Asian Jr. of Microbiol. Biotech. Env. Sc. Vol. 8, No. (2) : 2006 : 275-285

PRETREATMENT OF LIGNOCELLULOSIC WASTES WITH WHITE ROT FUNGI, *FOMES LIVIDUS, THELEPHORA SP.* AND *TRAMETES VERSICOLOR* FOR VERMICOMPOSTING

K. SELVAM,[1*] K. SWAMINATHAN [2], K. RASAPPAN[3], R. RAJENDRAN[1] AND S. PATTABI[4]

[1]Department of Biotechnology, Dr N.G.P. Arts and Science College, Coimbatore-35,
[2]Department of Biotechnology, Bharathiar University, Coimbatore-46,
[3]Department of Civil Engineering, Coimbatore Institute of Technology, Coimbatore-14,
[4]Department of Environmental Sciences, PSG College of Arts and Science Coimbatore-14,

Key words : *White rot fungi, Eudrilus eugeniae, Lignocellulosic wastes, Vermicompost, Soil fertility.*

Abstract–The lignocellulosic waste biomass, vegetable waste, agricultural waste and agro-industrial waste were pretreated with the white rot fungi, *Fomes lividus, Thelephora* sp. and *Trametes versicolor* for composting with earthworm aiming that the fungi will degrade the complex plant polymers, lignin, cellulose and hemicellulose by their enzymes thereby accessing simple compounds for earthworm composting. Five types of treatments were tried. In tretment I, the wastes were allowed for natural degradation and it served as control, in treatment II, the fungus alone was inoculated on the substrate, in treatment III, the earthworm, *Eudrilus eugeniae* alone was inoculated, in the treatment IV, the fungus and the earthworm were inoculated on the same time and in treatment V, the earthworm was inoculated after one month of fungal inoculation. The compost formed was analysed for organic carbon, nitrogen, phosphorus and potassium contents and the C/N ratio was calculated. The effect of application of compost on soil fertility was analysed. It was observed that treatment V was more efficient in composting the waste biomass; the compost obtained in this treatment enhanced the soil fertility than the composts from other treatments.

INTRODUCTION

The problem of waste disposal has become very acute in towns and cities in the country as disposal facilities have lagged far behind the quantity of wastes produced. The garbage disposal posed serious threat to the health of the environment. The garbage is either dumped as landfill material on the out skirts of the city or burnt, producing foul smoke and creating unhygienic conditions. Wastes containing organic matter like domestic waste (vegetable matter, paper, cardboard, meat and food wastes) or agro-industrial waste can be treated biologically. The microorganisms are used to bring out a biochemical change to reduce the carbon content in this shredded matter by the emission of carbon dioxide. This pulverized matter is pre digested to organic matter having a sufficiently low carbon to nitrogen ratio.

Muthukumar and Mahadevan, (1983) have observed that species of *Polyporus, Pleurotus, Collybia, Poria, Fomes, Trametes, Sporotrichum, Cyathus* and *Coriolus* degraded lignin molecules of waste materials. Bhardwaj and Gaur (1985) have compiled extensive information on the isolation, selection and use of fungal cultures for rapid composting of organic wastes. Most of the organisms reported are mesophilic fungi, but a few were thermophilic strains such as *Aspergillus fumigatus* and *Humicola lanuginosa*. The effectiveness of the process depends greatly on substrate nature. In general, the C:N ratio is used as an indicator for substrate compostability, with optimal values between 25 and 30. However, some organic wastes with optimum C:N ratio contain large proportion of lignin and/or cellulose and are not changed much by composting (Baca *et al.*, 1992). White-rot fungi are known as the most efficient ligninolytic microorganisms (Kirk and Farrell, 1987). *Phanerochaete chrysosporium* is probably the best-studied microorganism and it is often used as a reference. Other well-known white-rot fungi, *Coriolus versicolor* show even higher efficiency and a wider range of ligninolytic activities together with an important cellulolytic activity (Abdulnasser *et al.*,

[1*]**Author for Correspondence:** Department of Biotechnology, Dr. N.G.P. Arts & Science College, Coimbatore-35; E-mail: selsarat@yahoo.com

1997). Indigenous microorganisms naturally undertake lignin breakdown in composting (Tuomela *et al.*, 2000).

