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EFFECT OF BLACK SOLDIER FLY LARVAL FRASS ON YIELD AND QUALITY OF SWEET POTATO (*IPOMOEA BATATAS* L.)

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ABSTRACT

Hermetia illucens L., known as the black soldier fly (BSF), is a very efficient converter of organic waste into nutrient-rich organic fertilizer that benefits crop production and soil health. BSF larvae are capable of quickly consuming a wide range of organic materials, including agricultural wastes, animal manures and even human waste making them an important tool in sustainable waste management and organic agriculture. By considering BSF potential application the present study was conducted at block A3 at Regional Agricultural Research Station farm field at Agricultural College, Polasa, Jagtial, Telangana, during *Rabi* season of 2024–25 to evaluate the effect of BSF frass in comparison with inorganic fertilizers and their combinations on the yield and quality of sweet potato (*Ipomoea batatas* L.). The experiment was laid out in a Randomized Block Design with eight treatments and three replications. Treatments include T₁- Absolute Control, T₂ - 50% RDN, T₃ - 75% RDN, T₄ - 100% RDN, T₅ - 100 % RDN equivalent through BSF frass, T₆ - 50% RDN + 25% RDN equivalent through BSF frass, T₇ - 50% RDN + 50% RDN equivalent through BSF frass and T₈ - 75% RDN + 25% RDN equivalent through BSF frass. Among the treatments, the yield parameters viz., tuber length (18.2 cm), number of tubers plant⁻¹ (6.2), tuber weight plant⁻¹ (438 g) and tuber yield (26.36 t ha⁻¹) recorded highest in the treatment combination of 75% RDN + 25% N through BSF frass, which was comparable with 50% RDN + 50% RDN equivalent through BSF frass and the lowest tuber yield and yield attributes were recorded in control. Similarly, the high content of starch content (18.80 %) and total sugar content (10.33 °Brix) under the same treatment, while the control (T₁) recorded the lowest values (11.63 % and 5.00 °Brix, respectively). Thus, BSF frass can be considered a promising organic input in integrated nutrient management (INM) for enhancing yield and quality of sweet potato.

Keywords : Black soldier fly larval frass, sweet potato, Growth, Yield, Quality.

Introduction

Sweet potato (*Ipomoea batatas* L.) is regarded as one of the most important and versatile food crops globally. It is widely cultivated in tropical and subtropical regions and serves as a major source of energy and nutrition, especially for rural populations.

Sweet potato is very nutritive vegetable, producing substantially high edible energy per hectare per day as compared to rice, wheat, maize, cassava. This highly nutritious crop gives better and faster

production under diverse agro-ecological conditions with less inputs (Lim *et al.*, 2007). Sweet potato tubers are rich in starch, dietary fiber, β-carotene (pro-vitamin A) and several essential minerals like calcium, potassium, iron and zinc (Laurie *et al.*, 2012). Sweet potato is a critical food security crop and an excellent for nutritional enhancement in marginal environments due to its short duration, climate resilience and low input requirements. However, its productivity and tuber quality are significantly influenced by factors

such as soil fertility, nutrient availability, cultivar selection and agronomic practices (Uwah *et al.*, 2013).

In India, sweet potato is cultivated over an area of 110.66 lakh hectares, with a total production of 1306.14 lakh metric tonnes and an average productivity of 11.8 MT ha⁻¹ (Indiastat, 2023). In Telangana, the crop is grown on 0.27 lakh hectares, producing about 3.03 lakh MT with a productivity of 11.14 MT ha⁻¹ (Indiastat, 2023). Despite its significance, the productivity of sweet potato remains relatively low compared to its potential. Nutrient management plays a pivotal role for achieving optimal growth and yield in sweet potato. Nitrogen, phosphorus and potassium are among the most essential macronutrients for tuber development, physiological efficiency and dry matter accumulation.

However, excessive reliance on synthetic fertilizers can lead to nutrient imbalance, soil degradation that leads to decreasing sweet potato's yield. To achieve sustainable and cost-effective sweet potato cultivation, a balanced approach involving the integration of organic and inorganic fertilizers is necessary. Organic fertilizers enhance nutrient use efficiency, improve soil structure and contribute to microbial activity without causing harm to soil health.

