Raising Earthworms Successfully

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Introduction

Over the past several years, many people have begun raising earthworms as a source of income or as a means of managing organic waste. Some are drawn to the business by extravagant claims of vast potential markets for earthworms in large waste disposal systems and agriculture and as a source of food for animals. Despite these claims, the current major commercial use of earthworms is as bait for freshwater sport fishing.

Although several other outlets for sales of worms exist, there is much competition for markets. Research and development on uses for worms are under way throughout the world, but the opening of new markets for worms and castings will be slow and somewhat uncertain. Those interested in getting into the earthworm business should explore potential local markets carefully, particularly if a full-time occupation is the goal.

Earthworm growers can make money by selling earthworms and vermicompost or from tipping fees (charging to have organic materials normally disposed of in landfills "tipped" by a dump truck onto the worm grower's site, to be fed to the earthworms). Vermicomposting is the process of turning organic debris into worm castings (manure). The focus is on processing the waste rather than creating ideal conditions for raising earthworms. Earthworm size and their reproductive rates are frequently lower than those of the same species raised in vermiculture systems. Large vermicomposting facilities typically make money primarily from tipping fees, followed by sales of castings, and then, in a distant third place, by sales of earthworms.

Vermiculture is the raising of earthworms for resale, so the focus is on ideal conditions for worm growth, reproduction, and health. Worm farmers usually purchase and haul feedstock or pay for feedstock to be delivered to them. Others may get the material for free but pay for it to be pre-composted and hauled to their site. Worm growers make money from sales of earthworms and sometimes, but not always, by selling castings. In

addition, some operations sell related products, such as shipping boxes, worm bins, harvesters, soil mixes, books, and videos.

Potential Markets for Earthworms and Vermicompost

Several options are available for the sale of earthworms. Home vermicomposters, composters, and gardeners are interested in buying earthworms. Fish hatcheries, tropical fish stores, pet stores, zoos (with exotic fish and birds), game bird breeders, frog farmers, and poultry growers buy worms as feed for animals. Community educators, such as Extension agents or recycling coordinators, often need a steady supply of earthworms for setting up new worm bins. Private laboratories, universities, and high schools use worms for research and classroom needs.

Growers living near or on the way to fresh or salt water fishing resorts can sell earthworms directly to fishing enthusiasts (check with the local zoning authority to be sure such a business is permitted in the area). Placing advertisements in national magazines directed to fishing enthusiasts and home gardeners or advertising on the Internet may create sales for earthworms.

It may be possible to sell earthworms to locally owned sporting goods or fishing tackle stores, although most of the larger stores of this type rely on established wholesalers for their bait supplies. The bait market may not be the best choice for this enterprise because there is usually more interest in nightcrawlers (larger worms) than smaller compost worms, the market is often saturated, and the competition is stiff.

Other markets for earthworms include:

- Large-scale vermicomposting facilities.
- Worm growers just entering the business.
- Institutions and businesses that do on-site vermicomposting of their food scraps and other organic materials (including prisons, hospitals, schools, colleges and universities, restaurants, grocery stores, and office buildings).

- Farmers desiring to vermicompost animal manure (including livestock and poultry farms, rabbitries, and horse stables).
- Worm growers with orders too large to fill from their own stocks.
- Industries with organic wastes suitable as feedstock for worms, such as papermills, breweries, cardboard manufacturers, land reclamation sites, generators of sludge/biosolids, food processors, canneries, wineries, and cotton mills.

Many worm growers focus on selling vermicompost rather than earthworms. Vermicompost is a blend of castings and decomposed organic matter that has been placed in a worm bin. The nutrient content of vermicompost depends on the types of feedstocks and bedding provided for the worms. Studies have shown that vermicompost enhances plant growth, suppresses disease in plants, and increases microbial activity in soil. Vermicompost also improves water retention, aeration, and porosity in soils.

Due to its high cost, compared to commercial fertilizers, vermicompost is not commonly used as a soil amendment or plant growth enhancer by large commercial plant growers. Nonetheless, vermicompost is increasingly being used by organic gardeners and is sold commercially in some nurseries as a soil amendment or planting medium for ornamental plants. A growing body of research demonstrating the beneficial uses of vermicompost is helping to increase market outlets. Vermicompost may be sold in bulk by the cubic yard or bagged with a variety of compost and soil blends. Markets include home improvement centers, nurseries, landscape contractors, greenhouses, garden supply stores, grocery chains, flower shops, discount houses, and the general public.