Earthworms are one of the major soil macro invertebrates and are known for their contributions to soil formation. The earthworms play a role in the breakdown of organic debris on the soil surface and in the soil turnover process (Darwin, 1881). Utilization of earthworms to break down organic wastes is gaining popularity in different parts of the world (Edwards and Lofty 1972). From the literature it can be postulated that pretreatment of agro-industrial wastes by microbial system will enhance the composting process by the earthworms or otherwise earthworms will make the waste more accessible to microbial degradation. The aim of the present research was to determine the contribution of the white rot fungi, *F. lividus, Thelephora sp., T. versicolor* and the earthworms to mineralisation and humification of lignocellulosic wastes. To reach this objective, a lab-scale experiment was carried out using sterile substrates inoculated with the fungi and earthworms incubated under different ways. Using microbes and earthworms alternatively for composting of organic matter will help in minimising the time of composting, improving the quality of the compost, minimising the cost of labour and making it an economic venture for the spread of the technology to the rural areas.

MATERIALS AND METHODS

Microorganisms and media

The fungi, *F. lividus, Thelephora sp.* and *T. versicolor,* were isolated respectively from the logs of *Shorea robusta,* stumps of a burnt tree and *Acacia nilotica* in the Western Ghats region of Tamilnadu, India. The fungi were identified based on the keys provided previously (Bakshi 1971; Gilbertson and Ryvarden 1986). Fungal growth was cut out, sterilized with 1% mercuric chloride solution, repeatedly washed with sterile distilled water as described previously (Roy Watling, 1971) and inoculated on 2% malt agar medium. The fungal growth on a plate was allowed to grow for 6 days at 37°C. Then, the spores were harvested without disturbing the mycelial growth using camel hair brush and filter-sterilized. The spore concentration was adjusted to 10^5 spores/mL and used as an inoculum for further studies.

Organic wastes and earthworm

The wastes used as substrates were vegetable wastes from the market (house hold waste), agricultural wastes (paddy straw and sorghum stover) and the agro-industrial waste, the coir pith, were procured from the local area around Coimbatore city, India. The crop residues were air dried before use. The culture of earthworm (*Eudrilus eugenia*) was collected from local soil and was maintained on cattle dung.

Composting experiment

Composting of lignocellulosic wastes by fungi and earthworm were studied in pot cultures. The following treatments were tried. T1 natural degradation (control), T2 degradation by fungi only, T3 degradation by earth worm only, T4 simultaneous degradation by both fungi and earth worm, T5 degradation by fungi for one month and then by earth worm. For each treatment five replicates were maintained. Moisture was maintained to about 60% of water holding capacity. In the treatment with earthworm, 20 matured worms were introduced. Samples were analysed at every 15 days interval for organic carbon content (Sims and Haley,1971), available nitrogen content (Subbiah and Asija, 1956), available phosphorus content (Olsen *et al.*,1954) and available potassium content (Jackson, 1967); the C/N ratio of each sample was also calculated. All the determinations were carried out in five replicates. Data were analysed statistically and differences between treatment means were compared at the 5% and 1% level of significance.

RESULTS AND DISCUSSION

The results in general revealed that the fungal pretreatment increased the carbon and nitrogen content of the compost and decreased the C/N ratio, whereas phosphorus and potassium contents were decreased. In vegetable waste, in all the treatments, the carbon content was increased by 160 to 175.9 per cent and nitrogen content by 100 to150 per cent after 105 days composting; phosphorus content was decreased by 25 to 37.5 per cent and potassium by 22.22 to 38.89 per cent; C/N ratio was decreased by 9.57 to 37.94 per cent (Table 1 a,b). Among the treatments, the higher levels of increase in carbon and nitrogen contents or decrease in phosphorus and potassium contents were observed in treatment 5; the variations in carbon and nitrogen contents were significant at 1 and 5 per cent levels respectively, but variations observed in phosphorus and potassium contents were not significant.

