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INTERNATIONAL JOURNAL OF CURRENT RESEARCH

International Journal of Current Research
Vol.11, pp.154-165, December, 2010

ISSN: 0975-833X

REVIEW ARTICLE

VERMICOMPOSTING: A POSSIBLE SMALL SCALE INDUSTRY

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ARTICLE INFO

Article History:
Received 15th August, 2010
Received in revised form
13th September, 2010
Accepted 18th October, 2010
Published online 25th December, 2010

Key words:
Vermicompost,
Eisenia fetida,
Sugarcane trashes,
Gutflora,
Vermiwash,
Economic viability

ABSTRACT

Vermicompost appears to be generally superior to conventionally produced compost in a number of important ways; (i) Vermicompost is superior to most composts as an inoculant in the production of compost (ii) Worms have a number of other possible uses on farms, includingvalue as a high-quality animal feed (iii) Vermicomposting and vermiculture offer potential to organic farmers as sources of supplemental income. All of the above will be discussed in detail later in this document. At the same time, the reader should take note at the beginning that working with worms is a more complicated process than traditional composting: (i) It can be quicker, but to make it so generally requires more labour (ii) It requires more space because worms are surface feeders and won't operate in material more than a meter in depth (iii) It is more vulnerable to environmental pressures, such as freezing conditions and drought (iv) Perhaps most importantly, it requires more start-up resources, either in cash (to buy the worms) or in time and labour (to grow them).

INTRODUCTION

India is the second most populated country in the world, with the majority of the population living in the rural areas and who agriculturists. The increase in Population living standards and health quality are the main causes for the rapid increase in waste generation. The damaging long-term environmental impacts and resource depletion indicates un-sustainability of the current methods. Attention is once again on biochemical pathways using appropriate biological organisms. The use of chemical fertilizers usually implies a lump sum close of the three nutrients: Nitrogen, Phosphorus and Potassium.

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These minerals react with the soil and lead to unbalanced plant nutrition, loss of soil structure and fertility.The ready supply of the nutrients reduces the time of naturally occurring bioprocesses of the *in situ* decomposition of organic residues into nutrients, and hence erodes the biodiversity of spoil organisms. Earthworms are an important element in the bio nutrition, as they decompose organic residues, and increase the activity of an effective mix of bacteria which they harbour in their guts. Earthworm feeding increases the interaction among microflora, improving the flow and exchange of nutrients. Earthworms play a key role in soil biology by serving as versatile bioreactor to effectively harness the beneficial soil microflora and destroy soil pathogens thus converting organic waste into valuable products such as biofertilizers, biopesticides, vitamins, enzymes, antibiotics, growth hormones and proteinous worm biomass (Blakemore, 2000). Present studies reveal the progress achieved in vermicomposting could not only be use in farming, but also be used for commercial purposes, it was initially adapted by the farming community & agro-based industries and finally now it's commercial viable too.

Worm Selection for Compost

The selection of species of earthworms for vermicomposting should focus on species where, consumption of organic biomass, rapid growth and reproduction is within short time span (Gunasekaran and Desai, 1999). Some of the characteristics the worms should be as follows.

- Worms should be cabable of inhabiting high percentage of organic materials
- It should have high fecundity rate with short incubation period.
- The period of interval from hatching to maturity should be very short.
- It should have fast growth rate, consumption, digestion and assimilation
- rates.
- It should have less vermistabilization (period of inactivity after initial inoculation to organic wastes).

In temperate climate, the most vermicomposting worms is being recommended (Danne *et al* 1998).Even though a large number of earthworm species are available in nature, most of them undergo adiapause period. Only on the arrival of the rainy season, they will be active. Activities will maximum between June and December.

***Eisenia foetida* (Compost Worm)**

Various species of earthworms like *E.foetida, Lumricus rubellus, Perionyx excavates, Lampito mauritii, Eudrillus euginae* and *Pheretima elongate* have been used to digest and break down the organic matters during vermicomposting. *E. foetida* corresponds to the striped or banded worms, with the area having no pigmentation around the inter-segmental groove and with pale or yellow colour. Hence it is commonly known as brandling or tiger earthworm. The common "red worm" *E.andrei* possesses uniform reddish morph. The two species are syntopic, commonly living in mixed colonies in dung and compost heaps and therefore hybridization could be possible. The most promising earthworm species used for vermicomposting are *E. foetida, E. andrei, E. eugeniae and Perionyx excavates.* Among these *E.foetida* is commonly used for cow dung vermicomposting in Northern India (Gaddie,1975). *E.foetida* is more adaptable to tropical conditions which converts wastes into vermicompost with various other benefits including extra advantage as pest control in soil. Earthworms of the genus *Eisenia* are widespread and well known as laboratory test organisms, which are largely used for compost production.

