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Black Soldier Fly Larval Frass: A Multifaceted Organic Source for Sustainable Agriculture

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Abstract

Black Soldier Fly Larval (BSFL) frass as a sustainable and effective organic fertilizer amid rising concerns over declining soil fertility and limited organic nutrient sources. Derived from insect excreta, chitin and undigested matter, frass is nutrient rich and boosts plant growth, soil health and microbial activity. Its nutrient content is influenced by the larvae's feed substrate, making it adaptable. Frass improves nitrogen use efficiency, suppresses diseases and enhances crop yield. Beyond its application as fertilizer, it can be used in growing media, soil amendments, animal feed, and biochar production. BSFL frass also contributes to waste recycling, turning organic waste into high-value inputs for agriculture. Its efficacy across various crops and soil types, advocating for its broader adoption in sustainable agriculture and agroecosystem management, particularly in addressing the nutrient deficiencies prevalent in Indian soils.

1. Introduction

The use of organic manures to meet the nutrient requirement of crop would be an inevitable practice in the years to come for sustainable agriculture and generally improve the soil physical, chemical and biological properties and enhances crop productivity. A combined application of organic and inorganic fertilizers has been recommended to improve and sustain soil fertility, crop yields and agronomic nutrient use efficiency. A major challenge hindering the use of organic fertilizers is because of its limited source, therefore alternative sources of organic fertilizer for farm use such as insect compost are needed (Quilliam et al., 2020). Black soldier fly larval frass is one of the alternative resources in place of animal origin. Black soldier fly (BSF) (*Hermetia illucens* L.) belongs to the family

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Stratiomyidae and the larvae of BSF can be grown on a range of decomposable organic waste and have a high waste degradation efficiency (65% - 79%) (Rejeki et al., 2023). The frass, which is a byproduct contains substantial amounts of nutrients and use of this frass as an organic manure will improve growth and yield of crops.

2. Status of Soil Fertility in Indian Soils

The use efficiency (NUE) of nitrogen varies from 30–50%, 15–20% for phosphorus, 60 - 70% for potassium, 8–10% for sulphur and 1–2% for micronutrients. Nitrogen and phosphorus are main deficient elements in the world and also in India (Table 1).

Table 1: Nutrient deficiencies in world and India

| Nutrient | Percent deficiency in soils | |
|------------|-----------------------------|-------|
| | World | India |
| Nitrogen | 89 | 97 |
| Phosphorus | 80 | 83 |
| Potassium | 50 | 71 |
| Sulphur | 41 | 36 |
| Zinc | 49 | 39 |
| Boron | 33 | 47 |
| Iron | 15 | 37 |
| Manganese | 5 | 7 |
| Copper | 3 | 4 |

Source: IISS, Bhopal, (2018)

3. Why there is a Need of Novel Organic Manure?

- To match the future food demands with increasing population growth while conserving the soil resources.
- Address the issue of declining soil health.
- Reduce soil and water contamination.
- Enhance microbial diversity.

4. What is Frass and How does it Affect Plant Growth

- Black soldier fly (*Hermetia illucens*), a member of the Stratiomyidae family, has garnered significant attention in recent years for its remarkable larvae. These larvae excel as bioconverters, transforming a diverse range of food and crop waste into valuable biomass.
- Frass is defined as insect excrement, but in the

context of the insect farming industry, it refers to a mix of predominantly insect faeces, remnants of shed exoskeletons, and undigested feed.

- Frass is rich in readily extractable nutrients.
- Frass seems to be a fast-acting fertilizer.
- Frass deposition can result in a short-term pulse of plant-accessible nutrients due to stimulation of local activity of microbial decomposers, which can also accelerate the decomposition of recalcitrant organic matter.
- Fragments of chitin-containing exuviae, which are present in frass as a minor component, may also provide additional benefits of frass application on plant growth and health.
- In addition to improved plant productivity, frass application may also result in induced plant resistance to abiotic stresses.
- These beneficial effects of frass are mainly ascribed to plant-accessible nutrients, although frass-associated microbes are also likely to play a role.

Recent studies have reported improved crop growth, yield, nutrient uptake, N use efficiency, and disease suppression in different plants grown using composted BSF.

