

# IMPACT OF BLACK SOLDIER FLY LARVAL FRASS ON GROWTH AND YIELD OF CLUSTER BEAN (*CYAMOPSIS TETRAGONOLOBA* L.)

## ABSTRACT

*Hermetia illucens* L., commonly known as the Black Soldier Fly (BSF), has garnered global attention for its role in insect farming due to its efficient conversion of organic waste into nutrient-rich larval biomass, with frass as a primary byproduct. This study aimed to explore the potential of BSF larval frass (BSFF) as an organic fertilizer for agricultural production, especially evaluating its performance compared to vermicompost on cluster bean growth and yield under field conditions during *rabi* season at Rajendranagar, Hyderabad. Using a completely randomized block design with eight treatments, we assessed various growth parameters such as plant height, number of branches plant<sup>-1</sup> and dry matter production, along with yield attributes including number of clusters plant<sup>-1</sup>, number of pods cluster<sup>-1</sup>, number of pods plant<sup>-1</sup>, pod weight (g), pod yield plant<sup>-1</sup> and yield (t ha<sup>-1</sup>). Significant differences were observed among treatments, the highest growth and yield parameters were recorded in application of 25 % N through BSF frass + 75 % RDN (T<sub>5</sub>) and it was on par with 25 % N through vermicompost + 75 % RDN (T<sub>6</sub>), 50 % N through BSF frass + 50 % RDN (T<sub>7</sub>), 50 % N through vermicompost + 50 % RDN (T<sub>8</sub>) and RDF (T<sub>2</sub>) compared to 100 % N through BSF frass (T<sub>3</sub>), 100 % N through vermicompost (T<sub>4</sub>) and control (T<sub>1</sub>). These treatments resulted in yield increase of 35.7 % (T<sub>5</sub>), 24.7 % (T<sub>6</sub>), 23.4 % (T<sub>7</sub>), 22 % (T<sub>8</sub>) and 24.36 % (T<sub>2</sub>) respectively, compared to the control. These findings indicated that BSF larval frass holds as a promising sustainable alternative to vermicompost for enhancing cluster bean production, offering potential benefits for agricultural sustainability and organic waste management.

**Keywords:** *Hermetia illucens*, BSF larval frass, Vermicompost, Cluster bean, Organic fertilizer

## 1. INTRODUCTION

The intensification of agriculture has a negative impact on the environment and combined with a growing world population, it poses an enormous challenge to the global society of the twenty-first century. Food demand is constantly increasing with population growth and sustainable approaches are required to address the resulting challenges in agricultural production [1]. Organic fertilizer application is one of the most promising pathways for long-term improvement of soil and crop productivity [2]. These organic fertilizers are good source of nitrogen, one of the most limited soil nutrients for crop production. Despite many advantages they provide, the application of organic fertilizers in agriculture is still limited due to their scarcity. Most of the crop residues generated after harvesting of the crop are used to feed the livestock, leaving little or no organic resources to be used as manure for agricultural production [3,4]. Organic fertilizers at present are not widely used in intensive arable agriculture. High input agricultural systems that only provide major nutrients to the crop may lack secondary nutrients (Ca, Mg and S) and micronutrients (Fe, Cu, Mn and Zn), which was leading to reduced yield and nutritional quality of harvested products [5].

Organic fertilizers are typically required in large quantities, making it difficult for farmers to incorporate into soil. As a result, improving soil productivity with organic resources needs a new venture into organic fertilizer sources. In recent years, *Hermetia illucens* L., commonly referred as black soldier fly (BSF), had been shown to be a reliable recycler of organic waste products into nutrient rich organic fertilizer for crop cultivation and soil health management. As a result of their high efficiency of waste degradation (65 - 78 %) [6,7], BSF larvae are capable of reducing compost maturity time to 5 weeks, as compared to conventional composting methods which generally takes 8 - 24 weeks [8,9]. The primary by product of waste bioconversion into high-quality protein for insect feed is known as 'frass'. In general, frass refers to insect excretions, but in commercial context, it is described as a mixture of insect faeces, substrate residues and shed exoskeletons. The composition of BSF frass varies according to the composition of the substrates. Frass contains high levels of NPK, organic matter and chitin (from larvae skins). Frass has numerous applications, such as direct or as composted fertilizer and soil conditioner. To know the frass effect on the pulse crop, the present study was carried on cluster bean crop. Cluster bean (*Cyamopsis tetragonoloba* L.) belongs to the family Leguminaceae. It is a versatile and multipurpose legume crop of arid and semiarid regions cultivated for vegetables, feed, fodder and nitrogen fixation purposes. The endosperm of cluster bean contains protein ranging from 18-25 % [10], fiber (13-16 %) [11] and about 30-33 % gum or galactomannan [12]. Gum is used in a wide range of industries, including textiles, paper, petroleum, pharmaceuticals, food processing, cosmetics, mining, explosives and oil drilling [13,14].

