Review Article

Insect Frass as Organic Fertilizer in Sustainable Agriculture

Abstract

Agricultural producers are under growing pressure to maintain output while lowering synthetic fertilizer use in order to minimize environmental effects.Thusa wide range of organic compounds are now being investigated as alternative fertilizers and soil amendments.Given the rate of expansion of the human population, mass breeding of insects for feed and food is a more efficient and effective alternative to conventional animals for the production of animal protein. Due to the fact that the production of insect faeces (frass), which is up to 40 times greater than the production of animal biomass in these industries, is one of the main results of the process, its use as organic fertilizer to replace the use of agrochemicals is viewed as a viable alternative in the development of sustainable agriculture and a circular economy (Jorge poveda.2021). This article illustrates the advantages of using insect faeces as organic fertilizer in sustainable agriculture, Therefore, insect residue from the mass breeding of insects for feed and food represents an important source of effective organic fertilizer for use in sustainable agriculture.

Keywords: Insect frass, Fertilizer, Sustainable agriculture, Nitrogen, Plant growth

1. Introduction

The population of the world has increased quickly, from 1.6 billion in 1900 to 7.9 billion in 2021. According to the latest estimations, the world's population will reach 9.7 billion in 2050, increasing the demand for resources including water, food, and energy. Due to this scenario, food production should increase by about 70% by 2050 and quadruple or triple by 2100 while striving to reduce the environmental impact of food production activities (Chen et al. 2016; Crist et al. 2017).This tends to make farmers dependent on high inputs of synthetic fertilizers along with the breeding of newly developed high-yield cultivars to meet increasing food demands and enhance productivity. Even though conventional arable cultivation techniques can be highly effective, they are coming under more and more scrutiny due to the negative impacts of deep plowing, pesticides, and synthetic fertilizers on the environment. Food systems may have negative effects on the environment, including deforestation, habitat loss, biodiversity loss, resource depletion, air, soil, and water pollution, and land degradation. They contribute almost a quarter of human-caused greenhouse gas emissions, and agricultural production consumes 70% of the world's freshwater. The use of synthetic fertilizers and pesticides in agriculture, as well as chemical contamination of aquatic and terrestrial ecosystems, food products, and ecosystems, all have the potential to have very negative health effects. Food production has a clear adverse impact on the environment(Lindgren et al. 2018).

Therefore, it should be increased without causing much loss to biodiversity or converting more natural areas into cultivable land. Agronomists are currently looking at alternate approaches to maintaining yields while reducing farm environmental footprints to produce food more sustainably. To improve soil fertility, encourage a healthy soil biome, and increase soil carbon content—principles now underpinned by organic and regenerative agriculture systems—these initiatives often involve the introduction of several organic amendments. The use of organic fertilizer in place of chemical fertilizers is a long-term strategy for sustainable agriculture that is economically viable and environmentally friendly(Wang et al. 2018).However, organic nutrient sources are suggested as a sustainable method for producing nutritious and Fertilizers are a long-term strategy for sustainable agriculture that is economically viable and environmentally friendly. Therefore, there is a clear need for the search for new organic sources of nutrients to use as fertilizers in the advancement of sustainable agriculture(Timsina 2018).The production of insects has become a growing sector globally as it offers an exciting opportunity for the efficient recycling of organic waste. The most prominent by-product of insect production is insect feces, or "frass" in technical terms. To maintain a circular economy, frass must be used, as it is generated in greater quantities than actual insect products (Ortiz et al. 2016).

What is insect frass?

Insect frass, or excreta, is typically a vital byproduct of the insect rearing process. In other terms, "insect poop" is known scientifically as "frass." Insect frass is a specialized form of commercial insect farming (Zewaecosystem.com). A particular type of industrial insect farming is called insect frass. It is a natural fertilizer. Frass is an organic fertilizer due to its high nutrient content and its ability to promote plant growth. It is a viable alternative to conventional agrochemicals and artificial fertilizers used to boost plant development (Ortiz et al. 2016). The use of frass, a natural bio-fertilizer, greatly enhances agricultural fertility and boosts crop yields. It has been proven that using frass in organic farming promotes the growth of plants by serving as both a plant strengthener and nutrient-rich manure, enhancing the quality of the crops (Beesigamukama et al. 2022).

How to compose insect frass?

It is easier to understand the mixture of exoskeletons, dead eggs, residual feed, and insect faeces in terms of the insect rearing process. A bio-fungicide derived from insect faeces obtained from BSF larvae, which also contains chitin and helpful microorganisms(Zewa Ecosystem). When treated appropriately, insect frass is ideal compost manure and a rich source of nutrients. Microbial decomposers present in insect faeces can stimulate the uptake of micronutrients as well as strengthen and promote plant growth. Insects eat plant material or other organic material, which their guts then break down using enzymes and bacteria. The body of the insect subsequently takes in the nutrients and minerals while excreting the waste as frass. Depending on the species of insect and the type of food they consume, the composition of insect frass varies(VanHuiset al 2013). It is possible to gather insect frass from habitats in nature or from insect farms. In horticulture and agriculture, it may be used as a pest repellent, soil treatment, or fertilizer. Insect frass is gaining popularity among producers since it is a natural and sustainable product that helps to improve the health and production of their crops while reducing their environmental effects.

