EFFECT OF BLACK SOLDIER FLY LARVAL FRASS ON GROWTH AND YIELD OF RADISH (*Raphanus sativus* L.)

.

ABSTRACT

The utilization of Black Soldier Fly (BSF) larval frass as an organic manure is gaining more attention in sustainable agriculture because of it's potential to improve soil fertility and promote circular economy. Frass, the excrement of BSF larvae, is rich in nutrients and is a derivative from the larvae's processing of organic waste materials. The present study was carried out at the Horticulture garden, College of Agriculture, Rajendranagar, Telangana, India, during the *rabi* season of 2023-24 to examine the impact of frass when compared to vermicompost in combination with inorganic fertilizers and their combination on the growth and yield parameters of radish. The experimental design employed was the Randomized Block Design with eight treatments and three replications. Among the growth parameters plant height (cm), number of leaves and dry matter production (g m^{-2}) showed the highest values in the treatment 75% RDN + 25% N through black soldier fly larval frass at 20, 40 DAS and at harvest, which were comparable with 75% RDN + 25% N through vermicompost and Recommended dose of fertilizers. The lowest values were observed in untreated control. Similar trend was recorded in root length (19.95 cm), root diameter (2.96 cm), root girth (10.48 cm), fresh root weight (91.33 g $plant^{-1}$) and yield (60.27 t ha^{-1}) among the above treatments. The root length (11.74 cm), root diameter (1.45 cm), root girth (5.14 cm), fresh root weight (29.65 g $plant^{-1}$) and yield (19.77 t ha^{-1}) were notably lower in untreated control. Hence the BSF frass may be considered a suitable component in INM for production of radish.

Keywords: Black soldier fly larval frass, organic manure, vermicompost, radish, growth, yield.

1. INTRODUCTION

Two major challenges that controls us today are the need for increased food production to meet the demand of increasing global population and ways to recycle huge amount of wastage generated from the agriculture and food sectors, if unattended threatens the human health and environmental quality. Since the early twentieth century, excessive fertilizer use has resulted in deterioration in soil quality, reducing organic matter, loss of beneficial soil microorganisms and negatively impacting plant growth and human health [1]. To mitigate these adverse effects, ecological management strategies, like organic manures, are recommended to boost agricultural productivity without harming the environment [2]. However, a major challenge to the use of organic manures is the scarcity of organic matter sources due to competing uses such as animal feed (crop residues) and fuel [3]. In this situation there is a need to explore other alternative organic sources. A promising solution is the use of black soldier fly (BSF) larval frass. BSF (*Hermetia illucens*) belongs to the family Stratiomyidae and includes 76 species worldwide. These larvae can feed on various decaying materials, including plant, animal matter, food and municipal waste [4], allowing them to thrive in diverse environments. *Hermetia illucens* larvae can be used in organic manure production, waste disinfection and as animal feed [5]. Under optimal conditions, they can reduce over 50 % of organic waste within two weeks [6]. BSF larvae has high waste degradation efficiency (66-79%) [7] and pathogen reduction capability [8] making them effective organic waste recyclers. This insect-based method transforms biodegradable waste into two products: a protein and lipid rich larval biomass suitable for animal feed [9,10] and a residue called frass, which can be used as manure [11]. Previous studies had demonstrated the potential of BSF frass for improving the crop health, yield and on the fertility of the soil [12,13]. In order to investigate the effect of BSF frass on root crops a study was conducted to understand the effect of frass on growth and yield of radish (*Raphanus sativus* L.). It is a widely grown root vegetable in tropical, subtropical and temperate climates [14]. Radish, belonging to the Cruciferae family, with 2n = 18 chromosomes, is a herbaceous plant with a fusiform stem. Radish is gaining popularity across all socioeconomic groups. It is grown and consumed globally and is rich in carbohydrates, proteins, vitamin A, vitamin C, folic acid, potassium, riboflavin, magnesium, iron and calcium [15]. It also contains antioxidants such as catechin, pyrogallol, vanillic acid and other phenolic compounds.

