

AGRONOMIC PERFORMANCE, FRUIT QUALITY ENHANCEMENT AND SOIL HEALTH RESTORATION IN GREEN AND PURPLE OKRA (*ABELMOSCHUS ESCULENTUS* L.) CULTIVARS UNDER BLACK SOLDIER FLY LARVAL DIGESTATE REGIMES

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ABSTRACT

Sustainable nutrient management in intensive vegetable production requires high-value organic alternatives to chemical fertilizers that enhance soil health without sacrificing crop productivity. This study evaluated the comparative efficacy of Black Soldier Fly Larval (*Hermetia illucens* L., BSFL) digested poultry manure against aerobic poultry manure, farmyard manure (FYM), vermicompost and recommended inorganic fertilizer (RDF) across two phenotypic cultivars of okra (*Abelmoschus esculentus* L.): 'Parbhani Kranti' (Green, V₁) and 'Kashi Lalima' (Purple, V₂). Executed in a Factorial Randomized Block Design, during 2023-24, the treatment comprising BSFL-digested poultry manure at 7.5 t/acre (T₄) demonstrated statistically superior performance. T₄ recorded maximum plant height (78.34 cm), earliest flowering (43.00 days) and a peak total fruit yield of 13.09 t/ha, significantly outperforming RDF (11.89 t/ha), with the T₄V₁ interaction achieving a maximum yield of 14.41 t/ha. Biochemical profiling revealed that T₄ enhanced total chlorophyll (1.10 mg/100g FW) and anthocyanin content (8.91 mg/100g in T₄V₂), while decreasing crude fiber (9.51% in T₄V₁). Post-harvest soil analysis under T₄ showed reduced bulk density (1.15 g/cm³) and elevated organic carbon (0.53%), along with increased available nitrogen (223.36 kg/ha), phosphorus (64.17 kg/ha), and potassium (382.63 kg/ha). Economically, T₄V₁ yielded the highest benefit-cost ratio (4.30) with net returns of ₹3,48,305/ha, confirming BSFL-digested poultry manure as a viable, highly profitable bio-organic fertilizer for sustainable horticulture.

KEYWORDS: *Abelmoschus esculentus*, Black Soldier Fly Larvae, Bio-organic fertilizer, Soil organic carbon, Nutrient uptake and Yield optimization.

INTRODUCTION

Okra (*Abelmoschus esculentus* L. Moench), a warm-season vegetable crop belonging to the family Malvaceae, plays a pivotal role in human nutrition and economic agricultural output across tropical and subtropical regions (FAO, 2023). Originating in tropical Africa, India is currently the global leader in okra production, contributing approximately 72.9% of total world output (NHB, 2023). In India, okra spans an area of over 546 thousand hectares with an annual production exceeding 7,100 thousand tonnes (NHB, 2023). The tender pods are recognized for their low-calorie density (33 kcal/100g), high moisture content, rich dietary fiber profile and essential micronutrients including vitamins A and C, calcium, potassium and galacturonic/glucuronic acid-based mucilage (Gemede et.al., 2015).

Continuous and heavy reliance on synthetic chemical fertilizers in intensive vegetable production systems has led to severe soil degradation, loss of native microflora, reduced soil organic matter (SOM) and increased susceptibility to environmental stressors (Lal, 2020). Integrating organic manures such as farmyard manure (FYM), vermicompost, and poultry manure improves soil physical properties (bulk density, total porosity, water-holding capacity) and enhances enzymatic and biological processes (Ramesh et al, 2019). Poultry manure provides a concentrated pool of macro- and micronutrients with a lower carbon-to-nitrogen (C:N) ratio (Ramesh et al., 2019).

A major biotechnological advance in organic waste recycling involves insect-mediated bioconversion using Black Soldier Fly Larvae (*Hermetia illucens* L., BSFL) (Diener et al, 2011; Surendra et al., 2020). BSFL rapidly process animal manures and organic biowastes into insect biomass rich in proteins and fats, leaving behind a nutrient-dense residue termed BSFL digestate or frass (Diener et al, 2011). BSF frass organic fertilizer contains concentrated bio-available nitrogen (N), phosphorus (P₂O₅), potassium K₂O), residual chitin from larval exuviae and beneficial microbial populations that secrete growth-promoting hormones and enzymes (Surendra et al, 2020).

