IMPACT OF BLACK SOLDIER FLY LARVAL FRASS ON GROWTH AND YIELD OF CLUSTER BEAN (*Cyamopsis tetragonoloba* L.)

Original research article

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, various growth parameters such as plant height, number of branches plant^{-1} and dry matter production, along with yield attributes including number of clusters plant^{-1}, number of pods cluster^{-1}, number of pods plant^{-1}, pod weight (g), pod yield plant^{-1} and yield (t ha^{-1}) were assessed. 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_5) and it was on par with 25 % N through vermicompost + 75 % RDN (T_6), 50 % N through BSF frass + 50 % RDN (T_7), 50 % N through vermicompost + 50 % RDN (T_8) and RDF (T_2) compared to 100 % N through BSF frass (T_3), 100 % N through vermicompost (T_4) and control (T_1).These treatments resulted in yield increase of 35.7 % (T_5), 24.7 % (T_6), 23.4 % (T_7), 22 %(T_8) and 24.36 % (T_2) respectively, compared to the control. These findings indicated that BSF larval frass holds promise as a 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, Sustainable nutrient management

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 leads 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. Hence there is a need to explore new alternative sources that could be part of an integrated nutrient management plan. 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. The present study was carried out on cluster bean crop to understand the effect of frass on the pulse crop. Cluster bean (*Cyamopsis tetragonoloba* L.) belongs to the family Leguminaceae.Which is a versatile and multipurpose legume crop of arid and semiarid regions cultivated for food, 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

The field experiment was carried out at the Horticulture Garden, College of Agriculture, Rajendranagar, Hyderabad, Rangareddy district, Telangana state located at 17°19'26'' North latitude and 78°24'32'' East longitude. The soil at the experimental site, before imposition of treatments 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, pre-treatment imposition at the 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^{-3})	1.44	Core sampler method [16]
pH (1:2.5 soil: water)	7.6	"Eutech" digital pH meter [17]
Electrical conductivity (dS m^{-1}) (1:2.5 soil: water)	0.38	"Eutech" digital conductivity meter [17]
Organic Carbon (g kg^{-1})	5.2	Chromic acid wet digestion method [18]
Available Nitrogen (kg ha^{-1})	132.13	Alkaline permanganate method [19]
Available P_2O_5 (kg ha^{-1})	70.8	0.5M $NaHCO_3$ (pH 8.5) method [20]
Available K_2O (kg ha^{-1})	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_2O_5: K_2O 30-63-63 kg ha^{-1}). The vermicompost and NPK fertilizers were collected from college farm, Rajendranagar, Hyderabad. The BSF larval frass was generated from the feeding of BSF larvae on chicken feed at the ICAR NAHEP BSF Unit, college farm. The BSF larvae were reared following procedures described by [9]. Table 2 presents the characteristics of BSF larval frass and vermicompost used in the 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^{-1} in treatments. For cluster bean crop to receive 100 % nitrogen, 1.126 t ha^{-1} BSF frass was required. Similarly, 50 % nitrogen was obtained by BSF frass equivalent to 0.563 t ha^{-1} and 25 % nitrogen was obtained by adding 0.282 t ha^{-1}. For 100 % nitrogen, 3.704 t ha^{-1} vermicompost was required. Likewise, for 50 % nitrogen through 1.852 t ha^{-1} of vermicompost and 25 % nitrogen through 0.926 t ha^{-1} 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_1 – Control, T_2 – RDF, T_3 - 100 % N through BSF frass, T_4- 100 % N through vermicompost, T_5- 25 % N through BSF frass + 75 % RDN, T_6 - 25 % N through vermicompost + 75 % RDN, T_7 - 50 % N through BSF frass + 50 % RDN and T_8 - 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 dose. Manual weed control was practiced while water requirements were facilitated through check basin irrigation system.

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^{-1}	7.8	1.21	"Eutech" digital conductivity meter. [17]
C_{total} (%)	23.14	28	Dry combustion method. [21]
N_{total} (%)	2.64	0.9	Micro kjheldhal distillation. [22]
C:N ratio	8.7:1	31:1	-
P_{total} (%)	0.33	0.2	Vanadomolybdate - phosphoric acid method [22]
K_{total} (%)	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^{-1})	27	54	Diacid extraction method followed by ICP-OES. [22]
Fe (mg kg^{-1})	990	120	
Mn (mg kg^{-1})	74	96	

Zn (mg kg^{-1})	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 $plant^{-1}$ 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 $plant^{-1}$ 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 $plant^{-1}$, number of pods $cluster^{-1}$, number of pods $plant^{-1}$, pod weight, pod yield $plant^{-1}$ were counted on the randomly tagged plants. The total yield $plot^{-1}$ was calculated by summing the yields obtained from four pickings and expressed as t ha^{-1}.

