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Short communication

Different composting methods in bio recycling paddy straw to nutrient rich manure: A comparative analysis

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Abstract

An experiment on bio recycling of paddy straw to quality organic manure was conducted at the Integrated Farming System Research Station (IFSRS), Kerala Agricultural University, Karamana, Thiruvananthapuram during March to August 2018. The study aimed at standardizing an ideal technology for composting paddy straw, especially for the benefit of farmers practicing integrated farming. The experiment was laid out in Completely Randomized Design with eight treatments and three replications. Three different composting techniques viz., vermicomposting, co-composting with nitrogen-rich organic manures, and microbial composting were evaluated in the study. Time taken for maturation of composts, recovery of composts, different chemical properties including nutrient status of mature composts and microbial and enzymatic status of final composts were recorded. Co-composting performed better in comparison to vermicomposting and microbial composting methods in bio recycling paddy straw to quality manure. Among different co-composting treatments, paddy straw co-composted with cowdung and poultry manure in the ratio 8:1:1 (on volume basis) produced mature compost within the shortest period of 97 days. In terms of recovery, paddy straw co-composted with poultry manure in the ratio 4:1 performed better with the highest recovery of 45 per cent. Chemical properties (CEC and C: N ratio) were improved and status of major plant nutrients was higher and comparable for co-composting of paddy straw with poultry manure (4:1) and co-composting with cow dung and poultry manure in the ratio 8:1:1. These two treatments recorded comparable and higher microbial status as well as activity of dehydrogenase enzyme.

Key words: Bio recycling, Co-composting, Microbial composting, Paddy straw, Plant nutrients, Vermicomposting,

Paddy straw, a byproduct of rice cultivation, is a valuable and marketable commodity as dry fodder for cattle in Kerala. However, harvest of paddy during rainy season often limits the scope of spreading and drying straw to the required moisture level, thereby depriving straw of its feed value. Such straw, unfit for use as feed due to dampness and mouldy growth, could be effectively recycled as nutrient rich manure and could be utilised for crop production. For rice farmers practicing integrated farming, organic manures like cowdung and poultry manure could be generated on-farm and these organic inputs could be utilised well in composting of straw for effective recycling in crop production. Composting of paddy straw is therefore a viable option to recycle the nutrients contained in it and to enrich soil with organic matter. As about 8 lakh tons of paddy straw are generated annually in Kerala from an area of 1.98 lakh ha (FIB, 2017) of which a considerable quantity goes waste due to improper drying, there is urgent need to standardize technologies to recycle straw as manure. However, the high lignin (11-24%) and silica (7- 20%) contents make degradation of paddy straw a difficult

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process. In addition, wider C: N ratio of paddy straw (60-80:1) results in resistance to rapid microbial decomposition (Hu et al., 2016). However, if composted using improved technologies, the prospects are immense with regard to recycling of plant nutrients. Based on the above idea, an experiment was conducted with the objective to standardize an ideal technology for composting paddy straw to quality manure for use in crop production.

The study was conducted at the Integrated Farming System Research Station (IFSRS) functioning under Kerala Agricultural University, during March to August, 2018. The location had a total rainfall of 1154 mm, average maximum temperature of 31.5°C, average minimum temperature of 24.7 °C and relative humidity of 82.0 per cent during the composting period. The experiment was laid out in completely randomized design with eight treatments and three replications. Composting of paddy straw was carried out in concrete pits of size 1 m^3, maintained in roofed composting yards. Straw obtained from a medium duration rice variety Uma collected during crop harvest in March 2018, was soaked and drained upto 50 per cent moisture level and was then mixed with cow dung, poultry manure or both in different ratios on volume basis as per treatments described in Table 1. The composition