While studies have documented the potential of BSFL frass in cereal crops, research on its comparative agronomic and physiological performance across green and anthocyanin-rich purple cultivars of okra remains

limited. Therefore, this study evaluated the impact of BSFL-digested poultry manure on growth attributes, reproductive phenology, yield performance, bioactive fruit quality, post-harvest soil physicochemical properties and economic returns in green (Parbhani Kranti) and purple (Kashi Lalima) okra varieties.

MATERIALS AND METHODS

Experimental Site and Agro-Climate

The field research was conducted at the PG Research Block, Department of Vegetable Science, College of Horticulture, Sri Konda Laxman Telangana Horticultural University (SKLTGHU), Mojerla, Wanaparthy district, Telangana, India. The site belongs to the semi-arid, dry subtropical agro-climatic zone characterized by high summer ambient temperatures.

Baseline Soil and Manure Characterization

A composite soil sample was collected from a depth of 0–15 cm across the experimental plot prior to field preparation (Walkley and Black, 1934; Jackson, 1973). Samples were air-dried, crushed, passed through a 2 mm sieve, and analysed for baseline physicochemical properties.

Table 1: baseline physicochemical properties of experimental soil (0-15 cm depth)

Soil Parameter	Baseline Value	Method / Reference Protocol
Soil Texture Class	Sandy Clay Loamy	Hydrometer Method (Walkley and Black, 1934)
pH (1:2.5 Soil: Water)	8.60	Glass Electrode pH Meter (Jackson, 1973).
Electrical Conductivity (EC)	0.62 dS/m	Conductimetric Method (Jackson, 1973)
Bulk Density (BD)	1.46 g/cm ³	Core Sampler Method (Walkley and Black, 1934)
Organic Carbon (OC)	0.42 %	Walkley and Black Titration (Walkley and Black, 1934)
Available Nitrogen (N)	150.90 kg/ha	Alkaline KMnO ₄ Distillation (Subbiah and Asija, 1956)
Available Phosphorus (P ₂ O ₅)	42.85 kg/ha	Olsen's NaHCO ₃ Extraction (Olsen, 1954)
Available Potassium (K ₂ O)	328.20 kg/ha	Neutral Ammonium Acetate Flame Photometry (Jackson, 1973)

Experimental Design and Treatment Structure

The trial was laid out in a Factorial Randomized Block Design (FRBD) comprising two factors with three replications (Gomez and Gomez, 1984). Individual experimental net plot dimensions were 2.5 m x 1.5 m (3.75 m²) with a plant spacing of 45 x 30 cm.

Factor I (Organic and Inorganic Regimes - 9 Levels):

T₁: Aerobic decomposed poultry manure @ 7.5 t/acre

T₂: Aerobic decomposed poultry manure @ 5.0 t/acre

T₃: Aerobic decomposed poultry manure @ 2.5 t/acre

T₄: BSF-digested poultry manure @ 7.5 t/acre

T₅: BSF-digested poultry manure @ 5.0 t/acre

T₆: BSF-digested poultry manure @ 2.5 t/acre

T₇: Farmyard Manure (FYM) @ 10.0 t/acre

T₈: Vermicompost @ 5.0 t/acre

T₉: Recommended Dose of Fertilizers (RDF: 48:24:24 kg N: P₂O₅: K₂O per hectare)

Factor II (Varieties - 2 Levels):

V₁: Parbhani Kranti (Green pod phenotype)

V₂: Kashi Lalima (Purple pod phenotype)

Crop Management and Cultural Operations

Organic manures (T₁–T₈) were incorporated into designated plots in split applications and allowed to undergo soil incorporation for one week before sowing. For T₉ (RDF), inorganic inputs were applied at 48:24:24 kg N: P₂O₅: K₂O per hectare (2/3 N + full P and K as basal, 1/3 N top-dressed 45 DAS). Seeds were dibbled at 2 cm depth. Standard cultural management, including thinning at 25 DAS, manual hand weeding at 30 and 50 DAS and application of neem oil (5 mL/L) for sucking pest management, was uniformly executed.

Data Collection and Analytical Methods

Morphological & Yield Traits: Tagged representative plants were measured for height, node count, internodal length, days to 50% flowering, days to initial and final harvesting pickings, single fruit weight, fruit length/diameter, and cumulative pod yield (t/ha) (Gomez; Gomez, 1984).

Total Chlorophyll: Estimated via Dimethyl Sulfoxide (DMSO) spectrophotometric extraction reading at 645 nm and 663 nm [Surendra, et al., 2019].

Crude Fiber Content: Determined using standard acid-alkali digestion following AOAC protocols (AOAC, 2025).