2.5 Data analysis

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_5) being at par with treatments T_6 (25 % N through vermicompost + 75 % RDN), T_7 (50 % N through BSF frass + 50 % RDN), T_8 (50 % N through vermicompost + 50 % RDN) and T_2 (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 $plant^{-1}$ 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^{-1}) and pod (1.59 t ha^{-1}) 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 $plant^{-1}$ 30DAS (2.53), 60DAS (8.92) and at harvest (10.04) and total dry matter accumulation in stover (2.1 t ha^{-1}) and pod (0.95 t ha^{-1}) were recorded in control.

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

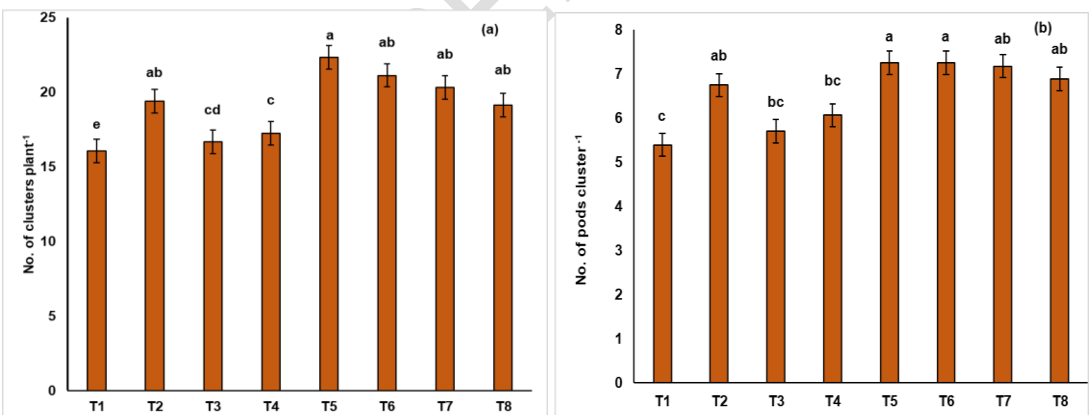
Treatments	Plant height (cm)			Branches $plant^{-1}$			Total dry matter (t ha^{-1}) at harvest	
	30DAS	60DAS	Harvest	30 DAS	60DAS	Harvest	stover	Pod
T_1	23.9	60.5	76.0	2.53	8.92	10.04	2.10	0.95
T_2	32.0	80.8	96.9	3.87	14.75	17.70	3.24	1.54
T_3	26.2	73.4	86.8	3.27	11.17	13.40	2.80	1.31
T_4	28.3	73.4	90.7	3.28	12.59	15.11	2.81	1.34
T_5	38.8	87.9	111.9	4.33	16.48	18.57	3.51	1.59
T_6	37.9	85.7	100.4	4.25	15.10	18.38	3.45	1.55
T_7	32.7	82.9	103.0	3.77	13.93	17.65	3.13	1.52

T_8	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

**RDF (Recommended dose of fertilizer), RDN (Recommended dose of nitrogen) Table 3. Treatment details: Control (T_1), RDF(T_2),100 % N through BSF frass (T_3), 100 % N through vermicompost (T_4), 25 % N through BSF frass + 75 % RDN (T_5),25 % N through vermicompost + 75 % RDN (T_6), 50 % N through BSF frass + 50 % RDN (T_7) and 50 % N through vermicompost + 50 % RDN (T_8). Means followed by the same letters are not significantly different at $P \leq 0.05$.*

3.2 Yield attributes and yield

Application of 25 % N through BSF frass+ 75 % RDN (T_5), 25 % N through vermicompost + 75 % RDN (T_6), 50 % N through BSF frass + 50 % RDN (T_7), 50 % N through vermicompost + 50 % RDN (T_8) and RDF (T_2) treatments were on par with each other with respect to yield attributes *viz.*, number of clusters plant^{-1}, number of pods cluster^{-1}, number of pods plant^{-1} 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) as shown in Fig.1. While the lowest was found in control (14.07, 5.39, 79.3 and 3.52). The results pertained to pod yield per plant (g) revealed significant differences among various treatments, wherein 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_5 (7.25 t ha^{-1}), T_6 (7.09 t ha^{-1}), T_7 (6.97 t ha^{-1}), T_8 (6.84 t ha^{-1}) and T_2 (7.06 t ha^{-1}) which were on par with each other. Whereas, lowest was observed in control (5.34 t ha^{-1}).