Table 1a. Nutrients content of vermicompost from vegetable waste
(Control- C: 0.79%; N: 0.28g/kg; P: 0.08g/kg; K: 0.36g/kg; C/N: 28.20%.

Incubation	Fungus					Worm					FW *					FW **				
Period	C	N	P	K	C/N	C	N	P	K	C/N	C	N	P	K	C/N	C	N	P	K	C/N
(days)	%	g/kg	g/kg	g/kg		%	g/kg	g/kg	g/kg		%	g/kg	g/kg	g/kg		%	g/kg	g/kg	g/kg	
F. lividus																				
45	1.94	0.42	0.08	0.32	46.20	1.90	0.28	0.07	0.33	67.90	1.94	0.42	0.07	0.33	46.20	1.94	0.28	0.07	0.34	69.30
60	2.06	0.42	0.06	0.32	49.00	2.06	0.28	0.06	0.32	73.60	2.04	0.56	0.06	0.34	36.40	1.90	0.28	0.07	0.35	67.90
75	2.11	0.56	0.05	0.31	37.70	2.09	0.42	0.06	0.32	49.80	2.11	0.56	0.06	0.33	37.70	2.09	0.42	0.06	0.33	49.80
90	2.14	0.70	0.06	0.28	30.60	2.11	0.70	0.06	0.28	30.10	2.16	0.56	0.06	0.26	38.60	2.14	0.56	0.06	0.30	38.20
105	2.16	0.70	0.05	0.28	30.90	2.16	0.70	0.06	0.20	30.90	2.18	0.70	0.06	0.28	31.20	2.18	0.56	0.05	0.22	38.90
Thelephora sp.																				
45	1.97	0.42	0.08	0.34	46.90	1.90	0.28	0.08	0.34	67.90	1.90	0.28	0.07	0.32	67.90	1.97	0.28	0.08	0.34	70.36
60	2.09	0.56	0.06	0.34	37.30	2.02	0.28	0.06	0.34	72.10	2.07	0.42	0.06	0.34	49.30	1.92	0.28	0.06	0.34	68.60
75	2.11	0.56	0.05	0.32	37.70	2.09	0.28	0.06	0.33	74.60	2.06	0.56	0.06	0.33	36.80	2.09	0.56	0.07	0.32	37.30
90	2.14	0.70	0.06	0.30	30.60	2.14	0.56	0.06	0.29	38.20	2.11	0.70	0.06	0.27	30.10	2.11	0.56	0.06	0.30	37.70
105	2.18	0.70	0.06	0.27	31.10	2.16	0.70	0.06	0.22	30.90	2.14	0.56	0.06	0.24	38.20	2.16	0.70	0.06	0.24	30.90
T. versicolor																				
45	1.92	0.42	0.08	0.33	45.70	1.90	0.28	0.08	0.34	67.90	1.90	0.28	0.07	0.32	67.90	1.92	0.28	0.08	0.33	68.60
60	2.06	0.42	0.06	0.33	49.00	2.04	0.28	0.06	0.34	72.90	2.06	0.42	0.06	0.34	49.00	1.94	0.56	0.06	0.33	34.60
75	2.09	0.42	0.05	0.32	49.80	2.11	0.42	0.06	0.34	50.20	2.09	0.56	0.07	0.34	37.30	2.06	0.56	0.06	0.32	36.80
90	2.18	0.70	0.05	0.28	31.10	2.14	0.70	0.06	0.29	30.60	2.14	0.70	0.06	0.28	30.60	2.11	0.56	0.07	0.29	37.70
105	2.21	0.70	0.05	0.26	31.60	2.16	0.70	0.06	0.24	30.90	2.06	0.56	0.06	0.26	36.80	2.14	0.70	0.06	0.25	30.60

FW * Fungus and worm inoculated at same time
FW ** Worm inoculated after one month
Values are mean of five replicates

Table 1b. Statistical analysis of the data presented in table 1a.