2. MATERIAL AND METHODS

2.1 Experimental Site

The field experiment was conducted at the Horticulture Garden, College of Agriculture, Professor Jayashankar Telangana State Agricultural University (PJTSAU), Rajendranagar, Telangana, during the rabi season of 2023-24. The experimental site is located at 17° 19’ 26’’ N latitude, 78° 24’ 32’’ E longitude, with an altitude of 800 meters above mean sea level (MSL). Before the experiment, an initial soil sample was randomly collected from various spots in the field at a depth of 0-15 cm. The soil was thoroughly mixed and a 500 g sample was obtained using the quartering technique. This sample was then shade-dried, pounded and passed through a 2 mm sieve. The soil at the study site is sandy in texture. The soil pH was neutral (7.23) and the electrical conductivity (EC) was within safe limits. The soil was found to be low in available nitrogen content (135 kg ha^{-1}), high in phosphorus (31.90 kg ha^{-1}) and medium in potassium content (213.7 kg ha^{-1}). The physico-chemical properties of the soil are detailed in Table 1.

Table 1. Properties of the soil before treatment imposition

Soil parameters	Contents	Method
Sand (%)	89.4	Bouyoucos hydrometer method [16]
Silt (%)	2.4	
Clay (%)	8.2	
Soil texture	Sandy	
pH (1:2.5 soil: water)	7.23	“Eutech” digital pH meter [17]
Electrical conductivity (dS m^{-1}) (1:2.5 soil: water)	0.35	“Eutech” digital conductivity meter [17]
Organic Carbon (g kg^{-1})	2.5	Chromic acid wet digestion method [18]
Available Nitrogen (kg ha^{-1})	135.0	Alkaline permanganate method [19]
Available P_2O_5 (kg ha^{-1})	32.0	0.5M $NaHCO_3$ (pH 8.5) method [20]
Available K_2O (kg ha^{-1})	213.7	Neutral normal ammonium acetate method followed by using flame photometer [17]

2.2 Source of Manures and Fertilizers

The experiment utilized two types of manures *i.e.*, black soldier fly larval frass and vermicompost. Recommended dose of fertilizers (NPK 60:100:50 kg ha^{-1}) was provided in the form of urea, SSP and MOP. The black soldier fly larval frass and vermicompost were obtained from the college farm at PJTSAU, Rajendranagar, Hyderabad. The BSF larvae were reared on a mixture of chicken feed and wheat bran (50:50) combined with water in a proportionate volume based on weight. The rearing procedures of the larvae followed the methods described by [21]. Sixty day old BSF larval frass and one month old vermicompost was used in the experiment. Manure samples were analyzed before the start of the experiment and the details are provided in Table 2.

Table 2: Chemical properties of BSF larval frass and vermicompost used in experiment.

Parameter	BSF larval frass	Vermicompost	Method
pH (1:10)	7.51	7.42	“Eutech” digital pH meter [17]
EC (1:10) dS m^{-1}	7.08	1.81	“Eutech” digital conductivity meter [17]
C_{total} (%)	23.14	27	Dry combustion method [22]
N_{total} (%)	2.66	0.86	Micro kjheldhal distillation [23]
C:N ratio	8.7:1	31.1:1	-
P_{total} (%)	0.31	0.12	Vanadomolybdate - phosphoric acid mehod [23]
K_{total} (%)	1.91	0.32	Diacid extraction method followed by flame photometer [23]

2.3 Treatments and Experimental Setup

The BSF larval frass and vermicompost were applied at uniform rates equivalent to 60 kg N ha^{-1} in the treatments. In treatments T_2, T_3 and T_4, 100% of the required nitrogen was supplied using either NPK alone or organic manures alone. The amounts of fertilizers needed to supply 60 kg ha^{-1} were 2.2 t ha^{-1} for sole BSF larval frass, 7.4 t ha^{-1} for sole vermicompost and 130 kg urea for 100% N through RDF. The phosphorus and potassium were applied as per the recommended dose of fertilizers for the treatments (T_5, T_6, T_7 and T_8), they were applied after deducting their respective amount provided through manures. Treatment T_1 did not receive any manures or fertilizers.

