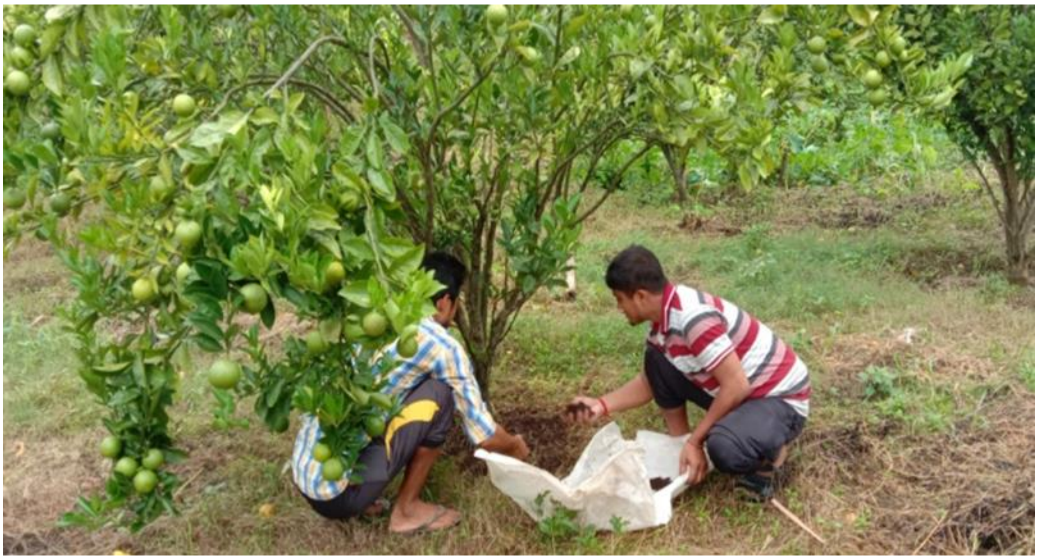
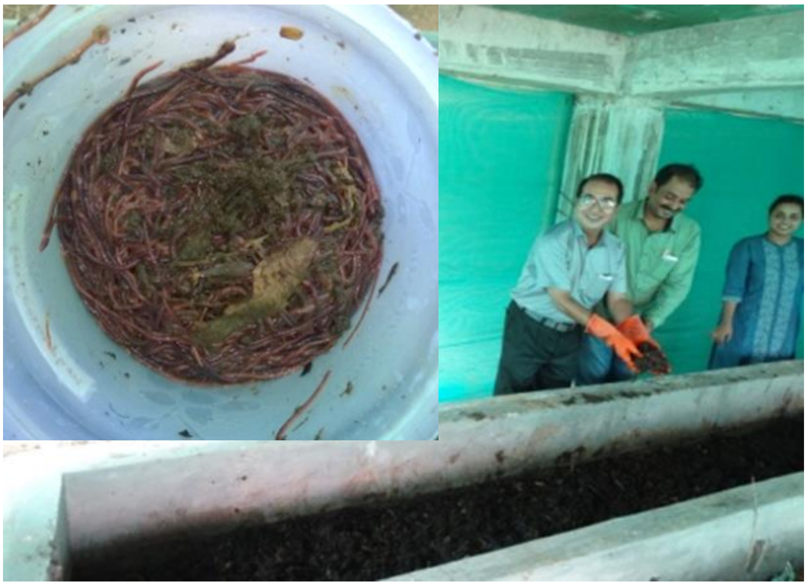
Manual on Reclamation cum development of wastelands for Organic Horti-agricultural farming and related Knowledge Generation





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Introduction: Vermicomposting

Environmental improvement is our national goal, as energy is now highly expensive. So recycling of waste materials is important and can save environment. In the present situation of acute energy crisis and environmental degradation with the growth of industries, urban cities and ever increasing human population, it has become essential to develop appropriate technology for recovery of energy from non-conventional sources like organic wastes which were once thought to be of no use.

India produces huge organic wastes which could be utilized for recovery of important resources like fertilizer, fuel, food and fodder. From this waste plant nutrients, biogas and alcohol can be produced. Earthworm is known to be the natures' best biological element for recovery of vermifertilizer and vermiprotein from the organic waste to be used in agroecosystem, aquaculture and poultry industry.

1.1 The Vermicomposting

Vermiculture is the rearing of earthworms in a suitable substrate in order to raise their population and biomass. Vermiculture is done using epigeic earthworms and organic waste as their food. Some selective endogeic species and anecic species can also be cultured under controlled conditions using soil bedding with organic additives. Casts of these soil dwelling earthworms should not be confused with vermicompost which is produced only by organic waste dwelling epigeic earthworms.

