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Impact of liquid bioconsortia on the composting dynamics and maturity of sugarcane trash

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Abstract
The use of liquid bioconsortia offers a promising approach to accelerate the biodegradation of agricultural residues through enhanced microbial diversity and enzymatic activity. A two-year field investigation was conducted to assess the impact of cellulolytic liquid bioconsortia on the composting dynamics and maturity of sugarcane trash. Among the treatments, application of cellulolytic liquid bioconsortium at 2 L per metric ton (T_4) of sugarcane trash exhibited superior composting performance, with the highest total organic carbon (20.45%), lowest C:N ratio (18.90), greatest weight loss (18.87 kg pit^{-1}), and maximum decomposition (41.93%). The same treatment also recorded the shortest composting period (129 days) and peak temperature of 66.15°C, indicating faster biodegradation and maturity compared with the control. Microbial analysis of matured compost revealed significantly higher populations in T_4, with mean bacterial counts of 22.28 × 10^7 cfu g^{-1}, fungal counts of 17.83 × 10^4 cfu g^{-1}, and actinomycetes counts of 17.53 × 10^5 cfu g^{-1}. Overall, the study demonstrated that cellulolytic liquid bioconsortia effectively enhance the decomposition rate and compost quality of sugarcane trash, promoting efficient organic waste recycling and sustainable soil nutrient management.

Keywords: Organic carbon, bioconsortia, decomposition, microbial populations, etc

Introduction

Liquid formulations have emerged as an advanced technology in India, characterized by unique physicochemical properties and production processes. Liquid biofertilizers are specialized formulations that contain beneficial microbial strains along with cell protectants and metabolic by-products that enhance the viability, shelf life, and tolerance of the microbes under adverse environmental conditions (Pindi *et al.*, 2012) [11]. Microorganisms such as bacteria, fungi, and actinomycetes play distinct yet complementary roles in the composting process. When applied as a mixed culture, their synergistic interactions accelerate the degradation of lignocellulosic residues by efficiently utilizing intermediate decomposition products. Hence, the use of microbial consortia facilitates the rapid breakdown of complex organic wastes.

Burning of crop residues has become a common but detrimental practice, significantly altering the chemical, biological, and physical properties of soil. This practice reduces soil organic matter (Malhi *et al.*, 2011) [8], disrupts soil aggregation and structure (Turmel *et al.*, 2015), and adversely affects nutrient cycling. Continuous residue burning depletes soil organic carbon, increases soil pH, and diminishes nutrient availability (Butterly *et al.*, 2011) [4]. Moreover, intensive crop harvesting without replenishment of organic inputs has led to a progressive decline in soil organic carbon levels. Traditionally, compost and farmyard manure served as vital amendments for maintaining soil fertility. However, modernization of agriculture and reduced livestock populations have limited their availability, prompting the exploration of alternative organic sources. In this context, agrowastes particularly sugarcane trash represent an abundant and renewable resource for compost production (Roohallah *et al.*, 2024) [13].

The main challenge lies in efficiently and rapidly converting agrowastes into mature compost. Conventional open-air composting often proceeds slowly and inconsistently due to suboptimal microbial and environmental conditions (Mohd Huzairi *et al.*, 2022) [9]. The introduction of liquid bioconsortia offers a promising solution. These formulations, composed of cellulolytic fungi, bacteria, and actinomycetes, enhance the degradation of lignocellulosic residues through a diverse enzymatic system. By providing functional microbial diversity and metabolic synergy, liquid bioconsortia accelerate decomposition, improve compost quality, and contribute to sustainable recycling of agricultural residues.

Materials and Methods

Experimental Site and Design

A field experiment was conducted at Mahatma Phule Krishi Vidyapeeth (MPKV), Rahuri, Maharashtra, to investigate the impact of liquid bioconsortia on the composting dynamics and maturity of sugarcane trash. The experiment was laid out in a Randomized Block Design (RBD) with four replications and six treatments.

The treatments were as follows:

- **T_1:** Cellulolytic liquid bioconsortia @ 0.5 L per metric ton (MT) of sugarcane trash
- **T_2:** Cellulolytic liquid bioconsortia @ 1.0 L per MT
- **T_3:** Cellulolytic liquid bioconsortia @ 1.5 L per MT
- **T_4:** Cellulolytic liquid bioconsortia @ 2.0 L per MT
- **T_5:** MPKV reference decomposing culture @ 1 kg per MT
- **T_6:** Absolute control (without inoculant)

The data were subjected to statistical analysis using analysis of variance (ANOVA) as per Panse and Sukhatme (1985). The standard error (SE) and critical difference (CD) at 5% significance level were computed to compare treatment means.