Recent advancements have highlighted the potential of using organic amendments derived from macro-faunal bioconversion, especially Black Soldier Fly (*Hermetia illucens* L.) frass. BSF larvae are highly efficient in converting a wide variety of biodegradable organic wastes into nutrient-rich biomass and residue. The frass produced is a by-product composed of insect feces, leftover substrate and shed exoskeletons, enriched with NPK, organic matter and chitin (Lalander *et al.*, 2014). It has high degradation efficiency (65- 78%) (Diener *et al.*, 2011 and Li *et al.*, 2011) due to this, it can be prepared within a short span of time (< 5 weeks) when compared to conventional composting methods (8-24 weeks) (Beesigamukama *et al.*, 2021). In recent studies, BSF frass has been found to significantly improve the growth, yield and quality of vegetable crops when applied alone or in combination with inorganic fertilizers (Chavez *et al.*, 2024 and Rejeki *et al.*, 2023).

BSF frass provides a sustainable, cost-effective and environmentally beneficial substitute for synthetic fertilizers, which are becoming more and more expensive and having negative effects on the environment. It not only enhances soil nutrient status but also contributes to circular agriculture by recycling organic waste streams. In light of these considerations, the present study was undertaken to evaluate the effect of organic (BSF frass) and inorganic fertilizers on the yield and quality performance of sweet potato (*Ipomoea batatas* L.), aiming to develop an integrated nutrient management strategy that enhances crop productivity while preserving soil health.

Materials and Methods

Experimental Site Characteristics

The present field experiment was carried out during Rabi 2024 -25 located at block A3 at Regional Agricultural Research Station farm field at Agricultural College, Polasa, Jagtial. The geographical location of the experimental site was 18° 84' 28.62" N latitude and 78° 95' 03.57" E longitude at an altitude of 243.4 m above mean sea level (MSL). A soil sample was taken from a depth of 0 to 15 cm prior to the start of the experiment and soil samples were analysed for soil texture, bulk density, water holding capacity, pH, electrical conductivity (dS m⁻¹), organic carbon (%), available N, P and K. Soil characteristics at the initiation of the experimental site are presented in table 1.

Source of fertilizers

The experiment involved black soldier fly (BSF) larval frass and mineral fertilizer (NPK). Recommended dose of fertilizers (40:60:40 kg of N: P₂O₅: K₂O ha⁻¹) was provided in the form of urea, SSP and MOP. The BSF larval frass was generated from the feeding of BSF larvae on chicken waste at the ICAR NAHEP (National Agricultural Higher Education Project) BSF Unit, college farm, PJTAU, Rajendranagar, Hyderabad. The BSF larvae were reared by following procedures described by Beesigamukama *et al.* (2021). Characteristics of BSF larval frass used in the experiment are presented in table 2.

Table 1: Salient soil characteristics at the initiation of the experimental site

Particulars	Values	Method of analysis
Sand (%)	63	Bouyoucos hydrometer method, (Piper, 1950)
Silt (%)	28.5	
Clay (%)	8.5	
Soil texture	Sandy loam	
Bulk density (Mg m ⁻³)	1.53	Core sampler method (Blake and Hartge, 1986)
Water holding capacity (%)	16.8	Keen cup method (Sankaram, 1966)

pH (1:2.5 soil: water)	6.94	Glass electrode pH meter (Jackson, 1973)
Electrical conductivity (dS m ⁻¹) (1:2.5 soil: water)	0.17	Conductivity meter (Jackson, 1973)
Organic Carbon (%)	0.40	Chromic acid wet digestion method (Walkley and Black, 1934)
Available Nitrogen (kg ha ⁻¹)	100	Alkaline KMnO ₄ method (Subbaiah and Asija, 1956)
Available Phosphorus (kg P ₂ O ₅ ha ⁻¹)	20	Olsen's method, Olsen <i>et al.</i> (1954)
Available Potassium (kg K ₂ O ha ⁻¹)	384	Flame photometer (Jackson, 1973)

