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RESEARCH ARTICLE

In-situ decomposition of sugarcane trash using microbial consortium and its impact on ratoon cane

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Abstract

Sugarcane trash, consisting of leaves and stalk residues left after harvesting, poses challenges such as slow decomposition, nutrient imbalance and environmental concerns. This study explores an eco-friendly approach to sugarcane trash management using a microbial consortium to accelerate decomposition and improve soil health and ratoon cane yield. These microorganisms facilitate sugarcane trash decomposition by reducing the C: N ratio and breaking down lignocellulosic compounds. Applying a trash decomposer at 30 kg/ha on the 3rd, 15th and 30th days after harvest, along with 100 % RDF fertilizers, significantly reduced sugarcane trashs' C: N ratio to 18.25 by the 60th day. This treatment also improved growth and yield parameters in the ratoon crop. FTIR analysis confirmed compost maturity, shifting from aliphatic to aromatic compounds. The nitrate band at 1384 per cm intensified, while peak ratio changes indicated intensified decomposition progress of the trash. A higher proportion of cellulose-degrading consortia in trash D promoted the breakdown of complex molecules and reduced humification during *in-situ* decomposition. The findings suggest that integrating microbial decomposition strategies with lignocellulosic residues could enhance soil fertility, thus enhancing nutrient availability.

Keywords: decomposition; microbial consortium; ratoon cane; sugarcane; trash; *in-situ*

Introduction

Sugarcane (*Saccharum officinarum* L.) is a vital crop in the agro-industry, primarily cultivated for sugar production and bioethanol. However, sugarcane cultivation generates significant residual biomass, known as sugarcane trash, which remains in the field post-harvest. Improper management of this residue poses challenges such as soil degradation, increased pest incidence and environmental pollution (1). Sustainable alternatives, including microbial-assisted decomposition, are gaining attention as eco-friendly solutions for efficient sugarcane trash management (2). After harvesting, sugarcane trash accounts for 10-20 % of the total crop biomass (3). If effectively decomposed, it can contribute significant nutrients to the soil, including 30 kg of nitrogen, 9 kg of phosphorus and 24 kg of potassium per hectare (4). Sugarcanes' remarkable dry matter output makes it a valuable crop for biofuel, which is also used to produce sugar. Climate, soil type, crop management strategies, fertilizer management, irrigation timing and soil moisture availability during the growth period are some elements that affect sugarcane productivity (5). However, due to its high lignocellulose and silica content, natural decomposition is slow, necessitating external interventions such as microbial decomposition for rapid nutrient recycling. Sugarcane trash can be beneficial when appropriately managed. Mulching with sugarcane trash improves soil moisture retention, reduces erosion and enhances microbial activity (6). However, its high carbon-to-nitrogen (C:N) ratio (often exceeding 124:1) limits microbial decomposition, making external microbial inoculation necessary to accelerate breakdown and improve nutrient availability (5-7).

Microbial inoculation has been widely studied to accelerate organic matter degradation (8, 9). Specific microbial consortia, including fungi and actinobacteria, have been shown to enhance cellulose degradation and improve substrate utilization (10). However, sugarcane trash presents decomposition challenges due to its high silica content and large C:N ratio (124:1), requiring microbial amendments for efficient breakdown. This study evaluates the potential of a microbial consortium-based trash decomposer to enhance *in-situ* decomposition and improve ratoon cane yield (11, 12). Wider usage of specific trash-decomposing fungal genera such as *Chaetomium globosum* and silica/potash solubilizing *Bacillus mucilaginosus* along with yeast molasses, rock phosphate and gypsum is highly limiting in most of the previous research and the present study aims to fill the research gap so to develop a microbial consortium for *in-situ* trash decomposition, especially in ratoon cane.

Materials and Methods

The experiment was conducted from July 2022 to August 2023 at the Sugarcane Research Station, Cuddalore. The site has a clayey loam soil type, with an annual mean rainfall of 1210 mm and an altitude of 4.6 m above sea level (Fig. 1).

Experimental design

A microbial consortium, Trash Decomposer (Trash D), was developed to accelerate sugarcane trash decomposition.