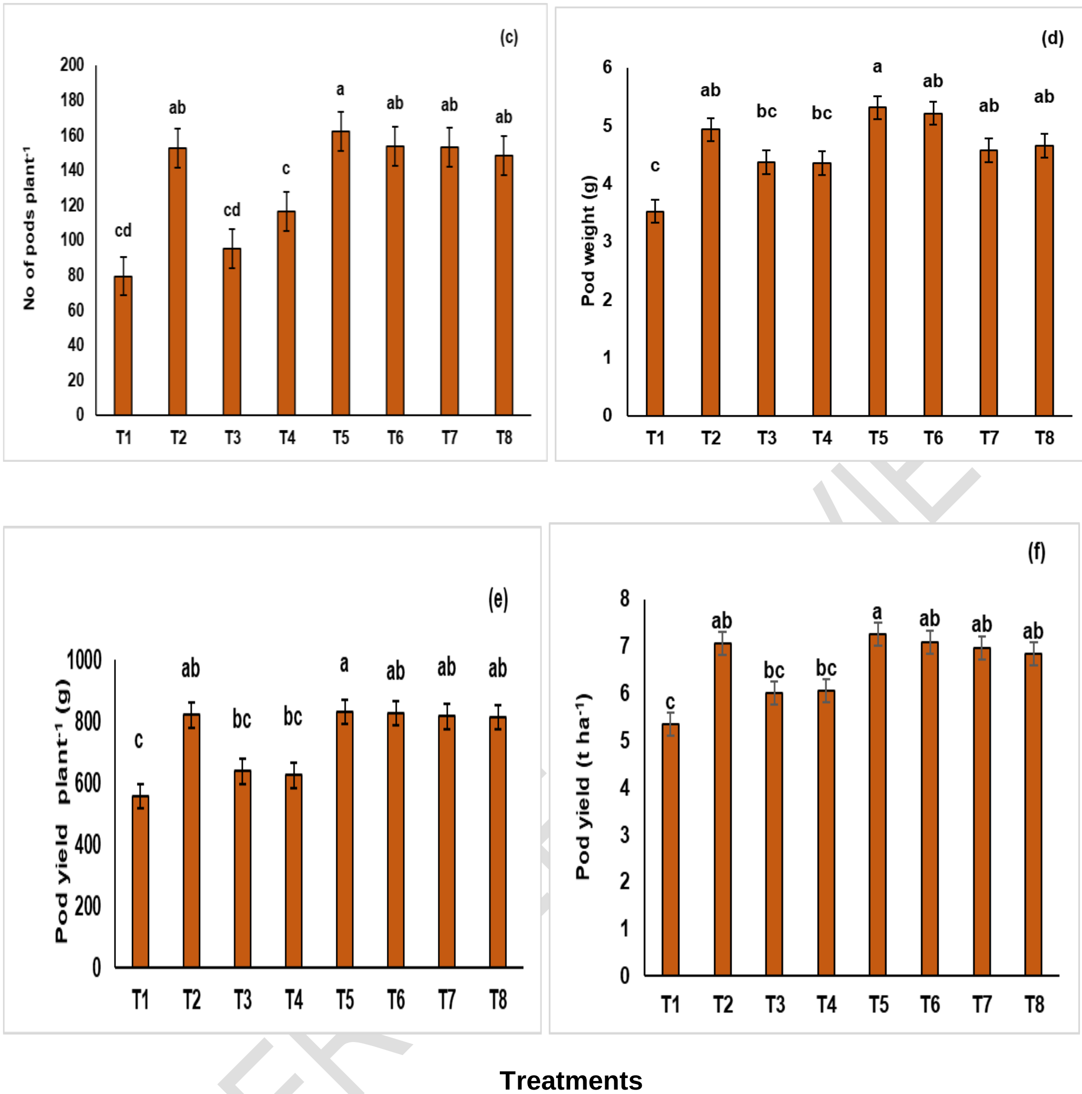


Figure 1. Effect of black soldier fly larval frass and vermicompost in combination with NPK fertilizers on yield attributes a) number of clusters plant^{-1} b) number of pods cluster^{-1}c) number of pods plant^{-1} d) pod weight (g) e) pod yield plant^{-1} f) pod yield t ha^{-1}. Control (T_1), RDF(T_2),100 % N through BSF frass (T_3), 100 % N through vermicompost (T_4), 25 % N through BSF frass + 75 % RDN (T_5), 25 % N through vermicompost + 75 % RDN (T_6), 50 % N through BSF frass + 50 % RDN (T_7) and 50 % N through vermicompost + 50 % RDN (T_8). Means followed by the same letters are not significantly different at P≤0.05.

3.3 Economics of cluster bean

Table 4. presents the total cultivation costs, gross returns, net returns and B: C ratio. The net returns from T_5 - 25 % N through BSF frass + 75 % RDN were the highest (84778.4 ₹ ha^{-1}). Similar patterns were noted for T_6 - 25 % N through vermicompost + 75 % RDN (75140.5 ₹ ha^{-1}), T_7 - 50 % N through BSF frass + 50 % RDN (74891.25 ₹ ha^{-1}), T_8 - 50 % N through vermicompost + 50 % RDN (60746.17 ₹ ha^{-1}) and T_2 - RDF (84655.33 ₹ ha^{-1}). Whereas, lowest (32472.67 ₹ ha^{-1}) was reported in T_4 (100% N through vermicompost). While, highest B: C ratio was recorded in T_2 - RDF (1.92). Lowest B: C ratio (1.27) was recorded in T_4 (100% N through vermicompost).

Table 4. Effect of black soldier fly larval frass and vermicompost in combination with NPK fertilizers on economics of cluster bean.

Treatments	Cost of cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	B:C ratio
T_1	84925	133532.5	48607.5	1.57
T_2	91795	176450.3	84655.33	1.92
T_3	98220	150098.7	51878.67	1.53
T_4	120441	151813.7	32472.67	1.27
T_5	96577	181355.4	84778.42	1.88
T_6	102132	177272.5	75140.5	1.74
T_7	99268	174159.3	74891.25	1.75
T_8	110378	171124.2	60746.17	1.55
SEm ±	-	9712.07	9712.07	-
CD (P=0.05)	-	29458	29458	-

