4. Earthworm Diversity

Earthworm is a ***terrestrial animal.*** They are ***nocturnal,*** living in ***burrows,*** found in ***moist, loose soil,*** distributed nearly over the entire surface of the earth.

About ***4600 species*** are widely distributed around the world.

About ***590 species*** of earthworms are known to occur in ***India***; But only a few species are used for composting.

Fig.4.1: Earthworm.

Earthworms are distributed throughout the world. This type of distribution is called ***peregrine*** or ***cosmopolitan*** distribution.

The earthworms are found in different zones in different ***soil types***, differing in ***burrowing*** and ***feeding behaviour***.

Classification of Earthworm

Earthworms are classified based on the following *factors:*

1. *Based on the habitat*
2. *Based on the soil layers*
3. *Based on the feeding habits and colour*
4. *Based on the behaviour*
5. *Based on the habits*
6. *Based on the food materials*
7. *Based on the place of living*

1. Based on the Habitat

Evans and ***Guild*** (1947) has classified the earthworms into ***two***. They are:

1. *Surface-dwelling worms*
2. *Deep-dwelling worms*

2. Based on the Soil Layers

Lee (1959, 1985 and 1989) has adopted a classification of earthworms based on the *soil* ***layers*** into ***three.*** They are:

1. *Litter species*
2. *Topsoil species*
3. *Subsoil species*

1. Litter species

These species do not ***live inside the burrow,*** but they live under the ***leaf litter.*** They are ***darkly pigmented*** and feed on ***decomposing litter.***

2. Topsoil species

These species live in ***permanent burrows.*** They are ***moderately pigmented*** and feed on ***decomposing litter*** and ***some soil.***

3. Subsoil species

These species live in ***deep permanent burrows.*** They are ***lightly pigmented.*** They feed on ***soil*** and ***organic matter*** in the soil.

3. Based on the Feeding Habits and Colour

Piearce (1972) has classified the earthworms into the following ***three*** groups based on their ***feeding*** habits and ***colour***:

1. *Pigmented,* ***litter feeders.***
2. *Less pigmented,* ***top soil feeders.***
3. *Less pigmented,* ***humus feeders.***

4. Based on the Behaviour

Based on ***morphological, behavioural, ecological*** and ***physiological characteristics, Perel*** (1977) classified the ***lumbricids*** into two. They are:

1. *Humus farmers*
2. *Humus feeders*

1. Humus farmers

These are feeding on ***coarse particles*** of plant debris that is ***slightly decomposed*** organic matter, e.g. *L. rubellus.*

2. Humus feeders

They feed on ***plant debris*** that is already ***much decomposed*** into fine organic matter e.g. *L. aporrectoidea.*

5. Based on the Habitat

Bouche (1971,1972,1977) classified earthworms into ***three*** forms. They are:

1. Epigeic forms or litter dwellers

2. Endogeic forms or the shallow soil dwellers

3. Anecic forms or the deep soil dwellers

This classification is mainly based on their ***dwelling habits.***

The classification of ***Bouche's*** is more widely used.

1. Epigeic Forms or Litter Dwellers

- ***Epigeic*** is a Greek word meaning "***upon the earth***".
- ***Epigeic*** worms live in decayed organic matter, not in soil.
- They do ***not have burrows.***
- They ***hide*** below the ***leaf litter.***
- They are ***small sized.***
- They are very ***active*** or ***quick moving.***

- They are good ***bio-degraders,*** feeding mainly on ***leaf litter*** (wastes). So they are called ***phytophagous.***
- The life cycle of epigeic species is ***short.***
- They ***grow*** and ***mature rapidly.***
- They have ***high reproductive rate*** (fecundity).
- They do not exhibit ***longitudinal contraction.***
- They have no ***hooked setae.***
- They are ***less*** sensitive to ***light.***
- They are ***darkly pigmented*** and ***homochromic*** (uniformly pigmented through out the body).
- ***Respiratory*** rate is ***high.***

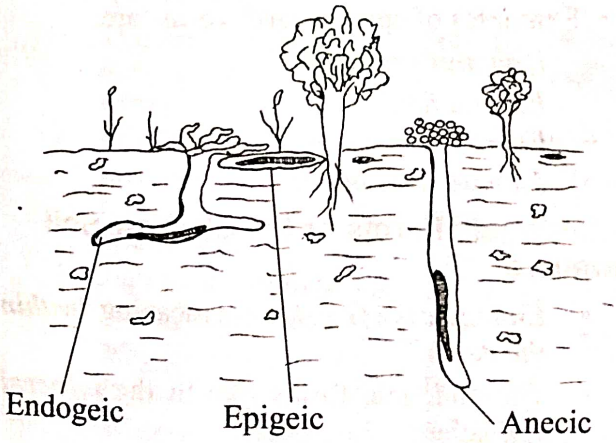

Fig.4.2: Habitat of earthworms.

- The cocoons survive the ***adverse*** seasons.
- As they cannot burrow into the soil, they do not have any effect on the soil structure.

According to ***Lavelle*** (1988) the main role of ***epigeic*** earthworm is ***fragmentation*** of the ***leaf litter*** and ***transformation*** into stabilized organic matter.

- These are suitable for ***vermicomposting*** and widely used.
- Epigeic worms are ***commercially*** produced.

The ***INORA*** (Institute of National Organic Agriculture) , Pune, also recommends epigeic worms because they consume all forms of garbage and multiply quickly.

Examples of epigeic earthworms are:

Perionyx excavatus
Eisenia fetida
Eudrilus eugeniae
Lumbricus rubellus.

2. Endogeic Forms or the Shallow Soil Dwellers

- ***Endogeic*** is a ***Greek*** word meaning ***"within the earth"***
- The endogeic forms live in the ***mineral soil*** layers.
- They have ***horizontal branched burrows.***

- These branched burrows are coated with ***mucus*** and ***mineral layer*** of soil.
- They are ***large sized.***
- They have ***sluggish*** movement.
- They are ***humus feeders.***
- They have ***no hooked*** setae.
- They are ***strongly*** sensitive to ***light.***
- They have ***no pigmentation.***
- ***Fecundity*** is limited.
- Growth and maturation are ***slow.***
- Respiratory rate is also ***slow.***
- Adverse condition is passed by ***quiescence.***
- Longitudinal contraction is ***less.***
- They feed on more ***mineral soil rich*** in ***organic matter***. So they are called ***geophagous.***
- The life cycle of endogeic forms have ***long period.*** These are also used for ***vermicomposting.***
- The ***endogeic*** earthworms have an important impact on the soil structure and have ***naturalistic*** relationship with ***soil microflora.***

Examples of endogeic earthworms are:

Pontoscolex corethrurus
Megascolex konkanensis
Polypheretima elongata
Metaphire posthuma
Octochaetona thurstoni.