Earthworms and Soil

Earthworms are often referred to as farmer's friends and nature's ploughmen (Jadia and Fuelekar, 2008). Karansingh *et al*. (2008) too have suggested that earthworms are natural ploughers of the soil throughout day and night, maintaining the fertility and porosity of the soil (Coleman, 2001). Earthworms play a key role in the biology of soil as versatile natural bioreactors. The earthworms, work as "fine drainage maker", which not only improve the water and air circulation in the soil, but also mixing of organic and mineral substances (Lee, 1985). During their feeding, they promote increased microbial activity, which in turn accelerates the breakdown of organic matter and stabilization of soil aggregates (Bhawalkar, 2007). Earthworms degrade all types of organic wastes such as agricultural wastes, animal droppings, weeds, forest litter and agro-industrial wastes (Ismail, 1997). Agricultural wastes like paddy straw, sugarcane trash, maize stubbles, vegetable wastes, haulms of potato and groundnut, soyabean harvest wastes, etc., favour faster development of worms and eventual compost production (Giraddi, 1998).The burrowing and swallowing of earth and organic matter by the earthworms increase the soil fertility in several ways;

(1) Penetration of air and moisture in the soil is facilitated, improving the drainage and stimulation of plant growth.
(2) Manure (castings) excreted by earthworms are an effective bio-fertilizer, with a high content of readily available minerals for plant growth.
(3) Organic matter dragged into the soil by earthworms are (partly) digested and thoroughly mixed with the castings; the added humus to the soil improves the water carrying capacity and decreases its vulnerability to soil erosion.
(4) Decomposition of organic litter and its removal from the surface in some cases prevent the development of pathogens that are harmful to the planted crops.

Interactions between earthworms and microorganisms

Earthworms are considered as 'ecosystem-engineers' and they can be efficiently employed as nature's unpaid labour force in the 'decomposer-industry' since earthworms in conjunction with microorganisms can decompose dead biomass (Fisher *et al.,* 1995) This process can also be initiated by the deliberate introduction of earthworms into a stack of biomass, the process being called as vermicomposting. Earthworms are very effective in initiating the decomposition processes and paving the way for subsequent microbial action (Pearson, *et al.,* 1963). Thus there exists a strong relationship between invertebrates and microorganisms to make use of soil organic matter (Reyes *et al.,* 1976).

The earthworm intestine contains about twice as much water as found in the soil and this could be a factor that might be the most rate-limiting relative to the activity of soil and earthworm – associated microbes (Jonathan, 2006). In addition, the increased organic carbon and nitrogen content of the worm gut might also stimulate the microbial activity (Blanchart *et al*., 1997). Microbes play an important part as a diet of earthworms which even prefer organic matter with high concentration of microbial life.

Role of Microorganisms in the Gut of Earthworms

(a) Microbial community has been observed in the gut of earthworms and Gram negative bacteria have been found to be a common inhabitant in the intestinal canal (Mahalingam *et al.,* 2008)
(b) When earthworms use organic matter as their nutrient source, the microorganisms are also ingested and they actually elaborate the enzymes that make the nutrients available for the worm's use (Edwards and Bohlen, 1996).
(c) Earthworms have to feed necessarily on microbes and in particular the fungi for their protein/nitrogen requirement (Prakash *et al.,* 2008)This may be the probable reason for the low diversity of fungal counts seen in the vermicompost collected (Parthasarathi, 2007).
(d) The indigenous microflora in the gut of earthworms play a significant role in the suppression of regrowth of pathogenic bacterial population in the composted sludges (Suthar, 2006).
(e) Enzymatic activity in earthworms for the decompostion process are regionally specialized and appear to be influenzed mainly by the microbial biota associated with them (Prabha *et al.,* 2007).