Total Anthocyanin Content: Extracted in Methanolic HCl (85:15 v/v ethanol:1 N HCl) and measured at 535 nm (Giusti and Wrolstad, 2001).

Soil Analysis: Post-harvest composite soil samples were analyzed for pH, EC, bulk density, soil organic carbon, and available N, P and K using established standard methods (Walkley, and Black, 1934; Subbiah and Asija, 1956; Olsen et al., 1954 and Jackson 1973).

RESULTS

Growth Dynamics

Vegetative traits responded significantly ($p \leq 0.05$) to nutrient regimes and cultivars (Table 2). Treatment T₄ (BSF-digested poultry manure @ 7.5 t/acre) produced the maximum plant height (78.34 cm), node count (18.83 per plant) and internodal length (5.00 cm), followed by chemical RDF (T₉: 76.44 cm height, 17.83 nodes). Cultivar Parbhani Kranti (V₁) was taller (71.30 cm) and produced more nodes (15.51) than Kashi Lalima (V₂). The interaction T₄ V₁ achieved the maximum plant height (79.13 cm).

Table 2: Influence of nutrient regimes and varieties on vegetative growth dynamics in okra

Treatment	Plant Height (cm)	Nodes per Plant	Internodal Length (cm)
T ₁ : Aerobic decomposed poultry manure @ 7.5 t/acre	67.85	14.50	4.15
T ₂ : Aerobic decomposed poultry manure @ 5.0 t/acre	63.42	12.16	3.82
T ₃ : Aerobic decomposed poultry manure @ 2.5 t/acre	59.52	10.50	3.54
T ₄ : BSF-digested poultry manure @ 7.5 t/acre	78.34	18.83	5.00
T ₅ : BSF-digested poultry manure @ 5.0 t/acre	71.20	15.66	4.38
T ₆ : BSF-digested poultry manure @ 2.5 t/acre	65.50	13.00	3.96
T ₇ : Farmyard Manure (FYM) @ 10.0 t/acre	66.18	13.50	4.01
T ₈ : Vermicompost @ 5.0 t/acre	72.84	16.33	4.49
T ₉ : Recommended Dose of Fertilizers (RDF: 48:24:24)	76.44	17.83	4.78
SE(m)± (Treatment)	0.82	0.41	0.06
CD _{0.05} (Treatment)	2.35	1.18	0.17
V ₁ (Parbhani Kranti)	71.30	15.51	4.30
V ₂ (Kashi Lalima)	66.82	14.28	4.02
SE(m) ± (Variety)	0.38	0.19	0.03
CD _{0.05} (Variety)	1.10	0.55	0.08
CD _{0.05} (T × V)	3.32	NS	0.24

Note: NS =Not Significant

Reproductive Phenology and Yield Outcomes

Treatment T₄ achieved the earliest onset of 50% flowering (43.00 days) and fastest fruit maturity (Table 3). Highest fruit length (15.19 cm), single fruit weight (13.65 g), pod count per plant (18.66) and overall fruit yield per hectare (13.09 t/ha) were recorded in T₄, outperforming inorganic RDF (T₉, 11.89 t/ha) and vermicompost (T₈, 11.68 t/ha). The combination T₄ V₁ achieved a peak fruit yield of 14.41 t/ha.

Table 3: Reproductive phenology, yield components and fruit productivity of okra as affected by nutrient management and variety

Treatment	Days to 50 % flowering	Days to 1 st picking	Fruit length (cm)	Average fruit weight (g)	Fruits per plant	Fruit yield (t/ha)
T ₁ : Aerobic decomposed poultry manure @ 7.5 t/acre	48.33	42.16	12.82	10.65	14.00	9.75
T ₂ : Aerobic decomposed poultry manure @ 5.0 t/acre	50.50	44.00	11.20	9.42	11.33	8.35
T ₃ : Aerobic decomposed poultry manure @ 2.5 t/acre	52.16	45.66	10.33	8.20	9.50	7.76
T ₄ : BSF-digested poultry manure @ 7.5 t/acre	43.00	36.16	15.19	13.65	18.66	13.09
T ₅ : BSF-digested poultry manure @ 5.0 t/acre	46.50	39.83	13.68	11.85	15.83	11.12
T ₆ : BSF-digested poultry manure @ 2.5 t/acre	49.66	43.16	11.85	10.12	12.66	9.15
T ₇ : Farmyard Manure (FYM) @ 10.0 t/acre	49.00	42.83	12.24	10.38	13.16	9.40
T ₈ : Vermicompost @ 5.0 t/acre	45.16	38.50	14.12	12.45	16.83	11.68