3. Anecic Forms or the Deep Soil Dwellers

- Anecic is a Greek word meaning "***out of the earth***"
- The anecic earthworms live in ***deep*** soil in ***vertical*** and ***permanent burrows.***
- The walls of the burrows are lined by their ***excreta*** and ***mucus.***
- They ***move*** into the burrows ***slowly*** and are ***humus farmers.***
- They are good ***soil aerators.***
- In the night, they come to the surface and ***drag dead leaves*** into their burrows.
- They play an important role in burying surface litter.
- They are ***medium sized.***
- They are strong burrowers.
- The setae are ***hooked.***
- They exhibit ***longitudinal contraction.***
- They are ***moderately*** sensitive to ***light.***
- ***Pigmentation*** is ***dorsal*** and ***anterior.***
- ***Fecundity*** is ***moderate.***
- ***Growth*** and ***maturation*** are ***moderate.***
- Respiration is ***moderate.***
- They ***exhibit diapause*** during ***adverse season.***

- They feed on ***mineral soil*** and ***plant matters.*** So they are known as ***geophytophagous.***
- They can leave big ***mounded casts*** on the surface of the soil.
- The ***life cycle*** of anecic species are ***short*** and are ***slower to*** reproduce.
- The ***anecics modify soil structure*** through the ***construction*** of ***burrows*** and ***enhance*** the ***decomposition*** of plant debris.

Eg. Lampito mauritii
Lumbricus terrestris
Aporrectodea longa
Polypheretima elongata.

Table.4.1: Salient features of major ecological groups of earthworms.

Character	Epigeic	Endogeic	Anecic
1. Habitat	On the surface among leaf litter and excreta Eg. *Perionyx excavatus*	In mineral soil Eg.*Octocha-etona hurstonis*	Deep Soil in burrows Eg. *Lum-bricus terrestris*
2. Burrow	No burrow	Horizontal and branched burrow in topsoil	Permanent vertical deep burrow
3. Size	Small	Large	Medium

4. Pigmentation	Darkly pigmented	Absent	Dorsal and anterior
5. Movement	Fast	Sluggish	Slow
6. Food	Litter ***Phytophagous***	Litter, excreta and some soil ***Geophagous***	Mineral soil rich in organic matter ***Geophytophagous***
7. Life cycle	Short	Long	Short
8. Longitudinal contraction	Nil	Less	Developed
9. Hooked setae	Absent	Absent	Present
10. Sensitivity to light	Less	Strong	Moderate
11. Fecundity	High	Limited	Moderate
12. Maturation	Rapid	Slow	Moderate
13. Respiration	High	Slow	Moderate
14. Survival of adverse	***Cocoons***	By ***quiescence***	True ***diapause***

6. Based on the Food Materials

Based on the type of ***food materials,*** the endogeic earthworms are classified into ***three*** types. They are:

1. Polyhumic
2. Mesohumic
3. Oligohumic

1. Polyhumic

They feed on ***soil*** with high ***organic matter.***

2. Mesohumic

They feed on both ***mineral*** and ***organic matter*** in the top 15 cm of soil.

3. Oligohumic

They feed on ***soil*** with ***poor inorganic matter*** in the deeper layers of soil.

7. Based on the Place of Living

Based on the place of living, the earthworms are classified into ***four*** different types. They are:

Night crawlers
Field worms
Manure worms
Palouse worms.

Night Crawlers

Night crawlers live in ***lawns*** and ***fields.***

Night crawlers are known as ***great fish bait*** and more common earthworms in ***Northern States***.

They can grow a little more than a ***foot long***.

Their bodies have ***visible sections*** and a ***thick band*** across the middle.

These worms remain in ***cool areas*** to ***survive***.

*They **reproduce slowly**; So it cannot be used for vermicomposting.*

Field worms

Field worms are also known as ***garden worm***. They are ***smaller*** in length and diameter.

These worms are known to ***wriggle*** a lot.

When these worms are held on hand they may ***curl up***.

They are ***not prolific breeders***.

So they are not recommended for composting.

Manure worms

Manure worms are living in ***manures***. They are also found in soils containing large quantities of organic matter.

Manure worms are one of the most commonly ***farmed worms.***

They are used for ***vermicomposting***.

They eat a ***wide range*** of ***food materials***.

They are also adapted to ***different environments***.

Manure worms may be ***red*** or ***black*** in colour.

They are ***active breeders*** and ***multiply*** within ***short*** period.

The worms are very ***skinny*** and hard to hook for fishing bait.

They are ***fast diggers*** and can stretch their bodies deep into the soil.

Manure worms are commonly called ***bandlings, red wigglers*** or ***angler worm*** because of their wriggling reaction when handled.

Palouse worms

It is found in the ***Palouse region*** of ***Eastern Washington State*** in ***America***.

It is commonly called ***giant Palouse earthworm*** or ***Washington giant earthworm*** (*Drilolerius americanus*).

The ***Palouse earthworm*** is a rarest species and it is not like other earthworms.

It measures more than ***3 feet*** long on average.

The Palouse has a ***light skin-toned*** colour.

The worm is ***albino in appearance***.

The worm is believed to give off a ***scent*** similar to the lily flowers. So it is said to be ***lily worm***.

They prefer ***fertile soil***, which consists of ***volcanic ash*** and rich layers of ***organic matter***.

They are able to sustain in ***dry season***.

The worms live in ***deep burrows during summer, drought seasons*** and able to conserve water in its ***nephridia.***

Diversity and Abundance of Indian Earthworms

Earthworms are distributed all over the world, so earthworms are ***cosmopolitan***. *Species that have wide distribution are known as* ***peregrine.***

Earthworms are unable to live in ***deserts, snow clad mountains***, places covered with ***ice, acid*** or ***alkaline soils, sandy beaches*** and in places ***devoid of soil*** and ***vegetation*** areas.

The families *Megascolecidae* and *Lumbricidae* are widely distributed. *Lumbricides* are well known for their adaptation to new environments.

Eudrilus eugeniae is a well known ***peregrine species.***

The family *Moniligastridae* has also a wide distribution. In Asia, particularly South-East Asia *Megascolicids* are common.

The genera *Lumbricus, Aporrectodea, Allolobophora, Eisenia, Dendrobaena, Dendrodrilus, Bimastos* and *Octalasion* are peregrine.

Totally ***590 species*** and sub species of earthworms, belonging to ***67 genera*** and ***10 families*** of earthworms are identified in the

country. Out of these, ***88.8%*** earthworm ***diversity*** is found in India.

