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The Production and Practices of Vermicompost

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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 worm's burrowing action, enhances the permeability of water in the soil. Worm castings can hold close to nine times their weight in water (Adhikary, 2012).

Vermicomposting is practiced on both small and large scales. During the 1996 Summer Olympics in Sydney, Australia, worms were used to manage the massive amount of waste generated. The resulting worm waste, known as castings, was discovered to be highly beneficial for plants and soil. In the U.S., there are commercial vermicomposting facilities where worms are raised and the castings are sold. Additionally, individuals who own farms or small gardens may introduce earthworms into their compost heap to use as fertilizer.

Vermicompost and its utilization

Vermicompost is essentially the waste produced by earthworms, which is filled with humus and nutrients. You can cultivate earthworms in a brick tank or near the base of trees, particularly horticultural ones. By feeding these earthworms with biomass and carefully monitoring their food, we can create the necessary amounts of vermicompost (Olle, 2019).

Materials for the 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

Phase of vermicomposting

Phase 1: Processing involves waste collection, shredding, mechanical separation of metal, glass, and ceramics, and storage of organic waste.

Phase 2: Organic waste is pre-digested for twenty days by mixing it with cattle dung slurry. This partially digests the material and makes it suitable for earthworm consumption. Cattle dung and biogas slurry can be used after drying. Wet dung should not be used for vermicompost production.
Phase 3: Prepare the earthworm bed by using a concrete base to put the waste for vermicompost preparation. Loose soil will allow the worms to burrow into the soil, and while watering, all the dissolvable nutrients will go into the soil along with water.
Phase 4: Collect earthworms after vermicompost collection and sieve the composted material to separate composted material. The partially composted material will be put back into a vermicompost bed.
Phase 5: Store the vermicompost in a proper place to maintain moisture and allow the beneficial microorganisms to grow.

Requirements needed for Earthworms

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

These five essentials are discussed in more detail below.
Bedding is any material that provides worms with a relatively stable habitat, which must have the following characteristics:
1. High absorbency: Worms breathe through their skins and need a moist environment to live. The bedding must be able to absorb and retain water well for the worms to thrive.
2. Good bulking potential: The bedding material should not be too dense or tightly packed, as this would reduce airflow. Worms need oxygen to live, so the overall porosity of the bedding is important. Factors affecting porosity include particle size, shape, texture, and the strength of the structure.
3. Low protein and/or nitrogen content (high Carbon: Nitrogen ratio): While worms consume their bedding as it breaks down, this process must be slow. High protein/nitrogen levels can lead to rapid degradation and heating, creating inhospitable conditions for the worms.
Additional requirements for worm farming include:
Housing: Culturing worms in sheltered environments is recommended to protect them from excessive sunlight and rain. Entrepreneurs have set up units in places like vacant cowsheds, poultry sheds, basements, and backyards.
Pits: Cement pits separated in half by a dividing wall were constructed for worm farming, along with additional tanks for preliminary decomposition.
Bedding and feeding materials: In the beginning, most entrepreneurs used cow dung to breed sufficient numbers of earthworms. Once they have large populations, they can start using various types of organic waste. Currently, half of the entrepreneurs have populations of 12,000 to 15,000 adult earthworms.

Vermicompost Production Methodology

i) Selection of suitable earthworm: For vermicompost production, it is important to use surface-dwelling earthworms such as the African earthworm (Eudrillus engenial), Red worms (Eisenia foetida), and composting worms (Perionyx excavatus). These worms are promising for vermicompost production and can be mixed. The African earthworm is preferred due to its higher production of vermicompost in a short time and the higher number of offspring during the composting period (Dominguez and Edwards, 2011).

African earthworm (*Eudrillus engine*)

Tiger worm or Red wrinkle (*Eisenia foetida*)

Asian worms (*perinonyx excavators*)

ii) Selection of site for vermicompost production: Vermicompost can be produced in any place with shade, high humidity, and cool temperatures. This can include abandoned cattle sheds, poultry sheds, or unused buildings. If it needs to be produced in an open area, a shady location should be chosen. A thatched roof can be provided to protect the process from direct sunlight and rain. The waste heaped for vermicompost production should be covered with moist gunny bags.

iii) Pits for vermicompost production: A pit measuring 2½ feet in height and 3 feet in width can be constructed at any desired length, depending on the room size. The bottom of the pit should be sloped to allow excess water to drain from the vermicompost unit, and a small sump should be installed to collect the drained water. An alternative option is to use hollow blocks or bricks on the floor, arranged to create a compartment that is one foot high, 3 feet wide, and with a length determined by your needs for convenient harvesting. This method makes it easy to assess moisture levels and does not require excess water drainage. Additionally, vermicompost can be prepared in wooden boxes, plastic buckets, or other containers, as long as there is a drain hole at the bottom.

Compost pit

Coir waste

Saw dust

Sugarcane trash

iv) Vermiculture bed: A vermiculture bed or worm bed (3 cm) can be prepared by placing after-saw dust husk coir waste or sugarcane trash in the bottom of the pit. 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.

