation as well as requirement of the operator.

Competing interests

The author declares that he has no competing interests.

Author's information

The author is a soil scientist (professor) in the Institute of Agriculture, Visva-Bharati University, India. He is working on vermicomposting biotechnology for more than 15 years and has supervised three Ph.D. programs and several post graduate dissertations on this subject.

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