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Research Article

IMPACT OF BED PREPARATION TECHNIQUES WITH DIFFERENT SUBSTRATES ON VERMICOMPOSTING OF PAPER MILL WASTES

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ABSTRACT
Dumping of Paper mill wastes containing heavy metals on nearby field or by the side of effluent release channel causes environmental pollution. Vermicomposting of paper mill solid wastes using epigeic earthworms is possible if this waste is amended with different nutrient rich organic materials like saw dust, cow dung, etc. The experiment is carried out for studying the role of bed preparation techniques on vermicomposting and quality of vermicompost. It is observed that mixing together waste paper based paper mill wastes with saw dust and cow dung and initial turning twice at 7 days interval gave better performance in relation to vermicompost production, growth of *Eisenia fetida* earthworms and growth of paddy seedlings as compared to other bed preparation techniques by placing different substrates layer wise following six different arrangements during vermicomposting.

Keywords: *Bed Preparation Technique, Cowdung, Eisenia Fetida, Paper Mill Wastes, Sawdust, Vermicomposting*

INTRODUCTION
Paper Mill wastes, which contain cellulose, wood fibers and lignin generated from the paper mill, are not easy material to compost and normally need both structural and nitrogen amendments to compost well (Tucker, 2005). Some researchers have used sewage sludge, pig slurry and poultry slurry at different ratios (Elvira *et al.*, 1997), saw dust (Thyagarajan *et al.*, 2010), fruit and vegetable wastes (Tucker, 2005), food processing industry's wastes (Quintern, 2011), mixture of Agricultural, municipal solid wastes and poultry wastes (Yadav and Madan, 2013), Leaf litter and cow dung (Ponmani *et al.*, 2014), mixture of Pig wastes, water hyacinth and cow dung (Natarajan and Gajendran, 2014), etc for composting or vermicomposting of paper mill wastes successfully. Mohapatra *et al*., (2017) produced good quality vermicompost from waste paper based Emami Paper Mill Waste amended with saw dust and cow dung at the ratio 1:0.5:0.5 by creating a favourable condition for growth of *Eisenia fetida* earthworms. Biswas and Sannigrahi (2009) reported that type of composting materials as well as height of composting beds played important role on initial rise of temperature in the composting beds. Different researchers used different techniques for making vermicomosting beds. Nagavallemma *et al.*, (2004) and Ranganathan (2006) suggested for bed preparation by putting organic wastes layer by layer along with cowdung inside tank or pit, while Sannigrahi and Sannigrahi (2006), Umamaheswari *et al.*, (2009), Chattopadhyay (2012) and Beyginiya *et al.*, (2013), on the contrary, suggested for making beds by mixing various substrates with cow dung as slurry by adding sufficient water. This experiment was, therefore, conducted to study the impact of bed preparation on vermicomposting of paper mill wastes, on nutrient status of vermicomposts and their performance in growth of paddy seedlings.

MATERIALS AND METHODS
Paper Mill waste (PMW) was collected from dump yard made near Effluent Release Channel at the outside of Emami Paper Mill at Balasore. The same was dried in sheds and powdered for conducting experiment. Saw dust was collected from Remuna Saw Mill at Balasore and cow dung from a nearby farm. Chemical analysis of three organic materials used in this experiment is presented in Table 1. The experiment was conducted in rectangular plastic trays of capacity 2 kg. The saw dust and cow dung were

mixed in 1:0.5:0.5 ratio with PMW in one treatment (T_1) while in other treatments these were put layer wise following the order from bottom to top as PMW-CD-SD (T_2), PMW-SD-CD (T_3), CD-PMW-SD (T_4), CD-SD-PMW (T_5), SD-CD-PMW (T_6) and SD-PMW-CD (T_7). All beds were made moist by sprinkling sufficient water. All treatment in triplicates were kept on the table inside the laboratory room following a randomized block design after covering each tray with hessian cloths. The bedding materials of treatment T_1 were thoroughly mixed twice after 7 and 14 days while in other treatments beds were kept undisturbed. Twenty healthy adult *Eisenia fetida* earthworms were released on top of each bed on 14th day (Figure 1) and covered each tray again with hessian cloths. Regular monitoring was done to maintain 70 to 80 % moisture by spraying of water as and when required. When composting material became black colored loosely granular structured material up-to lower layer, as observed by physical verification once in a week, the bed materials were taken out of the tray and spread on the floor for partial air drying and for hand sorting all earthworms. Vermicompost of each treatment was sieved separately through 2mm sieve and stored in plastic zipper bags. Nutrient status of these vermicomposts were determined by their chemical analysis like pH, EC, Oxidizable Organic carbon, Total N, P, K, Ca, S and Na following standard methods mentioned by Bhargava and Raghupati (1993). Results were calculated on oven dry basis and analyzed statistically.

