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The Potential of Insect Frass as a Sustainable Agricultural Solution

Hariharan Selvam[1], Logeshvararaj Balasubramaniam[2], Mangayarkarsi Sankar[3]

Introduction:

The escalating global population, projected to reach 9.7 billion by 2050, necessitates a substantial increase in food production while mitigating the environmental impact of agriculture. Conventional practices, reliant on synthetic fertilizers and high yield cultivars, are under scrutiny due to their adverse effects on environmental health, including deforestation, habitat loss, and pollution. To address these challenges, agronomists are exploring alternative approaches, such as organic and regenerative agriculture, which prioritize soil health and biodiversity conservation. Organic fertilizers, aligned with the principles of sustainable agriculture, offer promising avenues for reducing reliance on synthetic inputs. In this context, insect frass emerges as a valuable organic waste product from insect rearing practices, rich in nutrients and conducive to plant growth. The rapid expansion of insect production for food and feed has led to the emergence of substantial volumes of insect derived materials such as frass and exuviae.

Frass, comprising excreta, feeding substrate remnants, deceased eggs, and insects, is a primary organic byproduct. Consider this: a mere 220 grams of food consumption by yellow mealworms yields approximately 4 grams of insect biomass and a staggering 180 grams of frass. This offers a glimpse into the daily frass output of an insect farming operation. Meanwhile, exuviae, rich in chitin, serve as a valuable resource. Beneficial bacteria can break down chitin to bolster plant growth, development, and fortify against pathogens. Notably, the European Union's recent sanctioning of insects as vital components of pig and poultry diets has spurred a significant rise in insect residual streams. The integration of insect derived materials into soil yields numerous benefits. It fosters a healthy soil microflora, fostering plant growth and resilience. Moreover, it bolsters microbial antagonism against plant pathogens and insects, contributing to overall agricultural sustainability.

Effects of Insect Frass on Plants

Utilizing insect frass as part of organic

Hariharan Selvam[1], Logeshvararaj Balasubramaniam[2], Mangayarkarsi Sankar[3]
[1]PhD Scholar, Division of Entomology, ICAR-IARI Mega University Hyderabad Hub.
[2]Junior Scientist (R&D), Sathyam Kissan Care, Madurai.
[3]Assistant Professor, Sethu Bhaskara Agricultural College and Research Foundation, Karaikudi

soil amendments not only stimulates the growth of indigenous beneficial soil microflora but also enhances Induced Systemic Resistance (ISR) in plants. Furthermore, the presence of frass triggers the release of Host Induced Plant Volatiles (HIPVs), which attract parasitoids and predators, effectively reducing pest infestations. Moreover, incorporating both frass and exuviae into soil augments the population of PGPR (plant growth-promoting rhizobacteria) in the rhizosphere. These bacteria thrive on host root exudates, utilizing them for energy production. In return, they generate essential plant growth hormones such as cytokinins, auxins, and gibberellins, thereby promoting enhanced plant growth and development. Changes in the soil and rhizosphere microbiome induced by insect derived products can have profound effects on plant phenotype, including floral phenology. For instance, addition of chitin and its derivative, chitosan, has been shown to affect flowering phenology, accelerating flower production by as much as 15 days. These effects were associated with increase in chitinolytic microorganisms such as Actinobacteria, Gamma proteobacteria, Bacilli, and Mortierellomycetes.

Nutritional Composition of Frass and Its Role as Organic Matter

Insect frass serves as a rich source of both macro and micronutrients, making it highly suitable for use as fertilizer. For instance, frass from the black soldier fly (*Hermetia illucens*), showed elevated levels of nitrogen, potassium, and sulfur. On the other hand, phosphorus, calcium, and magnesium concentrations were found to be higher in frass obtained from *Gryllus bimaculatus*, *Bombyx mori*, and *Pachnoda sinuate*, respectively. Phosphorus (P) concentrations vary across different insect species, with *Gryllus bimaculatus* and *Bombyx mori* generating frass fertilizer with the highest and lowest P contents, respectively. Additionally, manganese (Mn) concentrations vary across frass fertilizer samples, with *Oryctes rhinoceros* and *Bombyx mori* producing the lowest and highest Mn values, respectively. Iron (Fe) concentrations are significantly higher in *O. rhinoceros* frass fertilizer compared to other insect derived fertilizers.

Beyond its nutrient richness, frass plays a pivotal role as a source of soil organic matter, contributing to the improvement of soil organic carbon content, water holding capacity, and soil porosity. By enhancing these soil properties, frass aids in restoring essential nutrients and making them readily available for plant growth. Frass obtained from mealworm farms undergoes rapid mineralization upon its incorporation into the soil. Within 7 days of incubation, approximately 37% of the total organic carbon

(TOC) is mineralized. Subsequently, a slower but continuous mineralization process occurs, with 56% of TOC mineralized after 91 days. Furthermore, insect frass contains compounds like sugars, alkaloids, and phenols that stimulate seed germination and seedling development.