Majority of the Indian species have specific preference for natural habitats. The exotic species are also able to be successfully colonized different agro ecosystems due to their inherent ability to withstand disturbance and interference.

Julka (2001) has divided India into ***five agro-climatic zones*** based on the ***diversity*** and ***abundance*** of ***earthworms***.

1. *Mega-earthworm diversity zone*
2. *High-earthworm diversity zone*
3. *Medium-earthworm diversity zone*
4. *Low-earthworm diversity zone*
5. *Poor-earthworm diversity zone*

1. Mega-earthworm Diversity Zone

In ***West coast plain*** and ***Western Ghats*** a large number of earthworm species is found. Nearly half of the known Indian species are found here.

Eg. Drawida
Megascolex
Hoplochaetella
Notoscolex
Plutellus
Moniligaster
Lampito
Perionyx
Wahoscolex.

2. High-earthworm Diversity Zone

More than 100 native specices are seen in the ***Eastern Himalayan Agro-climatic zone***. This region occupies the ***second place*** in the earthworm diversity. Exotic peregrine species also live in this region.

Eg. Perionyx
Drawida
Plutellus
Tonoscolex.

3. Medium-earthworm Diversity Zone

Western Himalayan region and the ***Southern Plateau*** hills occupy the ***third place*** in earthworm diversity.

Eg . Perionyx
Eutyphoeus
Plutellus.

4. Low-earthworm Diversity Zone

In the ***East coast plains***, ***Gangetic plain*** and most of the ***Eastern*** and ***Western plateau region*** the earthworm diversity is ***low***.

Eg. *Drawida*
Octochaetona.

5. Poor-earthworm Diversity Zone

In ***Gujarat*** and ***Hill regions***, ***Punjab***, ***Haryana*** and ***Western Dry region*** (Rajasthan) the earthworm diversity is poor.

In this area intensive cultivation and the frequent use of ***chemical fertilizers*** degrade the soil is the reason for the ***poor*** distribution of the earthworms.

Exotic Species

Exotic earthworm species are native of foreign countries like ***China***, ***Australia***, ***NewZealand*** and ***Russia***.

The Exotic species are suitable for vermicomposting, because-

- They have ***rapid growth.***
- They feed on almost any ***organic matter***.
- They have a wide ***temperature tolerance***.
- They can be ***easily handled***.
- They have high ***reproductive rate***.

So they are ***imported*** from foreign countries.

Eisenia fetida

(Savigny,1826)

- A ***Chinese*** worm known under various common names such as ***red worm, compost worm, manure worm, brandling worm, tiger worm*** and ***red wiggler worm,*** is a species of earthworm adapted to decaying organic material.
- These worms thrive in ***rotting vegetation, compost and manure.***
- They are ***epigeic.***
- It is ***cosmopolitan*** in distribution.

- The body is ***long, slender, cylindrical*** and ***bilaterally symmetrical.***
- It is about ***10*** to ***13*** cm ***long*** and ***3*** to ***6*** cm in ***thickness.***
- The dorsal surface is ***light pink*** to ***brown*** and the ventral surface is ***pale*** and ***buffy*** in ***nature.***
- It has ***100-120*** segments.
- ***Clitellum*** is ***saddle shaped.*** It occupies in the segments ***26-32.***
- The ***cocoons*** can be stored by ***freezing.***
- It can tolerate a ***wide range*** of ***temperature*** from ***0*** to ***35⁰ C.***
- It is a ***commercially*** produced earthworm.
- It is suitable for ***vermicomposting.***

Eisenia hortensis
(Michaelson, 1890)

- It is an European ***night crawler.***
- It is widely distributed in ***India, North*** and ***South America, South Africa, Australia*** and ***California.***
- The body length is ***5 cm.***
- They are generally ***pink grey*** in colour with a banded or ***striped appearance.***
- The tip of the tail is often ***cream*** or ***pale yellow*** in colour.

- The species is usually found in ***deep woodland litter*** and ***garden soils*** that are rich in organic matter.
- It is used for ***vermicomposting*** and ***sewage beds.***

Endrilus eugeniae
(Kingberg, 1867)

- It is widely distributed in ***North America, India, South America, Africa*** and ***Newzealand.***
- It is commonly called ***African night crawlers.***
- They are larger ***epigeic species.***
- They live on the soil surface.
- They feed on the ***decaying plants*** and ***animal parts.***
- The body is ***long, slender, cylindrical*** and ***metamerically*** segmented.
- The ***posterior end*** tapers and becomes flattend.
- It is about ***9-16.5*** cm long and ***4-8*** mm in thickness.
- The ***anterior end*** is ***bright blue*** or ***green in colour*** and ***posterior*** end is ***faded.***
- The ***dorsal surface*** is ***red-brown*** in colour and ***ventral side*** is ***light brown*** in colour.

- It has ***145-203*** segments.
- ***Clitellum*** occupies ***14-17th*** segments.
- It is used for ***vermicomposting***.

Lumbricus terrestris (Linneaus, 1758)

- It is a large ***reddish worm*** native to ***Europe***.
- Now it is distributed all over the world.
- Common names are ***dew worm, night crawlers, scrub worm,*** etc.
- It lives in permanent vertical ***burrows*** upto ***4-6 feet*** deep.
- They are ***anecic*** and ***feed*** on ***soil*** bound ***decaying organic matters*** in the subsoil.

Indian Species (Native Species)

Native species are the Indian species,

In India the following species are used for vermicomposting.

Endrilus eugeniae
Eisenia fetida
Perionyx excavatus
Perionyx sansibaricus

P. excavatus and *P. sansibaricus* are ***endemic species***.

E. fetida is suited for vermiculture throughout the country. It has wide tolerance for temperature (5^0 C to 43^0 C).

E. eugeniae, *P. excavatus* and *P. sansibaricus* are better suited for the Southern parts where the summer temperature does not rise as high as in ***Central*** and ***North India***.

E.eugenia, *E.fetida* and *P.excavatus* have the following favourable ***character*** for vermicomposting.

