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Vermicompost and verminculture: structure, benefits and usage

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ABSTRACT

Vermiculture is the culture of earthworms. The goal is to continually increase the number of worms in order to obtain a sustainable harvest. The worms are either used to expand a vermicomposting operation or sold to customers who use them for the same or other purposes. Vermicomposting is the process by which worms are used to convert organic materials (usually wastes) into a humus-like material known as vermicompost. The goal is to process the material as quickly and efficiently as possible.

Key words: Vermicompost, Worm, Vermiculture, Agriculture, Structure

Overview:

There are an estimated 1800 species of earthworm worldwide (Edwards & Lofty, 1972). This manual will focus on just one. Eisenia fetida (Savigny) is commonly known as (partial list only): the “compost worm”, “manure worm”, “redworm”, and “red wiggler” (see Figure 1). This extremely tough and adaptable worm is indigenous to most parts of the world and can be found on most Canadian farms wherever piles of manure have been left to age for more than a few months.

Fig1. E. fetida - the compost worm

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There are Three Types of Earthworm (Information sourced from Card et al., 2004.)

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.

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.

Outer Anatomy of the Earthworm (see Figure 2)

1. Anus—where waste is excreted from the worm
2. Segments—the areas of the worm's outer body that bend and stretch and aid in movement
3. Setae—stiff hairs on the exterior of the worm that serve as feelers or sensory aides
4. Clitellum—located near the front of the worm; the worm's genitalia is located here
5. Mouth—where the worm ingests food

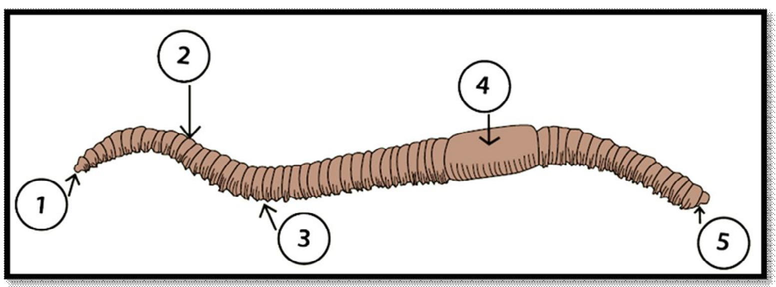

Fig2. Chematic section of Worm body

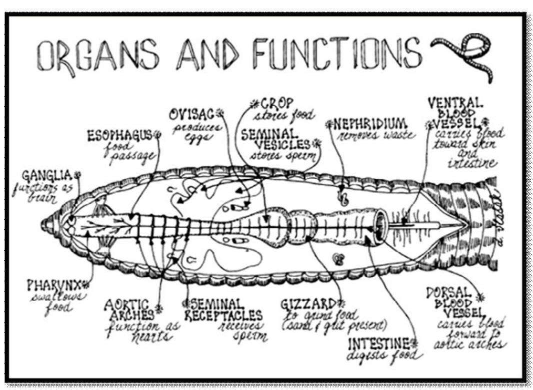

Fig3. Organ and Functions of worm body

Commercially raised worms are usually of the epigeic type. E. fetida is certainly not the only epigeic worm, but it is the one most often used for composting purposes in Northern climates. It can handle a wide temperature range (between 0 and 35oC) and can actually survive for some time almost completely encased in frozen organic material.

What are some benefits of castings?

Castings help air and water to permeate soil. When castings are added to soil, they boost nutrients that are available to the plant and enhance soil structure and drainage. Castings can be mulched or mixed into the soil in gardens and around trees and yard plants. They can also be used as a top dressing on outdoor plants or sprinkled on lawns as a soil conditioner.

How are some ways that earthworms might have affected history?

Earthworms have been mentioned in history as far back as Aristotle, who described them as “the intestines of the earth.” In the time of the Egyptian pharaohs, Cleopatra declared earthworms sacred and established laws protecting them. Charles Darwin studied earthworms for 39 years and demonstrated that they improve soil conditions and enhance plant productivity. Darwin went so far as to say, “It may be doubted whether there are many other animals in the world which have played so important a part in the history of the world.”

Descriptions for different type of worms as a vermicompost:

1) - Made of a large cardboard box used for moving trucks
- Bedding material made out of newspaper, shredded plastic bags, and pine needles
- No soil added
- A bucket of water poured on top of bedding material
- Food scraps delivered twice a week
2) - Worms which made of a large plastic container that is kept outside all year long
- Bedding material made out of toilet paper, napkins, and pre-moistened hand wipes
- Two pounds of soil added
- One cup of water added for every pound of bedding
- Food scraps consist of pizza crusts, beef jerky, and cottage cheese
3) – Worms which made from a large fireproof wooden box
- Bedding material made from shredded classroom handouts, tissue paper, and decayed leaves
- One handful of soil added
- 3 pints of water added for every 3 pounds of bedding
- Food scraps consist of dry cereal, raisins, and vitamins
4) - Worms which made from untreated, non-aromatic wood
- Bedding material made from shredded black-and-white newspaper, paper bags, white office paper and cardboard
- One handful of soil added
- Bedding was soaked in water, squeezed, and fluffed before put in the worm bin

- Food scraps consist of crushed pumpkin, cantaloupe, and peaches; ½ pound delivered each day during week.