The experiment was conducted under open field conditions in a randomized block design with three replications. Each replication included eight treatments: T_1 - Control, T_2 - RDF (60N, 100 P_2O_5 and 50 K_2O kg ha^{-1}), T_3 - 100% N through black soldier fly larval frass, T_4 - 100% N through vermicompost, T_5 - 75% RDN + 25% N through black soldier fly larval frass, T_6 - 75% RDN + 25% N through vermicompost, T_7 - 50% RDN + 50% N through black soldier fly larval frass and T_8 - 50% RDN + 50% N through vermicompost. The radish was sown at a spacing of 30 cm × 5 cm in plot sizes of 4.5 m × 3 m using the "Varsha Rani" variety, sown at a depth of 3 cm on ridges. The organic manures were added 15 days prior to the date of sowing and mixed thoroughly into the soil. Manual weeding was done to remove weeds and check basin irrigation was followed to meet the crop water needs.

2.4 Data Collection of growth and yield variables

Data was collected at 20 DAS, 40 DAS and at harvest from five randomly tagged plants. Plant height was measured using a tape from the base to the topmost leaf and number of leaves were determined by counting fully expanded leaves. For dry matter production, five plants were uprooted from each treatment and were washed, shade dried and then dried in a hot air oven at 65°C until a constant weight was reached. Root length was measured in centimetres from the proximal to the distal end and root girth was measured with a tape. Root diameter was measured using digital vernier callipers. Fresh root weight was determined by weighing the harvested radish after cutting off the leaves with a sharp knife. Root weights of individual plots were weighed and recorded in kilograms.

2.5 Data Analysis

The data collected from the research study was statistically analyzed using the analysis of variance (ANOVA) method for a randomized block design [24]. When treatment difference was found to be significant (F test), the critical difference was calculated at a 5% probability level. Non-significant treatment difference was indicated as NS. If the variation between two treatments exceeded the critical difference, the value was used for comparison using treatment means.

3. RESULTS AND DISCUSSION

3.1 Growth parameters

The effect of sole and combined use of organic manures and inorganic fertilizers on plant growth of radish had been presented in Table 3. Among the treatments, T_5 (75% RDN + 25% N through black soldier fly larval frass) exhibited highest plant height (12.75 cm, 30.44 cm and 32.36 cm) at 20 DAS, 40 DAS and at harvest respectively and it was on par with T_6 (75% RDN + 25% N through vermicompost) and T_2 (RDF). The lowest plant height (7.31 cm, 24.77 cm and 25.42 cm) was recorded in T_1 (control). In the similar way number of leaves per plant was more (6.12, 10.71 and 13.22) at 20 DAS, 40 DAS and at harvest in T_5 (75% RDN + 25% N through black soldier fly larval frass) and lowest number of leaves in T_1 (control). Same trend was followed for dry matter accumulation (g m^{-2}) at different growth stages *i.e*., 20 DAS, 40 DAS and at harvest, it was high in T_5 (75 % RDN + 25 % N through black soldier fly larval frass) and it was on par with T_6 (75 % RDN + 25 % N through vermicompost) and T_2 (RDF). The minimum was recorded in T_1 (control). The rapid release and availability of essential nutrients from chemical fertilizers and steady release of nutrients from the organic sources throughout the crop growth period might had led to increased plant height and vegetative growth. The outcomes are consistent with the findings of [25,26].

Table 3: Effect of black soldier fly larval frass, vermicompost in combination with inorganic fertilizers on growth attributes of radish

Treatments	Plant height (cm)			Number of leaves plant^{-1}			Dry matter production (g m^{-2})		
	20 DAS	40 DAS	At harvest	20 DAS	40 DAS	At harvest	20 DAS	40 DAS	At harvest
T_1	7.31	24.77	25.42	4.01	6.67	7.73	84.6	526.0	760.0
T_2	12.20	30.17	32.06	5.92	10.49	13.08	113.7	1146	1528
T_3	9.51	27.03	28.68	4.77	8.22	9.94	96.1	857.0	1147
T_4	8.31	25.97	26.75	4.39	7.47	8.90	90.5	767.0	1040
T_5	12.75	30.44	32.36	6.12	10.71	13.22	117.7	1219	1634
T_6	12.19	30.22	32.10	6.00	10.64	13.15	114.9	1172	1565
T_7	11.22	29.12	30.87	5.53	9.72	12.02	107.3	1044	1373
T_8	10.25	28.09	29.79	5.15	8.96	10.98	101.7	949.0	1256