## 2. MATERIAL AND METHODS

### 2.1 Experimental Site Characteristics

Field experiment was carried out at the Horticulture Garden, College of Agriculture, Rajendranagar, Hyderabad, Rangareddy district, Telangana state. Its geographical coordinates were 17°19'26" North latitude and 78°24'32" East longitude. Before the experiment initiation, a soil sample was collected from a depth of 0-15 cm and analysed for physical properties such as soil texture and bulk density, physico-chemical properties such as pH, electrical conductivity and organic carbon. To determine the soil fertility status, the sample was analysed for available nitrogen, available phosphorus, available potassium depicted in (Table 1).

**Table1. Properties of the soil during experimental site**

Soil parameters	Contents	Method
Sand (%)	63.4	Bouyoucos hydrometer method [15]
Silt (%)	16.0	
Clay (%)	20.6	
Soil texture	Sandy loam	
Bulk density (Mg m <sup>-3</sup> )	1.44	Core sampler method [16]
pH (1:2.5 soil: water)	7.6	"Eutech" digital pH meter [17]
Electrical conductivity (dS m <sup>-1</sup> ) (1:2.5 soil: water)	0.38	"Eutech" digital conductivity meter [17]
Organic Carbon (g kg <sup>-1</sup> )	5.2	Chromic acid wet digestion method [18]
Available Nitrogen (kg ha <sup>-1</sup> )	132.13	Alkaline permanganate method [19]
Available P <sub>2</sub> O <sub>5</sub> (kg ha <sup>-1</sup> )	70.8	0.5M NaHCO <sub>3</sub> (pH 8.5) method [20]
Available K <sub>2</sub> O (kg ha <sup>-1</sup> )	236.8	Neutral normal ammonium acetate method followed by using flame photometer [17]

## 2.2 Source of Fertilizers

The experiment involved three fertilizers: BSF larval frass, vermicompost and mineral fertilizer (N: P<sub>2</sub>O<sub>5</sub>: K<sub>2</sub>O 30-63-63 kg ha<sup>-1</sup>). The vermicompost and NPK were collected from college farm, Rajendranagar, Hyderabad. The BSF larval frass was generated from the feeding of BSF larvae on chicken waste. The BSF larvae were reared following procedures described by [9]. Table 2 presented the characteristics of BSF larval frass and vermicompost used in experiments.

## 2.3 Treatments and Experimental Setup

The BSF larval frass, vermicompost and NPK fertilizer were applied at uniform rates equivalent to 30 kg N ha<sup>-1</sup> in treatments. For cluster bean crops to receive 100 % nitrogen, 1.126 t ha<sup>-1</sup> BSF frass was required. Similarly, 50 % nitrogen was obtained by BSF frass equivalent to 0.563 t ha<sup>-1</sup> and 25 % nitrogen was obtained by adding 0.282 t ha<sup>-1</sup>. For 100 % nitrogen, 3.704 t ha<sup>-1</sup> vermicompost was required. Likewise, for 50 % nitrogen through 1.852 t ha<sup>-1</sup> of vermicompost and 25 % nitrogen through 0.926 t ha<sup>-1</sup> of vermicompost. 65.2 kg urea required for 100 % nitrogen correspondingly. P and K fertilizers were applied based on recommended dose.