A relatively new product coming on the market is vermicompost tea (a liquid). Organic matter, microorganisms, and nutrients are extracted from vermicompost to produce the tea. Unlike vermicompost and compost, this tea may be applied directly to plant foliage, reportedly to enhance disease suppression. Vermicompost tea also may be applied to the soil as a supplement between compost applications to increase biological activity.

Vermicompost tea is NOT leachate that leaks out of the bottom of a worm bin. Leachate is produced when excess liquid passes through organic material in the worm bin,

including undigested, decomposing organics. The liquid extract of undigested material may contain pathogens and chemicals that are toxic to plants and humans.

Before attempting to make vermicompost tea, investigate how to do it and what equipment to use by reading and conducting personal interviews with those who make it. Information on compost tea and vermicompost tea may be obtained through Internet search engines and the Compost Tea Industry Association (www.composttea.org).

Vermicompost tea may be sold in bulk to orchards, nurseries, greenhouses, landscapers, and retailers (who will bottle it for resale).

Earthworm Classification

Earthworms are terrestrial invertebrates with thousands of species grouped into three categories according to their behavior in the natural environment: anecic, endogeic, and epigeic.

Anecic species, represented by the common nightcrawler (*Lumbricus terrestris*), construct permanent vertical burrows as deep as 4 to 6 feet in the soil. They feed on organic debris on the soil surface and convert it into humus. If anecic species are deprived of their permanent homes, they will discontinue breeding and cease to grow.

Endogeic species, such as *Aporrectodea calignosa*, build wide-ranging, mainly horizontal burrows where they remain most of the time, feeding on mineral soil particles and decaying organic matter. They are the only species of earthworms that actually feed on large quantities of soil. As they move through the soil and feed, they mix and aerate the soil and incorporate minerals into the topsoil.

Epigeic species, represented by the common redworm (*Eisenia fetida*), do not build permanent burrows; instead, they are usually found in areas rich in organic matter, such as the upper topsoil layer, in the forest under piles of leaves or decaying logs, or in piles of manure. Since they don't burrow deeply into the soil and prefer to eat rich organic

matter, epigeic worms adapt easily to vermiculture and vermicomposting systems. *Eisenia fetida* and *Eisenia andreii* constitute about 80 to 90 percent of the earthworms raised on a large-scale commercial basis.

Biology of Earthworms

The physical structure of earthworms is similar among the different species. Earthworms belong to the phylum Annelida, which means "ringed." The "rings" around worms are called segments. Redworms have about 95 segments, while nightcrawlers have about 150. Earthworm bodies are streamlined, containing no protruding appendages or sense organs, to enable them to pass easily through soil. Worms have well-developed nervous, circulatory, digestive, excretory, muscular, and reproductive systems.

The head or anterior end of the earthworm has a prostomium, a lobe covering the mouth that can force open cracks in the soil into which the earthworm can crawl. Setae (bristles) on each segment can be extended or retracted to help earthworms move. Lubricating mucous, secreted by skin glands, helps worms move through soil and stabilizes burrows and castings.

The earthworm's digestive tract extends the whole length of its body. Worms swallow soil (including decomposing organic residues in the soil) or residues and plant litter on the soil surface. Swallowed matter is mixed by strong muscles and moved through the digestive tract while enzyme-filled fluids are secreted and blended with the materials. The digestive fluids release amino acids, sugars, bacteria, fungi, protozoa, nematodes, and other microorganisms, in addition to partially decomposed plant and animal materials from the food the worms have swallowed. Simpler molecules are then absorbed through intestinal membranes and are utilized by earthworms for energy and cell production.

Earthworms do not have specialized breathing devices. They breathe through their skin, which needs to remain moist to facilitate respiration. Like their aquatic ancestors, earthworms can live for months completely submerged in water, and they will die if they dry out.

A red pigment in earthworms' skin makes it sensitive to ultraviolet rays. Brief exposure to strong sunlight causes paralysis in some worms, and longer exposure kills them. Earthworms seen lying dead in puddles after a rainstorm likely were killed by exposure to light, not by drowning, since they can live submerged in water. However, worms will emerge from their burrows seeking oxygen when unoxygenated rainwater filters down through the soil and squeezes most of the rest of the oxygen from the soil spaces.

Taste cells are located in and near an earthworm's mouth, and worms show definite food preferences. Experiments have demonstrated that they will pass up cabbage if celery is available and shun celery if carrot leaves are offered.