Composting Procedure

Composting was carried out in pits of 1 × 1 × 1 m³. Chopped sugarcane trash (4-5 cm) weighing 45 kg per pit was used. A 1% urea solution was added to lower the C:N ratio and promote microbial growth. Treatments were applied according to protocol, while uninoculated pits served as control. Moisture was maintained at 60-65% and pits were turned fortnightly. Initial and final C:N ratios were recorded. The initial and final C:N ratios were determined following standard analytical procedures.

Physico-Chemical Analysis

Organic carbon was determined by the ignition method (Bremner *et al.*, 1970) [3]. Compost maturity was evaluated using established parameters (Ranalli *et al.*, 2001; Goyal *et al.*, 2005) [12, 6]. Temperature was measured weekly with a digital thermometer. Microbial populations (bacteria, fungi, actinomycetes) were determined using serial dilution techniques.

Determination of Organic Matter and Ash Content

The loss on ignition (LOI) method was used to determine the organic matter and ash content in compost samples. Approximately 5-10 g of air-dried compost (2 mm sieve) was weighed into a pre-weighed silica crucible (W_1). The crucible was then:

- Dried at 105°C for 4 hours and reweighed (W_2).
- Ignited in a muffle furnace at 550-600°C for 4 hours and reweighed after cooling (W_3).

The ash content (%) and organic matter (%) were calculated as follows:

i) $$\text{Ash content } (\%) = \frac{W2-W1}{W2-W1} \text{X } 100$$

ii) $$\text{Organic matter } (\%) = 100 - \text{ Ash content } (\%)$$

iii) $$\text{Organic Carbon } (\%) = \frac{\text{Organic matter } (\%)}{1.724}$$

Where 1.724 is the Van Bemmelen factor, assuming organic matter contains 58% organic carbon.

The C:N ratio was computed as:

iv) $$\text{C: N ratio } = \frac{\text{Organic Carbon } (\%)}{\text{Total Nitrogen } (\%)}$$

Results and Discussion

The total organic carbon content of the compost varied from 14.11% to 20.67% in 2022-23, from 14.65% to 20.23% in 2023-24, and from 14.38% to 20.45% on a two-year average basis (Table 1 and Fig 1). The highest total organic carbon was recorded in treatment T_4, where cellulolytic liquid bioconsortium was applied at 2 L per metric ton (MT) of sugarcane trash, with corresponding values of 20.67%, 20.23%, and 20.45% for the respective years and the average. This treatment was statistically superior to all other treatments. The lowest total organic carbon was recorded in T6 (absolute control), with values of 14.11%, 14.65%, and 14.38% for 2022-23, 2023-24, and the pooled average, respectively.

The C:N ratio ranged from 18.11 to 28.88 in 2022-23, 19.69 to 29.64 in 2023-24, and 18.90 to 29.26 for the pooled mean of both years (Table 1 and Fig 2). The maximum C:N ratio was observed in T6 (absolute control), while the minimum C:N ratio was recorded in T_4 (cellulolytic liquid bioconsortia @ 2 L/MT of sugarcane trash). A lower C:N ratio in the T_4 treatment indicated enhanced decomposition and better compost quality. These results are in line with earlier studies, where Dhapate *et al.* (2018) [5] reported that cellulolytic fungal isolates reduced the C:N ratio of sugarcane trash compost to 16.3 and organic carbon to 17.5%, while increasing nitrogen to 1.07%. Similarly, Bambharolia *et al.* (2024) [1] reported that lignocellulolytic microorganisms enhanced the biodegradation of sugarcane trash, resulting in an organic carbon content of 17.85% and a C:N ratio of 13.02.

The effects of liquid bioconsortia on weight loss and percentage decomposition of sugarcane trash compost are presented in Table 2, Fig 3 and Fig 4. The initial weight of the composting material was 45 kg per pit. Treatment T_4 exhibited the highest weight loss and decomposition, with 18.70 kg per pit and 41.54% in 2022-23, 19.04 kg per pit and 42.31% in 2023-24, and a pooled mean of 18.87 kg per pit and 41.93%. This treatment was significantly superior to all others. In contrast, T6 (absolute control) recorded the lowest weight loss and decomposition, with 7.44 kg per pit (16.53%) in 2022-23 and 5.51 kg per pit (12.24%) in 2023-24, giving a pooled mean of 6.47 kg per pit (14.39%). Hemalatha *et al.* (2024) [7] similarly reported that the application of a microbial consortium at 2 kg/ton of sugarcane trash accelerated decomposition by 39.45%, achieving a C:N ratio of 18.77, 37.34% mass loss, and 44.55% volume reduction within 89 days.

