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Research Article

Ameliorative effects of waste decomposer and effective microorganisms on composting of paddy straw

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Abstract
Composting is one of the most eco-friendly methods to manage paddy straw and reduce environmental pollution with added value to the soil. The present work aimed to investigate the effects of different treatments on composting paddy straw and identify the most effective method for managing paddy straw while also reducing environmental pollution and adding value to the soil. The study used a split plot design with ten treatment and three replications over two years, and measured various parameters such as total organic carbon, total nitrogen, total phosphorus, total potassium, and water-soluble carbon to evaluate the quality of the compost produced by each treatment. From the pooled data of the experiment, the lowest total organic carbon of the compost was obtained in M_1 (2.58%) and S_8 (15.58%). The highest total nitrogen was acquired in M_1 (12.04%) and S_8 (26.04%). The highest total phosphorus was recorded in M_1 (1.23%) and S_8 (33.75%). The highest potassium was observed in M_1 (25.67 %) and S_8 (55.61%). The least water-soluble carbon was recorded in M_1 (14.28%) and S_8 (14.92%). The results of the study provide insights into the effectiveness of various composting methods and can help inform best practices for managing paddy straw in an eco-friendly manner.

Keywords: Composting, Effective microorganisms, Farming methodology, Paddy straw, Waste decomposer

INTRODUCTION

Rice (*Oryza sativa* L.) is a crucial staple crop across the Asian subcontinent that plays a vital role in ensuring food security and providing a source of livelihood for millions of rural communities. The crop produces three significant by-products: rice straw, rice husk, and rice bran. About 760 million tonnes of paddy straw are produced annually, 1.5 times the yield of paddy grains per tonne (Srivastava *et al.,* 2023). The wrong way to dispose of paddy straw after crop cultivation, like landfills and burning can result in the loss of resources but can also negatively affect the environment (Wei *et al.,* 2022). Composting is a cost-effective and environmentally friendly method of degrading and turning crop straws into valuable products (Wu *et al.,* 2022). It produces a wide range of mineral nutrients and organic substances. Determining the total organic carbon (TOC) in composting rice straw significantly increased the TOC content from 34.87 g/kg to 68.39 g/kg when rice straw was supplemented with biochar and microbial inoculants (Wang *et al.,* 2022). One recent also highlights the importance of total nitrogen content in compost is a crucial aspect of sustainable agriculture and environmental management. Nitrogen is an essential nutrient for plant growth and development, and its availability in soil is a critical factor in determining crop productivity (Ghaly *et al.,* 2018). Additionally, total phosphorus content increased significantly during the composting process, with the highest value observed in the treatment with a carbon-to-nitrogen ratio of 30:1. The optimizing of the carbon-to-nitrogen ratio enhanced the total phosphorus content of rice straw compost and promoted its use as an organic fertilizer (Zhou *et al.,* 2022). The application of calcium magnesium phosphate and effective microorganisms significantly increased the total potassium content of the compost and these additives enhance the quality of rice straw compost and promote its use as an organic fertilizer (Li *et al.,* 2021). There is also a very close relationship between water soluble carbon (WSC) and the maturity of rice straw compost. The WSC content decreased gradually during the composting process and was negatively correlated with the degree of maturity that the WSC content can be used as an indicator of the maturity of rice straw compost (Zhang *et al.,* 2020). An Indian microbiologist developed an indigenous waste decomposer culture under the Ministry of Agriculture and Farmers' Welfare, Government of India, launched this culture to promote organic farming practices in India. The Indian Council for Agricultural Research (ICAR) has tested and approved this culture as a waste decomposer. Also, it has been found positively and is an efficient way to compost organic waste. The waste decomposer, according to him, functions as a *biofertilizer*, a biocontrol agent, and a Soil Health Reviver (Kora *et al.,* 2022). A Japanese scientist pioneered the concept of Effective Microorganisms (EM), which involves a synergistic combination of beneficial microorganisms. The impact of utilizing effective microorganisms (EM) in the composting process of paddy straw reveals notable enhancements in the decomposition rate, nutrient content, and reduction of greenhouse gas emissions (Zaman *et al.,* 2021). Numerous studies carried out to increase the decomposition rate of paddy straw. Only a few uses of waste decomposers and efficient microorganisms are reported in the literature in India, particularly in the Punjab region. Determining how paddy straw composting responds to environmentally friendly decomposition and the amount of total organic carbon, total nitrogen, total phosphorus, total potassium and water-soluble carbon generated during the paddy straw compost in *rabi* season of semi-arid circumstances was the aim of the present study.