An Overview of Potential Benefits and Constraints

Why should an organic farmer be interested in vermiculture and/or vermicomposting? The answers are several and may not apply to all organic producers. In summary, they are as follows:
• Vermicompost appears to be generally superior to conventionally produced compost in a number of important ways;
• Vermicompost is superior to most compost 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.

All of the above will be discussed in detail later in this document. At the same time, the reader should take note at the beginning that working with worms is a more complicated process than traditional composting:
• It can be quicker, but to make it so generally requires more labour;
• It requires more space because worms are surface feeders and won't operate in material more than a meter in depth;
• It is more vulnerable to environmental pressures, such as freezing conditions and drought;
• Perhaps most importantly, it requires more start-up resources, either in cash (to buy the worms) or in time and labour (to grow them).
Because of the benefits described above, and despite these drawbacks, farmers around the world have started to grow worms and produce vermicompost in rapidly increasing numbers. Warmer climes have tended to predominate so far, with India and Cuba being the leaders to date. Vermicomposting centres are numerous in Cuba and vermicompost has been the largest single input used to replace the commercial fertilizer that became difficult or even impossible to import after the collapse of the Soviet Union (Cracas, 2000). In 2003, an estimated one million tonnes of vermicompost were produced on the island (Koont, 2004). In India, an estimated 200,000 farmers practice vermicomposting and one network of 10,000 farmers2 produces 50,000 metric tonnes of vermicompost every month. In the past decade, farmers in Australia3 and the West Coast of the U.S. have started to use vermicompost in greater quantities, fuelling the development of vermicomposting industries in those regions. At the same time, scientists at several Universities in the U.S., Canada, India, Australia, and South Africa have started to document the benefits associated with the use of vermicompost, providing facts and figures to support the observations of those who have used the material.

What Worms Need

***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**

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. Some materials make good beddings all by themselves, while others lack one or more of the above characteristics and need to be used in various combinations. Table 1 provides a list of some of the most commonly used beddings and provides some input regarding each material's absorbency, bulking potential, and carbon to nitrogen (C:N) ratios. OACC[1] tested the first two materials in Table 1 – horse manure and peat moss – in a separate experiment within the EcoAction-funded pilot project in 2003-2004. Both materials performed well, with the horse manure having the edge. Since horse manure was available free of charge and is a renewable resource, it was used in the balance of the trial (See Appendix C for a full description of this experiment). If available, it is generally considered to be an ideal bedding. Its high C:N ratio (for a manure), good bulking characteristics (because of the high straw content), and relatively good moisture retention make it an excellent environment for E. fetida. It can be improved somewhat by the addition of a high-absorbency material such as peat moss or shredded paper/cardboard (which will increase absorbency and also increase the C: N ratio a bit – another positive).

Table 1: Common Bedding Materials

Bedding Material	Absorbency	Bulking Pot.	C:N Ratio[2]
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

[1] Organic Agriculture Centre of Canada

[2] Most of the C:N ratios were obtained from The On-Farm Composting Handbook (see Sources and Reference Sections); the balance were obtained from the other sources listed under References. The former document also compiled the ratios from reports in the literature. The averages or ranges quoted, therefore, are estimates and intended only to provide the reader with a general sense of how each material compares to the others with respect to nitrogen content.

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

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 day5[3]. 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 (Gaddie & Douglas, 1975). The former, being more often available in large quantities, is the feed most often used.

Moisture

The need for adequate moisture was discussed in relation to bedding in Section 2.1.2 above. 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 (1998) 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

[3] The actual amount of food that can be consumed daily by Eisenia fetida varies with a number of factors, not the least of which is the state of decomposition of the food. Manures, which consist of partially decomposed organic material, can be consumed more rapidly than fresh food, and some studies have found that worms can exceed their own weight in daily consumption of manure.

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.

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 Canada[4]. 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.

Other Important Parameters

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.".

Projecting Vermicompost Outputs:

[4] It may also be possible to grow worms outdoors in Canada's far north (e.g., the Territories and northern regions of BC, the Prairies, Ontario, Quebec, Labrador), but OACC has no experience or knowledge in these areas.

In the world of conventional composting, the rule-of-thumb is that one ton of inputs results in one cubic yard of compost, the weight of which varies with moisture content but is typically about ½ ton. In other words, 50% of the mass is lost, mostly as moisture and CO2. Some N is lost as ammonia, but if the process is well managed the N loss is minimized (Rink et al, 1992). Of course, the final weight and volume of product varies with original feedstock, bulking agent used, etc., but the above rule-of-thumb is a handy way to quickly calculate output. Vermicomposting is a bit more variable. This is because there is more variation in how the process is carried out. In composting, mixtures of high-N and high-C materials are made at the start and nothing is added to the mix thereafter. C:N ratios are calculated at the beginning and these fall as C is lost during the process in greater proportion than is N. In vermicomposting or vermiculture operations, the high-C materials are used as bedding, while the high-N materials are generally feed stocks.

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