The period required for compost maturity varied significantly among treatments. The maturity period ranged from 132 to 226 days in 2022-23, 126 to 239 days in 2023-24, and 129 to 233 days on average across both years (Table 3 and Fig 5). The shortest maturity period was recorded in T_4, with 132 days in 2022-23, 126 days in 2023-24, and a pooled average of 129 days. The absolute control (T6) took the longest time to mature, requiring 226, 239, and 233 days in 2022-23, 2023-24, and the pooled mean, respectively. The results are consistent with those reported by Patil *et al.* (2021) [10], who observed that sugarcane waste decomposed in 128 days, while a mixture of banana, cotton, and sugarcane residues required 144 days. Temperature dynamics during composting followed a typical thermophilic pattern (Table 4 and Table 5). In the 2022-23 cycle, T_4 (cellulolytic liquid bioconsortium @ 2 L/MT) reached a maximum temperature of 65.5°C during the ninth week, after which it gradually declined. In 2023-24, T_4 recorded a peak temperature of 66.8°C during the ninth week, followed by a decrease. Treatment T_3 (1.5 L/MT) exhibited a temperature peak of 63.2°C in the thirteenth week during 2022-23 and 64.4°C during the eighth week in 2023-24. In contrast, the absolute control (T_6) showed delayed peaks, reaching 65.8°C in the twenty-second and twenty-first weeks during 2022-23 and 2023-24, respectively. These results agree with the findings of Hemalatha *et al.* (2024) [7], who observed temperature variations ranging from 47.8°C to 28°C during sugarcane trash decomposition, indicating a progression from the thermophilic to the maturation phase.

Microbial population dynamics of bacteria, fungi, and actinomycetes also showed significant variation among treatments (Table 6). In matured compost, T_4 recorded the highest bacterial population, with mean values of 20.95×10^7 cfu g^{-1} in 2022-23, 23.61×10^7 cfu g^{-1} in 2023-24, and a pooled average of 22.28×10^7 cfu g^{-1} (Fig. 6). The absolute control showed the lowest bacterial counts (11.74×10^7, 9.74×10^7, and 10.74×10^7 cfu g^{-1} for the respective years and pooled average). Similarly, T_4 recorded the highest fungal populations of 16.82×10^4 and 18.84×10^4 cfu g^{-1} in 2022-23 and 2023-24, respectively, with a pooled mean of 17.83×10^4 cfu g^{-1} (Fig. 7). The lowest fungal population was observed in T6. Actinomycetes counts were also highest in T_4 (18.48×10^5 and 16.59×10^5 cfu g^{-1} in 2022-23 and 2023-24, respectively) with a pooled mean of 17.53×10^5 cfu g^{-1}, while T6 recorded the lowest values (Fig. 8). Similar trends were reported by Beary *et al.* (2002) [2], who noted substantial increases in bacterial (2×10^8 cfu g^{-1}) and fungal (1×10^7 propagules g^{-1}) populations following the application of microbial consortia to sugarcane residues.

Overall, the findings of the present study demonstrate that the application of cellulolytic liquid bioconsortia significantly enhances the rate of sugarcane trash decomposition, improves compost maturity, and supports the proliferation of beneficial microbial populations. These combined effects contribute to the production of high-quality compost and sustainable recycling of agrowaste resources.

Table 1: Total organic carbon and C:N ratio recorded in matured compost influenced by liquid bioconsortia

Tr. No.	Treatments	Organic Carbon (%)		Pooled (%)	C:N ratio		Pooled
		2022-23	2023-24		2022-23	2023-24	
T_1	Cellulolytic liquid bioconsortium @ 0.5 litre per MT of sugarcane trash	14.80	17.28	16.04	24.33	24.50	24.41
T_2	Cellulolytic liquid bioconsortium @ 1 litre per MT of sugarcane trash	15.62	16.78	16.20	22.87	23.51	23.19
T_3	Cellulolytic liquid bioconsortium @ 1.5 litre per MT of sugarcane trash	16.57	18.88	17.73	21.61	21.94	21.77
T_4	Cellulolytic liquid bioconsortium @ 2 litre per MT of sugarcane trash	20.67	20.23	20.45	18.11	19.69	18.90
T_5	MPKV's decomposing culture @ 1gm/kg of Sugarcane trash	15.24	12.92	14.08	26.61	24.85	25.73
T_6	Absolute control	14.11	14.65	14.38	28.88	29.64	29.26
	S.E m.±	1.13	1.16	0.81	0.86	0.52	0.50
	CD at 5%	3.42	3.51	2.35	2.59	1.56	1.45