The experiment was laid out in a randomized complete block design (RCBD) with three replicates and 8 treatments viz., T<sub>1</sub> – Control, T<sub>2</sub> – RDF, T<sub>3</sub> - 100 % N through BSF frass, T<sub>4</sub>- 100 % N through vermicompost, T<sub>5</sub>- 25 % N through BSF frass + 75 % RDN, T<sub>6</sub> - 25 % N through vermicompost + 75 % RDN, T<sub>7</sub> - 50 % N through BSF frass + 50 % RDN and T<sub>8</sub> - 50 % N through vermicompost + 50 % RDN. The cluster bean seeds (variety: Samrat) were sown at a spacing of 45 cm × 15 cm. After 15 days of germination, thinning was done to maintain one plant. The experiment was carried out in plot size of 4.5 m x 3m. The BSF larval frass and vermicompost were applied 15 days before sowing, whereas the mineral fertilizer (NPK) was applied as basal. During experiments, weeds were controlled manual by pulling, whereas check basin irrigation system was used for crop water requirements.

**Table 2: Characteristics of BSF larval frass (60 days old) and vermicompost used in experiment.**

Parameters	BSF frass	Vermicompost	Method
pH (1:10)	7.55	7.62	“Eutech” digital pH meter. [17]
EC (1:10) d Sm <sup>-1</sup>	7.8	1.21	“Eutech” digital conductivity meter. [17]
C <sub>total</sub> (%)	23.14	28	Dry combustion method. [21]
N <sub>total</sub> (%)	2.64	0.9	Micro kjeldhal distillation. [22]
C:N ratio	8.7:1	31:1	-
P <sub>total</sub> (%)	0.33	0.2	Vanadomolybdate - phosphoric acid method [22]
K <sub>total</sub> (%)	1.95	0.84	Diacid extraction method followed by flame photometer. [22]
Ca (%)	0.20	0.92	
Mg (%)	0.58	0.43	
S (%)	0.59	0.16	
Cu (mg kg <sup>-1</sup> )	27	54	Diacid extraction method followed by ICP-OES. [22]
Fe (mg kg <sup>-1</sup> )	990	120	
Mn (mg kg <sup>-1</sup> )	74	96	
Zn (mg kg <sup>-1</sup> )	120	78	

## 2.4 GROWTH AND YIELD

Five cluster bean plants were randomly selected and tagged from each treatment replicate for the determination of growth parameters. Plant height and number of branches plant<sup>-1</sup> was determined by collecting data on 30, 60 DAS and at harvest stage. The plant height was measured from ground level to tip of the upper leaf. Number of branches plant<sup>-1</sup> were determined by hand counting. Five plants from the second row of the border were selected to assess dry matter accumulation at harvest. The weight of oven-dried samples was measured after drying at 65°C and reported in tonnes per hectare, while yield attributes viz., number of clusters plant<sup>-1</sup>, number of pods cluster<sup>-1</sup>, number of pods plant<sup>-1</sup>, pod weight, pod yield plant<sup>-1</sup> were counted on the randomly tagged plants. The total yield plot<sup>-1</sup> was calculated by summing the yields obtained from four pickings and expressed on hectare basis (t ha<sup>-1</sup>).

## 2.5 Data analysis

The experiment data was analysed to know the significance of variation in experimental data obtained for various treatment effects. Data were statistically analysed as described by [24]. The critical difference was calculated to assess the significance of treatment mean wherever, the 'F' test was significant at 5 percent level.

## 3. RESULTS

### 3.1 Growth Parameters

The results revealed (Table 3) that BSF larval frass and vermicompost in combination with NPK fertilizers significantly influenced the different growth characters of cluster bean. Application of 25 % N through BSF frass + 75 % RDN (T<sub>5</sub>) being at par with treatments T<sub>6</sub> (25 % N through vermicompost + 75 % RDN), T<sub>7</sub> (50 % N through BSF frass + 50 % RDN), T<sub>8</sub> (50 % N through vermicompost + 50 % RDN) and T<sub>2</sub> (RDF) recorded significantly highest plant height at 30 DAS (38.8 cm), 60 DAS (87.9 cm) and at harvest (111.9 cm) and number of branches plant<sup>-1</sup> at 30 DAS (4.33), at 60 DAS (16.48) and at harvest (18.57) and higher dry matter accumulation in stover (3.51 t ha<sup>-1</sup>) and pod (1.59 t ha<sup>-1</sup>) at harvest over rest of the treatments. The significantly lowest plant height at 30DAS (23.9 cm), 60DAS (60.5 cm) and at harvest (76.0 cm), number of branches plant<sup>-1</sup> 30DAS (2.53), 60DAS (8.92) and at harvest (10.04) and total dry matter accumulation in stover (2.1 t ha<sup>-1</sup>) and pod (0.95 t ha<sup>-1</sup>) were recorded in control.

