BASIC AND APPLIED ASPECTS OF VERMICOMPOST

PRODUCTION AND USE IN AGRI-HORTICULTURE AND SOME EXPERIENCES IN VERMICOMPOSTING OF COCONUT PLANTATION WASTES

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"Nature produced no waste, therefore so-called waste products result from man's failure to apply his intelligence to the use of natural resources".

George Washington Carver

COMPOSTING OF ORGANIC WASTES: A WAY TO TURN LIABILITY INTO ASSET

The present day farming community and the scientists concerned are passing through a transition phase in their thinking and practical approach to the farming methods. After more than three decades of application of so called green revolution technologies, during which overall production had increased substantially, modern agriculture is facing serious environmental problems, In addition, due to constant and indiscriminate use of chemical fertilizers and depletion of soil organic matter (SOM) content, soil physical properties are damaged, affecting short and long term soil fertility and productivity. All these strongly suggest that high chemical input technologies cannot conserve the quality of soils in long run. As a result, currently there is a revival of interest in long external input and sustainable agriculture (LEISA), mainly based on organics. There is also an awareness among farming communities that yields can be sustained only if adequate organic matter is added regularly to maintain and improve soil physical,chemical and biological properties. The major mistake committed over the years was to consider and treat soil as a non–living entity, which in reality is a living one, harbouring a highly diverse population of microflora, microfauna and macrofauna. These organisms mediate organic matter and nutrient transformations, making them available to plants in a sustained manner and are inevitable in maintaining healthy soil for raising healthy crops. For their growth, multiplication and activity, these organisms require adequate supply of food in the form of organic matter. So, when soil is fed with organic manures, it will in turn feed plants. This is the basis of organic farming and in recent years, there has been a lot of demand for organically grown agricultural produce and subsequently for quality organic manures. There exists immense potential to produce the required organic manures at individual farm or community level. India is endowed with immense organic resources and over 2200 million tons of organic wastes from agricultural, domestic and industrial sources become available every year, which often form a major source of various environmental problems. These organic wastes if recycled meaningfully, can supply a share of nutrient needs of crops, in addition to improving soil physical properties.

Organic wastes cannot be used as such and should be stabilized by a process called **composting.** This yields a relatively stable humus – like material with reduced volume and enhanced nutrient percentage and may be stored and spread with little odour and insect/microbial breeding potential. Composting is essentially a biological process of degradation of organic refuse brought about by the growth and activity of microorganisms and invertebrates, which together form the **decomposer system.** This system occurs naturally, but can be accelerated and improved by human intervention. If inoculation of organic wastes with superior strains of microbes and efficient earthworm species is combined with the provision of necessary favourable conditions for their multiplication and activity, composting process can be accelerated to a very great extent. Though the actual decomposition or chemical decay is mediated by microorganisms, macrofauna, especially earthworms play a leading role in the decomposer system. Earthworms in addition to increasing the surface area for the activity of microbes by fragmenting larger particles into smaller ones, transform organic matter into more digestible form for microbes through their intestinal enzymes. Use of earthworms for composting also results in reduced composting period, much greater volume reduction and better quality of the final composted product with higher nutrient percentage. As the earthworms create aerobic environment in compost beds by their continuous movement the need for turning during composting process is completely eliminated. As a result, in recent years, there has been a lot of interest and importance for this composting method and the resulting compost.

EARTHWORMS: NATURE'S EFFICIENT ORGANIC WASTE MANAGERS

Earthworms, the most known of all soil dwelling animals belong to the phylum **Annelida** and class **Oligochaeta.** The first species of earthworm (*Lumbricus terrestris*) was described by Linneaus in 1758 and now about 3627 species are known in the world including over 500 reported from India. The importance of earthworms in agriculture was recognized by Charles Darwin in 1881, who had remarked that ***"It may be doubted whether there are many other animals which have played so important a part in the history of the world as have these lowly organized creatures"***. Since then thousands of research papers have appeared on various basic and practical aspects of earthworms and the information available to date reveals that their potential is greater than anything Darwin could have imagined. To the environment – conscious organic farmer, earthworms represent a way of food production without the use of chemical fertilizers. Earthworm activity and resulting physico–chemical changes affect a number of soil biological properties and processes which decide the suitability of soil as habitat for other organisms including plants, and hence they are known as **ecosystem engineers**. Again, earthworms are highly sensitive to the soil physico–chemical environment and serve as true **bio–indicators of soil quality**. Earthworms are also important as the most important bait used by sport fishermen. Earthworms after drying contain up to 72 percent protein by weight depending on the species and they are in demand as feed for poultry birds and fishes. As a consequence, the demand for earthworms has increased immensely and small and medium scale commercial earthworm cultivation units are flourishing in many parts of the world, including India and this industry of controlled raising of earthworms is known as **vermiculture.**

Earthworms vary greatly in size, colour, food habit, habitat preference, behaviour, reproductive potential etc. and may be broadly classified into **detrivorous** or **phytophagous** (organic matter eating) types generally known as **humus formers** and soil eating or **geophagous** types known as **humus feeders.** Based on their ecological strategies, the earthworms have been classified under **epigeics, anecics** and **endogeics**. The main differentiating characteristics of these groups are presented in Table 1.