Processing of Frass Before using as an Organic Fertilizer

The concerns surrounding the effective use of frass as fertilizer primarily revolve around the potential presence of harmful organisms from the digestive tracts of insects, which could be passed on to plants or humans upon application. To address this concern, thorough sanitization and sterilization processes are essential to ensure the safe use of frass in agriculture as an organic fertilizer. By subjecting frass to these processes, any dangerous bacteria present in the organic matter can be eliminated, making it safe for use in organic agriculture.

Advantages of Insect Frass over Chemical Fertilizer

Frass serves as a renewable source of nutrients and contributes to soil health and fertility by promoting loose structured soil and supporting the growth of nitrogen fixing bacteria. Additionally, frass is biodegradable, sustainable, and environmentally friendly. In contrast, chemical fertilizers, while faster acting and initially less expensive, lead to soil acidification, compaction, and the destruction of nitrogen-fixing bacteria. Moreover, repeated applications of chemical fertilizers can result in a toxic buildup of chemicals in the soil and negatively impact microbial ecosystems.

Development of Plant Resistance Through Insect Derivatives

- **Against Biotic Stresses:** Research on how insect derivatives affect plant resistance is limited, but findings suggest that effects vary depending on the plant species, insect species that produced the frass, and the plant organ to which the frass was applied. For instance, caterpillar frass can suppress caterpillar induced defences in maize plants while enhancing defence against pathogens and aphids. Conversely, when rice plants exposed to caterpillar frass, caterpillar induced defences increased while pathogen defences decreased. Chitin, a component of insect frass, is recognized by plants as a microbe-associated molecular pattern (MAMP), triggering various defence responses such as systemic expression of defence related genes, programmed cell death, and release of reactive oxygen species. Moreover, integrating insect exuviae into soil has shown to enhance the colonization of root by *Bacillus* strains, like *B. cereus* and *Bacillus subtilis*. These strains exhibit antagonistic activity against a wide range of plant pathogens and pests. Further, the application of chitin containing amendments has been shown to reduce disease incidence caused by root infecting fungi such as *Verticillium dahliae*, *Fusarium oxysporum*, and *Rhizoctonia solani*. This suppression of pathogens is primarily attributed to an increase in the abundance and activity of chitinolytic microorganisms. These microbes produce chitinases and other cell wall-degrading enzymes that weaken and disrupt the fungal cell wall, thereby impeding pathogen development. Notably, chitinases also influence the development of root herbivores by breaking down chitin within the insect midgut peritrophic membrane, thereby impeding larval feeding and growth. However, the effectiveness of insect frass in activating plant defence responses may vary depending on the crop and the specific pathogens or pests involved. For example, *Hermetia illucens* frass did not reduce disease severity in sugar beetroot.

- **Against Abiotic Stresses**: Insect frass shows promise in boosting plant resilience against a range of abiotic stressors, including salt, drought, and floods. By applying mealworm frass to bean plants, researchers observed increased tolerance to these stressors. This suggests that insect frass could serve as a valuable tool in enhancing plant resilience and promoting sustainable agricultural practices.

Insect Frass as a Carrier Agent to Improve Efficacy

Combined application of chitin containing materials with beneficial microbes has shown synergistic positive effects on plant growth and disease suppression. For example, formulations of *Bacillus subtilis* in combination with chitin containing materials resulted in better control of pathogens like *Aspergillus niger* and *Fusarium udum* in groundnut and pigeon pea plants, respectively. Similarly, *Bacillus thuringiensis*, known to use chitin as a carbon source, can have increased insecticidal activity when applied in combination with chitinase, enhancing its effectiveness against caterpillars.

Application Rate of Insect Frass

It is advisable to incorporate insect frass into the soil or compost before planting, ensuring even distribution of nutrients. For established plants, soaking insect frass in water for several hours and then using it to drench the roots proves effective in delivering essential nutrients directly to the plants. In raised beds, applying approximately a pound of insect frass per 20 square feet of plant space and thoroughly mixing it into the top half foot of soil ensures optimal nutrient distribution. For sustained benefits throughout the growing season, additional top dressing of insect frass every few weeks can further enhance soil fertility. When potting plants, incorporating one cup of insect frass per cubic foot of potting soil provides a nutrient rich growing medium. Regularly sprinkling insect frass on top of the soil every few weeks ensures a continuous supply of nutrients to the plants.

Conclusion

The escalating global population necessitates innovative solutions for sustainable food production, prompting a shift towards environmentally conscious practices like mass insect rearing. Insect frass obtained as a byproduct from insect rearing emerges as a promising organic fertilizer, rich in nutrients and beneficial microorganisms, offering a sustainable alternative to conventional agrochemicals. Despite the promising potential, research on insect frass remains in its nascent stages, with a majority of studies conducted in the past few years. Future investigations should delve into the diverse compounds and microorganisms present in insect frass, exploring their roles in promoting plant growth and resilience against environmental stressors. Moreover, insect frass presents a promising avenue for research into its role in enhancing plant nutrition, activating defence mechanisms, and fostering sustainable agricultural systems.

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