Lesson 3

Materials for vermicompost. Substrates, beds, and earthworms

Learning outcomes

- The trainee knows the substrates commonly used in vermicompost production.
- The trainee explains the substrates that increase or decrease the efficiency in worm compost production.
- The trainee explains the materials to be used to balance the pH of the environment in vermicompost production.
- The trainee knows the physical parameters (size, temperature, humidity, etc.) that the substrates must have for the earthworms to work efficiently.
- The trainee explains the bed term.
- The trainee knows the substrates that should not be present in the production environment.
- The trainee knows the common materials used for bed and their properties.
- The trainee knows the earthworm species used in vermicompost production.
- The trainee compares the physiological characteristics of the earthworm species used in vermicompost production and the characteristics of their living environments.

- The trainee determines the appropriate bed materials, earthworms and substrates for vermicompost production, taking into account the characteristics of the environment.

Instructions for the trainer

Trainer, explain to students the terms commonly used in vermicomposting using Supplementary Material 1 (SM-1). The setup of the presentation was designed to display first the image of vermicompost production and then the term associated with the image.

- The instructor shares theoretical knowledge through presentation.
- The trainer shows the students the materials brought to the class and asks whether they are suitable for worm compost production.
- The trainer asks the trainees to mark materials suitable for vermicomposting using the SM-2.
- The trainer asks the trainees to put the necessary components for vermicompost production into the bin in the appropriate order.

Basic requirements:

Bokashi bin, dairy products, leaves, vegetable waste, meat, paperboard, paper waste, egg shells, cattle dung, plastic bag, coffee grounds, citrus waste, sawdust, bark-softwoods, corn-stalks, projector, computer, disposable gloves, paper checklist (SM-2)

3. Materials for vermicompost. Substrates, beds, and earthworms

3.1. Substrates

Vermicomposting substrate can be made from a variety of materials. Organic wastes are an important substrate for vermicomposting in order to control waste while also producing alternative manure for soil fertility and plant growth. The waste is decomposed by earthworms through feeding, fragmentation, aeration, turnover, and dispersion, as well as enzymatic digestion by the associated microbes. According to estimates, India has the capacity to produce 4.3 million tons of compost per year. Municipal solid waste is a problem, and solid municipal wastes containing at least 35%–40% organic material can be used for vermicomposting. City garbage, agricultural waste, industrial organic waste, cow and other cattle dung, kitchen waste, coir pith, grass, rice straw, food, animal waste, sewage waste, soil, etc. are the main substrate for Vermicomposting. Scotch broom (Cytisus scoparius), an invasive plant native to the Mediterranean basin, is a symbiotic nitrogen-fixing plant with high phosphorus, calcium, and potassium levels that can be used as a substrate for vermicomposting. It also has a high polyphenol content, making it phytotoxic. This vermicomposting procedure significantly reduces phytotoxicity, allowing this invasive plant to be used as manure. Many crop diseases are hosted by Ageratum conizoides, and Lantana camara is a weed plant that contains toxic phytochemicals that are toxic to grazing animals. These weed plants are also used in vermicomposting, which reduces the occurrence of plant disease and plant toxicity.

Both cow and goat dung is used for vermicomposting but it has been studied with P. excavatus that cow dung provides more nutrition to the vermicomposting substrate than the goat.

Poultry waste contains a diverse mixture of litter that is used for vermicomposting. Intensive breeding causes a huge deposal of bedding mixture, feather, food material, manures from the farms of broiler and layers of chicken, ducks, turkeys, quails, etc. Poultry waste contains a high amount of ammonia and organic salt which kills worms so, before the composting process starts, the addition of freshly prepared $CaCO_3$ is needed to neutralize them.

Fruits are the most wasteful food item due to an inefficient post-harvest system. Approximately 2.7 metric tons of bananas go to waste due to a lack of a cold chain system. Banana stems also contribute significantly to agricultural waste. Papaya's seed, skin, pomace, and rind contain a high amount of organic matter such as carotenoids, dietary fibers, vitamins, enzymes, carbohydrate, oils, and polyphenols. Together with these biologically active metabolites, a good substrate for vermicomposting that will form good peat-like manure can be produced. Furthermore, crop residue from cauliflower, cabbage, broccoli, and other crops is collected after harvesting and used as vermicomposting material. However, this materials should come from a field that has not been treated with insecticides or pesticides.

Paper is a versatile waste generated by municipal solid waste and industries. India accounts for approximately 1.5% of total global paper and paperboard production. There is a risky situation because there is no effective paper collection and management system. Paper is generally made from plants and contains a significant amount of organic material, making it an excellent material for composting.

