RAISING EARTHWORMS
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Interest in raising earthworms has increased in recent years for a number of reasons. The most common reason for raising earthworms is the demand for bait sold to sport fishermen. But earthworms may be used:

- in decomposing solid wastes (municipal garbage, sewage, sludge)
- inorganic gardening - as a protein source

In almost all cases, worm growing businesses have not been profitable. For use as bait, the cultured worms are neither as prized as the dew worm by anglers nor can they be raised as cheaply as the dew worm can be harvested from golf courses.

If the price of harvested worms is $25/1000 worms to the wholesaler (the average price in 1980), then the worm grower must be able to grow his worms for about $15/1000 worms (1.5¢/worm) in order to make a profit and compete with the harvested worms.

However, when all the costs for labor, material and interest on money borrowed are considered, I don't believe worms can be raised profitably for a selling price of 2.5¢/worm.

The only time that cultured earthworms can be sold profitably is when dew worms are in short supply and bait worm wholesalers make up shortages with cultured worms, as happened in the drought years of 1978 and 1979. If the wholesale price rises to $40-45/1000 worms (as it did in 1979 for a short time) it might be possible for growers to supplement the market profitably. In the wet year of 1980, worm growers were left with large unsold surpluses.

A recent engineering study could see no future in using worms to decompose solid wastes on a large scale because it was too expensive and unreliable.

Earthworms can be used as natural tillers of the soil in organic gardens as long as the appropriate species are used. There is no point in adding tropical worms (e.g. African night crawlers) or manure worms to your garden because they cannot survive in soils of low organic matter content or will be killed by cold Canadian winters.

As a protein source, earthworms are prohibitively expensive and suffer bacteriological problems in processing. Dried earthworm meal (about 65% protein) costing about $10/kg can't compete in price with dried soya meal or fish meal (60-65% protein) currently selling at $2.50/kg. This calculation is based on 3300 manure worms weighing 1 kg (dry) and costing about $3/1000 worms.
Raising earthworms

If, despite the cautionary notes about raising earthworms, some readers would still like to try, basic rearing principles are outlined below:

1. **Soil pH**—the best soil pH for most worm species is 6-7.

2. **Suitable drainage**—drainage of the worm beds is critical to prevent the soil from becoming anaerobic and suffocating the worms.

3. **Appropriate food source**—earthworms derive their nutrition from many forms of organic matter. Plant matter, protozoans, rotifers, nematodes, bacteria, fungi and decomposing remains of other animals are known sources of worm food. For the manure worm, there is strong evidence that protozoans form the basis of their diet. If this is true, it means that successful culture requires that protozoan populations be high in the food medium whether it be shredded paper, manure or waste fôds.

4. **Proper soil mixture**—different species of earthworms are adapted to different soil types (high organic carbon content to mineral soils with very low carbon content).

5. **Adequate ventilation** if you are cultivating large numbers of worms in a confined space, ventilation to remove carbon dioxide and bring in fresh oxygen can also be critical. Worms cannot survive in very low or no oxygen environments, but different species have different oxygen requirements.

6. **Suitable moisture levels in the soil**—all earthworms species require fairly moist soil environments to meet their respiratory demands. Earthworms may survive for considerable lengths of time in water if the dissolved oxygen content is high enough and the water temperature is suitable for the particular species.

7. **Appropriate temperature**—earthworms cannot maintain a steady body temperature like humans or other mammals. This means their respiration rate rises with increasing temperature. Increased respiration rates increase metabolic rates resulting in increased energy requirements. Therefore, worms must feed more frequently or food must be "stolen" from reserves in the worms' body tissues. The reverse is true for decreasing temperatures. This has implications for the shelf-life, storage temperatures, and feeding requirements of earthworms.

8. **Appropriate worm density conditions**—the density (the number of worms per unit volume of soil) at which different worm species can survive (or increase) varies enormously. Dew worms seem to require a minimum of 1600 cm$^3$ of soil/worm. Manure worms and African night crawlers thrive at densities of 30-65 cm$^3$/worm. This obviously plays an important part in determining whether it is economically possible to culture a particular worm species. It just doesn't make economic sense to culture the dew worm—it requires too much space (20 million worms would require a minimum sized room of 30 x 30 x 30 m plus ventilation and access).

9. **Knowledge of the worms' life cycle** (varies with different species).