Functional diversity is very much pronounced among earthworms and each category of earthworms has specific roles in the functioning of soil systems. The epigeics have no preference for soil either to feed or to settle. They remain confined to the decaying organic matter layer on the surface of soil, play a leading role in the decomposer system and are better known as **manure worms** or **compost worms**. They derive their nutritional needs by feeding on a wide variety of decaying organic substances. Anecics and endogeics live in soil and hence have direct influence on soil properties. They enhance soil aeration, mixing of organic matter with soil, formation of soil aggregate etc. and are commonly known as **field worms**. Majority of there types have overlapping characteristics and have been classified accordingly.

Though the commercial application of soil dwelling earthworms in upgrading degraded soils have been realized recently, only epigeics, the organic matter decomposing manure worms have large scale commercial applications at present. This paper deals with the basic and applied aspects of these commercially important earthworms.

THE JOURNEY FROM NATURAL PROCESS TO COMMERCIALIZATION

Earthworms form a small but very important link in the chain of life. As nature's alchemists and grist mills, they transform dead organic matter into powerful soil. By helping them prosper, humankind can help to save itself.

The role of epigeic earthworms in organic matter decomposition

An ecosystem can be seen as integration of three subsystems: the plant subsystem, the herbivore

Table 1. The main differentiating characteristics of three ecological categories of earthworms.				
Sl. No.	Character	Ecological category		
		Epigeics	Anecics	Endogeics
1.	Habitat	Decaying organic matter layer on soil surface	Deep vertical burrows connecting surface soil and mineral	Shallow horizontal burrows in organo-mineral soil
2.	Food habit	Organic matter only	Soil and organic matter	Soil along with humus
3.	Body pigmentation	Uniformly dark pigmented	Pigmented on dorso-anterior sides	Unpigmented
4.	Body size	Small	Large	Medium
5.	Soil burrowing character	Poorly developed	Strongly developed	Developed
6.	Movement	Rapid	Moderate	Feeble
7.	Skin moistening	Developed	Developed	Feeble
8.	Sensitivity to light	Feeble	Moderate	Strong
9.	Reproductive potential- (number of cocoons and young ones produced per worm)	High	Moderate	Limited
10.	Attainment of reproductive maturity	Rapid	Moderate	Slow
11.	Survival of adverse conditions	As cocoons	As true suspended animation or diapause	As temporary inactive state or quiescence and respond quickly to changing situations
(Modified after Bouche (1977))				

subsystem (including herbivores and carnivores) and the decomposer subsystem. Decomposition of organic biomass is the primary mechanism by which organic matter and nutrients are returned to soil. Even though the actual decomposition process is mediated by microorganisms, soil fauna such as litter– dwelling epigeic earthworms take active role in decomposition process by their unique ability to stimulate microbial activity. The role of earthworms as a stimulator of decomposition is much pronounced in the case of hard–to–decompose organic wastes such as plant materials rich in lignin. They enhance decomposition process by 25 to 40 per cent by ensuring an aerobic environment and by increasing the surface area of litter available for the activity of microbes through fragmentation, feeding and casting activity. One kilogram of epigeic earthworms can ingest and digest about 4–5 kilograms of organic wastes having 40–50 per cent moisture content. The organic wastes consumed by the earthworms undergo a thorough grinding in the intestine and get mixed with mucus rich in easily absorbable carbohydrates. This favours the growth and activity of intestinal microflora. The intestine acts as a fermenter and biopolymers are broken into simple compounds by the combined action of microbial and earthworm enzymes. Thus, the earthworm is physically an aerator, crusher and mixer and chemically a degrader and biologically a stimulator in the decomposition system. The C/N ratio of the organic matter ingested by the earthworm decreases and bound nutrients are converted into easily available forms. A small portion of this digested organic matter is absorbed by the earthworm and the left over, which is relatively stable humus–like organic matter is egested in the form of pellets or granules, frequently referred to as **vermicastings**. The gut passage of organic matter results in enhanced availability of nutrients, increased counts of microbes and enrichment with a number of bio–active compounds. In addition, a large reduction in the volume, usually measuring to 40–60 per cent of the raw wastes occurs, and is much higher than that in other composting methods. This is one of the reasons for higher percentage of nutrients in vermicomposts in comparison with other composts. This process of digesting organic matter by employing earthworms is known as **vermicomposting** or **annelidiç consumption**.

Commercial exploitation of epigeic earthworms for organic manure production

In natural and man– made agro–ecosystems, these epigeic earthworms remain active only for a short period of time, as their activity is limited by a number of factors. Being surface feeders, frequently they have to face wide fluctuations in temperature, moisture, availability of food and attack from predators, as compared to the soil dwelling ones. To counteract this disadvantage, nature has endowed them with a very high reproductive potential and with sufficient food, moisture space and shelter. They multiply very fast and remain as active feeders throughout the year. In semi–natural or even artificial environments, they can be cultured and with optimal conditions, they will breed heavily. The worm biomass may increase 40 to 100 times in 2–6 months unlike in other categories of earthworms.

