The Black Soldier Fly How-to-Guide

ENST 698-Environmental Capstone
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Statement of Purpose

This How-to Guide is meant to serve as a resource for farms of all types and sizes and individuals who are interested in implementing a black soldier fly-based waste management system. It was produced by a group of eight students at the University of North Carolina at Chapel Hill as part of their senior capstone project with the support of UNC's Institute for the Environment and Pickards Mountain Eco-Institute in Orange County, North Carolina.

Introduction

Black soldier flies are small, harmless insects that have the potential to provide promising solutions to two of modern agriculture's growing problems: the high cost of animal feed and the disposal of large amounts of animal waste. Many farms now operate as linear systems, purchasing animal feed and then paying to eliminate waste from farm animals. Recent research has indicated that black soldier fly may be instrumental in closing the loop between animal waste and animal feed (Watson, 2005). Black soldier fly larvae (BSFL) will eat nearly any kind of organic waste ranging from animal waste to food scraps. As the BSFL mature, they grow into ½-inch-long grubs, at which point they climb out of their food source and turn into pupae. The pupae can immediately be fed to chickens and are a good source of protein. They can also be dried and processed into feed for use at a later time. Small composting operations also allow them to turn into flies and breed, propagating the population.

Black Soldier Fly Larvae

Black Soldier Fly Adult

Black soldier flies are beneficial in several ways. The adults are not attracted to human habitation and thus pose a significantly lower risk of disease transmission than other fly species (Newton et al., 2005). Furthermore, they prevent houseflies and other insects from laying eggs in the material inhabited by BSFL. The adults do not have digestive organs, relying on stores of body fat from the larval stage. Their short life cycle makes them a reliable source of food for chickens and potentially other farm animals. Previous work has also shown that black soldier flies are effective in reducing the mass as well as nutrient and moisture content of various kinds of organic waste.

This how-to guide will help anyone interested in using BSFL for composting, animal waste reduction, or feeding animals. This guide suggests a few potential set-ups, depending on the desired scale of BSFL cultivation. It also outlines many of the logistics of raising BSFL successfully, including where to get BSFL to start an operation, how to build the set-up, how BSFL can be used to substitute chicken protein supplement, and how to breed BSFL in captivity.

Optimal conditions for BSFL

Temperature

The optimal temperature at which BSFL consume their food is around 95 °F. The minimum temperature for survival is 32 °F for no more than four hours, whereas the maximum temperature allowing survival is 113 °F. The larvae will become inactive at temperatures less than 50 °F and temperatures higher than 113 °F, where their survival decreases dramatically. The best range of temperature for the larvae to pupate is from 77 to 86 °F. For mating purposes, optimal temperature is around 82 °F (Zhang, 2010).

Diet

BSFL can tolerate a widely varied diet. The BSFL feed on many kinds of organic waste such as table scraps, composting feed, and animal manure. They can also survive off of coffee grounds for a few weeks, but coffee grounds are not a sustainable diet. The caffeine from the coffee grounds helps to boost the metabolism and makes the grubs more active. A diet combining kitchen scraps and coffee grounds may help to boost their metabolism. The BSFL have a limited ability to process any animal products such as meat and fat.

Humidity

Black soldier fly larvae develop most rapidly at 70 percent humidity. The rate of weight loss for the BSFL increases with decreasing humidity. The optimal humidity for black soldier fly mating is around 30 to 90 percent. It is very important to monitor humidity for captive rearing and breeding. We found that it is especially important to keep the grubs' feeding medium at a proper moisture level—not so dry that it cements the grubs into the feed, and not so wet that they cannot breathe through the pores in their exoskeleton.

Additional environmental conditions

BSFL do not survive well in direct light or in extreme dry or wet conditions. They prefer to be 8-9 inches deep in their food source. If they are too far below the surface, they will perform little bioconversion. Female flies avoid any sites that are anaerobic when trying to lay eggs.

Where to get BSFL

Black soldier fly larvae can be purchased from the Phoenix Worm Store. You can reach their webpage by following this link: www.phoenixworm.com/. The name 'Phoenix worms' is a term commonly used for BSFL sold for pet feed. The Phoenix Worm Store guarantees live delivery of your order when the daytime temperatures are between 35 and 85 °F. You can order varying quantities and sizes of BSFL from this company. When deciding on the quantity of BSFL to order, consider the time frame for getting an operation running at the desired capacity. To reach a large capacity in a short amount of time, consider buying the larger quantity (600+ for $27.95). For most cases, the smallest amount (100+) will be sufficient and only costs $5.99. The portions received are very generous.