"F" test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
Sem±	0.24	0.32	0.35	0.12	0.23	0.34	1.79	27.75	35.01
CD (0.05)	0.72	0.98	1.07	0.37	0.71	1.03	5.43	84.17	106.21

3.2 Yield parameters

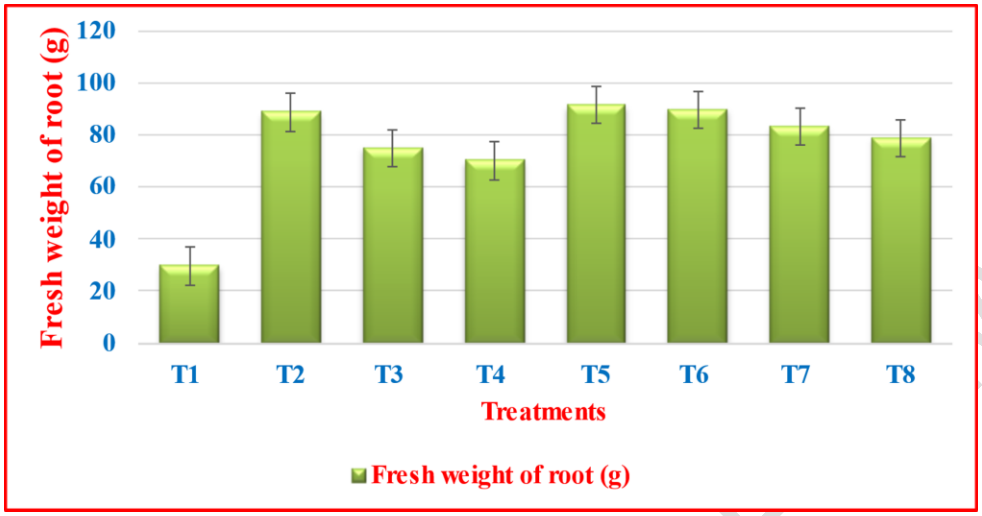
All the yield attributing characters *i.e*., root length (cm), root girth (cm), fresh root weight (g plant^{-1}) and yield (t ha^{-1}) showed a significant difference with the organic manures and their combination with inorganic fertilizers (Table 4). From the given treatments T_5 (75 % RDN + 25 % N through black soldier fly larval frass) shown the maximum increase in the root length (19.95) and it was at par with T_6 (75 % RDN + 25 % N through vermicompost) and T_2 (RDF) and they were significantly superior over other treatments. The minimum root length was recorded in control treatment (11.74 cm). Similar trend was followed for root diameter: T_5,T_6 and T_2 are on par with each other (2.96, 2.85 and 2.83 cm respectively). While the lowest was observed in control (1.45 cm). The root girth was significantly different among application of 75 % RDN + 25 % N through black soldier fly larval frass (10.48cm) increased root girth and it was on par with 75 % RDN + 25 % N through vermicompost (10.23 cm) and RDF (9.96 cm). Whereas least was reported in control (5.14 cm). The increase in yield related parameters (root length, root diameter and root girth) might be due to the improved accumulation of carbohydrates in plants and the translocation of photosynthates from the source to sink (leaves to root). Similar findings are reported by Yadav et al [27].

The fresh root weight per plant in grams was found highest in T_5, T_6 and T_2 and at par with each other (91.33, 89.61 and 88.66 respectively). The lowest fresh root weight was recorded in control (49.65). The maximum yield (t ha^{-1}) registered from T_5 (75 % RDN + 25 % N through black soldier fly larval frass, 54.25 t ha^{-1}) and it was statistically on par with T_6 (75 % RDN + 25 % N through vermicompost, 52.93 t ha^{-1}) and T_2 (RDF, 52.37 t ha^{-1}). The minimum was perceived from T_1 (control, 17.02 t ha^{-1}). Increase in root fresh weight and root yield might be due to the combination of organic and inorganic nitrogen sources leading to increase in number of leaves, leaf length and leaf area which ultimately resulted in photosynthetic efficiency and better assimilation of photosynthates. These findings were in agreement with the findings of Yadav et al [27].