Table 2: Loss of weight and Decomposition per cent in matured compost influenced by liquid bioconsortia

Tr. No.	Treatments	Loss of weight (kg/pit)		Pooled (kg/pit)	Decomposition (%)		Pooled (%)
		2022-23	2023-24		2022-23	2023-24	
T_1	Cellulolytic liquid bioconsortium @ 0.5 litre per MT of sugarcane trash	13.94	14.50	14.22	30.98	32.23	31.60
T_2	Cellulolytic liquid bioconsortium @ 1 litre per MT of sugarcane trash	16.02	15.88	15.95	35.61	35.29	35.45
T_3	Cellulolytic liquid bioconsortium @ 1.5 litre per MT of sugarcane trash	17.13	16.42	16.78	38.07	36.48	37.28
T_4	Cellulolytic liquid bioconsortium @ 2 litre per MT of sugarcane trash	18.70	19.04	18.87	41.54	42.31	41.93
T_5	MPKV's decomposing culture @ 1gm/kg of Sugarcane trash	12.32	11.91	12.11	27.38	26.46	26.92
T_6	Absolute control	7.44	5.51	6.47	16.53	12.24	14.39
	S.E m.±	0.59	0.73	0.47	1.32	1.63	1.05
	CD at 5%	1.79	2.21	1.36	3.97	4.91	3.02

Table 3: Average days required for maturity of composting using liquid bioconsortia

Tr. No.	Treatments	Days required for maturity		Pooled
		2022-23	2023-24	
T_1	Cellulolytic liquid bioconsortium @ 0.5 litre per MT of sugarcane trash	166	158	162
T_2	Cellulolytic liquid bioconsortium @ 1 litre per MT of sugarcane trash	152	143	148
T_3	Cellulolytic liquid bioconsortium @ 1.5 litre per MT of sugarcane trash	133	139	136
T_4	Cellulolytic liquid bioconsortium @ 2 litre per MT of sugarcane trash	132	126	129

T_5	MPKV's decomposing culture @ 1gm/kg of Sugarcane trash	178	187	183
T_6	Absolute control	226	239	233
	S.Em.±	1.76	2.24	1.42
	CD at 5%	5.29	6.75	4.11

Sr. No.	Treatments	Weekly average temperature variations during composting (^0c)															
		17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
1	T_1	59.6	56.3	50.1	46.5	40.1	36.5	30.4	27	27	26	-	-	-	-	-	-
2	T_2	56.3	48.3	39.1	36.2	30.6	30.3	28	27	26	27	-	-	-	-	-	-
3	T_3	38.4	35.4	30.2	30	28.6	28.4	27	27	26	27	-	-	-	-	-	-
-4	T_4	33.6	30.4	28.1	27.6	27	27.4	27.3	27	27	27	-	-	-	-	-	-
5	T_5	62.6	59.9	56.7	54.3	50	46.2	40.1	36.6	30.4	27	-	-	-	-	-	-
6	T_6	57.4	60.1	63.6	64.2	65.3	65.8	61.7	59.2	54.7	50.8	46.5	43.3	40.4	36.6	33.5	30.6

Table 4: Temperature variations recorded during sugarcane trash composting treated with liquid bioconsortium (2022-2023)

Sr. No.	Treatments	Weekly average temperature variations during composting (^0c)															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	T_1	32	35.4	38.8	40.4	42.3	44.3	46.2	47.7	50.3	52.4	54	56.3	58.6	61.8	62.3	64.2
2	T_2	34.2	36.8	39.8	41.8	43.5	45.9	47.7	49.5	52.6	54.5	56.2	59.1	61.8	62.7	64.8	59.3
3	T_3	35	38.2	42.7	45.9	47.3	49.2	51.9	53.2	55.7	57.1	59.4	62.5	63.2	60.3	56.5	47.7
4	T_4	35.7	39.6	46.6	49.4	50.6	54.8	60.2	63.7	65.5	59.4	56.4	49.3	44.4	41.2	38.4	34.4
5	T_5	32.4	34.3	36.2	38.2	41.5	43.8	45.3	46.3	48.7	50.2	52.4	55.7	57.8	60.4	62.1	64.7
6	T_6	31.5	33.2	35.6	37.6	39.5	40.5	42.2	43.6	44.3	46.9	48.2	50.4	51.9	52.7	54.8	56.1

Table 5: Temperature variations recorded during sugarcane trash composting treated with liquid bioconsortium (2023-2024)

