

Mealworm Farm Prototype Usage and Management Instructions

Developed for the University of Wisconsin Climate Quest Competition

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Setup

Materials:

Trays (# as required)
Stands (# as required)
Bedding/feed (e.g. corn stover)
Sanitizer (e.g. bleach or ammonia solution)
Clean rags
Starter batches of worms
Petroleum jelly
Moisture source (e.g. carrots)
Panel of clean, untreated fabric (~55cm x 95cm) 1x for the top tray in each stack

Operation size:

First, decide how many stands trays you will be using. Minimum usage requires one stand and one tray. Each stand should not hold more than 7 trays. The necessary operation size for a given output can be calculated with the mealworm production model:

<https://docs.google.com/spreadsheets/d/12RMKW4CwhS8jaevSg1vWuhC7C3i88QTtewsnSuiNrGI/edit?usp=sharing>

Each 60cmx100cm tray will house about 13,333 mealworms, 96% of which will be harvested (12,800) for a harvested output of approximately 1.41kg.

The mealworm life cycle in optimal conditions lasts approximately 90 days, so a minimal operation that harvest monthly will require 3 trays and one stand. A hypothetical setup intending to harvest 5kg every 2 weeks will require 28 trays and a minimum of 4 stands. Shorter stacks may be desired for improved usability depending on the physical constraints of the site and height of the farmer.

Equipment Setup:

Stands

Each stand should be fully weighed down with at least one full row of bricks stacked across the baseboards, and a stack two high may be most appropriate for higher stacks of trays. The stands should be cleaned of any dust or dirt and a band of petroleum jelly about 6" wide should be applied around each of the legs, starting 6-8" up from the base boards. The petroleum jelly will prevent ants from invading the trays and should help deter small rodents. The bands of petroleum jelly are applied up the legs to prevent rodents from simply reaching over them, and to reduce the amount of dust/dirt accumulating on the bands that may be kicked up during day to day interaction.

Trays

The trays should all be cleaned of dust and dirt, and the tray liner should be wiped with a rag wetted with sanitizer solution, then wiped with a clean wet rag and then dried thoroughly. Just before they are populated, trays should be filled with 1-1.5" deep layer of bedding/feed. Each tray should be labeled (e.g. with a piece of tape marked with a name, number, or symbol for the generation)

Lifecycle

Initial colonies / Breeding

Each tray being brought into use should be inoculated with about 533 breeders. Ideally newly emerged adults are used as breeders for initial colonies, however any life stage will work and the time to first harvest will be correspondingly delayed by the time required for the breeders to mature.

If starting with worms, try to keep them at a steady temperature between 72 and 86 degrees Fahrenheit, and a relative humidity between 50-75%. Replace the moisture sources regularly to avoid mold growth. As they reach maturity the worms will start to transform into pupae, which look like small, motionless white tear-drop shaped creatures. Over the course of 6-8 days the pupae will darken to a golden brown color, and then a lightly colored adult beetle will emerge. The adult beetle will darken over the next 4-7 days to a dark brown or black and after that time will be ready to breed. When raised in proper conditions, mealworm populations will tend to evenly distribute male/female, so any given sample should provide an appropriate breeding group.

Allow the adult beetles to mate and lay eggs for 1 week. The females lay small white eggs, about the size of a grain of sand, and each female will lay several hundred eggs if the humidity is maintained right around 80%. Be sure to provide fresh sources of moisture for the adult beetle to prevent cannibalism of the eggs (softer feeds like radishes and potatoes are particularly suitable for the adult beetles). After the allotted egg laying period, harvest the beetles and feed chickens or fish, or allow to continue their lifecycle in another breeder bin to seed a parallel population. The adults can live and breed for as long as 1-2 months. Beetles can be picked out by hand, or harvested using a 1/8" screen mesh.

A new generation will need to be seeded at the same intervals that harvesting is desired. For example, if monthly harvesting is desired then a new generation will need to be started each month (new initial colonies for the first 3 months, after which the surplus of the harvests will be available to seed subsequent generations). If biweekly harvesting is desired then a new colony must be seeded every two weeks for 90 days.

When initially seeding parallel generations, be sure that the breeding stock are being introduced at the same stage of life so that the subsequent generational offsets remain in line. For example, if late stage larvae are introduced for the first generation, be sure to use larvae of the same stage for

each of the subsequent seeded generations, and likewise if newly emerged adults are used then use newly adults for each subsequent generation's breeders.

Eggs/ hatching

After removing the beetles, ideally keep eggs close to 86 degrees Fahrenheit, and 80% humidity. Eggs will hatch after 6-8 days, and the tiny hatchlings will remain mostly buried in the lower layers of bedding except when surfacing to consume moisture from provided sources.

Larval development

During larval growth carrots are a preferred source of moisture because they have a higher resistance to mold growth than potatoes and apples. Monitor mealworm growth and check for signs of mold growth. If any is detected, remove the surrounding area of bedding and replace with fresh meal. Mold can be avoided by regularly replacing moisture sources and avoiding over-feeding such to the young worms.

Ideally maintain temperatures around 80-86 F and humidity close to 75%. As the worms grow they will consume greater quantities of moisture source quickly, and they will also generate more heat as they move through their bedding and past each other. You should monitor closely the temperature within the habitat if possible, to avoid local over-heating if the ambient temperature is too high to disperse the local heat generated by the worms' movement.

If during the course of their development, the worms consume all or most of their bedding, replace with additional bedding. The worms require the bedding as food, and as a medium to move around without too much direct contact with each other.