10. A low power light bulb or fluorescent tube over rearing beds turned on at night to keep worms in the beds.
**Manure or red worm (Eisenia fetida)**

This worm species is commonly found in mass cultures in North America. It will reproduce well in the temperature range 20°- 25°C. Below 15°C reproductive rates are so slow as to make culture uneconomic. This means that cultures outside in frost climates will require heating and insulation in winter to maintain a high rate of growth in the culture. At 25°C a full life cycle can be completed in about 52 days under optimum laboratory conditions, a rate which might not be matched in mass cultures.

Red worms are adapted to exploit rapidly decomposing organic matter (e.g. manure, decaying vegetation) under high density conditions which means that large numbers can be reared in confined spaces as long as basic food, oxygen, temperature, ventilation and moisture conditions are met. Recent research suggests that manure worms actually feed on protozoa (single-celled animals) which live on the decaying organic matter; however, to eat them, the worms ingest the decaying matter along with its protozoan content, extract the food value of the protozoans, and then pass on the extraneous organic matter in the form of castings.

These worms can be reared in containers (made of wood, cement blocks, or plastic buckets) with drainage holes. The bottom layer should be a 9 cm layer of coarse gravel underlying 9 cm of sand all of which is covered by 18 cm organic matter.

Stock the bed with 100-500 adult worms per 0.1 m². Overcrowding results in smaller worms. Sparingly populated beds produce larger worms (at greater cost, of course). Beds should be shaded from the sun to reduce water loss by evaporation and overheating. Feed may be fresh (but leached) manure, kitchen waste, poultry mash feeds, canning wastes, etc, but the objective is to maximize protozoan populations (on which the red worm feeds) in the beds. Feeding rate must be controlled carefully; new diets should be tested on 25-50 worms for at least 48 hours before feeding to your mass cultures.

The substrate should be kept moist, but not soggy with the pH between 6 and 7. Fresh animal manures should be leached with water to reduce production of toxic ammonia. Care must be taken that not too much undeveloped vegetable matter is placed in the worm beds at one time for the following reasons: the vegetable matter could undergo bacterial decomposition which would raise the temperature of the bed and kill the worms; toxic waste products of fermentation and composting may be produced; lack of sufficient ventilation to remove carbon dioxide and to add oxygen may kill the worms; other animals (especially mites) may invade the worm bed to exploit the food resource (thus competing with the earthworms).

Under optimum conditions, cultures of manure worms can double or triple in numbers (but not weight) in 50-60 days. However, it may be difficult to maintain optimum conditions on a large scale for long periods.
Dew worm or Canadian night crawler (Lumbricus terrestris)

The dew worm is harvested from golf courses and pastures from early spring to late fall by pickers working through the night when this worm surfaces to feed and mate. The worms are kept in cold storage by distributors, and sold off to meet the demands of bait dealers (mostly in the U.S.) during the fishing season. This bait market is usually strong and all worms harvested can be sold. This worm is highly prized by fishermen because it remains active in cold water and does not break up quickly on the hook.

The dew worm is picked rather than cultured, because it is cheaper and less difficult than rearing. The dew worm does not reproduce under high density conditions. This fact prevents them from being cultured at an economically competitive price with field harvested dew worms.

Dew worms can be raised, however, in damp organic soil at a stable temperature in the range of 4-15°C and a soil pH of 7, in rot-resistant wooden boxes or drums which have screened drain holes in the bottom. If you need to move containers at some point during the culture process, containers should not exceed 28 L. The soil medium should be composed of 3-4 parts clay loam, 1 part horse or cattle manure and 6 parts peat moss (or well rotted leaf litter). The addition of a small amount of fine sand also seems to help. Sand and gravel should be used at the bottom of the container to assist drainage. Covering the surface with damp sacking or partially decomposed leaf litter helps to maintain stable soil moisture levels (which should be about 30-35% water). Do not over water.

African night crawler (Eudrilus eugeniae)

The environmental and food requirements for this species are similar to the manure worm. Optimum temperature for raising this species seems to be about 24° C, but it can tolerate temperatures from 20-26°C; growth and development rates will be a function of temperatures and feeding. This species will not tolerate cold temperatures (less than 15°C) and growth and reproductive rates will drop dramatically below 20°C. This worm species is sold under several trade names. Maximum attainable size for this species is about 3-4 g. Note, however, that these larger worms can only be obtained by culturing at lower density, feeding them at higher rates, and keeping them for more than 3 months. These are all factors which will increase your costs.