Compostable Organics

Compostable organics is a generic term for all organic materials that are appropriate for collection and use as feed stocks for composting. There are numerous sources of waste where degradable organic matter is either partially or fully generated (Cegarra *et al.,* 1992). The degradable organic matter from these wastes, when dumped in the open undergoes either aerobic or anaerobic degradation. waste disposed on the land has resulted in various environmental impacts including leachate contamination, pest problems, etc. (Fauziah and Angamuthu, 2009). The organic wastes available in India are estimated to supply about 7.1, 3.0 and 7.6 million tonnes of nitrogen, phosphorous and potassium respectively. Dumping of wastes on land not only reduces the availability of fertile land, but also pollutes air, water and soil (Prabha *et al*., 2007). However, the safe disposal of hazardous wastes using land as the dumping ground requires an active and diverse microbial population which can metabolize the various components (Kaushik *et al.,* 2003). Enhanced production as well as the accumulation of hazardous waste materials has led to numerous disposals methods such as land filling, incineration, recycling, conversion to biogas, disposal into sea and composting, etc. In view of escalating cost of fertilizers and their hazardous polluting effects on environment, there is a growing awareness among the farming community about the alternative agricultural systems, known as Biological farming or Organic farming (Piet *et al.,* 1990). Though India has a huge bio-mass of crop residues like sugarcane trash, straw and bagasse, coir pith waste, cotton waste, farm land waste, industrial wastes, aquatic weeds, etc., the potentiality of the organic resources has not yet been fully tapped (Shweta *et al.,* 2004).

Vermiwash

Vermiwash is a brown coloured liquid collected after the passage of water through a column of worm culture. This liquid partially contains water from the body of earthworms (as worm's body contain plenty of water) and is rich in amino acids, vitamins, nutrients like nitrogen, potassium, magnesium, zinc, calcium, iron, and copper, as well as some growth hormones like auxins and cytokinins. It also contains plenty of nitrogen fixing and phosphate solubilizing bacteria (nitrosomes, *Nitrobacter*, and actinomycetes) Fayez *et al.,* 1985. As per Prabu (2006), it is alkaline in nature and contains nitrogen, phosphorus, potash, calcium, magnesium and zinc in appreciable quantities. Subasashri (2004) has envisaged that vermiwash has enzymes that stimulate plant growth and yield, and enables the development of resistance in crops.

Vermicomposting

Vermicomposting is a simple process of composting, using certain species of earthworms to accelerate the process of waste conversion to get a better end product-

Details of degradable organic wastes

S.No.	Sources of Wastes	Types of wastes Generated
1.	Agricultural wastes Agricultural fields Plantation Animal wastes	Stubbles, weeds, husk, straw, and farm yard manure, Stems, leaf wastes, fruit rid, stubbles Dung, and biogas slurry.
2.	Urban Solid wastes	Kitchen wastes from households and restaurents, waste from market yards and sludge from sewage treatment
3.	Agro Industry waste	Fruit processin units – Peels, rinds and unused pulp of fruits and vegetables.
4.	Sugar factories	Pressmud, fine bagasse and boiler ash
5.	Vegetable refineries	Pressmud and seed husk
6.	Breweries and distilleries	Spent wash, barley waste and yeast sludge
7.	Seed processing Units	Core of fruits
8.	Aromatic oil extraction units	Stem, leaves and flowers after extraction of oil
9.	Coir Industry	Coirpith

vermicompost. It is a simple procedure, using cheap & simple technology which could be practiced by a common farmer. Vermicompost is the best alternative to chemical pesticides; it not only helps farmers but also paves a way for a new type of small scale industry which is feasible without a major investment (Ananthakrishnasamy *et al.,* 2009). A range of agricultural residues, for example, sorghum straw and rice straw (after feeding cattle), dry leaves of crops and trees, pigeonpea (*Cajanus cajan*) stalks, groundnut (*Arachis hypogaea*) husk, soybean residue, vegetable waste, weed (*Parthenium*) plants before flowering, fiber from coconut (*Cocos nucifera*) trees and sugarcane (*Saccharum officinarum*) trash remain availble throughout year. In addition, animal manure, dairy and poultry wastes, food industry wastes. All these (organic waste) serve as good raw materials for vermicompositing. The quantity of raw materials required are a cement ring of 90 cm in diameter and 30 cm in height or a pit or tank measuring 1.5 m × 1 m × 1 m ,50Kgs of Dry organic wastes (DOW), 15 kgs of Dung slurry (DS), 2 kgs of Rock phosphate (RP), 500–700 of Earthworms (EW) and 5 Liters of Water (W) every three days (Singh, N.B. *et al*., 2004).

