Earthworm (**மண்புழு**)

Different names of earthworm in tamil

- **நாக்குப்பூச்சி**
- **நாங்கூழ்**
- **பூநாகம்**
- **நாக்கிளிப்புழு**
- **நாக்கிளிப்புழுமண்புழு**
- **கண்டபதம்**
- **நிலவேர்**
- **பூமிவேர்**
- **மண்ணுளிப்பாம்பு**
- மண்ணில் உண்டாம் புழு வகை
- **மேகத்தின்விந்து**

உயிரியல் வகைப்பாடு	
திணை:	விலங்கினம்
தொகுதி:	வளைத்தசைப்புழுக்கள்
வகுப்பு:	en:Clitellata
வரிசை:	en:Haplotaxida
துணைவரிசை:	**Lumbricina** பர்மிசுடர், 1837

The farmer's friend, the humble earthworm is an annelid that helps retain the fertility of the soil. This is an invertebrate animal that lives mostly in the upper layer of the soil.

An earthworm is a segmented worm; a terrestrial invertebrate belonging to the phylum Annelida. They are the common inhabitants of moist soil and feed on organic matter.

Earthworms are commonly called as farmer's friend. This is because the worm casting (faecal deposit) increases the fertility and burrowing helps in proper aeration of the soil.

Earthworms are commonly found in soil, eating a wide variety of organic matter includes plant matter, living protozoa, rotifers, nematodes, bacteria, fungi, and other microorganisms.

Generally, within a species, the number of segments found is consistent across specimens, and individuals are born with the number of segments they will have throughout their lives.

The first body segment (segment number 1) features both the earthworm's mouth and, overhanging the mouth, a fleshy lobe called the prostomium, which seals the entrance when the worm is at rest, but is also used to feel and chemically sense the worm's surroundings. Some species of earthworm can even use the prehensile prostomium to grab and drag items such as grasses and leaves into their burrow.

An adult earthworm develops a belt-shaped glandular swelling, called the clitellum, which covers several segments toward the front part of the animal. This is part of the reproductive system and produces egg capsules.

The posterior is most commonly cylindrical like the rest of the body, but depending on the species, it may also be quadrangular, octagonal, trapezoidal, or flattened. The last segment is called the periproct; the earthworm's anus, a short vertical slit, is found on this segment.

Earthworms have a tube-like arrangement or cylindrical shaped and reddish-brown segmented body. The body is divided into small segments.

The dorsal side is characterized by a dark line of blood vessels and the ventral side is characterized by the genital openings.

The mouth and the prostomium (an organ helps in burrowing) distinguish the anterior end.

The segments 14-16 of a matured earthworm consist of a glandular tissue called clitellum which helps us to distinguish the mouth and tail ends.

The body is divided into three segments with respect to clitellum- preclitellar, clitellar and postclitellar.

Earthworms are hermaphrodites i.e., they carry both male and female sex organs. Segments 5-9 accommodate four pairs of spermathecal apertures.

The female genital pore is situated at the 14^{th} segment and a pair of male genital pores is situated at the 18^{th} segment.

The body consists of S-shaped setae, which help in locomotion in the earthworm. Setae are present in each segment except in the first, last and clitellum segments.

Locomotion

Earthworms travel underground by the means of waves of muscular contractions which alternately shorten and lengthen the body (peristalsis).

The shortened part is anchored to the surrounding soil by tiny clawlike bristles (setae) set along its segmented length.

In all the body segments except the first, last and clitellum, there is a ring of S-shaped setae embedded in the epidermal pit of each segment (perichaetine).

The whole burrowing process is aided by the secretion of lubricating mucus.

As a result of their movement through their lubricated tunnels, worms can make gurgling noises underground when disturbed.

Earthworms move through soil by expanding crevices with force; when forces are measured according to body weight, hatchlings can push 500 times their own body weight whereas large adults can push only 10 times their own body weight

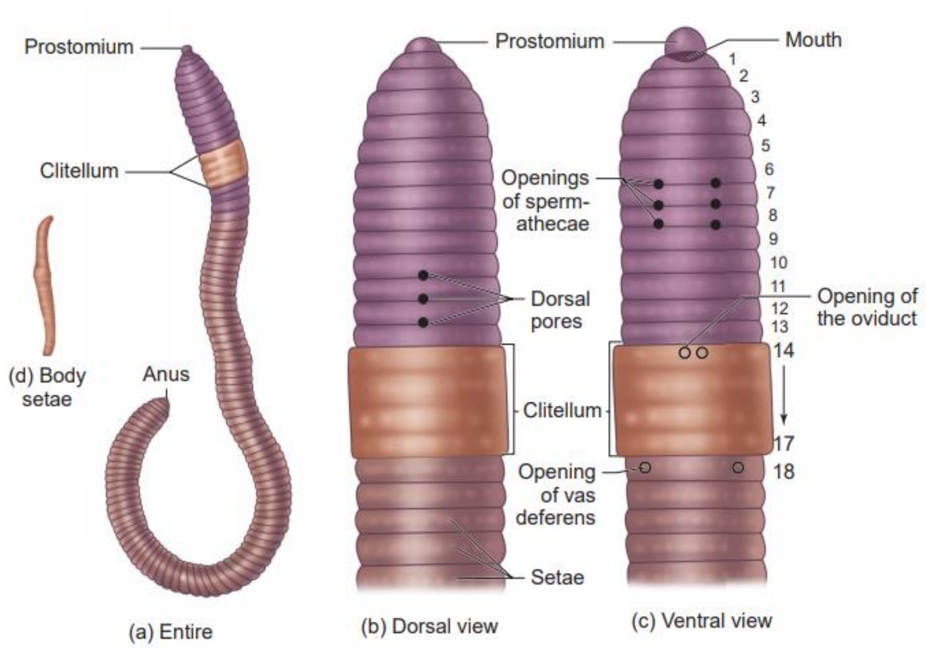
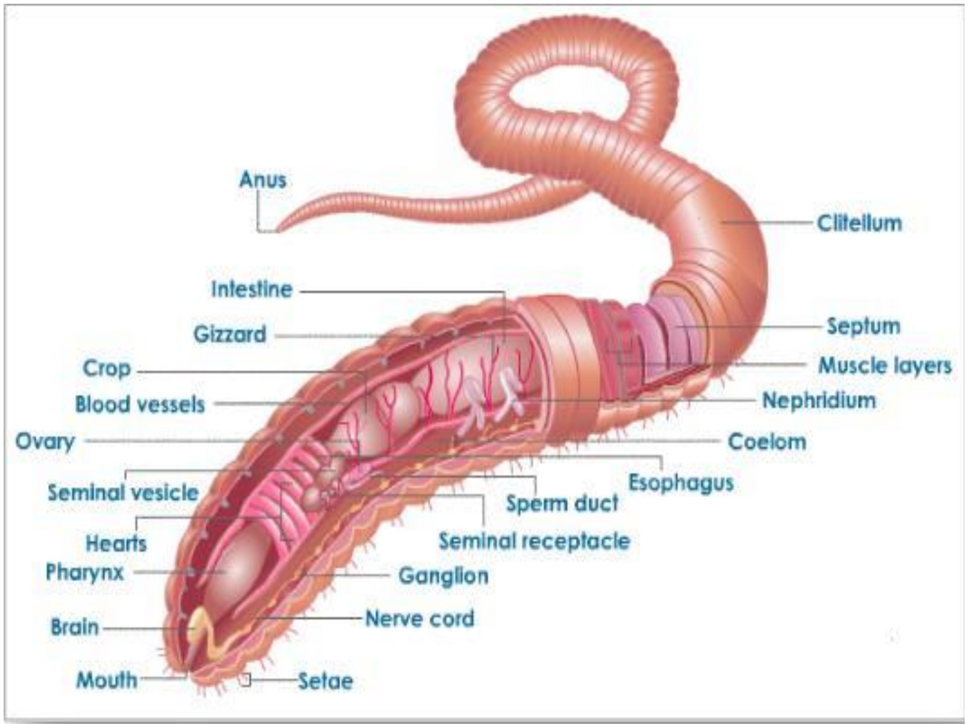