MATERIALS AND METHODS

Site selection

The study was conducted in Punjab, Lovely Professional University, an agronomy research field that was purposively selected as it is one of the major paddy-growing states of India.

Composting process and sampling

After harvesting rice crops, the straw was chopped up in the field according to the plot of treatment allotted. The paddy straw was then immersed overnight in water prior to the beginning of the composting process. The composting heaps were made using the following ratios 100% paddy straw 100% WD and 100% EM. The paddy straws of 10 kg were mixed with 15 litres of WD and 15 litres of EM solution in accordance with the treatment with three replicates each. The present study used waste decomposer released from the National Corporation of Organic Farming (NCOF), which contained a collection of beneficial microorganisms originating from Indian cow's excrement along with EM (EM*1W) that contained Bacteria as well as lactic acid bacteria, yeasts, actinomycetes and fermenting fungi.

Physiochemical parameters

The amount of moisture was determined by employing gravimetric method. The compost weight of 5 grams was assessed after the compost dry for 24 hours at 105°C (repeatedly weighing until a stable weight was attained). After cooling the samples to room temperature, the weight was measured. Kjeldahl's method (Bremner and Mulvaney, 1982) was utilized to calculate the total nitrogen. Dry combustion (Nelson and Sommers, 1996) was used to calculate the amount of organic carbon (TOC). Total phosphorus was determined by measuring the amount of colour absorbance noted at 882 nm on Systronic 106 spectrophotometer (John Methods, 1970). Direct feeding on flame Photometer method was employed to calculate total potassium and the wet digestion method (Kalimbas and Jenkinson, 1973) was used to estimate water soluble carbon (WSC).

Statistical tools

The statistical analysis was conducted by using the statistical tool for agriculture research (STAR) along with ANOVA to study the significance of the variation in data. The data pooled was calculated by taking the mean between 2021 and 2022.

RESULTS AND DISCUSSION

Total organic carbon of the compost

By analysing the pooled data, the lowest total organic carbon (TOC) in main plots, M_1: System of paddy intensification (SRI) of 2.58% was observed to be significant as compared to M_2: conventional methods of paddy cultivation (Table 1). In sub-plots (S), the least TOC was recorded in S_4 and S_8 with 15.76 % and 15.58 % as compared to S_1. The results of a comparative study found that microbial compounds decreased TOC when composting paddy straw (Chen *et al.,* 2022). Studies in the past have confirmed that when composting paddy straw with bacterial and fungal communities, there is a higher reduction in TOC (Wu *et al*., 2022)

Total nitrogen content of the compost

In the pooled data of the two subsequent years, total nitrogen in main plots, M_1 (12.04 %), was observed best treatment as compared to M_2 (Table-2). In sub-plots (S), the highest nitrogen content was recorded in S_4 (waste decomposer + effective microorganisms + paddy straw) and S_8 (paddy straw + waste decomposer + effective microorganisms + soil) was on par with 24.46 % and 26.04 % as compared to S_1 (paddy straw alone). The similar study found that pre-treatment of paddy straw by a fungal consortium increases total nitrogen levels during composting (Sajid *et al.,* 2022). A recent study has also demonstrated that fungal communities enhance the nitrogen content of totals in the manure of cattle and straw composting (Zhu *et al.,* 2022)

Table 1. Effect of waste decomposer (WD) and effective microorganisms on total organic carbon contents of the compost