Table 2: Characteristics of applied BSF frass

Parameters	BSF frass	Reference
pH (1:10)	6.91	Glass electrode pH meter (Jackson, 1973)
EC (1:10) dSm ⁻¹	6.15	Conductivity meter (Jackson, 1973)
C _{total} (%)	20.15	Tiessen and Moir (1993)
N _{total} (%)	1.72	Micro- kjeldhal method (Piper, 1966).
P _{total} (%)	0.13	Vanadomolybdate- phosphoric acid yellow colour method, Piper (1966)
K _{total} (%)	1.2	Jackson (1973)
C:N ratio	11.72: 1	-

Treatment Details

The experiment was laid out in randomized block design (RBD) with three replications. Each replication has eight treatments which are represented in table 3.

The sweet potato vine cuttings (variety: Kiran) were planted at a spacing of 60 cm × 20 cm. After 1 week of planting, gap filling was done to maintain optimum plant population. The experiment was carried out in plot size of 4.2 m x 3.8 m.

A recommended dose of nutrients 40-60-40 kg of N: P₂O₅: K₂O ha⁻¹ as urea, single superphosphate and muriate of potash. Black soldier fly larval frass is incorporated into respective plots as per treatment required after 1 week of planting. For sweet potato crop to receive 100 % nitrogen from BSF frass 2.33 t ha⁻¹ was required, 50 % nitrogen from BSF frass, 1.16 t ha⁻¹ was required, 25 % nitrogen from BSF frass, 0.58 t ha⁻¹ was required. Entire dose of urea and phosphorus was applied as basal, while potassium was applied at basal and top dressing. Manual weed control was practiced while water requirements were facilitated through check basin irrigation system.

Table 3: Treatment details of the experiment

T ₁	Absolute Control
T ₂	50 % RDN
T ₃	75 % RDN
T ₄	100 % RDN
T ₅	100 % RDN equivalent through BSF frass
T ₆	50 % RDN + 25 % RDN equivalent through BSF frass
T ₇	50 % RDN + 50 % RDN equivalent through BSF frass
T ₈	75 % RDN + 25 % RDN equivalent through BSF frass

(Note: Amount of P and K contents in the BSF frass was deducted and remaining amount of P and K applied through inorganic fertilizers).

The crop was harvested at 120 DAP and yield parameters like length of tuber, number of tubers plant⁻¹, tuber weight plant⁻¹ and tuber yield were recorded at harvest, whereas quality parameters such as total soluble solid and starch content of tuber were recorded after the harvest. Five plants were randomly selected from each plot and tagged in each replication and the mean value was calculated for yield and quality parameters.

Total sugar content was determined with the help of hand refractometer at the time of harvesting of tubers and expressed in percentage.

Starch content of sweet potato tubers was determined by anthrone reagent. In a tube containing 0.1–0.5 g of the sample, hot 80 % ethanol was added and homogenized to remove sugars. The mixture was centrifuged and the residue was retained. The residue was repeatedly washed with hot 80 % ethanol until the washings showed no color reaction with anthrone reagent, then dried over a water bath. To the dried residue, 5.0 ml of water and 6.5 ml of 52 % perchloric acid were added. The extraction was carried out at 0°C for 20 minutes, followed by centrifugation and the supernatant was collected. The extraction was repeated with fresh perchloric acid and the pooled supernatants were diluted to 100 ml. For colorimetric estimation, 0.1 or 0.2 ml of the supernatant was taken and adjusted to 1 ml with water. Then, 4 ml of anthrone reagent was added to each tube, heated in a boiling water bath for eight minutes and rapidly cooled. The intensity of the green to dark green colour was measured at 630 nm.

Data Analysis

The data collected from the research study was statistically analyzed using the analysis of variance (ANOVA) method for a randomized block design as described by Panse and Sukhatme (1978).

Results and Discussion

Yield parameters and Yield

All the yield-contributing parameters *i.e.*, number of tubers plant⁻¹, tuber weight plant⁻¹ (g), tuber length (cm) and tuber yield (t ha⁻¹) were significantly influenced by the application of BSF frass and its combinations with inorganic fertilizers (Table 4).

