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Effect of Different Treatments on Composting of Turmeric Leaves: Compost Maturity, C: N Ratio and Microbial Population

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Authors' contributions

This work was carried out in collaboration among all authors. All authors contributed to the study and preparation of the manuscript, read and approved the final manuscript.

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Abstract

An experiment was conducted to standardize the composting process for turmeric leaves using various decomposing cultures and nutrients at the Agricultural Research Station, Kasabe Digraj, Sangli, Maharashtra, during 2025. The experiment comprised seven treatments with three replications arranged in a Completely Randomized Design (CRD). Turmeric leaves were composted with FYM, MPKV decomposing culture, Pusa decomposer, and nutrients (urea and single super phosphate), applied separately and in combinations. Temperature, pH, electrical conductivity, total organic carbon, total nitrogen, C:N ratio, compost recovery, and maturity period were recorded during composting. The C:N ratio decreased progressively in all treatments and reached 13.14-19.85 at 120 days. Among the treatments, T_7 (turmeric leaves + FYM + Pusa decomposer + urea + SSP) reached maturity in the shortest time (78.77 days), followed by T_4 (83.02 days), whereas T_2 took the longest time (119.84 days). T_7 recorded the maximum compost recovery (45.43%), followed by T_4 (45.13%). Bacterial, fungal, and actinomycete populations increased during the active composting phase, with T_7 generally recording higher populations, followed by T_4, before declining towards maturity. It was concluded that the combination of FYM, decomposing culture, and nutrients improved the composting and stabilization of turmeric leaves.

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Keywords: Turmeric leaves; composting; decomposing cultures; FYM; nutrient amendments; C:N ratio; compost maturity; microbial population.

1. Introduction

Turmeric (*Curcuma longa* L.) is an important spice crop cultivated in India, particularly in tropical and subtropical regions. India is a major producer, consumer, and exporter of turmeric, with an area of approximately 3.05 lakh hectares and production of 10.74 lakh tonnes. Sangli, Satara, Hingoli, Nanded, and Parbhani are the major turmeric-producing districts of Maharashtra. Turmeric cultivation generates a substantial quantity of biomass residue, particularly leaves, which are generally discarded or burnt after harvest. This practice results in the loss of valuable organic matter and plant nutrients and may contribute to environmental pollution (Estévez-Schwarz *et al.*, 2012).

Turmeric leaves contain 1.10, 0.57, and 1.41 per cent nitrogen, phosphorus, and potassium, respectively, along with considerable amounts of organic matter (Joke *et al.*, 2021; Braga *et al.*, 2018). Therefore, appropriate utilisation of turmeric leaf biomass can help recycle nutrients and convert agricultural residue into a valuable organic resource.

Composting is a sustainable method of converting biodegradable agricultural residues into a stable organic amendment through decomposition (Li *et al.*, 2023). Composting provides an effective approach to residue disposal while recycling organic matter and nutrients into the agricultural system. Its efficiency depends on residue characteristics, nutrient availability, moisture, aeration, and microbial activity. Suitable decomposing cultures and nutrient additives can accelerate the decomposition of fibrous residues and enhance compost quality (Dhapate *et al.*, 2018; Jothimani *et al.*, 2025; Jusoh *et al.*, 2013; Karanja *et al.*, 2019; Yang *et al.*, 2023). Recent evidence from the composting of sesame stalks, shredded mulberry shoots, groundnut residues, and rice straw further supports the use of microbial consortia or decomposer inoculants to accelerate lignocellulosic residue degradation and improve composting performance (Chaitanya *et al.*, 2026; Sumanraj *et al.*, 2026; Roy *et al.*, 2024; Kumar *et al.*, 2024). Limited information is available on standardized approaches to composting turmeric leaves using decomposing agents together with nutrient supplements under local conditions. However, comparative information on the combined use of FYM, locally available decomposing cultures, and nutrient supplements for turmeric-leaf composting under the conditions of Sangli remains limited, particularly with respect to compost maturity and microbial population dynamics. With this background, the present investigation was conducted with the objective of evaluating various combinations of farm yard manure (FYM), decomposing cultures, and nutrients for enhancing the composting of turmeric leaves.