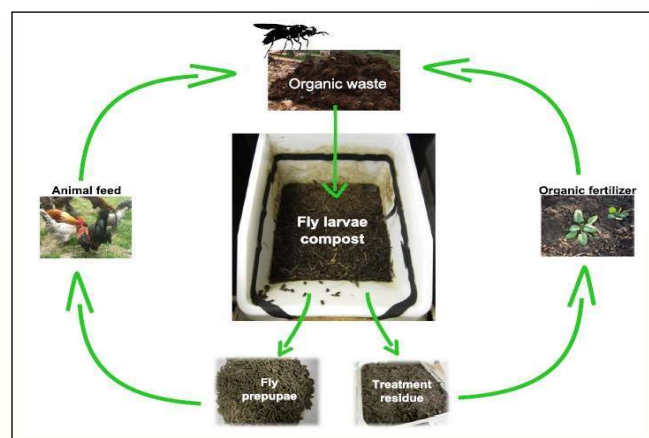


Figure 1: BSF as efficient organic waste decomposers

Table 2: Composition of different manures and composts and BSF frass

| Parameter | Cow dung | Poultry manure | Vermi compost | BSF frass |
|---------------|-----------|----------------|---------------|-----------|
| Nitrogen (%) | 0.5-1.5 | 1.5-4.5 | 1.0-2.5 | 2.0-5.0 |
| Phosphate (%) | 0.2-0.8 | 1.5-3.5 | 0.5-1.5 | 1.5-3.5 |
| Potassium (%) | 0.5-1.2 | 1.0-2.5 | 0.8-1.5 | 1.0-3.0 |
| C/N ratio | 20:1-30:1 | 10:1-15:1 | 15:1-25:1 | 10:1-20:1 |

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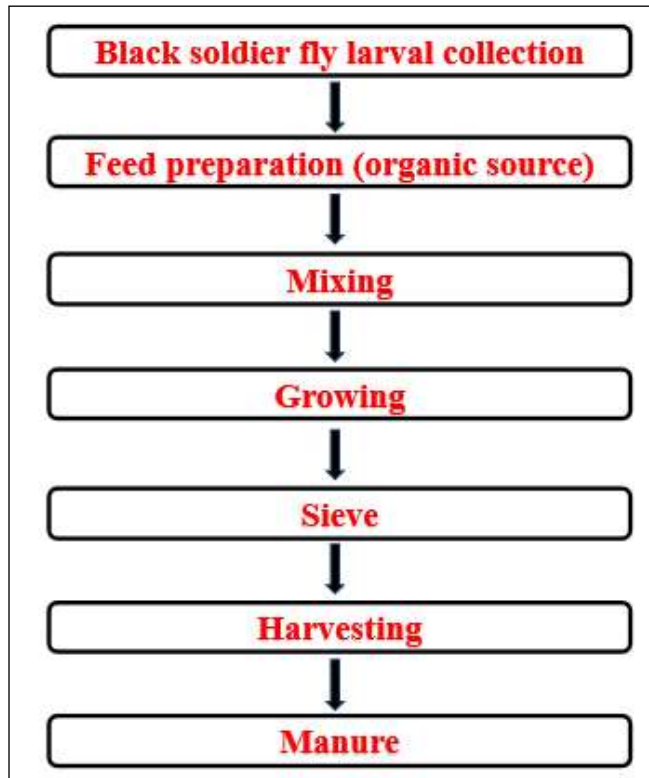


Figure 2: Flow Chart of BSF Rearing/Composting

BSF frass nutrition content depends on the feeding material less complex food will takes low time for conversion than the complex, hardy feed (Table 3).

5. Benefits of BSFL Frass

- BSFL frass contains chitin that improves the soil microbiome
- Rich in nutrients (macronutrients, micronutrients and organic matter)
- High phosphorus concentrations in the BSFL frass promote nitrogen accumulation in plants
- BSFL frass contains chitin that naturally produces antimicrobial peptides, which serve as a defence barrier for the plant
- Beneficial for microorganism population in soil

6. Applications of BSFL Frass

6.1. Organic fertiliser

- BSFL frass is rapidly gaining global attention as an organic fertiliser.
- BSFL frass has shown similar results in performing as organic fertiliser, even by feeding BSFL to different type

Table 3: Physiochemical characteristics of BSFL frass from different food waste types

| Type of Food Waste | pH | Nitrogen (%) | Phosphorus (%) | Potassium (%) |
|--|---------|--------------|----------------|---------------|
| Household food waste | 7.4 | 2.2 | 0.1 | 0.1 |
| Food waste, chicken faeces and sawdust (3:2:1 ratio) | 6.1-8.0 | 1.7 | 1.1 | 2.1 |
| Fruits and vegetables | 5.6 | 1.8 | | |
| Maize straw | 8.0 | 0.6 | 2.5 | 2.1 |
| Okra and wheat bran | 7.5 | 4.8 | 1.0 | 0.9 |
| Brewery spent grain | 7.7 | 2.1 | 1.2 | 0.2 |