Table 1a: Chemical Analysis of Organic Materials

Organic Materials	**pH (1:2)**	**EC (dS/m)**	**Oxidisable Organic C (%)**	**Total**					
				N (%)	**P (%)**	**K (%)**	**Ca (%)**	**S (%)**	**Na (%)**
Paper Mill Waste	7.65	3.0	16.17	1.14	0.24	0.65	12.0	0.15	0.19
Sawdust	7.49	0.4	42.70	0.89	0.48	0.54	2.4	0.02	0.04
Cowdung	7.23	0.8	26.53	0.35	0.29	0.38	-	-	-

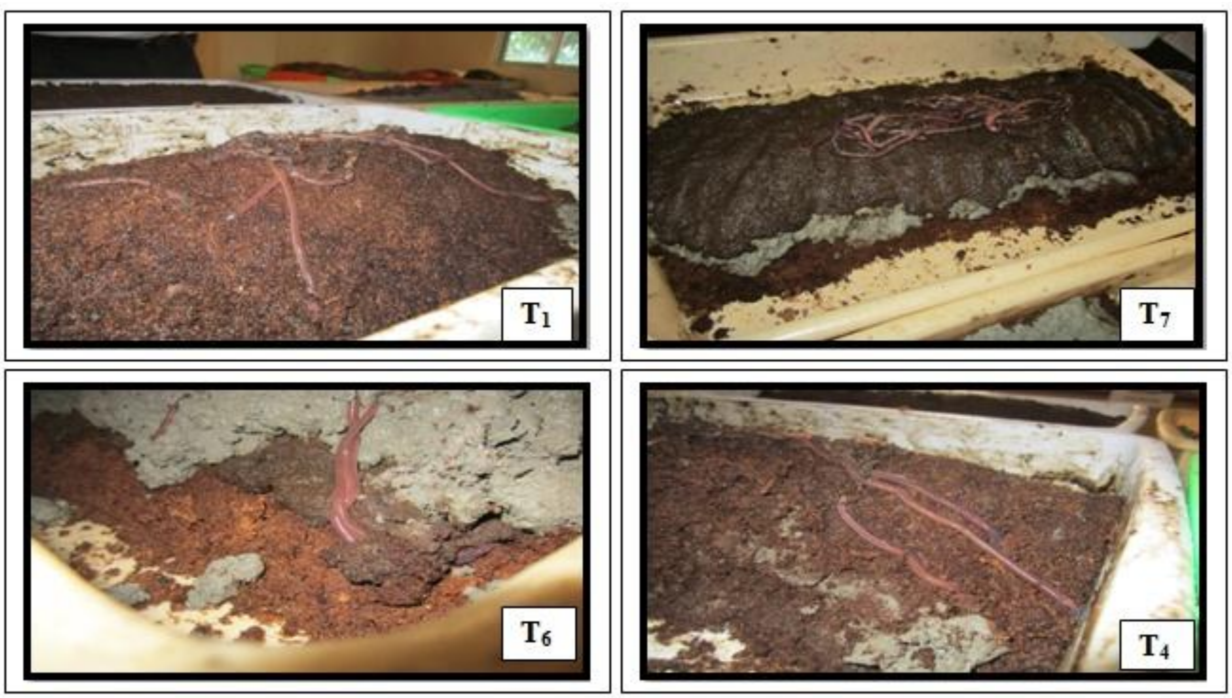

Figure 1: Glimpses of some Bed Preparation as per Treatments

Growth of paddy seedlings was studied in pot culture (Figure 2). Vermicomposts at the rate of 12 g/pot was mixed with 48 g sand taken in plastic pots of 100 ml capacity in triplicate and kept in randomized block design. Fifteen paddy (*Oryza sativa*) seeds were placed on each pot and water was added to submerge seeds. Germination percentage of these seeds was recorded up to 10 days. After 15 days seedlings were taken out of sand beds, washed thoroughly to remove sands and put on blotting papers to soak out excess water attached to seedlings. Plant weight was measured in electronic weighing machine. Shoot length and root length were measured for each seedling. Seedlings were kept in oven for overnight drying at 100 ^{0}C. Dry weight of all seedlings of each pot was measured together. Average results were calculated.

Figure 2: Growth of Paddy Seedlings on Sand with Vermicomposts in Plastic Pots

RESULTS AND DISCUSSION

The quantity of vermicomposts prepared from Paper Mill wastes, non-composted portion and number of earthworms with their weight during final harvesting are presented in Table 1. On the 1st day of release, all earthworms went to suitable layers for feeding. In case of T_1 where substrates were mixed initially, vermicomposting was completed in 40 days while in other treatments where layer-wise substrates were placed vermicomposting was completed partially even after waiting for longer period since the sawdusts as well as the cowdung being palatable finished quickly by *Eisenia fetida*. Where PMW was the top layer small amount was converted to white color excreta of earthworms (vermicompost). The compost part of Treatments T_5 and T_6 were very less in amount. However, the PMW sandwiched between cow dung and sawdust gave slightly better result. Best performance in comparatively lesser time with survival and multiplication of more earthworms was obtained from beds prepared after mixing together all substrates and turning twice after words (T_1 treatment). Several researchers such as Thyagarajan *et al.