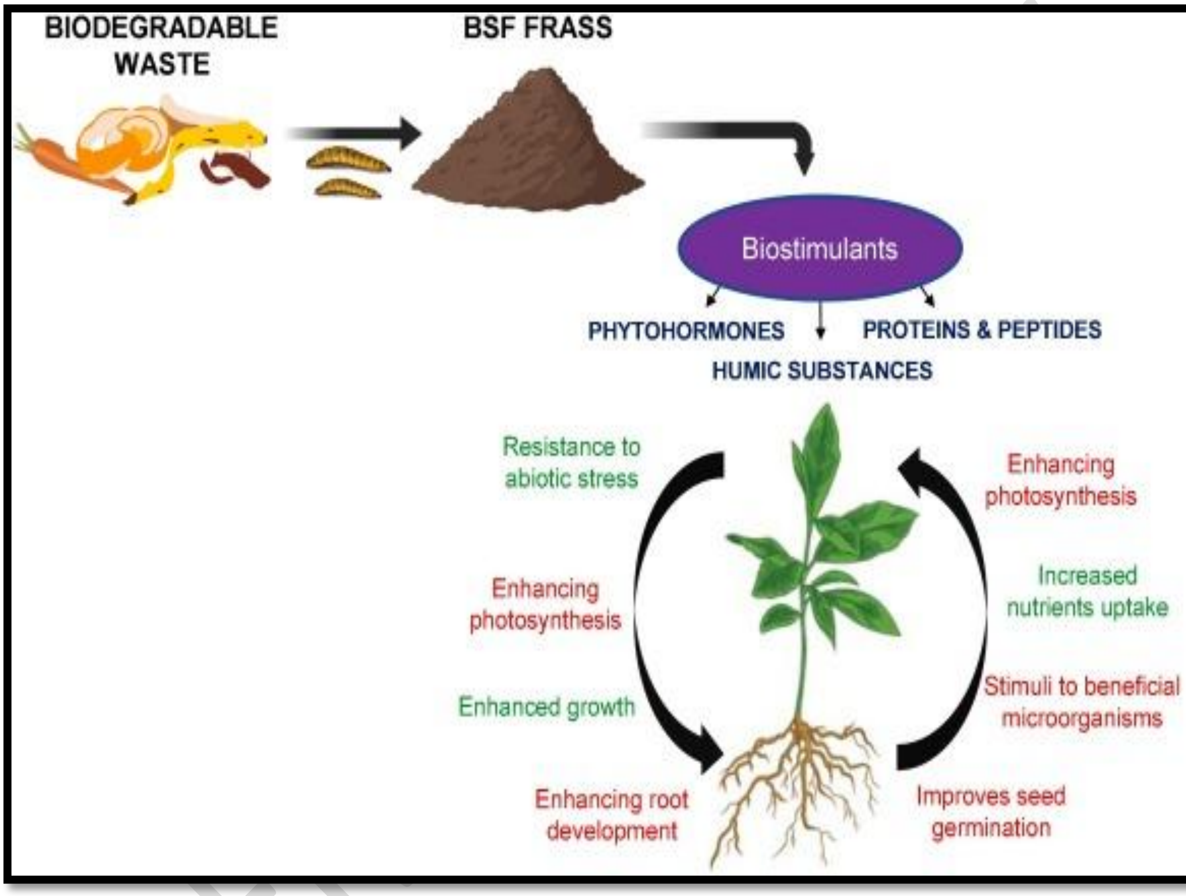

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Figure-1 Bio stimulants of insect frass

Use of insect frass as organic fertilizer

The unsustainable practices of using synthetic and chemical fertilizers have resulted in long-term soil deterioration and a progressive loss of soil fertility.The use of organic fertilizers and comparable eco-friendly practices are necessary to prevent the indiscriminate use of chemical fertilizers(Wang et al. 2018).Using insect frass as a natural fertilizer to enhance plant growth is an excellent option in that regard.The exuviae and frass left behind from the insect farming procedure can be better utilized as organic manure.The growing of vegetables, fruits, grains, herbs, and other plant species falls under the purview of organic agriculture. Because insect frass contains a lot of NPK (nitrogen, phosphorus, and potassium), its use as a soil quality enhancer is further expanded(Poveda et al. 2019).

Growing vegetables, fruits, grains, herbs, and other plant species comes under the purview of organic agriculture. Because insect frass contains a lot of NPK (nitrogen, phosphorus, and potassium), its use as a soil enhancer is further expanded. Insect frass and exuvia can be added to soil to enhance its physical characteristics (Zewa Ecosystem).