2. Material and Methods

An experiment was conducted at the Agricultural Research Station, Kasabe Digraj, Sangli, Maharashtra, in a Completely Randomized Design (CRD) with seven treatments and three replications. Composting beds made of HDPE sheets, each 1.0 m in diameter and 1.0 m high, were used. Turmeric leaves were the main substrate in all treatments and were mixed with FYM, MPKV decomposing culture, FYM + MPKV decomposing culture, FYM + MPKV decomposing culture + Urea + SSP, Pusa Decomposer, FYM + Pusa Decomposer, and FYM + Pusa Decomposer + Urea + SSP. FYM was mixed with turmeric leaves in a 1:1 ratio (w/w), decomposing culture was added @ 1 kg t-1, and urea and SSP were mixed @ 8 and 10 kg t-1 of turmeric leaves, respectively. Moisture was maintained at 40% for up to 30 days of the composting period, and turning was carried out at 15-day intervals from 30 days onwards. Temperature was measured at 15-day intervals during composting. Representative compost samples were collected at 0, 30, 60, 90, and 120 days of composting for physicochemical and nutrient analyses. Compost maturity was determined on the basis of the C:N ratio of the composting substrate. The treatment that took the shortest time to attain maturity was considered the most efficient treatment for turmeric-leaf composting. The mature compost was further characterised for moisture content, particle size, compost recovery, and nutrient composition. Bacterial, fungal, and actinomycete populations were estimated using the serial dilution plate count method and expressed as CFU g^{-1} for bacteria and actinomycetes and spores g^{-1} for fungi.

The maturity of compost was estimated on the basis of the C:N ratio, which is widely accepted as an indicator of compost stabilization (Chang *et al.*, 2023). Compost was considered mature when the C:N ratio reached 20:1. The linear interpolation method (Chapra & Canale, 2015) was used to estimate the exact maturity time in days.

3. Results and Discussion

3.1 Organic Carbon Content during Composting

The total organic carbon (TOC) content declined progressively in all treatments during composting. Initially, TOC ranged from 40.18–52.87% and decreased to 22.74–31.17% at 120 days of composting (Table 1). The reduction ranged from 33.23 to 43.85%. The maximum reduction of 43.85% was noted with turmeric leaves + FYM + Pusa Decomposer + Urea + SSP. At all stages of composting, treatment T_2, *i.e.*, turmeric leaves + MPKV decomposing culture, recorded significantly higher TOC, with an initial value of 52.87%, which was at par with turmeric leaves + Pusa decomposer (52.34%). At 120 days of composting, turmeric leaves + FYM + Pusa Decomposer + Urea + SSP recorded the lowest TOC (22.74%). The greater reduction in TOC in these treatments suggests more effective conversion of carbonaceous material during composting. Overall, TOC reduction reflects the progressive transformation of readily decomposable carbon into more stable forms and the loss of carbon through microbial respiration. Similar declines in TOC during the composting of agricultural residues have been reported by Varma *et al.* (2015) and Goyal *et al.* (2005).

Table 1. Effect of treatments on organic carbon at different periods of composting

Treatment	Total Organic Carbon (%)				
	Composting period (days)				
	0	30	60	90	120
T_1	40.18	38.62	36.69	35.27	26.83
T_2	52.87	48.61	46.35	40.29	31.17
T_3	40.41	38.78	36.01	34.53	25.22
T_4	40.46	37.33	35.23	31.67	23.37
T_5	52.34	47.68	45.44	39.19	30.67
T_6	40.45	38.33	35.27	32.86	24.24
T_7	40.50	37.08	35.50	31.07	22.74
SE ±	0.85	0.89	1.13	0.62	0.55
CD @ 5%	2.56	2.71	3.43	1.87	1.66

3.2 Changes in Total Nitrogen during Composting

Total nitrogen (N) increased progressively throughout the composting period in all treatments, with values increasing from 1.14–1.33% initially to 1.57–1.73% at 120 days of composting (Table 2). At 0 and 30 days of composting, T_5 recorded the highest N content (1.38%), followed by T_2 (1.37%). From 60 days onwards, T_7 recorded the highest N content, reaching 1.73% at 120 days, followed by T_4 (1.71%), while T_2 recorded the lowest value (1.57%). The increase in N was more pronounced in T_7 and T_4, which showed increases of 50.43 and 48.70%, respectively, over their initial values. The progressive increase in N concentration may be attributed mainly to carbon loss during composting, while the transformation of organic N into stable forms may have favoured N retention in the mature compost. Similar increases in total N during composting have been reported by Hulage *et al.* (2025) and Anand *et al.* (2023).