Total Organic Carbon (%)	DAY 7		DAY 15		DAY 30	
M - Main Plot	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**
M_1	43.03^{a}	42.65^{a}	39.82^{a}	41.56^{a}	37.86^{b}	36.02^{a}
M_2	43.17^{a}	43.87^{a}	41.05^{a}	42.04^{a}	38.45^{a}	37.60^{a}
SEM (±)	0.31	0.27	0.24	0.32	0.05	0.27
CD P≤0.05)	1.91	1.65	1.48	1.95	0.33	1.63
S-Sub Plot						
S_1	45.70^{a}	45.59^{a}	42.31^{a}	44.60^{a}	46.51^{a}	44.96^{a}
S_2	43.91^{ab}	43.32^{ab}	40.51^{b}	41.34^{b}	36.04^{c}	35.41^{c}
S_3	44.57^{ab}	43.37^{ab}	40.61^{b}	44.40^{a}	38.17^{b}	39.13^{b}
S_4	41.50^{cd}	42.96^{cd}	38.84^{c}	40.71^{bc}	33.41^{d}	34.11^{c}
S_5	43.04^{bc}	42.97^{bc}	40.04^{b}	40.09^{bc}	39.71^{b}	34.72^{c}
S_6	42.73^{bc}	42.86^{bc}	40.71^{b}	40.75^{bc}	39.07^{b}	33.33^{cd}
S_7	43.66^{b}	43.92^{b}	42.22^{a}	42.07^{b}	40.05^{b}	37.66^{c}
S_8	39.72^{d}	41.10^{d}	38.24^{c}	40.45^{bc}	32.31^{d}	35.15^{c}
SEM (±)	0.43	0.44	0.44	0.41	0.46	0.34
CD (P≤0.05)	1.24	1.27	1.27	1.19	1.35	0.97

Where, CD = Critical difference, M_1 = *SRI*, M_2 = Conventional methods of paddy cultivation, S_1= Control (paddy straw alone), S_2= waste decomposer + paddy straw, S_3= effective microorganisms + paddy straw, S_4 = waste decomposer + effective microorganisms + paddy straw, S_5= paddy straw + soil, S_6= paddy straw + waste decomposer + soil, S_7= paddy straw + effective microorganisms + soil, S_8= paddy straw + waste decomposer + effective microorganisms + soil.

Table 2. Effect of waste decomposer (WD) and effective microorganisms on total nitrogen content of the compost

Total Nitrogen (%)	DAY 7		DAY 15		DAY 30	
M - Main Plot	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**
M_1	0.71^{a}	0.58^{a}	0.68^{a}	0.84^{a}	0.82^{a}	0.84^{a}
M_2	0.56^{b}	0.56^{b}	0.66^{b}	0.58^{b}	0.72^{b}	0.74^{b}
SEM (±)	0.001	0.002	0.001	0.006	0.004	0.007
CD P≤0.05)	0.004	0.014	0.004	0.034	0.027	0.045
S-Sub Plot						
S_1	0.54^{c}	0.52^{d}	0.53^{f}	0.69^{c}	0.71^{c}	0.72^{e}
S_2	0.61^{b}	0.56^{b}	0.73^{c}	0.71^{c}	0.81^{b}	0.79^{c}
S_3	0.59^{b}	0.55^{c}	0.67^{d}	0.68^{d}	0.72^{c}	0.75^{d}
S_4	0.61^{b}	0.59^{a}	0.77^{b}	0.89^{b}	0.91^{a}	0.97^{b}
S_5	0.72^{a}	0.57^{b}	0.66^{d}	0.62^{e}	0.70^{c}	0.72^{e}
S_6	0.72^{a}	0.58^{b}	0.61^{e}	0.63^{e}	0.70^{c}	0.71^{e}
S_7	0.71^{a}	0.58^{b}	0.62^{e}	0.58^{f}	0.68^{c}	0.67^{f}
S_8	0.61^{b}	0.61^{a}	0.80^{a}	0.92^{a}	0.92^{a}	1.01^{a}
SEM (±)	0.007	0.006	0.007	0.006	0.008	0.008
CD (P≤0.05)	0.019	0.016	0.020	0.017	0.024	0.024

Where, CD = Critical difference, M_1 = *SRI*, M_2 = Conventional methods of paddy cultivation, S_1= Control (paddy straw alone), S_2= waste decomposer + paddy straw, S_3= effective microorganisms + paddy straw, S_4 = waste decomposer + effective microorganisms + paddy straw, S_5= paddy straw + soil, S_6= paddy straw + waste decomposer + soil, S_7= paddy straw + effective microorganisms + soil, S_8= paddy straw + waste decomposer + effective microorganisms + soil.