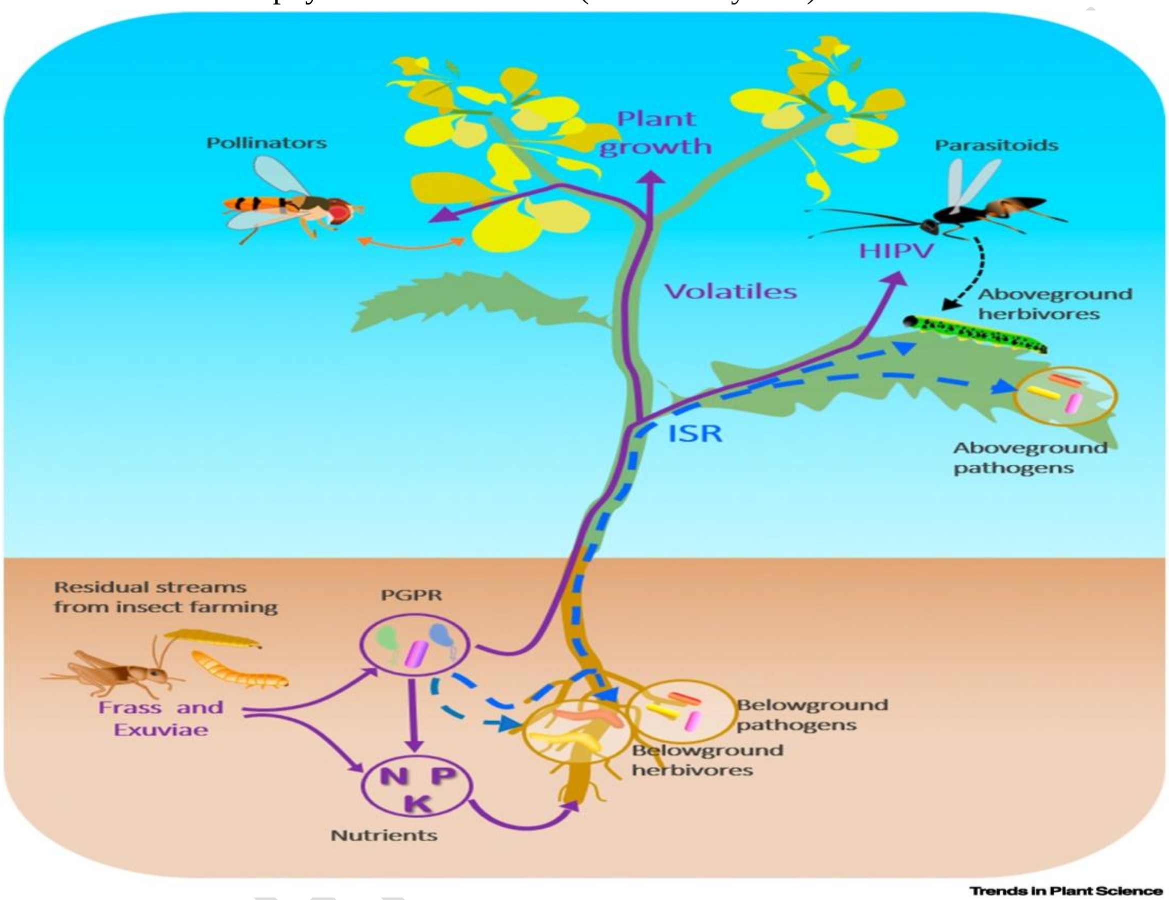

Figure-2 Circular economy of insect frass

Table 1. COMPARISION BETWEEN FRASS AND CHEMICHAL FERTILIZER

FRASS AS FERTILISER	**CHEMICAL FERTILIZER**
Requires more time for the nutrients of these fertilizers to reach the plant.	Work faster than organic fertilizers as they get immediately dissolved in water and supply nutrients to plants

Renewable source.	Non-renewable source.
Makes the soil healthier and more fertile	Soil life will not be enriched or stimulated.
It ensure an airy soil structure.(COMPECTION)	Chemical fertilizers lead to soil acidification.
It is biodegradable, sustainable, and environmentally friendly.	Repeated applications affect microbial ecosystems and the soil’s pH, a toxic buildup of chemicals in the soil.
It supports the growth of nitrogen-fixing bacteria..	Destroys the growth of the nitrogen-fixing bacteria as it contains high acid content.
It is more expensive as compared to chemical fertilizers	It is less expensive compared to bio-fertilizers.

Industry of mass insect breeding

Recent years have experienced a rise in interest in using insects as food and feed, which has resulted in an increase in the number of scientific publications and businesses that produce insect products on a private basis. According to Van Huis 2020, there are more than 250 enterprises worldwide that are engaged in the production of insects for food and feed, excluding insect industry associations. In terms of science, the use of insects as food and feed generates hundreds of articles every year, which are regularly examined by different authors (Sogari et al. 2019; Tang et al. 2019; da Silva-Lucas et al. 2020). Although there are aspects common to all of them noted by different authors (Dossey et al. 2016; Ortiz et al. 2016; Cohen 2018) The design and operation of a mass insect breeding industry require adapting industrial processes to the insect's lifecycle. The production of frass (insect excrement) by insects, which is believed to be a significant end product within the system, is a crucial component of the mass rearing process. Because of this, frass has been regarded in these industrial systems as an organic fertilizer and even as food for other animal farms (Ortiz et al. 2016). It has been determined that yellow mealworms (*Tenebrio molitor*) can feed 220 g of food in the form of corn and carrots, assuming an insect biomass production of 4 g and 180 g of frass and residues, respectively (Wang et al. 2017). This gives an idea of the amount of frass that this type of industry can accumulate daily.