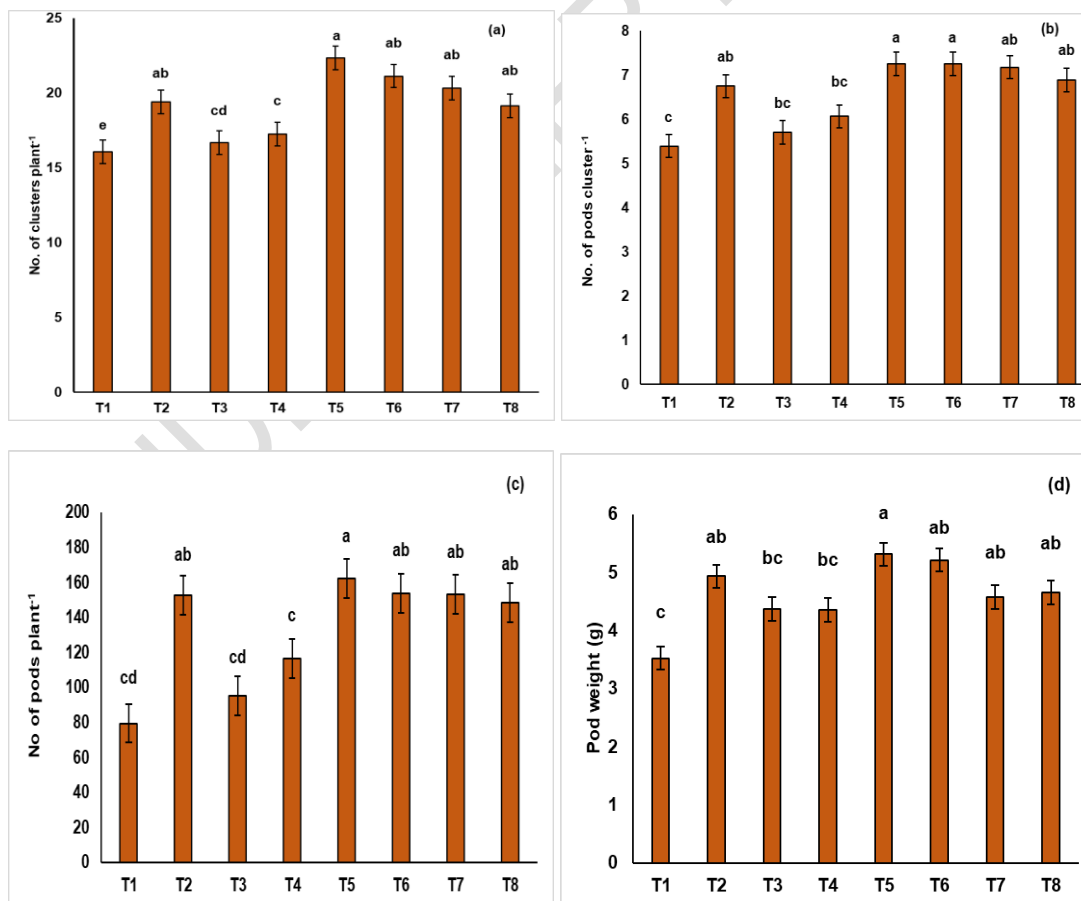
**Table 3. Effect of black soldier fly larval frass and vermicompost in combination with NPK fertilizers on growth parameters.**