Rice straw, mycostraw that is the residue after mushroom cultivation is left as waste material but is full of nutrition. So can also be a hospitable bedding material for vermicomposting. Rice hulls ash, coconut husk, tea waste, cotton balls are also used as the bed of vermicomposting [19]. However, the substrates (nutrients) commonly used in vermicomposting;

Kitchen Waste: Kitchen wastes such as vegetable and fruit peels, vegetable scraps, coffee grounds, and tea bags are suitable materials for compost.

Garden Waste: Garden waste such as grass cuttings, pruning residues, leaves, plant stems and flower residues can also be used in composting.

Leaves: Leave collected from the garden in autumn are valuable compost material.

Wood Crumbs: Wood chips, wood scraps, and wood pellets can also be used for compost.

Paper and Cardboard: Especially recyclable paper and cardboard materials can be suitable for composting. However, the use of colored and glossy paper should be avoided.

Animal Manure: Some animal manure, especially the manure of grazing animals such as horses, chickens, cows, and horses, can be used in composting. However, ineffective animal manure such as dog and cat manure should not be preferred in composting.

Food Waste: Food waste and vegetable waste are organic materials that can be used in compost.

Coffee Pulp: Used coffee pulp is a valuable material with its nitrogen content in compost.

Egg Shells: Egg shells are a suitable material for compost with their calcium content.

Grass Cutting: Grass cutting can be used as green material and with its nitrogen content it promotes rapid decomposition of the compost.

In addition, tea bags, hazelnut pulp and shell, indoor plants, stalks and straw, grain stalks, cotton and wool pieces, wood ashes, pistachio processing wastes, olive oil production wastes (except black water), tea processing wastes, fruit juice factory pulps, sugar beet heads and leaves, etc. materials can be counted.

Among the materials to be used for composting, it should be noted that animal wastes such as meat or fish residues, milk, and dairy products should not be used. Also, painted or treated wood, wastes containing chemicals, and diseased plant materials should not be used in composting.

For healthy and high-quality compost, a balanced carbon/nitrogen ratio and a variety of organic materials should be used.

In general, compost contains food and plant waste, recycled organic matter, and fertilizers. The compost mix is also rich in plant nutrients and beneficial organisms such as bacteria, protozoa, nematodes, and fungi. Composting is an effective, environmentally beneficial method to reduce dependence on commercial chemical fertilizers. It is an important method to increase soil fertility in landscaping, urban agriculture, gardens, horticulture, and organic farming.

3.2. Beds

Bedding represents a suitable living environment for worms. Earthworm bedding should retain moisture, remain loose, and not contain much protein or organic nitrogen compounds that readily degrade (Table 2). These compounds would quickly degrade and release ammonia, and this might temporarily increase the pH of bedding material to 8 or higher, which is not good for the worms. The bedding material will heat up in the beds if it has not already substantially decomposed or if it contains excessive amounts of readily degradable carbohydrates. These conditions can cause the worms to die. Make sure all bedding materials are fully aged or composted before use. Place moist bedding in the beds to a depth of 6 inches. After adding worms, keep the upper 4 inches of the bedding moist but not soggy [20, 21]. Bedding is a material that provides the worms with a relatively stable habitat with following characteristics:

High absorbency: As earthworms breathes through their skins and therefore bedding must be able to absorb and retain water fairly well. Worms die if their skin dries out.

Good bulking potential: Worms respire aerobically and different bedding materials affect the overall porosity of the bedding, including the range of particle size and shape, the texture, and the strength and rigidity of its structure. If bedding material is too dense or packs too tightly, then the flow of air is reduced or eliminated. This overall effect is referred as the material's bulking potential.

Table 2. **List of some of the commonly used earthworm bedding material [20]**			
Bedding Material	**Absorbency**	**Bulking Potential**	**C:N Ratio**
Horse manure	Medium-good	Good	22–56
Peat moss	Good	Medium	58
Corn silage	Medium-Good	Medium	38–43
Hay–general	Poor	Medium	15–32
Straw–general	Poor	Medium-Good	48–150
Straw–oat	Poor	Medium	48–98
Straw–wheat	Poor	Medium-Good	100–150
Paper from municipal waste stream	Medium-Good	Medium	127–178
Newspaper	Good	Medium	170
Bark–hardwoods	Poor	Good	116–436
Bark–softwoods	Poor	Good	131–1285
Corrugated cardboard	Good	Medium	563
Lumber mill waste–chipped	Poor	Good	170
Paper fibre sludge	Medium-Good	Medium	250
Paper mill sludge	Good	Medium	54
Sawdust	Poor-Medium	Poor-Medium	142–750
Shrub trimmings	Poor	Good	53
Hardwood chips, shavings	Poor	Good	451–819
Softwood chips, shavings	Poor	Good	212–1313
Leaves (dry, loose)	Poor-Medium	Poor-Medium	40–80
Corn stalks	Poor	Good	60–73
Corn cobs	Poor-Medium	Good	56–123
Paper mill sludge	Good	Medium	54
Sawdust	Poor-Medium	Poor-Medium	142–750
Shrub trimmings	Poor	Good	53
Hardwood chips, shavings	Poor	Good	451–819
Softwood chips, shavings	Poor	Good	212–1313
Leaves (dry, loose)	Poor-Medium	Poor-Medium	40–80
Corn stalks	Poor	Good	60–73
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Low protein and/or nitrogen content/high Carbon: Earthworms consume their bedding as it breaks down and it is very important for this process to be slow. High protein/nitrogen levels can result in rapid degradation of bedding and its associated heating, creating inhospitable or fatal conditions. High carbon content is required as earthworms and microbes in the feed mixtures activate microbial respiration and degradation of organic wastes, thereby increasing the loss of organic carbon during the vermicomposting process [22]. Various bedding material according to absorbency, bulking potential and C:N are enlisted in Table 2.