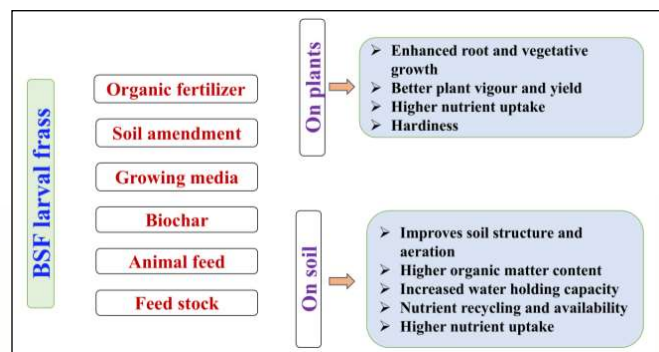


Figure 3: Title

of substrates: organic municipal solid waste food waste manure brewery spent grains mixture of poultry, brewery waste and green market waste mixture of pig manure, dog food and human faeces and fermented maize straw (Beesigamukama et al., 2020).

- Studies on the quality of BSFL frass as organic fertiliser revealed a significant increase in NPK concentrations and a considerable reduction in heavy metals to the acceptable levels set by the regulatory authorities (Tanga et al., 2022).
- BSF derived manure applied on soil provided remunerative growth of Pakchoi (*Brassica rapa* L.) (Agustiyani et al., 2021).

6.2. Soil amendment

- Adding BSFL frass to the soil in agricultural settings is beneficial to the plant or insect ecosystem and has

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improved the organic matter quality of intensively cultivated soils.

- BSFL frass can be a source of soil nutrients without affecting soil hygiene.
- Klammsteiner et al. (2020) has suggested that regular addition of BSFL frass to the soil will prevent fungal disease pathogens, such as *Rhizoctonia*, *Fusarium* and *Pythium*.

6.3. Growing media

- It was proved that BSFL frass is a suitable growing media to promote soil less agriculture because it can replace the commercial peat used in potted plants.
- Using 80% commercial peat and 20% BSFL frass as growing media has a beneficial effect on crop growth without causing abiotic stress, especially in the increase in total dry weight, increased leaf area and the number of the production has increased up to 20% for potted plants, such as baby leaf lettuce, basil, and tomato when compared to potted plant production by using commercial peat (Anyega et al., 2021).

6.4. Biochar

- Researchers have investigated using insect frass pyrolysed to biochar as a bio-adsorbent for wastewater detoxification in industrial environments.
- Even though frass from BSFL is not known to produce high-efficiency biochar, insect frass from mealworms feeding on wheat straw showed the best adsorption performance for bio-adsorbents and have the better capacity (1738.6 mg g^{-1}) of absorbing malachite green, (a cationic dye which is a highly toxic dye that may be found in wastewater) when compared to frass fed with wheat bran, raw wheat straw, and raw wheat bran.
- Researchers are starting to turn their attention to producing biochar from insect frass because of the presence of chitosan, which might lower the cost of commercial adsorbents.
- The chitosan derived from chitin is a naturally available bio-sorbent that could purify wastewater containing dyes in aqueous solutions.

6.5. Animal feed

- Research into BSFL frass for animal feedstock has shown excellent results in improving the growth of hybrid tilapia and enhancing the resistance of innate immune components and resistance to bacterial infection.
- This study fed five diets containing varying percentages

of BSFL frass of 0, 5, 10, 20 and 30% to juvenile hybrid tilapia as a partial substitute for a mixture of soybean meal, wheat short, and corn meal on an equivalent protein basis (Boudabbous et al., 2023).

- The improvement in hybrid tilapia growth could be due to the high protein content of BSFL frass.
- The fish diet containing 5 to 30% BSFL frass has a slightly higher protein efficiency than the diet without BSFL frass fed to the control group.
- BSFL frass could be used as a partial replacement for commercial animal feed.

6.6. Feedstock

- If necessary, BSFL frass can be fed to a biogas plant for anaerobic digestion for further processing. This post-processing of BSFL frass could simultaneously resolve problem with the handling of wet, high moisture content BSFL frass and to reuse the potential energy sources from wet BSFL frass to run the plant.

7. Conclusion

Black soldier fly frass significantly enhanced the growth and yield of crops when applied directly or in combination with NPK fertilizers at a specified ratio. The use of insect frass as organic fertilizer in sustainable agriculture supposes the contribution of nutrients, beneficial microorganisms and biomolecules of interest to the soil could help limit the use of agrochemicals. The composition of the BSF frass is strongly dependent on the feed substrate and as such there is no universal BSF frass composition.

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