Earthworms are hermaphroditic, meaning each individual possesses both male and female reproductive organs. The eggs and sperm of each earthworm are located separately to prevent self-fertilization. When worms mate, they face in opposite directions and exchange sperm; the eggs are fertilized at a later time. Mature eggs and sperm are deposited in a cocoon produced by the clitellum, a swollen, saddle-shaped structure near the worm’s head. Within the cocoon, the sperm cells fertilize the eggs, and then the cocoon slips off the worm into the soil. The number of worms inside each cocoon and the length of time it takes them to hatch varies according to worm species and environmental conditions. Approximately four *Eisenia fetida* baby worms will emerge from a cocoon in 30 to 75 days, and another 53 to 76 days must pass for the newly hatched worms to reach sexual maturity.

Earthworm cocoons resemble grape seeds in size and shape, with one end rounded and the other slightly pointed. Cocoons are initially pearly-yellow in color, then deepen to brown as the young inside mature and get ready to hatch.

Earthworms can only reproduce using sperm from members of their own species. Claims of hybrid worms are not valid.

Earthworm Production

Earthworms have certain minimum care requirements that must be met on a regular schedule. The key environmental factors affecting earthworm growth, reproduction, and health are temperature, moisture, aeration, pH (acidity-alkalinity), and food material.

Temperature

Earthworms live and breed at temperatures between 55 and 85 degrees Fahrenheit. For commercial earthworm production, the ideal temperatures for growth and activity range from 60° to 80°. Bed temperatures should be between 60° and 70° to facilitate intensive cocoon production and hatching. If bed temperatures rise too high, they may be lowered by adding water, activating fans in or near the system, and reducing the amount of feedstock applied.

Moisture

Earthworms need adequate moisture to help them breathe through their skin. Beds need to sustain a moisture range of 60 to 85 percent and feel crumbly-moist, not soggy-wet. They should be sheltered from direct sunlight so they do not dry out and overheat. One method of increasing cocoon production after worms are fully established is to stop watering the beds for several days or until the top 1 or 2 inches are scarcely moist. Then dampen the beds enough to restore them to their recommended moisture content.

Aeration

Earthworms can survive in relatively low oxygen and high carbon dioxide environments and even stay alive when submerged in water if it contains dissolved oxygen. If there is no oxygen, however, earthworms can die. Oxygen may be depleted if earthworm beds are kept too wet or if too much feed is introduced. By reducing the amount of moisture, cutting back on feed, and turning the pile with a pitchfork or three-prong garden tool, oxygen will be restored. Turning the materials in the beds every two to three weeks will help keep the beds aerobic.

pH (acidity-alkalinity)

The pH of soil indicates whether it is acidic (1 to 6), neutral (7), or alkaline (8 to 14). Earthworms will grow in a pH range of about 4.2 to 8.0. For commercial production, however, earthworm beds should be kept at a pH range of 6.8 to 7.2. Check levels weekly with a pH kit, available in garden supply centers or feed stores. Take readings at different levels in the bed: the top feed area, 3 inches deep, and 8 inches deep. If an acid condition is detected in an earthworm bed, agricultural lime (calcium carbonate) may be mixed with bedding material to remedy the condition. Sprinkle half a pound of limestone on each 24 square feet of bedding surface, and water the bed. It is far less common for an overalkaline condition to exist. To remedy alkalinity, mix enough dry peat moss into the bedding until pH readings indicate a range of 6.8 to 7.2.

Setting Up an Earthworm-Growing Operation

The first question to ask when considering starting a vermiculture or vermicomposting business is, "How can I market the product(s)?" not "How will I produce the product(s)?" Other questions to consider include:

- What income do I want or expect?
- Will I work at it part-time or full-time?
- What business experience do I have? Have I run a business, developed a business plan, or marketed products?
- Does my region have marketing opportunities for earthworms and castings?
- Who are my competitors, and how can I be different?
- What financial resources are available to me?
- What physical resources do I have (land, buildings, machinery, labor)?
- Will I work solo or in partnership with others?
- In what type of climate do I reside? (This affects how I will need to shelter the earthworms.)

The next step is to learn as much as possible about earthworm farming and the current and projected needs of the industry. Read books, bulletins, pamphlets, and newsletters; watch videos; and consider attending workshops, seminars, and conferences. The

following resources will help (this is not an exhaustive list nor is it an endorsement or criticism of others not listed):