The treatment 75% RDN + 25% RDN equivalent through BSF frass (T₈) produced the maximum tuber length (18.2 cm), which was statistically on par with 50% RDN + 50% RDN equivalent through BSF frass (T₇). The lowest tuber length (10.5 cm) was recorded under T₁ (control).

The number of tubers plant⁻¹ followed a similar trend, with T₈ (6.2) and T₇ (5.9) significantly outperforming the rest of the treatments, while T₁ (1.7) was recorded lowest.

The tuber weight plant⁻¹ was also significantly increased by integrated treatments, with T₈ (438 g) being the highest and statistically comparable to T₇ (414 g). The lowest tuber weight (200.4 g) was recorded in the control treatment. The integrated treatments facilitated balanced and sustained nutrient availability, enhancing plant growth and tuber development.

Regarding tuber yield the highest was recorded in T₈ (26.36 t ha⁻¹) followed by T₇ (25.35 t ha⁻¹) which were significantly superior over other treatments. While, the minimum yield was reported in T₁ (11.20 t ha⁻¹).

The enhanced yield attributes and overall yield associated with the application of BSF larval frass and NPK fertilizer 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 Vasavi *et al.* (2024).

The enhancement in yield attributes and productivity may be due to the synergistic effect of BSF frass and inorganic N, which not only improved nutrient availability but also promoted better physiological processes and carbohydrate synthesis. These findings are in agreement with the reports of Nileesha *et al.* (2024) and Vasavi *et al.* (2024), who highlighted that organic residue like BSF frass, when used in combination with synthetic fertilizers, result in improved crop growth and yield.

The enhanced yield attributes and overall productivity observed with the combined application of Black Soldier Fly (BSF) larval frass and NPK fertilizers can be attributed to the complementary and synergistic effects of organic and inorganic nutrient sources. BSF frass is rich in essential nutrients such as nitrogen, phosphorus, potassium, and trace elements and also contains beneficial microorganisms that improve nutrient cycling, soil microbial activity and overall soil health (Menino *et al.*, 2021; Beesigamukama *et al.*, 2020). When used in conjunction with inorganic fertilizers, the slow-release nature of nutrients in frass complements the immediate availability from synthetic fertilizers, ensuring a balanced and sustained nutrient supply throughout the crop's lifecycle (Barragan *et al.*, 2017).

Additionally, the organic matter in frass enhances soil structure, moisture retention and aeration, which promotes healthier root systems and better tuber development (Lalander *et al.*, 2015). These favourable soil and plant physiological conditions lead to increased photosynthate production and translocation, efficient carbohydrate partitioning and ultimately, higher tuber number, size and yield.

The significantly lower yield observed in the absolute control (T₁) further emphasizes the crucial role of nutrient supplementation. Overall, the study highlights that partial substitution of RDN with BSF frass, especially at 75% RDN + 25% frass, is a promising and sustainable nutrient management strategy for improving sweet potato yield and soil health.

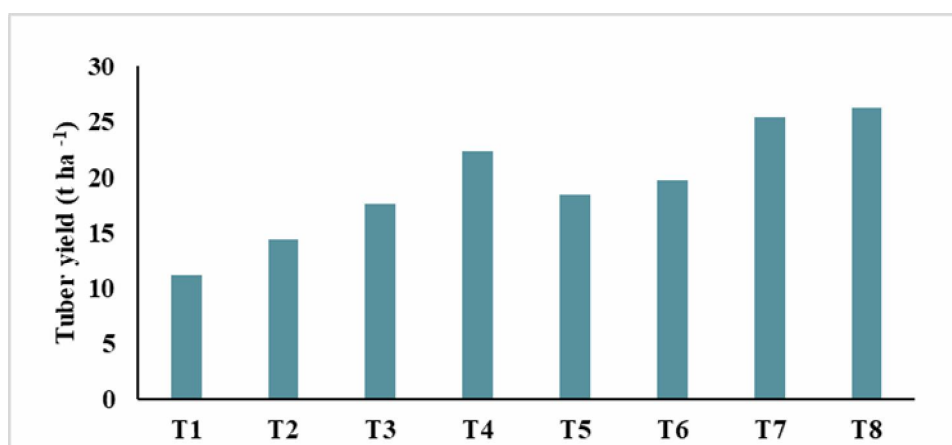


Fig. 1 Effect of black soldier fly larval frass in combination with NPK fertilizers on tuber yield (t ha^{-1})