S. N	Treatments	Weekly average temperature variations during composting (^0c)																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	T_1	31.8	34.5	35.7	38.9	40.4	42.9	44.6	48.7	50.2	52.6	55.3	58.5	60.7	62	63.8	59.2	56.5
2	T_2	34.9	35.4	37.5	40.5	43.6	46.6	49.4	51.8	53.6	56.3	59.7	60.6	62.7	64.3	58.8	55.3	47.6
3	T_3	35.7	37.7	44.3	46.4	48.9	50.8	52.6	54.7	57.2	61.5	64.4	61.6	57	46.4	37.5	36.7	33.8
4	T_4	36.5	38.4	47.7	49.8	51.4	55.3	61.4	64.3	66.8	60.2	55.7	49.8	46.4	44.6	42.5	38.5	35.7
5	T_5	31.4	33.6	34.2	35.6	38.8	40.8	42.9	43.2	45.1	47.6	50.8	52.3	54.6	57.3	59.9	61.5	63.8
6	T_6	30.5	32.8	33.6	34.6	36.3	38.6	39.9	41.6	42.3	44.7	46.4	49.3	51.5	54.2	55.1	58.5	59.4

SN	Treatments	Weekly average temperature variations during composting (^0c)																
		18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
1	T_1	50.6	46.9	38.6	35.9	30.1	29.5	27	26	27	26	27	-	-	-	-	-	-
2	T_2	43.7	37.9	32.8	31.7	29.5	28.4	26	26	27	26	27	-	-	-	-	-	-
3	T_3	31.2	30.6	28	27	26	26	26	25	26	27	26	-	-	-	-	-	-
4	T_4	30.1	26.1	26	27	26	26	26	25	26	27	26	-	-	-	-	-	-
5	T_5	64.6	62.5	59	56.4	49.3	38.8	38.8	32.7	30.2	27	26	-	-	-	-	-	-
6	T_6	60.1	62.7	64.3	65.8	65.1	59.1	59.1	57.3	54.8	53.1	51.8	48.3	44.3	40.2	38.7	34.7	30.6

Tr. No.	Treatments	Bacteria x 10^7 cfu/g of dry matter		Pooled	Fungi x 10^4 cfu/g of dry matter		Pooled	Actinomycetes x 10^5 cfu/g of dry matter		Pooled
		2022-23	2023-24		2022-23	2023-24		2022-23	2023-24	
T_1	CLB @ 0.5 litre per MT of sugarcane trash	17.05	16.41	16.73	13.89	14.84	14.37	13.52	14.43	13.98
T_2	CLB @ 1 litre per MT of sugarcane trash	16.88	18.13	17.50	13.77	15.87	14.82	14.86	15.17	15.01
T_3	CLB @ 1.5 litre per MT of sugarcane trash	20.19	20.88	20.54	15.27	17.17	16.22	15.38	17.45	16.42
T_4	CLB @ 2 litre per MT of sugarcane trash	20.95	23.61	22.28	16.82	18.84	17.83	18.48	16.59	17.53
T_5	MPKV's decomposing culture @ 1gm/kg of Sugarcane trash	17.12	14.98	16.05	13.14	12.93	13.04	13.80	13.78	13.79
T_6	Absolute control	11.74	9.74	10.74	9.98	11.20	10.59	10.24	11.06	10.65
	S.Em.±	0.86	0.78	0.58	0.66	0.61	0.45	0.72	0.65	0.48
	CD at 5%	2.60	2.36	1.68	2.00	1.84	1.30	2.16	1.97	1.40

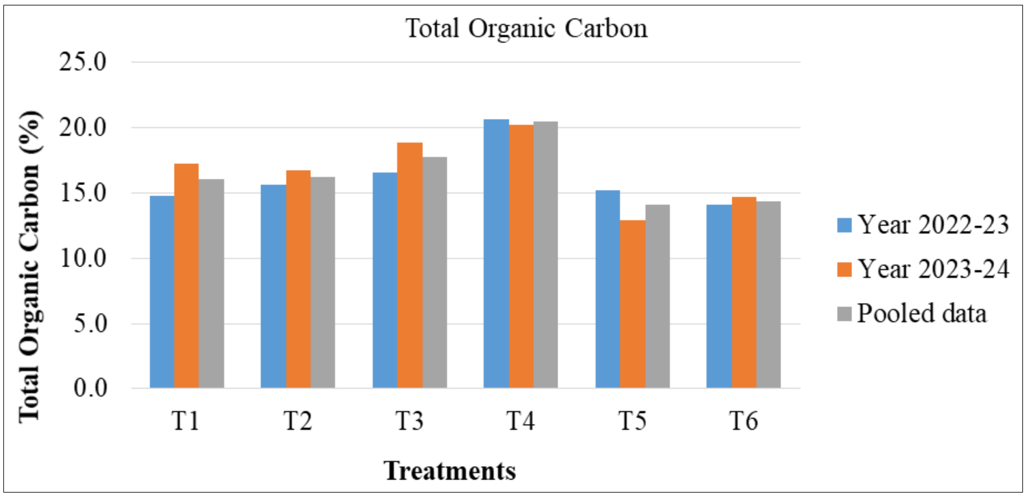

Fig 1: Total organic carbon (%) in matured compost influenced by liquid bioconsortia