- Periodicals
  - *BioCycle Journal of Composting and Organics Recycling* (www.jgpress.com)
  - *Casting Call* (www.vermico.com)
  - *Worm Digest* (www.wormdigest.org)
  - *In Business* (www.jgpress.com
  - *Entrepreneur* (www.entrepreneur.com)
- Books and manuals (find vendors by typing in titles on an internet search engine)
  - *Commercial Vermiculture: How to Build a Thriving Business in Redworms* by Peter Bogdanov (1996).
  - *Raising Earthworms for Profit* by Earl Shields (1994-revised).
  - *Earthworms for Ecology & Profit,* Vols. 1 & 2 by Ronald Gaddie, Sr., and Donald Douglas (1977).
  - *Profitable Earthworm Farming* by Charlie Morgan (1975, revised). Other titles by Morgan include *Earthworm Selling and Shipping Guide; Earthworm Feeds and Feeding;* and *The Worm Farm*.
- Websites (use an Internet search engine in addition to www.bae.ncsu.edu/people/faculty/sherman/vermiculture/directory-by-state.html)
  - Worm growers
  - Vermiculture clearinghouses
  - Vermicomposting experts
  - Listserves on vermicomposting and composting
- Agencies (use an Internet search engine to find updated contact information)
  - State and local offices of Cooperative Extension
  - State solid waste agencies
  - State composting councils
  - U.S. Composting Council (www.compostingcouncil.org)
  - State recycling associations

- National Recycling Coalition (www.nrc-recycle.org)
- Solid Waste Association of North America (SWANA) (www.swana.org)

While gathering information, set up a small-scale system by buying or building a worm bin. This will enable you to learn first-hand what it is like to raise worms as you discover the challenges and demands of maintaining the system. Refer to the Extension publication *Worms Can Recycle Your Garbage* (http://www.bae.ncsu.edu/people/faculty/sherman/ag473-18.html) for instructions on getting started. Once confidence is gained in raising earthworms, expand the operation.

An important issue to address is compliance with state and local regulations. Many city, county, and state governments classify earthworm farming as agriculture for zoning purposes. Check with local government agencies for the zoning classification and any restrictions. Find out if a business license, permit, or resale license is required. Contact the state solid waste management agency and the state Department of Agriculture and Consumer Services to inquire if permits are required for raising worms, using particular feedstocks, and selling worms and/or vermicompost. If food residues and yard debris are to be imported as feed for the worms, a permit from the state solid waste agency likely will be required. Obtaining this type of permit can be a costly and time-consuming process. In North Carolina, contact Ted Lyon, Solid Waste Section, Division of Waste Management, N.C. Department of Environment and Natural Resources, (919) 733-0692, ext. 253. If vermicompost is to be sold, contact Danny Turner, Fertilizer Section, N.C. Department of Agriculture and Consumer Services, (919) 733-3933, ext. 219.

Some new growers choose to sign contracts with earthworm wholesalers who sell breeder stock and promise to buy their offspring back. Many people are attracted to this arrangement because they will already have a steady market for earthworms. Those considering becoming a contract grower should check the wholesaler's reputation with the state attorney general (and other states, if possible) and try to talk to the wholesaler's customers. The Federal Trade Commission has a fact sheet, “Franchise and Business Opportunities,” with tips for investigating a business before investing with it

(http://www.ftc.gov/bcp/conline/pubs/invest/franchse.html). Even if a wholesaler is reputable, something unexpected could cause that company to go out of business, and then the worm grower's sole market would disappear. It is wise in any business to have backup plans for markets and other contingencies.

Growing earthworms in conjunction with livestock operations is often a successful way to diversify. Raising earthworms in the waste products of live stock and then feeding the animals with crops that have been enhanced with worm castings completes a nutrient cycle. Many rabbit growers have developed a second income from the sales of earthworms by placing worm bins directly beneath the rabbit cages where the worms automatically receive manure as feed.

Choosing whether to set up a worm-growing operation indoors or outdoors depends on climate, the type of system to be used, available finances, and goals for worm production. As mentioned earlier, redworms tolerate temperatures between 55° to 80° F. The closer the temperature is to the extremes, the less active the worms will be at feeding and reproducing. For maximum earthworm production, temperatures should be maintained between 60° and 70° F. To achieve this level may require providing some sort of shelter or insulation that can hold heat in the winter and cool the system during the summer.

Outdoor beds should be located in a well-shaded spot or under an open-shed roof. Indoor beds should be placed where there is adequate drainage and ventilation.

Ensure that water and electricity can be supplied to the site. Plenty of water is needed to keep the worm beds moist. Electricity is needed for lighting and temperature control, such as fans to cool the worm beds and auxiliary heating systems for warmth. Lights are the most effective method for preventing worms from leaving their bins.

Earthworm beds may be constructed from many materials, including lumber, concrete or cinder blocks, brick, concrete, or hollow tile. Do not use cedar, redwood, or other aromatic lumber for the beds, as they contain tannic acid and resinous saps that are

harmful to earthworms. Furthermore, do not use pine, as it soaks up water and softens, allowing earthworms to eat right through it.

