Worms for Bait or Waste Processing (Vermicomposting)

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Contents

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This publication is for entrepreneurs interested in a commercial earthworm enterprise. Information about vermiculture – raising earthworms for bait or feed – is included. Information about using these worms, usually *Eisenia fetida,* to process waste into vermicompost is also included. Vermicompost is used in nurseries or the landscape industry as an ingredient in potting soil mixes and performs pest and disease control functions as a soil amendment. Production and marketing issues are covered for both types of earthworm businesses. Whether you are raising worms for bait or using them to produce vermicompost, you will need to learn how to raise earthworms. For your worm-based business, you will have to separate earthworms from their growing environment and sell your product—either the worms or the vermicompost.

Many people use earthworms on a much smaller scale for processing their personal garbage as a means to reduce the amount of their garbage going to the landfill. This publication has information that can serve this audience as well.

Introduction

Before you decide to begin an earthworm venture:

- Read about worms
- Start a worm bin of your own
- Identify markets
- Visit a worm enterprise and ask questions
- Decide whether to sell the worms or to sell the vermicompost
- Locate inexpensive or free sources of bedding and feed
- Develop a business plan
- Decide on a marketing plan

This might not be the proper order for your investigation and research. However, each activity will help you determine if you should start an earthworm enterprise. Marketing is important, so you must develop a plan for selling your product before you make any serious investment in this new venture.

Eisenia fetida*, a good composting worm of many names. Photo courtesy of Bentley Christie,* RedWormComposting.com.

Produce earthworms or use worms for waste processing?

The two main reasons that people grow worms are to sell them as bait or feed or to use earthworms to process waste materials (sometimes with purchased amendments) into vermicompost, a valuable soil amendment. Although the needs of the worms must be met in either type of system, the objectives are different.

Raising worms for bait requires closer management than raising them to process agricultural or food wastes. When you choose to sell worms for bait or as feed for fish or poultry, you will sell off the livestock from the system periodically. Bait worms must meet a certain size standard and will need to be separated from smaller worms and eggs. You should be consistent in your feed and bedding. You will also need to optimize

Castings are pure worm waste. Vermicompost includes castings, organic material and bedding in various stages of decomposition, along with living worms, eggs and other worm bin creatures. There are not many commercial systems that produce pure castings. The terms *castings* and *vermicompost* are often used interchangeably and, because pure castings haven't proved more effective than vermicompost, they won't be distinguished in this publication.

temperature, aeration, pH and moisture conditions to promote worm reproduction and growth. All of this requires consistent management and attention to detail.

For a waste processing system, the goal is low-cost production. The materials that you process might not be ideal for feed or bedding, but if the source is consistent, you can design a workable system. With skillful marketing, it's possible to be paid tipping fees for waste removal and be paid again by the end user for the final product. Tipping fees are charged to those who generate garbage for the service of hauling it away.

Do some market research and consider what type of worm farming system fits your situation before you commit resources to setting up your operation. Producing worms will require considerable attention, especially at the start. If you have never managed a household worm composting system, begin with a small-scale trial and learn the basics.

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Production systems

Worm production takes place at scales that range from a bin in the kitchen for processing household scraps or raising fishing worms to large mechanized systems able to accommodate tons of organic material on a continuous basis. This publication is focused on commercial-scale operations. In general, these production methods can be grouped into four types:

- *Batch reactors* (containers on legs or on the ground) are filled, allowed to work and then emptied. This type of processing is being tested at various scales throughout the United States. These systems can be used to raise worms or for waste processing.
  - *Stacked bins* or containers are a type of batch reactor and require considerable handling and lifting. It is difficult to monitor bed conditions and to add feedstuffs. Systems using stacks of large, shallow drawers reduce some of the drawbacks. Considerable labor is involved.
- *Windrow systems* on concrete or on the ground require the least capital investment, but they are slow and labor-intensive, even with machinery. Although windrows have been used for worm production, they are most appropriate for waste processing.
- *Continuous flow reactors* are the most expensive of these systems. Labor costs may be less, however. Equipment, skilled management and excellent marketing are necessary to ensure a profitable enterprise.

Continuous processing has emerged as the preferred method for commercial production of vermicompost. The worms never leave the bed, so tedious harvesting procedures are avoided entirely. Feeding, misting and collecting the finished product can be automated, and it is much easier to produce a consistent product.

Raising worms

The kinds of worms used in commercial systems are not the species commonly found living in the soil. Likewise, the worms raised in these systems will not survive long living outdoors.

The most common species raised in the United States is *Eisenia fetida.* They require high levels of nutrients, reproduce quickly and tolerate being raised in captivity. Their preferred temperature range is about 65 to 80 degrees Fahrenheit.

Often called red wigglers, manure worms or tiger worms, there are many common names used to market this type of worm. Some are called hybrids; some are even called

nightcrawlers. True nightcrawlers, *Lubricus terrestris,* are not well-adapted to commercial production. However, if you check the species of the worms you are buying, you will be fine, no matter what the seller is calling them.

When stocking a bin, start with a pound of worms for every cubic foot of bed. This allows plenty of room and ensures that the worms will be in close enough proximity to continue breeding. Populations are self-adjusting. When conditions become crowded, larger worms will eat less and try to avoid younger or smaller worms. Reproduction rates then decline and worms will try to leave the bin (Gaddie and Douglas, 1975)

As stated earlier, the emphasis is different if you are selling worms or if you are using worms to produce a valuable soil amendment. In either case, you will need to tend to the needs of your worms. Consider them as livestock that have feed and housing requirements. Worms are vulnerable to pests, but less susceptible to diseases. Care for them well to create a profitable business.

Key environmental conditions for growing worms are:

- High moisture percentage throughout the bedding
- Continuous oxygen within the growing container
- Optimal bedding temperature
- Slightly acid pH (acidity or alkalinity) in the system

Oxygen: Oxygen is critical to the worm production system. The worm needs oxygen, which passes through its moist skin, to live. The microbes that live with the worms and help process the worm feed also need oxygen. If the bedding becomes matted or water-logged, the system will become anaerobic (oxygen-limited). Incorporate some coarse bedding materials that won't mat when they get wet.

Pay close attention to this critical environmental factor. It is difficult to maintain high moisture and high oxygen conditions, but that is what worm production requires.

Some things to know about worms:

- They don't tolerate light. One hour of exposure to sunlight will completely paralyze an earthworm and several hours will kill it (Gaddie and Douglas, 1975).
- Their skin must be kept moist so that they can breathe through it.
- Their bedding must be kept moist, but not wet.
- Aeration is critical to maintaining healthy worms.
- If conditions in the bed don't suit them, the worms will leave.
- Once acclimated to their environment, worms can eat half their weight – or more – daily.
- Reproduction rates slow down when worms are too crowded.
- Optimal bedding temperature ranges for growth and for reproduction vary by species.

Moisture: The bedding should be very damp. In order to breathe, a worm's skin must stay moist. A moisture meter will accurately measure the moisture percentage in bedding. The ideal moisture range, from 80 to 90 percent, is higher than is practical for maintaining aerobic conditions, so optimal percentage is about 65 to 70 percent. Worms in an over-watered bed will become large, soft and sluggish. Breeding rates decline under such waterlogged conditions. It is useful to know how bedding with the optimal amount of moisture feels. Taking a handful of bedding and squeezing it should produce a few droplets of water between the fingers. This indicates about 70 percent moisture.