Determining scale (calculator)

In order to determine the scale we needed to apply to Pickards Mountain to fully replace their protein supplements for chicken feed, we created a calculation tool using the amount of feed they currently buy & the percentage of raw protein in it. This turned out to be 100 lbs at 16%. According to a study performed in Texas by ERS International (ERSI 2008), BSFL are composed of 42.1% protein. Using the amount of protein we needed to replace each week from their feed, we determined that a little over 17 kilograms of larvae would be necessary. According to the same study, a diagram of the area needed showed ratios of the input of waste and the output as five to one. Using the same proportions, we determined that about 86 kilograms of waste per week is needed to cover an area of 0.82 m^2. We also determined that if we were able to produce 1.2 million larvae, we would be able to efficiently remove that much waste per week. Using this data, we would be able to create a structure that, should we produce sufficient larvae, would grow and harvest enough BSFL to replace PMEI's chicken feed protein supplement.

This calculation can be run by embedding the following lines of code into an html website.

```
<html>
<head>
Input desired protein form here: <!-- This will change the wording above the text box -->
<br>
</br>
<div id='main'>
<form onsubmit="return redirect()">
<input id="search_form_input" type="number" name="query" />
kg/m^2 <!-- This will change the wording next to the text box -->
<input type="submit" value="Calculate" />
</form>
```

```
</div>
<script type="text/javascript">
   function redirect()
   {
      var query = document.getElementById('search_form_input').value;

      if (query != '') {
       // The variables below are fine, but the numbers can change
                        var grubs = (query * 1.585600625459897);
                        var tub = (query * 22198.417954378219279);
                        var grubtub = (query * 0.015085853568801);

                        document.write("You will need approximately " + grubs + "kg of waste to feed approximately " + tub + " grubs.  You will need " + grubtub + " m^2 area for your grub tub.");

      }
      return false;
   }

</script>

"Be sure to hit refresh in order to input new calculations" <!-- This will change the wording below the text box -->

</head>
</html>
```

How to build a BSFL feeding operation

The first step is to determine the scale of the operation for BSFL feeding based on the amount of waste that is produced or the quantity of chicken feed that is desired. See the previous section for more information on how to determine the scale of your operation.

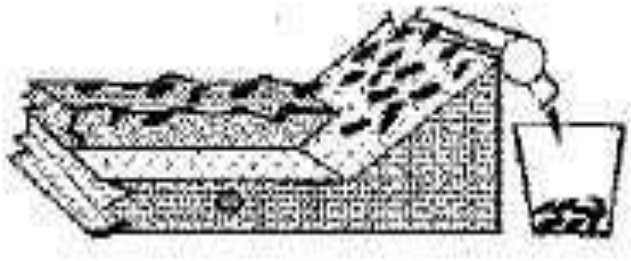
Large Scale

Large-scale operations will likely be classified as Animal Feed Operations (AFO) which can include swine, cattle, and poultry.

1. Materials will include concrete and wood to form the basin, gutter/PVC piping, and 5 gallon collection buckets (see description for information on automation).
2. Costs are highly variable depending on setup and scale.

This large-scale design is based on a study done by NC State researcher Wes Watson. The researchers found that "Black Soldier Flies are most easily managed in concrete basins directly under caged layers of swine" (Watson). Depending on the existing infrastructure, this can be an effective and low-cost option. The researchers also built a separate facility for BSFL feeding. For the separate facility, waste from the drained AFO travels along a conveyor belt, allowing liquid waste to drain off into collection troughs running alongside the conveyor. The separated solids are spread onto a larvae culture basin using a compressed air pump to deliver swine waste to a spreader that travels on a dolly along a beam above the basin. This exemplifies an effective automated method of growing BSFL, albeit costly. The residue (digested manure) was manually removed before new manure was placed in the basin.

The larvae culture basin was made of poured concrete. The surface area is dependent on the scale of the project, as noted in the calculations section. The basin is enclosed by 1ft-high vertical walls on three sides, and the fourth side has a 40-degree incline leading to a rain gutter or halved PVC pipe, closed on one side, and emptying into a bucket on the other.