Figure 4.2 *Lampito mauritii*

Earthworm Anatomy

The body of the earthworm is segmented which looks like many little rings joined or fused together. The earthworm is made of about 100-120 segments.

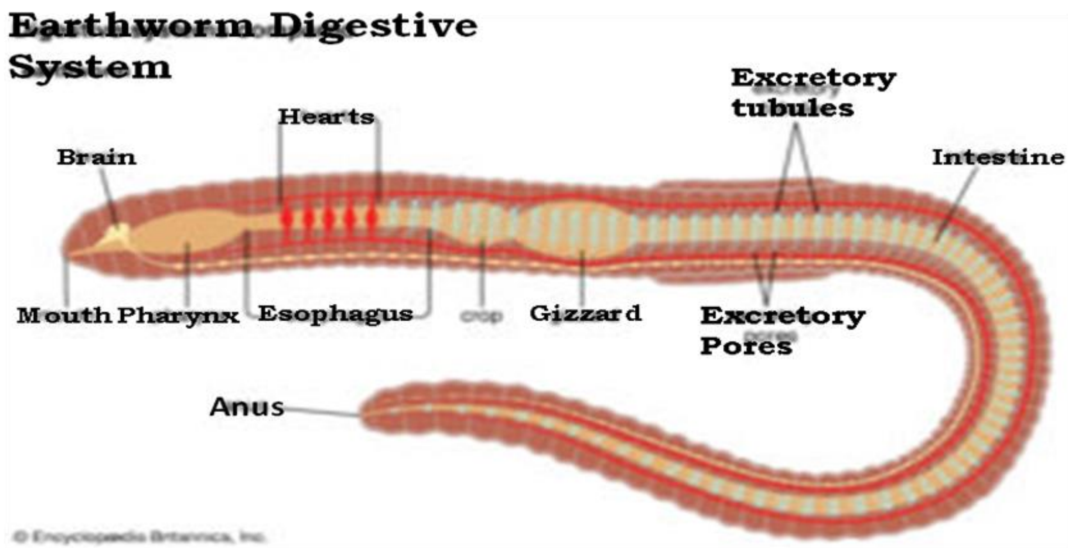
- The segmented body parts provide important structural functions. Segmentation can help the earthworm move. Each segment or section has muscles and bristles called setae.
- The bristles or setae help anchor and control the worm when moving through soil.
- The bristles hold a section of the worm firmly into the ground while the other part of the body protrudes forward.
- The earthworm uses segments to either contract or relax independently to cause the body to lengthen in one area or contract in other areas. Segmentation helps the worm to be flexible and strong in its movement.
- If each segment moved together without being independent, the earthworm would be stationary.
- The body of the earthworm is covered externally by a thin noncellular cuticle.
- This is followed by an epidermal layer, two muscle layers, and inner coelomic epithelium.
- The epidermis has columnar epithelial cells, which are present in a single layer.
- There are also some secretory gland cells present



Earthworm – Digestive system

- It is a straight tube that is present from the 1st segment to the last segment of an earthworm's body.
- The anterior part of the body has the mouth that leads to a buccal cavity.
- This, in turn, leads to the muscular pharynx, after which is present the oesophagus and the muscular gizzard.
- The muscular gizzard is a structure that helps in the grinding of the soil particles that are mixed with the organic matter and other decayed leaf particles.
- The gizzard leads to the stomach, which is present from 9th to 14th segments.
- In the stomach calciferous glands are present.
- They neutralize the humic acid that is present in the humus.
- The stomach leads to the intestine which begins from the 15th segment and continues till the last segment of the earthworm's body.
- On the 26th segment, there is a pair of short and conical intestinal caecae.

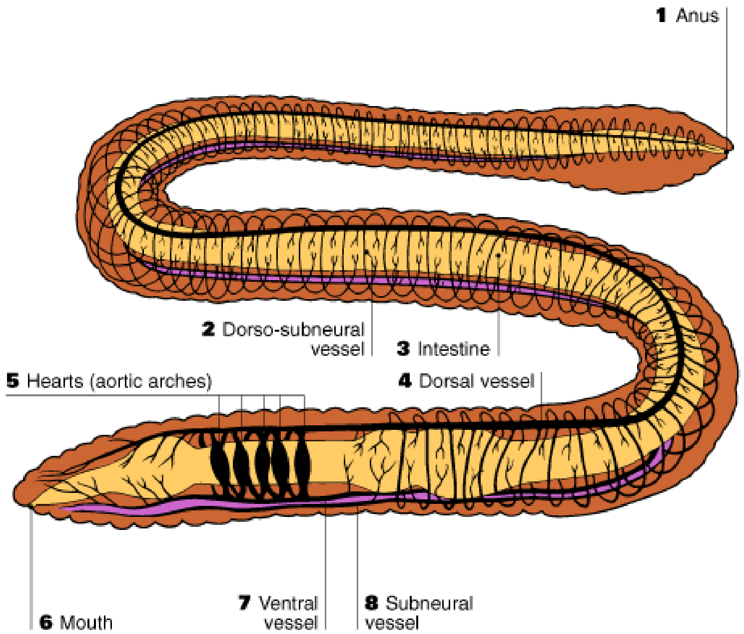
- After the 26th segment, there is an internal median fold of dorsal wall called typhlosole, which is a characteristic feature.
- Typhlosole helps in increasing the area of absorption.
- The anus is the small aperture through which the alimentary canal opens out.