Harvest

When the larvae weigh about 100-110mg, they are ready to harvest. Refer to detailed harvesting instructions below. Around 533 larvae should be reserved at harvest time and moved to a clean new tray to seed the next generation. The time from initial seeding to first harvest will depend on the stage at which the initial breeders are introduced. Given ideal conditions, the time from harvest to harvest will be about 90 days (using reserved harvestable larvae as breeders).

Colony Maintenance

Daily Tasks

Check all trays for feed level, state of moisture source (e.g. dryness or development of mold), presence of pests, and incidence of mortality.

As necessary add additional bedding, and replace moisture sources.

Remove any dead larvae immediately if discovered (they turn black).

Check state of larvae for harvest readiness, and track the days from seeding to harvest.

Use fan to gently blow fresh air through the trays, removing carbon dioxide buildup

If pests are discovered:

Invertebrate pests (insects, arachnids)

For pest such as flies, mites, beetles, and moths, the tray should be removed from the site of the farm and larvae harvested from bedding. The tray should be cleaned thoroughly and filled with fresh bedding. If the harvested population appear healthy, they can be returned to the tray. A note should be made about the type of pest, and any contextual information such as the date, time of year, and observations such as if the door to the farm structure had been left open for a prolonged period.

For larger predators such as spiders or scorpions, the intruder should be carefully removed and trays cleared of any webs and dead insects.

Vertebrate pests (rodents/birds/reptiles)

Carefully remove the intruder, and check trays for contamination (such as faecal matter). In the case of rodents, any tray known to have been physically contacted by the animal should be harvested, cleaned, and repopulated as with the invertebrate pests. In the case of known disease vectors, potentially contaminated trays should be thoroughly cleaned and their contents safely destroyed.

Periodic Tasks

Frass removal

When a tray has accumulated a high level of frass (1-2cm), the frass should be sifted. slowly / in batches, pour the contents of the tray over a fine screen and gently shake over a bucket to sift out the frass. Cover the nose and mouth with a dust mask or damp cloth during this activity to avoid ingesting frass particles. Return remaining bedding and larvae to the tray and refill bedding.

Harvesting

NOTE - The process described here is based on direct experience, but has not been tested at the scale of the prototype with the corn stover bedding.

Materials:

Large bucket (3-4x)

Large mesh screen (¼" openings)

Fine mesh screen (< 1/16" openings)

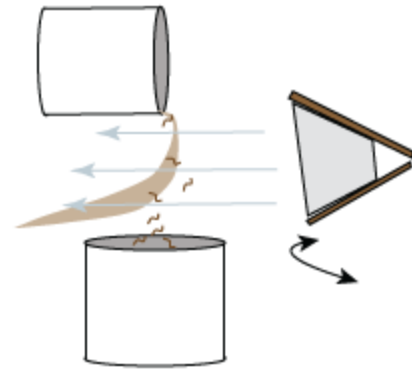
Hand operated fan

Harvesting via the following process should take place outdoors, ideally downwind of habitations. Frass, shed exoskeletons, and bedding particles will be airborne and should not be inhaled. A minimum of two individuals are required unless there is a steady breeze that is strong enough (and not too strong) to separate the mealworms from their bedding.

The individuals carrying out the harvest should wear masks or damp cloths over their nose and mouth during the process to avoid excess exposure to the particles.

1. Empty the tray of mealworms into one of the large buckets through the large mesh screen (to remove large pieces of bedding). Work in batches if necessary, clearing the screen of large pieces of bedding to keep the process moving quickly and smoothly.
2. Slowly (in batches) pour the contents of the first bucket over the fine mesh screen and sift out frass into the second bucket. As each batch is cleared of frass, transfer the remaining bedding and worms into the third bucket.

3. Once all of the worms and bedding are cleared of frass, set the frass bucket aside for later use as fertilizer, and set up the first bucket (now empty). One harvester will stand next to the empty bucket, and fan above it, creating an air current across the top. The other harvester will slowly pour the bedding/worm mixture through the air current into the waiting bucket below. The air current will catch the lightweight particles of bedding, blowing them away, while the heavier larvae will drop through into the bucket. Depending on the ambient air movement, and strength of the fan operator, the harvesters will have to adjust the height of the drop, speed of the pour, and distance at which the fan operator is positioned. Alternatively, if a steady breeze is blowing, it may be possible for a single individual to slowly pour the worm/bedding mixture from a height such that separation is achieved and the worms are successfully collected in the bottom bucket.



4. The process may be repeated back into the first bucket to remove further bedding if necessary, and heavier bits can be picked out by hand.
5. If multiple trays are being harvested, reserve a fourth bucket to collect all of the harvested worms as the first 3 are used in the collection process.
6. After harvesting, reserve ~533 worms for each tray that has been harvested. Clean the trays, refill with fresh bedding, and return those worms to mature and breed the next generation.

Data Collection

Ideally detailed records can be maintained during the management of the farm to inform future design decisions, and to help tune the farm operation plan. Outline below is a basic outline for a data collection plan.

Each tray should have an ID of some sort, whether a name, number, or symbol that can be used for reference in notes. A system could be devised with pre-printed pads that allow illiterate farmers to simple circle or check activities each day to maintain records.

Daily make note of:

- weather and approximate temperature range
- any events and the relevant trays, such as removing pests, adding bedding (with amount), removing moldy feed, harvesting,
- amount of feed (vegetable and/or bedding) provided
- average size (and ideally the size range) of worms in each tray
- other observations such as mortality, odd smells, etc..

The records will help pinpoint key events and conditions that affect the success of each generation (temperature, feeding schedule, pest invasion), and provide high resolution data on the growth rate throughout the various seasons which can be used to optimize output planning (e.g. the number of trays and breeding/harvest schedule) and farm design (e.g. shelter and pest protection). The data will also be invaluable for helping to assess various feeds.