- *Voracious feeders*
- *Feed a wide variety of organic wastes*
- *High growth rate*
- *Culturable*

Eisenia fetida, Lumbricus rubellus and *Pheretima elongata* - "They play the role of emergency ***clean up crew***"

South Indian Species

Moniligaster perrier
Drawida willsi
Megascolex mauritii
Endrilus eugeniae
Perionyx excavatus
Perionyx sansibaricus

North Indian Species

Metaphire posthuma
Metaphire birmanica
Metaphire anomala
Polypheretina elongata
Lampito mauritii
Perionyx sansibaricus

Eutyphoeus incommodus
Eutyphoeus pharpingianus
Eutyphoeus orientalis
Eutyphoeus waltoni
Pellogaster bengalensis

Perionyx excavatus

- They are commonly called ***Indian blue worms.***
- It is an ***epigeic*** earthworm.
- It lives in ***organic wastes.***
- It is a ***commercially*** produced Earthworm.
- It is a ***North Indian*** species.
- They belong to the *Perionyx* genus.
- They originated from the ***Himalayan mountain.***
- The body is elongated with ***115-178 segments.***
- It is about ***3*** to ***18 cm*** in ***length*** and ***2.5*** to ***7 mm*** in ***width.***
- The ***dorsal side*** is ***violet-red*** with ***blue iridescence*** and ***ventral side*** is ***pale cream*** in colour.
- ***Clitellum*** occupies ***13-18 segments.***
- This species is particularly good for vermicomposting in ***tropical*** and ***subtropical regions.***
- They prefer the ***loose topsoil layer*** and ***leaf litter*** rich in organic matter.

- They have ***no permanent burrows.***
- They are commonly found in ***rainforest vegetation.***

Moniligaster perrier and *Drawida willsi*

- They are the ***South Indian*** worms.
- The colour of the worm is ***greenish brown.***

Megascolex mauritii or *Lampito maurittii (Kingberg-1867)*

- They are commonly found in ***South India.***

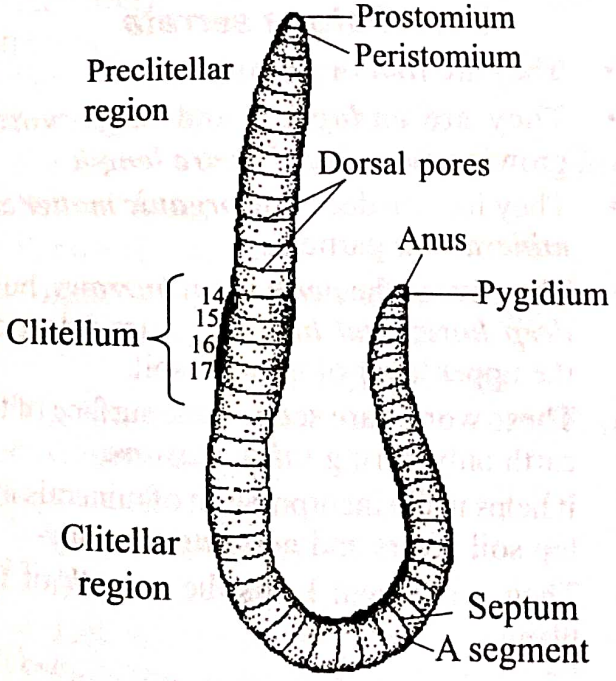

Fig.4.3: Earthworm - Megascolex.

- They are ***nocturnal in habit*** and ***light yellowish*** in colour.
- The body is ***long, slender, cylindrical*** and ***bilaterally symmetrical.***
- It is about ***8-21 cm long*** and ***3-4 mm width.***
- It has ***100-125 segments.***
- The ***clitellum*** occupies ***14 -17th*** segments.
- The food of the earthworm consists of ***decaying animal*** and ***vegetable matters*** contained in the soil.
- The species are good for ***vemiculture.***

Octochatona serrata

- They are ***Indian*** worms.
- They are ***endogeics*** and large worms growing more than ***1 metre length.***
- They feed on decaying ***organic matter*** and ***mineral soil*** particles.
- They live in the ***permanent burrows***, build ***deep horizontal burrows*** extending upto the upper layer of mineral soil.
- These worms are seen on the surface of the earth only during ***rainy seasons.***
- It helps in the incorporation of minerals into top soil layers and ***aerating*** the soil.
- Their movement helps the ***growth*** of the plants.

5. Collection of Earthworms

The process of gathering earthworms is known as collection of earthworm.

Need for Collection

Earthworms are collected for the following purposes:

For *vermiculture*
For *observation*
For *morphological* and *anatomical studies*
For *fish bait*
For *medicinal purposes*
For *dissection in schools* and *colleges*
For *research purposes.*

Methods of Collection

The methods used for the collection of earthworms are:

1. *Manual method*
2. *Chemical method*
3. *Electrical method*
4. *Vibration method*
5. *Tunnel trap method*

1. Manual Method

The manual method is the collection of earthworms by digging the soil and picking worms by hands. This is one of the best method of collection of earthworms because it reduces ***damage*** and ***mortality***.

Using the tools, the soil is dug for sufficient depth and the worms are picked carefully by hands. Avoid sharp edged tools because they affect the worms.

The earthworms are collected from the natural environments like ***grasslands, orchards*** and ***forests.***

Some amount of ***parent soil*** is collected along with the worms. The parent soil will help to the ***acclimatization*** of the worms in the new environment and helps in the multiplication of ***microorganisms*** on which the worms are feeding.

2. Chemical Method

Collection of earthworms using ***chemicals*** *is called chemical method.*

Formaldehyde, is used for the collection of earthworms.

0.5% formalin is applied to the soil.

It causes ***irritation*** to the worms. So they come to the surface of the soil.

The worms are picked gently by hands.

1.5 g/litre of ***potassium permanganate*** solution is also used to bring the worms to the soil surface.

The ***weak formalin*** solution is less ***toxic*** than potassium permanganate solution.

The solution from the residue, remaining after the extraction of oil from the seeds of the tree, *Bassia longifolia* is used to bring the worms to the soil surface.

The suspension of ***mustard powder*** is also used in the soil to bring the worms to the soil surface.

The ***Allyl isothiocyanate*** (AITC) has also been used for earthworm collection.

3. Electrical Method

Electrical shocks bring the worms to the surface of the soil.

An ***electrode*** of ***8-10 mm*** diameter and ***75 mm*** long using ***220-240*** v at 3-5A is useful to bring out the worms. Sometimes current penetrate deep into the soil and kills the worms.

4. Vibration Method

Passing vibration into the soil is found to bring earthworms to the soil surface.

Vibrations are made by a ***flexible rod***. The rod has been inserted into the soil. This method is practiced in ***United States***. Vibration method is useful in collecting some species of *acanthodrillids.*

5. Tunnel Trap Method

Collecting earthworms in a capture pot buried underground is called ***tunnel trap method.***

The tunnel trap consists of a ***capture pot,*** a ***lid*** and a ***PVC tube.***

The ***capture pot*** is a ***plastic pot.*** It is closed by a ***perforated lid.***

The lid is provided with ***spikes*** to prevent the ***steping*** of animals.