The ingredients are used in the ratio of 5:1.5:0.2:50–75:0.5 of DOW: DS: RP: EW: W. The tank or pit system is filled 100kg of raw material and 15–20kg of cow dung for each cubic meter of the bed. **The non-burrowing types** earth worms (*Eisenia spp, Eudrilis spp*), which are easily available in local markets are used (**Kale** et al 1986). They are **red or purple, live on the soil surface** and help digest 90% organic waste materials (Brown *et al*., 2000).

Bedding

Bedding is any material that provides the worms with a relatively stable habitat. This habitat must have the following characteristics:

High absorbency. Worms breathe through their skins and therefore must have a moist environment in which to live. If a worm's skin dries out, it dies. The bedding must be able to absorb and retain water fairly well if the worms are to thrive.

Good bulking potential: If the material is too dense to begin with, or packs too tightly, then theflow of air is reduced or eliminated. Worms require oxygen to live, just as we do. Different materials affect the overall porosity of the bedding through a variety of factors, including the range of particle size and shape, the texture, and the strength and rigidity of its structure. The overall effect is referred to in this document as the material's bulking potential.

Low protein and/or nitrogen content (high Carbon: Nitrogen ratio): Although the worms do consume their bedding as it breaks down, it is very important that this be a slow process. High protein/nitrogen levels can result in rapid degradation and its associated heating, creating inhospitable, often fatal, conditions. Heating can occur safely in the food layers of the vermiculture or vermicomposting system, but not in the bedding. Some materials make good beddings all by themselves, while others lack one or more of the above characteristics and need to be used in various combinations. In general, it should be noted by the reader that the selection of bedding materials is a key to successful vermiculture or

Table 1. Common Bedding Materials

Bedding Material	Absorbency	Bulking Pot.	C:N Ratio4
Horse ManureMedium-	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 strea	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	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
L:eaves(dry,loose)Poor-Medium	Poor	Medium	40-80
Corn talks	poor	Good	60-73

vermicomposting. Worms can be enormously productive (and reproductive) if conditions are good; however, their efficiency drops off rapidly when their basic needs are not met (see discussion on moisture below). Good bedding mixtures are an essential element in meeting those needs.

Worm Food

Compost worms are big eaters. Under ideal conditions, they are able to consume in excess of their body weight each day, although the general rule-of-thumb is ½ of their body weight per day 5.They will eat almost anything organic (that is, of plant or animal origin), but they definitely 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 *Eisenia*, with the possible exception of rabbit manure. The former, being more often available in large quantities, is the feed most often used. Table 2 summarizes the most important attributes of some of the more common foods that could be used in an on-farm vermicomposting or vermiculture operation. Please note that the provision of instructions for composting high protein wastes (e.g., animal mortalities) is beyond the scope of this manual.

Moisture

The need for adequate moisture was discussed in relation to bedding in above. The bedding used must be able to hold sufficient moisture if the worms are to have a livable environment. They breathe through their skins and moisture content in the bedding of less than 50% is dangerous. With the exception of extreme heat or cold, nothing will kill worms faster than a lack of adequate moisture. The ideal moisture-content range for materials in conventional composting systems is 45-60% (Rink *et al.,* 1992). In contrast, the ideal moisture content range for vermicomposting or vermiculture processes is 70-90%. Within this broad range, researchers have found slightly different optimums: Dominguez and Edwards (1997) found the 80-90% range to be best, with 85% optimum, while Nova Scotia researchers found that 75-80% moisture contents produced the best growth and reproductive response (GEORG, 2004). Both of these studies found that average worm weight increased with moisture content (among other variables), which suggests that vermiculture operations designed to produce live poultry feed or bait worms (where individual worm size matters) might want to keep moisture contents above 80%, while vermicomposting operations could operate in the less mucky 70-80% range.