T ₉ : Recommended Dose of Fertilizers (RDF: 48:24:24)	43.83	35.00	14.82	13.04	17.50	11.89
SE(m)± (Treatment)	0.51	0.46	0.18	0.16	0.22	0.14
CD _{0.05} (Treatment)	1.46	1.32	0.52	0.46	0.63	0.40
V ₁ (Parbhani Kranti)	47.07	40.88	13.40	11.23	15.29	10.78
V ₂ (Kashi Lalima)	48.07	42.07	12.43	10.72	13.55	9.71
CD _{0.05} (Variety)	0.68	0.62	0.24	0.21	0.29	0.18
CD _{0.05} (T × V)	NS	NS	0.73	0.65	0.89	0.56

Note: NS =Not Significant

Fruit Quality and Biochemical Profiling

Treatment T₄ significantly increased total chlorophyll (1.10 mg/100g FW) and decreased crude fiber content to a desirable low of 9.82%, compared to 15.33% crude fiber under synthetic RDF (T₉) (Table 4). Total anthocyanin content reached its peak in purple cultivar V₂ receiving T₄ (T₄ V₂: 8.91 mg/100g FW).

Table 4: Biochemical fruit quality traits of okra under different fertilization regimes and varieties

Treatment	Total Chlorophyll (mg/100g FW)	Crude Fiber (%)	Total Anthocyanin (mg/100g FW)
T ₁ : Aerobic decomposed poultry manure @ 7.5 t/acre	0.82	13.52	3.82
T ₂ : Aerobic decomposed poultry manure @ 5.0 t/acre	0.76	14.18	3.65
T ₃ : Aerobic decomposed poultry manure @ 2.5 t/acre	0.71	14.90	3.52
T ₄ : BSF-digested poultry manure @ 7.5 t/acre	1.10	9.82	4.47
T ₅ : BSF-digested poultry manure @ 5.0 t/acre	0.95	10.63	3.49
T ₆ : BSF-digested poultry manure @ 2.5 t/acre	0.80	12.85	3.75
T ₇ : Farmyard Manure (FYM) @ 10.0 t/acre	0.81	13.10	3.78
T ₈ : Vermicompost @ 5.0 t/acre	0.98	11.45	4.12
T ₉ : Recommended Dose of Fertilizers (RDF: 48:24:24)	1.03	15.33	4.37
SE(m)± (Treatment)	0.01	0.12	0.04
CD _{0.05} (Treatment)	0.03	0.34	0.11
V ₁ (Parbhani Kranti)	1.75	12.08	0.02
V ₂ (Kashi Lalima)	0.02	13.22	7.72
CD _{0.05} (Variety)	0.01	0.16	0.05
CD _{0.05} (T × V)	0.04	0.48	0.15

Soil Physicochemical Restoration

Soil health parameters improved significantly following T₄ application (Table 5). Soil organic carbon increased from a baseline of 0.42% to 0.53%, while bulk density dropped from 1.46 g/cm³ to 1.15 g/cm³. Post-harvest available nitrogen (223.36 kg/ha), phosphorus (64.17 kg/ha) and potassium (382.63 kg/ha) were highest under T₄.

Table 5: Post-harvest soil physicochemical properties and available nutrient status under key nutrient management treatments.

Soil Property	Baseline	T ₄ (BSF 7.5 t/ac)	T ₄ (Vermicompost)	T ₄ (RDF Control)	CD _{0.05}
pH (1:2.5)	8.60	8.14	8.16	8.65	0.08
EC (dS/m)	0.62	0.58	0.59	0.63	0.02
Bulk Density (g/cm ³)	1.46	1.15	1.28	1.58	0.03
Organic Carbon (%)	0.42	0.53	0.46	0.36	0.02

Soil Property	Baseline	T ₄ (BSF 7.5 t/ac)	T ₄ (Vermicompost)	T ₄ (RDF Control)	CD _{0.05}
Avail. N (kg/ha)	150.90	223.36	198.40	212.20	4.12
Avail. P ₂ O ₅ (kg/ha)	42.85	64.17	52.10	58.34	1.85
Avail. K ₂ O (kg/ha)	328.20	382.63	352.10	360.40	6.25