Earthworm – Circulatory sytem

- Earthworms show a closed blood vascular system.
- It means that blood flows in closed blood vessels.
- The circulatory system consists of blood, blood vessels, capillaries, and heart.
- Blood is circulated in one direction due to the contractions.
- The 4th, 5th and 6th segments have the blood glands, which produce the blood cells and haemoglobin.
- The blood cells do not have haemoglobin and are phagocytic.
- It is dissolved in the blood plasma.
- There are five pairs of aortic arches, which have the responsibility of pumping blood into the dorsal and ventral blood vessels.
- The dorsal blood vessels are responsible for carrying blood to the front of the earthworm's body.

- The ventral blood vessels are responsible for carrying blood to the back of the earthworm's body.

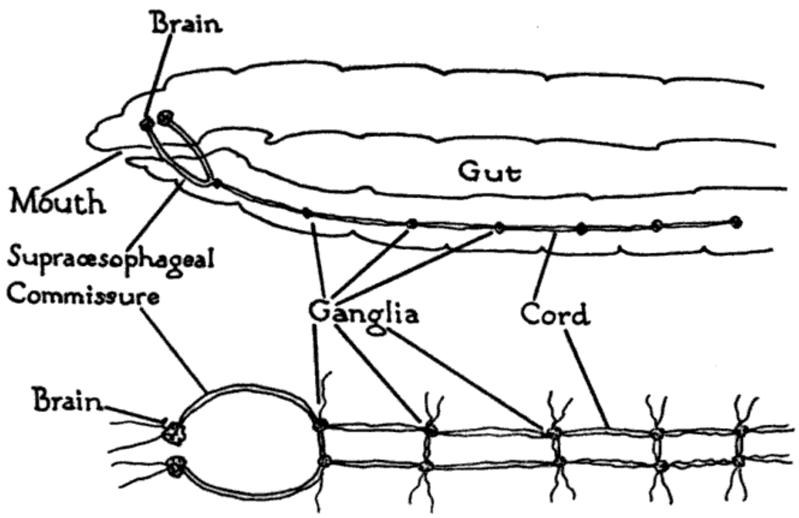


Earthworm – Respiratory system

- Earthworms do not have lungs.
- They breathe through their skin. Oxygen and carbon dioxide pass through the earthworm's skin by diffusion.
- For diffusion to occur, the earthworm's skin must be kept moist. Body fluid and mucous is released to keep its skin moist.
- Earthworms therefore, need to be in damp or moist soil. This is one reason why they usually surface at night when it is possibly cooler and the "evaporating potential of the air is low."
- Earthworms have developed the ability to detect light even though they cannot see. They have tissue located at the earthworm's head that is sensitive to light.
- These tissues enable an earthworm to detect light and not surface during the daytime where they could be affected by the sun.

Earthworm – Nervous system

- There are ganglia that are arranged in a segment-wise manner on the ventral paired nerve cord.
- Ganglia are nothing but the mass of nerve cells.
- The nerve cord in the 3rd and 4th segments bifurcates and laterally encircles the pharynx and joins the cerebral ganglia dorsally to form a nerve ring.
- This integrates the sensory input and also commands the muscular responses of the earthworm.
- Earthworms' brains consist of a pair of pear-shaped cerebral ganglia.
- These are located in the dorsal side of the alimentary canal in the third segment, in a groove between the buccal cavity and pharynx.
- A pair of circum-pharyngeal connectives from the brain encircle the pharynx and then connect with a pair of sub-pharyngeal ganglia located below the pharynx in the fourth segment.
- The ventral nerve cord (formed by nerve cells and nerve fibres) begins at the sub-pharyngeal ganglia and extends below the alimentary canal to the most posterior body segment.
- The ventral nerve cord has a swelling, or ganglion, in each segment, i.e. a segmental ganglion, which occurs from the fifth to the last segment of the body.
- There is also three giant axons, one medial giant axon (MGA) and two lateral giant axons (LGAs) on the mid-dorsal side of the ventral nerve cord



Earthworm – Excretory system

- The excretory system consists of coiled tubules called nephridia.
- They are arranged on the segments of the body.
- Depending on the location, these nephridia are of three types.
- They are septal nephridia, integumentary nephridia, and pharyngeal nephridia.
- All the nephridia have a similar structure.
- They are responsible for maintaining the volume of the body fluids.

Earthworm – Reproductive system

- Earthworms are hermaphrodites where each earthworm contains both male and female sex organs.
- The male and female sex organs can produce sperm and egg respectively in each earthworm.
- Although earthworms are hermaphrodites, most need a mate to reproduce.
- During mating, two worms line up inverted from each other so sperm can be exchanged.

Male Reproductive System

The male reproductive system comprises testes, testis sacs, seminal vesicles, spermatic funnel, prostate glands and other accessory glands.

Testes:

- Two pairs, present on 10th and 11th segment.
- Each testis consists of 4 to 8 finger-like projections.
- Testes contain spermatogonia cells in the lobules.
- They produce sperm.

Testis Sacs:

- Testes are present within fluid-filled sacs called testis sacs.
- Large spermatic funnel is present.
- Testis sacs are connected to seminal vesicles.
- Spermatogonia cells pass from testis sacs to seminal vesicles, where they mature to form spermatozoa.

Seminal Vesicle:

- Two pairs, present on 11th and 12th segment.
- Each seminal vesicle is connected to the testis sac.
- Spermatogonia cells pass from testis sacs to seminal vesicles, where they mature to form spermatozoa.

Spermatic Funnel:

- Two pairs, present on 10th and 11th segment behind each testis.
- They are folded and ciliated.
- It connects testis sacs to vasa differentia. Sperms matured in seminal vesicles come back to testis sacs and transported to vasa differentia via spermiducal funnel.

Female Reproductive Organ

The female reproductive system of earthworm comprises ovaries, oviduct and spermatheca.

Ovaries:

- One pair of ovaries, present at 13th segment.
- Each ovary consists of several finger-like projections.
- In these projections, developing ova are present in a row, which looks like a series of beads.
- The mature ova are found at the distal end and immature ova are found at the proximal end of the lobules.