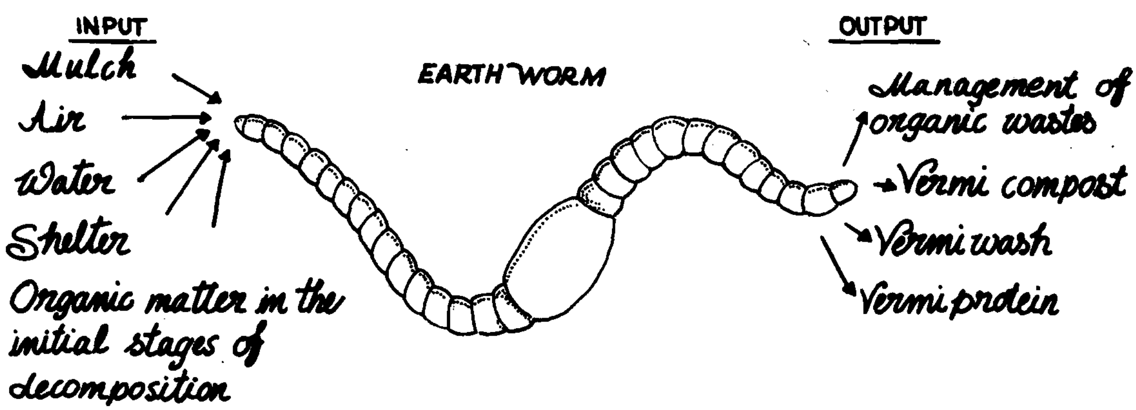
This most important character, the amenability for culturing or domestication has immense commercial implications and is taken advantage of in employing these worms in irrigated gardens and in–door composting systems for simultaneously achieving three benefits namely,

1. Management of organic wastes and abatement of pollution by rapid reduction in bulk density and elimination of foul odour.
2. Production of **vermicompost** containing easily available nutrients and plant growth promoting microbes and bio–chemicals.
3. Production of **vermiprotein** as feed for poultry and fishes. It contains important amino acids in a balanced proportion and is one of the cheapest and fastest ways to produce animal protein supplements.

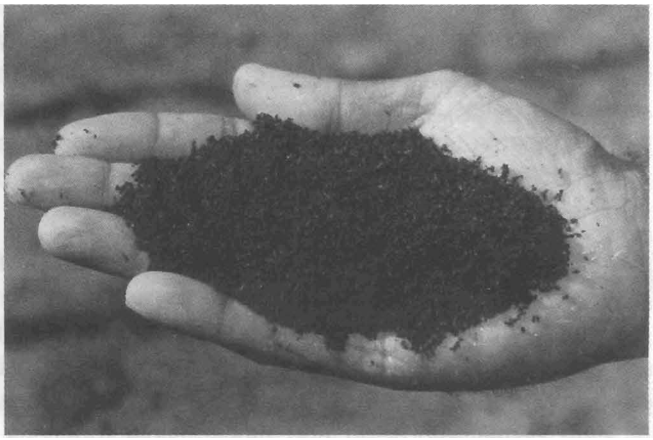
SOME BASIC FACTS ABOUT THE HABITAT REQUIREMENTS OF EARTHWORMS FOR BETTER MANAGEMENT OF VERMICOMPOSTING

Vermicomposting is essentially a biological process and the conversion rate of organic wastes into vermicompost will be directly proportional to the number of worms in the system and the extent of microbial activity. It has been established that earthworms consume a quantity approximately equal to their own weight per day. Hence, for successful management of vermicomposting, all the conditions required for survival, growth multiplication and activity of earthworms and microorganisms should be ensured.

EARTHWORM S SILENT SERVICES TO THE MANKIND



Vermicompost from Coconut palm wastes



Vermicompost from Coconut palm wastes

Being rich in nutrients, earthworms are attacked by a number of predators. So, it is clear that vermicomposting demands more care and attention compared to other composting methods. The purpose of managing vermicomposting should be to meet the earthworm's basic requirements. The following points may be considered while managing vermicomposting.

- **Availability of sufficient quantity of suitable food** compost worms remain close to their food source as they feed on decaying organic matter. Earthworms avoid fresh organic matter, and prefer organic matter that is in the initial phases of decomposition. Studies indicate that all earthworm species prefer animal manure over other organic materials. Succulent vegetation such as vegetable wastes was second, then tree leaves, and hard materials such as pine needles and strongly flavoured plants like mint are least preferred. The palatability of all vegetative matter will increase on weathering and even the hard plant litters with high amounts of lignin, polyphenols and aromatic compounds will be consumed by them on sufficient weathering. The worms will eat human food refuse, but only some items should be avoided. The food preparation forms an important aspect in commercial vermicomposting and will be dealt later.