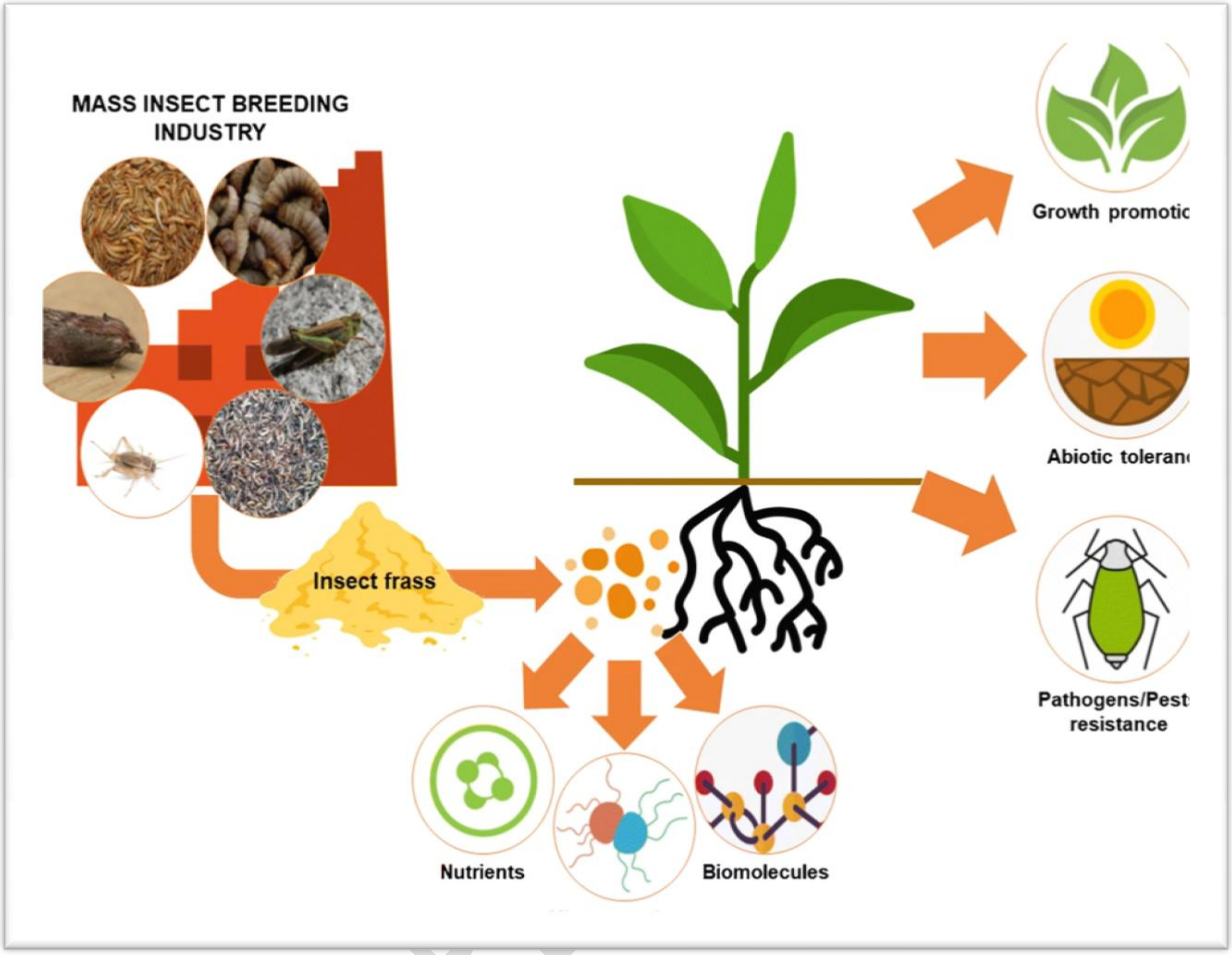

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Figure-3 Production of insect frass in mass breeding inustry

Processing of frass before use as organic fertilizer

Concerns have always been raised about effectively using frass as fertilizer. Due to the application of frass directly to the soil, there is a possibility that some harmful organisms may survive in the digestive tracts of insects and be passed on to plants or people. To ensure the safe use of frass after adequate sanitization and sterilization, the advantages of insect frass in agriculture as organic fertilizer are important. The frass has to go through several sanitization processes before it can be used as an insect fertilizer in agriculture to get rid of the dangerous bacteria present in the organic matter. With this, we can be confident that there are no longer any organisms that are dangerous to human health or unsafe for use in organic agriculture(Zewa Ecosystem).

Advantage of insect frass in agriculture as organic fertilizer

A. Nutrient quality and maturity status of frass fertilizer

1. The quality of frass fertilizer produced by insect species and its practical application for enhanced soil health and agricultural yield
2. The different frass fertilizer products' high nutrient contents, fertilizing indices, and prospective nutrient supply capabilities suggest that they are suitable as sustainable substitute sources of plant nutrients.
3. Utilizing the circular economy concept, there is significant interest globally in recycling organic waste into high-quality frass fertilizer by applying insect larvae.
4. All insect species had sufficient levels of the macronutrients potassium, phosphorus, and nitrogen.(DBeesigamukama. 2022)
5. Global food and nutritional security, as well as environmental health, are seriously threatened by soil degradation and improper waste management.

Nearly 40% of soils in SSA are deficient in most nutrients needed for crop growth, with 25% of soils affected by aluminum toxicity, 18% vulnerable to leaching, and 8.5% having phosphorus fixation as a distinguishing feature. Despite the difficulties, due to the high costs and limited access, most smallholder farmers use little (10 ($\leq$ 10 kg ha^{-1} year^{-1}) or no mineral fertilizer.(Nowakowski AC et al 2022) Low soilorganic matter, a lack of micronutrients, and high soil acidity all reduce the effectiveness of mineral fertilizers, even in situations where they are widely used.(Vanlauwe B, et al 2015.) Farmers may use organic fertilizer, and it is both acceptable and economical; but, because of its low quality, lengthy production processand lack of supplies of organic matter on farms, there has been little uptake in SSA. Insect frass fertilizer is only one of the widely available, inexpensive, and high-quality organic fertilizer sources that should be investigated. Insects are being used to bio-convert low-value organic materials into items including food, feed, fibre, and organic fertilizer that are accessible, economical, and of high quality.

B.As sources of nutrients and compound interest for plant growth.