DISCUSSION

Vegetative Growth Dynamics and Canopy Architecture

The prominent enhancement in plant height, node accumulation, and internodal elongation observed under BSFL-digested poultry manure (T₄) highlights the superior nutritional bio-availability of insect bioconversion products (Anyanwu et al., 2022; Klammersteiner, 2020). Unlike unprocessed or aerobically composted poultry manure (T₁–T₃), Black Soldier Fly Larvae digestate undergoes intense enzymatic breakdown and gut microbial processing within the insect digestive tract (Diener, 2011; Anyanwu, 2022). This process rapidly mineralizes organic bound nitrogen into highly accessible ammonium (NH₄⁺) and nitrate (NO₃⁻) pools (Anyanwu, 2022; Gebremikael, 2016).

Furthermore, BSFL frass inherently contains residual chitin derivatives shed from larval exuviae (Quilliam et al., 2021; Kebli et al., 2023). Soil incorporation of chitin stimulates chitinolytic bacteria (e.g., *Streptomyces* and *Bacillus* species), which release plant growth-promoting rhizobacteria (PGPR) traits, auxins, and gibberellin-like substances (Klammersteiner et al., 2020; Quilliam et al., 2021). These biostimulants accelerate cell division and apical meristematic activity, driving canopy expansion and structural frame development (Sivasankari et al., 2022). The vegetative vigour of green cultivar Parbhani Kranti (V₁) over purple Kashi Lalima (V₂) reflects genetic differences in photosynthetic carbon assimilation and biomass partitioning rates (Sivasankari et al., 2022; Premsekhar and Rajashree, 2009).

Reproductive Phenology, Yield Components, and Sink Strength

The shift toward earlier 50% flowering (43.00 days) and earlier fruit harvesting under T₄ stems from optimized, steady-state mineral nutrient supply particularly bio-available phosphorus (P₂O₅) and key micronutrients (Zn, Fe, B), which are essential for floral bud initiation, pollen viability and fertilization (Kasongo et al., 2021). The presence of bio-mineralized phosphorus in BSF frass accelerates reproductive phenology without triggering vegetative overgrowth (Gemedede et al., 2015 ; Kasongo et al., 2021).

The remarkable pod yield achieved under T₄ (13.09 t/ha overall, and 14.41 t/ha in T₄ V₁) represents a 10.09% increase over chemical fertilizer (T₉, 11.89 t/ha) and a 39.25% yield advantage over traditional aerobic poultry manure (T₁, 9.75 t/ha). Yield expansion in okra depends directly on fruit count per plant, mean fruit weight and fruit length (Premsekhar and Rajashree, 2009). The continuous supply of macro- and micronutrients from BSF frass prevents premature senescence, sustaining photosynthate transport from source leaves to developing pod sinks throughout the multiple picking cycles (Premsekhar and Rajashree, 2009; Tanga, et al., 2022). In contrast, inorganic NPK fertilizers (T₉) release nutrients rapidly, leading to leaching losses in light-textured sandy clay loam soils and reduced nutrient availability during late-stage pod development (Lal, 2020; Gebremikael et al., 2019).

Biochemical Profiling: Chlorophyll, Crude Fiber and Anthocyanin Biosynthesis

Chlorophyll Accumulation: Nitrogen and magnesium availability from T-4 direct the biosynthesis of chlorophyll a and b molecules (Hiscox and Israelstam, 1979), Liu et al, 2019. Enhanced soil nitrogen availability supports functional chloroplast ultrastructure and rubisco enzyme activity, resulting in elevated fruit chlorophyll concentrations (1.10 mg/100g FW) (Hiscox and Israelstam; 1979; Premsekhar and Rajashree, 2009).

Lignification and Crude Fiber Dynamics: Fiber accumulation in tender okra pods is a primary quality determinant; elevated crude fiber leads to tough, unpalatable fruits (Gemedede, et al, 2015, Premsekhar and Rajashree, 2009). Inorganic fertilizer (T₉) recorded the highest fiber level (15.33%), likely due to rapid tissue maturation and structural cell wall lignification under salt-induced osmotic stress (Lal, 2020). Conversely, T₄ maintained lower fiber levels (9.82%), as organic amendments foster balanced, steady tissue growth and delay secondary xylem lignification (Premsekhar and Rajashree, 2009; Agbede et al., 2019).