TNAU Trash D formulation

Trash D formulation consisted of the following components per tonne of trash (Fig. 3):

- *Bacillus mucilaginosus* (10^9 cfu/mL at 40 mL)
- *Chaetomium globosum* TNAU cg 6 and *Trichoderma viridi* TNAU TV1 each (10^6 cfu/mL at 30 mL each).
- Yeast molasses (20 L)
- Rock phosphate (20 kg)
- Gypsum (20 kg)

Treatments

T_1	:	Trash D at 20 kg/ha* + 125 % RDF
T_2	:	Trash D at 30 kg/ha* + 125 % RDF
T_3	:	Trash D at 20 kg/ha* + 100 % RDF
T_4	:	Trash D at 30 kg/ha* + 100 % RDF
T_5	:	Trash D at 20 kg/ha* + 75 % RDF
T_6	:	Trash D at 30 kg/ha* + 75 % RDF
T_7	:	100 % RDF alone + untreated trashes (Control)

* Trash D was applied in three stages: (i) on the 3rd day after harvest, (ii) on the 15th day and (iii) on the 30th day. Irrigation was provided uniformly to enhance microbial activity. Standard ratoon management practices were followed across all treatments, including stubble shaving, root pruning, thinning and earthing up.

Compost analysis

Trash decomposition was monitored by collecting samples on the 10th, 30th and 60th days after harvest. Organic carbon was estimated per Walkley and Blacks' procedures and total nitrogen was calculated using the Macro-Kjeldhal method (13, 14). The samples were analyzed using standard procedures for pH, organic carbon, total nitrogen, phosphorus, potassium and C: N ratio.

Effect of Trash D on crop yield

At harvest, tiller population, cane height, number of nodes, cane girth, individual cane weight, Commercial Cane Sugar (CCS %) and total cane yield (t/ha) were recorded.

Statistical Analysis

The experimental data were statistically scrutinized using the standard method (15). The critical difference was achieved at a 5 % (0.05) probability.