Vermicomposting is the process by which worms are used to convert organic materials (usually wastes) into a humus-like material known as vermicompost. The goal is to process the material as quickly and efficiently as possible. Earthworm is physically an aerator, crusher, mixer and chemically a degrader and biologically a stimulator in the decomposer system. Microbial composting of organic wastes through earthworm activity is called vermicomposting which does not involve a thermophilic stage. Products of vermicomposting are organic fertilizer, called vermicompost and earthworm biomass that forms vermiprotein. Infact, vermicomposting is a kind of vermiculture where only organic wastes are used as food source for epigeic earthworm with a main aim to produce vermicompost rich in nutrients within a minimum time span.
Biological conditioning of wastes through vermicomposting has the following advantages: i) reduce the pollution of organic wastes ii) production of vermifertilizer (worm cast) for application in agroecosystem iii) produce more earthworms to extend the vermicomposting areas iv) production of high quality protein-vermiprotein from waste and utilization of this protein as feed for poultry, fish, pig and other domestic animals.

Principle of Vermicomposting:

1. While eating, epigeic earthworms turn and maintain the substrate in aerobic condition and cover the surface of the substrate with their faecal matter, thus

reducing bad odours.

2. As the earthworms feed on organic wastes their muscular gizzard of the digestive tract act as a crusher and breaks up larger particles into finer ones, thus increasing the exposed surface area, enhancing the beneficial action of the symbiotic microbes and the enzymes present in the earthworm gut. During the process about 5% of the ingested matter is assimilated and the rest is ejected out as vermicast.

3. Active phase of vermicomposting is characterized by mesophilic bacteria and fungi which are stimulated and encouraged by the activity of earthworms.

4. Different casts mix to earthworm mucous and its excreted ammonia / urea and allow an optimal combination and composition of the nutrient content producing a much finer fragmented and uniform material than by any other composting method. Collective mass of vermicasts of epigeic earthworms is called vermicompost.
5. Thus earthworm's major contribution is in fragmentation of the organic matter. The microenvironment that they provide for the establishment of microorganisms is of utmost importance in the composting process.

1.2 The Compost Worm

There are an estimated 1800 species of earthworms worldwide (Edwards & Lofty, 1972).This manual will focus on just one. ***Eisenia fetida*** (Savigny) is commonly known as the "compost worm", "manure worm", "red worm", and "red wiggler" (see Figure 1). This extremely tough and adaptable worm has been adapted to most parts ofthe world. In Tripura the indigenous manure worm is called ***Perionyx excavatus*** **(Indian blue).**

Three ecological categories of Earthworms

Anecic (Greek for "out of the earth") – these are burrowing worms that come to the surface at night todrag food down into their permanent vertical burrows deep within the mineral layers of the soil. Example: the Canadian Night crawler. These earthworms are phytogeophagous.

Endogeic (Greek for "within the earth") – these are geophagous, non pigmented earthworms forming horizontal burrows. They come to the surface only rarely. The anecic and endogeic earthworms are called "**ecosystem engineers".**

Epigeic (Greek for "upon the earth") – these worms live in the surface litter and feed on decaying organicmatter. They do not have permanent burrows. These "decomposers" are the type of worm used in vermicomposting.

Commercially raised worms are usually of the epigeic type (Card et al., 2004). The *E. fetida* is certainly not the only epigeic worm, but it is the most commonly used earthworm for composting purposes in Northern climates. It can handle a wide temperature range (between 0 and 35^{o}C) and can actually survive for some time almost completely encased in frozen organic material. (as long as it can continue to take in nourishment). Its cocoons (eggs) have been shown to remain viable after having been frozen for several weeks. In addition, it can well tolerate handling and rough treatment. Perhaps most importantly, like most if not all litter-dwelling worms, the compost worm has the capacity for very rapid reproduction. This is an evolutionary nature's gifted creature whose environment is extremely changeable. All of these characteristics make *E. fetida* the natural choice for those who wish to do year-round vermicomposting outdoors, in climates with harsh winter conditions.

1.3 Components of the vermicomposting system

To run successfully and produce an efficient and valuable plant growth medium, four principal components are needed for vermicomposting:

i) The proper substrates of plant origin

ii) The optimum environmental conditions (temperature, moisture, pH, organic matter content)

iii) Appropriate species of earthworms

iv) The design and operations to be implemented

Substrates:

A wide variety of organic wastes for culturing earthworms are available in the tropics. These come from vegetable, urban and industrial residues of organic origin. Many of them are common in temperature climates also (e.g: cattle, pig, horse, rabbit, sheep, turkey or poultry manures, kitchen wastes, brewery paper pulp solids, spent mushroom substrates, trimming from floriculture industries, garden refuse, sawdust, urban and municipal solid wasters etc.) but some others are found exclusively in tropical countries (e.g: coffee pulp, sugarcane wastes, coconut and betel-nut residues, aquatic weeds like water hyacinth , banana "stems", bamboo leaf litters and other tropical plant leaves).