Table 1. Common Bedding Materials

Bedding Material	Absorbency	Bulking Pot.	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 the 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
Corn cobs	Poor-Medium	Good	56 - 123

If available, shredded paper or cardboard makes excellent bedding when combined with on-farm organic resources such as straw and hay (Barik et al., 2011). However, organic producers need to ensure that these materials comply with their organic certification standards. Paper or cardboard fiber from municipal waste programs cannot be approved for certification purposes. Specific fiber resources from certain generators may be sourced and approved on a case-by-case basis. Another material to consider is paper-mill sludge, which pairs well with straw, bark, shipped brush, or wood shavings due to its high absorbency and small particle size. Nevertheless, organic certification is required for the use of paper-mill sludge.

Selecting bedding materials plays a crucial role in successful vermiculture or vermicomposting. Worms can be highly productive if their basic needs are met. Good bedding mixtures protect worms from extreme temperatures, maintain moisture levels, and provide adequate oxygen. Having good bedding mixtures is generally not difficult on farms, but ensuring proper absorption can be challenging. Mixing aged or composted cattle or sheep manure with straw can address moisture retention issues, resulting in bedding characteristics similar to aged horse manure.

v) Worm Food: Compost worms are voracious eaters. In optimal conditions, they can consume more than their body weight each day, although generally, they eat about half of their body weight per day. They will consume nearly any organic material (of plant or animal origin), but they do have preferences. Manures are often used as worm feed, with dairy and beef manures typically considered the best natural food for Eisenia, possibly followed by rabbit manure. Dairy and beef manures are more readily available in large quantities and are thus the most commonly used feed.

Table 2. Common Feed Stocks for Earthworms

Food	Advantages	Disadvantages
Cattle manure	Good nutrition; natural food, therefore little adaptation required	Weed seeds make pre-composting necessary
Poultry manure	High N content results in good nutrition and a high-value product	High protein levels can be dangerous to worms, so must be used in small quantities; major adaptation is required for worms not used to this feedstock. Maybe pre-composted but not necessary if used cautiously
Sheep/Goat manure	Good nutrition	Require pre-composting (weed seeds); small particle size can lead to packing, necessitating extra bulking material
Hog manure	Good nutrition; produces excellent vermicompost	Usually in liquid form, therefore must be dewatered or used with large quantities of highly absorbent bedding
Rabbit manure	N content second only to poultry manure, therefore good nutrition; contains a very good mix of vitamins & minerals; ideal earth-worm feed	Must be leached before use because of high urine content; can overheat if quantities too large; availability usually not good
Fresh food scraps (e.g., peels, other food prep waste, leftovers, commercial food processing wastes)	Excellent nutrition, good moisture content, the possibility of revenues from waste tipping fees	Extremely variable (depending on source); high N can result in overheating; meat & high-fat wastes can create anaerobic conditions and odors, and attract pests, so should NOT be included without pre-composting
Pre-composted food wastes	Good nutrition; partial decomposition makes digestion by worms easier and faster; can include meat and other greasy wastes; less tendency to overheat.	Nutrition is less than with fresh food waste.
Biosolids (human waste)	Excellent nutrition and excellent product; can be activated or non-activated sludge, septic sludge; possibility of waste management revenues	Heavy metal and/or chemical contamination (if from municipal sources); odor during application to beds (worms control fairly quickly); possibility of pathogen survival if process not complete
Seaweed	Good nutrition; results in excellent products, high in micronutrients and beneficial microbes	Salt must be rinsed off, as it is detrimental to worms; availability varies by region
Legume hays	Higher N content makes these good feed as well as reasonable bedding.	Moisture levels are not as high as other feeds and require more input and monitoring
Legume hays	Higher N content makes these good feed as well as reasonable bedding.	Moisture levels not as high as other feeds require more input and monitoring
Corrugated cardboard (including waxed)	Excellent nutrition (due to high-protein glue used to hold layers together); worms like this material; possible revenue source from WM fees	Must be shredded (waxed variety) and/or soaked (non-waxed) before feeding
Fish, poultry offal; blood wastes; animal mortalities	High N content provides good nutrition; and the opportunity to turn problematic wastes into a high-quality product	Must be pre-composted until past the thermophilic stage

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

vii) Putting the waste in the pit: The pre-digested waste material should be a mud mixture containing 30% cattle dung by weight or volume. Fill the waste mixture into the pit up to the brim. Ensure that the moisture level is maintained at 60%. Spread the selected earthworms uniformly over the material. For a pit with dimensions of one meter in length, one meter in breadth, and 0.5 meters in height, 1 kg of worms (approximately 1000 worms) is required. It's not necessary to place the earthworms inside the waste, as they will move into it on their own.

viii) Watering the vermibed: Daily watering is not required for vermibed. However, 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.

ix) Harvesting vermicompost: In the pit method of composting, the castings formed on the top layer are collected periodically, usually once a week. The castings are scooped out by hand and put in a shady place in a heap-like structure. The harvesting of castings should be limited to the top layer where earthworms are present. Periodical harvesting is necessary to ensure free flow and to maintain compost quality. If not harvested, the finished compost may become compacted when watering is done. In the 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 complete.

x) Harvesting earthworm: After producing vermicompost, the earthworms in the pit can be harvested using the trapping method. To do this, a small, fresh cow dung ball is made and placed inside the vermibed in five or six spots. After 24 hours, the cow dung ball is removed, and all the worms will be attached to it. By putting the cow dung ball in a bucket of water, the adhered worms can be separated. These collected worms can then be used for the next batch of composting.