Table 3. Effect of waste decomposer (WD) and effective microorganisms on total phosphorus content of the compost

Total P (mg/kg)	DAY 7		DAY 15		DAY 30	
M - Main Plot	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**
M_1	214.20[a]	215.63[a]	310.25[a]	315.78[a]	652.14[a]	655.60[a]
M_2	211.76[a]	212.63[b]	306.22[a]	308.96[a]	643.91[b]	647.65[b]
SEM (±)	0.35	0.37	1.46	1.04	0.53	0.65
CD P≤0.05)	2.13	2.27	4.24	6.34	3.22	3.96
S-Sub Plot						
S_1	205.95[d]	206.50[d]	299.41d	303.51[c]	466.04[c]	468.73[c]
S_2	213.90[b]	214.50[a]	308.51[b]	312.73[b]	687.18[b]	689.17[b]
S_3	212.77[b]	213.50[b]	311.76[b]	316.05[a]	663.43[d]	662.00[d]
S_4	217.29[a]	218.50[a]	314.05[a]	315.56[a]	699.99[a]	707.42[a]
S_5	212.81[b]	213.50[b]	305.53[c]	308.73[b]	659.63[e]	663.12[e]
S_6	209.75[c]	211.50[b]	304.42[c]	307.82[b]	638.24[f]	644.66[f]
S_7	213.85[b]	215.50[a]	308.30[c]	316.23[a]	666.82[c]	669.80[c]
S_8	217.55[a]	219.50[a]	313.90[a]	318.34[a]	702.91[a]	708.11[a]
SEM (±)	1.32	2.25	1.46	1.62	1.65	1.36
CD (P≤0.05)	3.83	6.53	4.24	4.68	4.77	3.95

Where, P= phosphorus, CD = Critical difference, M_1 = SRI, M_2 = Conventional methods of paddy cultivation, S_1= Control (paddy straw alone), S_2= waste decomposer + paddy straw, S_3= effective microorganisms + paddy straw, S_4 = waste decomposer + effective microorganisms + paddy straw, S_5= paddy straw + soil, S_6= paddy straw + waste decomposer + soil, S_7= paddy straw + effective microorganisms + soil, S_8= paddy straw + waste decomposer + effective microorganisms + soil.

Table 4. Effect of waste decomposer (WD) and effective microorganisms on total potassium content of the compost

Total k (%)	DAY 7		DAY 15		DAY 30	
M - Main Plot	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**
M_1	0.93[a]	1.89[b]	1.11[a]	2.91[a]	1.60[a]	4.31[a]
M_2	0.88[b]	1.99[a]	1.03[b]	2.20[b]	1.51[b]	2.88[b]
SEM (±)	0.01	0.00	0.00	0.02	0.01	0.02
CD P≤0.05)	0.04	0.01	0.03	0.12	0.09	0.11
S-Sub Plot						
S_1	0.81[d]	1.41[c]	1.00[b]	1.56[d]	1.20[e]	1.80[d]
S_2	0.88[c]	1.98[b]	1.01[b]	2.67b	1.50[b]	3.75[b]
S_3	0.88[c]	1.98[b]	0.99[bc]	2.57[d]	1.48[c]	3.73[b]
S_4	0.90[b]	1.99b	1.06[b]	2.61[b]	1.55[b]	3.77[b]
S_5	0.88[c]	1.98[b]	1.02[b]	2.62[c]	1.50[b]	3.75[b]
S_6	0.85[c]	1.95b	0.99[c]	2.63[c]	1.50[b]	3.75[b]
S_7	0.86[c]	1.96[b]	0.98[c]	2.55[e]	1.39[d]	3.64[bc]
S_8	1.15[a]	2.26[a]	1.52[a]	3.25[a]	2.34[a]	4.59[a]
SEM (±)	0.01	0.02	0.01	0.03	0.02	0.04
CD (P≤0.05)	0.03	0.06	0.03	0.09	0.05	0.13

Where, K= potassium, CD = Critical difference, M_1 = SRI, M_2 = Conventional methods of paddy cultivation, S_1= Control (paddy straw alone), S_2= waste decomposer + paddy straw, S_3= effective microorganisms + paddy straw, S_4 = waste decomposer + effective microorganisms + paddy straw, S_5= paddy straw + soil, S_6= paddy straw + waste decomposer + soil, S_7= paddy straw + effective microorganisms + soil, S_8= paddy straw + waste decomposer + effective microorganisms + soil.

Total phosphorus content of the compost

In the pooled dataset (2021-22), the most effective treatment, M_1(1.23%), was deemed to be to have a similar ratio contrasted to M_2 (Table3). In sub-plots, statistically speaking, the highest total phosphorus was in parity, but S_8 (33.75%) was identified as the best treatment, followed by S_4. (33.58%) as in comparison to S_1 (control-paddy straw alone). The study by Zhang *et al. (*2021) also revealed that the total phosphorus content of rice straw composting increased during the thermophilic phase of composting and then decreased during the maturation phase.