Aeration

Worms are oxygen breathers and cannot survive anaerobic conditions (defined as the absence of oxygen). When factors such as high levels of grease in the feedstock or excessive moisture combined with poor aeration conspire to cut off oxygen supplies, areas of the worm bed, or even the entire system, can become anaerobic. This will kill the worms very quickly. Not only are the worms deprived of oxygen, they are also killed by toxic substances (e.g., ammonia) created by different sets of microbes that bloom under these conditions. This is one of the main reasons for not including meat or other greasy wastes in worm feedstock unless they have been pre-composted to break down the oils and fats. Although composting worms O2 requirements are essential, however, they are also relatively modest. Worms survive harsh winters inside windrows where all surfaces are frozen: they live on the oxygen available in the water trapped inside the windrow. Worms in commercial vermicomposting units can operate quite well in their well insulated homes as long as there are small cracks or openings for ventilation somewhere in the system. Nevertheless, they operate best when ventilation is good and the material they are living in is relatively porous and well aerated. In fact, they help themselves in this area by aerating their bedding by their movement through it. This can be one of the major benefits of vermicomposting: the lack of a need to turn the material, since the worms do that work for you. The trick is to provide them with bedding that is not too densely packed to prevent this movement.

Temperature Control

Controlling temperature to within the worms' tolerance is vital to both vermicomposting and vermiculture processes. This does not mean, however, that heated buildings or cooling systems are required. Worms can be grown and materials can be vermicomposted using low-tech systems, outdoors and year-round, in the more temperate regions. Discusses the different vermicomposting and vermiculture systems in use world-wide and provides some basic information on how these systems address the problem of temperature control.

Low temperatures

Eisenia can survive in temperatures as low as 0º C, but they do not reproduce at single-digit temperatures and they do not consume as much food. It is generally considered necessary to keep the temperatures above 10ºC (minimum) and preferably 15ºC for vermicomposting efficiency and above 15ºC (minimum) and preferably 20ºC for productive vermiculture operations.

Effects of freezing

Eisenia can survive having their bodies partially encased in frozen bedding and will only die when they are no longer able to consume food. Moreover, tests at the Nova Scotia Agricultural College (NSAC) have confirmed that their cocoons survive extended periods of deep freezing and remain viable (GEORG, 2004).

High temperatures

Compost worms can survive temperatures in the mid-30s but prefer a range in the 20s (ºC). Above 35ºC will cause the worms to leave the area. If they cannot leave, they will quickly die. In general, warmer temperatures (above 20ºC) stimulate reproduction.

Worms's response to temperature differentials

Compost worms will redistribute themselves within piles, beds or windrows according to temperature gradients. In outdoor composting windrows in wintertime, where internal heat from decomposition is in contrast to frigid external temperatures, the worms will be found in a relatively narrow band at a depth where the temperature is close to optimum. They will also be found in much greater numbers on the south-facing side of windrows in the winter and on the opposite side in the summer.

Other Important Parameters

There are a number of other parameters of importance to vermicomposting and vermiculture:

pH

Worms can survive in a pH range of 5 to 9 (Edwards, 1998). Most experts feel that the worms prefer a pH of 7 or slightly higher. Nova Scotia researchers found that the range of 7.5 to 8.0 was optimum (GEORG, 2004). In general, the pH of worm beds tends to drop over time. If the food sources are alkaline, the effect is a moderating one, tending to neutral or slightly alkaline. If the food source or bedding is acidic (coffee grounds, peat moss) than the pH of the beds. This can be a problem in terms of the development of pests such as mites. The pH can be adjusted upwards by adding calcium carbonate. In the rare case where they need to be adjusted downwards, acidic bedding such as peat moss can be introduced into the mix.

Salt content

Worms are very sensitive to salts, preferring salt contents less than 0.5% (Gunadi *et al.,* 2002). If salt water seaweed is used as a feed (and worms do like all forms of seaweed), then it should be rinsed first to wash off the salt left on the surface. Similarly, many types of manure have high soluble salt contents (up to 8%). This is not usually a problem when the manure is used as a feed, because the material is usually applied on top, where the worms can avoid it until the salts are leached out over time by watering or precipitation. If manures are to be used as bedding, they can be leached first to reduce the salt content. This is done by simply running water through the material for a period of time (Gaddie, 1975). If the manures are pre-composted outdoors, salts will not be a problem.

Urine content

Gaddie and Douglas (1975) state: "If the manure is from animals raised or fed off in concrete lots, it will contain excessive urine because the urine cannot drain off into the ground. This manure should be leached before use to remove the urine. Excessive urine will build up dangerous gases in the bedding. The same fact is true of rabbit manure where the manure is dropped on concrete or in pans below the cages".