One of the most important characteristics of substrates supporting earthworm growth is the C/N ratio which should be approximately 30/1. When wastes with different C:N ratios are present, an appropriate mixture (either high carbon or high nitrogen residues) is recommended to attain close to this ratio. A substrate suitable for one earthworm species may not be a food of choice for another species.

The quality of vermicompost produced from organic wastes depends very much on the original material that was used. It cannot be expected that a product with excellent fertilizing qualities will be obtained from raw materials of inferior quality.

1.3 Physical and Chemical characteristics of vermicompost:

The final physical and chemical characteristics of vermicompost produced by earthworms from variety of wastes depend on the nature of output. However, the final product from most of the organic wastes is usually a finely divided homogeneous material with excellent structure, porosity aeration, drainage and moisture holding capacity. The nutrient level in the vermicompost is always at a lower level than in the original material but the level of macro or micronutrients is much higher than in the compost derived from any other method. Most important feature of vermicompost is that during processing of the various organic wastes by earthworms, many of the nutrients are changed to available forms that are more readily taken up by plants such as nitrate or ammonium nitrogen exchangeable phosphorus and soluble potassium calcium and magnesium. So, vermicompost have a higher level of available nutrients from the wastes from which they were formed. Humic acid is very important constituent of vermicompost. A few among many of its important properties are slow release of plant nutrients improvement of soil physical properties enhancement of micronutrient element nutrition of plants through chelation reactions etc. Plant growth regulators, belonging to the auxin, gibberellin and cytokinin groups present in the worm worked materials are produced by a wide range of soil microorganisms, many of which live in guts of earthworms or within the castings.

Another important feature is that during production of vermicompost bioavailable heavy metals and pathogens are eliminated. Major nutrient contents in the vermicompost derived from various organic wastes are nitrogen, potassium phosphorus, calcium and manganese.

2 Working with Worms: The Basics

Worms can live for about one year. Worms are hermaphrodites, which means they are both male and female at the same time. In order to mate, they still require two worms. The worms line up in opposite directions near their band (or clitellum), which contains some of the sexual organs. The worms are attached for about 15 minutes while they exchange sperm cells. Several days later, eggs come in contact with the sperm cells and form a cocoon, or egg case. The cocoon separates from the worm, then fertilization takes place. Inside the cocoon, 2-5 baby worms may be found.

2.1 What Worms Need

Worms need moisture, air, food, darkness, and warm (but not hot) temperatures. Bedding, made of newspaper strips or leaves, will hold moisture and contain air spaces essential to worms.

2.1.1 The Five Essential factors

Compost worms need five basic things:

1. An hospitable living environment, usually called “bedding”;
2. A food source;
3. Adequate moisture (>50% water content by weight);
4. Adequate aeration;
5. Protection from temperature extremes.

These five essentials criteria are discussed in more detail below.

2.1.2 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 the flow 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.

- **High Carbon: Nitrogen ratio.** Although the worms do consume their bedding as it breaks down, it is very important that this would 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 ofthe above characteristics and need to be used in various combinations. Table 1 provides a list of some of the most commonly used in beddings and provides some input regarding each material's absorbency, bulking potential, and carbon to nitrogen (C:N) ratios. Its high C:N ratio (for a manure), good bulking characteristics (because of the high straw content), and relatively good moisture retention make it an excellent environment for *E. fetida*. It can be improved somewhat by the addition of a high-absorbency material such as peat moss or shredded paper/cardboard (which will increase absorbency and also increase the C:N ratio a bit – another positive).

Table 1: Common Bedding Materials

Bedding Material	Absorbency	Bulking Pot.	C:N Ratio[4]
Horse Manure	Medium-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 stream	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	Medium	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
Leaves (dry, loose)	Poor-Medium	Poor-Medium	40 - 80
Corn stalks	Poor	Good	60 - 73
Corn cobs	Poor-Medium	Good	56 - 123

If available, shredded paper or cardboard makes an excellent bedding (Georg, 2004), particularly when combined with typical on-farm organic resources such as straw and hay. Organic producers, however, must be careful to ensure that such materials are not restricted under their organic certification standards. Paper or cardboard fiber collected in municipal waste programs cannot be approved for certification purposes. There may be cases, however, where fiber resources from specific generators could be sourced and approved. This must be considered on a case-by-case basis. Another material in this category is paper-mill sludge (Elvira et al., 1996; 1997), which has the high absorbency and small particle size that so well complements the high C:N ratios and good bulking properties of straw, bark, shipped brush or wood shavings. Again, the sludge must be approved if the user has organic certification.