- **Adequate dissolved oxygen**. Earthworms are air–breathing animals and therefore, dissolved oxygen in their habitat is essential for respiration. Being surface active earthworms, manure worms used for vermicomposting demand good aeration and hence composting will be faster in methods that favour ample aeration. The organic refuse used for composting should not form a hard mass, restricting the movement and activity of the worms. In large scale operations, if hard to decompose materials such as twigs, coconut leaf petioles etc. are mixed in some proportion, will ensure aerobic environment throughout the bed and composting period can be reduced. If composting is done in pits or boxes, worms will be active only on the surface and for quick results, the waste layer should be shallow, preferably 2 feet and should in any case be not more than 1 meter thick. Heaping of wastes under a roof is the best method, as it favours aeration and the worms can feed effectively from all sides.

- **Adequate moisture** Water invigorates earthworms and the whole consortia of microorganisms involved in the decomposition process. Earthworms breath through their body and hence a moist habitat is essential to allow respiration. For their optimal activity, it is best to maintain about 40 to 50 per cent moisture by regular watering of the vermi beds. Higher moisture content will reduce aeration and earthworm activity. To ensure aerobic environment, provision for drainage of excess water should be ensured. A layer of saw dust, coir pith or river sand may be provided as the base layer in pits and boxes used for vermicomposting to facilitate fast drainage of excess water.

- **Suitable temperature** The optimal temperature range for the development of most earthworm species is 15–32°C. Some species are tolerant to high and low temperatures. Mulching of vermibed can protect the worms from heat and frost.

- **Suitable p^H and absence of toxic substances** The p^H of the substrate should be preferably neutral, but can be between 4.5–7.5. Even though earthworms are tolerant to high concentrations of certain pesticides and heavy metals and are capable of accumulating them in the tissues, organic wastes containing high concentrations of salts and toxic substances are not suitable for optimum activity of worms and should be avoided.

- **Mulching** A thorough mulching of vermicomposting bed should be ensured for creating good microclimate required for optimal activity of earthworms. This is one of the most important, but at the same time cheap operations in vermicomposting and has multiple functions. This operation helps to retain enough moisture for longer periods of time and can very much reduce watering frequency. It can maintain enough humidity and protect the worms from direct sun light and heat, especially during summer months. UV radiation is lethal to worms in a short time period. A good mulch with broad leaves can also prevent or reduce the attack of birds and rodents in out door composting systems.

SYSTEMS OF VERMICOMPOSTING

Vermicomposting can be carried out in the following two systems:

1. Indoor systems are used usually for commercial production of vermicompost and a number of options are available based on the scale of operation. Vermicomposting can be carried out inside permanent or temporary structures such as sheds. For large scale composting permanent structures are preferred, as there will be proper protection for the worms from predators like rodents, wild boars and birds. Small scale vermicomposting at individual house level may be carried out in plastic buckets, wooden boxes or cement tubs. Medium and large scale composting may be done in cement rings or tanks built of bricks or cement. Large scale vermicomposting is best carried out by heaping the solid wastes in the shape of a cone under a roof. This has been found to favour fast composting by ensuring proper aeration, allowing the worms to feed from all sides.

Large scale vermicomposting of coconut palm wastes

2. Out door systems are usually followed for large scale composting for the use at the garden itself. In this, composting is done at the source of organic wastes such as orchards and plantations with grown up trees and proper shade. These systems have advantages that the wastes as well as compost require very little transport, thus saving a lot of labour. The organic wastes may be composted in the basins or pits taken inside the garden. The free space available in the garden may also be utilized for composting by heaping method.

VARIOUS STEPS INVOLVED IN VERMICOMPOST PRODUCTION

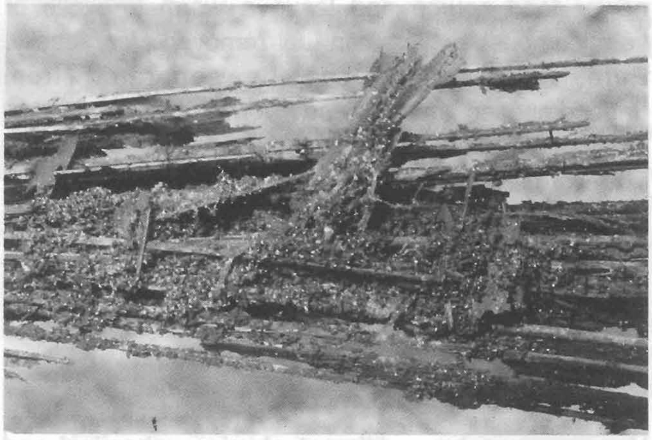
The whole process of vermicomposting may be divided into 5 main steps.

1. Selection of suitable earthworm species Not all epigeic earthworms can be utilized for composting all types of organic wastes and in all situations. When the proper earthworm species is used, the time required for decomposition can be reduced to a great extent. Only a very few species are used throughout the world. The important domesticated compost worms are:

- ***Eisenia fetida*** (European compost worm, Brandling worm, Tiger worm).
- ***Eudrilus eugeniae*** (African night crawler)
- ***Perionyx excavatus*** (Oriental compost worm)
- ***Lumbricus rubellus*** (Red worm)

Eisenia fetida and *Lumbricus rubellus* can tolerate low temperatures and are more suited for temperate regions. *Eudrilus eugeniae* is suited for tropical countries. For composting city waste, *Eisenia fetida* and *Perionyx excavatus* are preferred. *Perionyx sansbaricus* may be of use in composting of organic wastes with very high moisture content. A number of other species are also used on a small scale or suggested for vermicomposting.