Anthocyanin Biosynthesis in Purple Okra: In cultivar Kashi Lalima (V₂), anthocyanin synthesis reached its maximum under T₄ V₂ (8.91 mg/100g FW). Chitin present in BSF digestate acts as a biological elicitor, triggering the phenylpropanoid metabolic pathway and upregulating key biosynthetic enzymes, including phenylalanine ammonia-lyase (PAL) (Quilliam et al., 2021; Al-Turki et al., 2022). This increased accumulation of flavonoids and anthocyanins enhances both colour intensity and antioxidant capability (Al-Turki et al., 2022).

Soil Physicochemical Restoration and Nutrient Bioavailability

Bulk Density and Structure: Incorporating BSF frass reduced bulk density from 1.46 g/cm³ to 1.15 g/cm³ (Agbede et al., 2019; Liu et al., 2019). The organic matter added via BSF digestate promotes soil particle aggregation, improves macro-porosity, lowers soil compaction, and enhances aeration and root penetration (Agbede et al., 2019 and Yeboah et al., 2021).

pH Modulation and Carbon Sequestration: The baseline alkaline soil pH (8.60) dropped to 8.14 in T₄ plots. During the microbial decomposition of BSF frass, organic acids (fulvic and humic fractions) and carbonic acid are released, buffering soil alkalinity (Liu et al., 2019 ;Gebremikael et al., 2016). Furthermore, soil organic carbon (SOC) increased significantly from 0.42% to 0.53%, proving that insect digestate builds active carbon pools and enhances carbon sequestration (Tanga et al., 2022 ; Watson et al., 2020).

Macronutrient Availability: Post-harvest available N, P and K reached maximum levels under T₄ (223.36, 64.17 and 382.63 kg/ha, respectively). BSF frass supplies balanced nutrients while stimulating native soil microbial enzymatic activities (urease, dehydrogenase and phosphatase enzymes) (Yeboah et al., 2029; Gebremikael et al., 2016). This microbial activation mineralizes fixed organic phosphorus complexes and reduces ammonium volatilization and nitrate leaching, maintaining higher residual fertility (Tanga et al., 2022; Kumar et al., 2020).

Economic Feasibility and Agronomic Viability

Economic feasibility governs the farm-level adoption of new soil management practices (Kumar et al., 2020). The monetary valuation of treatments confirms that T₄ V₁ achieved maximum financial returns.

Table 6: Economic analysis of different treatment combinations on the cost of cultivation, gross returns, net returns, and benefit-cost ratio (B:C)

Treatment Combination	Total Cost of Cultivation (₹/ha)	Gross Returns (₹/ha)	Net Returns (₹/ha)	Benefit-Cost Ratio (B:C)
T ₄ V ₁ (BSF 7.5 t/ac + Green)	₹1,05,500	₹4,53,805	₹3,48,305	4.30
T ₄ V ₂ (BSF 7.5 t/ac + Purple)	₹1,08,500	₹4,22,500	₹3,14,000	3.89
T ₉ V ₁ (RDF + Green)	₹82,400	₹3,99,000	₹3,16,600	3.84
T ₈ V ₁ (Vermicompost + Green)	₹98,200	₹3,68,100	₹2,69,900	2.75
T ₃ V ₂ (Aerobic PM 2.5 t/ac + Purple)	₹86,100	₹2,24,700	₹1,38,600	1.61

Treatment T₄ V₁ produced net returns of ₹3,48,305/ha and achieved the highest benefit-cost ratio (B:C ratio of 4.30), surpassing synthetic fertilizer treatment (T₉ V₁, B:C 3.84) (Kumar et al., 2020). The superior yield response offsets the input cost of BSF frass, confirming that insect digestate is an economically profitable alternative for horticultural crop production (Tanga et al., 2022).

CONCLUSION

This study demonstrates that Black Soldier Fly Larval (BSFL) digested poultry manure serves as an exceptional bio-organic soil amendment for okra production. Application of BSFL digestate @ 7.5 t/acre (T₄) significantly enhanced growth attributes, accelerated flowering, boosted fruit yield (13.09 t/ha vs. 11.89 t/ha under RDF), improved bioactive quality (elevating chlorophyll and anthocyanin while lowering crude fiber) and restored soil health (reducing bulk density and increasing SOC and available NPK). Combining green cultivar Parbhani Kranti with BSFL digestate @ 7.5 t/acre (T₄ V₁) delivered the highest agronomic output and financial profitability (B:C ratio of 4.30). Implementing BSFL bioconversion technology converts organic waste into valuable biofertilizer, advancing sustainable agriculture, circular economic principles and soil health restoration in horticultural systems.

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