In general, it should be noted that the selection of bedding materials is a key to successful vermiculture or vermicomposting. Worms can be enormously reproductive if suitable conditions prevail; 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. They provide protection from extremes in temperature, the necessary levels and consistency of moisture, and an adequate supply of oxygen. Fortunately, given their critical importanceto the process, good bedding mixtures are generally not hard to come by on farms. The most difficult criterion to meet adequately is usually absorption, as most straws and even hay are not good at holding moisture. This can be easily addressed by mixing some aged or composted cattle or sheep manure with the straw. The result is somewhatsimilar in its bedding characteristics to aged horse manure.

2.1.3 Worm Food

Compost worms are voracious feeders (*Eudrilus eugeniae, Perionyx excavatus*). 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 mostly of plant 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* and *Perionyx* sp. Citrous and spicy foods avoided by earthworms.

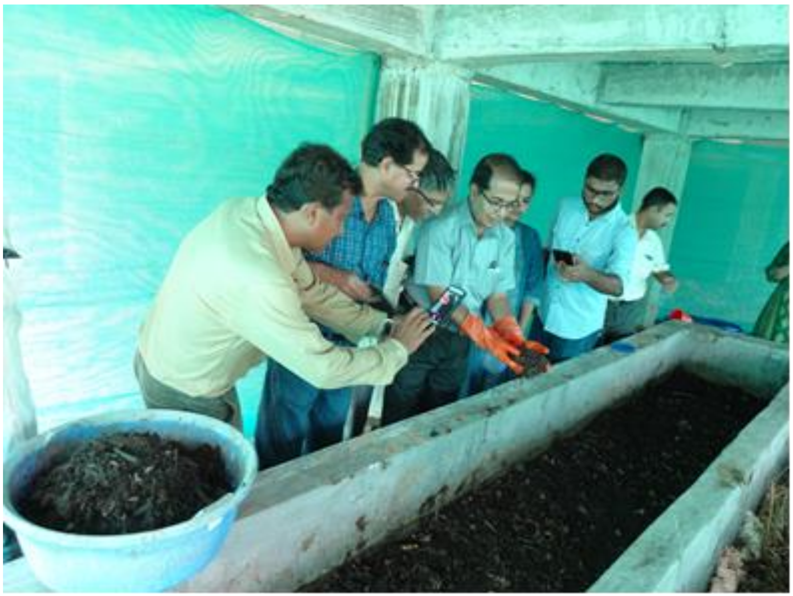
Table 2: Summarizes the most important attributes of some of the more common foods that could be used in an on-farm vermicomposting or vermiculture operation.

Food	Advantages	Disadvantages	Notes
Cattle manure	Good nutrition; natural food, therefore little adaptation req'd	Weed seeds make pre-composting necessary	All manures are partially decomposed and thus ready for consumption by worms

Poultry manure	High N content results in good nutrition and a high-value product	High protein levels can be dangerous to worms, so must be used in small quantities; major adaptation required for worms not used tothis feedstock. May bepre-composted but not necessary if used cautiously (see Notes)	Some books (e.g., Gaddie & Douglas, 1975) suggest that poultry manure is not suitable for worms because it is so "hot"; however, research in Nova Scotia (GEORG, 2004) has shown that worms can adapt if initial proportion of PM to bedding is 10% by volume or less.
Sheep/Goat manure	Good nutrition	Require pre- composting (weed seeds); small particle size can lead to packing, necessitating extra bulking material	With right additives to increase C:N ratio, these manures are also good beddings
Hog manure	Good nutrition; produces excellent vermicompost	Usually in liquid form, therefore must be dewatered or used with large quantities of highly absorbent bedding	Scientists at Ohio State University found that vermicompost made with hog manure outperformed all other vermicomposts, as well as commercial fertilizer
Rabbit manure	N content second only to poultry manure, there-fore good nutrition; contains very good mix of vitamins & minerals; ideal earth-worm feed (Gaddie, 1975)	Must be leached priorto use because of high urine content; can overheat if quantities too large; availability usually not good	Many U.S. rabbit growers place earthworm beds under their rabbit hutches to catch the pellets as they drop through the wire mesh cage floors.
Fresh food scraps (e.g., peels, other food prep waste, leftovers, commercial food processing wastes)	Excellent nutrition, good moisture content, possibility of revenues from waste tipping fees	Extremely variable (depending on source); high N can result in overheating;meat & high-fat wastes can create anaerobic conditions and odours, attract pests, so should NOTbe included without pre-composting (see below)	Some food wastes are much better than others: coffee grounds are excellent, as they are high in N, not greasy or smelly, and are attractive to worms; alternatively, root vegetables (e.g., potato culls) resist degradation and require a long time to be consumed.