The candidate species of earthworm for vermicomposting may be selected based on their unique ability to quickly consume organic wastes and to grow, reproduce and complete life cycle in a short



Coconut leaf in advance stage of vermicomposting

period. The selective characters of earthworms for composting were suggested by Dash and Senapati (1985).

Some of the important characteristics that may be easily followed for selection are:

1. Earthworm should be capable of inhabiting and completing life cycle in a medium rich in organic matter.
2. It should have high cocoon production rate.
3. The incubation period required for hatching of cocoons from the time of laying should be short.
4. The newly hatched juveniles should attain reproductive maturity in a shortest period.
5. The quantity of organic wastes consumed and subsequently digested and egested per unit time should be high. For this, they should be active feeders throughout the year and the mature worms should have good size and weight. The amount of organic matter consumed per day by the earthworms used for composting is usually more than the half of their own body weight and hence these parameters have relevance.
6. The efficiency of assimilation of food and growth rate should be high.
7. It should be amenable for domestication, handling and culturing in semi–natural or artificial conditions and media.
8. It should have good adaptability to a number of environmental variables.

II Mass multiplication of earthworms for processing huge quantities of organic wastes

Earthworm selected for vemicomposting of a particular type of organic waste should be mass multiplied at the outset for composting huge quantities of wastes. This is needed only at the initial stages of the project and once started, earthworms obtained after the removal of compost may be utilized for composting the next batch of wastes.

For composting one ton of wastes, about one kilogram of earthworms is required. About 1000 average sized worms will weigh one kilogram. The worms can be easily propagated fast in a mixture of animal dung and compost, properly mulched with decaying straw or grasses. Addition of locally available cheap nutrient supplements such as oil cakes, rice/wheat bran or gram powder will enhance the multiplication rate. Multiplication rate reduce with increasing density and to avoid this, large plastic or cement tubs with ample space may be used for the purpose. *Eudrilus engeniae* is much affected by density as compared to *Eisenia fetida* and *Perionyx excavatus*.

Even epigeic worms reduce or even completely stop reproduction for a short period of yearly cycles, but remain as active feeders. At Kasaragod, Kerala, the local strain of *Eudrilus* did not lay cocoons from December to March. Nucleus culture procured during this period will not increase in numbers appreciably and compost makers should wait for some period.

III Collection and processing of wastes for vermicomposting

Feed preparation step in an important operation in vermicomposting. Biodegradable organic solid refuse should be sorted out from non–degradable materials and should be shredded to the extent possible. The increased surface area ensures faster action of microorganisms and earthworms. If the organic waste is woody, with less nitrogen content, it may be blended with green leaves or cow dung. Similarly, if the material is rich in nitrogen, it may be suitably blended with carbon–rich organic wastes such as saw dust. The nutrient content of the compost will depend on the type of base materials used and all the available organic wastes may be blended suitably at the time of feed preparation to get vermicompost of desirable composition. It is important to remember that earthworms cannot eat fresh organic materials and for desirable results, organics should be in the preliminary phases of decomposition. Provision of some quantity of easily digestible food materials will enhance microbial activity, initiate the decay of organic refuse and thus prepare it for the activity of earthworms. The process of making the organic waste palatable for earthworms is simple. The materials may be mixed with 10 per cent by weight of cow dung in the form of slurry. The use of bio gas slurry may be the best option. If vermicompost prepared earlier is available, a small amount of it may also be added, as it contains millions of microbes capable of initiating fast decomposition of organic matter. This mixed organic refuse may be watered regularly to maintain sufficient moisture and incubated for 2–3 weeks to initiate microbial action. One or two turnings may be given to reduce the heat generated. In case the materials used for vermicomposting have high moisture content, as in the case of vegetable market wastes, provision should be made to drain large quantities of solution released during this initial phase of decomposition.

IV Actual vermicomposting process

Earthworms may be introduced in the processed organic wastes, preferably at the rate of 1 kilogram per ton of wastes and composting should be managed so as to create micro environment suitable for optimum growth, multiplication and activity of earthworms and aerobic microorganisms. The bed should be mulched thoroughly with decaying straw, grasses, banana leaves or even wet gunny bags. The bed should be watered regularly to maintain about 40 per cent moisture. Being surface feeders, the worms start feeding from top to bottom and earthworm casts accumulate on the surface of the bed. If possible, castings may be removed from the surface as and when they accumulate, because their own excreta is detrimental to earthworms and the timely removal of vermicastings will hasten vermicomposting process.