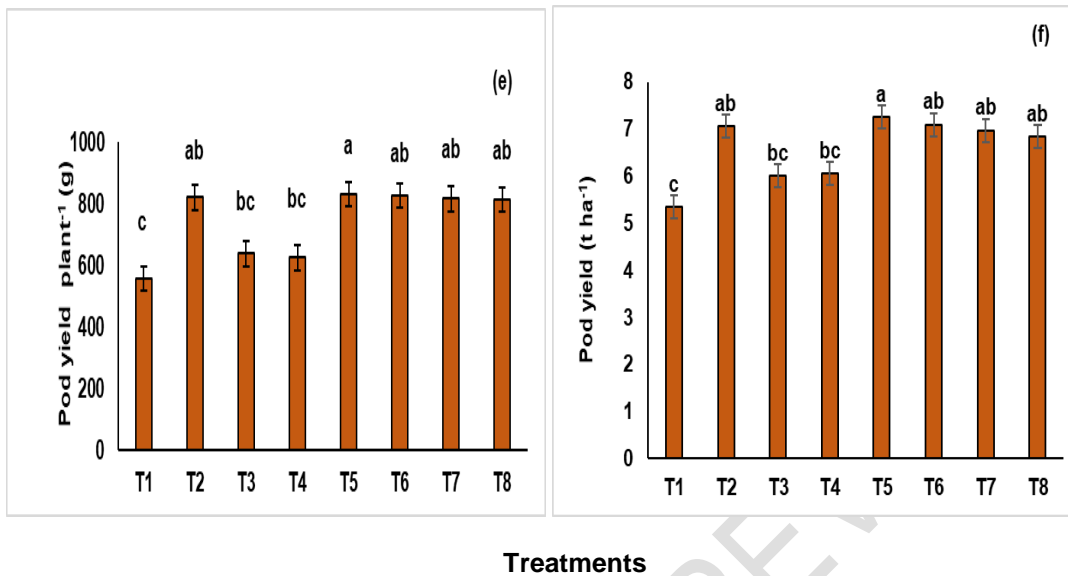
Treatments	Plant height (cm)			Branches plant <sup>-1</sup>			Total dry matter (t ha <sup>-1</sup> ) at harvest	
	30DAS	60DAS	Harvest	30 DAS	60DAS	Harvest	stover	Pod
T <sub>1</sub>	23.9	60.5	76.0	2.53	8.92	10.04	2.10	0.95
T <sub>2</sub>	32.0	80.8	96.9	3.87	14.75	17.70	3.24	1.54
T <sub>3</sub>	26.2	73.4	86.8	3.27	11.17	13.40	2.80	1.31
T <sub>4</sub>	28.3	73.4	90.7	3.28	12.59	15.11	2.81	1.34
T <sub>5</sub>	38.8	87.9	111.9	4.33	16.48	18.57	3.51	1.59

T <sub>6</sub>	37.9	85.7	100.4	4.25	15.10	18.38	3.45	1.55
T <sub>7</sub>	32.7	82.9	103.0	3.77	13.93	17.65	3.13	1.52
T <sub>8</sub>	34.3	77.2	98.4	3.76	13.86	17.70	3.15	1.50
S.E m±	2.87	4.58	6.26	0.24	0.96	1.01	0.23	0.08
CD (5 %)	8.70	13.91	18.98	0.72	2.91	3.06	0.69	0.25

### 3.2 Yield attributes and yield:

Based on data presented in Figure 1. reported that application of 25 % N through BSF frass+ 75 % RDN (T<sub>5</sub>), 25 % N through vermicompost + 75 % RDN (T<sub>6</sub>), 50 % N through BSF frass + 50 % RDN (T<sub>7</sub>), 50 % N through vermicompost + 50 % RDN (T<sub>8</sub>) and RDF (T<sub>2</sub>) treatments were on par with each other with respect to yield attributes viz., number of clusters plant<sup>-1</sup>, number of pods cluster<sup>-1</sup>, number of pods plant<sup>-1</sup> and pod weight (g). Number of clusters per plant (22.34, 21.14, 20.34, 19.14 and 19.39), Number of pods per cluster (7.25, 7.25, 7.17, 6.88 and 6.74), Number of pods per plant (162.2, 153.4, 152.9, 148.2 and 152.3) and pod weight in grams (5.31, 5.21, 4.57, 4.65 and 4.93). While the lowest was found in control (14.07, 5.39, 79.3 and 3.52). The results pertained to pod yield per plant in grams reported that significant difference among various treatments, application of 25 % N through BSF frass + 75 % RDN (831.2), 25 % N through vermicompost + 75 % RDN (825.5), 50 % N through vermicompost + 50 % RDN (813.5), 50 % N through vermicompost + 50 % RDN (816.4) and RDF (556.9). The similar trend was reported for pod yield per hectare for T<sub>5</sub> (7.25 t ha<sup>-1</sup>), T<sub>6</sub> (7.09 t ha<sup>-1</sup>), T<sub>7</sub> (6.97 t ha<sup>-1</sup>), T<sub>8</sub> (6.84 t ha<sup>-1</sup>) and T<sub>2</sub> (7.06 t ha<sup>-1</sup>) which were on par with each other. Whereas, lowest was observed in control (5.34 t ha<sup>-1</sup>).