Oviduct:

- One pair of the ovarian funnel is present at 13th segment, below ovaries.
- These funnels are ciliated and folded and open in the oviduct.
- Oviducts are a short conical funnel. they are ciliated.
- Both the oviducts converge and form a single female genital aperture at the 14th segment.

Spermatheca:

- Four pairs, situated inter-segmentally between 5-6, 6-7, 7-8, and 8-9th segment.
- They are also known as seminal receptacles as they store sperms from another earthworm during copulation.
- Each spermatheca is flask shaped.
- The main body of spermatheca is called the ampulla, which stores sperms and short small lobe called diverticulum.
- In *Pheretima,* the diverticulum stores sperms.
- The spermatheca opens externally by small ducts.

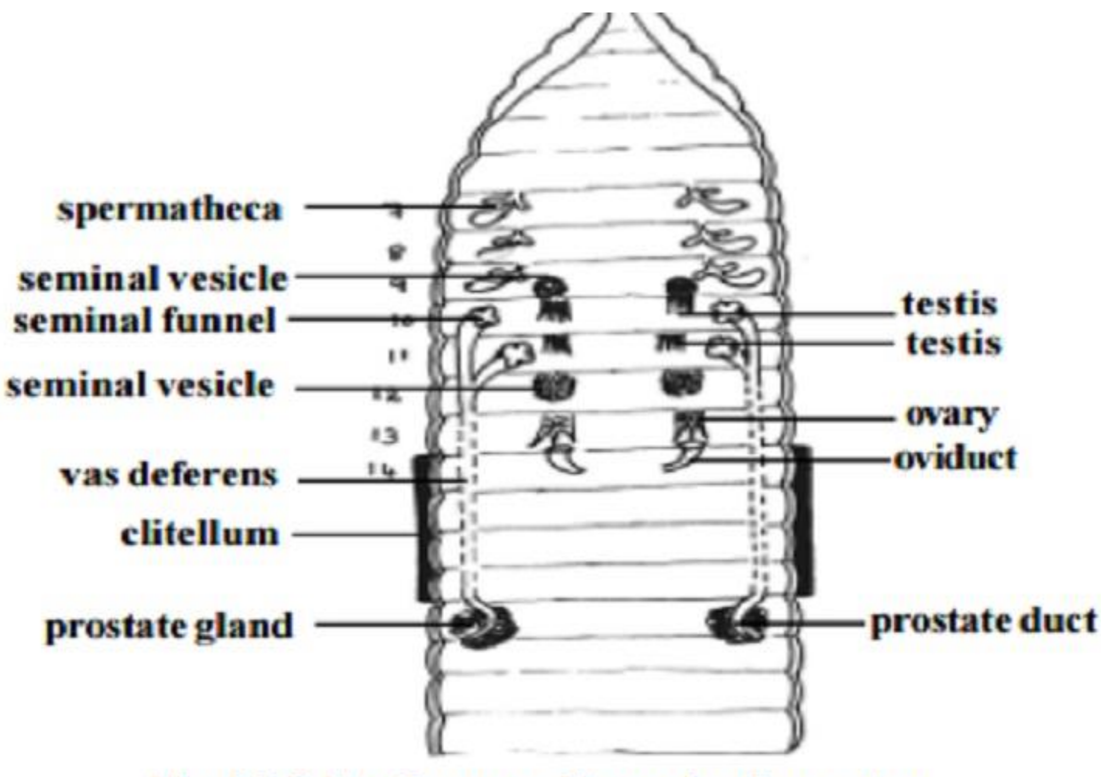
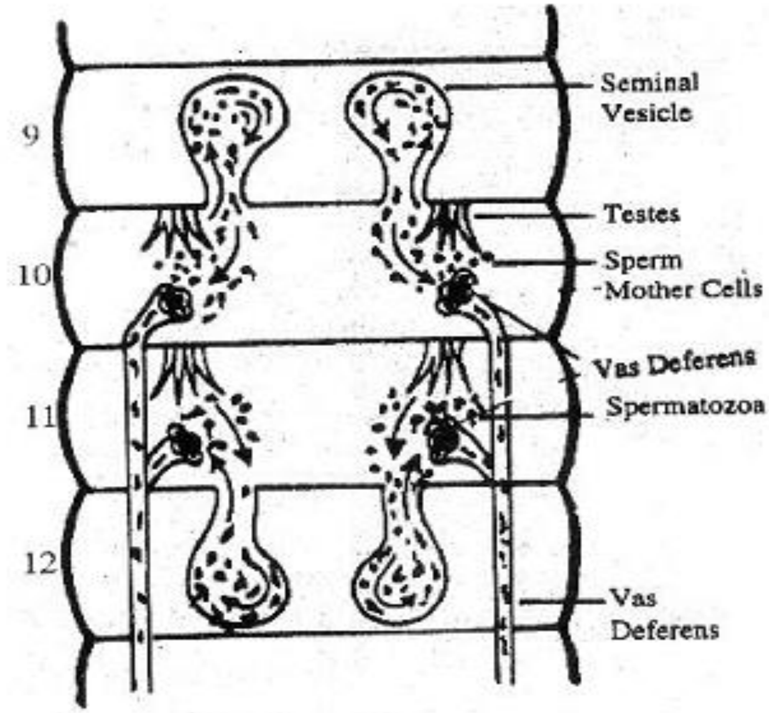
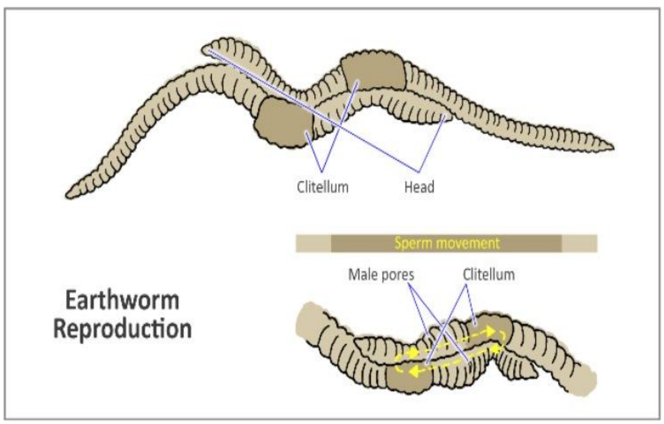
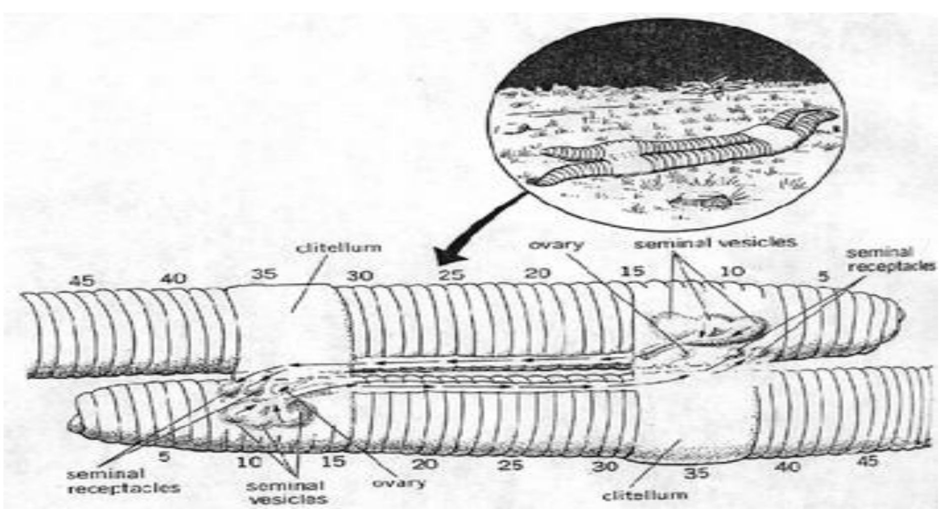