Table 1. Details of treatments

Treatments	Details
Vermicomposting	
T_1	Paddy straw + cowdung (8:1) + earthworms
T_2	Paddy straw + cowdung (6:1) + earthworms
T_3	Paddy straw + cowdung (4:1) + earthworms
Co - composting	
T_4	Paddy straw + poultry manure (8:1)
T_5	Paddy straw + poultry manure (6:1)
T_6	Paddy straw + poultry manure (4:1)
T_7	Paddy straw + cowdung + poultry manure (8:1:1)
Microbial composting	
T_8	Paddy straw + Urea + *Pleurotus* (For 100 kg straw, 500 g urea and 150 g *Pleurotus*)

Table 2. Characteristics of paddy straw, cow dung and poultry manure used for the experiment

Parameter	Content
Paddy straw	
Lignin (%)	26
Cellulose (%)	54
N (%)	0.68
P (%)	0.12
K (%)	1.35
Fe (mg kg^{-1})	544.2
Cu (mg kg^{-1})	23.88
Zn (mg kg^{-1})	36.31
B (mg kg^{-1})	3.24
C: N ratio	60:1
Cowdung	
N (%)	1.21
P (%)	0.40
K (%)	0.60
Poultry manure	
N (%)	2.30
P (%)	1.40
K (%)	1.35

Table 3. Microbial count in composting materials

Composting materials	Microbial count (cfu g^{-1})		
	Bacteria ($\times 10^6$)	Fungi ($\times 10^3$)	Actinomycetes ($\times 10^4$)
Paddy straw	92.67	62.00	9.66
Cow dung	86.00	15.50	18.00
Poultry manure	216.00	40.33	17.33

and characteristics of the different inputs used in composting are detailed in Tables 2 and 3. For the vermicomposting technique in composting paddy straw, earthworm species *Eudrillus euginea* @ 1000 numbers per pit was introduced into the composting material after an initial degradation period of two weeks. Sufficient moisture levels were maintained in the composting material by periodic sprinkling of water. The materials were turned twice a week, to ensure aeration and uniform decomposition. Towards the end of the study, maturity of composts was determined based on visual observation first, and then confirmed upon narrowing down of C: N ratio to less than 20: 1, as suggested by Khater (2015). Mature composts were sieved, shade dried and stored.

Observations on time taken for maturation of composts, percentage recovery, chemical properties as well as nutritional status of different composts were recorded by following standard procedures. Compost samples were mixed with water in the ratio 1:5 to determine pH using pH meter with glass electrode (Jackson, 1973). Cation Exchange Capacity (CEC) of composts were determined by extracting cations using $BaCl_2$ and reading the content of cations in Atomic Absorption Spectrophotometer and Flame photometer (Hendershot and Duquette, 1986). Organic carbon content of compost samples was determined by assessing weight loss through ignition method (FAI, 2017) and the total N content was determined using Microkjeldhal method (Jackson, 1973). The ratio of organic carbon to nitrogen was worked out and expressed as C:N ratio. Content of major nutrients (N, P and K) of composts were determined by following standard procedures (Microkjeldhal method for N, Nitric-Perchloric Acid digestion (9:4) and spectrophotometry using Vanadomolybdate phosphoric yellow colour method for P and Nitric-Perchloric Acid digestion (9:4) and flame photometry for K) suggested by Jackson (1973) and were expressed on oven dry weight basis. Micro nutrients like Fe, Cu and Zn were determined by nitric-perchloric acid digestion (9:4) and Atomic Absorption Spectrophotometry (Jackson, 1973). Boron content in composts was determined by Spectrophotometry Azomethane H method described by Wolf (1971). Total microbial population (bacteria, fungi and actinomycetes) in composts were determined using serial dilution and plate count technique as described by Johnson and Curl (1972). Activity of soil enzyme dehydrogenase, which is a reflection of the microbial activity in composts was measured using colorimetric determination of 2,3,5- Triphenyl Formazan (TPF) as outlined by Casida et al. (1964). Compost quality was evaluated through the comparison between time taken for compost maturation, recovery, chemical properties, nutrient and microbial status of composts. The data obtained were statistically analysed using OPSTAT software package. Critical differences at 5 per cent significance level were used to compare the differences between treatments when the treatment effects were found significant.