If there is not enough moisture, the worms have trouble breathing. Other pests will also move into a very wet environment, especially if it becomes so wet that oxygen is limited.

Be sure that excess moisture can drain away from the production area, but be careful to control such runoff, because it is considered livestock effluent. The laws designed to prevent livestock effluent from contaminating water resources apply to worm production as well.

Excess water that drains from a worm production system is not the same as

vermicompost or worm tea. Such teas are made by soaking vermicompost for a predetermined period, either with or without amendments, often with a bubbler to maintain aerobic conditions. Teas have been shown to provide benefits similar to vermicompost but with the advantages of liquid application.

Temperature: Each worm species has different ranges for optimal growth and reproduction. Keep the temperature of the bedding between 60 and 80 degrees Fahrenheit for all worms except tropical species. Although the worms will survive relatively extreme temperatures (some will even tolerate gradual freezing), the goal is to maximize growth and reproduction, which is most efficient in comfortable conditions.

What's the best feed? The most microbe-active, diverse material that can be obtained for little or no cost.
–Kelly Slocum, worm consultant

Where cold temperatures are a concern, electric heating mats or cables can be used underneath the production area to keep the bedding warm. You can also insulate the production facilities with straw bales or other available materials. In areas where the soil doesn't freeze deeply, burying the beds below ground level helps protect the worms from extreme temperatures, although drainage issues must be addressed.

Increased microbial activity will raise the temperature in the beds. This is helpful in keeping beds active in colder climates, but it is a problem if the bedding or feedstock has not been pre-composted and the bed becomes very hot. When using raw materials for this purpose, be sure the worms can move away from the source of heat.

In hot climates, shade is essential to maintaining an optimal temperature range. Half-buried production facilities can be helpful in these situations as long as there is plenty of moisture and air flow for evaporative cooling. Some producers have used mist systems. Remember, consistent temperatures provide consistent results.

pH: The pH (acidity or alkalinity) of the system is important, but only if conditions range too far from neutral or changes occur too rapidly. Worms can tolerate a pH range from 5 to 9, which is broad, because the difference of one number means that the lower number is 10 times more acidic than the next number up. Some feed and bedding materials will change the pH when added to the growing area. For example, high-protein feeds tend to make the system more acidic, as do many vegetable wastes. Nevertheless, changes in pH are usually gradual and don't affect the worm population.

Kelly Slocum, a worm production consultant, says that, contrary to what many have said, worms prefer a pH of 5, which is acidic (7 is neutral). She suggests that if you have a problem with your worm production, pH should be the last item you evaluate. If you decide that pH is the problem and you want to adjust it, remember that this affects all of the bin residents that are adapted to the current conditions. The whole ecology of the bin will shift and it will take time to adjust to the new pH (Slocum, 2000).

When conditions are not within tolerable limits, worms will be stressed. How can you tell that there's a problem?

- When worms are climbing up and exiting the bin
- When worms are staying low and not coming up to feed
- When worms mass together in a ball

If you see these symptoms, something is seriously wrong with the worms' environment. You should immediately determine what it is and fix it.

Feeds and bedding

Some materials can serve as feed and bedding. Successful producers provide for their livestock's (worms) need for both. Both the feed and the bedding will be consumed by the diverse population of organisms in a worm production system and both will need to be replaced as the material is converted to worm castings.

Feeds

Worms eat a wide variety of organic materials – or, more accurately, a wide variety of the microbes that feed on organic materials. Almost any plant or animal waste could

Worms with vegetable scraps and paper bedding. Photo by Amy Weishuhn.

be used as worm feed. But remember that, like other livestock, worms need vitamins, minerals, protein and carbohydrates. Feeds should contain more carbohydrates and cellulose than protein.

Usually the feed has nitrogen and is balanced by the high level of carbon in the bedding. A carbon-to-nitrogen ratio of 30 parts carbon to 1 part nitrogen is about right for a worm production system. Too much nitrogen creates ammonia, which is toxic to worms and to many of the microbes that the production system relies on. Excess carbon slows microbial activity and reduces overall productivity. Fat or oily materials such as soybean or sunflower meals should be avoided because oil slows bacterial breakdown, shifting the pH toward an acid bed.

Animal by-products, dairy products and meat are generally avoided because they attract flies, rodents and other pests. However, animal waste – especially livestock manure mixed with straw or sawdust – is good for a worm business because the feed and bedding are already combined. Use good sanitary procedures when handling raw manure to prevent the spread of infection from possible pathogens in the manure.

Worms have no teeth, so it is best to use small feed particles. If you grind feed materials very finely, worms can utilize them more readily, but be sure that there are enough coarse materials for bedding so that the materials will not pack tightly and limit oxygen. Another way to reduce particle size is to soak feed before adding it to the bed.

Worms have gizzards, as chickens do, and need some kind of grit to help them reduce the size of the food particles they eat. Adding sand or clean garden soil periodically will help the worms consume their feed. If the bed is tending toward a pH that is too acidic, a small amount of agricultural lime (calcium carbonate) can serve as the grit and neutralize the living conditions. A limited number of egg shells will also serve this purpose, but watch for pest problems.

Bacteria, fungi and other soil-dwelling microbes also help break organic material into usable particle sizes. Bacteria and molds begin to digest organic matter very quickly. Their activity softens and breaks down food to further prepare it for the worms.

Scientists believe that microbes themselves constitute a sizable portion of the worm diet. Protozoa may in fact be the dominant nutrient source. However, rotifers, nematodes, bacteria and fungi – as well as the decomposing remains of plants and other animals – are also eaten and probably provide some

Feeds

Animal manures (no antibiotics or deworming medications)
Cardboard, shredded
Hay, either legume or grass types
Waste products and compost
Commercial feeds
Wood and paper products
Sewage sludge
Food scraps (avoid meat and dairy)
Synthetic feeds
Almost any decaying organic material

Do not feed:

Meat scraps or bones, fish, greasy or oily foods, fat, tobacco or pet or human manure.

nourishment. This is why worms like feed materials that have already started to spoil.

Monitor how quickly the feed is being processed, and don't overfeed. Producers who top-feed either remove unused feed or wait until visible feed has been consumed before adding more.

You might choose to offer a fattening ration just before harvest if your system goal is to raise worms to sell to the bait market or if you are selling some worms as breeding stock. Because maximum growth is desired, you might purchase feed formulated for this purpose. If you would rather formulate your own ration, a commonly used recipe contains the following ingredients, very finely ground:

5 parts chicken starter (high-protein corn, ground)
2 parts bran (wheat or rice)
1 part wheat flour
1 part powdered milk
1 part agricultural lime
3 parts alfalfa, ground

If the focus of your operation is to use worms to process plant or animal wastes into vermicompost, few purchased inputs are required. Look around your area for confined livestock operations, canning factories and mushroom facilities for potential sources of waste. Groceries and restaurants are other possibilities if vegetable matter can be separated from animal and other waste products. Pre-consumer wastes are easier to handle than post-consumer garbage.