**RDF (Recommended dose of fertilizer), RDN (Recommended dose of nitrogen) Table 3. Treatment details: Control (T_1), RDF(T_2),100 % N through BSF frass (T_3), 100 % N through vermicompost (T_4), 25 % N through BSF frass + 75 % RDN (T_5),25 % N through vermicompost + 75 % RDN (T_6), 50 % N through BSF frass + 50 % RDN (T_7) and 50 % N through vermicompost + 50 % RDN (T_8). 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 in conjunction with mineral fertilizers. Vermicompost and BSF larval frass may have improved 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 could have potentially to met the nitrogen requirements, which are often deficient in Indian soils [24]. Data in Table 3 demonstrated that plant height, number of branches plant^{-1} 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 enhanced yield attributes and overall yield associated with the application of BSF larval frass, vermicompost and NPK fertilizer (refer to Fig. 1) might be attributed to 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 bulky and high in nutrients. Consequently, relying on costly mineral nitrogen fertilizers could potentially be reduced by addition of high-quality organic fertilizers like BSF larval frass which in the long term may result in sustainable soil health management.

The Table 4. indicated that application of T_5 - 25% N through BSF frass+ 75% RDN optimizes net returns without compromising yield or soil health, potentially reducing inorganic nitrogen fertilizer usage. For an environmentally sustainable approach, a combination of T_7 - 50 % N through BSF frass + 50% RDN was recommended. B: C ratio was highest in T_2 - RDF due to less cost of cultivation. Conversely, applying organic manure results in lower nutrient concentrations per unit, necessitating larger quantities for desired effects, thereby increasing overall cultivation cost. Similar conclusions were drawn by previous studies conducted by [28]

5.CONCLUSION

The study findings indicate that nitrogen released from both BSF larval frass fertilizer (BSFF) 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 the current research, applying 0.28 t ha^{-1} 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^{-1} 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.

Disclaimer (Artificial intelligence)

Option 1:
Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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