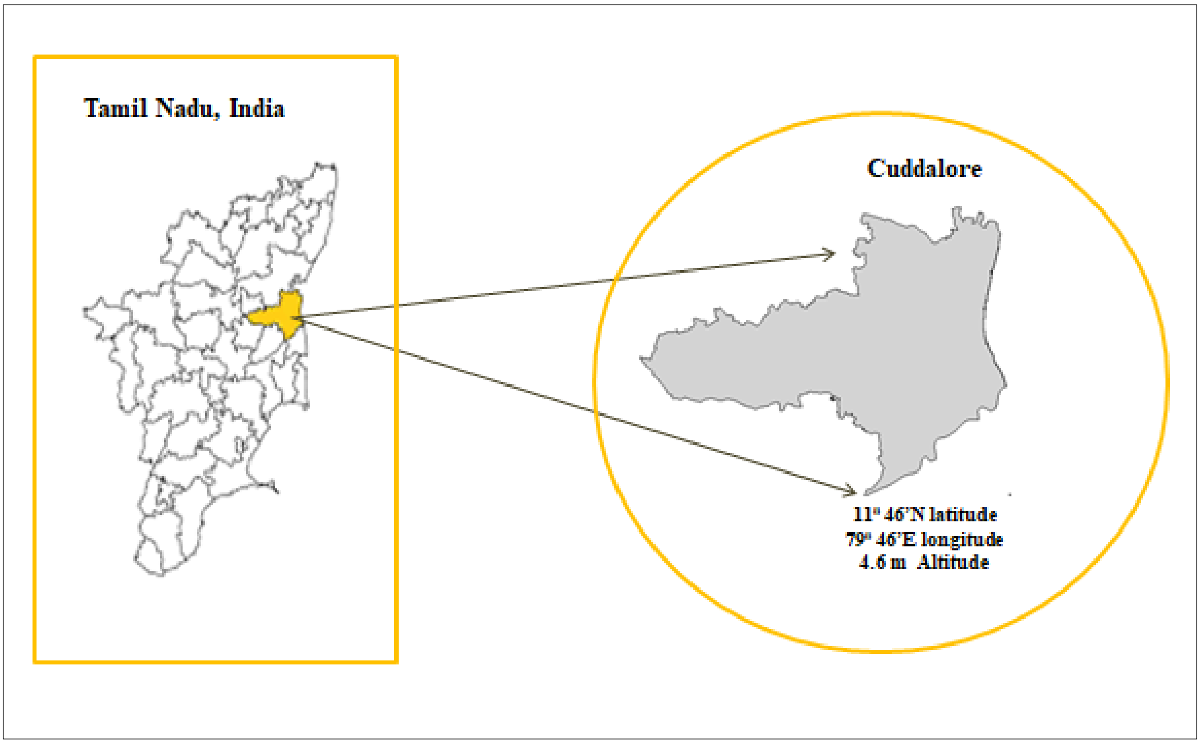


Fig. 1. Study area.

Result and Discussion

Characterization of soil

The experimental soil had a pH of 6.9 (slightly acidic to neutral) and an EC of 0.25 dSm^{-1}, indicating low to moderate salinity. Organic carbon content was 0.32 %, while available nitrogen, phosphorus and potassium levels were 157.5, 35.0 and 145.0 kg/ha, respectively, sufficient for sugarcane growth.

Overall, the soil characteristics suggest that the soil has a pH close to neutral and moderate organic carbon content. Favourable levels of essential nutrients such as nitrogen, phosphorus and potassium (Fig. 2). If soil organic matter is consistently cultivated for agricultural production, it decomposes quickly due to changes in the soils' physical qualities, particularly in tropical and semiarid countries (16). This results in a decrease in soil productivity and soil carbon depletion (17). Applying appropriate input management techniques can improve carbon sequestration and decrease atmospheric CO_2 enrichment (18). Furthermore, the addition of plant remains may have an impact on the soil microclimate (19).

FTIR analysis

FTIR analysis confirmed compost maturity, shifting from aliphatic to aromatic compounds. The nitrate band at 1384 cm^{-1} intensified, while peak ratio changes (1384/2925 and 1034/1384) indicated decomposition progress (Fig. 4). The presence of amides, alkanes, phenols and aromatics further validated microbial activity in degrading sugarcane trash. Vibrations of the methylene group in the spectral range from 1375 to 1150 per cm can be observed in the FTIR spectra (Table 1). Similar results were observed in straw materials. Cellulose and hemicellulose are the most easily broken down by bacteria, whereas lignin is the most difficult (20).

In the closed pile, the quantity of this band was gradually increased and then decreased in composting. This band intensity of inoculated compost by microorganisms increased slightly after the composting process and the highest intensity was observed in closed piles in 16 days (21, 22). The FTIR spectra of the dissolved organic matter showed a decline in aliphatic compounds, protein class and carbohydrates in the infected pile compared to the closed pile (Fig. 7). FTIR absorption peaks confirmed and supplemented the previous results related to the rapid disappearance of compost readily biodegradable components and increased concentration of aromatic compounds due to the compost of microorganisms (23).

Scanning electron microscopy (SEM) analysis

The morphology of sugarcane fresh leaf and composted material was analyzed using SEM, providing insights into their shape, growth mechanisms and size. SEM analysis revealed the structural breakdown of sugarcane trash after decomposition. Composted material showed reduced fibre integrity and increased microbial colonization compared to