**Figure 1.** Effect of black soldier fly larval frass and vermicompost in combination with NPK fertilizers on yield attributes a) number of clusters plant<sup>-1</sup> b) number of pods cluster<sup>-1</sup>c) number of pods plant<sup>-1</sup> d) pod weight (g) e) pod yield plant<sup>-1</sup> f) pod yield t ha<sup>-1</sup>. Control (T<sub>1</sub>), RDF(T<sub>2</sub>), 100 % N through BSF frass (T<sub>3</sub>), 100 % N through vermicompost (T<sub>4</sub>), 25 % N through BSF frass + 75 % RDN (T<sub>5</sub>), 25 % N through vermicompost + 75 % RDN (T<sub>6</sub>), 50 % N through BSF frass + 50 % RDN (T<sub>7</sub>) and 50 % N through vermicompost + 50 % RDN (T<sub>8</sub>). Means followed by the same letters are not significantly different at P≤0.05.

#### 4. DISCUSSION

The findings indicated that the combination of BSF larval frass and vermicompost with NPK fertilizers significantly enhanced plant growth compared to both the control and the application of 100 % nitrogen solely through BSF larval frass and vermicompost. This suggests that these organic amendments effectively supported plant growth. Vermicompost and BSF larval frass likely beneficial to the soil by increasing organic matter, thereby improving soil physical properties such as water retention and fostering a diverse population of beneficial microbes. Additionally, the composted organic material provided the essential nutrients, particularly nitrogen and potassium, crucial for plant development, as detailed in Table 2. The solid organic manure derived from BSF larval frass potentially to meet the nitrogen requirements, which are often deficient in Indian soils [24]. Data in Table 3 demonstrated that plant height, number of branches plant<sup>-1</sup> and dry matter production were relatively higher when manure was integrated with NPK fertilizer compared to using manure alone or the control. However, the treatment 25 % nitrogen from BSF larval frass with 75 % recommended dose of nitrogen (RDN) showed the highest and most favorable plant growth performance.

The higher growth rate was observed in cluster bean crop by application of BSF larval frass. It might be due to its high maturity and stability as indicated by parameter, such as the lower C/N ratio (8.6) reported in (Table 2). This suggests that the enhanced vegetative growth, dry matter production and yield while using BSF larval frass, vermicompost and mineral fertilizers could be due to improved nutrient supply and availability. Moreover, the rapid mineralization rate of BSF larval frass likely contributed to a more synchronized nutrient

release, supporting both vegetative growth and yield, in accordance with findings of [25]. Additionally, the presence of chitin in BSF frass fertilizer had been reported to enhance plant health by boosting crop disease resistance [26].

The yield attributes and overall yield associated with the application of BSF larval frass, vermicompost and NPK fertilizer (refer to Fig. 1) might be resulted from the integrated use of organic manures along with inorganic fertilizer, facilitating greater translocation of photosynthates from source to sink and thereby increasing yield, consistent with the findings of [27]. These findings are pivotal in shifting perceptions towards organic fertilizer usage, given their advantages of being less bulkiness and high in nutrients. Consequently, relying on costly mineral nitrogen fertilizers could potentially be reduced by adopting high-quality organic fertilizers like BSF larval frass.

## **5. Conclusion:**

The study findings indicate that nitrogen released from both BSF larval frass fertilizer (BSFFF) and vermicompost was slow during the early stages of crop growth, resulting in inadequate nitrogen availability during periods of peak demand. This necessitates supplementation with inorganic nitrogen to compensate for nitrogen immobilization observed in the early growth stages. The significant pod yields associated with BSFFF highlight its potential to enhance crop productivity. Based on our research, applying 0.28 t ha<sup>-1</sup> of BSF larval frass along with 49 kg of urea can maximize yields by ensuring sufficient nutrient supply in cluster bean production. For an environmentally safe and sustainable approach to increase cluster bean yields, applying 0.56 t ha<sup>-1</sup> integrated with 32.6 kg of urea is recommended. Over the long term, we expect that sustainable use of BSF larval frass fertilizer will reduce dependence on expensive mineral fertilizers that can adversely affect soil and environmental health. Future studies should explore the effects of BSF larval frass fertilizer on soil physical properties, water retention capacity and soil microbiome across diverse agro-ecological zones and cropping systems.

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