Other toxic components

Different feeds can contain a wide variety of potentially toxic components. Some of the morenotable are: De-worming medicine in manures, particularly horse manure. Most modern deworming medicines break down fairly quickly and are not a problem for worm growers. Nevertheless, if using manure from another farm than your own, it would be wise to consult your source with regard to the timing of de-worming activities, just to be sure. Application of fresh manure from recently de-wormed animals could prove costly.

Detergent cleansers industrial chemicals, pesticides. These can often be found in feeds such as sewage or septic sludge, paper-mill sludge, or some food processing wastes. Some trees, such as cedar and fir, have high levels of these naturally occurring substances. They can harm worms and even drive them from the beds (Gaddie, op. cit.). Gunadi *et al.* (2002) point out that pre-composting of wastes can reduce or even eliminate most of these threats. However, pre-composting also reduces the nutrient value of the feed, so this is a definite trade-off.

Calculating Rates of Reproduction

Epigeic worms such as *E. fetida* do reproduce very quickly, given good to ideal conditions. Compost worm populations can be expected to double every 60 to 90 days, but only if the following conditions are met:1). Adequate food (must be continuous supply of nutritious food, such as those listed in Table 2); Well aerated bedding with moisture content between 70 and 90%; 2). Temperatures maintained between 15 and 30ºC; Initial stocking densities greater than 2.5 kg/m2 (0.5 lb/ft2) but not more than 5 kg/m2 (1.0 lb/ft2).

The issues of food, aeration, moisture and temperature are discussed above. The issue of initial stocking density, however, was not discussed previously and requires elaboration here. Stocking density refers to the initial weight of worm biomass per unit area of bedding. For instance, if you started with 5 kg of worms and put them in a bin with a surface area of 2 m2, then your initial stocking density would be 2.5 kg/m2. Starting with a population density less than this will delay the onset of rapid reproduction and, at very low densities, may even stop it completely. It seems that worms need a certain density in order to have a reasonable chance of running into each other and reproducing frequently. At lower densities, they just don't find each other as often as the typical worm grower would like. On the other hand, densities higher than 5 kg/m2 begin to slow the reproductive urge, as competition for food and space increase. While it is possible to get worm densities up to as much as 20kg/m2 or 4 lbs per square foot (Edwards, 1999), the most common densities for vermicomposting are between 5 and 10 kg/m2 (1 to 2 lbs per ft2). Worm growers tend to stock at 5 kg/m2 (Bogdanov, 1996) and "split the beds" when the density has doubled, assuming that the optimum densities for reproduction have by that point been surpassed. If the above guidelines are followed, a grower can expect a doubling in worm biomass about every 60 days.

Theoretically, this means that an initial stock of 10kg of worms can become 640 kg after one year and about 40 tonnes after two years. In practice, this is difficult to achieve, though not impossible. For instance, American Resource Recovery, a recycling firm in northern California, started with 50 pounds of earthworms. In four years, they had enough to cover over 70 acres of windrows, within which the worms convert huge quantities of sludge from a cardboard recycling plant into worm castings (VermiCo, 2004). The main barriers to achieving optimum rates of reproduction appear to be the following:

Lack of knowledge and experience

Growing worms is part science, part "green thumb". You need the knowledge (as in this Manual), but you also need to do it to learn how to do it well.

Lack of dedicated resources

Increasing worm populations requires paying attention to what is happening and responding accordingly. This takes time and effort. If the beds or windrows are neglected, the worms will likely survive, but the population will not increase at an optimum rate.

Lack of preparation for winter

Although harsh winter conditions are unlikely to completely destroy a worm population10, they can (as in the OACC pilot project) reduce the rate of increase considerably. The various vermicomposting and vermiculture systems have different ways of dealing with this problem.

MAKING VERMICOMPOST:

- Cover the bottom of the cement ring with a polythene sheet.
- Next, spread a layer (15-20 cms) of organic waste on top of the sheet.
- Sprinkle rock phosphate on top of the organic material (2kgs).
- Prepare cowdung slurry (15kgs) and add the slurry as a layer on top of the mixture.
- Fill the ring completely in layers as described above.
- Paste the top of the ring with soil or cow dung.
- Allow the material to decompose for 20 days. After 20 days, put the earthworms on top. They will enter the material through the cracks developed.
- Cover the ring with wire mesh or gunny bags to prevent birds from eating the worms.
- Sprinkle water over the whole mixture at 3-day intervals for 2 months, to maintain adequate moisture and body temperature of the worms.
- After 2 months, (or when the compost is ready), remove the ring and heap the material in a cone shape on the floor. Leave the heap undisturbed for 2-3 hours, to let the worms move slowly to the bottom.
- Separate the upper portion of the heap.