Since landfills in many areas will not accept organic materials, some establishments might pay you to receive their wastes. This tipping fee is commonly charged for the disposal of garbage. Similarly, livestock manure is subject to legal restrictions so that it doesn't contaminate nearby water sources. Diverting these waste streams to worm production is an opportunity for the entrepreneurial worm farmer.

Manure for feed or bedding

Manure is a great feed or bedding material. Try to find a trustworthy source of manure that is free of antibiotics, dewormers and other chemical medications. Check for an acceptable level of urine and salts. If the product is consistent, and you are observant about your system, you will not need to test it often.

A pile of fresh manure, even when mixed with straw or sawdust bedding, immediately begins a thermophilic (heat-producing) composting process. Bacteria cause this activity and the resulting compost is microbe-rich, but make sure the thermal composting process is done before using this manure in your worm beds.

Many vermicompost systems rely on thermal composting prior to feeding the organic material to the worms. Pre-composting, as it is sometimes called, can disable viable seeds and kill some human pathogens that may have been in the feedstock.

Pre-composting takes much less time than completely composting the feedstock material. Since pre-composting is designed to allow some of the potential heat to dissipate, it is usually a short (often two weeks) but closely monitored process. Materials are combined and the pile is built. Proper moisture and aeration help create an active pile that heats to 160 degrees F for three days. The compost is often turned and allowed to heat a second time. After this stage, the material can be cooled and carefully added to a working bin.

Testing material for use as bedding

Fill a small container that has aeration holes with the prospective bedding material. Introduce a small number of worms into the container. If the worms are still there 12 hours later, it is safe to use the material as bedding. If they are dead or have crawled out of the container, further processing is needed. Leach or age the manure for a longer period and test again before using it as bedding.

Bedding

Bedding and feedstock sometimes come together. Manure mixed with straw is an

Possible bedding materials

- Shredded paper (newsprint, paper bags, cardboard, office paper, but not cross-cut shredded)
- Sawdust (but not from redwoods, pine or other aromatic softwoods; test first)
- Composted animal manure (cow, horse, rabbit)
- Shredded, decaying leaves
- Straw
- Peat moss (consider sustainability and cost issues)
- Coconut coir (consider transportation cost and sustainability)

example. Worms will process the bedding as well as the feed, so why make the distinction?

Bedding is typically a carbonaceous material that will break down more slowly than the feed. It is usually a coarse material that won't pack tightly and therefore maintains air pockets within the growth chamber. It helps to absorb excess moisture from feedstock as well.

Some commercial systems use peat moss as bedding, but this is an expensive, nonrenewable input that might be better used in other applications. Coconut coir, a renewable resource, has replaced peat moss in many systems. Its disadvantage, from a sustainability perspective, is that it is transported long distances. Sustainable, economic opportunity in worm production lies in using easily obtainable inexpensive or free materials for as many of the inputs as is possible.

Worm bin ecology

A successful worm bin is an ecosystem containing a wide diversity of plants (fungi, bacteria, and molds) and animals, all adapted to similar conditions. There are many more species than just the worm that the system is managed for. These critters, both microscopic and visible to the eye, are interdependent; they all work toward breaking down and stabilizing the organic materials in a worm bin. Because worms don't have teeth and have only rudimentary digestive fluids, they depend on other creatures for help to make nutrients available. The large, visible organisms reduce the size of particles in the bed so that the smaller creatures have access to more surface area. Microorganisms use their own enzymes or digestive acids to process food for themselves, which makes the organic material more available to worms and other critters in the system. Each species has a niche. Any given organism feeds on materials or other organisms in the bed and is likely to become food to others in the ecosystem.

To the new producer, some of the organisms in the worm ecosystem will be unfamiliar and might cause concern. However, most are not dangerous to the worms and are extremely beneficial to the efficient functioning of the system. Few of them eat living plant material, so they are rarely a danger to plants that will receive the vermicompost.

Some of the critters commonly found in vermiculture systems are listed and described in the **Appendix.** These descriptions are very brief, serving as an introduction to the residents of the worm-producing ecosystem that you are managing. Learn more about each of them as you observe them in the system. If certain critters seem to be overwhelming the system, study them, learn what conditions are causing the increase and adjust your management to bring the system back into equilibrium.

Included in the **Appendix** are lists of animals that might threaten worms in a production system as well as benign critters that are potential competitors for feed.

Because this is an extremely intricate biological system, using chemicals to control any member within it will affect the others. If you use chemicals, they may persist in the bedding or castings. Later, when the material is added to the soil, it might be hazardous to the growing plants.

Diseases

Worms are not generally susceptible to diseases; however, they are sensitive to conditions in their environment. Protein poisoning

Because worms don't have teeth and have only rudimentary digestive fluids, they depend on other creatures for help to make nutrients available.

or sour crop will result from the accumulation of unused feed in the bin. When this happens, the bed becomes acidic and gases are released into the bedding.

Symptoms include:

- Swollen or burst clitellum
- Knots along the worm's body
- Worms that are stringy or crawl around aimlessly on the bed's surface
- Worms that stay low in the beds and refuse to come up to eat
- Worms that turn white and die in the bedding
- An increase in the population of acid-loving worm bin residents

Separating worms from vermicompost

No matter what product you're selling, separating worms from vermicompost is necessary. If you're selling the worms, the larger worms may be separated by one of the methods below and then fed a fattening feed ration to increase their size or to clear their guts if they are being sold as feed.

You should periodically harvest to redistribute worms, even if they are not being sold, in order to keep populations from becoming overcrowded. Start with a 30-day harvest interval (after your production area is fully occupied) and adjust it according to your system's requirements.

Sorting systems use worms' natural aversion to light, their tendency to move upward to fresh food offered and mechanical screening devices to separate worms from the vermicompost.

Hand sorting worms

Removing the top 3-4 inches of bedding from the growing area to a sorting table is a labor-intensive way to sort worms. A strong light is maintained in the work area so that as layers of vermicompost are brushed away the worms are exposed and immediately burrow into the remaining material. The larger worms move down faster than smaller ones, so that the top layer of bedding and the smaller worms are swept back into the growing area. The worms are allowed to move to the bottom again. After several sweepings, the remaining bedding is swept toward the center of the table, and the worms are allowed to move to the bottom, and the top of this pile is swept away. Finally, the large worms are hand-picked into containers with damp bedding and readied for further fattening or for immediate sale.

Using screens to separate worms

The simplest method of screening worms from their bedding involves shaking a box with a screen bottom. The screen size allows vermicompost to fall through and the worms remain in the box. When screens of different sizes are used, the vermicompost can be separated from the small worms and eggs as well. This method has obvious drawbacks because of size limitations and labor requirements.

Some production systems are based on using stacked boxes with screen bottoms. As the feed and bedding is used in a box, another box with fresh feed and bedding is placed on top of it. Worms naturally migrate away from the castings-rich environment to the next level above it. At intervals, another similar box with fresh bedding and feed is added to the top of the stack. After the worms have moved up, the bottom box is removed and the vermicompost is processed for sale.