Earthworm growers sometimes choose to use the following items as beds, as they can be obtained for free or inexpensively: half barrels of steel or wood, discarded refrigerators, old livestock water tanks partly buried, washing machine tubs, or other large metal or wooden containers. If any of these containers have a solid bottom, holes should be drilled in them for drainage. The frames or containers can be partially buried in the soil to help control temperature. Moles eat earthworms, so if they are common in the area, it will be necessary to install bottom coverings or screen linings in the beds.

The most convenient width for the short sides of an earthworm bed is 3 feet. For length, worm growers generally construct beds of at least 8 feet. If beds are longer than 8 feet, some growers like to install dividers every 8 to 10 feet for ease in dividing, harvesting, cleaning, or feeding. Others prefer not to use dividers.

Bed depth should be 12 to 24 inches. If continuous freezing or excessively hot temperatures occur in the area, consider building beds 12 to 24 inches below ground where the constant ground temperature will keep the worms from freezing or overheating.

The ideal distance between beds is 3 feet. This allows room for manually or mechanically operated equipment to be used between the beds for feeding, harvesting, or cleaning.

The lengthwise direction of the earthworm beds and their shelters should parallel the prevailing winds. For example, if the wind generally blows from west to east, the beds should be laid out in a west-east direction. This will prevent intense winds from hitting the largest part of the shelter and will help prevent covers, if they are used, from blowing off.

As described earlier, under certain conditions, earthworms have a tendency to crawl away from their beds. Many growers seek to prevent worms from migrating or at least try to capture them before they crawl away or perish. Some growers keep lights on over the beds all night and on rainy or foggy days. Others fit fine screens over the beds or install ledges extending at least 1.5 inches over the rim of the beds. Others pile moist manure, castings, compost, or old carpet next to the bins to capture worms that have crawled out.

Although beds and bins are most commonly used by worm growers, some choose other methods, such as windrows, the wedge system, or continuous-flow reactors.

Windrows are linear piles on the ground containing feedstocks up to 3 feet high. They are being used extensively both in the open and under cover, but require either a lot of land or large buildings.

The wedge system is a modified windrow system that maximizes space and makes harvesting easier because there is no need to separate worms from vermicompost. Organic materials are applied in layers against a finished windrow at a 45-degree angle. The piles can be inside a structure or outdoors if they are covered with a tarp or compost cover to prevent leaching of nutrients. A front-end loader can be used to set up a windrow 4 to 10 feet wide by whatever length is appropriate. The windrow is started by spreading a 12- to 18-inch layer of organic materials at one end of the area being used. Up to one pound of redworms may be added per square foot of windrow surface area. Subsequent layers of 2 to 3 inches of organics are added weekly, although 3- to 6-inch layers can be added in colder weather. After the windrow reaches 2 to 3 feet deep, the next layers are added at an angle against the first windrow. Worms in the first windrow will eventually migrate toward the fresh feed. Organic materials are added to the second pile until it reaches the depth of the first one, and then a new windrow is started. Worms will continue to move laterally through the windrows. After 2 to 6 months, the first windrow and each subsequent pile may be harvested.

Continuous-flow reactors have raised beds with side walls and mesh bottoms. The mesh floor openings are usually either 2 inches by 4 inches or 2 inches by 2 inches. When the system is being set up, a few layers of newspapers are laid on top of the mesh to prevent the bedding from falling through. Approximately 12 inches of bedding are spread on top of the newspapers. Earthworms are placed on top of the bedding at a rate of 1/2 to 1 pound per square foot of surface area of the bed. Feedstocks are added in layers on top of the bed. Finished vermicompost is harvested by scraping a thin layer from just above the grate, and letting it fall into a chamber below. These systems can be relatively simple and manually operated or fully automated with temperature and moisture controls. For maximum efficiency, they should be under cover.

Bedding Materials

Practically any organic residue, including plant wastes and most bulky animal manures, may be used for bedding. Horse and rabbit manures are considered ideal bedding materials. Some growers prefer to mix sandy loam topsoil with the bedding material, but this is not necessary. It also increases handling time and costs and may even reduce yields.