Worm harvesting is typically done to sell the worms, rather than to start new worm beds. Expanding the operation (creating new beds) can be achieved by splitting the existing beds, removing a portion of the bed to start a new one, and replacing the material with new bedding and feed. When worms are sold, they are usually separated, weighed, and transported in a relatively sterile medium, such as peat moss. To do this, the worms must first be separated from the bedding and vermicompost.

There are three main methods used by growers to harvest worms: manual, migration, and mechanical. Each of these methods is described in more detail in the following sections.

a) Manual Methods: Manual methods are often used by hobbyists and small-scale growers who sell worms to home vermicomposting or bait markets. This method involves hand-sorting or picking the worms directly from the compost. To facilitate this process, the worms can be lured to the bottom of a pile of material by using a light. A harvester can then remove a layer of compost, stop when the worms become visible again, and repeat this process several times until only a mass of worms under a thin covering of compost is left on the table. These worms can then be scooped into a container, weighed, and prepared for delivery.

There are a few minor variations and enhancements to this method. For example, instead of using a flat surface, you can use a container. Another option is to create multiple piles at once, allowing the person harvesting to move from one pile to another and then return to the first one in time to remove the next layer of compost. However, all these methods are labor-intensive and only make sense if the operation is small and the worms are of high value.

b) Self-Harvesting (Migration) Methods: These methods, similar to those used in vermicomposting, take advantage of the natural tendency of worms to move to new areas in search of food or to avoid unfavorable conditions such as dryness or light. Unlike manual methods, these techniques often utilize simple mechanisms like screens or onion bags.

The screen method is a popular and straightforward approach. It involves constructing a box with a screen bottom, typically using a ¼" mesh, although a 1/8" mesh can also be used. There are two variations of this method. In the downward migration system, the worms are encouraged to move downward through the screen into a container of moist peat moss. Once the worms have migrated, the compost in the box is removed, and a new batch of worm-rich compost is added. This process is repeated until the desired weight of the peat moss container is reached. Like the manual method, this system can be set up in multiple locations simultaneously to streamline the harvesting process.

The upward-migration system follows a similar process, with the box placed directly on the worm bed, filled with damp peat moss, and sprinkled with worm-attracting food. A few centimeters of the material are placed in the box, which is then removed and weighed after visual inspection indicating that sufficient worms have moved up. In Cuba, this system is widely utilized, with large onion bags instead of boxes. One advantage of this approach is that it minimizes disturbance to the worm beds. However, the harvested worms may be in material containing unprocessed food, potentially leading to messiness and the risk of heating during shipment. To address this, any obvious food can be removed, and the worms can be given some time to consume the remaining food before packaging.

xi) Nutritive value of vermicompost: The nutrient content in vermicompost varies depending on the waste materials that are being used for compost preparation. If the waste materials are heterogeneous, there will be a wide range of nutrients available in the compost. If the waste materials are homogenous, there will be only certain nutrients are available. The commonly available nutrients in vermicompost are 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
Sulfur	:	128 – 548 mg kg-1

xii) Storing and packing of vermicompost: After harvesting, the vermicompost should be stored in a dark, cool place with a minimum of 40% moisture. It's important to keep the composted material out of direct sunlight as this can lead to loss of moisture and nutrient content. It's recommended to store the composted material openly rather than packing it in sacks, with packing done at the time of selling. If storing the material openly, periodic sprinkling of water may be necessary to maintain moisture levels and beneficial microbial populations. If packing is required, laminated sacks are used to minimize moisture evaporation. Vermicompost can be stored for up to a year without loss of quality as long as the moisture level is maintained at 40%.

Advantages of vermicompost

- Vermicompost is rich in all essential plant nutrients.
- It enhances overall plant growth, encourages the growth of new shoots and 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 a bad odor.
- It improves soil structure, texture, aeration, and water-holding capacity, and prevents soil erosion.
- Vermicompost is rich in beneficial microflora including nitrogen fixers, phosphate solubilizers, and cellulose-decomposing micro-flora, which improve the soil environment.
- It contains earthworm cocoons and increases the population and activity of earthworms in the soil.
- Vermicompost neutralizes soil pH, prevents nutrient losses, and increases the use efficiency of chemical fertilizers.
- It is free from pathogens, toxic elements, and weed seeds, minimizing the incidence of pests and diseases.
- Vermicompost enhances the decomposition of organic matter in the soil and contains valuable vitamins, enzymes, and hormones like auxins and gibberellins.

Pests and Diseases of vermicompost

Compost worms are not susceptible to diseases caused by microorganisms, but they are vulnerable to predation by certain animals and insects (red mites being the most problematic) and to a condition known as "sour crop" caused by environmental factors.

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