Note: When the compost is black, lightweight and has a pleasant earthy odour, It is a sign that it is ready to harvest Sieve the lower portion of the heap to separate the worms. They can be used again for preparation of more vermicompost. Pack the compost in bags and sell. Store in a cool place.

Precautions

- Use only plant based materials (such as vegetable peelings, leaves or grass). Egg shells, meat, bone, chicken droppings, are not suitable for preparing Vermicompost. Remove glass, metal and plastic materials from the organic material Protect worms against birds, termites, ants and rats. Sprinkle water regularly and maintain moisture levels Prepare compost in the shade to protect it from sun and rain.

Vermicompost Extract

Compost tea which is a highly concentrated microbial solution extracted from the beneficial microbes of vermicompost is also known as compost watery extract (Sadasivam *et al.,* 1985). The plant nutrients by the microbial activity have been shown to be transferred from vermicomposts into the tea. It is a source of foliar and soil organic nutrients that contain chelated micronutrients which are made biologically available for easier absorption by the plant (Hendawy, 2008). Though the extract can be prepared in various ways, the usual method is in a ratio of one part compost to five to ten parts water. Increased crop yield with response to soil nutrients status and nutrients uptake are proven (Singh and Sharma, 2003; Roberts *et al.,* 2007). Addition of selected microbes to the extract has been shown to improve their efficacy, and the fermented extract of at least 10 days old is found to reduce the disease by 56 to 100% (Sailaja Kumari *et al.,* 2002).

Chemistry of Vermicompost

The nutrient level of vermicompost depends on the nature of the organic waste used as food source for earthworms (Kawaguchi and Nishi, 2007). It is found that a heterogeneous waste mix will have balanced level of nutrients than from any one particular waste (Jackson, *et al.,* 1973). It contributes to the supply of micronutrients essential for the crops (Bucht and Eriksson, 1969). Apart from this, the stimulatory effect of vermicompost for nutrient uptake, growth and yield of crops is linked to the secretions of earthworms and the associated microbes mixed with the cast. (Lindsay *et al* 1978).

Chemical Composition of Vermicompost

S.No	Nutrient	Level
1.	Organic Carbon(%)	9.5 to 17.89
2.	Nitrogen (%)	0.50 to 1.50
3.	Phosphorus (%)	0.10 to 0.30
4.	Potassium (%)	0.15 to 0.56
5.	Sodium (%)	0.06 to 30
6.	Calcium & Magnesium (meq. /100g)	22.67 to 70.00
7.	Copper (ppm)	2.00 to 9.50
8.	Iron (ppm)	2.00 to 9.30
9.	Zinc (ppm)	5.70 to 11.50
10.	Sulphur (ppm)	128.0to 48.50

Applications of Vermicompost

- Increases the nutrient holding capacity of soil.

- Acts as a nutrient pool for plants.
- Chelates with nutrients and there by preventing them from becoming permanently unavailable to plants or getting leached away.
- Serves food for soil organisms ranging from bacteria to worms which hold on the nutrients and release them in available forms to plants.
- Improves the water infiltration in the soil
- Decreases water evaporation from the soil
- Increases the water holding capacity of soil especially in sandy soils.
- Reduces the crusting of soil especially in fine-textured soils.
- Increases root development in plants
- Improves the aggregation of soil particles preventing erosion.
- Prevents compaction and other effects of soil organic matter; breaking down of some pesticides more quickly and converting them into organic matter.
- Improving soil health to resist soil pathogens
- Encourage natural biological agents and naturl enemies of pests for control of diseases, insects and weeds.

Advantage: Apart from the benefit of a minimum investment to start a business, vermicompost protects plants against bacterial & fungal pathogens and can reduce usage of pesticides & chemical fertilizers by 90%, thus retaining the natural qualities of agricultural soil.

Market: The vermicompost can be sold to the farmers and others in local markets and extra worms obtained can be also sold to new unit holders.