In nature, insect frass is a crucial component of the interchange between soil and plant matter and is a part of the nutrition cycle. In this situation, insect frass may be used to keep track of the variety of insects that are present in a certain area (Sweetapple and Barron 2016). Since insect frass contains a lot of nutrients, it may be used as fish food, such as in the diets of hybrid tilapia (*Oreochromisniloticus* x *O. mozambique*) or channel catfish (*Ictalurus punctatus)* (Yildirim-Aksoy et al. 2020a, b). In terms of plants, insect frass provides nutrients that are readily absorbed by the roots since the insect has physiol`ogical systems in place to form its own waste. Usually nutrients like nitrogen or phosphorus are available in plant tissues that herbivores eat in higher concentrations than insects require to maintain their bodies' N:P stoichiometric equilibrium Therefore, they have to carefully regulate how these nutrients are excreted in their waste, encouraging high concentrations. (Zhang et al. 2014).Nitrogen is often unavailable to plants because of low nitrogen levels in the soil due to inappropriate agricultural practices, biological processes such as denitrification and microbial competition, or soil erosion (Goulding et al. 1998). Insects may be an important source of nitrogen for plants at the ecosystem level since they act as storage for nitrogen and are crucial to the soil's nitrogen cycle. (Behie and Bidochka 2013). The most widely studied method of using this input as fertilizer in agriculture is the transfer of nitrogen to plants via insect frass. The majority of research has been done in the field, but it has also been demonstrated in pots how frass from the cabbage moth (*Mamestrabrassicae)* can supply nitrogen to the soil, which encourages the growth of cabbage plants *(Brassicarapavar. perviridis*) and increases total nitrogen concentration, as well as accumulate inorganic nitrogen and ammonium nitrogen in the leaves in response to the application as fertilizer (Kagata and Ohgushi 2011, 2012a). Regarding its application in the field, we discover different kinds of defoliating insects whose droppings add nitrogen to the plants they feed on, such as the grasshoppers *Chorthippuscurtipennis* and *Melanoplus borealis*, which consume grass (Fielding et al. 2013). During two year cumulative study the lepidopteran *Doratiferaquadriguttaa*nd the Eucalyptus defoliating beetle *Parapsistomaria*were able to produce between 160 and 270 kg of pests and accumulate 2 to 4 kg of nitrogen per hectare (Gherlenda et al. 2016). In other cases, such as the defoliation pest Lymantriamonacha on *Pinussylvestris*, trees did not respond by increasing their nitrogen acquisition but instead invested resources in defence by accumulating amino acids and proteins as a survival strategy (Grüning et al. 2017). In addition, the nitrogen that was added to the roots might take on other forms, such as amides. In an attempt to boost plant growth in dragon fruit cactus (*Hylocereusundatus*) plants, the *Zophobasmorio* beetle was fed polystyrene in order to create frass rich in amides. This process was done in an effort to create a circular economy by recycling plastics used in agriculture.In an attempt to promote plant growth in dragon fruit cactus (*Hylocereusundatus)* seedlings, *zoophobasmorio* beetles were fed polystyrene to produce feces rich in amides. The process was done in an effort to create a circular economy by recycling plastic used in agriculture (Koh et al. 2020). In place of nitrogen, additional nutrients are returned to the soil through insect waste in the field, such as carbon from the waste of the defoliation moth *M. americanum* on red oak, which raises the overall amount of carbon, total nitrogen, and ammonium in the soil while also promoting microbial activity. (Frost and Hunter 2004). This emphasises the part that insects play in the cycle of many different minerals, for example by eating decaying wood and returning nutrients to the soil, as is the case with many types of subterranean termites (Chen and Forschler 2016). The frass from *T. molitor,* one of the most frequently bred insects utilised in industrial farming today for food and feed, has also been examined for its nutritional contribution. Using several feeds in 2019 Poveda et al. Poveda et al. extracted frass from mealworms with an NPK balance of 3-2-2 (g/100 g) and an iron content of 140 mg/Kg, which, when grown in pots, was able to accelerate the growth of chard plants by increasing the chlorophyll content of the leaves, the length of the stem, the width of the stem, and the fresh weight of the aerial part. (Product of economic interest) (Poveda et al.2019). Mealworm frass has since been found to be an effective natural NPK fertilizer that increases biomass and nutrient uptake in crops such as barley, thanks partly to stimulating soil microbial activity. This is because it is quickly mineralized and contains nutrients in a readily available form (Houben et al. 2020). Also, it has been demonstrated that, in addition to nutrients, insect frass can give plants access to other substances that are crucial for their growth. Frass from *saproxylic-cerambycid* larvae of *Chlorophorusannularis* that dined on the wood of dead twigs of *Acacia stenophylla* provides sugars, alkaloids, and phenols to the soil in part due to the presence of microorganisms like the helpful fungus *Trichodermahamatum*. It has been demonstrated that these substances promote seed germination and seedling development in lettuce (Khan et al. 2016).