Table 2. Effect of treatments on total nitrogen content at different periods of composting

Treatment	Total Nitrogen (%)				
	Composting period (days)				
	0	30	60	90	120
T_1	1.14	1.23	1.42	1.56	1.66
T_2	1.33	1.37	1.43	1.51	1.57
T_3	1.14	1.25	1.44	1.63	1.68
T_4	1.15	1.26	1.47	1.67	1.71
T_5	1.33	1.38	1.45	1.53	1.60
T_6	1.14	1.25	1.46	1.65	1.69
T_7	1.15	1.28	1.49	1.70	1.73
SE ±	0.02	0.02	0.02	0.02	0.02
CD @ 5%	0.06	0.05	0.05	0.06	0.06

3.3 Changes in C: N Ratio during Composting

Table 3. Effect of treatments on C:N ratio at different periods of composting

Treatment	C:N ratio				
	Composting period (days)				
	0	30	60	90	120
T_1	35.25	31.40	25.83	22.61	16.17
T_2	39.78	35.56	32.40	26.68	19.85
T_3	35.46	31.01	25.01	21.23	15.03
T_4	35.19	29.63	23.96	18.97	13.68
T_5	39.36	34.65	31.33	25.62	19.17
T_6	35.48	30.67	24.17	19.95	14.36
T_7	35.21	29.00	23.83	18.29	13.14
SE ±	0.02	0.02	0.02	0.02	0.02
CD @ 5%	0.06	0.05	0.05	0.06	0.06

The C:N ratio is an essential parameter for assessing decomposition and compost maturity (Table 3). A steady decrease in the C:N ratio was observed throughout the composting period in all treatments. Initially, the C:N ratio ranged from 35.19 to 39.78. Treatment T_7 had a C:N ratio of 29.00 at 30 days, which further decreased to 23.83, 18.29, and 13.14 at 60, 90, and 120 days, respectively. The consistent decline in the C:N ratio could be due to microbial degradation of carbonaceous material, with consequent carbon loss as CO_2, while nitrogen remained relatively conserved during composting. The reduction in the C:N ratio from the initial value to 120 days was greatest in T_7 (62.68%), followed by T_4 (61.13%) and T_6 (59.53%). A C:N ratio below 20 in all treatments indicated progression towards compost maturity. The greater reduction in T_7 indicates faster conversion of carbonaceous material and better progression towards stabilization. A decline in the C:N ratio during composting has been reported by Game *et al.* (2016), Goyal *et al.* (2005), Dhapate *et al.* (2018), and Awasthi *et al.* (2017).

3.3.1 Compost Recovery at Maturity

Percentage compost recovery at maturity represents one of the key indicators for quantifying the amount of stabilised compost produced from the raw material used for composting. Variation in compost recovery was evident among the different treatments (Table 4). The percentage recovery of compost varied between 35.08% and 45.43%. The maximum compost recovery was observed in T_7 (45.43%), while T_4 (45.13%) and T_6 (43.36%) had the second- and third-highest recoveries, respectively. Recovery in T_3 and T_1 was 42.78% and 40.79%, respectively, while the lowest recovery was observed in T_2 (35.08%) and T_5 (37.66%). The higher compost recovery in T_7, T_4, and T_6 might have been due to the addition of FYM and decomposing cultures, along with nutrient amendments in T_4 and T_7, which helped in the efficient conversion and stabilization of the composting material. In contrast, the comparatively lower recovery in T_2 and T_5 might have been due to differences in treatment composition and decomposition of turmeric leaf material. Similar treatment-related variation in compost recovery has been reported by Attayee *et al.* (2017) and Narayanan and Sarala (2025).

3.3.2 Moisture Content at Maturity

There was a significant difference in the moisture content of mature turmeric-leaf compost, with values ranging from 20.11 to 23.57 per cent (Table 4). Treatment T_7 showed the minimum moisture content (20.11%), which was equal to that of T_6 (20.66%) and T_4 (21.18%), while the maximum moisture content was found in T_2 (23.57%) and T_5 (23.45%). The comparatively low moisture content in T_7, T_6, and T_4 could be due to greater decomposition and moisture loss during composting. The higher moisture content in T_2 and T_5, on the other hand, could be due to comparatively lower decomposition and moisture loss. Similar findings have been reported by Hajizadeh *et al.* (2015) and Okoli *et al.* (2024).

3.3.3 Particle Size of Turmeric Leaves Compost at Maturity

The results for particle size of the compost at maturity are presented in Table 4. The percentage of compost passing through the 4.0 mm IS sieve ranged from 85.76 to 93.09 per cent. The highest value was 93.09 per cent in T_7, which was on par with T_1 (90.63%), T_3 (91.25%), T_4 (92.26%), and T_6 (91.59%). The lowest value was recorded in T_2 (85.76%), followed by T_5 (86.10%). As per FCO standards, the minimum requirement is that at least 90 per cent of the compost should pass through the 4.0 mm IS sieve. Hence, T_1, T_3, T_4, T_6, and T_7 fulfilled the required standard, while T_2 and T_5 did not fulfil the required standard.