(Watson, 1/18/2013)

Medium to Small Scale

Medium- to small-scale operations include free-range animal husbandry, farms that have a mix of animals, or residential homes that have pet waste and/or compost. For a medium- to small-scale operation, a modular approach will be more effective, allowing for the BSFL operation to be easily scalable. Each modular unit is referred to as a grub tub.

1. Materials for a single grub tub will include a plastic tote bin (>20 gallon, depends on the quantity of waste available), 2"x10' PVC pipe, 2x 90-degree PVC elbow joints, and a 5-gallon collection bucket
2. Cost of each grub tub is about $60. An alternative is to purchase a pre-made system called the BioPod which retails for around $200.

To build a grub tub, cut two equal sections of PVC pipe so that the grubs can travel from the center of the tub, out the side of the tub (through a hole cut in the plastic), and into a collection bucket. The PVC pipe should protrude approximately six inches from the tub. From

the protruding end, place the elbow joint and a small section of PVC to reach the lip of the collection bucket. Cut the bottom 6 inches of the PVC in half along the length of the pipe to create a larger opening for the larvae to enter. The goal is to have the migrating BSFL drop in the 5-gallon collection bucket, from which they cannot escape.

The grub tub must be filled with a food source manually. When filling, be sure that the opened end of the PVC lies above the level of the manure so that BSFL have easy access to the point of exit.

Source: http://www.redwormcomposting.com/the-share-board/vermimans-diy-bsfl-bin/

Attracting your own colony of Black Soldier Flies

Natural Distribution of Black Soldier Flies

The black soldier fly is a native insect to North America and is found throughout many parts of the United States. In the U.S. they are most active and common in the southeast. They are also found throughout the Western Hemisphere. Black soldier flies are especially abundant in the subtropics and warm temperate regions (Tomberlin, 57). Attracting black soldier flies for natural breeding will be easiest in the regions of the United States where they are most abundant.

Black Soldier Breeding

Within a few days of becoming an adult, the black soldier fly finds a mate. During their natural breeding process, the black soldier flies lay their eggs near a potential food source (Diclaro II and Kaufman). Because they are found outdoors and often near agriculture settings, black soldier flies are often found around decaying matter. They are known to thrive in various kinds of decaying matter like manure, carrion, plant refuse, and waste products of beehives (Black Soldier

Fly). When the female lays her eggs, she deposits close to 500 eggs (Black Soldier Fly). Unlike other species of flies, the black soldier fly does not lay their eggs directly on the decaying organic material. The black soldier flies like to lay their eggs in cracks and crevices near the organic material since the larvae will then consume this material upon hatching. The adults fly only during the warm months of the year, beginning in April and lasting through October (Tomberlin, 58).

A native colony of black soldier flies can be started in the warm months by attracting the female black soldier flies to lay their eggs near a source of food with a strong odor. One method to attract the black soldier flies is to start a compost bin using a mix of kitchen scraps that are a couple of days old. This mix of kitchen scraps can include any kind of vegetable scraps, corn on the cob, rotten potatoes, coffee grounds, fruit scraps or other types of putrescent compost. The females ready to lay eggs can detect in the air the chemical signal of a future larval-food source.

Black soldier flies will likely be more abundant in rural areas of the country. In these areas it is probably sufficient to attract the BSF using old kitchen scraps. In urban locations, black soldier flies may be more difficult to attract with kitchen scraps. Another method to attract black soldier flies in urban areas is to ferment dried corn kernels by soaking them in the water ("Attracting Black Soldier Flies"). Once the corn kernels ferment, the mixture releases a strong odor that can be useful for attracting black soldier flies. Sour milk may be another good option.

Black soldier flies like to lay their eggs in cracks and crevices that are removed from their food source. You can provide an ideal place for females to lay their eggs using common corrugated cardboard. Cut small strips of corrugated cardboard and attach them to the container holding the food scraps or fermented corn kernels. Make sure the crevasses of the cardboard are exposed to the female in order to have a place for her to lay the eggs.
The average time it takes to start a colony using this natural method is roughly two weeks. However it will also depend on the concentration of black soldier flies in the area ("How the Biopod Works"). Larvae won't develop into adults until the weather is warm so it is necessary to wait until the warmer months of the year to start a BSF colony (April through November).

In the warm months, you can maintain a colony of flies by building an outdoor screen enclosure in order to keep the black soldier flies from migrating. The structure needs to be several feet wide and tall because the flies need ample space to fly and breed.