B. Frass as an aspect of abiotic stress resistance and abiotic stress tolerance for plants

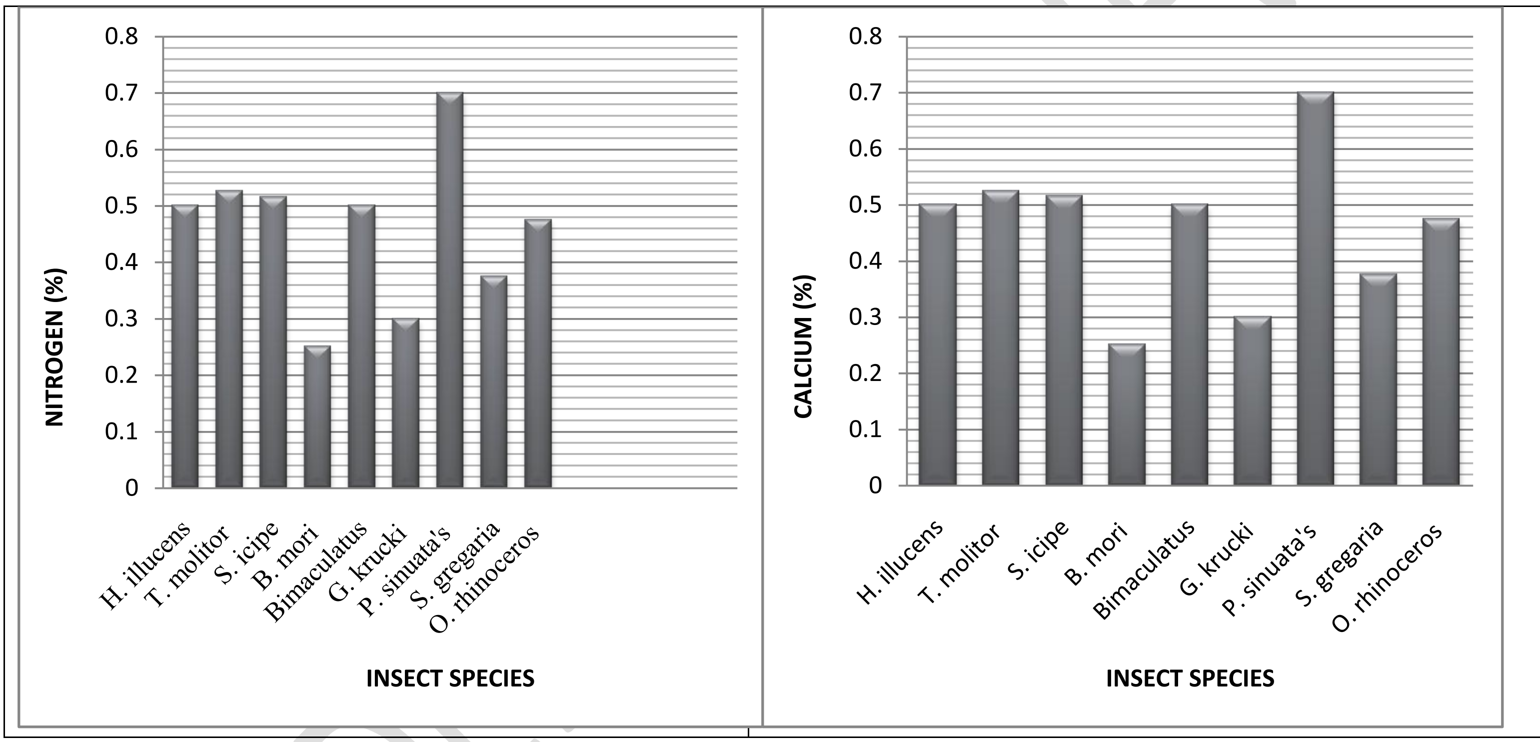
It has been noted that insect frass can help plants become more resilient to various abiotic stressors. Frass from mealworms was applied to bean plants to boost the seedlings' resistance to salt, drought, and floods. The study identifies numerous bacterial and fungal isolates capable of fixing atmospheric nitrogen, solubilizing phosphates and potassium, and producing siderophores, auxins, and 1-aminocyclopropane-1-carboxylic acid (ACC) deaminize to explain how this increase in tolerance is caused by the microorganisms present in the frass due to the sterilization of the frass(Poveda et al. 2019). There have been several studies on the direct influence of the usage of frass as a fertilizer on the activation of plant defense mechanisms in relation to the defense against pests and/or diseases. The activation of plant systemic resistance via the SA and/or JA/ethylene (ET) pathways may be influenced by the roots' identification of microbes and macromolecules found in insect frass. This protective reaction is based on the identification of chemical patterns by cellular receptors linked to microbes and herbivores, such as chitin (Poveda 2020). In a study conducted in a greenhouse, it was shown that the excreta of certain herbivorous insects may activate the plant's defensive responses, which were mediated by SA and JA. For this, a variety of interactions were employed, including those between the tomato fruit worm (*Helicoverpaxea)* and tomato, the European corn borer (*Trichoplusian*i) and cabbage, the autumn armyworm (*Spodoptera frugiperda*) and rice, and the cabbage looper (*Trichoplusiani*) and cabbage.(Ray et al. 2016). When insect frass is used as fertiliser, the presence of initiating chemicals or specific microorganisms triggers defensive reactions in the plant. In 2015, Ray et al. revealed that the presence of eliciting molecules in corn plants exposed to frass from *S. frugiperda* resulted in the induction of pathogenesis-related expression (PR) defence genes against the pathogenic fungus, activating plant defensive responses when in contact with insect frass. *Cochliobolusheterostrophus* (Ray et al. 2015). Chitin, which makes up a portion of the periotrophic gut membrane of insects and is found in their frass, is one of these compounds. Due to the presence of chitin, it was feasible to demonstrate in cowpea plants how brewery waste-fed frass from *H. illucens*may activate plant defence mechanisms and lessen Fusarium wilt disease (Quilliam et al. 2020). They may also be chitinase enzymes, which are important for the proper development of the periotrophic membrane. It was discovered that the chitinases present in maize plants exposed to S. frugiperda frass were able to increase pathogen defences against C. heterostrophus while reducing herbivore defences (Ray et al. 2016a). The ability of the insect frass to activate plant defensive responses against chewing insects but not against sucking insects like the maize leaf aphid (*Rhopalosiphummaidis)* was later proven in the same system (*S. frugiperdamaize*).(Ray et al. 2020). Furthermore, the microorganisms found in insect frass may be able to trigger the plant's defence mechanisms. In keeping with the *S. frugiperdamaize* system, the bacterium *Pantoeaananatis* was isolated and identified in insect frass, demonstrating its capacity to increase the expression in the plant of the gene encoding for the herbivore-induced maize proteinase inhibitor (mpi), which results in a reduction in insect attack. It was not possible to activate plant defence responses to the same extent using tomato plants as opposed to maize.(Acevedo et al. 2017). It is interesting that not all insect frass exhibit the same outcomes in all crops when it comes to the activation of defensive responses in plants against diseases and/or pests. Frass from *H. illucens* was applied to sugar beetroot and staff seedlings that were infected with the infections *Rhizoctonia solani* and *Pythiumultimum*, respectively; however, this did not result in a reduction in the illnesses brought on by the pathogens.(Elissen et al. 2011)

Compression of the nutritional value and maturity status of some edible insects as fertilizers

Frass fertilizers from various edible insect species contain acceptable levels of the **macronutrients** nitrogen (N), phosphorus (P), and potassium (K), as well as the **secondary nutrients** calcium, magnesium, and sulfur, and the **micronutrients** manganese, copper, and iron, zinc, boron and salt.