Data on effect of different composting methods on the time taken for maturation of composts are presented in Table 4. Co-composting of paddy straw with nitrogen-rich organic manures registered faster maturation of composts compared to vermicomposting and microbial composting. Paddy straw co-composted with cowdung and poultry manure in the ratio 8:1:1 (T_7) recorded significantly faster (98 days) maturation of compost compared to all other treatments. This could be attributed to the rapid mineralization of N from poultry manure which could lower the C: N ratio of composting material in a speedy manner (Dorivar and Ruiz, 2007). Activity of dehydrogenase enzyme, a reflection of microbial activity, also was higher for this treatment which could be attributed to the addition of higher quantities of organic manure (Table 1). Hence it could be assumed that enhanced microbial activity hastened the decomposition process resulting in faster maturation of compost. Composting was greatly delayed with the microbial composting method (144 days). This could be attributed to the non addition of organic manures and lower microbial activity in the treatment. This observation was in agreement with Toumela et al. (2000), who reported prolonged composting time with higher carbon content of the substrate and less addition of nitrogenous suppliments. Singh and Sharma (2002) reported that the use of *Pleurotus sajor-caju* alone as microbial inoculant in pre-decomposition of wheat straw was less effective in lowering the C: N ratio as compared to the use of a consortium of microbial inoculants.

Co-composting of paddy straw with higher quantities of poultry manure added as nitrogen source was observed to be an efficient method of composting in terms of better recovery (Table 4). Paddy straw co-composted with highest dose of poultry manure (T_6) registered significantly higher recovery of 44.59 per cent. Low moisture and high dry matter content of poultry manure, resulted in addition of more organic matter to the composting lot, in turn contributing to better recovery (Nicholson et al., 1996). N richness of poultry

Table 4. Effect of different treatments on maturation and recovery

Treatment	Time taken for composting (Days)	Recovery of compost (%)
T_1	138.67	10.03
T_2	130.00	11.42
T_3	130.00	14.58
T_4	119.33	27.38
T_5	108.33	41.22
T_6	108.00	44.59
T_7	97.67	27.29
T_8	144.00	13.52
SE m (±)	2.03	0.50
CD (0.05)	6.152	1.517

manure compared to cowdung resulted in faster proliferation of microbes. Higher microbial activity could lead to complete decomposition, resulting in non-wastage of base materials and hence better recovery. Degradation of paddy straw was thus complete with the use of poultry manure as nitrogen source, avoiding wastage of raw material and resulting in higher recovery. Vermicomposting treatments with addition of lower quantities of cow dung (T_1 and T_2) recorded lower recovery of compost. This could be related to the addition of lower quantity of organic matter to the composting lot, thereby resulting in lower recovery.

Major chemical properties of the compost viz., pH, CEC and C: N ratio were determined (Table 5). Different composting methods could not influence the pH of the final product. However, all the composts generated as part of the present study were within the acceptable pH range of 6.5 to 7.5 as per

Table 5. Chemical properties of paddy straw composts

Treatment	pH	CEC (c mol kg^{-1})	C:N ratio
T_1	7.39	65.01	18.48
T_2	7.45	69.29	16.37
T_3	7.42	74.07	12.09
T_4	7.42	73.38	12.92
T_5	7.39	74.32	11.11
T_6	7.39	77.91	9.54
T_7	7.40	74.02	10.32
T_8	7.47	65.18	19.29
SE m (±)	0.03	1.91	0.71
CD (0.05)	NS	5.780	2.148