*, (2010), Yadav and Madan (2013), Sonowal *et al.*, (2014), Ponmani *et al.*, (2014), Natarajan and Gajendran (2014) etc. converted Paper Mill wastes to good quality vermicompost successfully after mixing with different amendment. The non-composted portion was found highest in T_2 and T_3 where PMW was placed as bottom layer.

The number and weight of earthworms harvested from different beds after completion of vermicomposting showed that only the mixing of substrates treatment alone was good for earthworm growth, survival and multiplication (Table 1). The availability of more number of adult and juvenile earthworms during vermicomposting of PMW with both cowdung and sawdust in mixing condition suggested that *Eisenia fetida* earthworms liked the food in mixing condition. The least number of earthworms in Treatments T_5 and T_6 indicated that presence of non- palatable paper mill wastes as top layer forced earthworms either to move away or to die within few days. The total body weight was also recorded highest in T_1 and lowest in T_5 and T_6. The quality and amount of food material influences not only the population of earthworm but also their rate of growth (Dominguez *et al.,* 2000; Chaudhari and Battacharjee 2002).

Table 1: Period of Vermicomposting and Quantity of Vermicomposts Produced from Emami Paper Mill Wastes under Different Bed Preparation Techniques

Treatment No.	Pattern of Layer of Raw Material [PMW (1kg), SD (0.5kg) and CD (0.5kg)] from Bottom to Top	Period of Vermicomposting (Days)	Vermicompost Harvested (kg)	Non-composted Portion (%)	Earthworms Harvested	
					Nos. (Big + Small)	Total Weight (g)
T_1	Mixture of PMW, CD and SD	40	0.79 ± 0.04	19.48 ± 1.44	22+150	50
T_2	PMW – CD – SD	65	0.26 ± 0.18	41.69 ± 0.87	15+10	22
T_3	PMW – SD – CD	70	0.29 ± 0.17	40.45 ± 3.83	10+8	15
T_4	CD – PMW – SD	55	0.37 ± 0.15	25.02 ± 0.80	10+20	20
T_5	CD – SD – PMW	65	0.19 ± 0.08	31.06 ± 3.12	7+5	8
T_6	SD – CD – PMW	70	0.14 ± 0.06	33.65 ± 1.15	5+0	5
T_7	SD – PMW – CD	53	0.43 ± 0.14	29.2 ± 0.49	10+15	12