- *G. krucki* and *O. rhinoceros*, respectively.(Beesigamukama, D. *et al.2022)*Black soldier fly (BSF) frass fertilizer exhibited much greater amounts of K (17-193%) and N (20–130%) than other fertilizers. When compared to other insect species' frass fertilizers, the P content of *Gryllusbimaculatus*frass was 3–800% greater.
- The seeds that received BSF treatment had the highest seed germination rates (over 90%) and germination indices (267%).
- The samples of frass fertilizer ranged in total organic carbon content from 24 to 50%, with *T.molitor* and *O. rhinoceros* frass fertilizer having the lowest and highest values, respectively.
- Ammonium content of the frass fertilizer samples ranged from 0.01 mg kg-1 to 174 mg kg-1. *P. sinuata's*frassfertilizer has the highest ammonium content ever seen.
- Between 0.01 and 174 mg kg1, ammonium was present in the frassfertiliser samples. Frass fertilizer created by *P. sinuata* has the highest ammonium content ever seen.
- The *H. illucens*-produced frassfertilizer had a total N content that was 20–30% greater than that of other insect-made frass fertilizer, which was considerably ($p \leq 0.001$) higher.

- *Bimaculatus*and*B. mori* generated frassfertilizer with the greatest and lowest P contents, respectively. The overall P concentration varied between 0.17 and 1.5%.
- The content of K in *H. illucens*-generated frassfertilizer was 17-193% higher ($p \leq 0.001$) than in frass fertilizer produced by other insects.
- The Mn concentration varied between 128 and 4600 mg kg1, with *O. rhinoceros* and *B. mori* producing the lowest and highest Mn values, respectively.
- The concentration of Fe in *O. rhinoceros* frass fertilizer was 2–99 folds higher ($p \leq 0.001$) than that of frass fertilizer produced by insects.



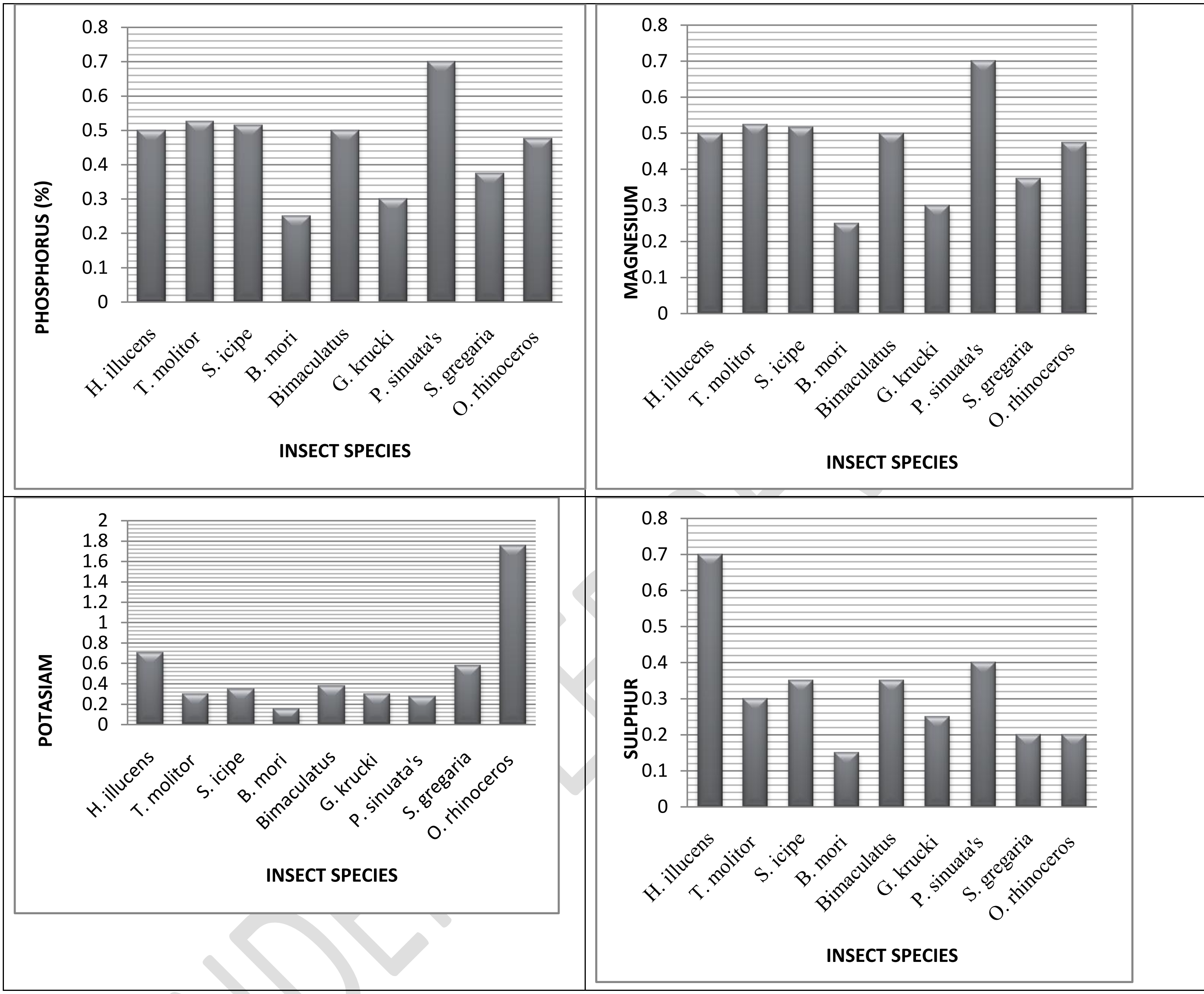


Figure 4. Total amounts of nitrogen, phosphorous, potassium, calcium, magnesium, sulphur, and other nutrients were measured in frass fertilizer produced by various edible insects (natureportfolio).