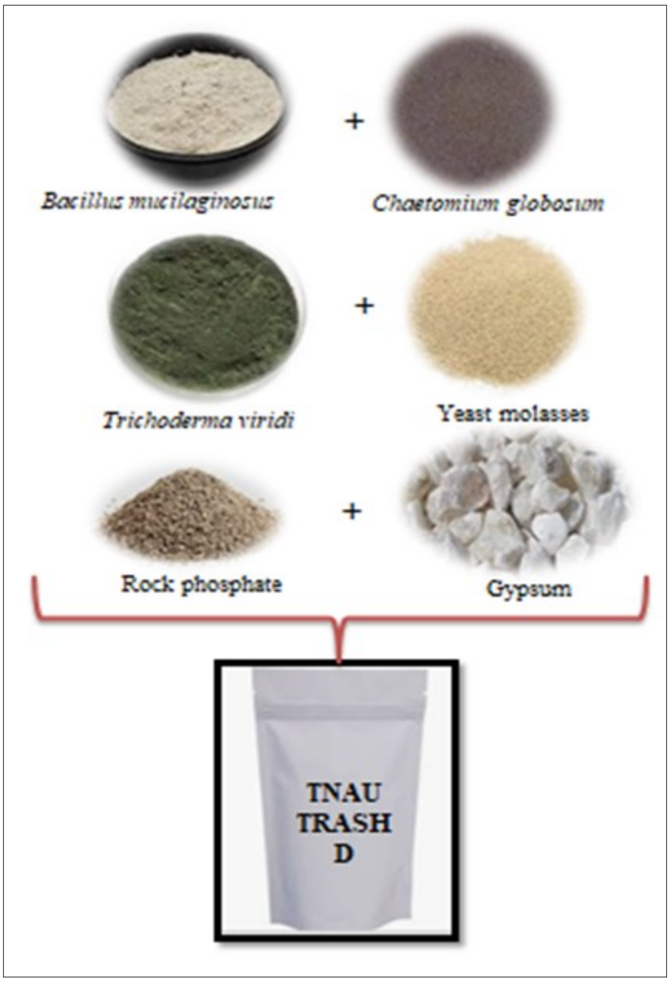


Fig. 3. Trash decomposer (Trash D formulation).

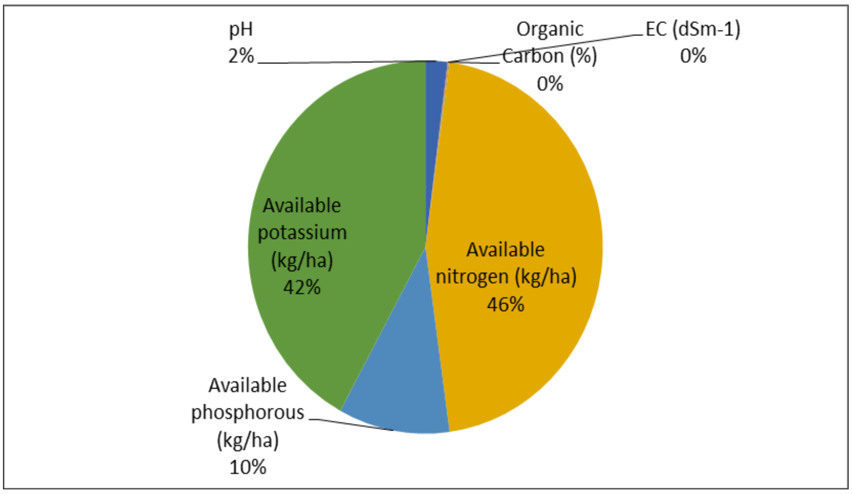


Fig. 2. Chemical properties of the experimental soil.