Table 4: Effect of black soldier fly larval frass, vermicompost in combination with inorganic fertilizers on yield attributes of radish

Treatments	Root length (cm)	Root diameter (cm)	Root girth (cm)	Fresh root weight (g plant^{-1})	Yield (t ha^{-1})
T_1	11.74	1.45	5.14	29.65	17.02
T_2	19.71	2.83	9.96	88.66	52.37
T_3	16.38	2.08	7.71	74.92	43.27
T_4	15.28	1.83	7.11	70.07	40.23
T_5	19.95	2.96	10.48	91.33	54.25
T_6	19.81	2.85	10.23	89.61	52.93
T_7	18.60	2.58	9.41	83.00	48.75
T_8	17.49	2.32	8.26	78.97	45.97
"F" test	Sig.	Sig.	Sig.	Sig.	Sig.
Sem±	0.35	0.07	0.17	1.32	0.76
CD (0.05)	1.08	0.23	0.54	4.02	2.31

Figure 1: Effect of black soldier fly larval frass, vermicompost in combination with inorganic fertilizers on root weight of radish (g plant^{-1})



4. CONCLUSION

A new source of organic manure, BSF larval frass was evaluated along with vermicompost on growth and yield of radish. The results revealed that 75% RDN + 25 % N through black soldier fly larval frass improved the growth and yield parameters of radish on par with 75% RDN + 25% N through vermicompost. Hence it can be concluded that 25% N through black soldier fly larval frass is equivalent to vermicompost and is a potential organic source substitute to vermicompost. Frass not only provides the plant with essential nutrients but also reduces the quantity of synthetic fertilizers usage, which in turn reduces the environmental pollution.

Acknowledgements

The author wishes to express gratitude to the PJTSAU for providing the research grant, chairperson, Dean-PG Studies, members, Department of Agronomy, family and friends, for their invaluable support during the entire work.

Authors' Contributions

"Palaparthi Nileesha conducted the field experiment, performed the lab and statistical analysis. Dr. Y. S. Parameswari, G. S. Madhu Bindu, V. Anitha and A. Madhavi designed the study, wrote the protocol, and wrote the first draft of the manuscript and 'managed the literature searches…… All authors read and approved the final manuscript."

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.
Option 2:
Author(s) hereby declare that generative AI technologies such as Large Language Models, etc have been used during writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology
Details of the AI usage are given below:
1.
2.
3.

REFERENCES

1. Bhatt MK, Labanya R, Joshi HC. Influence of long-term chemical fertilizers and organic manures on soil fertility-A review. Universal Journal of Agricultural Research. 2019; 7(5): 177-188.
2. FAO. 2019. Key facts on food loss and waste you should know! save food: Global initiative on food loss and waste reduction. Available online: http://www.fao.org/save-food/resources/keyfindings.
3. Ndambi OA, Pelster DE, Owino JO, De Buisonje F, Vellinga T. Manure management practices and policies in sub-Saharan Africa: implications on manure quality as a fertilizer. Frontiers in Sustainable Food Systems. 2019; 29.
4. Cickova H, Newton GL, Lacy RC, Kozanek M. The use of fly larvae for organic waste treatment. Waste management. 2015; 35: 68-80.
5. Ushakova NA, Ponomarev SV, Bakaneva YM, Fedorovykh, YV, Levina OA, Kotel Nikov AV, et al. Biological efficiency of the prepupae *Hermetia illucens* in the diet of the young Mozambique Tilapia Oreochromis mossambicus. Biology bulletin. 2018; 45: 382-387.
6. Salomone R, Saija G, Mondello G, Giannetto A, Fasulo S, Savastano D. Environmental impact of food waste bioconversion by insects: application of life cycle assessment to process using *Hermetia illucens*. Journal of Cleaner Production. 2017; *140*: 890-905.
7. Diener S, Studt Solano NM, Roa Gutierrez F, Zurbrugg C, Tockner K. Biological treatment of municipal organic waste using black soldier fly larvae. Waste and Biomass Valorization. 2011; 2: 357-363.
8. Lalander CH, Fidjeland J, Diener S, Eriksson S, Vinneras B. High waste-to-biomass conversion and efficient Salmonella spp. reduction using black soldier fly for waste recycling. Agronomy for Sustainable Development. 2015; *35*: 261-271.
9. Ewald N, Vidakovic A, Langeland M, Kiessling A, Sampels S, Lalander C. Fatty acid composition of black soldier fly larvae (*Hermetia illucens*)–Possibilities and limitations for modification through diet. Waste management. 2020; 102: 40-47.
10. Wang YS, Shelomi M. Review of black soldier fly (*Hermetia illucens*) as animal feed and human food. Foods. 2017; 6(10): 91.
11. Beesigamukama D, Mochoge B, Korir NK, Fiaboe KKM, Nakimbugwe D, Khamis FM, et al. Biochar and gypsum amendment of agro-industrial waste for enhanced black soldier fly larval biomass and quality frass fertilizer. Plos one 2020a; 15: e0238154. https://doi.org/10.1371/journal.pone.0238154
12. Beesigamukama D, Mochoge B, Korir N, Musyoka MW, Fiaboe KKM, Nakimbugwe D, et al. Nitrogen fertilizer equivalence of black soldier fly frass fertilizer and synchrony of nitrogen mineralization for maize production. Agronomy 2020b; 10: 1395.