Higher percentages of compost passing through the 4.0 mm IS sieve in treatments containing FYM and decomposing cultures could be attributed to increased decomposition and fragmentation of organic matter. Lower values in T_2 and T_5 may have been due to reduced breakdown of coarse and resistant fractions of turmeric leaves. Similar trends were reported by Narayanan and Sarala (2025), who observed that treatments promoting greater microbial activity produced finer compost particles due to enhanced degradation of organic materials.

3.3.4 Days Required for Compost Maturity

The maturity period of turmeric-leaf compost differed significantly among treatments (Table 4). T_7 recorded the shortest maturity period (78.77 days), followed by T_4 (83.02 days), whereas T_2 required the longest period (119.84 days), followed by T_5 (115.74 days). Compared with T_1 (107.23 days), the maturity period was reduced by 28.46 and 24.21 days in T_7 and T_4, respectively. The shorter maturity period in T_7 and T_4 corresponded with their faster reduction in the C:N ratio, indicating more rapid stabilization of the composting material. The combined application of FYM, decomposing culture, and nutrient sources appeared to enhance the composting process and shorten the time required for maturity. Similar reductions in composting duration through microbial inoculation and nutrient supplementation have been reported by Preethu *et al.* (2021) and Sangeetha *et al.* (2023).

Table 4. Effect of treatments on moisture content, particle size, compost recovery and days required for maturity of turmeric leaves compost

Treatment	Moisture (%)	Particle size (%)	Compost Recovery (%)	Days Required for maturity
T_1	22.49	90.63	40.79	107.23
T_2	23.57	85.76	35.08	119.84
T_3	22.48	91.25	42.78	95.13
T_4	21.18	92.26	45.13	83.02
T_5	23.45	86.10	37.66	115.74
T_6	20.66	91.59	43.36	88.84
T_7	20.11	93.09	45.43	78.77
SE ±	0.76	1.73	1.23	0.77
CD @ 5%	2.33	5.26	3.76	2.34

3.3.5 Changes in Bacterial Population during Composting

Variation in bacterial population during composting was evident (Table 5). The bacterial population increased gradually from the initial phase, peaked at 60 days, and then decreased towards maturity. Initially, the bacterial population ranged from 9.00 to 14.00 ×

10^6 CFU g^{-1} and increased to 32.67–41.33 × 10^6 CFU g^{-1} at 60 days. The highest bacterial population at 30 and 60 days was recorded in T_7 (26.00 and 41.33 × 10^6 CFU g^{-1}, respectively), followed by T_4 and T_6. At 120 days, the population decreased to 11.33–18.33 × 10^6 CFU g^{-1}, with T_2 recording the highest population (18.33 × 10^6 CFU g^{-1}). The increase in bacterial population during the active phase of composting might have resulted from the availability of readily decomposable organic material and nutrients that favour rapid multiplication of microorganisms. Subsequently, the decrease in bacterial population could have resulted from depletion of readily available substrates. A similar trend in bacterial population during composting was observed by Zhang and Sun (2018) and Kutu *et al.* (2019).

Table 5. Effect of treatments on Bacterial count at different periods of composting

Treatment	Bacterial count (x 10^6 CFU/g)				
	Composting period (days)				
	0	30	60	90	120
T_1	11.67	19.67	36.00	24.33	15.33
T_2	9.00	15.67	32.67	29.67	18.33
T_3	12.33	22.00	37.67	19.67	14.00
T_4	13.00	25.33	40.67	16.67	12.33
T_5	9.33	17.00	33.67	28.33	17.33
T_6	13.00	23.33	39.00	19.00	13.67
T_7	14.00	26.00	41.33	15.33	11.33
SE ±	0.92	0.98	1.34	0.85	0.38
CD @ 5%	2.78	2.98	4.06	2.56	1.15

3.3.6 Changes in Fungal Population during Composting

Variation in fungal population across treatments was evident throughout the composting process (Table 6). The population increased consistently up to 30 days and gradually declined thereafter until compost maturity. Initially, the population ranged from 5.67–12.33 × 10^5 spores and increased to 10.67–24.67 × 10^5 spores after 30 days. The highest fungal population during the initial and subsequent phases of composting occurred in T_7, with values of 12.33, 24.67, 19.67, 16.00, and 13.33 × 10^5 spores at 0, 30, 60, 90, and 120 days, respectively. In contrast, T_1 exhibited a lower population towards compost maturity (8.00 × 10^5 spores). The abundance of fungi during the active phase might be attributed to the high availability of cellulose, hemicellulose, and other readily degradable organic compounds. Such substances promote fungal proliferation and enzymatic degradation of lignocellulosic substrates. In contrast, the lower populations observed later may be linked to carbon depletion and stabilization of organic matter. Similar observations have been reported by Rebollido *et al.* (2008) and Devi *et al.* (2012).