Earthworm bedding should retain moisture, remain loose, and not contain much protein or organic nitrogen compounds that readily degrade. These compounds would be quickly degraded with the release of 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. Hence, materials of this type should be composted, or aged beyond the heating stage by forming them into piles. Supplemental nitrogen can be added if needed in the form of inorganic nitrogen fertilizers, blood meal, chicken manure, or urea at the beginning of the composting process (about 1/2 to 1 pound of nitrogen to 100 pounds dry-weight bulky residue). Moisten the piles and turn them periodically to enhance aeration and to incorporate material on the edges and top into the

middle of the piles. After the heating stage has passed, the material may be placed in the beds to a depth of 8 to 10 inches.

After worms are added, keep the bedding moist but not soggy, and turn it once every 2 or 3 weeks to keep it loose and aerated. The bedding should be replaced about every 6 months by removing the top 5 or 6 inches (where most of the worms are) and harvesting the remaining worms, as described below. Then remove the remaining old bedding, which has been converted to castings, and pile it for other uses. Fill the bins with new bedding, add worms, and resume feeding.

Feeding Worms

Earthworms will consume animal manures, compost, food scraps, shredded or chopped cardboard or paper, or almost any decaying organic matter or waste product. Horse, rabbit, swine, dairy, or steer manures are excellent feeds. Poultry manure is not recommended as it is too high in nitrogen and mineral.. If feeds are low in nutrients, they must be supplemented with high protein or nitrogen materials such as grains, mashes, and cottonseed meal. Feeds containing high amounts of carbohydrate or woody residues should be composted beyond the heating stage. The feed and supplements can be applied straight or mixed with 20 to 30 percent horse manure or aged pine sawdust or shavings and spread on top of the bedding about 1 inch deep.

When using manure as feedstock or bedding, always test its suitability for the earthworms. The same goes for any organic material in question. Place the material in a container along with about a dozen worms and observe their behavior over the next 12 to 24 hours. If the worms consume the material, it's fine, but if they crawl away or die, it's not suitable. Composting the material may solve the problem. Continue to experiment with the substance until deciding whether it should be fed to the worms.

Feed the worms regularly, once or twice a week. Set the feeding schedule and amount of feed according to the rate of consumption of the last feeding and the condition of the worms and beds. When most of the feed has been consumed, it is time to feed again.

If too much feed is added, the beds may overheat or become anaerobic (oxygen-deprived) or too acidic. Adding calcium carbonate and mixing the bedding can alleviate these problems. If the worms do not appear to be growing bigger or producing offspring, more protein may be needed in the feed. Add grains, mashes, or cottonseed meal.

Harvesting

Harvest the earthworm beds regularly, about every 30 days, to optimize worm production. Thinning the population provides more feed and space for the remaining worms and keeps the bedding loose and porous so the worms can move more easily to eat and reproduce.

Harvesting Beds and Bins

Harvesting beds or bins may be accomplished by several methods. A commonly used technique is called "table harvesting." Place a table or board covered with a waterproof plastic sheet next to or across the worm bed frame. Next to it, place one or two containers with about 2 inches of pre-soaked bedding for the harvested worms. Using a pitchfork or three-pronged garden tool, carefully lift the top 4 inches of bedding (which contain most of the worms), and place it on the harvesting board. Make sure that either brilliant sunlight or a bright light is shining overhead to drive the worms deeper into the bedding to escape the light. Gently remove the top inch of the bedding pile. Wait a few minutes for the worms to burrow deeper, and then repeat the process until eventually mostly a solid mass of worms remains. Place the worms in the containers with the pre-soaked bedding.

Another method is to make a box with wooden sides and a mesh bottom and put manure or watermelon in it. Place the box on top of the worm bed and earthworms will crawl through the mesh bottom to eat the food. Then simply pick up the box and either set up a new bed or package the worms for sale.

A similar but more elaborate box method captures more worms and grades them as they are harvested. Build 4 square boxes 2.5 to 3 feet long, using 1-inch by 4-inch lumber. Staple or nail a different size wire screen to each box with the following size openings: 1/4-inch, 3/16-inch, 1/8-inch, and 1/16-inch. Put moist bedding and worm food in each box. Place the boxes in sequence with the largest screen size on the bottom, and put the boxes either on the bed to be harvested or slightly buried in it. After several days of keeping the bedding properly moistened, remove the boxes to find earthworms in each box according to size, with the largest worms trapped in the bottom box and the smallest ones in the top. This technique works because earthworms head for the surface to feed.

Another simple harvesting method is to set a plastic sheet with fresh manure on top of the worm bed. A significant number of worms will crawl onto the sheet, and it can be lifted off the bed.

Harvesting Windrows

Worm growers with long 2-foot high windrows typically use a front-end loader to remove the top 6 to 8 inches of material, where most of the worms can be found. This material is deposited in a new windrow. Then the remaining castings are scooped up and screened, using a mechanical harvester.