FCO (1985). Cation exchange capacity of different composts was significantly influenced by different composting methods. Higher and comparable CEC values were recorded in co-composting treatments T_4, T_5, T_6 and T_7 and in T_3, where cow dung was added to the composting material in higher quantity. The increase in CEC could be attributed to the increased amount of humified materials obtained in composts by following the above treatments. In these treatments, decomposition of paddy straw was almost complete as evident from higher recovery percentage (Table 4). CEC is directly related to the humified organic matter as reported by Harada and Inoko (1980). Hence, higher humification could be attributed to the increased CEC in these treatments. Different composting methods could significantly influence the C:N ratio of composts. A reduction in C: N ratio was observed with the progress of composting. Release of CO_2 during composting by microbial activity reduced the total carbon content (Devi et al., 2012). Simultaneously an increase in N levels also occurs due to the activity of N fixing bacteria (Raj and Antil, 2011). This decrease in carbon content and increase in N resulted in lowering of C: N ratio. The C: N ratio of fresh paddy straw was as high as 60:1 at the start of composting trial and all the composting treatments could narrow down the C: N ratio. Comparable and lower C: N ratios of 9.54:1, 10.32:1 and 11.11:1 were observed with co- composting treatments T_6, T_7 and T_5 where the nitrogen source used was poultry manure. Though a C: N ratio of < 20:1 is considered as maturity parameter, a ratio < 15:1 is preferred by plants for better nutrient uptake (Bernal et al., 2009). In this regard, the above mentioned co-composting treatments could be considered ideal.

Composting could ensure higher levels of major and micro nutrients in the final product compared to raw paddy straw. Data on nutrient concentration of mature composts are presented in Table 6. Co-composting treatments which added poultry manure as N source could record higher N content in the final compost when compared to vermicompost and microbial composts. Paddy straw co-composted

Table 6. Nutrient status of paddy straw composts

Treatments	Major nutrients (%)			Micro nutrients (mg kg^{-1})			
	N	P	K	Fe	Cu	Zn	B
T_1	1.83	0.48	2.18	1189.67	28.15	174.27	12.92
T_2	1.90	0.51	2.22	1244.33	33.72	186.1013.16	
T_3	2.12	0.58	2.58	2001.33	37.80	187.77	13.50
T_4	2.06	0.63	2.70	2251.33	27.32	180.23	14.61
T_5	2.22	0.79	2.78	2998.67	32.30	191.83	16.55
T_6	2.67	0.93	3.15	3586.67	34.21	217.37	19.74
T_7	2.40	0.85	3.03	2358.67	28.45	170.90	17.90
T_8	1.57	0.27	1.71	1084.33	26.61	163.20	11.28
SE m (±)	0.11	0.04	0.20	205.03	4.54	12.821	0.91
CD (0.05)	0.317	0.129	0.591	619.975	NS	NS	2.749

with the highest quantity of poultry manure recorded the highest N content (2.67 %) and was comparable to T_7 (2.40 % N), the treatment in which paddy straw was co- composted with cowdung and poultry manure. This result could be connected with the richness of poultry manure in plant nutrient nitrogen (2.30 %), well above that of cowdung (1.21 %). Lowest N content of 1.57 per cent recorded with microbial compost could be due to the very low addition of N in the form of urea and no supply of organic manures. Phosphorus content in all the composts was found well enhanced with composting, compared to the initial content in paddy straw (0.12 %) and varied with different treatments (Table 6). Differences in P content of composts could be attributed to the variation in P content of the organic manures supplied as nitrogen source for hastening decomposition. P content was high in poultry manure (1.40 %) compared to cowdung (0.40 %) and hence composts that were generated with the addition of poultry manure recorded high P content. Treatment T_6 recorded the highest P content (0.93 %), closely followed and comparable to T_7 (0.85 %). As poultry manure was added as N source in both these treatments, the increased P content could be related with the richness of poultry manure in P. Microbial compost with non-addition of organic manure recorded significantly lower P content of 0.27 %. Similar to N and P, the K content also was found higher for co-composting treatments. Paddy straw co-composted using poultry manure in the ratio 4:1 (T_6) recorded the highest content of K (3.15 %) and was comparable to T_7 (3.03 %), T_5 (2.78 %) and T_4 (2.70 %) which again could be attributed to the richness of the manure in K. With respect to micronutrients, Fe and B content were found significantly influenced by different treatments, whereas Cu and Zn content were unaffected. Paddy straw co-composted with higher quantity of poultry manure (T_6) registered higher Fe (3586 mg kg^{-1}) and B (19.74 mg kg^{-1}) and was found comparable with treatment T_5 (2998 mg kg^{-1}) in terms of Fe and with treatment T_7 (17.90 mg kg^{-1}) in terms of B content. High contents of