Table 2: pH, EC, Oxidizable Organic Carbon and Moisture Content of Vermicomposts

Treatment No.	Pattern of Layer of Raw Material [PMW (1kg), SD (0.5kg) and CD (0.5kg)] from Bottom to Top	pH (1:2)	EC (ds/m)	Oxidizable Organic Carbon (%)	Moisture Percentage (%)
T_1	Mixture of PMW, CD and SD	7.51 ± 0.11	1.96 ± 0.15	12.55 ± 4.03	39.60 ± 09.53
T_2	PMW – CD – SD	8.04 ± 0.24	1.20 ± 0.10	18.26 ± 2.74	36.44 ± 14.26
T_3	PMW – SD – CD	7.83 ± 0.20	1.36 ± 0.06	18.51 ± 5.77	27.90 ± 04.66
T_4	CD – PMW – SD	8.05 ± 0.06	1.16 ± 0.06	22.07 ± 3.05	41.74 ± 09.87
T_5	CD – SD – PMW	7.89 ± 0.20	1.50 ± 0.10	16.29 ± 1.26	43.14 ± 09.89
T_6	SD – CD – PMW	7.91 ± 0.08	1.60 ± 0.10	17.37 ± 2.09	43.14 ± 11.89
T_7	SD – PMW – CD	7.91 ± 0.16	1.30 ± 0.10	16.61 ± 3.24	33.37 ± 05.75

Table 2 presents analytical data on pH, Electrical conductivity, oxidizable organic carbon and moisture contents of vermicomposts prepared from Emami Paper Mill wastes following different bed making techniques. The pH ranging from 7.51 to 8.05 was comparatively less in T_1 where all substrates are mixed properly and uniform decomposition took place. Lowering the pH of vermicomposts might be due to the production of CO_2 and organic acids by the combined action of earthworms and microbial decomposition during vermicomposting (Elvira *et al.*, 1998). The pH was slight higher in other treatments where three different substrates are placed separately without mixing. The highest pH above 8.0 was recorded where sawdust was on top. This was in agreement with earlier findings of Mohapatra *et al.*, (2017).

The Electrical Conductivity of these vermicomposts varied from 1.16 to1.96 dS/m (Table 2). Since the substrates combination is same for all treatments, variation in EC was due to difference in bed making techniques only. Less EC in vermicomposts prepared from beds having sawdust on top layer (T_2 and T_4 treatments) might be due to less EC of sawdust materials only. The salt content of both PMW and CD helped to increase EC of vermicompost in T_1 treatment than that of others.

Oxidizable organic carbon was considerable less (12.55% in T_1) in vermicomposts prepared from mixed substrate than that of other treatments (16.29 to 22.07%). This was obvious as vermicomposting was completed in T_1 where as partially completed in other treatments. Reduction of organic carbon with maturity of compost is due to loss in organic carbon with more earthworm activity (Atiyeh *et al.*, 2000). Vermicomposts prepared from beds with saw dust on top recorded higher organic carbon contents which might be due to presence of some saw dust with sieved vermicompost.

The moisture percentage of processed vermicomposts was varied from 33.37 to 43.14 percent, indicating well maintenance of moisture in vermicomposts of all the treatments. Slight higher moisture percentage was recorded in vermicomposts prepared from beds where saw dust and PMW were placed as top layer.

Total nutrient status presented in Table 3 showed that the total nitrogen of vermicomposts prepared after mixing substrates (T_1 treatment) was about 0.92%, which was comparatively lower than that of other treatments (1.21 to 1.36%) where layer wise placements of raw materials was carried out. Partial vermicomposting of later treatments as well as nitrogen status of raw materials present as top layer might be the cause of this variation.

Even though not much variation among treatments in case of total phosphorous (0.24 to 0.29%) was noticed, but trend was opposite to total nitrogen (Table 3). Layer wise placements of substrates during bed preparation recorded slight lesser total phosphorus than that of mixing of substrate (T_1 treatment). PMW and sawdust as top layer recorded better phosphorus than cowdung as top layer. This was in agreement with findings of Tucker (2005), Thyagarajan *et al.*, (2010), Yadav and Madan (2013) and Mohapatra *et al.*, (2017).