V Compost recovery

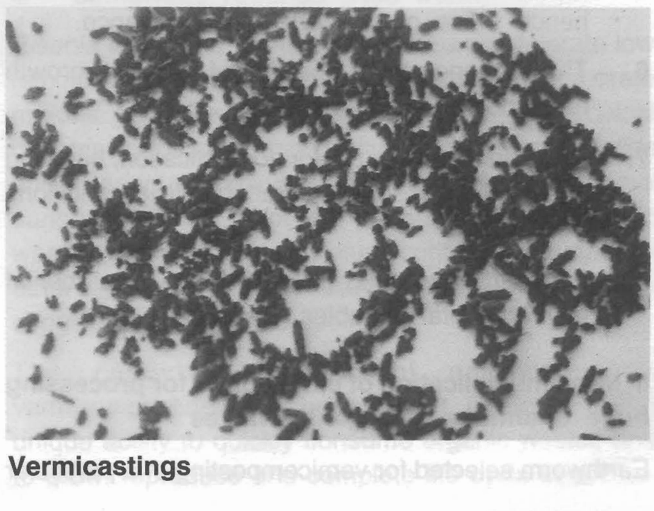
The time required for vermicomposting depends on the type of base material used. Hard and lignocellulosic organic wastes will take more period. Normally, in about 60 days more than 70 per cent of materials will be converted into odourless, granular and humus–like vermicompost. If the compost recovery is delayed, the worms will start dying and this in turn will increase the attack of predatory ants. For the recovery of compost, stop watering the compost bed about 2 weeks in advance. This will trigger the worms to migrate to wet bottom layers. Vermicompost can be recovered from the top layers. Alternatively, the composted matter along with earthworms can be moved into a pile at one end of vermicomposting tank, while a new pile of fresh organic refuse is placed at the other end. Over time, worms will migrate to the newer food source and leave a worm–free pile of vermicompost, which can be removed very easily. Pure vermicastings can be separated from undecomposed matter and worms by manual or mechanical sieving of the dried worm–worked matter. The worms congregated at the bottom layers may be recovered and used for composting the next batch of organic wastes or for feeding poultry birds or fish.

VERMICOMPOSTS: PROPERTIES, APPLICATIONS AND BENEFITS

Properties of vermicomposts

Vermicastings have different physico– chemical and biological properties from the base materials and vermicompost has the following advantages over the conventional composts.

1. Vermicompost is a loosely packed, granular aggregats of enzymatically digested organic matter containing nutrients in easily available or mineralizable form. It is also rich in earthworm mucus containing energy sources. So, when vermicompost is added to soil, it will act as top soil and enhance soil microbial activity, thus making soil alive.
2. Because of its granular nature, vermicompost improves soil aeration, water holding capacity and thus root growth.
3. Earthworms and associated microbes mediate degradation of chemicals such as hydrogen sulphide, mercaptans and ammonia, which cause foul odours in composting yards and for composts. The final vermicompost is quite odourless and has earthy smell.
4. Vermicomposts contain more counts of plant beneficial microbes such as nitrogen fixing bacteria, phosphate solubilizing bacteria, fungi,



Vermicastings

actinomycetes, plant growth promoting bacteria, and microbes capable of degrading a number of biopolymers such as cellulose and lignin.

5. Vermicomposts contain a number of bioactive compounds such as auxins, gibberellins, cytokinins, vitamins and aminoacids, which have the capacity to influence plant growth, development, reproduction and yield.

6. Vermicomposts contain a number of humic acids which have plant growth promoting activity. They also improve cation exchange capacity and soil physical conditions.

7. Vermicompost is easy to handle, store, and incorporate into soil compared to the conventional composts. As it is less bulky, contain higher percentage of nutrients.

8. Vermicomposts contain less human and plant pathogens.

The potential applications of vermicompost in horticulture.

Vermicompost is a finely divided peat – like organic material with excellent structure, porosity, aeration, drainage and water holding capacity. It has appearance and many characteristics of peat. It can influence a number of soil physical, biological and chemical processes which have their bearing on plant growth, development and yield and is a better source of organic matter than other composts. It has got special importance in plant propagation and in ornamental horticulture, as it contains plant growth promoting substances. There is considerable potential as a plant growth media and its utilization in horticulture had been proposed for several years. Growth improvement in a variety of plants, quick and visible fast response, compatibility with technology in use and low cost compared to other commercial growth media are the main reasons which supported their employment as growth media in horticulture. But its potential benefits have not been properly documented or utilized commercially on a large scale.

Vermicompost is recommended for enhancing seed germination in seed beds, enhancing seedling growth, flowering and fruit set in a number of vegetables, fruit crops, ornamental plants and grain crops. It is also recommended for enhancing root initiation and root growth in artificial plant propagation methods such as layering and cuttings.

Worm castings mixed with other rooting medium make excellent plant growth media for a variety of purposes and have considerable commercial potential. Undiluted compost is not suitable as a plant growth media and can even adversely affect plant growth. Vermicompost can form 10 to 30 per cent of the growth media and is recommended as potting medium for a variety of nursery plants. Irrespective of other growth media used in the mixture and with full dose of chemical fertilizers, vermicompost enhanced the growth and health of nursery plants. It is reported that even 5 per cent vermicompost can mediate significant plant growth improvement.