Vermiculture bed: Vermiculture bed can be prepared by placing a first layer of saw dust, newspaper, straw, coir waste, sugarcane trash etc. at the bottom of tub/container. Newspaper is one of bedding material that is high in absorbency whereas for the sawdust the level of absorbency is poor to medium. A second layer of moistened fine sand of 3 cm thick should be spread over the culture bed followed by a layer of garden soil (3 cm). The floor of the unit should be compacted to prevent earthworm's migration into the soil.

3.3. Earthworm

Earthworm is one of the major kinds and a key component of tropical and subtropical ecosystems. It helps with soil aggregation, nutrient recycling, litter decomposition, etc. Earthworm improves the soil environment by producing cast, pellets, and galleries. Mucus secretion from the gut of earth worm enhances microbial activity. Earthworms are terrestrial invertebrates comprising more than 3200 species, grouped into three categories according to their behavior in the natural environment: anecic, endogeic, and epigeic [21, 23] (Figure 6).

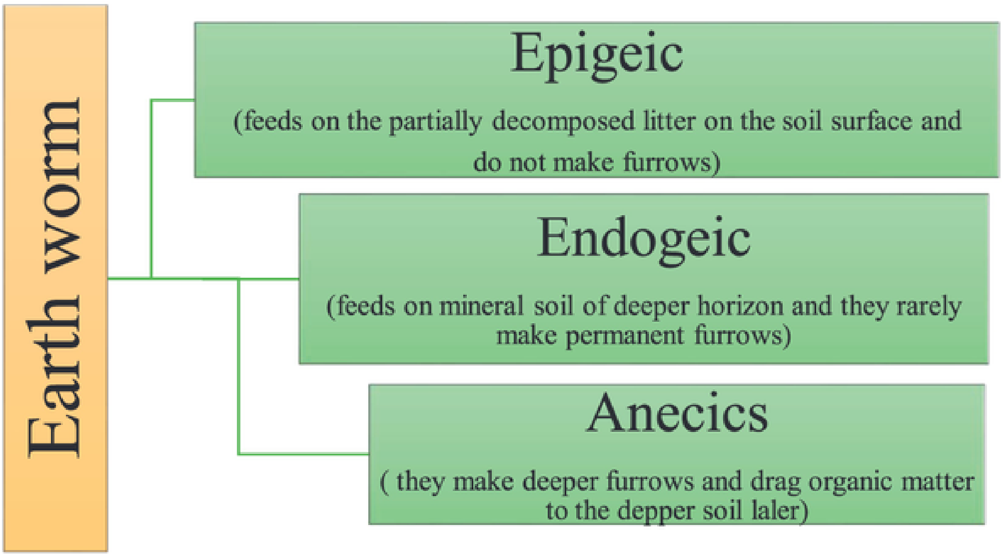

Figure 6. Earthworm classification [24]

Epigeics species are useful for biosolid waste management as these worms can hasten the composting process to a significant extent and produce better quality of vermicomposts, compared with those prepared through traditional methods [25].

Two tropical species, African night crawler, *Eudrilus eugeniae* (Kinberg) (Figure 7a) and Oriental earthworm, *Perionyx excavates* (Perrier) and two temperate ones, red earthworm, *Eisenia andrei* (Bouche), tiger earthworm, *Eisenia fetida* (Savigny) (Figure 7b), and *Lumbricus rubellus* are extensively used in vermicomposting [26, 27]. Most vermicomposting facilities and studies are using the worms *E. andrei* and *E. fetida* due to their high rate of consumption, digestion, and assimilation of organic matter, tolerance to a wide range of environmental factors, short life cycles, high reproductive rates and endurance and resistance during handling [28]. *Eisenia fetida* is used throughout the world for this purpose as it is ubiquitous, can tolerate a wide range of temperature and can live in wastes with good moisture content [29, 30]. *Eudrilus eugeniae* and *Perionyx excavatus* are the other commonly used worms. *Eudrilus eugeniae* is large in size, grows rapidly but has poor temperature tolerance, hence, may be suitably used in the areas with less fluctuation of temperature (tropical areas).