Fig. 1.3.8. Earthworm - Reproductive system


9
10
11
12
Seminal Vesicle
Testes
Sperm Mother Cells
Vas Deferens
Spermatozoa
Vas Deferens


Clitellum
Head
Sperm movement
Male pores
Clitellum
Earthworm Reproduction


clitellum
ovary
seminal vesicles
seminal receptacles
45
40
35
30
25
20
15
10
5
seminal receptacles
seminal vesicles
ovary
clitellum

Life cycle of earthworm

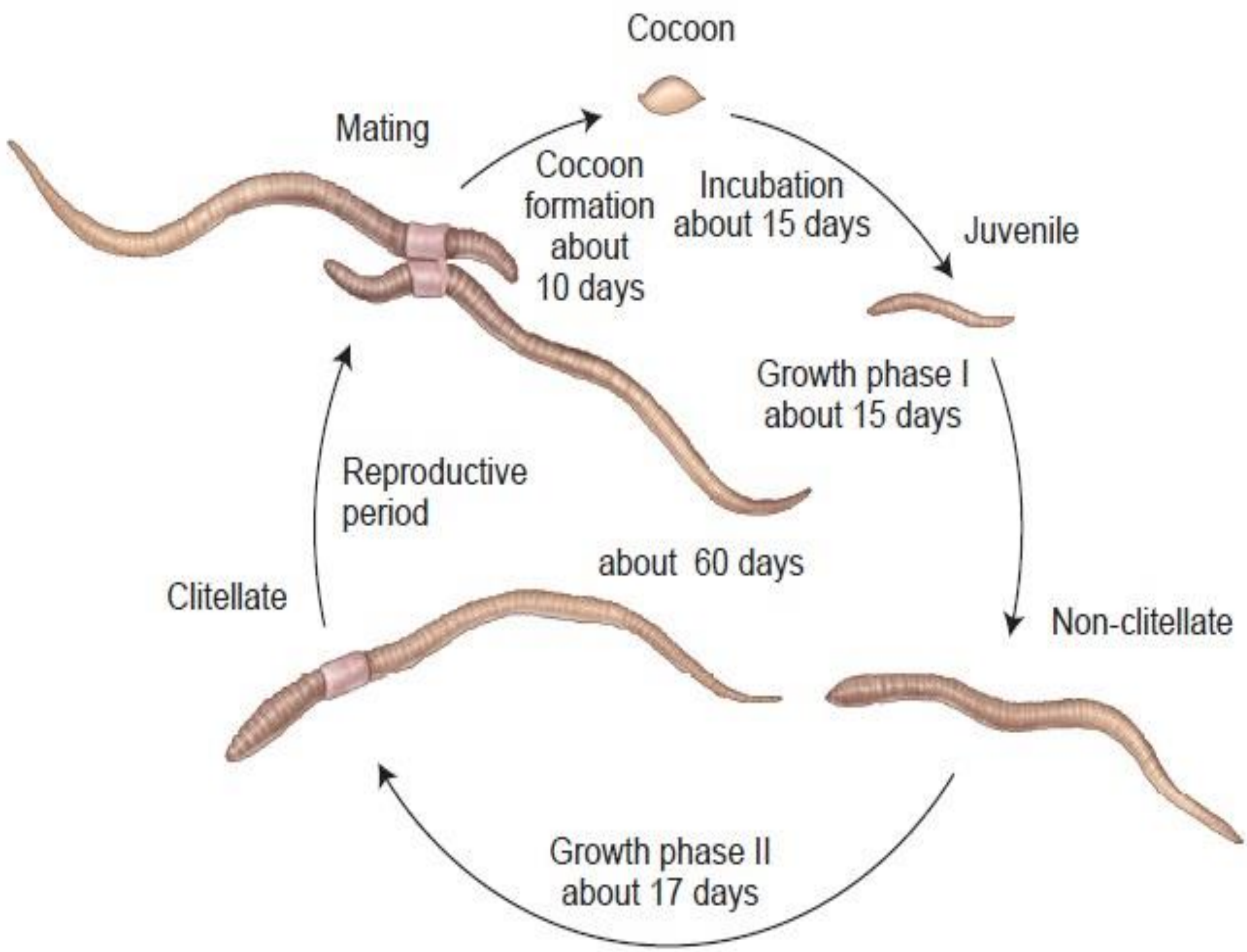


Figure 4.7 Life cycle of *Lampito mauritii*

Vermiculture and vermicomposting

Vermiculture means worm farming or culturing worms for selling them either to fishermen or to compost manufacturers. When earthworms are used for the production of compost it is called **vermicomposting.** Earthworms burrow through the soil and feed on decaying organic matter, excreting castings that are rich in nutrients and beneficial micro-organisms, which are about 20 times more in worm castings than in normal soil. These beneficial organisms not only make available nutrients to the plants but also suppress the growth of pathogens leading to healthy plants.

The most common worms used in vermiculture are, red worms *(Eisenia foetida, Eisenia andrei,* and *Lumbricus rubellus).* These worms thrive at temperatures between 20-30°C and can be cultured indoor in boxes. Other worms like *Perionyx excavatus* and *Eudrillius eugiene*are are suitable for warmer climates.