Plant response to vermicompost application

Plants respond to vermicompost much better than any other commercial potting or rooting media. Seed germination of a wide variety of vegetables, flowering plants and ornaments such as aubergines, cabbage, capsicum, cucumber, lettuce, tomato, radish, coleus, marigold, asparagus, polyanthus, and sweet pea has been reported to be more rapid with vermicompost. Early and vigorous seedling growth has also been reported. When used in plant propagation, it enhanced root initiation, root elongation, root biomass and rooting percentage. Vermicompost could be an excellent soil amendment for main fields and nursery beds and has been reported to be useful in raising nursery of spices plants. In mature plants, it had harmone – like effect, influencing plants to follow some times altered growth patterns such as negative geotropism of roots. Stem elongation, dwarfing, shortening of vegetative phase, enhancement of leaf area, photosynthetic rate, flowering and fruiting are the main responses shown by matured plants. The compost application has also been reported to increase nitrate reductase activity of plants. Because of the physical modification of soil and due to harmonal effects, roots get colonized by more mycorrhizal fungi and other plant beneficial bacteria and all these factors enhance plant growth, health and flowering. When used as casing layer, it stimulates canophore formation in Button mushroom (*Agaricus bisporus*). Increased oyster mushroom yield has also been reported when vermicompost was used. Vermicompost application is also known to reduce the content of heavy metals and nitrates in economically important parts of plants. Increased concentration of carbohydrates and vitamins have also been reported. As a result of all these changes, it has been reported that plants grown with vermicompost yield economic produce with better taste. The type of overall plant response will depend on dose, application time, plant species, physiological phase of plants etc.

The plant responses obtained on vermicompost application emphasize some effects of vermicompost which cannot be explained by the presence of chemical or physical fertility factors. These effects may be associated with biological components such as microflora or microbial metabolites that are able to influence plant metabolism, growth and reproduction. The plant response to vermicompost depends to a great extent on increased uptake of plant nutrients and better use of edaphic factors. Humic acids have harmone– like activity and along with PGRs secreted by microbes, they may stimulate nutrient uptake. The biological components are adversely affected by sterilization of vermicomposts and for maximum benefits, vermicompost should be used fresh.

The worm–worked wastes are currently marketed in both solid and liquid forms in many countries. All the physiologically active water soluble components of vermicompost such as humic acids, plant growth regulators, amino acids, vitamins, micro nutrients and microbial cells are extracted in water and is known as **vermiwash**. The water soluble components from vermicompost may be collected by passing water slowly through the worm beds or by simple suspension of vermicompost in water. This is used for foliar applications as such or after sufficiently diluting based on the need. Vegetables and ornamental plants have been reported to respond very well to this treatment.

Prospects of vermicomposting industry in India

There is no doubt that vermicomposting has immense potential in India, where, environmental problems are surfacing because of the accumulation of enormous quantity of organic wastes on one hand and on the other, there is an acute shortage of plant nutrients and quality organic manures for improving soil fertility and productivity. India has unparalleled human resource, which is not utilized to the potential level. Solid organic refuse available can be used in a meaningful way by way of vermicomposting and has potential to generate job opportunities for unemployed youths. Already, vermicomposting is done on medium and large scales in many states in India. In order to meet the demand from internal and export – oriented markets, floriculture, vegetable cultivation and ornamental horticulture industry is fast expanding in many states in India. With the realization of the benefits of vermicomposting and is expanding applications in organic farming and commercial horticulture, there is immense scope to develop vermiculture as a small scale or cottage industry throughout India. There is also scope for the large scale use of superior strains of microbes isolated from the intestine of. earthworms for developing microbial inoculants suitable for enhancing composting process.

VALUE ADDITION TO THE WASTES FROM COCONUT PALM: EARTHWORMS SHOW THE WAY

Studies conducted in the Central Plantation Crops Research Institute, Kasargod have revealed that one hectare of coconut plantation produces about 8000 kg dry organic biomass per year. As the use of this biomass as fuel and thatching material has declined over the years, its disposal in a meaningful way has become a problem in many coconut gardens. If we can recycle all the organic wastes available from a plantation, it can supply the major portion of nitrogen and a part of other nutrients required by the palms. This waste is rich in ligno–cellulosic complexes and polyphenols which have the potential to produce humus, nitrification and urease inhibitors respectively. These biochemicals can influence soil health and long term soil fertility. But, because of high proportion of lignin, these wastes undergo decomposition rather slowly. The possibility of using earthworms to enhance the decomposition rate was examined, as it is known that the action of earthworms is more important and pronounced on recalcitrant wastes than easily decomposable ones. This hypothesis was strengthened by the fact that earthworms can mediate decomposition of lignin and accelerate humification process. Preliminary studies conducted at CPCRI, Kasargod have revealed that coconut plantation wastes could be effectively converted into rich vermicompost. While searching for a suitable species of earthworm suited for composting coconut palm wastes, a wide diversity of earthworm fauna in coconut plantation at Kasargod was observed. It comprised of *Perionyx excavatus, Perionyx sansbaricus, Perionyx spp., Octochaetona spp., Lampito mauritii, Amynthas alexandri, Eisenia fetida, Megascolex travencorensis, Megascolex spp., Dichogaster spp., Eudrilus* spp.