Harvesting Wedge Systems

This system is basically self-harvesting because worms in the first, oldest windrow will migrate toward the fresh feed in the newer windrows. After 2 to 6 months, the first windrow and each subsequent pile can be harvested.

Harvesting Continuous-Flow Reactors

Activate a hand-operated crank or a hydraulic system to pull a bar across and just above the grill, scraping off a thin layer of finished vermicompost that falls through the widely spaced bars to the chamber or floor below.

Mechanical Screening

Worm farmers operating on a mid to large scale use a mechanical worm harvester. These devices may use a vibrating or shaking flat screen, but the most common types are trommels, which are rotating cylinders with screen mesh sides of varying sizes. A 1/4-inch screen is the most commonly used. The average trommel used in the vermiculture industry is 8 to 10 feet long and 2 to 3 feet in diameter. A small electric motor mounted on one end of the cylinder turns it. As the cylinder rotates, the material inside rolls across the screen as it moves from the input end to the output end. This forward motion is accomplished by tilting the harvester at an angle. As the material rolls, anything smaller than the holes in the screen falls through, and the rest continues until it comes out the output end. At the output end, a cone may be installed that separates most of the worms from the other material that did not fall through the screen. Commercial trommel screens used for harvesting worms typically cost between $1,600 and $3,500. Some growers choose to build their own trommel screens at a fraction of the cost of a new one.

Grading and Counting

Earthworms are sold by weight or by count. There are two grades, bed-run (worms of all sizes) and bait-size (worms 2 1/2 inches or longer when drawn up and with bodies at least 1/8 inch in diameter). Breeding stock are large earthworms with a fully developed clitellum. If worms are to be sold for bait or breeding stock, they need to be sorted from the rest by hand; this is best accomplished while harvesting. Put the smaller worms immediately back into the beds, and count the larger ones as they are placed into containers or set them aside for weighing. Most growers pick out the desired size or type of earthworms by hand to ensure uniformity.

Instead of hand-counting worms, many growers use a sample count and weighing method. This involves hand-counting 1,000 worms of one grade (bed-run or bait-size) and placing them on a scale that weighs in pounds and ounces. Make sure the scale is set at zero (*i.e.*, adjust for the weight of the container) before putting any worms on the scale. A 10 percent overcount is considered good business in the earthworm industry, so add another 100 worms to the 1,000 on the scale. Record the weight in ounces so that a single

unit of measurement is used instead of two (pounds and ounces). Continue this method of measurement for the other grades of worms to be sold so that you end with a standard weight for 1,000 worms of each grade, including overcount. Thus, the worms will no longer need to be counted by hand, except to recheck base weights periodically to ensure their accuracy.

Packaging and Shipping

Earthworm growers use a variety of packaging methods and containers, but most of the successful ones use containers specially designed for holding and shipping worms. These containers may be purchased from various suppliers, including earthworm growers, wholesalers, or distributors. Containers range in size from half-pints (holding 50 bait-size worms) to gallon cartons holding 1,000 bait-size or 1,500 to 2,000 bed-run earthworms. To retain moisture and to discourage the worms from eating the containers, the cartons should be made of wax-coated cardboard or plastic and have small holes for air. Earthworms should always be stored in cool, well-shaded areas. Shipping boxes should be securely fastened with heavy shipping tape, and clearly marked on the outside: LIVE EARTHWORMS. HANDLE WITH CARE. DO NOT EXPOSE TO EXTREME HEAT OR COLD.

To help keep the worms moist and alive, pack them in moist bedding. Canadian sphagnum peat moss is considered by many to be the best material for shipping worms. Other types of peat moss may be too acidic. The peat moss should be soaked in water for at least 24 hours and then squeezed by hand to remove excess water. This produces a damp, but not soggy, packing material that will keep the worms comfortable for up to two weeks. If the peat moss is too wet, it could cause acid buildup. Some agricultural lime can be sprinkled on the peat moss to reduce acidity and bring the pH level to 6.5. Pack the shipping container about half full of peat moss and then add the worms.

Worm growers typically ship earthworms by ground transportation, using either United Parcel Service (UPS) or the U.S. Postal Service (USPS). Bear in mind that UPS does not make Saturday or Sunday deliveries, and USPS does not deliver on Sundays. Therefore,

always ship worms at the beginning of the week so they do not end up spending the weekend where they could be harmed by temperature extremes. As a courtesy, notify customers when their shipments leave and when they should expect delivery.