A ***hole*** is made in the neck of the capture pot.

One end of a ***PVC tube*** is inserted horizontally in the hole.

The other end is kept immersed in the soil, and is buried under the soil.

The PVC tube is filled with ***soil*** and ***chemoattractants.***

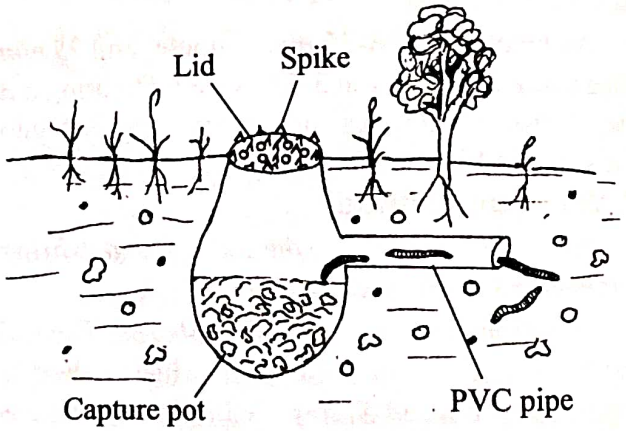

Fig.5.1: Tunnel trap.

The pot is ***buried*** under the soil.

The capture pot can be filled with ***soil*** and ***food*** for the earthworms to survive for a long period.

Only half of the capture pot is filled with suitable medium to prevent the ***captured earthworm*** back to the field.

Surface migrating earthworms are ***attracted*** by the ***chemoattractant*** into the traps through ***PVC tube.***

Tunnel traps have been successfully used for collecting worms from the field.

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6. Preservation of Earthworms

Preservation is the storage of earthworms without decay.

For preservation the earthworms are ***killed*** using ***70% ethyl alcohol.***

There are two types of preservation. They are:

1. Dry preservation

2. Wet preservation

1. Dry preservation

In ***dry preservation,*** the killed earthworms are kept in between folds of ***blotting paper*** in a straight position. It is a ***temporary preservation.***

2. Wet preservation

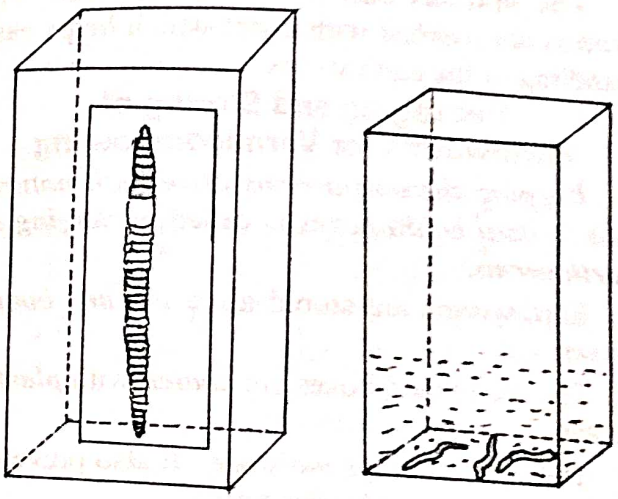
The earthworms are ***killed*** in ***70% ethyl alcohol.*** The worms are then transferred to a *vessel* with flat bottom containing ***9% formalin*** and kept for a day.

Any distortion from a straight position has to be corrected at this pre final stage.

The worms are ***stored*** as such in the *glass jar* or they are mounted on ***glass plate.***

The earthworms are mounted on a *glass plate.*

Finally the glass plate is placed in a suitable ***vertical cylindrical*** or ***rectangular glass*** jar containing adequate ***9% formalin.***



Dry Preservation **Wet Preservation**

Fig.6.1: Preservation of earthworm.

For long-term use, the preservative has to be changed at least once in a year.

The preserved worms are used to study the ***morphological*** and ***anatomical*** structures.

In schools and colleges the earthworms are used for ***dissection.*** The earthworms are brought to the ***laboratory*** and are dropped into a glass container filled with ***70% alcohol.***

After 30 minutes, the earthworms are whipped with a glass rod. This helps to ***aggregate*** the mucus ***into a ball.***

The ***mucous ball*** has to be removed. The worms are ***washed*** with water which helps easy handling of the earthworms.

Packaging and Storing of Earthworms for Vermicomposting

Keeping the earthworms alive with natural soil in card board boxes is called ***packaging of earthworms.***

Earthworms are stored alive in ***card board boxes.***

The card board boxes are ***coated*** with ***plastic*** or ***wax.***

The coating keeps ***moisture.*** It also prevents the ***eating*** of boxes by the worms.

Pin holes are made on the box for ***aeration.***

Boxes holding about ***50*** to ***1000*** worms are suitable for packaging.

The containers are available from various ***suppliers*** or it can be purchased from a wholesale company.

Worms should always be stored in ***cool*** and well ***shady locations.***

Boxes should be securely tied or pasted with heavy ***shipping tape*** and clearly marked on the out side.

Live earthworms should be handled with care and ***not*** to be ***exposed*** to ***extreme heat*** or ***cold.***

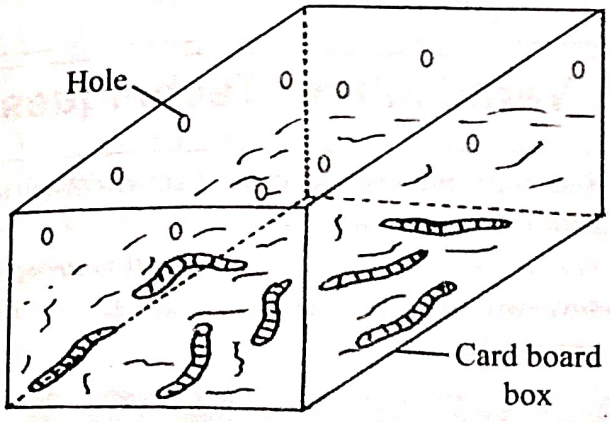


Fig.6.2: A package of earthworms.

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7. Vermiculture Techniques

Rearing and multiplication of earthworms constitute vermiculture.

The vermiculture is the ***artificial rearing*** *of earthworms in controlled condition to multiply the population.*

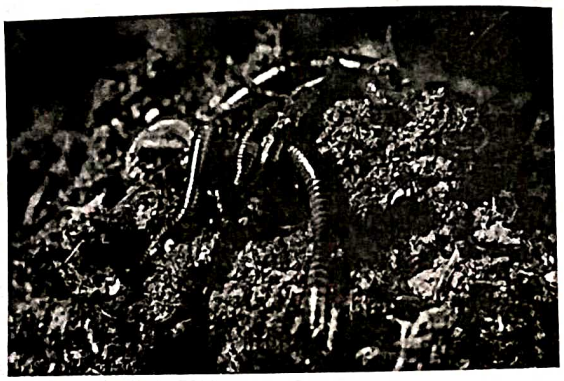


Fig.7.1: Vermiculture.