Assistance: In this regard, assistanace would be provided by the government of all Indian States.

Economic Approach: Vermitechnology: This process is very popular not just because of its simple methodology but also for its low investment (Berewith, *et al*., 2000) Adoption of this technology does not call for sophisticated infrastructure. Mentioned below are some of the basic requirements to incept a commercial vermicomposting unit.

Requirements to incept a commercial vermicompost unit

Shack: The basic need to function a vermicompost unit is an open shed , It should be supported by stone pillars for the corners and a shed on top with bamboo rafters, wooden tie ups and purlins to prevent the vermicompost bed from getting soaked from rain water or from wind. The shed should be designed with sufficient place for movement of labourers to do their work.

Vermi-beds: The thickness of the vermin-bed should be 75cm-90cm with adequate drainage facilities to drain out excess water. The entire bed should be in uniform height to ensure equal production. The width of the bed should not be more than 1.5m so that the centre of the bed can be easily reached.

Land: The land required to initiate a vermiculture production & extension unit is about 0.5 – 1 acre on which about 8 to 10 shacks sized 180-200sq.ft could be built. The land should have adequate water supply with watering facilities. Sub Marginal land could also be used. In case one does not own land, he or she could take a piece of land on lease for a 10 to 15 year period.

Building: If vermicomposting is started on a big scale for commercial use, one has to invest for an office; warehouses for raw material & finished goods, the infrastructure should have accommodation facilities for the manager and workers.

Seed Stock: Seeds are the primary requirement to start vermicomposting and they fall under investment. Worms multiply within a period of 6 months to 1year, but to start the vernmicompiost bed should have about 350 worms per m3 to increase the worm population in about 2 to 3 cycles withour affecting the production.

Roads, Paths & Fencing: The site needs adequate infrastructure with roads & paths for easy movement of workers, trolleys & wheel barrows to transport the raw materials to the bed & carry out the finished compost. The site should be fenced to prevent entry of animals or unwanted elements onto the site. The investment should be minimum for this purpose but these facilities are pivotal to ensure undisturbed production.

Water Supply System: The vermicompost beds have to be kept most with about 50% water content. Adequate water supply with well designed water distribution mechanism is mandatory. Drippers with nonstop water flow would be viable for continuous water supply and also helps in saving water. This may be a costly investment but reduces operational costs of manual watering and economical in the long run.

Machinery: For efficient operation of a vermicompost unit, the following machinery is needed. A shredding machin to shred the raw material , wheel barrows & trolleys for transportation to and fro the site for loading & unloading of compost, aeration, for air drying, machinery for stitching & automatic packing.

Transport: A good transport system is a vital need for a Vermicompost unit. Transport is required in order to shift raw materials to the site, especially if the source of the raw materials is far away from the unit. For a unit that produce about 1000 tones of compost per annaum , a truck with the minimum capacity of 3-tonnes is required, smaller units can use smaller vehicles depending on their production. On-site vehicles, like trolleys are required to transport the raw material from the warehouses to the shacks. These expenses could be included in the project cost.

Furniture: A decent amount could be used to furnish the office which could also be used as a store house, spending on the basic requirements for an office and racks for storage.

Operational Costs: In the operational cost , some expenses are recurrent. These expenses include cost of raw materials, fuel & Transport costs, power, Insurance, repair & Maintenance, wages for labourers & staff salaries. The number of staff & workers hired should be according to the need of workers of each level of the production depending on the size of the unit. Manpower should be properly managed and used properly at all work points.

Extension Service: A vermicomposting unit could serve the vicinity by providing cultural material of desired species and train farmers and aspiring entrepreneurs who are interested in vermicomposting. Those who have the idea to set up commercial vermicomposting units too can get practical advice & culture material at reasonable prices from the existing units. These vermicomposting units could benefit from extension services unit by selling Culture material at the rate of 5 to 10 paisa, charge a consultancy fee of about `.1000/- to give ideas to interested party's as to how to set up shop, wherein if we advice 10 customers ,we can earn `10000/-. Units could also construct smaller, simpler models which could serve as demonstrations for farmers & give wide publicity & to popularize vermicomposting.

Conclusion

This study endorses vercomposting as a feasible economic possible small scale industry which can not only be used by farmers & agro based industries but also for commercial use.

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