Table 6. Effect of treatments on Fungi count at different periods of composting

Treatment	Fungi count (x 10^5 spore count)				
	Composting period (days)				
	0	30	60	90	120
T_1	5.67	10.67	9.67	9.00	8.00
T_2	8.00	16.33	14.33	12.67	10.67
T_3	10.33	20.33	17.33	14.00	12.33
T_4	12.00	23.00	19.00	15.67	13.33
T_5	8.67	18.33	15.67	13.33	11.00
T_6	11.00	21.67	18.33	14.67	12.67
T_7	12.33	24.67	19.67	16.00	13.33
SE ±	0.59	0.72	0.76	0.59	0.64
CD @ 5%	1.80	2.20	2.29	1.79	1.95

3.3.7 Changes in Actinomycete Population during Composting

The actinomycete population varied significantly among the composting treatments, increasing up to 60 days and then declining with progression towards maturity (Table 7). Initially, the actinomycete population ranged from 2.00–3.33 × 10^4 CFU g^{-1}; after 60 days, it increased to 4.00–9.67 × 10^4 CFU g^{-1}. The maximum actinomycete population was observed in T_7 (8.67 and 9.67 × 10^4 CFU g^{-1}) at 30 and 60 days, respectively, whereas the population decreased to 3.33–6.00 × 10^4 CFU g^{-1} after 120 days. The maximum actinomycete population occurred in T_7, while the minimum occurred in T_1. Growth of the actinomycete population during the initial phases of composting may be attributed to the presence of partially degraded and resistant organic substrates such as cellulose and lignocellulosic compounds. The greater populations observed in T_7 and T_4 indicated a favourable environment for the degradation of resistant organic compounds, whereas the decline in population towards maturity might be linked to exhaustion of degradable substrates and 377tabilization of organic matter. An increasing trend in actinomycete population during the active phase, followed by a decline at later stages of composting, was reported by Wei *et al.* (2019) and Zhang and Sun (2018).

Table 7. Effect of treatments on Actinomycetes count at different periods of composting

Treatment	Actinomycetes count (x 10^4 CFU/g)				
	Composting period (days)				
	0	30	60	90	120
T_1	2.00	2.67	4.00	3.67	3.33
T_2	2.33	6.67	8.00	5.67	4.33
T_3	2.67	7.67	8.67	7.00	5.33
T_4	3.00	8.33	9.33	7.33	5.67
T_5	2.67	7.00	8.00	6.00	4.67
T_6	3.33	7.67	8.33	7.33	5.33
T_7	3.33	8.67	9.67	7.67	6.00
SE ±	0.28	0.31	0.50	0.28	0.27
CD @ 5%	0.84	0.94	1.53	0.85	0.81

4. Conclusion

The results showed that composting of turmeric leaves could be expedited through the combined application of FYM, decomposing cultures, and nutrients. Treatment T_7 (turmeric leaves + FYM + Pusa decomposer + urea + SSP) was the most efficient, achieving the shortest maturity period (78.77 days), the minimum C:N ratio (13.14), and the maximum compost recovery (45.43%). Treatment T_4 ranked second to T_7 in terms of efficiency. The higher bacterial, fungal, and actinomycete populations during the active phase of composting in T_7 and T_4 indicated favourable microbial activity for the decomposition of turmeric leaves. A continuous reduction in the C:N ratio and temperature during the later stages of composting indicated progression of the material towards stabilization. Hence, T_7 can be regarded as the most efficient treatment in the context of the present study.

5. Limitation

The findings are limited to the treatment combinations, composting conditions, substrate, location, and observation period used in this experiment. Compost maturity was assessed primarily using the c:n ratio, supported by physicochemical and microbial observations. Consequently, the results should be interpreted within these experimental conditions, and treatment performance may vary under different environmental conditions, substrate characteristics, composting scales, or management practices. Further validation under additional composting environments would strengthen the general applicability of the findings.

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Declaration of AI Use

This manuscript was prepared through the intellectual contributions of the author(s) to the study design, data analysis, interpretation of results, and scholarly content. Grammarly and ChatGPT were used solely to assist with grammatical refinement and reference formatting during manuscript revision. The author(s) accept full responsibility for the accuracy, integrity, and final content of the manuscript.

Competing Interests

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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