Nutrient component	F value	Level of significance (%)	CV (%)	SED	LSD 5%	LSD 1%
A. Among treatments						
F.lividus						
C	192.66	1	5.1	0.0580	0.1217	0.1661
N	3.59	5	29.9	0.0869	0.1282	0.2472
P	3.39	5	15.5	0.0064	0.0133	0.0182
K	2.39	5	12.4	0.0247	0.0515	0.0702
Thelephora sp.						
C	223.94	1	4.7	0.0540	0.1126	0.1536
N	2.87	5	33.3	0.0955	0.1992	0.2717
P	2.60	NS	15.7	0.0066	0.0138	0.0189
K	2.04	NS	12.1	0.0242	0.0505	0.0689
T. versicolor						
C	33.69	1	12.1	0.1355	0.2826	0.3855
N	2.38	NS	33.0	0.0971	0.2025	0.2763
P	2.74	NS	16.6	0.0070	0.0146	0.0199
K	2.75	NS	10.1	0.0203	0.0424	0.0578
B. Among fungi						
C	5.37	5	31.7	0.3604	0.7852	1.1006
N	19.64	1	11.3	0.0358	0.0780	0.1094
P	10.33	1	8.4	0.0040	0.0086	0.0121
K	56.15	1	2.3	0.0052	0.0113	0.0159

Composting of agrowastes resulted in tremendous increase in carbon and nitrogen contents when compared to other two substrates. The treatments increased the carbon content by 3066 to 3583 per cent; maximum being in *F. lividus* pretreated samples; similarly nitrogen content was also increased by 100 to 200 per cent after 105 days composting; phosphorus content was decreased by 14.29 to 28.60 per cent and potassium content by 26.09 to 34.28 per cent; C/N ratio was decreased by 47.04 - 69.3 per cent revealing an increase of nitrogen content of the compost. Statistical analysis of the data showed that the variations observed in carbon and nitrogen contents were significant at 1.0 per cent and that of phosphorus was not significant; in *F. lividus* treatment, potassium content was decreased significantly (1.0% level); but in the other two fungal treatments the potassium content was not significantly altered. Among fungi, alterations in all the parameters were significant at 1.0 per cent level except that of phosphorus which was significant at 5.0 per cent level (Table 2 a,b).

Either fungal pretreatment alone or in combination with earthworm, could not decompose coir pith effectively (Table 3 a,b). The increase in carbon and nitrogen contents and also the decrease in phosphorus content in *F. lividus* and *Thelephora sp.* pretreatment were not significant; similarly alteration in the carbon and phosphorus content of *T. versicolor* pretreated samples were also not significant; but the potassium content was significantly (1% level) decreased by all the treatments; the decrease was in the range of 48.4 to 64.5 per cent; C/N ratio was decreased by 47.1 to 66.7 per cent.

The increase in carbon and nitrogen contents might be attributed to decomposition of plant polymers into simpler molecules by the fungi as well as the earthworm and decrease in phosphorus and potassium content might be due to leaching of these nutrients in to the soil.

When the compost amended soil samples were analysed, it was observed that vegetable waste compost increased the soil carbon content by 147.0 to 250.0 per cent (significant at 1.0% level); but the nitrogen content was not much affected; the phosphorus and potassium contents were significantly increased (both at 1.0% level); phosphorus content was increased by 183.3 to 250.0 per cent and potassium content by 56.9 to 109.2 per cent; C/N ratio was increased by 56.9 to 109.2 per

Table 2a. Nutrients content of vermicompost from agrowaste
(Control - C: 0.06%; N: 0.14g/kg; P: 0.07g/kg; K; 0.23g/kg; C/N: 147.1%)