The effectiveness of using frass fertiliser produced by various edible insect species to boost soil health and crop yield, along with precise directions for its use. Numerous frass fertiliser products are suitable as sustainable alternative sources of plant nutrients due to their high nutrient levels, fertilising indices, and potential nutrient supply capacities. It is expected that the availability and use of insect frass fertilisers will greatly reduce the overreliance on expensive commercial mineral fertilisers and subpar organic fertilisers.In terms of nutrient content and prospective supply capability, frass fertiliser products from *H. illucens* and two cricket species (*G. bimaculatus* and *S. icipe*) were the best. However, with the exception of *H. illucens*, the frass fertiliser from all of the insects would require further composting to increase their maturity and stability. More agronomic research is needed to determine the best amendment rates of different frass fertilisers to ensure high nutrient release and synchrony for crop absorption, better yield, and nutritional quality of food crops.

Beneficial effects of frass

- Insect farming is a very sustainable means of producing alternative proteins.
- A beneficial by-product of this industry, frass, offers immense benefits in agriculture as an organic fertilizer.
- The idea of using waste from the insect-rearing process has both economic and ecological benefits, leading to a zero-waste strategy.
- Contributes essential nutrients such as nitrogen, phosphorus, and potassium for plant growth.
- Contains adequate amounts of micronutrients for soil fertilization and amendment
- Improves plant health by increasing microbial activity for nutrient uptake.
- High nutritional content at cheaper rates.
- Contains growth-promoting components such as insect exuviae, chitin, and related macromolecules, which improve plant production.
- Frass treatment in crops gives substantial insect resistance as well as increased resilience to abiotic stressors.
- The use of frass improves soil fertility, structure, and water retention.(Zewa Ecosystem).

Frass application rates

- There are several applications for insect frass in the garden. Furthermore, the procedure is determined by the intended application of the garden compost.
- It's typically advisable to pre-mix insect frass into soil or compost before using it in the garden. If the plants are already developing, we may add some insect frass to the water and soak it for several hours.Then, use it to drench the roots of plants.
- For fertilizing raised beds, apply a pound of insect frass to every 20 square feet of plant space. Then, carefully dig up the top half foot of soil, soaking well before mixing in the frass.
- For sustained advantages, we can top-dress the bed with extra frass every few weeks during the growth season.
- To make a mix for potted plants, add one cup of insect frass per cubic foot of potting soil. Then, every few weeks, sprinkle some on top of the soil for further advantages.

- ✓ For an insect frass tea extract, mix 12 cups of insect frass into a gallon of de-chlorinated water and apply it to drench plant roots within two hours after mixing. If we have excess, you may keep it in the fridge for up to a week. This is because keeping it at room temperature causes it to spoil quickly.(Zewa Ecosystem).

Conclusion

The current rate of population expansion necessitates the development of new solutions for sustainable food production. Because of its advantages over conventional livestock in the production of animal protein, mass breeding insects can be an environmentally conscious approach. Insect frass could be used as fertilizer to reduce the use of agrochemicals and promote the development of sustainable agriculture due to its high nutritional content and abundance of substances and microorganisms that are beneficial to agriculture. However several studies have suggested its effective use, the vast majority have only been conducted in the previous years, which is indicative of the enormous novelty that this agricultural resource provides. There are currently very few studies on compounds or microorganisms capable of promoting plant growth or activating tolerance and defense responses in plants against biotic and abiotic stresses, which provide crucial directions to develop in the future. Instead, these studies focus on the contribution of nutrients to the soil and the plant, particularly nitrogen. Since this agricultural resource is so novel, several studies have suggested its effective usage, although the vast majority was conducted in the previous five years. Despite this, more studies on agricultural systems need to be done to determine whether or not insect fertilizer could be used as a full alternative to mineral fertilizer. In an effort to manage plant nutrition and health in sustainable agriculture systems and as an alternative to traditional fertilizer and pesticides, insect fertilizer should be taken into consideration given the predicted substantial increase in insect rearing in the near future. In the scenario of huge insect production for food and feed, the use of insect frass as organic fertilizer responds to the requirement to create a circular economy without residues. The use of insect frass as organic fertilizer in sustainable agriculture presupposes the addition of nutrients, beneficial microorganisms, and interesting biomolecules to the soil, similar to the excreta of animals. Insects are uricotelic animals, and their frass contains a significant N content since this is how the residue is eliminated.This property occurs in the same way as bird excrement, but unlike that, the microbial diversity present can be significantly greater. In addition, because of its lower humidity, it is more stable in storage and easier to use. Regarding how it comes to the market, animal excrement used in agriculture needs to undergo a certain kind of sanitizing process in order to eliminate any potential pathogenic germs. Insect frass must be incorporated into the same regulations as other animal excreta because there aren't any laws yet that directly regulate the use of insect waste as fertilizer in agriculture. A lot of the benefits that insect frass provides as fertilizer's could be completely eliminated by sanitizing processes, such as high temperatures, by eliminating the advantageous microorganisms and/or biomolecules that it is capable of supplying to soils.

- ➢ It is expected that the availability and use of insect fertilizer's will greatly reduce the overreliance on expensive commercial mineral fertilizer's and inferior organic fertilizers.

- The insect frass's nutritional composition, which included good concentrations of various micronutrients and macronutrients, indicates that it has potential as a fertilizer.
- The use of insect frass as fertilizer could help reduce the use of agrochemicals and contribute to the development of efficient, sustainable agriculture due to its high nutritional content and the presence of compounds and microorganisms of interest in agriculture. However, the vast majority of studies have not been conducted, which is indicative of the great novelty that this agricultural resource represents.
- These insects concentrate on the contribution of nutrients to the soil and plant, particularly nitrogen compounds or microorganisms capable of promoting plant growth or activating tolerance and defence responses in plants against biotic and abiotic stresses. These are potent areas for future research.
- It is necessary to do research on agricultural systems to determine whether insect frass can completely replace mineral fertilizer.
- Insect frass should be viewed as a sustainable resource for regulating plant nutrition and health in sustainable farming systems and as a possible substitute for traditional fertilizer and pesticides given the predicted rapid growth of insect rearing in the near future.

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