Total potassium content of the compost

According to the pooled data, total potassium content in main plots, M_1 (825.67%) was observed best treatment as compared to M_2 (Table 4). In sub-plots (S) S_8 (33.75%), there was the highest total potassium content as compared to S_1 (control). A similar study found that adding a microbial inoculant to rice straw compost in-

Table 5. Effect of waste decomposer (WD) and effective microorganisms on water soluble carbon content of the compost

WSC (%)	DAY 7		DAY 15		DAY 30	
M - Main Plot	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**
M_1	6.52^a	5.55^a	7.77^a	7.83^a	6.65^a	7.68^a
M_2	5.42^b	5.42^b	7.67^b	7.85^b	6.26^b	6.85^b
SEM (±)	0.02	0.01	0.07	0.04	0.07	0.03
CD P≤0.05)	0.14	0.09	0.41	0.23	0.41	0.16
S-Sub Plot						
S_1	6.67^a	6.32^a	7.95^a	8.05^a	6.29^c	7.00^e
S_2	5.92^b	5.42^b	7.88^a	7.58^c	6.60^b	7.21^d
S_3	5.93^b	5.43^b	7.69^a	7.86^b	6.33^c	7.36^{ab}
S_4	5.79b	5.29^b	7.56^b	7.54^c	6.68^a	7.17^b
S_5	6.04^a	5.54^b	7.95^a	7.94^b	6.22^c	7.36^{ab}
S_6	5.84^b	5.34^b	7.66^b	7.91^b	6.19^{cd}	7.38^a
S_7	6.02^a	5.52^b	7.94^a	7.98^b	6.58^b	7.37^a
S_8	5.54^b	5.04^b	7.13^c	7.82^b	6.76^a	7.31^c
SEM (±)	0.05	0.07	0.09	0.08	0.07	0.06
CD (P≤0.05)	0.14	0.20	0.25	0.22	0.19	0.17

Where, WSC = water soluble carbon, CD = Critical difference, M_1 = SRI, M_2 = Conventional methods of paddy cultivation, S_1= Control (paddy straw alone), S_2= waste decomposer + paddy straw, S_3= effective microorganisms + paddy straw, S_4 = waste decomposer + effective microorganisms + paddy straw, S_5= paddy straw + soil, S_6= paddy straw + waste decomposer + soil, S_7= paddy straw + effective microorganisms + soil, S_8= paddy straw + waste decomposer + effective microorganisms + soil

creased the compost's potassium content depending on the compost's maturity (Wang *et al.,* 2019).

Water-soluble carbon content of the compost

In the pooled data, the highest water-soluble carbon (WSC) in main plots: M_1 (12.28%) was observed best treatment as compared to M2 (Table-5) In sub-plots (S). The highest WSC recorded in S_8 (14.92%) compared to S_1 compared to control. The research done by Li *et al.* (2019) also inoculated the compost with a mixture of microbial strains and monitored the changes in water-soluble carbon content over time. They found that the addition of microbial inoculants accelerated the decomposition of rice straw and increased the production of water-soluble carbon.

Conclusion

Treatment plots and sub-pots showed similar patterns based on the composting parameters. When compared with those in the controlled, variables measured showed that decomposition occurred throughout the treatment. The total organic carbon, total nitrogen, total phosphorus, total potassium and water-soluble carbon changes show that paddy straw degradation happens over the course of 30 days. The decline of TOC values and the total nitrogen indicated that microorganisms consumed the organic compounds inside the paddy straw. The ANOVA test and statistical tool for agriculture software (STAR) recorded a significant difference in the compost treated with (S_4 and S_8) waste decomposer with effective microorganisms and the compost that was not treated. These facts provided evidence in support of this when compared to the controls. The compost that had undergone waste decomposer with effective microorganisms' treatment had a larger total phosphorus and total potassium content (P ≤ 0.05). However, the water-soluble carbon (WSC) changes in compost that had waste decomposer with effective microorganisms were significantly reduced with time (P ≤ 0.05) than those in compost that was not treated with waste decomposer or effective microorganisms. In terms of the C/N ratio, there was a significant high difference between the SRI and conventional methods for cultivating paddy-promoting SRI over conventional rice cultivation methods.

Conflict of interest

The authors declare that they have no conflict of interest.

Authors' Contribution

Each co-author involved helped the author with data interpretation and language in writing.

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