These are the common garden worms which can also be used as fishbait and can be reared simply in containers similar to those previously described. Based on field observations I would set the bedding temperature at 16-20°C. A suitable bedding is a mixture of 1/3 clay loam soil mixed with 2/3 organic matter (composted hay, leaves, manure, straw, kitchen scraps, grains).
The ecology of earthworms

Earthworms live in the soil, but the species "mix" and types of soil they inhabit vary widely. Because nearly all the earthworm species found in Canada were introduced from Europe and Asia, the natural Ontario earthworm populations at the present time resemble European worm populations.

Some worm species occupy their place in the soil by moving vertically in the soil (dew worm). Other species such as Aporrectodea (garden worms) occupy the top 5-10 cm of soil and move horizontally. Other species such as the manure worm (Eisenia fetida) require soil with a high carbon content (muck soils) or manures to survive.

Most earthworms are very susceptible to toxic chemicals. This means most pesticides (insecticides, fungicides, herbicides) should be kept away from your worm cultures. In addition, fertilizers and even some plastics can be toxic to dew worms and African night crawlers. Other worm species could be equally as susceptible to these types of chemicals.

The reproduction of earthworms

Earthworms may reproduce biparentally (by exchanging genetic material with another worm of the same species) or uniparentally (no sexual fertilization by another worm takes place). The method of reproduction is characteristic of the species; both methods of reproduction are not normally found in the same species - but relatively little is known about this. Where biparental reproduction occurs, for example in the dew worm, both male and female organs are present in the same animal and each worm cross fertilizes the other worm (of the same species) simultaneously. Both worms will then produce cocoons (capsules). In uniparental worms, some mechanism triggers production of an ovum, which is then released as a cocoon without being fertilized and develops into a mature worm.

Normally each cocoon produces one or two worms (but occasionally as many as eleven in the manure worm). Depending on the species, it takes from 3 weeks (manure worm) to a year (dew worm) to reach reproductive maturity. This slow development to sexual maturity is another reason why it is not economical to raise dew worms.

Some species are able to regenerate amputated segments of the body. Regeneration of tail segments occurs more readily than head segments. There does seem to be a limit to the number of segments that can be regenerated, but this number varies from species to species. No known worm species, if cut in half, will form two viable worms.

Although different earthworm species may look alike, they are, in fact, quite different. Of the 19 species known in Ontario, for example, no individual of one species can breed with a worm of another species, and certainly no fertile offspring would result if interbreeding was possible. Therefore, culturing worms that are "hybrids" of two or more species is biologically impossible.
Parasites and predators of earthworms

Predators

Birds (e.g. gulls following plows in fields), moles, hedgehogs, foxes, toads and snakes are known to eat earthworms. Beetles, leeches, slugs and flatworms also feed on worms. Most of these are unlikely to be a problem in earthworm cultures.

Parasites

Bacteria, protozoa (single-celled animals), flatworms, nematodes (roundworms) and dipterous larvae are internal parasites of earthworms. The cluster fly (Pollenia rudis), often a nuisance pest in house attics, parasitizes worms of the species Eisenia rosea which may be a contaminating worm in worm cultures. There is no indication, though, that this parasitic fly has been a problem in worm cultures. There are other fly species which can parasitize worms, but so far I have received no reports from commercial worm growers of such problems.

I have had several reports of mites (small spider like animals) causing problems in worm beds. One species, Histiostoma murchiei, is reported to parasitize cocoons of A. chlorotica worms. Another, Uropoda agitans, also attacks earthworm cocoons. Other species of mites, which don't attack earthworms directly, can become so numerous in the earthworm beds that the worms' food supply is endangered and the worm population declines.

Castings

Castings are the fecal material passed by worms. Depending on the quality of the starting soil and organic matter in the bedding material, castings can make a good potting soil or soil amendment which can be added to house plants or gardens. Some people are prepared to buy such a product for as much as $1.50/kg or more. As far as can be determined, earthworm castings are no better for plants than well composted manure. However, castings could be a profitable business on a regional scale where transportation costs would not be prohibitive and willing buyers for the product can be found. Worm castings vary widely in quality (depending on the starting bedding materials of course) and do not conform to any known standards. Worm castings do not qualify as fertilizers (a good N-P-K content for castings might be 1-2-2, again depending on worm bedding starting mixtures). The critical cost component of fertilizers is the nitrogen content which has no possibility of being increased by worm processing of organic materials. In fact, organic wastes with high nitrogen content are quite toxic to earthworms.

Availability of earthworms

The dew worms and dug worms are available from home gardens in small numbers. Large numbers could be obtained from bait wholesalers.

The two cultured species, the manure worm and African night crawler, can be obtained from suppliers who advertise in the magazine Organic Gardening.
References


NOTE: The Edwards' and Reynolds' books are quite readable and both have extensive references

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