Table 4: Effect of black soldier fly larval frass with NPK fertilizer application on yield attributes and yield

Treatments	Number of tubers plant ⁻¹	Weight of tuber plant ⁻¹ (g)	Length of tuber (cm)	Tuber yield (t ha^{-1})
T ₁ - Absolute Control	1.71	200.42	10.52	11.20
T ₂ - 50% RDN	3.40	261.33	12.41	14.38
T ₃ - 75% RDN	4.20	310.00	13.92	17.60
T ₄ - 100% RDN	5.15	389.87	16.07	22.35
T ₅ - 100 % RDN equivalent through BSF frass	4.54	341.67	13.95	18.50
T ₆ - 50% RDN + 25% RDN equivalent through BSF frass	4.37	324.00	14.15	19.77
T ₇ - 50% RDN + 50% RDN equivalent through BSF frass	5.86	414.00	17.79	25.35
T ₈ - 75% RDN + 25% RDN equivalent through BSF frass	6.20	438.00	18.24	26.36
SEm $\pm$	0.19	15.53	0.47	0.92
CD ($P=0.05$)	0.58	47.11	1.42	2.79
CV (%)	7.52	8.03	5.54	8.20

Quality Parameters

Quality parameters *i.e.*, starch content (%) and total sugar content ($^{\circ}\text{Brix}$), exhibited significant variation among the treatments due to the application of different combinations of BSF frass and inorganic sources (Table 5).

The treatment 75 % RDN + 25% RDN equivalent through BSF frass (T₈) recorded the highest starch content (18.80%) which was statistically on par with T₇ (50 % RDN + 50% RDN equivalent through BSF frass). These were significantly superior to the remaining treatments. The lowest starch content (11.63%) was observed in the control treatment (T₁).

This increase in starch content under integrated nutrient management can be attributed to enhanced nutrient availability, particularly nitrogen and potassium, which play a vital role in photosynthesis and carbohydrate synthesis. The strong positive correlation observed between starch content and tuber yield ($R^2 = 0.8303$) further supports the role of balanced fertilization in improving tuber quality. (Figure 3).

The total sugar content (TSS) increased progressively with integrated nutrient management involving chemical fertilizers and BSF frass. The highest TSS content (10.33 $^{\circ}\text{Brix}$) was recorded in treatment T₈ (75% RDN + 25% RDN equivalent through BSF frass), which was on par with T₇ (50% RDN + 50% RDN equivalent through BSF frass). The lowest TSS value (5.00 $^{\circ}\text{Brix}$) was observed in the absolute control (T₁).

The increase in TSS with combined use of BSF frass and chemical fertilizers may be attributed to improved nutrient availability, especially potassium, which plays a key role in sugar accumulation and translocation in tubers. These findings are supported by the observed strong correlation between TSS and tuber yield ($R^2 = 0.8294$), suggesting that better nutrient uptake promotes both yield and quality traits like TSS. (Figure 4).

The application of inorganic and organic manure boosted above-quality parameters in tubers, which might be attributed to improved nutritional availability in the crop's root zone as a result of organic matter solubilization and nutrient chelation. The significant improvement in starch and total sugar content observed

in treatments receiving combined applications of BSF frass and inorganic nitrogen, particularly T₈ (75 % RDN + 25 % RDN equivalent through BSF frass), can be attributed to the better carbohydrate metabolism and accumulation in the tubers. This may be due to improved nutrient assimilation, especially nitrogen and potassium, which play crucial roles in starch biosynthesis and sugar transport. The organic matter

and bioactive compounds present in BSF frass likely improved microbial activity and nutrient uptake efficiency, contributing to better metabolic functioning and quality parameter enhancement. Similar findings have been reported in shallots and red chillies where BSF frass-based liquid organic fertilizer (LOF) increased vitamin C, total soluble solids (Sopha *et al.*, 2025).