How to build an indoor Black Soldier Fly breeding operation

If you are looking for a year-round or large-scale BSFL operation, you will need an indoor (enclosed and heated) breeding setup. Breeding tends to be more successful when there is open space to fly around and mate (adult black soldier flies mate in flight). Netting can be used to enclose the adult flies. Light is crucial because black soldier fly breeding typically only happens

when direct light is present. Natural sunlight from a window or skylight works best, but mating can occur with bright fluorescent lights set on a timer to mimic sunlight. High relative humidity is necessary for the larvae to successfully pupate into adults, and mating between adult flies has been shown to occur between 30 and 90% relative humidity. Some kind of plant (real or artificial) is needed to serve as a lekking location. Lekking is a mating behavior exhibited by the males of a species, where they congregate in certain areas and "call" to the females of the species. For black soldier flies, these lekking areas are characterized by the presence of leafy vegetation. As females approach the lekking areas, males rise and grasp onto a nearby female and descend back to the ground *in copula*. Small pieces of corrugated cardboard provide an ideal location for the females to lay their eggs. The cardboard should be placed near an odorous food source (which will attract the female by smell). Once deposited, eggs can take anywhere from 4 days to 3 weeks to hatch and should be kept out of water. They can be collected and stored in cool conditions to slow incubation. It is worth noting that experimental efforts at rearing black soldier flies in indoor cages have had mixed results. You may have to try various methods in order to successfully breed black soldier flies indoors.

Feasibility of off-season breeding

Off-season breeding is dependent on access to a suitable location for a breeding setup, and the characteristics of that location will affect materials, costs, and success. Black soldier flies can survive in very cold temperatures by slowing their metabolism and going dormant. Although larvae and flies can survive near-freezing conditions during the off-season, they will slow their rate of development and not be able to breed. Black soldier flies require warm temperatures for breeding in order to ensure higher likelihood of egg survival. This brings up two possible scenarios that could result in a successful and continuing influx of new eggs and larvae to your feeding operation during cold months.

Indoor off-season breeding is not out of the question, but is difficult. If the right temperature and humidity are maintained in your setup, the larvae may grow and reach the pupating stage, but actual breeding is much harder to induce. Black soldier flies mate while in flight, so configuring a setup that is indoors and provides enough space to allow flight is necessary. The enclosed space needs to be several feet tall and wide. A well-sealed greenhouse or lab space may suffice.

This guide has previously discussed ways to create an outdoor environment that will attract mating black soldier flies and allow them to lay their eggs in targeted areas where they can be collected. In the off-season, the only feasible way to breed outdoors is in a semi-open structure that mimics these same conditions but is insulated heavily and is temperature regulated by an external source, such as heat lamps or heated floors. This setup requires more materials

and energy costs, as well as increased likelihood of losing eggs. This should be taken into consideration if an indoor location is unavailable.

A third option that is not as well-documented or tested is the collection and storage of eggs produced during the regular season by freezing them and thawing them out as needed. There is mixed literature regarding other species of flies that can be frozen and thawed without mortality. To our knowledge, nothing specifically about BSFL has been researched. Many BSFL users have expressed their interest in this topic on BSF forums, and have gotten no concrete answers. It is known that the larvae and flies themselves can survive at low—but not freezing—temperatures, but nothing has been done with the eggs. Other fly eggs, such as screwworm flies, have been lab frozen, thawed, and reared to adulthood with low mortality (Suszkiw). However, fruit fly eggs have been seen to die when facing extended exposure to below-freezing temperatures. If it is possible to freeze black soldier fly eggs, it might be the most feasible option for continuing off-season larvae growth.

Value of BSFL and their byproduct:

If BSFL production exceeds the need for chicken protein supplements on-site, they can be sold as a dried food stock. Given the price of 16% protein chicken feed (Purina Layena Pellets) and the feed consumption for 45 free-range chickens at PMEI, we estimate the value of BSFL at approximately $1.05/lb. The manure byproduct produced from BSFL operations is another valuable end product that can be used in the same manner as compost. After treatment by BSFL the manure is no longer too hot (nutrient-rich) to apply to crops. Given that the manure byproduct is derived from animal waste, there are likely restrictions on usage and trade; thus the BSFL would be most appropriate for onsite use.

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