2.1.4 Moisture

The moisture is the limiting factor in earthworm distribution. The bedding used must be able to hold sufficient moisture as the worms in general are moisture loving. They breathe through their vascularized skins and moisture content in the bedding of less than 50% is dangerous for their life processes. 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% (Rinke 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 & 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 best in 70-80% range.

2.1.5 Aeration

Worms are oxygen breathers and cannot survive anaerobic conditions. Although in composting worms O_2 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.

2.1.6. Temperature

Temperature controls the growth and reproduction in earthworm. Under tropical climate suitable temperature for the growth and reproduction in earthworms ranges from 22°C to 28°C.

- **Low temperatures.** *Eisenia* can survive in temperatures as low as 0°C, but they don't reproduce at single-digit temperatures and they don't consume as much food. It is generally considered necessary to keep the temperatures above10°C (minimum) and preferably 15°C for vermicomposting efficiency and above 15°C (minimum) and preferably 20°C for productive vermiculture operations.

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

2.2 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. 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 can drop well below 7. The pH can be adjusted upwards by adding calcium carbonate. In the rare case where they need to be adjusteddownwards, 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). 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.

Pests and Diseases

Compost worms are not subject to diseases caused by micro-organisms, but they are subjected to predation by certain animals and insects (red mites are the worst) and to adisease known as “sour crop” caused by environmental conditions.

Moles. Earthworms are moles’ natural food, so if a mole gets access to worm bed, a huge amount of worms can be lost very quickly (Gaddie, op. cit.). This is usually only a problem when using windrows or other open-air systems in fields.It can be prevented by putting some form of barrier, such as wire mesh, paving,or a good layer of clay, under the windrow.

Birds. If the birds by any means discover earthworm beds they will come around regularly to feed . Putting a windrow cover of some type over the material will eliminate this problem. These covers are also useful for retaining moisture and preventing too much leaching during rainfall events. .

Centipedes. These insects eat compost worms and their cocoons. Fortunately, they do not seem to multiply to a great extent within worm beds or windrows, so damage is usually light.

Ants. These insects are more of a problem because they consume the feed meant for the worms (Myers, 1969). Ants are particularly attracted to sugar, so avoidance of sweet feeds in the worm beds reduces this problem. Keeping the bedding above pH 7 also helps (see mites and sour crop below).

Mites. There are a number of different types of mites that appear in vermiculture and vermicomposting operations, but only one type is a serious problem: red mites. White and brown mites compete with worms for food and can thus have some economic impact, but red mites are parasitic on earthworms. They suck blood or body fluid from worms and they can also suckfluid from cocoons (Sherman, 1997). The best prevention for red mites is to make sure that the pH stays at neutral or above. This can be done by keeping the moisture levels below 85% and through the addition of calcium carbonate.

Management during vermicomposting

By proper management, compost with good quality is produced within a short period. The key to maximum productivity is to maintain aerobicity in the waste combined with optimal moisture and temperature conditions. The quantity of water to be mixed depends upon the nature of wastes. The vegetable and fruit wastes do not require much water because such kind of waste gives out water during the process of decomposition. When agricultural waste is used, it is to be mixed with cow dung slurry to hasten up the initial decomposition. Fresh kitchen wastes, poultry and pig manures contain significant amount of inorganic salts and ammonia that may kill earthworms. Prior to earthworm inoculation these should be removed through composting, washing or aging. High quality substrates like pig manure, kitchens wastes tend to decompose rapidly even in absence of earthworms. If it is felt that greatest gain in containment of nutrients can be achieved by placement of bulking carbonaceous wastes to increase the C to N ratio and extend the biological activity, maximizing earthworm yields, thus the proportion of nutrients extracted.

During the process of vermicomposting worms multiply. The overcrowding population of worms will reduce and hamper their growth and reproduction. So once the population reaches a peak, harvesting of worms will provide scope for continuous development of progeny in the worm beds. Culture beds should be kept free from giant flat worms, termites, rodents and centipedes. As far as possible, worms should not be injured while handling.