Another harvest method uses screen wire that is placed in the bed. Again, fresh food and bedding are placed on the screen wire to entice the worms away from the worked material toward the bottom of the bed. The worms move up through the screening and feed near the surface. After the worms have been feeding and growing above the screen for some time, the screen is removed with the worms in it. What remains below the screen is mostly vermicompost ready to be processed for use or sale.

The worms' natural inclination to move upward and toward fresh bedding is used to harvest worms in windrow systems as well.

In fact, this is the most common way to prepare the finished vermicompost for harvest. New bedding is placed on the top of the windrow and worms move into it. When most of the worms have moved, the top layer of the windrow is removed to start the next one, leaving the castings behind. Some systems place the new bedding next to the existing windrow, forming a wedge, but the separation of worms from vermicompost is less complete.

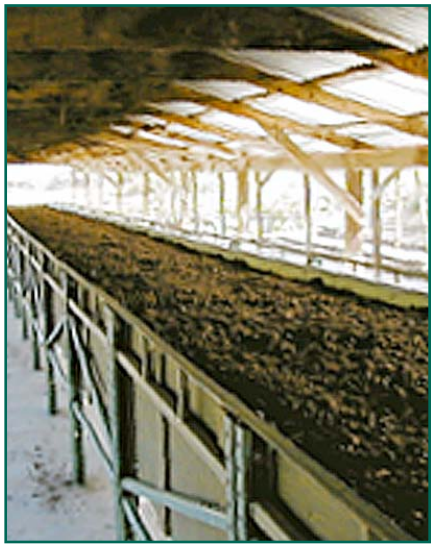
Mechanical screen trommel

Mechanical screening can be used for separating worms from vermicompost in any of the production systems. A slanted cylindrical harvesting machine, called a trommel, is commonly used in large-scale commercial operations. A motor turns a cylinder that is made of progressively larger screens. The material from the beds is fed into the raised end. As it moves downward, different sizes of screens allow the vermicompost, the small worms and eggs and finally the larger worms to fall into separate areas. The eggs and small worms are returned to fresh bedding. If only large worms are wanted, only two screen sizes are necessary.

***VermiCo Electric Worm Harvester, plans available. Photo courtesy of Peter Bogdanov,* www.vermico.com.**

Continuous processing

A continuous bed processor is a long, raised growing area. New bedding and feed are added at the top. Feed and moisture, when needed, are applied along the entire length of the bed, sometimes with an overhead conveyor belt system and mist system. Finished vermicompost is harvested from the bottom using a bar dragged along the screening that is the floor of the bin. This movement separates the bedding material from the bottom of the bed and vermicompost falls to a concrete floor where it is collected for use. It may be allowed to dry before collection.



***Continuous bed processor. Photo courtesy of* www.sonomavalleyworms.com.**

Oregon Soil Corporation in Oregon City, Ore., began using a continuous reactor process in 1988. Many adaptations have been built to suit a given system and plans are available from several vendors. Large amounts of vermicompost can be produced without ever having to stop to separate the worms.

This type of system requires a capital investment on the front end. Savings in labor expense for harvesting and handling might justify such an investment.

Handling the worms

Whatever method is chosen to separate worms from vermicompost, consider the worms' needs during the process. The worms will die if exposed to light or very dry conditions for too long. Wear damp gloves to handle the worms and move the worms that will stay in your system to fresh bedding as soon as possible. Worms that will be shipped should be quickly weighed and placed into the damp medium they will be shipped in.

Marketing worms and vermicompost

Marketing your product is an area to address long before you actually have anything to sell. It doesn't matter if you will be selling worms or vermicompost, you must have a buyer if you are going to make money. Where will you sell your product? Will you sell wholesale or retail? Who are your customers in each case? Approach and begin to educate potential buyers as you develop the rest of the business. As your market grows, you can increase production as well.

The worm market, though stable, is not growing much. The vermicompost market is more likely to grow because of these trends:

- Increased interest and understanding about recycling
- Awareness about sustainable systems
- Laws banning organic materials from landfills
- Expansion of the market for organic farming products
- Increased awareness in the general public about vermicomposting (Quillian, 1998)

Rhonda Sherman at North Carolina State University published a list of potential markets for worms and vermicompost. Find it on her comprehensive website at *www.bae.ncsu.edu/topic/vermicomposting/vermiculture/markets.html.*

Selling worms

The main markets for worms are:

- As bait
- For feed
- For household food waste processing

Approach local bait stores and ask if they would be interested in buying directly from a local grower rather than a distant seller. When you are in production, provide samples for their consideration. Once you've made a sale, you must provide continuing good service and produce a quality product to cultivate a customer that will buy from you repeatedly.

Worms for the bait market. Photo by Amy Weishuhn.

Vending machines that dispense bait are a relatively new development. An excellent location and conscientious servicing can make this option worthwhile.

Besides face-to-face sales, the Internet provides another direct sales channel. Create a website that details your products and services. Because most of your customers will be remote, your presentation will be in competition with all other worm outlets on the Internet. Learn the strategies for increasing your website's exposure. You will also have to decide how you will ship your product and set up a secure payment system.

Pet stores buy worms as feed for some of their animals. They will probably want to buy live worms. Likewise, pet owners are potential customers.

Alternatively, worms can be dried and made into a meal to be used as feed. This worm meal is easier to transport and store than live worms. Producing meal requires further processing. Can you get a price that justifies the extra expense? Packaging and labeling must also be considered.

Although selling worms to businesses and municipalities that are beginning to process their organic wastes by vermicomposting is a possibility, this is not a large or recurring market. A 2003 scam claimed to be supplying worms for start-up municipal vermicomposting operations. Even if this had been true, it is unlikely that a huge supply of worms would have been required. Each new facility would most likely make one initial purchase of worms and then maintain a working population without need for further purchases.

Selling to individuals and families who want to use worms to process their waste is another opportunity. However, this is usually a one-time, relatively small sale. You will

need many customers of this type to generate significant worm sales.

Packaging and shipping worms

Depending on where you will be selling your worms, you will need individual containers or bulk containers for packaging and shipping. If your market is local bait shops, you will probably count or weigh and cup the worms yourself. You or an employee will deliver and provide service to your customers. However, if your market is farther away, packaging and shipping require a different type of system.

Ship worms as quickly as possible after harvest and be sure to maintain optimal conditions for their survival. Peter Bogdanov, in his excellent book *Commercial Vermiculture: How to Build a Thriving Business in Redworms,* recommends sphagnum peat moss as a shipping medium. The bedding should be damp and air must be available. Bogdanov has determined that, for his operation, waxed cardboard containers are best for a small to medium amount of worms. Other authors have described many types of containers, including plastic foam, wax-coated paper and rigid plastic. Breathable paper or cloth bags are also used for bulk shipping.

Choose a shipping company according to accessibility and services offered. Since worms will not survive extreme temperatures, plan for their protection. Label the container so people handling them in transit can safeguard the contents. *Live earthworms* and *Perishable* and *Do not expose to extreme temperatures* are suggested. Precooling the shipping medium and worms to 68-72 degrees F results in lower fatalities in hot weather, according to Roy and Dianne Fewell in *As the Worm Turns* (Fewell and Fewell, 2007).

Bogdanov recommends doing practice runs by shipping to friends or relatives to make sure your containers, shipping material and methods will succeed in delivering the worms in good condition. Your first customers will appreciate the results, and you may save the expense of having to repeat orders because you had not perfected your shipping system.