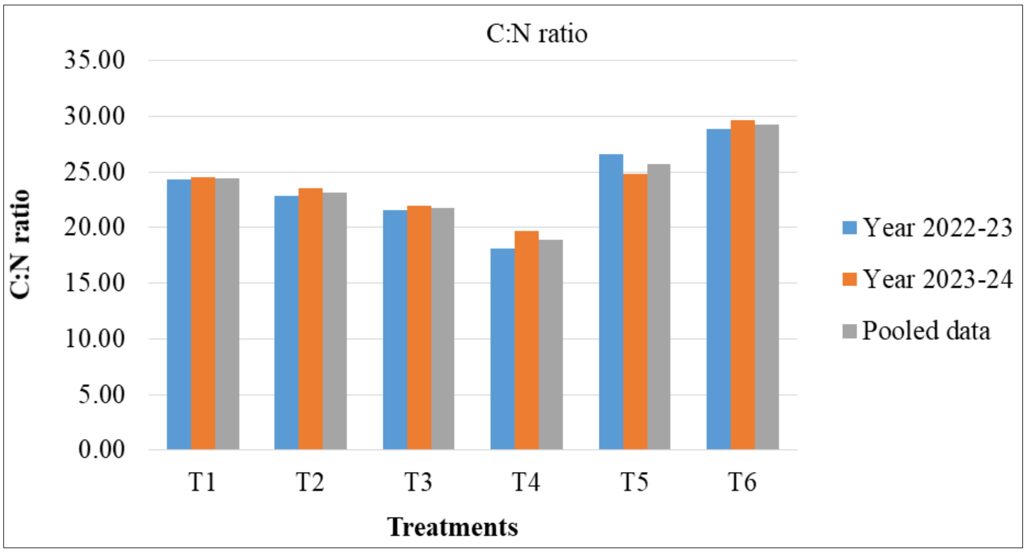

Fig 2: C:N ratio in matured compost influenced by liquid bioconsortia

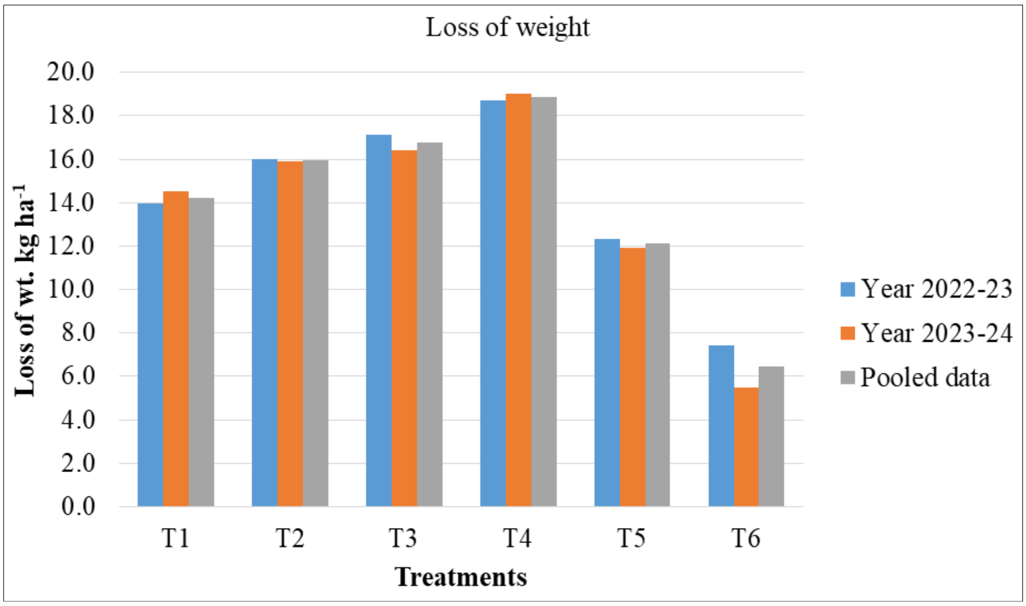

Fig 3: Loss of weight (kg ha^{-1}) in matured compost influenced by liquid bioconsortia