13. Quilliam RS, Nuku-Adeku C, Maquart P, Little D, Newton R, Murray F. Integrating insect frass biofertilizers into sustainable peri-urban agro-food systems. Journal of Insects as Food and Feed. 2020; 6: 315-322.
14. Vavilov NI. 1926. *Studies on the Origin of Cultivated Plants..*. Institut de Botanique Appliquée et d'Amélioration des Plantes. 1926.
15. Bakhsh KHUDA, Ahmad BASHIR, Gill ZA, Hassan SARFRAZ. Estimating indicators of higher yield in radish cultivation. International Journal of Agriculture and Biology. 2006; 8(6): 783-787.
16. Bouyoucos GJ. Hydrometer method improved for making particle size analysis of Soils. Agronomy Journal. 1962; 54: 464-465.
17. Jackson ML. Soil Chemical Analysis. Printer Hall of India Pvt, Ltd, New Delhi. 1973; 151-153.
18. Walkley A, Black CA. Estimation of soil organic carbon by the chromic acid titration method. Soil Science. 1934; 37: 28-29.
19. Subbaiah BV, Asija GL. A rapid procedure for estimation of available nitrogen in the soil. Current Science. 1956; 25: 258-260.
20. Olsen SR, Cole CV, Watanabe FS, Dean LA. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. United States Department of Agriculture 1954; 939.
21. Beesigamukama D, Mochoge B, Korir NK, Fiaboe KK, Nakimbugwe D, Khamis FM, et al. Low-cost technology for recycling agro-industrial waste into nutrient-rich organic fertilizer using black soldier fly. Waste Management. 2021; 119: 183-194.
22. Nelson DW, Sommers LE. Total carbon, organic carbon, and organic matter. Methods of soil analysis: chemical and microbiological properties. 1982; 9: 539-579.
23. Piper CS. Soil and Plant Analysis. Hans Publication. Bombay. India. 1966;251-350.
24. Gomez KA, Gomez AA. Statistical Procedures for Agricultural Research. John Wiley and Sons Publishers, New York. 1984; 97-107.
25. Aravind SA, Somasundaram E, Sanbagavalli S. Effect of Organic Nutrient Management Practices on Growth and Yield of Short-duration Cassava (*Manihot esculenta* Crantz). Indian Journal of Agricultural Research. 2023; 1: 7.
26. Channakeshava S, Manjunathaswamy TS, Pankaja HK, Reddy GSK. Effect of foliar application of vegetable special on growth and yield of potato. International Journal of Current Microbiology and Applied Sciences. 2017; 6: 1348-1354.
27. Yadav BN, Reddy PSS, Sadarunnisa S, Srinivasarao G, Kiran YD, Reddy AR. Root yield and nutrient uptake of Radish (*Raphanus sativus* L.) as influenced by the application of organic and inorganic sources of nitrogen and their combinations. IJCS. 2018; 6(4): 3116-3119.