Selling castings or vermicompost

Vermicompost is a high-quality soil amendment that has been shown to offer growth and yield advantages as well as resistance to plant pests and diseases. Likewise, vermicompost tea has been recognized as a provider of considerable benefits in plant production systems when it is used as a soil drench or a foliar spray. However, the general public and even many businesses that would clearly benefit from its use are often unaware of the advantages of using vermicompost. Do not assume that if you have it, people will buy it.

Plan to educate your customers and develop a market as you generate the product. Spending time and resources with nurseries, landscapers and garden supply store managers could be well worth your time. Other potential buyers of bulk vermicompost might include organic farmers or turf farms, as well as golf course and sports field managers.

You may even want to conduct trials comparing your product with whatever is currently being used. Perhaps you can help clients set up a trial at their place of business. Remember, once you secure the business of a customer that requires large volumes of materials repeatedly and you can deliver a consistent product, you will be on your way.

Some buyers will want to buy small amounts for gardens and others will buy by the truck load. These are issues you must evaluate during your market research. You will need to decide how to sell your product. Who is your target market? Will you need to package or

The effects of vermicompost and vermicompost teas in plant production systems are being studied at several universities. Although vermicompost doesn't test high in nitrogen, phosphorus or potassium, it does contain significant micronutrients. Biological activity is very high, and evidence of plant growth hormones has accumulated. Disease suppression, pest resistance, better growth and higher yields have been documented and are under investigation.

For more information about the research into these qualities – especially if you need it for promoting your product – please contact ATTRA at 1-800-346-9140 or *www.attra.ncat.org*.

Reasons that current demand for vermicompost is low:

- Lack of consistent supply
- Lack of large producers
- Uneducated consumers
- Lack of tests for content and quality
- Lack of field-tested research
- Lack of research in commercial settings (Quillian, 1998)

further process the product? If you package the vermicompost, you will likely have to create a legal label; this can be a challenge in itself. Consult with your state Department of Agriculture for applicable regulations.

Remember that your vermicompost product must be consistently available and be of dependable quality. These attributes are key to return business

How to ensure consistent quality vermicompost

The nutrient content of vermicompost is extremely variable. Although you will see analyses for various manures or vermicomposts, the actual content depends on two main factors:

- The feedstock and bedding
- The environmental conditions under which it is produced

Feedstock and *bedding* are the two major inputs. The nutrient analysis of the vermicompost will reflect these materials. Cattle manure with straw produces a different product from chicken litter with wood shavings. The relative amount of nitrogen and carbon will also affect the composition of the biological community inhabiting the final product (Slocum, 2000).

In addition to the nutrient content, the material fed or used as bedding can potentially contain substances toxic to plants or humans. If landscape waste materials are included, be sure they don't contain persistent pesticide residues. Livestock waste can contain residues from medications or feed additives. Know your inputs.

Seeds in the feedstock provide an additional challenge. Be sure that no viable seeds make it through the worms, or your product might cause weed problems for customers. Such a mistake is not easily fixed, especially when you have lost your customers' trust. Pre-composting the feedstock and bedding materials, if they contain seeds, can prevent such problems.

Be very careful with any input that might contain human pathogens that might survive worm processing. Develop a system to handle such resources by isolating them from contact with the finished product, maintaining aerobic production conditions and separately pre-composting them in a thermal system to ensure that they are safe to use. This is serious business and your liability here is absolute.

The second factor that affects the final product is the *environmental conditions* in the worm bins. Temperature, moisture and pH all determine which organisms thrive and which do not. If these conditions are kept constant, the microorganism community will also remain relatively steady. In a similar way, the microbes that live in the worm gut processing the organic matter adapt to whatever conditions they are subjected to. Continually changing these conditions reduces the efficiency of your production system and affects the uniformity of the final merchandise (Slocum, 2000).

The length of time the material is in the bed affects the final product. If the temperature is not optimal or other environmental conditions are not ideal, worms will take longer to process the same materials. If conditions are not stable, monitor them and adjust your procedures to ensure the reliability of your product.

Your product will be consistent if your production system uses known materials in unvarying proportions. Monitor environmental conditions and establish routines so that you do not have to test often to be confident that your product doesn't vary in content or quality.

Check with your local Cooperative Extension Service about testing the macronutrients and micronutrient content of your product. Many states provide this service. Labs that specialize

in testing the biological components of compost or vermicompost are a little harder to find. Consult ATTRA's *Alternative Soil Testing Laboratories* for a list.

When you bag your product to sell, the label will probably be regulated by law. Check with your state Department of Agriculture for information on what is required.

Economics and budget

This publication is about raising worms as a commercial venture. The focus of the operation might be on using animal or food wastes to produce a valuable soil amendment or on producing worms for the bait worm or animal feed markets. In any case, the goal is to make the venture pay. As was stated earlier, if bait worms are the product, inputs might cost more and management must be attentive in order to produce a larger, marketable worm. Vermicomposting is often less demanding, and the inputs should be inexpensive or free.

Profitability depends on the price received for the final product minus the costs of inputs, labor and capital expenses. These will vary for every business situation. Therefore, it is essential that you research and build a business plan. Business plans will go a long way toward ensuring a profitable business later on and can be instrumental in securing start-up funds.

Here are some tools to help with evaluating your potential new enterprise:

- USDA Risk Management Agency *http://farm-risk-plans.usda.gov*
- Building a Sustainable Business: A Guide to Developing a Business Plan for Farms and Rural Businesses *www.sare.org/publications/business/business.pdf*
- Starting an Ag Business? A Pre-Planning Guide *http://agviability.cornell.edu/pdf/Pre-businessPlanWorkbook.pdf*
- Cornell has developed many other business planning tools. *www.nybeginningfarmers.org/index.php?page=plan*

The records you have kept on your small-scale learning experiments will serve you well as you put together your own business plan. You should have already found and tested materials that can serve as bedding and feedstock. You will have learned how much feed the worms need and decided on the type of system to raise your worms.

It is time to build your budget. It should include at least these items. Make your estimates as realistic as possible.

Budget

	Price/ unit	Quantity	Amount	Your estimate
Receipts				
Worm or vermicompost sales				
Other sales				
Tipping fees				
Total receipts				
Variable costs				
Feed				
Bedding				
Labor to feed				
Harvest labor				
Packaging				
Advertising				
Cost to operate the system				
Other var. costs				
Total var. costs				
Fixed costs				
Initial investments				
Equipment				
Building				
Other fixed costs				
Total fixed costs				

Source: *http://agalternatives.aers.psu.edu/Publications/earthworm.pdf*

Your business plan and budget estimates serve at least two functions:

1. To evaluate your potential for developing a viable business
2. To convince a bank or other lending prospect that you are serious and have done your homework.

Continuing to keep financial records, and taking the time to analyze them, are keys to building and maintaining a profitable business. If you assume that there are always places that you can improve your efficiency or reduce your costs, and search them out, it will prevent unwelcome financial surprises.