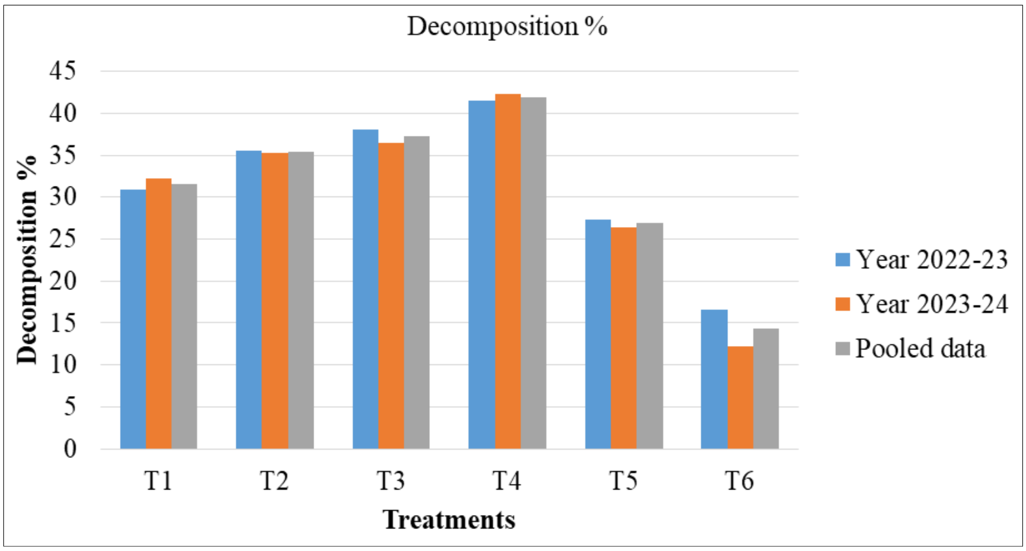

Fig 4: Decomposition % in matured compost influenced by liquid bioconsortia

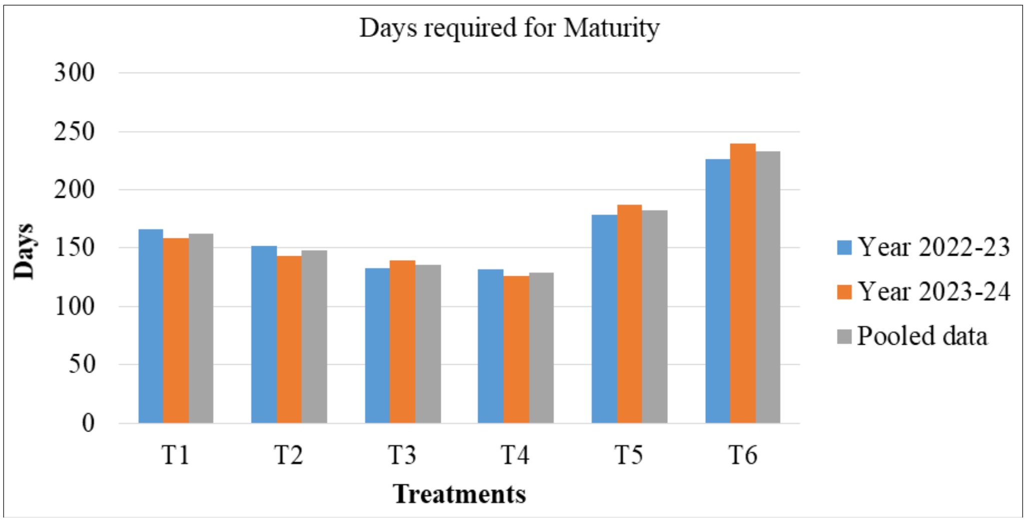

Fig 5: Average days required for maturity of composting using liquid bioconsortia