Vermiculture focuses on the ***production of worms*** rather than vermicompost.

The requirements for ***vermiculture*** differ from that of vermicomposting.

The goal of vermiculture is to increase ***the number of worms.***

Need for Vermiculture

- To get plenty of earthworms.
- For ***vermicomposting.***
- For ***inoculating*** earthworms into agricultural and horticultural fields (***ex-situ vermiculture***).
- To get ***vermicasts.***
- To get ***vermicompost.***
- To get ***vermiwash.***
- To use earthworms as ***feed*** in aquaculture, dairy farming, poultry, etc.
- To use earthworms as ***bait.***
- To use earthworms as ***medicines.***

Steps Involved in Vermiculture

The vermiculture involves the following steps:

1. *Site selection*
2. *Species selection*
3. *Vermibed*
4. *Feedstock*
5. *Inoculation of earthworms*
6. *Feeding*
7. *Harvesting.*

1. Site Selection for Vermiculture

1. The site should be a ***slope area.***
2. It should be on an ***elevated*** place.
3. There should not be any ***stagnation of water.***
4. There should be ***drainage*** facility.
5. ***Thatched huts*** should be raised over the place where vermiculture is done.
6. Plant and animal ***residues*** should be available near the site.
7. ***Shady areas*** of trees can be used.
8. ***Transport facility*** should be there for daily visit, marketing, etc.

2. Species Selection

The species should possess the following characters:

1. The worms should have ***short life cycle.***
2. ***High*** rate of ***reproduction*** and ***growth.***
3. They should feed ***voraciously.***
4. High output of ***wormcasts.***
5. Wide range of ***feeding.***
6. ***Resistance*** to disease.
7. ***Adaptable*** to climatic changes.

The ***biology*** and ***ecology*** of the earthworms should be known.

Fig.7.2: Earthworm.

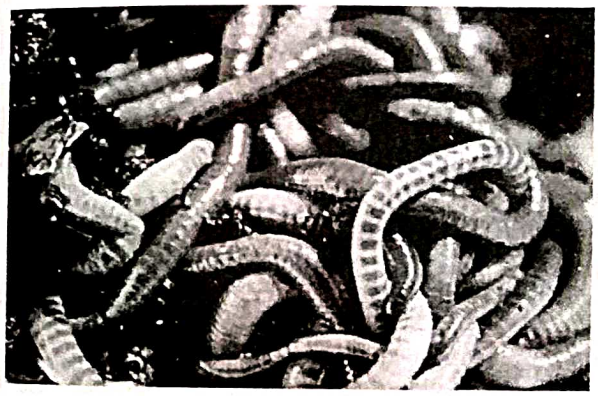


Fig.7.3: Earthworm for vermiculture.

Suitable species used for vermiculture

Eisenia fetida
Dendrobaena veneta
Perionyx excavatus
Lampito mauritii

Metaphire houlleti
Lumbricus rubellus
Perionyx sansibaricus, etc.

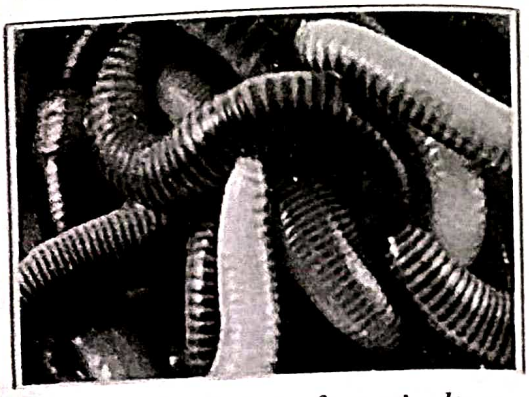


Fig.7.4: Heroes of vermiculture.

3. Vermibed

The earthworm is reared on a vermibed. ***Vermibed*** is the substratum on which the earthworms live, work and multiply.

It is the ***house*** for the earthworms.

Vermibed Materials

The materials used for the culture of earthworms constitute ***vermibed materials***.

The success of vermiculture depends on the selection of suitable ***vermibed materials***.

The following materials can be used for making vermibed.

Shredded cardboard
Shredded paper waste
Packed papers and boards
Grass clippings
Weeds
Dried leaves

Saw dust
Coir waste
Coconut husk
Paddy husk
Crushed egg shells
Grain husks
Coffee grounds
Used tea leaves
Crop wastes
Hay
Straw
Crop residues

Fig.7.5: Hay.

Fig.7.6: Paper wastes.

Fig.7.7: Grass clipppings.

Fig.7.8: Coconut husk.

Good Qualities of Vermibed Materials

- Selection of suitable bed materials is a key to successful vermiculture and vermicomposting.

- The bedding materials should be ***light*** enough to allow air and water.
- It should not be ***packed down***.
- It should provide adequate ***temperature*** 25-30° C.
- It should have high ***absorbency***.
- It should retain ***moisture 75 to 90%***
- It should allow ***air*** penetration.
- It should contain more ***carbon*** source.
- It should contain ***less protein*** source.
- Excess protein will produce more ***heat*** and ***ammonia*** which will kill the worms.
- It should provide a good ***medium*** on which the worms must live and work.

Containers for vermibed

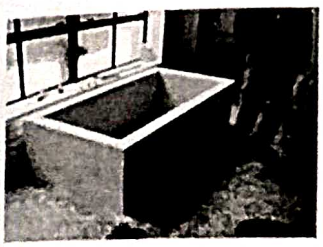
The vermibed is prepared in a ***pit*** or on ***open ground*** or in ***containers***.

The following containers can be used.

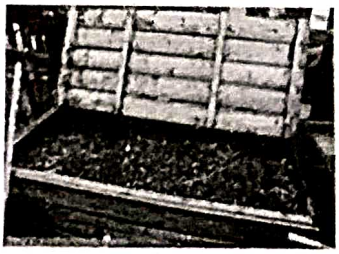
- *Plastic bucket*
- *Plastic basin*
- *Wooden box*
- *Concrete tank*
- *Well rings*
- *Card board box*

Circular cement tub

Bucket



Rectangular cement tub



Wooden box

Fig.7.9: Containers used for vermiculture.

When culture is made in a pit, a ***rectangular pit*** is dug. The floor should have a ***slope*** on one side to drain excess water. The pit is lined with a ***polythene*** sheet to prevent the escape of worms.