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A word about pyramid schemes

For some reason, the worm business has repeatedly been plagued by dishonest schemers. The promoters use a pyramid scheme. They sell the initial batch of worms with the promise of buying back all of the worm production at "guaranteed" high buy-back prices. Often, exaggerated claims are made about how quickly the worms will reproduce. In reality, all the worms are being sold to others to begin their production systems.

A worm scam promoted during 2002-03 fooled many honest people across the United States. Many of the people who got into production enjoyed raising the worms, but when it came time to sell them, the promised market was not there. Homes and pensions were lost. The perpetrators were not brought to justice.

If approached with such a business proposal, be wary. If it sounds too good to be true, it might be. Ask a prospective company for references of satisfied clients who have been in business with the company for several years. Talk with those producers. Do not be rushed into something that you may later regret.

The Federal Trade Commission maintains a website with information for prospective business or franchise buyers. Here is advice worth heeding to protect yourself in the marketplace: *www.ftc.gov/bcp/edu/pubs/consumer/invest/inv07.shtm.*

What about certifying worms or vermicompost as organic?

Recently interest has been high in everything organic. Here are a few thoughts about so-called organic vermicompost and worm production.

The use of the word *organic* is controlled by a federal law. For more information about the law and its application to organic production, see ATTRA's publication *Organic Farm Certification and the National Organic Program.*

Organic vermicompost

Organic certification is restricted to agricultural products such as food and livestock feed. One could argue that vermicompost is such a product and get it certified. However, there is no need to do so. Vermicompost can be used as it is in organic production just like compost can be used without being certified organic. The main stipulation is that no prohibited materials be used in its production – neither as feed nor as bedding. Treated wood chips or sawdust from treated wood are examples of materials that would not be allowed if the vermicompost were going to be used in a certified organic production system. Carefully examine commercial worm feed formulations, if used, to be sure that they contain no prohibited materials.

It is unlikely that there is a market of any size for organic certified vermicompost. If there were, it would probably be non-commercial gardeners who want to be "*elite-green.*" Be sure that you have identified customers who will pay a premium price that will cover the cost of certifying your product and maintaining its certification before pursuing this option.

In order to promote their products to organic producers, manufacturers often seek OMRI listing. OMRI (Organic Materials Review Institute) reviews commercial products to determine if they comply with National Organic Standard requirements. Several products with vermicompost have gone through the exacting procedure required to obtain OMRI listing. You can learn more about how to qualify by visiting *www.omri.org.*

Organic worms

Just as in the case of vermicompost, it is difficult to imagine the market for certified organic worms. What would they be used for? Would potential buyers pay a premium for organic worms?

If worms were the major feed ingredient for some other animal that is being raised in a certified organic production system, then the worm production system might also have to be certified. This is a grey area on which the National Organic Program has not set standards. Officially, if you apply the federal Rule, feed formulas for certified organic livestock production cannot contain manure This might be applied to worms, but possibly only if the worms were for direct human consumption.

If manure were not allowed, organic worms could be fed a ration of certified organic grains, though that would be very expensive. Is there a market that would bear this cost? Another option would be to feed wastes from an organic food processor. The production waste from, for instance, organic baby food might become the main input for an organic worm ranch. Your certification agency would be the one to interpret and apply the federal law to all aspects of your production system.

It is much more likely that worms would be used as a relatively small proportion of the feed ration in a separate certified organic livestock system. In the case of chickens, worms have been considered as an organic source of the amino acid methionine. The amount of worm meal or fresh worms required would probably be small enough to be considered a supplement. If used as a supplement, the worms or worm meal would not have to be certified organic as long as no prohibited materials were used to raise the worms. This is, again, an area in which the person who certifies that livestock system would have authority to interpret the law.

Conclusion

Worms can be used to process animal waste that was considered a potential environmental problem. Worms can process food garbage that would have gone to a landfill. These are worthy services. Many worm growers report that working with worms is a satisfying activity. What if you could make it a profitable business?

Realistic planning will reduce the risks that accompany such a venture. Raise worms on a small scale first. Create business and marketing plans based on your experience and thorough research. Always remember that you will have to sell your product to create a commercial enterprise. Concentrate on combining the satisfaction of raising worms in a sustainable system with a profitable business model.

Steps toward developing a national vermicompost market

(ideally some of these would be accomplished by a producers' association)

1. Consolidate existing research results and knowledge into a useful form.
2. Field test vermicompost in a commercial setting. Producers must:
   - Work with growers' associations and university agriculture departments to fund and/or conduct field research
   - Work with Sustainable Agriculture Research and Education (SARE) and organic farming groups to do on-farm research
3. Develop a program for testing and quality assurance (pH, organic matter, moisture, biological activity)
4. Make marketing a significant part of the business plan and budget. This includes targeted market research, educational materials, package design, trade shows, and promotional events (Quillan, 1998).

References

Fewell, Roy and Dianne Fewell. 2007. As the Worm Turns: New and Easy Methods for Raising Earthworms. Shields Publications, PO Box 669, Eagle River, WI 54521. p. 43.

Gaddie, Ronald E., Sr. and Donald E. Douglas. 1975. Earthworms for Ecology & Profit. Volume I: Scientific Earthworm Farming. Bookworm Publishing Co., PO Box 3037, Ontario, CA 91761. p. 59.

Quillian, Mike. 1998. Earthworm castings—the key to unleashing the vermiculture market. Worm Digest. August. p. 13, 25, 27, 29-30.

Slocum, Kelly. 2000. Going Sour on Lime. Worm Digest. No.24. p. 20.

Further resources

Inclusion in this list is not an endorsement nor is exclusion meaningful.

Web resources

If you have access to the Internet, there are many websites with information about worm farming. Many resources for the producer, including books, breeding stock and equipment, can be located by visiting the sites listed below. Many include links to other sites of interest. Under the **Website** section below, there is a list of websites that offer information or products of interest for those raising worms. Web addresses frequently change, but a search of "worm farm" or "worm production" will locate these and many other sites.

Manuals related to vermiculture/vermicomposting

Sherman, Rhonda. 2003. Raising Earthworms Successfully. EBAE 103-83. North Carolina Cooperative Extension Service, Raleigh, NC. 26 p. *www.bae.ncsu.edu/topic/vermicomposting/pubs/earthworms.pdf*

Mason, William T., Jr., Roger W. Rottmann, and John F. Dequine. 1992. Culture of Earthworms for Bait or Fish Food. Circular 1053. University of Florida IFAS Extension. *http://edis.ifas.ufl.edu/FA016*

Munroe, Glenn. N.d. Manual of On-Farm Vermicomposting and Vermiculture. Organic Agriculture Centre of Canada. 52 p. *www.oacc.info/DOCs/Vermiculture_FarmersManual_gm.pdf*

Ferris, Amanda, Mark Jackson and Angus Campbell. 2002. Best Practice Guideline to Managing On-site Vermiculture Technologies. Recycled Organics Unit, University of New South Wales, Sydney, Australia. 106 p. *www.recycledorganics.com/publications/reports/vermiculturebpg/vbpg.htm*

This publication provides an easy-to-read account of how to establish and manage an on-site, mid-scale vermiculture unit for the commercial and industrial sector. The guide includes practical information on development, including feedstock preparation, monitoring, maintenance procedures and use of the vermicompost.