Figure 7. Earthworms, a) Eudrilus eugeniae, b) Eisenia fetida

Earthworms grow best on easily metabolised organic matter and unassimilated carbohydrates, which also support their reproduction. There was a positive correlation between the volatile solids content of the waste and growth and reproduction. Earthworm growth slows down when the C:N ratio and temperature are high. Biomass gain in E. fetida was found to depend on population density and food type during vermicomposting [31, 32]. Scientific studies have revealed that a single earthworm can gain biomass at a higher rate than those reared in groups. Some studies reported a decrease in worm biomass in some cases in worms that were continuously supplied with food [33, 34]. Thus, the physico-chemical or nutrient properties of the waste may be related to the temperature, pH and moisture content as well as the growth of the earthworm. The interaction between the palatability of these physico-chemical organic wastes and the feeding power by the earthworm is directly related to the interaction of these parameters and consequently affects the growth and reproduction of the earthworm.

Earthworms promote the growth of "beneficial decomposing aerobic bacteria" in organic waste material and also act as grinders, crushers, chemical degraders and biological stimulators of waste material [35]. The earthworm is home to millions of decomposing (biodegrading) microbes, hydrolytic enzymes and hormones, which help in the rapid decomposition of complex organic matter into vermicompost in a relatively short period of one-two months, compared to the traditional composting method, which takes about five months. The mechanism of vermicomposting by earthworms takes place in the following steps; The organic matter consumed by the worm is softened by the saliva in the worm's mouth. The food in the oesophagus is further softened and neutralised by calcium, and physical disintegration in the muscle gizzard results in particles < 2 μ in size, thus providing an enhanced surface area for microbial processing. Finally, this ground material is exposed to various enzymes secreted in the lumen by the stomach and small intestine, such as protease, amylase, lipase, cellulase and chitinase [20, 35, 36].

3.3.1. Physiology and life conditions of earthworms

Earthworm body is almost cylindrical but may have an end cross-sectional area of quadrilateral, octagonal or trapezoidal and in some species may be flat shape. Body length varies from 15 mm to 300 mm and its diameter varies from 1- 10 mm. External grooves, Furrow, on the worm body specify the place of internal curtains,Septa,. These curtains divide the body into a series of similar parts which are called Somite or Metamere. External secondary grooves, Annuli, often form three rings. The secondary grooves is a virtual division and do not exist in internal anatomy of the body. The first body segment, Peristomiom, surrounds the mouth and on the dorsal area has a lobe which called Prostmium. How to connect the mouth and Prostmium in earthworm is variable depending on the species and are used for their classification. Earthworms are androgyny and have both male and female reproductive system which is mainly limited to the front parts of body. Earthworms have a simple digestive system. Earthworms eat almost everything such as plant roots, leaves and seeds, microscopic organisms such as protozoa, Larvae, the Rotifers, bacteria, fungi, and larger animals, especially cattle, feces. The food is ingested with soil and passed along the earthworm's digestive canal. Earthworms continuously or semi-continuous are do egg-laying most often along the year. Worm eggs are placed in the cocoon. The cocoon shape is different depending on the species of worm. In moist conditions and the temperature of 16 to 27 ° C for the eggs, within 14 to 20 days the small worms come forth. Natural life of many earthworms is short and some species in case of being protected from natural hazards live longer than 1.5 Year.

Activity, metabolism, growth and reproduction of worms are strongly affected by the temperature. Temperature and humidity usually have an inverse relation. High temperature and dry environment are more limiting than low temperatures and water saturated environment, for the worms. Earthworms setting cocoon and coming out of egg are also affected by temperature. For example, setting cocoon in Eisenia fetida increases linearly with increasing temperature from 10 to 25 ° C, although the number of worms per cocoon out in 25°C is less than 20 °C. Cocoon opening period also depends on temperature. Growth of new worm out of the eggs to mature at 18 ° C reaching in 9.5 weeks and at 28 °C only 6.5 weeks is needed.

Worms are sensitive to hydrogen ion concentration which is stated as pH. According to sensitivity to pH in some texts have been divided into three categories: resistant to soil acidity, sensitive to soil acidity and a variety that can live in a wide range of pH. However, many researchers have expressed that more species of earthworms show interest to live in neutral pH. Eisenia fetida is preferred in the soils that pH is between 6.5 and 7.5. The role of organic carbon and inorganic nitrogen for synthesis of cell, growth and metabolism is essential in all organisms. Proper ratio of carbon to nitrogen is needed for optimal growth of earthworms [17, 37].