Table 5: Effect of black soldier fly larval frass with NPK fertilizer application on quality parameters

Treatments	Starch content (%)	Total sugar content (^o Brix)
T ₁ - Absolute Control	11.63	5.00
T ₂ - 50% RDN	13.68	6.35
T ₃ - 75% RDN	15.43	7.33
T ₄ - 100% RDN	16.75	7.91
T ₅ - 100 % RDN equivalent through BSF frass	17.93	9.29
T ₆ - 50% RDN + 25% RDN equivalent through BSF frass	17.67	8.60
T ₇ - 50% RDN + 50% RDN equivalent through BSF frass	18.77	9.84
T ₈ - 75% RDN + 25% RDN equivalent through BSF frass	18.80	10.33
SEm ±	0.27	0.17
CD (P=0.05)	0.83	0.53
CV (%)	2.89	3.72

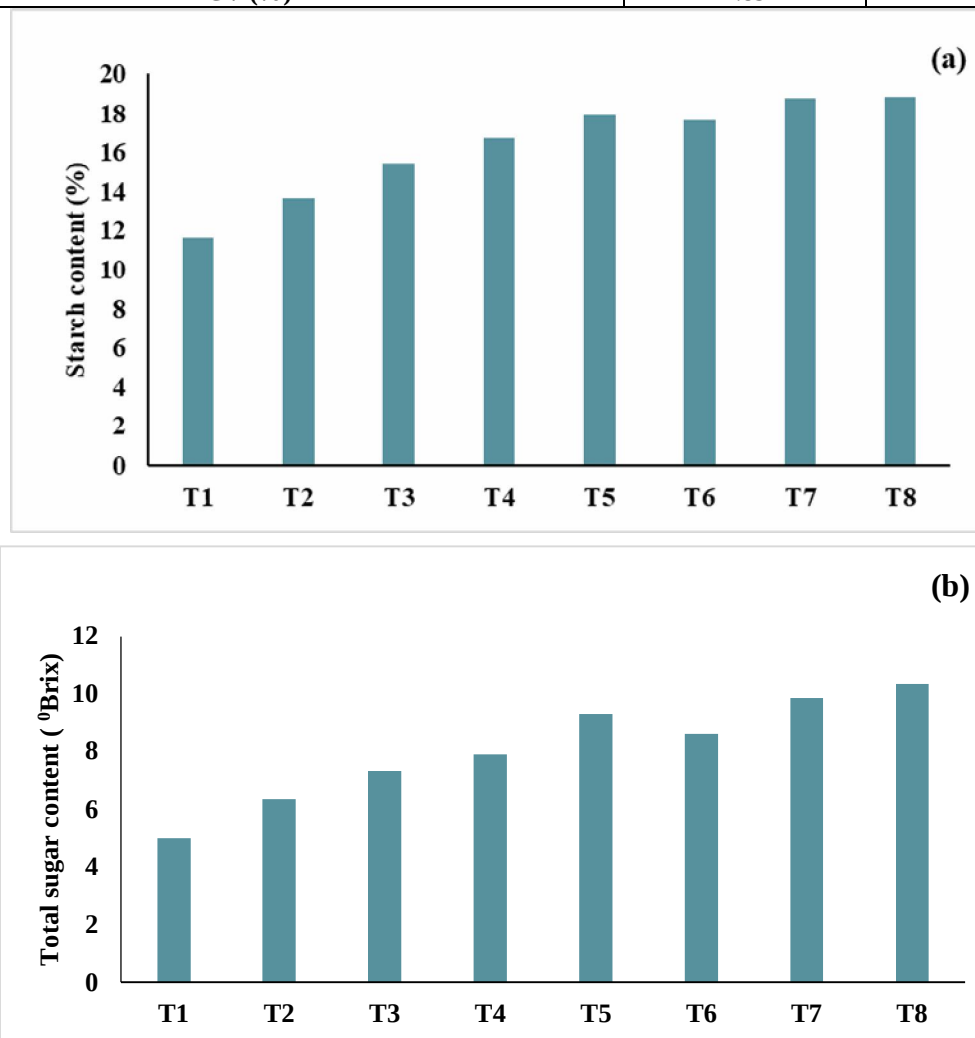


Fig. 2 : Effect of black soldier fly larval frass in combination with NPK fertilizers on quality parameters a) Tuber yield (t ha⁻¹) b) Starch content (%) c) Total sugar content (^oBrix)