General worm farming

Worm Power
www.wormpower.net

A vermicomposting business site. Tom Herlihy, the author, has a lot of videos and information about the actual process as well as who uses the material and how.

Sonoma Valley Worm Farm
www.sonomavalleyworms.com

Experienced producer Jack Chambers uses a continuous processing unit. He also sells vermicompost to vineyards and others.

Rhonda L. Sherman's home page
www.bae.ncsu.edu/people/faculty/sherman/index.html

Sherman is an Extension specialist with vermiculture/vermicompost expertise. She hosts an annual worm conference in early summer. Scroll down to the vermicomposting link for access to many resources.

California Vermiculture LLC – George Hahn
www.wormgold.com

Worm farms in several states produce consistent branded products, complete with testimonials.

Worms Wrangler
http://wormswrangler.com

This site contains many useful articles related to worm production.

Happy D Ranch
www.happydranch.com/index.html

Commercial site offering worms, bins, books, articles on home- and farm-scale vermicomposting. Specials for teachers.

VermiTechnology Unlimited
www.vermitechnology.com
Florida worm farmer Larry Martin has lots of experience setting up systems in several locations. He offers organically certified castings (not vermicompost) products, worms and books.

Trinity Ranch
http://mypeoplepc.com/members/arbra/trinity/id14.html
This website has a wealth of information about worms and vermicomposting. They sell worms, equipment and books.

Flowerfield Enterprises, Mary Apelhof's site
www.wormwoman.com/acatalog/index.html
Emphasis on using worms for education. Also provides worm composting and compost tea products and information including books, videos, worms, worm bins and other vermicomposting resources.

Unco Industries
www.vermiculture.com/uncosystem.html
Offers a worm growing system, complete with equipment and training.

Bentley Christie's worm site
www.redwormcomposting.com
A very active hobby worm grower experimenting with worms and gardens.

Worm species photo album

Amy Weishuhn's Worm photo album
http://community.webshots.com/album/93031731AZXEzc
Photos of many worm species.

Commercial worm equipment sources

Oregon Soil Corporation
www.oregonsoil.com
Experienced in vermicomposting, offers commercial and residential scale equipment and consultation services.

VermiCo, Peter Bogdanov's site
www.vermico.com
This site has an emphasis on business and marketing. It offers blueprints for building a continuous harvest worm production system as well as tools to monitor production beds. Items for sale include a rotating screen harvester (electric and gas models) and plans to build a harvester, as well as compost tea brewers and applicators.

Worm World Inc. and Brian Paley's The Burrow
www.jetcompost.com/burrow/index.html
Worm harvesters for sale and a lot of older material on vermicomposting.

Books on vermiculture & vermicomposting

Appelhof, Mary. 1997. Worms Eat My Garbage. Flowerfield Enterprises, 10332 Shaver Rd,. Kalamazoo, MI 49024. 162 p.

Barrett, Thomas J. 1942. Harnessing the Earthworm. Shields Publications, Eagle River, WI. 166 p.

Bogdanov, Peter. 1996. Commercial Vermiculture: How to Build a Thriving Business in Redworms. VermiCo, PO Box 1134, Merlin, OR 97532. 83p.

Edwards, C.A. and P.J. Bohlen. 1996. Biology and Ecology of Earthworms (3rd ed.). Chapman & Hall, London. 426 p.

Edwards, Clive, Norman Arancon, and Rhonda Sherman (eds.). 2010. Vermiculture Technology: Earthworms, Organic Wastes, and Environmental Management. CRC Press, Boca Raton, FL.

Fewell, Roy and Dianne. 1998. As the Worm Turns: New and Easy Methods for Raising Earthworms. Shields Publications, PO Box 669, Eagle River, WI 54521. 56 p.

Gaddie, Ronald E., Sr., and Donald E. Douglas. 1975. Earthworms for Ecology & Profit. Volume I: Scientific Earthworm Farming. Bookworm Publishing Co., PO Box 3037, Ontario, CA 91761. 180 p.

Gershuny, Grace. 2004. Compost, Vermicompost and Compost Tea: Feeding the Soil on the Organic Farm. A Project of the Northeast Organic Farming Association. Highland Press, Athol, MA. 90 p.

Minnich, Jerry. 1977. The Earthworm Book: How to Raise and Use Earthworms for Your Farm and Garden. Rodale Press, Emmaus, PA. 372 p.

Morgan, Charlie. (1975-revised). Profitable Earthworm Farming. Published by Shields Publications, P.O. Box 669, Eagle River, WI 54521. 95 p. Other titles by Morgan include:
Earthworm Selling and Shipping Guide (82 p.)
Earthworm Feeds and Feeding (90 p.)
The Worm Farm (70 p.)
How to Raise, Store and Sell Nightcrawlers (40 p.)
Raising the African Nightcrawler or Tropical Giant (53 p.)
Therapeutic Medications & Pesticides for Worm Growers (100 p.)

Payne, Binet. 1999. The Worm Café: Mid-Scale Vermicomposting of Lunchroom Wastes. Flower Press, Kalamazoo, MI. 180 p.

Shields, Earl. (1994-revised). Raising Earthworms for Profit. Shields Publications, P.O. Box 669, Eagle River, WI 54521. 128 p.

Sellers of worm books

Note that many vermicomposting sites also sell books.

Shields Publications offers many practical books about raising worms. *www.wormbooks.com/index.htm*
Publisher of many practical books about raising worms, including a current buyer's guide. Small books at reasonable prices.

New York Books – Earthworm books
www.nyworms.com/books.htm
Annotated list of practical worm farming books.

Rhonda Sherman's list of worm farming books and book vendors *www.bae.ncsu.edu/topic/vermicomposting/vermiculture/booklist.html*

Worm periodicals

VermiCo
PO Box 1134
Merlin, OR 97532
(541) 476-9626
www.vermico.com
www.vermico.com/newsletter1.htm
Publishes: Casting Call
Six bimonthly issues for $18
e-subscription for $10
Back issues available individually and in volumes; also electronically.

The JG Press, Inc.
419 State Avenue
Emmaus PA, 18049
(610) 967-4135, ext.22
www.jgpress.com/biocycle.htm
Publishes: BioCycle: Advancing Composting, Organics Recycling, and Renewable Energy. Monthly annual subscription for $74.

Worm Digest
www.wormdigest.org
This site has been reconfigured and is under different management from the original, very useful website and periodical. The Worm Digest that contained practical, hands-on articles and news relevant to worm producers is no longer being published. However, some of the old materials are available for purchase on this site. The new periodical has not been evaluated, so no opinion is offered.

Budget and economics

Building a Sustainable Business: A Guide to Developing a Business Plan for Farms and Rural Businesses. *www.sare.org/publications/business/business.pdf*

Doherty, Brigid A., and John C. McKissick. 2000. Market Opportunities for Biosolid-Based Vermiculture in Georgia. Center Special Report No. 9. Center for Agribusiness and Economic Development, The University of Georgia. *www.agecon.uga.edu/~caed/Pubs/vermiculture.html*

Warco, Dan. 2002. Shipping and Handling Included. Worm Digest. No. 29. p. 7.

Budgets for building a traditional on-the-ground bed about 12' X 3'. *http://agalternatives.aers.psu.edu/Publications/earthworm.pdf*
Also a sample budget with production estimates.