When containers are used, a ***hole*** is made at the bottom to drain water.

Preparation of Vermibed

1. The preparation of vermibed is started with a ***basal layer*** at the bottom of the container.

It includes:

- A layer of broken ***bricks*** or ***pebbles*** at the bottom.
- A layer of ***coarse sand***
- A layer of ***loamy soil.***
- A layer of ***coconut husk.***

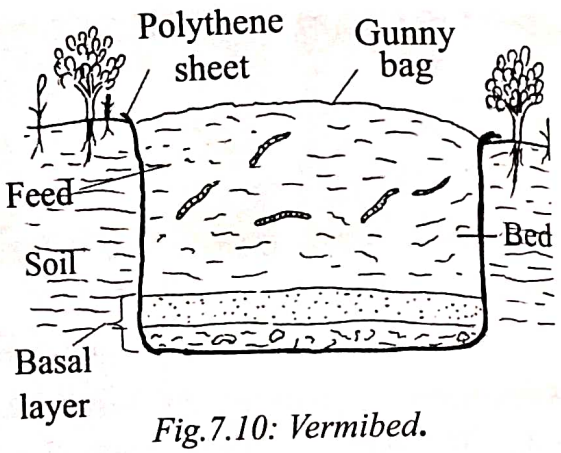


Fig.7.10: Vermibed.

The basal layer ***filters*** out excess water and drains excess water. It also provides shelter for the worms.

2. Then a layer of ***saw dust*** or ***shredded cardboard*** or ***shredded paper*** or ***grass clippings*** or ***crop residues*** is laid.

3. Above this a layer of ***hay*** or ***straw*** is spread.

4. It is covered with broad leaves such as ***coconut leaves, palmyrah leaves*** or ***gunny bag.***

5. Above each layer ***water*** is sprinkled.

6. Watering is continued on alternate days.

7. The above set up is the ***vermibed.*** It is allowed to ***decompose*** for 15 days.

8. The total height of the vermibed should be ***4 inches.***

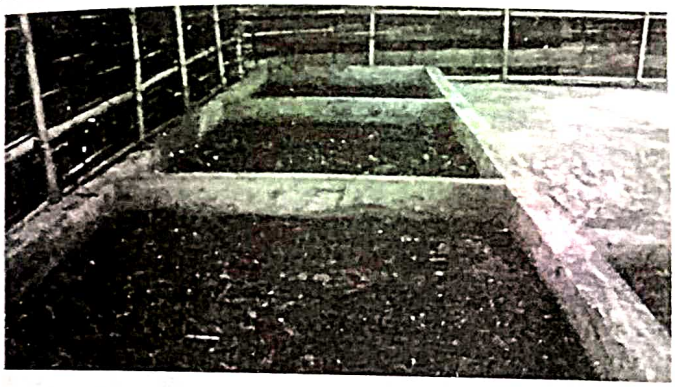


Fig.7.11: Pit method of vermiculture.

4. Feed stock

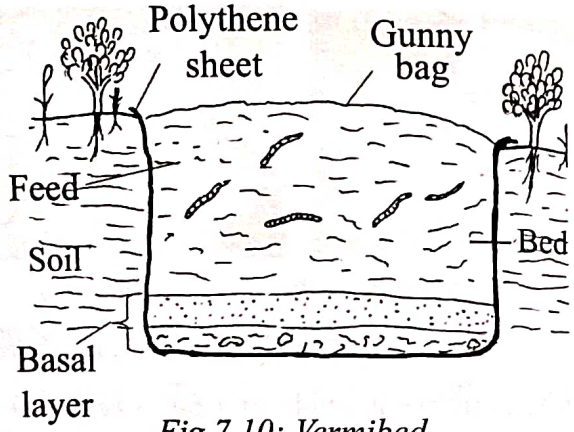
Earthworm is a ***detritivore*** and ***omnivore.*** It feeds on plant and animal materials.

The following materials are selected for feeding earthworms:

- *Cow dung*
- *Sheep dung*

It includes:

- A layer of broken ***bricks*** or ***pebbles*** at the bottom.
- A layer of ***coarse sand***
- A layer of ***loamy soil.***
- A layer of ***coconut husk.***



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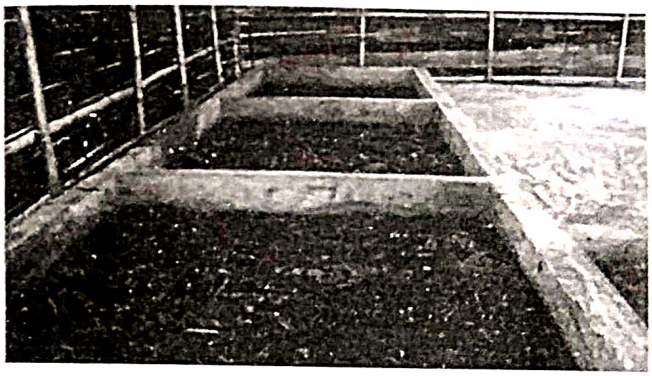

Fig.7.11: Pit method of vermiculture.

4. Feed stock

Earthworm is a ***detritivore*** and ***omnivore.*** It feeds on plant and animal materials.

The following materials are selected for feeding earthworms:

- *Cow dung*
- *Sheep dung*

- *Pig dung*
- *Discarded food items*
- *Vegetable wastes*
- *Fruit peels*

The feed items are selected and mixed into a ***heap***. It is watered and allowed to decompose for 15 days. The ***microorganisms ferment*** and ***digest*** the materials.

Fig.7.12: Cow dung and sheep dung.

The fermentation produces ***heat***. Heat increases. In 15 days the heat is decreased to 25 to 30°C. The ***predigested*** feedstock is used to feed the worms.

5. Inoculation of Earthworms

About 100 earthworms are introduced on the pre- decomposed vermibed after removing the covering.

The worms penetrate into the bed.

Types of Vermiculture

There are two types of vermiculture namely:

1. Monoculture

2. Polyculture

1. Monoculture

In monoculture method only ***one species*** of earthworm is cultured.

2. Polyculture

In polyculture method ***epigeic*** and ***anecic*** species of earthworms are used jointly.

6. Feeding

The earthworms are fed-with ***pre-decomposed*** feedstock. The feed is ***loaded*** on the top of the vermibed to a thickness of 8 inches.

The entire feed may be loaded at one time or at instalments of ***thrice*** in a week.

Watering is continued daily or on alternate days.

The entire system is again covered by gunny bag or broad leaves.

The earthworms ***breed*** and ***multiply*** in the vermibed.