Vermicomposting is the process of turning organic debris into worm castings. The worm castings are very important to the fertility of the soil. The castings contain high amounts of nitrogen, potassium, phosphorus, calcium, and magnesium. Castings contain: 5 times the available nitrogen, 7 times the available potash, and 1 ½ times more calcium than found in good topsoil. Several researchers have demonstrated that earthworm castings have excellent aeration, porosity, structure, drainage, and moisture-holding capacity. The content of the earthworm castings, along with the natural tillage by the worms burrowing action, enhances the permeability of water in the soil. Worm castings can hold close to nine times their weight in water. “Vermiconversion,” or using earthworms to convert waste into soil additives, has been done on a relatively small scale for some time. A recommended rate of vermicompost application is 15-20 percent.

Vermicomposting is done on small and large scales. In the 1996 Summer Olympics in Sydney, Australia, the Australians used worms to take care of their tons and tons of waste.They then found that waste produced by the worms was could be very beneficial to their plants and soil. People in the U.S. have commercial vermicomposting facilities, where they raise worms and sell the castings that the worms produce. Then there are just people who own farms or even small gardens, and they may put earthworms into their compost heap, and then use that for fertilizer.

Three Types of Earthworm

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

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

Endogeic (Greek for "within the earth") – these are also burrowing worms but their burrows are typically more shallow and they feed on the organic matter already in the soil, so they come to the surface only rarely.

Vermicompost and its utilization

Vermicompost is nothing but the excreta of earthworms, which is rich in humus and nutrients. We can rear earthworms artificially in a brick tank or near the stem / trunk of trees (specially horticultural trees). By feeding these earthworms with biomass and watching properly the food (bio-mass) of earthworms, we can produce the required quantities of vermicompost.

Vermicompost appears to be generally superior to conventionally produced compost in a number of important ways;

• Vermicompost is superior to most composts as an inoculant in the production of compost teas;

• Worms have a number of other possible uses on farms, including value as a high-quality animal feed;

• Vermicomposting and vermiculture offer potential to organic farmers as sources of supplemental income.

Materials for preparation of Vermicompost

Any types of biodegradable wastes-

1. Crop residues
2. Weed biomass
3. Vegetable waste
4. Leaf litter
5. Hotel refuse
6. Waste from agro-industries
7. Biodegradable portion of urban and rural wastes
8. **Phase of vermicomposting**

Phase 1	:	Processing involving collection of wastes, shredding, mechanical separation of the metal, glass and ceramics and storage of organic wastes.
Phase 2	:	Pre digestion of organic waste for twenty days by heaping the material along with cattle dung slurry. This process partially digests the material and fit for earthworm consumption. Cattle dung and biogas slurry may be used after drying. Wet dung should not be used for vermicompost production.
Phase 3	:	Preparation of earthworm bed. A concrete base is required to put the waste for vermicompost preparation. Loose soil will allow the worms

		to go into soil and also while watering, all the dissolvable nutrients go into the soil along with water.
Phase 4	:	Collection of earthworm after vermicompost collection. Sieving the composted material to separate fully composted material. The partially composted material will be again put into vermicompost bed.
Phase 5	:	Storing the vermicompost in proper place to maintain moisture and allow the beneficial microorganisms to grow.

The Five Essentials Compost worms need five basic things:

1 An hospitable living environment, usually called “bedding”;

2 A food source;

3 Adequate moisture (greater than 50% water content by weight);

4 Adequate aeration;

5 Protection from temperature extremes.

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.

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.

Requirements

- **Housing:** Sheltered culturing of worms is recommended to protect the worms from excessive sunlight and rain. All the entrepreneurs have set up their units in vacant cowsheds, poultry sheds, basements and back yards.
- **Containers:** Cement tanks were constructed. These were separated in half by a dividing wall. Another set of tanks were also constructed for preliminary decomposition.
- **Bedding and feeding materials:** During the beginning of the enterprises, most women used cowdung in order to breed sufficient numbers of earthworms. Once they have large populations, they can start using all kinds of organic waste. Half of the entrepreneurs have now reached populations of 12,000 to 15,000 adult earthworms.

Vermicompost Production Methodology

Selection of suitable earthworm

- For vermicompost production, the surface dwelling earthworm alone should be used. The earthworm, which lives below the soil, is not suitable for vermicompost production. The African earthworm (*Eudrillus engenial),* Red worms (*Eisenia foetida)* and composting worm (*Peronyx excavatus)* are promising worms used for vermicompost production. All the three worms can be mixed together for vermicompost production. The African worm (*Eudrillus eugenial)* is preferred over other two types, because it produces higher production of vermicompost in short period of time and more young ones in the composting period.

Selection of site for vermicompost production

- Vermicompost can be produced in any place with shade, high humidity and cool. Abandoned cattle shed or poultry shed or unused buildings can be used. If it is to be produced in open area, shady place is selected. A thatched roof may be provided to protect the process from direct sunlight and rain. The waste heaped for vermicompost production should be covered with moist gunny bags.

Containers for vermicompost production

- A cement tub may be constructed to a height of 2½ feet and a breadth of 3 feet. The length may be fixed to any level depending upon the size of the room. The bottom of the tub is made to slope like structure to drain the excess water from vermicompost unit. A small sump is necessary to collect the drain water.
- In another option over the hand floor, hollow blocks / bricks may be arranged in compartment to a height of one feet, breadth of 3 feet and length to a desired level to have quick harvest. In this method, moisture

assessment will be very easy. No excess water will be drained. Vermicompost can also be prepared in wooden boxes, plastic buckets or in any containers with a drain hole at the bottom.

Vermiculture bed

- Vermiculture bed or worm bed (3 cm) can be prepared by placing after saw dust or husk or coir waste or sugarcane trash in the bottom of tub / container. A layer of fine sand (3 cm) should be spread over the culture bed followed by a layer of garden soil (3 cm). All layers must be moistened with water.
- If available, shredded paper or cardboard makes an excellent bedding, 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 fibre collected in municipal waste programs cannot be approved for certification purposes. There may be cases, however, where fibre 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, 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 by the reader that the selection of bedding materials is a key to successful vermiculture or 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. They provide protection from extremes in temperature, the necessary levels and consistency of

moisture, and an adequate supply of oxygen. Fortunately, given their critical importance to 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 somewhat similar in its bedding characteristics to aged horse manure.

- Mixing beddings need not be an onerous process; it can be done by hand with a pitchfork (small operations), with a tractor bucket (larger operations), or, if one is available, with an agricultural feed mixer. Please note that the latter would only be appropriate for large commercial vermicomposting operations where high efficiency levels and consistent product quality is required.

v) 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. 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.