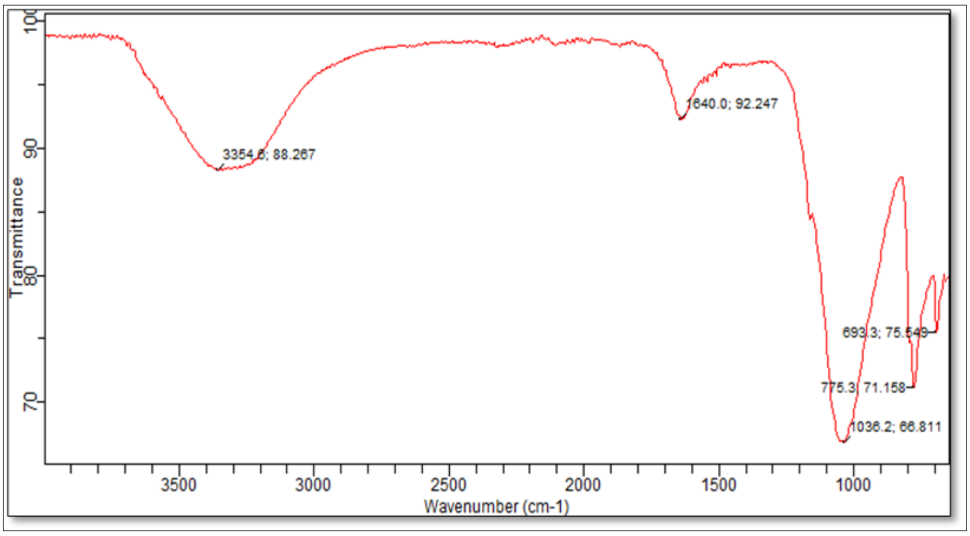
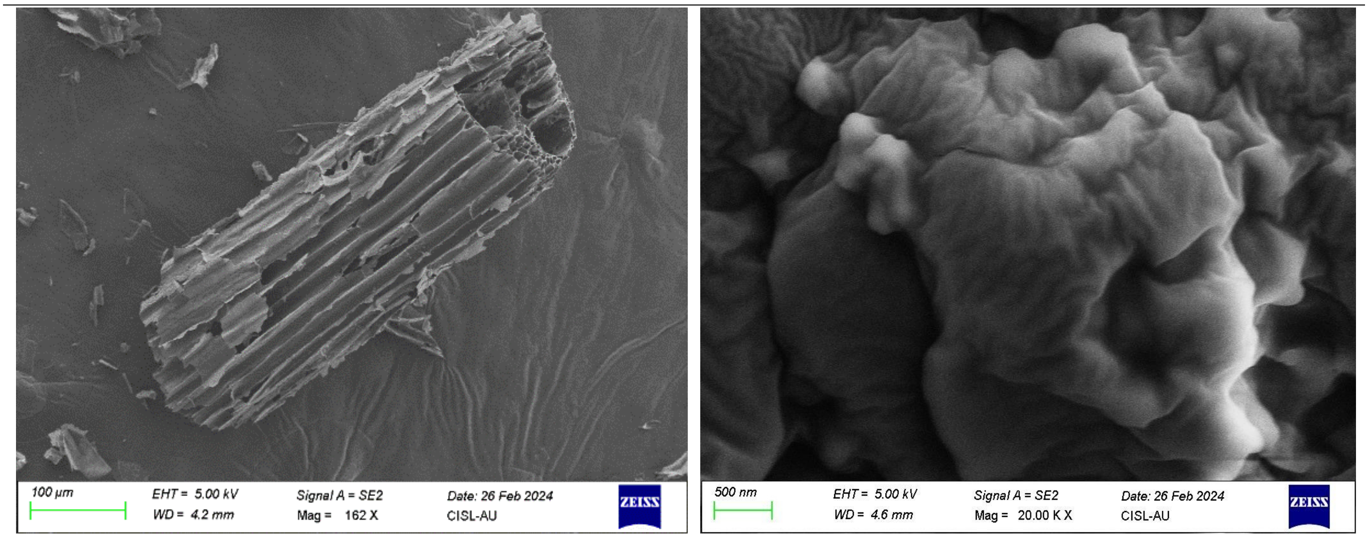


Fig. 4. FTIR analysis of trash D treated sugarcane trash.

Table 1. Effect of Trash D on sugarcane trash *in-situ* decomposition by FTIR analysis

Absorbed Peak value (cm^{-1})	Bonds	Functional groups
3918.30 2000.86	C-H stretch	Alkanes (Aliphatic)
3776.30 2062.80 2374.86	N-H stretch	1°, 2° amines, amides, alkalides
1654.92	N-C=O	Amide carbonyl stretching vibration in carbon bond
1960.41 2508.33	C=C	Secondary aromatic
1384.89	O-H	Phenolic; ligneous



A) Fresh sugarcane trash **B) Composted sugarcane trash**

Fig. 5. a) SEM analysis of fresh; **b)** Composted sugarcane trash.

fresh leaves, confirming microbial action in lignocellulose degradation (Fig. 5).