Harvesting of vermicompost

When organic wastes are decomposed and appear dark brown colour, watering to the composing pit is being stopped for 7-10 days. The earthworms migrate downwards at basal zone of vermicomposting pit. After 10days vermicompost is harvested from the tank. Upon a large plastic sheath the whole harvested materials i.e. vermicompost plus earthworms are kept making a cone shaped heap for 3-4 days. The earthworms go deep towards the plastic sheath. The vermicompost is then sieved and earthworms are being isolated and inoculated in an empty tank with pre composted materials to start vermicomposting. When the amount of earthworms is so high to produce population pressure, then new tanks are prepared to expand the composing areas. The harvested vermicompost were then packed in bags and carried to field for application.

The Value of Vermicompost

Vermicompost, like conventional compost, provides many benefits to agricultural soil, including increased ability to retain moisture, better nutrient-holding capacity, better soil structure, and higher levels of microbial activity. A search of the literature, however, indicates that vermicompost may be superior to conventional aerobic compost in a number of areas. These include the following.

- **Level of plant-available nutrients**. Atiyeh et al. (2000) found that compost was higher in ammonium, while vermicompost tended to be higher in nitrates, which is the more plant-available form of nitrogen. Similarly, work at NSAC by Hammermeister et al. (2004) indicated that "Vermicomposted manure has higher N availability than conventionally composted manure on a weight basis". The latter study also showed that the supply rate of several nutrients, including P, K, S and Mg, were increased by vermicomposting as compared with conventional composting. These results are typical of what other researchers have found (e.g., Short et al., 1999; Saradha, 1997, Sudha & Kapoor, 2000). It appears that the process of vermicomposting tends to result in higher levels of plant- availability of most nutrients than does the conventional composting process. Major plant nutrients in earthworm processed wastes are **N%: 1.80% to 3.00; P%: 0.50 to 2.70; K%: 0.40 to 3.74; Ca%: 1.55% to 4.80; Mg: 0.25 to 1.89** (Chaudhuri, 2019)

- **Level of beneficial microorganisms.** The literature has less information on this subject than on nutrient availability, yet it is widely believed that vermicompost greatly exceeds conventional compost with respect to levels of beneficial microbial activity. Much of the work on this subject has been done at Ohio State University, led by Dr. Clive Edwards (Subler et al., 1998). In an interview (Edwards, 1999), he stated that vermicompost may be as much as 1000 times as microbial active as conventional compost, although that figure is not always achieved.

Role of earthworm and vermicompost in growth of Plants:

The importance of earthworm for plant growth has been recognized for over 100 years. Earthworms, due to their large body size, peculiar food and feeding habit, high consumption rates and burrowing activities are considered to be nature's best ecosystem engineers. They convert organic wastes to useful fertilizers and modify the physical, chemical and biological properties of soil, promoting growth of above ground vegetation. Earthworms not only modify nutrient availability to plants but many alter the whole rhizosphere environment. The mechanism by which earthworms affect plant growth includes different effects such as root feeding, predatory action on herbivorous nematodes and transposal of plant seeds. However, plant growth is modified mainly indirectly by changing soil physical structure, mineralization processes, hormone like effects, dispersal of plant growth stimulating microorganisms antagonistic to root pathogens. Recently "In soil earthworm technologies" based on the inoculation of earthworms produced 3000 and 3500 kg tea/ha/year in the tea garden of Annamalai and in Nilgiri's tea garden of south India in comparison to earlier production of 1000 to 1800kg/ha/year. In soil technologies not only influence soil physical structure but also regulate the dynamics of soil organic matter. In the Department of Zoology of Tripura University, in a microcosm experiment in-situ earthworm technology using paddy field earthworm, *Glyphidrilus* sp. dramatically increased paddy grain and straw yield (Dhar & Chaudhuri, 2019). Vermicompost has been shown to promote growth of a wide range of cerelals, vegetables ornamental plants etc. It is reported that integration of vermicompost with inorganic fertilization tended to increase the yield of crops viz. potato, rape seed, mulberry and marigold over that with traditional compost prepared from the same substrate.

Dramatic effects of vermicompost on growth of plants are absolutely due to improvement of soil physicochemical properties (soil aggregation, porosity, water holding capacity). Presence of growth regulators, control of plant pathogens and to a greater extent increase in microbial population and plant available nutrients. In fact, slow release of nutrients from vermicompost has a sustainable effect on agriculture (Chaudhuri, 2019).