Selection for vermicompost production

- Cattle dung (except pig, poultry and goat), farm wastes, crop residues, vegetable market waste, flower market waste, agro industrial waste, fruit market waste and all other bio degradable waste are suitable for vermicompost production. The cattle dung should be dried in open sunlight before used for vermicompost production. All other waste should be predigested with cow dung for twenty days before put into vermibed for composting.

Putting the waste in the container

- The predigested waste material should be mud with 30% cattle dung either by weight or volume. The mixed waste is placed into the tub / container upto brim. The moisture level should be maintained at 60%. Over this material, the selected earthworm is placed uniformly. For one-meter length, one-meter breadth and 0.5-meter height, 1 kg of worm (1000 Nos.) is required. There is no necessity that earthworm should be put inside the waste. Earthworm will move inside on its own.

Watering the vermibed

- Daily watering is not required for vermibed. But 60% moisture should be maintained throughout the period. If necessity arises, water should be sprinkled over the bed rather than pouring the water. Watering should be stopped before the harvest of vermicompost.

Harvesting vermicompost

- In the tub method of composting, the castings formed on the top layer are collected periodically. The collection may be carried out once in a week. With hand the casting will be scooped out and put in a shady place as heap like structure. The harvesting of casting should be limited up to earthworm presence on top layer. This periodical harvesting is necessary for free flow and retain the compost quality. Other wise the finished compost get compacted when watering is done. In small bed type of vermicomposting method, periodical harvesting is not required. Since the height of the waste material heaped is around 1 foot, the produced vermicompost will be harvested after the process is over.


Harvesting earthworm

After the vermicompost production, the earthworm present in the tub / small bed may be harvested by trapping method. In the vermibed, before harvesting the compost, small, fresh cow dung ball is made and inserted inside the bed in five or six places. After 24 hours, the cow dung ball is removed. All the worms will be adhered into the ball. Putting the cow dung ball in a bucket of water will separate this adhered worm. The collected worms will be used for next batch of composting.

Worm harvesting is usually carried out in order to sell the worms, rather than to start new worm beds. Expanding the operation (new beds) can be accomplished by splitting the beds that is, removing a portion of the bed to start a new one and replacing the material with new bedding and feed. When worms are sold, however, they are usually separated, weighed, and then transported in a relatively sterile medium, such as peat moss. To accomplish this, the worms must first be separated from the bedding and vermicompost. There are three basic categories of methods used by growers to harvest worms: manual, migration, and mechanical. Each of these is described in more detail in the sections that follow.

a) Manual Methods

Manual methods are the ones used by hobbyists and smaller-scale growers, particularly those who sell worms to the home-vermicomposting or bait market. In essence, manual harvesting involves hand-sorting, or picking the worms directly from the compost by hand. This process can be facilitated by taking advantage of the fact that worms avoid light. If material containing worms is dumped in a pile on a flat surface with a light above, the worms will quickly dive below the surface. The harvester can then remove a layer of compost, stopping when worms become visible again. This process is repeated several times until there is nothing left on the table except a huddled mass of worms under a thin covering of compost. These worms can then be quickly scooped into a container, weighed, and prepared for delivery.

There are several minor variations and/or enhancements on this method, such as using a container instead of a flat surface, or making several piles at once, so that the person harvesting can move from one to another, returning to the first one in time to remove the next layer of compost. They are all labour-intensive, however, and only make sense if the operation is small and the value of the worms is high.

b) Self-Harvesting (Migration) Methods

These methods, like some of the methods used in vermicomposting, are based on the worms tendency to migrate to new regions, either to find new food or to avoid undesirable conditions, such as dryness or light. Unlike the manual methods described above, however, they often make use of simple mechanisms, such as screens or onion bags.

The screen method is very common and easy to use. A box is constructed with a screen bottom. The mesh is usually ¼”, although 1/8” can be used as wel. There are two different approaches. The downward-migration system is similar to the manual system, in that the worms are forced downward by strong light. The difference with the screen system is that the worms go down through the screen into a prepared, pre-weighed container of moist peat moss. Once the worms have all gone through, the compost in the box is removed and a new batch of worm-rich compost is put in. The process is repeated until the box with the peat moss has reached the desired weight. Like the manual method, this system can be set up in a number of locations at once, so that the worm harvester can move from one box to the next, with no time wasted waiting for the worms to migrate.

The upward-migration system is similar, except that the box with the mesh bottom is placed directly on the worm bed. It has been filled with a few centimeters of damp peat moss and then sprinkled with a food attractive to worms, such as chicken mash, coffee grounds, or fresh cattle manure. The box is removed and weighed after visual inspection indicates that sufficient worms have moved up into the material. This system is used extensively in Cuba, with the difference that large onion bags are used instead of boxes. The advantage of this system is that the worm beds are not disturbed. The main disadvantage is that the harvested worms are in material that contains a fair amount of unprocessed food, making the material messier and opening up the possibility of heating inside the package if the worms are shipped. The latter problem can be avoided by removing any obvious food and allowing a bit of time for the worms to consume what is left before packaging.

Nutritive value of vermicompost

The nutrients content in vermicompost vary depending on the waste materials that is being used for compost preparation. If the waste materials are heterogeneous one, there will be wide range of nutrients available in the compost. If the waste materials are homogenous one, there will be only certain nutrients are available. The common available nutrients in vermicompost is as follows

Organic carbon	:	9.5 – 17.98%
Nitrogen	:	0.5 – 1.50%
Phosphorous	:	0.1 – 0.30%

Potassium	:	0.15 – 0.56%
Sodium	:	0.06 – 0.30%
Calcium and Magnesium	:	22.67 to 47.60 meq/100g
Copper	:	2 – 9.50 mg kg-1
Iron	:	2 – 9.30 mg kg-1
Zinc	:	5.70 – 11.50 mg kg-1
Sulphur	:	128 – 548 mg kg-1

Storing and packing of vermicompost

The harvested vermicompost should be stored in dark, cool place. It should have minimum 40% moisture. Sunlight should not fall over the composted material. It will lead to loss of moisture and nutrient content. It is advocated that the harvested composted material is openly stored rather than packed in over sac. Packing can be done at the time of selling. If it is stored in open place, periodical sprinkling of water may be done to maintain moisture level and also to maintain beneficial microbial population. If the necessity comes to store the material, laminated over sac is used for packing. This will minimize the moisture evaporation loss. Vermicompost can be stored for one year without loss of its quality, if the moisture is maintained at 40% level.