Do Feed Worms

- *Vegetable scraps*
- *Crop waste*
- *Tree, bush leaves and grasses*
- *Fruit scraps and peels*
- *Moldy bread and grains*
- *Used tea leaves*
- *Non-greasy food leftovers*
- *Coffee grounds*
- *Crushed egg shells*
- *Shredded paper products*
- *Shredded card board boxes*
- *Manures*

Dont Feed Worms

- *Don't **overfeed citrus** products*
- *Meat, fish*
- *Greasy foods*
- *Dairy products*
- *Twigs and branches*
- *Dog faeces*
- *Cat faeces*
- *Poultry manures*

Suitable Condition Required for Earthworms

1. Hospitable ***bed***
2. Feeding
3. Moisture 75-90%
4. Adequate ***aeration***
5. Optimum temperature ***25-30°C***
6. ***Neutral*** pH
7. The ***salinity*** of the soil should be less than 0.5%.

7. Harvesting

Harvesting is the collection of earthworms from the culture bed. The worms are ready for harvest in two months.

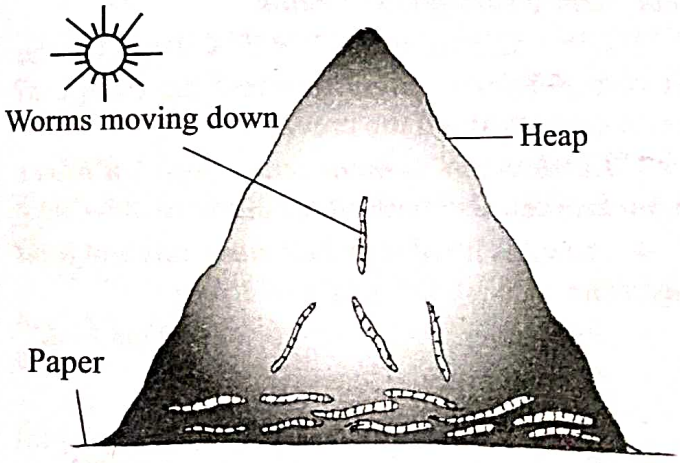

Fig.7.13: Harvesting the earthworms.

Spread a ***paper*** on the ground and empty the contents of the tank slowly in sunlight making a ***pyramid*** like heap.

Let this heap remain in ***daylight*** for about ***half to one hour***. A ***electric light*** can also be used. This will make the earthworms to penetrate deep and reach the bottom.

Now the upper layers of organic manure can be removed.

Later the earthworms are harvested from the bottom and they are separated from one another.

Vermiculture

Process

1. Select a ***cool, shady*** place away from ***direct heat, strong sunlight*** and ***rains***.

2. Dig a pit measuring 2 × 2 × 2ft. Line the pit with ***polythene sheet*** to arrest the escape of earthworms through the crevices.

3. ***Earthen pot, cement tanks, wooden boxes*** or ***buckets*** can also be used to culture earthworms.

4. The pit is filled with ***bed materials*** and ***food materials*** with a total height of ***1 foot***.

- First layer - Broken bricks or pebbles.
- Second layer - Coarse soil.
- Third layer - Loamy soil.
- Fourth layer - Coconut husk, saw dust, paddy husk
- Fifth layer - Hay straw

- Dampen the bed by ***sprinkling water***.
- All the above layers form a ***basal layer***. The height of the basal layer should be ***4 inches***. It ***filters*** and ***drains*** excess water. It also provides ***sheller*** to worms.

5. Above the basal layer ***bed materials*** are loaded to a height of 4 inches. The bed materials include

Shredded card board box
Shredded paper
Grass clippings
Coir waste,
Saw dust
Coconut husk

6. Above this layer ***water*** is sprinkled.

7. Microorganisms ***ferment*** the bed materials. As a result ***heat*** rises. After two weeks, the heat begins to decrease.

8. By the 2^{nd} to 3^{rd} weeks, production of heat inside the pit will cease and will come to 25 to 30^{0} C .

9. Incase no warmth is felt by hands, understand that the predigested vermibed is ready for inoculation of worms.

10. The feed of earthworms include the following raw materials

- ***Cow dung***
- ***Green foliage***

- ***Vegetable remnants***
- ***Discarded parts of fruits***
- ***Droppings of horses, asses, pig, sheep***
- ***Biogas slurry***

The feed materials are mixed, heaped and allowed to decompose for 15 days in a cool, shady place.

11. Release 50 ***earthworms*** per 10 kg of bed on the ***top*** of the vermibed.

12. The earthworms will ***penetrate*** in to the ***bottom.***

13. Predecomposed feed is loaded on the top of the vermibed- Feeding is done thrice in a week.

14..Cover the surface with jute bags and keep them wet by ***sprinkling water.***

15. The vermibed is turned upside down once in 15 days (fortnightly)

16. The earthworms ***breed*** and ***multiply in the vermibed.***

17. The earthworms are ready for harvest in 60 days.

Factors Influencing the Culture of Earthworms

1. Oxygen

Earthworms are ***aerobic, air-breathing*** animals. They absorb oxygen directly through their ***skin.***

Oxygen is dissolved into the mucous covering of the earthworm. Then the oxygen passes through the skin and the walls of ***blood capillaries*** to the ***blood.***

In the blood the oxygen is picked up by hemoglobin. It is then carried throughout the body.

Earthworms require ***moderate*** amount of oxygen.

2. Moisture

The earthworms need ***moist environment.***

The ideal moisture range for most of the earthworm species is from ***75-90%.***

George (2004) found that 75 to 80% moisture content is suitable.

According to ***Dominguez*** and ***Edwards*** (1997) 85% is optimum.

3. Temperature

In vermiculture the temperature is kept ***at 25-30°C.*** Most of the species used in vermicomposting require ***moderate temperature*** from ***25*** to ***30°C,*** while tolerances and preferences vary from species to species.

In general the earthworms tolerate ***cold*** and ***moist*** conditions far better than ***hot*** and ***dry*** condition

4. Light

Earthwoms need cool, shady places.

Earthworms are sensitive to ***light.*** The ***photo-receptor cells*** of the earthworms detect light and move deep into the soil to avoid light. The deep burrowing ***anecics*** and ***other species*** emerge out to the ***surface*** only at ***night.***

5. pH

Earthworms are sensitive to changes in pH. They prefer ***neutral pH.*** Earthworms find it difficult to survive with pH below 6 and above 7.6.

6. Salinity

The optimum salinity of the soil should be 0.5%. High salinity will kill earthworms.

7. Predator control

Earthworms are ***preyed*** upon by many species of *flatworms, ants, centipedes, beetles, birds, toads, salamanders, snakes, moles, cats, rats, dogs,* etc.