Application of vermicompost in Mosambi Orchard in Tripura University campus

Mosambi

This is a very distinctive variety with its fruits being small to medium in size and broadly sub-globose. Its colour varies from light yellow to pale orange at maturity, its surface is moderately to roughly pebbled with faint stripes, narrow longitudinal grooves and ridges. The variety is marked by the presence of shallow areolar ring at the apex. The juice has low acidity and no marked flavour. The flesh is pale yellow or whitish with 20-25 seeds. It is early in maturity and ripens in November. Vermicompost produced in the Tripura University Vermicomposting centre has been applied in the rhizophere zone of mosambi plants. The organic fertilizer applied was in the ratio, soil vs. vermicompost in 7:3 ratio. Regular irrigation was made through water pipes. Dramatic increase in mosambi production was recorded in the TU campus.

Nutritional Value of Mosambi

Sweet lime is a low-calorie fruit and high in Vitamin and mineral profile. One sweet lime on average weighs 106 gms. It can provide approx.

- **Energy:** 45 calories
- **Protein:** 0.8 gms
- **Vitamin C:** 53 mg
- **Fats:** 0.3 gms
- **Vitamin A:** 90.2 mcg
- **Dietary Fibre:** 41.64 gms

Health Benefits of Mosambi

1. Helps Improve Immunity

Vitamin C and other antioxidants present in sweet lime or its juice can help strengthen immunity. It helps stay away from colds and flu. Stimulate blood circulation and thus strengthen the immune system.

2. Help Improve Digestion

Eating fresh Mosambi can help solve gastrointestinal problems such as **constipation and indigestion**. This refreshing drink has a unique taste that stimulates the salivary glands to secrete enzymes that help digestion, and it also contains compounds called flavonoids that can increase its content. Bile, certain gastric acid and digestive juices work together to help digestion. It also provides a lot of potassium, which can help relieve diarrhoea.

3. Helps in Dehydration

When you are thirsty and dehydrated, do not drink soda but drink Mosambi juice, because it not only quenches thirst but also contains important minerals and vitamins, which can reduce the occurrence of dehydration and the risks of complications. It should be an option for athletes to prevent dehydration and muscle cramping.

4. Great for Eyes, Skin and Hair

As Musambi is rich in antioxidants and antibacterial properties, this fruit is considered very beneficial for the eyes. Eating fruits can protect the eyes from infection, which is mainly caused by allergies to pollution or foreign objects. Mosambi helps treat dandruff by providing the hair and roots with the moisture and nutrients they need.

When the roots are firm, it can also reduce hair loss and **acne and pigmentation** used in many creams. Apply the Mosambi juice to the skin and leave it overnight to make the skin radiant. It not only moisturizes but also improves skin tone and lightens skin tone.

5. Aids Weight Loss

Mosambi juice, which is low in fat and calories, is very helpful for weight loss. You can drink a mixture of Mosambi juice and honey to **burn off the extra calories**.

6. Helps Treat Ulcers

One of the main benefits of Mosambi juice is that it can help treat ulcers. It is a natural acidic substance that will react with the alkalinity of your body and help treat stomach ulcers and reduce stomach acid.

7. Excellent Source of Vitamin C

Sweet limes are an **excellent source of vitamin C**. Scurvy is a disease caused by vitamin C deficiency. This condition is characterized by bleeding, swollen gums, frequent cold and flu outbreaks, mouth ulcers, tongue ulcers, and cracks. Regular consumption of sweet limes can prevent scurvy, and it has been observed that applying sweet lime juice to bleeding gums can reduce bleeding gums.

8. May Protect Bone Health

Mosambi or sweet lemon has high vitamin C content, which can relieve inflammation and swelling, so it plays an important role in the treatment of symptoms of osteoarthritis and rheumatoid arthritis. It also improves calcium absorption, stimulates bone formation in cells, and promotes overall bone health.

9. Relieves Nausea and Vomiting

Nausea or aversion towards foods can be caused due to various factors including pregnancy, indigestion, hormonal imbalance or poor functioning of the vital organs. You can have sweet lime when you experience nausea and vomiting. The pleasant aroma and taste of the sweet lime can bring down the symptoms instantly.

10. Flushes Out Kidney Stones

Kidney stones are usually hard, small mineral crystal-like deposits that can cause excruciating pain in the lower back and are hard to pass in the urine. According to studies, consuming citrus fruits as a part of a daily diet will decrease the chances of kidney stones. You can eat sweet lime to prevent these painful stones in the kidneys and to flush them out naturally.

11. May help with UTI

Urinary Tract Infection or UTI, is a common complication that especially affects women. UTI, as the name suggests, is a condition that causes discomfort while urinating. Discomfort, pain in the lower abdominal area and difficulty in urinating are all symptoms of UTI. There are several health benefits of sweet lime and the presence of potassium in it helps to combat UTIs and helps to improve the functioning condition of the kidneys and urinary bladder.