Similar to total phosphorus, total potassium content was also found comparatively higher in vermicomposts of T_1 treatment where complete mixing of substrates was carried out than those obtained from beds made by layer wise placements of substrates. Cowdung placed as top layer recorded slight higher potassium content due to its initial better potassium status.

Table 3: Macro Nutrients Status of Vermicomposts

Treatment No.	Pattern of Layer of Raw Material [PMW (1kg), SD (0.5kg) and CD (0.5kg)] from Bottom to Top	Total N (%)	Total P (%)	Total K (%)
T_1	Mixture of PMW, CD and SD	0.92 $\pm$ 0.06	0.29 $\pm$ 0.02	0.89 $\pm$ 0.13
T_2	PMW – CD – SD	1.31 $\pm$ 0.16	0.27 $\pm$ 0.01	0.74 $\pm$ 0.11
T_3	PMW – SD – CD	1.21 $\pm$ 0.16	0.24 $\pm$ 0.04	0.79 $\pm$ 0.13
T_4	CD – PMW – SD	1.36 $\pm$ 0.39	0.27 $\pm$ 0.01	0.65 $\pm$ 0.07
T_5	CD – SD – PMW	1.21 $\pm$ 0.28	0.28 $\pm$ 0.02	0.67 $\pm$ 0.12
T_6	SD – CD – PMW	1.21 $\pm$ 0.79	0.27 $\pm$ 0.02	0.70 $\pm$ 0.05
T_7	SD – PMW – CD	1.23 $\pm$ 0.27	0.26 $\pm$ 0.02	0.75 $\pm$ 0.04

As per analytical data given in Table 4, the total calcium varied from 5.94 to 11.22%, indicating clear influence of top layer in the trend PMW > SD > CD. The calcium content in T_7 was, however, found little higher than corresponding treatments having SD and CD as top layers. This might be due to partial vermicomposting of PMW placed as second layer. Paper Mill wastes as top layer showed higher total calcium (10.98 to 11-22%) in vermicomposts, which was obvious due to higher presence of calcium in PMW itself.

Mohapatra *et al*., (2017) recorded earlier higher total calcium (13.38%) in vermicomposts of PMW alone as compared to that of amended PMW. Vermicomposts prepared from mixed substrates, however, recorded about 7.32% total calcium, lower value was due to mixing of low calcium content substrate with PMW.

Table 4: Calcium, Sulphur and Sodium Status of Vermicomposts

Treatment No.	Pattern of Layer of Raw Material [PMW (1kg), SD (0.5kg) and CD (0.5kg)] from Bottom to Top	Total Ca (%)	Total S (%)	Total Na (%)
T_1	Mixture of PMW, CD and SD	7.32 $\pm$ 0.55	0.23 $\pm$ 0.07	0.30 $\pm$ 0.00
T_2	PMW – CD – SD	7.98 $\pm$ 1.36	0.23 $\pm$ 0.02	0.29 $\pm$ 0.04
T_3	PMW – SD – CD	5.94 $\pm$ 0.36	0.23 $\pm$ 0.06	0.32 $\pm$ 0.01
T_4	CD – PMW – SD	7.50 $\pm$ 0.73	0.21 $\pm$ 0.05	0.34 $\pm$ 0.03
T_5	CD – SD – PMW	11.22 $\pm$ 2.15	0.27 $\pm$ 0.05	0.38 $\pm$ 0.12
T_6	SD – CD – PMW	10.98 $\pm$ 1.57	0.25 $\pm$ 0.01	0.38 $\pm$ 0.02
T_7	SD – PMW – CD	9.00 $\pm$ 0.32	0.25 $\pm$ 0.07	0.36 $\pm$ 0.05

Treatment wise variation in total sulphur (0.21 to 0.27%) was not prominent like calcium (Table 4). However, comparatively higher sulphur was also recorded with PMW as top layer in layer-wise placement technique of bed preparation.