Advantages of vermicompost

- Vermicompost is rich in all essential plant nutrients.
- Provides excellent effect on overall plant growth, encourages the growth of new
- shoots / leaves and improves the quality and shelf life of the produce.
- Vermicompost is free flowing, easy to apply, handle and store and does not have bad
- odour.
- It improves soil structure, texture, aeration, and waterholding capacity and prevents

- soil erosion.
- Vermicompost is rich in beneficial micro flora such as a fixers, P-solubilizers,
- cellulose decomposing micro-flora etc in addition to improve soil environment.
- Vermicompost contains earthworm cocoons and increases the population and activity of earthworm in the soil.
- It neutralizes the soil protection.
- It prevents nutrient losses and increases the use efficiency of chemical fertilizers.
- Vermicompost is free from pathogens, toxic elements, weed seeds etc.
- Vermicompost minimizes the incidence of pest and diseases.
- It enhances the decomposition of organic matter in soil.
- It contains valuable vitamins, enzymes and hormones like auxins, gibberellins etc.

மண்புழு உரம் தயாரிக்கும் முறைகள்

1. **தொட்டி முறை (Tank method)**
2. **குழி முறை (Pit method)**
3. **குவி முறை (Heap method)**
4. **படுக்கை முறை (Windrow method or Banglore method)**

Method Of Culturing Earthworms in Tank / Pit method

1) Select a container or dig a pit of suitable dimensions in shady areas.

2) At the bottom of the pit or container, make a **wormibed** of 10 cm height using coir waste, paddy husk, sugar cane trash, old papers etc. and spread a layer of soil over it. Wet the bed by sprinkling sufficient water over it to obtain a relative humidity of 40-45%.

3) Mix the organic waste, cattle dung and slurry from biogas plant or any other organic material and spread it over the bed. Keep this mixture for two weeks for **half digestion,** during which heating of substrate will take place and temperature will rise to 50-55°C. Add 5-10 % of neem cake in this material. Neem cake has beneficial effect on the growth of worms and kills harmful microorganisms.

4) Once the organic feeding material has cooled down to about 30°C, introduce worms by spreading them over the bed at the rate of 500 worms for every 100 kg of organic material.

5) Cover the bed with jute cloth, straw or similar material to provide shade and protection to the worms. Water has to be sprinkled over this cover to maintain the moisture content at 45-50% and temperature between 20-30°C. The pH of the raw material should not exceed 6.5-7.

The worms feed actively on organic matter and excrete mounds of castings near the surface. In about 60 days the compost will be ready

Heap method

Figure 4: Vermicomposting windrows of shredded cardboard and manure

INM: Vermicompost

- It can be applied in any crop at any stage, but it would be more beneficial if mixed in soil after broadcasting. The rate of application is as
  - Field crops 5-6 t/ha;
  - Vegetables 10-12 t/ha;
  - Flower plants 100-200 g/sq ft;
  - Fruit trees 5-10 kg/tree.

VERMICOMPOSTING TECHNIQUE FOR FARMERS

- The vermicomposting is done by digging pits 3.0 m long, 1.0 m wide and 1.0 m deep
- At the bottom of the pits, broken pieces of earthen pots or bricks are spread to provide adequate drainage.
- Over the layer of bricks, a bed of paddy husk or dry leaves is spread and then a layer of 2.5 cm thick soil is spread over it.
- Cattle dung and other organic wastes are then spread over the bed in about three inches thick layer.
- This organic material is allowed half digestion for about two weeks when temperature will increase to about 50°C.
- Worms can be introduced after this incubation period is over and when the temperature has come down to about 30°C. About 500 earthworms are then introduced into the pit, and a layer of paddy straw is placed over them. Water should be sprinkled and the pit is covered with coconut

fibres or paddy straw or dry leaves to protect the worms from sunlight and predators.

- Fresh layers of organic waste can be added over this material every 3 or 4 days and covered with a layer of soil and paddy husk.
- The earthworms will move to the upper layer after finishing food material in the lower layers.
- The pit can be charged with all kinds of organic wastes in layers of about 5 cm, covered with a layer of soil till the material reaches the top of the pit.
- When the pit is full, it should be covered with husk and a layer of soil, and left for 30-60 days, during which compost will be fully formed.
- To procure the compost, top layer should be exposed to sunlight to force the earthworms to move to the deeper layers, so that compost could be removed from the top.
- The worms collected at the base can be used for inoculating new vermicomposting pits.
- The quality of vermicompost is far superior to other composts in terms of nutrients and other plant growth promoting substances.

Vermicompost production using worms such as *Eisenia foetida*, *Lumbricus rubellus* and *Eudrilus eugeniae* can be enhanced by using cattle urine for moistening organic wastes during the preliminary composting stage before the addition of worms. This simple technique can yield vermicompost of a higher Nitrogen content. Moreover, worms have been found to become more active and vermicompost can be harvested at least 10 days earlier if cattle urine is used

Factors necessary for vermicomposting

Moisture

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 of Canada7 . Section 3 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 don't reproduce at single-digit temperatures and they don't consume as much food. It is generally considered necessary to keep the temperatures above 10o C (minimum) and preferably 15 oC for vermicomposting efficiency and above 15 oC (minimum) and preferably 20 oC 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 food8 . 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 (o C). Above 35o C will cause the worms to leave the area. If they cannot leave, they will quickly die. In general, warmer temperatures (above 20o C) 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 southfacing side of windrows in the winter and on the opposite side in the summer.

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 can drop well below 7. 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 saltwater 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 more notable 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.

• Tannins. 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.).

Pests and Diseases

Compost worms are not subject to diseases caused by micro-organisms, but they are subject to predation by certain animals and insects (red mites are the worst) and to a disease known as "sour crop" caused by environmental conditions. The following is a brief overview of the most common pests and diseases likely to be experienced in Canada.

• **Moles**.

Earthworms are moles' natural food, so if a mole gets access to your worm bed, you can lose a lot of worms 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.**

They are not usually a major problem, but if they discover your beds they will come around regularly and help themselves to some of your workforce. 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. Old carpet can be used for this purpose and is very effective.

• **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. If they do become a problem, one method suggested for reducing their numbers is to heavily wet (but not quite flood) the worm beds. The water forces centipedes and other insect pests (but not the worms) to the surface, where they can be destroyed by means of a hand-held propane torch or something similar

• **Ants.**

These insects are more of a problem because they consume the feed meant for the worms. Ants are particularly attracted to sugar, so avoiding sweet feeds in the worm beds reduces this problem to a minor one. Keeping the bedding above pH 7 also helps

• **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 suck fluid 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, as required.

Other enemies are snake, rats, human beings etc.