Uses of Mosambi

Sweet limes can be eaten as a snack, just peel them and enjoy them. You can also use it as a salad, sometimes even in seasoning sauce or chutney. Sweet lime is used as a fruit juice in India, you will always find this juice sold at a street stall. Salt can be added to freshly squeezed juice to enhance the taste.

You can also prepare sweet lime cucumber detox water. Mix both the ingredients and fill it with water and let it infuse for 3 to 4 hours.

How to consume Mosambi

Another yummy way to consume and feel the health benefits of sweet lime is to make some Sweet Lime Sherbet! It is the best drink if you want to beat the heat in the scorching summers. Here's how to make it:

Ingredients:

- 2 cups of chilled sweet lime juice
- ½ cup of sugar
- ½ cup of salt
- 1 tablespoon of fresh lemon juice
- 1 tablespoon of cumin powder
- 1 cup of chilled water
- Some mint leaves for freshness

Procedure:

- First, combine and mix the lime juice with the lemon juice. Take out the seeds, if any.
- Add in the sugar and stir till it melts. Then, add the salt and cumin powder.
- Add the chilled water according to taste.
- Finally, garnish the drink with some fresh mint leaves.

The health benefits of sweet lime juice include hydrating one's self during the hot summer months and also providing a good amount of Vitamin C to the body. However, one must not consume large quantities of the beverage as it may lead to nausea and vomiting. Be sure to brush your teeth after consuming this sweet drink as it may result in cavities if unattended to.

Difference between Lemon and Mosambi

Both lemon and mosambi belong to the citrus family of foods and is loaded with vitamin C. The few significant differences between both the varieties are in the way they are used separately in cuisines.

Lemons are large, oval-shaped, yellow-coloured fruits while sweet limes are green and spherical. Lemons are sour to taste but sweet lime juice turns sweeter as they are ripe. Lemons are slightly more acidic in nature and when it comes to health benefits, both are equally good.

Orange and Mosambi on the other hand are two popular fruits. While mousambi provides instant hydration, reduces muscle cramps, oranges are rich in fibre and stimulate digestion. Mosambi and oranges are a source of natural sugars, improve heart function and keep high blood pressure in check.

Vermicompost application in crops outside the campus:

In Paddy: In West Tripura, Lembuchhera, I.C.A.R research station, a field trial was conducted on upland rice (var. TRC-87-281) using 10 tons vermicompost/ hectare and 5 tons vermicompost along with NPK/hectare that led to significantly higher straw and grain yields coupled with better soil aggregation, water use efficiency and uptake of nutrient in vermicompost treated plots than the control and NPK treated plots (Bhattacharjee et al., 2001)

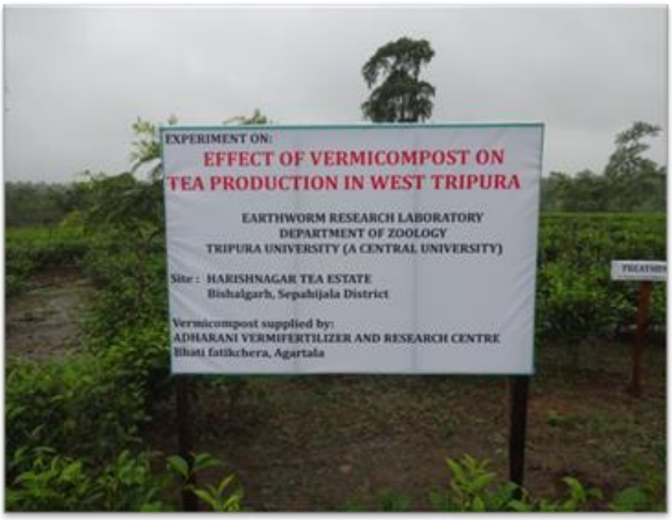
In Pineapple: Significant increase in the Pineapple (*Ananus comosus*) yield coupled with rise in earthworm population was recorded following application of 20 tons of vermicompost/ hectare (Chaudhuri et al., 2016).

In Tea (*Camellia sinensis*): A study conducted in Harishnagar Tea Estate (2015-2016) indicated that application of vermicompost significantly influenced the tea plantation soils, significantly increased the tea yield along with earthworm population and was dependent on the vermicompost doses applied (Chaudhuri & Jamatia, 2021). In Tea plantation, vermicompost applied at a rate of 15 tons/ hectare showed the best result.

Production of upland paddy through application of vermicompost in West Tripura

Application of vermicompost in different plantations in Tripura

Pineapple plantation



Tea plantation

Revenue generation from Mosambi orchard from the university fraternity