Eudrilus spp. was located from a heap of coconut palm wastes, which were seen fully converted into vermicasts, leaving behind only mid ribs of the leaves. Further surveys have confirmed their occurrence in cow dung heaps in the Agrostology unit of the Institute. Among the local earthworms tested for their ability to multiply and produce vermicompost from coconut palm wastes, this strain of *Eudrilus* was the best and hence more studies were conducted. Methods of maintenance and large scale multiplication have been standardised. In a 1:1 mixture of cow dung and decayed leaves mulched properly with grasses, it can be multiplied fast.

Preliminary studies conducted have revealed that this local strain of *Eudrilus* is different from *Eudrilus eugeniae*, the African night crawler, which has its origin in tropical and subtropical Africa. There is a mention in the *Fauna of British India* published in 1923 that *Eudrilus eugeniae* was located in south and south – western coastal belt in India. But no systematic studies have been conducted on this Indian *Eudrilus* spp. The strain of *Eudrilus* located at Kasaragod differs from the African strain in its colour, vigour, behaviour, cocoon colour and reproductive rate on coconut wastes. The local strain is more darkly pigmented and vigorous and the cocoon case is thick and dark. Interestingly, it is also capable of burrowing in coarse soils such as sandy loam and in soft bedding materials. It is also capable of actively feeding on soil and digested soil in the form of pellets is deposited around burrow holes. Much faster multiplication of this worm on coconut palm wastes and coir pith was also observed as compared to the African one. This local strain of *Eudrilus* may belong to a sub species or a new species.

A low cost technology has been standardized for vermicomposting the biomass from coconut palms left exposed in the action of weather in the field for about 3 months. The weathered wastes obtained during rainy season may be preferred. This wastes can be used without chopping, thus saving labour. The coconut wastes used for oyster mushroom cultivation were also found suitable for vermicomposting. These organic wastes are to be treated with cow dung at the rate of 10 per cent by weight in the form of slurry and must be allowed to undergo a preliminary decomposition for about 2 weeks. After giving one or two turnings to reduce the heat generated, earthworms may be introduced at the rate of 1 kg per ton of material. The compost bed should be mulched properly using any locally available plant material or gunny bags and has to be protected from direct sun light. Watering is to be done to maintain enough moisture. As full leaves are used for composting, compact mass is not formed, thus allowing free movement of air in the bed. In about 2–3 months compost will be ready, leaving behind only mid ribs of the leaves. This method was tested in cement tanks and under the roof of a shed by heaping. Composting was faster in heaps and the earthworms were seen feeding and casting from all sides, may be due to better aeration and exposure. On an average 70 per cent recovery of vermicompost was obtained. The same technology for vermicomposting was also tested in large pits taken in the inter spaces for four coconut palms in sandy loam and coastal sandy soils and was found to work well. As composting is done in the field itself, lot of labour required for transportation of the biomass and compost can be saved. This technology may be tried even in plantations with very limited irrigation facilities, as only a limited number of pits or trenches need to be watered. The coconut palm waste was also vermicomposted in the basins and inter spaces and these methods are suited for irrigated gardens. If all the available biomass from a plantation can be recycled through vermicomposting, can meet a part of nutrient requirements and especially in coastal regions, could improve soil organic matter content. Efforts are being made to popularize this technology and earthworm cultures are being supplied to the interested farmers.

The average nutrient composition of the vermicompost recovered was: N% (1.8), P% (0.216), K% (0.16), Organic carbon % (17.84), and C/N (9.95). Total microbial counts and beneficial microbial population were also more in the compost compared to the base material. Two types of active nitrogen fixing bacteria not commonly isolated from soils have also been found regularly associated with vermicasts.

Coir pith is yet another organic material resistant to decomposition, available in huge quantities from coir processing units and can improve soil physical properties and moisture holding capacity to a great extent. But this can be applied to soil only after composting. Efforts were made to prepare vermicompost from this waste also using the local strain of *Eudrilus* spp. Coir pith alone was not able to support the growth of earthworms. Encouraging results were obtained when coir pith was mixed with about 30 per cent by weight of cow dung or other organic wastes.

When shallow layers of coir pith was used, composting was full and in about 90 days the waste was converted into vermicastings, leaving behind only coconut fibres. The nutrient composition of this vermicompost was N% (I.O), P% (0.48), K% (0.7), Organic carbon % (22.24) and C/N (22.06). One main problem encountered while vermicomposting of coir pith on a large scale was that after a few days of composting, a hard layer of coir pith forms and this prevents the movement and activity of the earthworms.

While searching for an alternative earthworm for this process, two soil dwelling local earthworms could be located and were able to borrow into coir pith efficiently. These earthworms were *Amynthas alexandri* and *Lampito mauriti*. A three tier composting system with soil as bottom layer, coir pith as middle layer and coconut leaves as top layer was tested utilizing these two soil dwelling worms and the local strain of *Eudrilus*. The final quality of compost obtained was better. Further studies are in progress to perfect the method and if it succeeds to make vermicompost from coir pith on a large scale, would bring back both economic and environmental benefits.