Effect of TNAU Trash D on C: N ratio

The graphical data on different treatments (T_1 to T_7) and their impact on trash properties, including total carbon percentage, total nitrogen percentage and the carbon to nitrogen (C: N) ratio at various time points such as the initial, 10^{th} day, 30^{th} day and 60^{th} day is presented in Fig. 6. The total carbon percentage represents the proportion of carbon in the sample. A reduced C: N ratio typically indicates higher decomposition and nutrient mineralization. The C: N ratio varies among treatments and periods, reflecting differences in nutrient dynamics and decomposition rates (Table 2). Sugarcane trash mulch conserves soil organic matter, essential for maintaining soil fertility and better crop growth over a more extended period (24). These parameters are crucial for understanding nutrient cycling, decomposition processes and soil health.

Trash D significantly reduced the C: N ratio, indicating enhanced decomposition and nutrient mineralization. The initial C:N ratio was significantly varied and was recorded as 40.75:0.59 at and after the different treatment effects; the lowest C: N ratio (18.25) was observed in trash D at 30 kg/ha + 100 % RDF. At the same time, the control had the slowest breakdown. The treatment details are provided in Table 3. The data helps identify treatments that may promote more favourable carbon and nitrogen dynamics in the soil, influencing plant growth and crop yield. Treatments with a

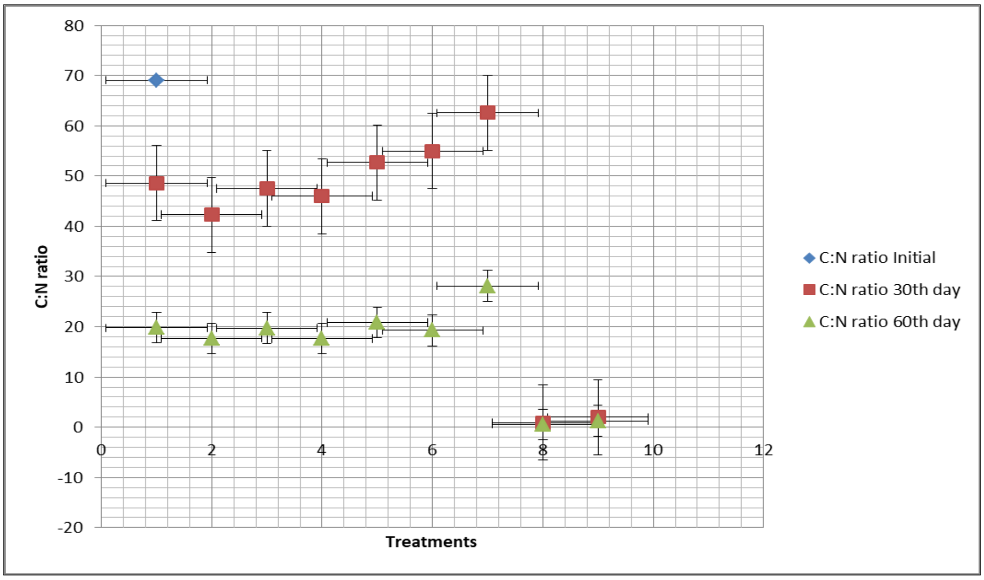


Fig. 6. C: N ratio of sugarcane trash decomposed *in-situ* by trash D.

Field level application of trash D in ratoon cane | **Field condition on 30 days** | **Field condition on 60 days after trash decomposition *in-situ***

Fig. 7. Field application of trash D over the trashes and its effect on growth.

reduced C: N ratio (trash D @ 30 kg/ha+ 100 % RDF) indicate more efficient decomposition and potential for higher nutrient mineralization. Conversely, treatments with a higher C: N ratio (control) suggest slower organic matter breakdown and nutrient release. Overall, in all treatments, compost maturity was obtained after 60 days of decomposition except for control (25). The C: N ratio is considered one of the simple indices used to evaluate any organics for its suitability for soil application and it is the index traditionally used to establish the maturity degree of the compost (26). The integrated system of composting with bioinoculants followed by vermicomposting in recent years has gained worldwide attention to overcome the problem of the degradation of lignocellulosic waste of various agricultural residues and waste industrial by-products (27). In another study, sugarcane trash treated with EM-F exhibited C: N ratio value (14.44:1) on 60 days of composting (28). Effective microorganisms extract (EM), yeast (*Saccharomyces*), actinomycetes (*Streptomyces*), fungi (*Aspergillus*); EM-F rich in lactic acid bacteria (*Lactobacillus* were used in the above study (29).