Before getting into shipping, find out how other growers in the area do it, and ask UPS and USPS how packages are handled to determine the best method of shipment. Try shipping a small amount of worms to a family member or friend to find out how they survive the trip. Planning ahead can help avoid having to replace lost inventory.

Earthworm Pests

Earthworm pests are birds, rats, snakes, moles, mice, gophers, toads, and other insects or animals that feed on worms or molest them. Arthropods such as mites and ants are probably of the greatest concern to earthworm growers.

Mites

Mites are natural inhabitants of manures and similar organic materials. All worm beds contain small populations of mites, which under certain conditions may reach extremely high levels. If worm beds are not cared for properly, acidity can build up and create conditions that allow mites to thrive. Routinely check pH and add agricultural lime if the pH is less than 6.8.

White or Brown Mites

White or brown mites are not predaceous and tend to feed only on decaying or injured worms. During infestations, however, these mites can devour much of the food in earthworm beds, depriving worms of needed nutrients. This increases worm growers' costs and time spent feeding worms. Mite populations at high levels also can cause worms to stay deep in the beds and not come to the surface for feeding, resulting in poor growth and reproduction.

Red Mites

The red mite is parasitic to earthworms. It attaches itself to the worm and sucks its blood or body fluid. Red mites also are capable of piercing and sucking fluids from egg cocoons. These mites first appear as small white or gray clusters resembling mold. Magnification will reveal clusters of juvenile red mites in various stages of development. The adult red mite, which is smaller than the white or brown mite, has an egg-shaped body, is bright red, and has eight legs.

Mite Prevention

The best control for earthworm mites is prevention. Proper care of worm beds can prevent a harmful buildup of mites. Bed conditions ideal for worm production are not conducive to high mite populations. Conversely, beds with high mite populations are being improperly managed for optimum worm production. One or more of the following conditions are usually associated with high mite populations:

Too much water—Beds that are too wet create conditions that are more favorable to mites than worms. Avoid excessively wet beds by adjusting watering schedules, improving drainage, and turning bedding frequently.

*Overfeeding—T*oo much food can cause an accumulation of fermented feed in worm beds and lower the pH of the beds. Adjust feeding schedules so that all feed is consumed within a few days. Modify feeding schedules as the seasons (and temperatures) change because worms consume less food in colder temperatures. Maintain beds around a neutral pH 7; use calcium carbonate to adjust the pH level.

Excessively wet or fleshy feed—Vegetables with high moisture content can cause high mite populations. Limit the use of such feed, and if high mite populations are discovered, discontinue the use of this feed until mite populations are under control.

Mite Removal

Several methods have been suggested for removing mites from earthworm beds. Bear in mind that any type of mite removal, physical or chemical, will only be temporary unless worm bed management is altered to make conditions less favorable for mites. The following techniques range from low- to high-intensity measures.

Method #1—Uncover the worm beds and expose them to sunlight for several hours. Reduce the amount of water and feed. Mites will not like this environment and they may leave the worm beds.

Method #2—Place moistened newspapers or burlap bags on top of the beds, and remove the paper or bags as mites accumulate on them. Repeat this procedure until mite populations are substantially reduced.

Method #3—Place pieces of watermelon or cantaloupe rind or potato slices on top of the worm beds. Mites are attracted to the sweetness of the rinds or peels and will accumulate on them. The rinds or peels can then be removed and dropped in water or buried.

Method #4—Water heavily, but do not flood, the worm beds. Mites will move to the surface, and worms will stay below the surface. Use a hand-held propane torch to scorch the top of the beds and kill the mites. Take appropriate safety precautions when using the torch. This procedure may be repeated several times, at three-day intervals, if needed.

*Method #5—U*se a light dusting of soil sulphur to kill the mites. After soaking the worm bed with water and causing the mites to surface, apply a rate of 1/16 ounce of sulphur per square foot of bed surface. Sulphur will not harm the worms, but in time, it may increase the acidity of the bed and reduce earthworm populations.

Popular literature on mite removal from earthworm beds is somewhat contradictory. In the past, chemical pesticides have been used in worm beds. However, it is now known that some pesticides have the potential to harm humans, and recommendations for such treatments are not given here. Although newer, safer, miticides exist, sufficient scientific research has not been conducted in worm beds to merit mention at this time.

Ants

Several species of ants may occasionally be a problem or annoyance to worm growers. Ants are attracted to high-concentrate feed in worm beds, and some species are reported to feed on eggs and small worms. Physical barriers can be placed around worm beds to keep ants out. Ants can be controlled with baits and insecticidal sprays outside the bins, but take precautions to prevent injury to the worms.

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