Marketing resources

Anon. N.d. Earthworm Buyers Guide & Directory 2008-09. Shields Publications, P.O. Box 669, Eagle River, WI 54521. *www.wormbooks.com*

Bogdanov, Peter. 1996. Commercial Vermiculture: How to Build a Thriving Business in Redworms. VermiCo, PO Box 1134, Merlin, OR 97532. 83p.

Quillian, Mike. 1998. Earthworm castings—the key to unleashing the vermiculture market. Worm Digest. August. p. 13, 25, 27, 29-30.

Research review articles

Three review articles in popular press:

Arancon, Norman Q., Clive A. Edwards, Richard Dick, and Linda Dick. Vermicompost tea production and plant growth impacts. BioCycle. November 2007. p. 51-52.

Edwards, Clive A., Norman Q. Arancon, Eric Emerson, and Ryan Pulliam. 2007. Suppressing plant parasitic nematodes and arthropod pests with vermicompost teas. BioCycle. December. p. 38-39.

2007 Literature Review of Worms in Waste Management, Vols. 1 and 2. Recycled Organics Unit, University of New South Wales (Australia). *www.recycledorganics.com/publications/reports/vermlitreview/vermlitreview.htm*

Scientific Research on Benefits of Vermicompost

The Soil Ecology Laboratory
The Ohio State University
www.biosci.ohio-state.edu/~soilecol/index.htm

Vermicompost pioneer, Clive A. Edwards, anchored this program for many years. Research reports on many aspects of vermiculture and vermicompost with emphasis on its benefits for production. Vermicompost tea research continues. Many scientific papers are available on-line.

Cornell Vermicompost Research
http://cwmi.css.cornell.edu/vermicompost.htm

This site provides access to all the vermicompost research that Cornell is conducting. A video about how to produce and use vermicompost as well as its function in biological control in greenhouses is available. Fact sheets cover field soil and greenhouse applications and a section about suppression of Pithium.

Appendix

Critters you might find in a worm bin

Ants, Formicidae
Ants prefer a dry environment. If there are a lot of ants, it is an indicator that the bins are too dry. Ants can occasionally become a problem when they are attracted to high-concentrate feed. When ants are very numerous, they might feed on small worms or eggs.

Centipede, Chilopoda
These are worm predators that usually live on the surface of the bed. They also feed on larger organisms in the bin. Remove these predators if there are more than a few in a bed. *Description:* Reddish-tan cylindrical, segmented body with one pair of legs per segment. They are equipped with pincers just behind the head.

Fruit flies, Diptera
These are often considered a nuisance, especially when populations are high and bins are indoors. They are very active decomposers, however. Because their eggs and larvae are commonly on food scraps, they are usually present in any system using those items as a feedstock. Prevention includes pre-treating the material by freezing or microwaving it before adding it to the bin and burying it below the surface. Beneficial nematodes can be employed to control an infestation if it becomes serious.

Fungus gnats, Diptera
They eat fungi in the worm bin, but will eat plant roots and are a problem if transferred to the growing bed. They don't usually grow to high populations in worm bins *Description:* Tiny black fly species similar to fruit flies but looks more like a mosquito.

Millipedes, Diploda
These occur throughout the bedding, are good decomposers and should not be a problem. *Description:* Rounded segmented body with two pairs of legs per segment; darker than the centipede and slower moving.

Mites, Acarina
Small, brown to reddish arthropods, readily visible without magnification. Natural inhabitants of manures and other organic materials, mites are usually very numerous in worm bins. They are found near the surface and edges of the beds and around feed concentrations. There are both predatory and plant-feeder types. There may be one mite that actually attacks worms, but they might just ride on worms and be an irritant. Very high populations probably stress the worms. *Prevention*: Because high mite populations occur when beds are over-watered, overfed, and/or fed fleshy, high-water-content garbage, good management is the best prevention. Do not overfeed. Remove feed that has spoiled. Be sure there's plenty of aeration in the beds and that excess water can escape. If you are feeding garbage and mites are still a problem, stop until they are under control and then feed more carefully. Another tactic is to expose the beds to sun for several hours. *Description:* They are tiny relatives of spiders, with four pairs of legs, large bodies and small heads.

Molds and fungi
These decomposer plants are common in all worm beds and are a source of food for the worms. They secrete enzymes that break down some of the most resistant materials in the bin. Mold allergies, however, can become a problem for worm workers in enclosed spaces.

Nematodes
A very tiny roundworm. They eat bacteria and fungi ordinarily. Very rarely a parasitic nematode will show up, but not in healthy vermiculture systems.

Pot worms, Enchytaeidae
Often show up in healthy worm bins; not usually a problem. *Description:* Tiny white segmented worms.

Protozoa
Microscopic animals that eat bacteria and are, in turn, eaten by worms.

Pseudoscropion
This is a predator, but is not a problem in worm bins.

Slugs, Stylommatophora
Usually not a problem in worm bins, because they will help to break down organic matter. A few carnivorous species of slugs exist, but even when present, they usually don't eat many worms.

Soldier fly larvae, Diptera
These are voracious decomposers, but often considered unpleasant in the worm bin. No need to control them unless the worms show signs of stress. They can be removed by scooping them out of the beds. *Description:* One-half inch to an inch long, segmented cylindrical body with coloring that darkens from orange to black at the front end to dirty white or grey toward the back.

Sowbugs and pill bugs, Isopoda
These are crustaceans that feed on woody material resistant to attack by other worm residents. However, since they eat living or dead plant material, they can be a problem if they are transferred to plant production areas along with the vermicompost. *Description:* Light brown to dark grey with segmented shell. Seven pairs of legs and antennae.

Springtails, Colembola spp.
Usually very common in worm bins, but not a problem, even at high populations. They eat fungi. They can be so numerous as to turn the surface of a bed white. If worms are not coming to the surface to feed, pay attention to good water management and sanitary feed practices. *Description:* Some are dark brown with the ability to jump; others are tiny and range from white to brown in color. Body has three distinct segments, four pairs of legs and antennae.

Enemies of worm producers
These animals will eat worms. Some, like snakes and moles, can completely destroy a worm bin before the grower is even aware that they are there. Be vigilant!
Birds
Snakes
Moles
Gophers
Toads
Mice *and* rats *won't eat the worms, but they will nest in a bin and eat the feed meant for the worms.*

Other possible invaders
These invaders might show up from time to time. They won't eat the worms, but they can become competitors for the food.
Spiders
Earwigs
Grasshoppers
Crickets
Beetles
Silverfish
Termites
Aphids
Stinkbugs

Worm bin creatures on Trinity Ranch website
http://mypeoplepc.com/members/arbra/bbb/id16.html
Contains photos of many of the creatures described above with descriptions and suggestions for preventing problems.

Worms for Bait or Waste Processing (Vermicomposting)
By Alice Beetz
NCAT Program Specialist

Holly Michels, Editor
Amy Smith, Production

This publication is available on the Web at:
www.attra.ncat.org/attra-pub/vermicomp.html
or
www.attra.ncat.org/attra-pub/PDF/vermicomp.pdf

IP110
Slot 28
Version 052710