Table 7. Microbial and enzymatic status of paddy straw composts

Treatment	Microbial count (cfu g^{-1})			Dehydrogenase enzyme
	Bacteria (×10^6)	Fungi(×10^3)	Actinomycetes(×10^4)	(µg TPF hr^{-1} g^{-1})
T_1	86.00	37.6726.33	16.84	
T_2	101.33	49.6730.33	17.54	
T_3	133.00	83.67	28.00	19.14
T_4	120.00	71.67	35.33	21.95
T_5	142.67	84.00	32.67	23.87
T_6	147.33	112.00	39.00	26.87
T_7	156.33	95.33	41.67	27.55
T_8	87.67	38.33	23.00	13.24
SE m (±)	4.50	5.26	0.86	1.48
CD (0.05)	13.602	15.917	2.594	4.483

micronutrients registered with these treatments might be due to the nutrient rich character of poultry manure added in these treatments.

Different composting methods could significantly influence the microbial status as well as enzymatic activity (Table 7) of mature composts. In general, the microbial population was higher with co-composting treatments. The treatments which received more of poultry manure at the start of composting could register higher population of bacteria, fungi and actinomycetes (T_6 and T_7). This could be related with the higher microbial activity of poultry manure, compared to cowdung (Table 3). Also, the low moisture and high dry matter content of poultry manure added more of organic material to the composting lot, in turn contributing to microbial proliferation. C: N ratios were much narrower in T_6 and T_7. A narrow C:N ratio of organic substrate favours rapid multiplication of microbes in it compared to that having a wider ratio (Azim et al., 2017) as nitrogen required for the protein build up of microbes is ensured under narrow C:N ratio. This also could be very well related to the enhanced microbial activity in treatments T_6 and T_7. Enzymatic activity was also higher with co-composting treatments. Paddy straw composted using cow dung and poultry manure in the ratio 8:1:1 (T_7) recorded higher dehydrogenase activity (27.55 µg TPF hr^{-1} g^{-1}) and was comparable with treatments T_6 (26.87 µg TPF hr^{-1} g^{-1}) and T_5 (23.87 µg TPF hr^{-1} g^{-1}). Dehydrogenase enzyme is considered as a reflection of biological activity (Neyla et al., 2009). Enhanced activity of the enzyme registered in the above treatments could be attributed to the proliferation of microbes observed in them.

Paddy straw with wide C:N ratio and lignin rich nature though difficult to be decomposed, can be bio recycled to quality organic manure using effective composting techniques. Among different methods of composting as tested in the present study, co-composting of paddy straw with poultry manure in the ratio 4:1 (v/v) or with cowdung and poultry manure in the ratio 8:1:1 (v/v) were identified much promising in generating nutrient rich composts. Co-composting of straw with cowdung and poultry manure (T_7) could yield mature compost within a relatively shorter period of 98 days. But the recovery of compost was only 27 per cent. Treatment T_6, i.e., co- composting of paddy straw with poultry manure (4:1) could register the highest recovery of 45 per cent within a period of 108 days. Recovery of compost was thus 1.65 times higher in T_6, though with a time lag of 10 days compared to T_7. Plant nutrients (N, P, K, Fe, B), microbial load (bacteria, fungi, actinomycetes) and activity of soil enzyme dehydrogenase were higher and comparable for both these composts. Both these composting strategies with unique advantages could be popularised, especially among farmers practising integrated farming for efficient recycling of resources and on farm generation of quality manures for effective use in crop production.

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