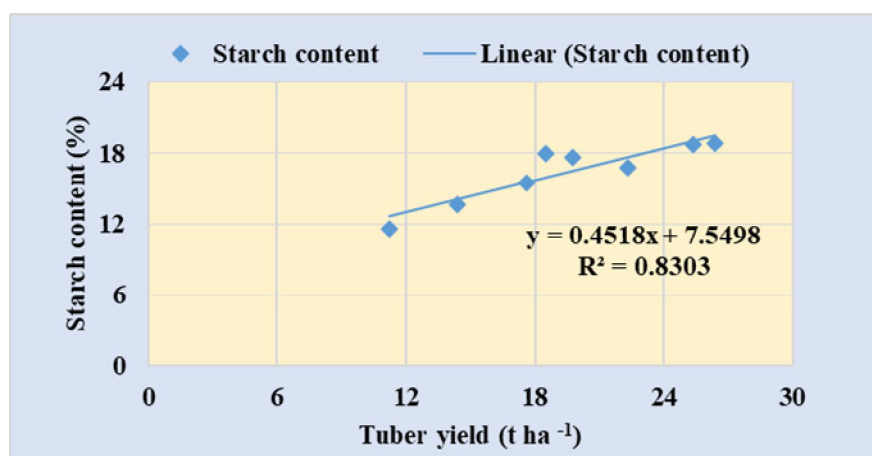


Fig. 3 : Correlation between starch content (%) and tuber yield (t ha⁻¹)

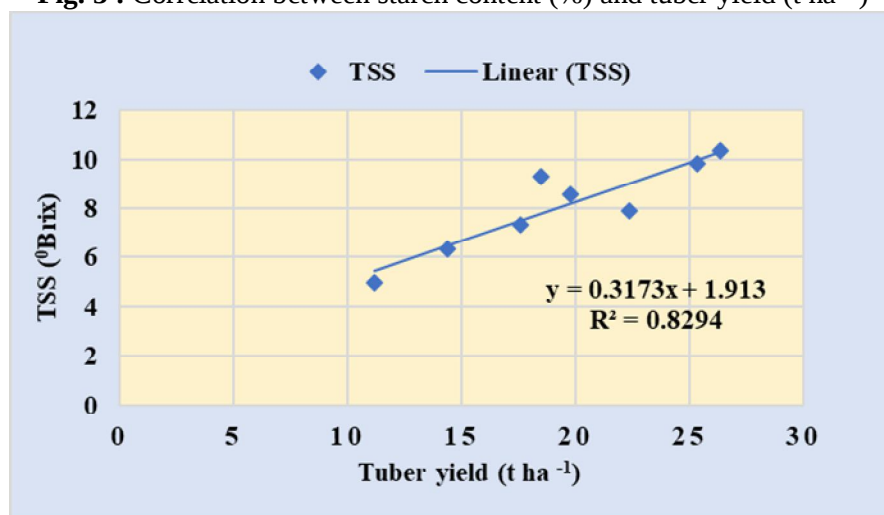


Fig. 4 : Correlation between total sugar content (°Brix) and tuber yield (t ha⁻¹)

Conclusion

Overall, the study demonstrated that black soldier fly larval (BSFL) frass positively influences sweet potato yield and quality when integrated with inorganic fertilizers. The combination of 75% RDN + 25% N through BSF frass resulted in the highest tuber yield and improved starch and sugar content. As a slow-release organic input, BSFL frass supports steady nutrient availability while reducing dependence on synthetic fertilizers.

Sweet potato responded well to this integrated approach, showing both agronomic and nutritional benefits. For growers, applying BSFL frass with reduced urea is recommended to optimize productivity and soil health. Incorporating frass contributes to circular agriculture by recycling organic waste and promoting sustainable farming practices.

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