Table 2. Effect of Trash D on sugarcane trash *in-situ* decomposition and its impact on C: N ratio

Treatments	Total carbon (%)		Total nitrogen (%)	
	30th day	60th day	30th day	60th day
T_1	28.54	21.97	0.84	1.11
T_2	26.2	21.24	0.92	1.20
T_3	28.97	22.91	0.88	1.16
T_4	25.37	21.56	0.9	1.22
T_5	29.74	22.51	0.89	1.08
T_6	28.94	21.78	0.85	1.13
T_7	33.67	25.89	0.73	0.92
SE±	0.69	0.59	0.02	0.02
CD (0.05)	**1.49**	**1.31**	**0.04**	**0.04**

Yield and quality parameters

Yield was highest in Trash D at 30 kg/ha + 125 % RDF (137.1 t/ha), followed by Trash D at 30 kg/ha + 100 % RDF (135.2 t/ha). Control recorded the lowest yield (115 t/ha). Trash D treatments also improved cane height, girth and CCS %, aligning with previous studies (30, 31). The research data highlight that trash mulching had additional benefits, including moisture conservation, weed control, enhanced soil biological activity and increased number of earthworms, which

Table 3. Effect of TNAU Trash D on *in-situ* sugarcane trash decomposition and yield attributes of sugarcane

Treatments	Tiller population ('000/ha)	Yield parameters					CCS (%)
		Cane height (cm)	No. nodes / cane	Cane girth (cm)	Individual cane weight (kg)	Cane yield (t/ha)	
T_1	181.5	210	20	2.30	1.88	126.9	11.4
T_2	186.1	208	22	2.88	1.99	137.1	12.2
T_3	181.5	202	20	2.36	1.82	126.5	11.6
T_4	184.4	204	23	2.56	1.87	135.2	12.0
T_5	182.3	200	20	2.48	1.76	120.2	11.6
T_6	183. 5	203	22	2.49	1.80	129.4	11.4
T_7	166.7	189	18	2.17	1.72	115.0	10.2
SEd	3.15	3.86	0.31	0.05	0.04	1.57	NS
CD (0.05)	6.86	8.40	0.67	0.10	0.09	3.43	-

finally leads to higher yield. It also found that garbage mulching enhances sugarcane productivity and soil health (32).

Conclusion

This study demonstrates that microbial decomposition using trash decomposer (Trash D) at 30 kg/ha , combined with balanced fertilization, significantly enhances soil health and sugarcane yield. Trash D treatments at 30 kg/ha + 100 % RDF and at 30 kg/ha + 125 % RDF improved decomposition efficiency, reduced the C: N ratio and increased crop performance, confirming the benefits of integrating microbial technology in sustainable agriculture. Compost maturity was achieved within 60 days in all Trash D-treated plots, enhancing soil nutrient dynamics. The significant improvements in yield and soil fertility observed in T_2 (30 kg Trash D + 125 % RDF) and T_4 (30 kg Trash D + 100 % RDF) highlight the potential of microbial decomposition as an eco-friendly alternative to traditional trash management methods. Future studies should optimize microbial formulations for different soil types and climates. Large-scale field trials and economic analyses will further validate the feasibility of microbial trash decomposers in sustainable sugarcane production systems.

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Authors' contributions

SMP and GG contributed to conceptualization, writing of the original draft, as well as reviewing and editing the manuscript. PG, KP, KM, NK, SD and BKK contributed to the writing of the original draft, and was involved in reviewing and editing the manuscript. SMP, GG and SD contributed to formal analysis. SMP, GG and KP was responsible for funding acquisition. All authors read and approved the final version.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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