Total sulphur content in vermicomposts of this experiment is in agreement with earlier findings of Mohapatra *et al*., (2017).

Similar to sulphur content total sodium content was also recorded little variation (0.29 to 0.38%) among treatments with slight higher values in vermicomposts prepared from beds where PMW was kept as top layer. The technique of mixing of substrates during bed preparation recorded about 0.30% Na.

Influence of Vermicomposts on Germination of Paddy Seeds and Growth of Paddy Seedlings

Table 5 presents the data on germination of paddy seeds. Delay in germination in presence of vermicomposts prepared from beds made by layer wise placements of substrate proved the supremacy of mixing technique in bed preparation for vermicomposting.

In treatment T_1 all seeds were germinated within 5 days where as in all other treatments only 60 to 73% germination was recorded up to 9 days (Table 5).

No further germination proved that some toxic effects remained in vermicomposts prepared from beds where substrates were placed layer wise.

In fact mixing of substrates initially and turning twice after words in 7 days interval might have reduced the toxic properties of paper mill wastes.

The data presented in Table 6 clearly indicates that Treatment T_1 recorded highest performance in shoot length, root length, average weight of fresh and dry plants in comparison to all other treatments. This result confirms that vermicomposts prepared after mixing all substrate together is advantageous than making bed by putting substrates layer wise.

Growth of seedlings was hindered much in Treatments T_5 and T_6 supporting the fact that toxic properties remains in vermicomposts if bed is prepared keeping PMW as top layer.

Table 5: Germination of Paddy Seeds

Treatment No.	Pattern of Layer of Raw Material [PMW (1kg), SD (0.5kg) and CD (0.5kg)] from Bottom to Top	Germination of Seed Noticed after	Germination of Seeds after			
			3rd day	5th day	7th day	9th day
T_1	Mixture of PMW, CD and SD	48 hours	7 (47)*	15 (100)	15 (100)	15 (100)
T_2	PMW – CD – SD	72 hours	2 (13)	6 (40)	8 (53)	10 (67)
T_3	PMW – SD – CD	60 hours	3 (20)	5 (33)	10 (67)	10 (67)
T_4	CD – PMW – SD	56 hours	2 (13)	5 (33)	9 (60)	9 (60)
T_5	CD – SD – PMW	72 hours	1 (7)	4 (27)	8 (53)	11 (73)
T_6	SD – CD – PMW	68 hours	2 (13)	3 (20)	11 (73)	11 (73)
T_7	SD – PMW – CD	72 hours	3 (20)	5 (33)	8 (53)	9 (60)

*Data in parenthesis are germination percentage of paddy seedlings

Table 6: Growth of Paddy Seedlings

Treatment No.	Pattern of Layer of Raw Material [PMW (1kg), SD (0.5kg) and CD (0.5kg)] from Bottom to Top	Shoot Length (cm)	Root Length (cm)	Plant Weight (g)	
				Fresh Weight	Dry Weight
T_1	Mixture of PMW, CD and SD	16.53	11.15	1.86	0.30
T_2	PMW – CD – SD	12.52	9.02	1.01	0.21
T_3	PMW – SD – CD	13.47	8.45	0.78	0.17
T_4	CD – PMW – SD	9.45	9.06	0.65	0.12
T_5	CD – SD – PMW	8.02	7.6	0.43	0.10
T_6	SD – CD – PMW	7.98	7.89	0.54	0.13
T_7	SD – PMW – CD	10.43	9.05	0.49	0.07

Conclusion

The experiment, therefore, revealed that quantity and quality of vermicompost prepared from paper mill wastes highly dependent on initial bed preparation using different amendments. Mixing of all substrates together followed by at least two turnings not only helped on quick vermicompostings but also reduced the toxic properties of vermicompost prepared from paper mill wastes. All the above data through analysis of various parameters showed that earthworm preferred half decomposed material prepared by mixing technique. Vermicomposts prepared from mixed substrates were, no doubt, nutrient rich, odour free, more matured and stabilized than those prepared from layer wise preparation of beds. It also highlighted about comfort zone for earthworms.

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