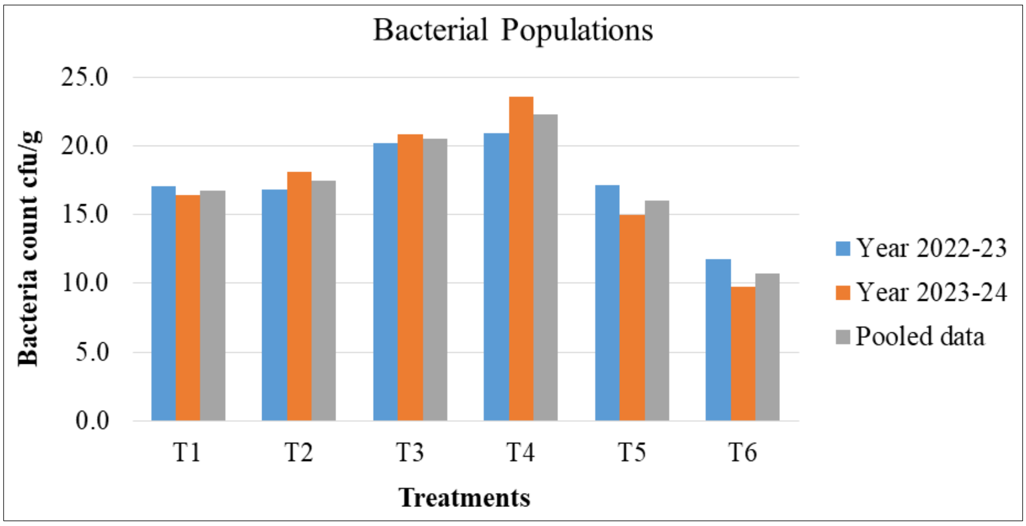

Fig 6: Population dynamics of Bacteria (x 10^7 cfu/g of dry matter) in matured compost influenced by liquid bioconsortia

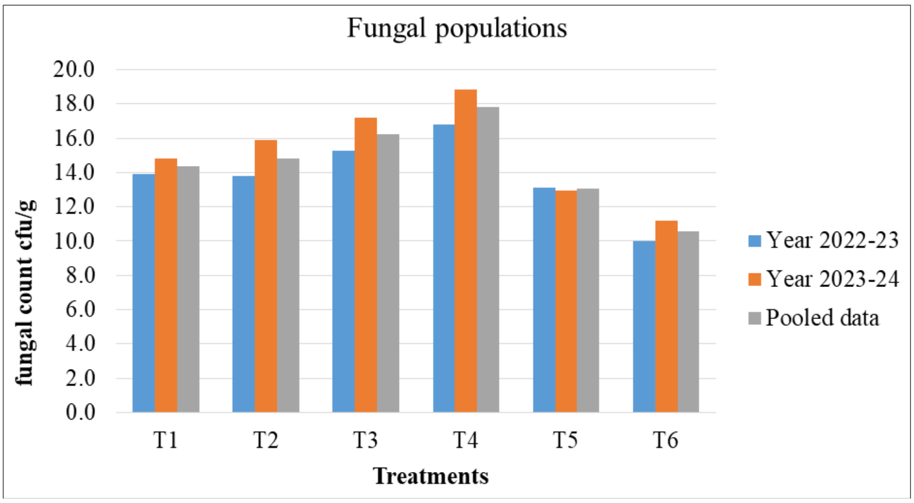

Fig 7: Population dynamics of Fungi (x 10^4 cfu/g of dry matter) in matured compost influenced by liquid bioconsortia

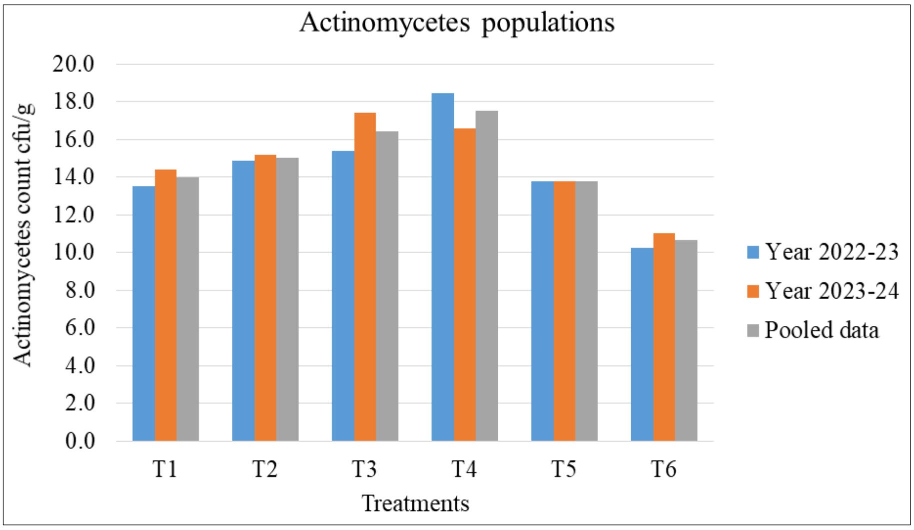

Fig 8: Population dynamics of Actinomycetes (x 10^5 cfu/g of dry matter) in matured compost influenced by liquid bioconsortia

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