Incubation	Fungus					Worm					FW *					FW**				
period (days)	C %	N g/kg	P g/kg	K g/kg	C/N	C %	N g/kg	P g/kg	K g/kg	C/N	C %	N g/kg	P g/kg	K g/kg	C/N	C %	N g/kg	P g/kg	K g/kg	C/N
F. lividus	1.90	0.14	0.06	0.15	135.7	1.94	0.28	0.06	0.22	69.30	1.94	0.28	0.07	0.21	69.30	1.89	0.14	0.06	0.21	135.0
60	2.09	0.28	0.06	0.14	74.60	2.09	0.28	0.06	0.20	74.60	2.06	0.28	0.06	0.20	73.60	1.94	0.28	0.06	0.20	69.30
75	2.16	0.28	0.06	0.14	77.10	2.09	0.42	0.06	0.20	49.80	2.29	0.28	0.06	0.22	74.60	2.06	0.28	0.06	0.20	73.60
90	2.18	0.42	0.05	0.13	51.90	1.94	0.42	0.05	0.17	46.20	2.11	0.28	0.06	0.16	75.40	2.09	0.42	0.06	0.19	49.80
105	2.21	0.42	0.05	0.13	52.60	1.90	0.42	0.05	0.16	45.20	1.99	0.28	0.05	0.16	71.10	2.18	0.42	0.05	0.16	51.90
Thelephora sp.																				
45	1.94	0.14	0.06	0.21	138.5	1.92	0.14	0.06	0.22	137.1	1.90	0.28	0.06	0.20	67.90	1.94	0.14	0.06	0.21	138.6
60	2.11	0.28	0.05	0.21	75.40	2.06	0.28	0.06	0.20	73.60	2.09	0.28	0.06	0.24	74.60	1.90	0.28	0.05	0.20	67.90
75	2.14	0.28	0.05	0.21	76.40	2.06	0.28	0.06	0.24	73.60	2.11	0.42	0.06	0.22	50.20	2.09	0.28	0.06	0.20	74.60
90	2.14	0.28	0.06	0.18	76.40	2.11	0.28	0.06	0.17	75.40	2.14	0.28	0.06	0.17	76.40	2.09	0.28	0.06	0.18	74.06
105	2.18	0.28	0.05	0.15	77.90	1.99	0.28	0.05	0.16	71.10	2.02	0.28	0.05	0.14	72.01	2.14	0.28	0.06	0.17	76.04
T. versicolor																				
45	1.09	0.28	0.07	0.21	67.90	1.90	0.28	0.05	0.22	67.90	1.95	0.14	0.07	0.21	139.3	1.90	0.14	0.07	0.21	135.7
60	2.06	0.28	0.06	0.20	73.60	2.06	0.28	0.06	0.21	73.60	2.11	0.14	0.05	0.21	150.7	1.92	0.28	0.06	0.21	68.60
75	2.11	0.28	0.06	0.20	75.40	2.09	0.28	0.06	0.24	74.60	2.14	0.28	0.05	0.20	76.40	2.09	0.28	0.06	0.21	74.60
90	2.16	0.42	0.05	0.19	51.4	2.14	0.42	0.05	0.18	50.90	2.16	0.28	0.06	0.17	77.10	2.11	0.28	0.06	0.18	75.40
105	2.18	0.42	0.05	0.16	51.90	2.06	0.42	0.05	0.15	49.10	2.06	0.42	0.05	0.15	49.00	2.16	0.42	0.05	0.16	51.40

FW * Fungus and worm inoculated at same time
FW ** Worm inoculated after one month
Values are mean of five replicates

Table 2b. Statistical analysis of the data presented in table 2a.

Nutrient component	F value	Level of significance (%)	CV (%)	SED	LSD 5%	LSD 1%
A. Among treatments						
F. lilvidus						
C	355.79	1	6.4	0.669	0.1395	0.1903
N	4.75	1	29.1	0.0518	0.1081	0.1475
P	2.24	NS	14.5	0.0055	0.0115	0.0157
K	13.66	1	10.6	0.0125	0.0261	0.0356
Thelephora sp.						
C	191.16	1	8.1	0.0863	0.1800	0.2456
N	5.91	1	23.4	0.0357	0.0745	0.1016
P	2.71	NS	13.8	0.0052	0.0109	0.0148
K	1.68	NS	14	0.0178	0.0370	0.0505
T. versicolor						
C	13.6	1	78.43	0.1405	0.2931	0.3998
N	4.58	1	31.4	0.0533	0.1112	0.1517
P	2.02	NS	16.4	0.0062	0.0129	0.0176
K	2.29	NS	12.4	0.0158	0.0330	0.0450
B. Among fungi						
C	1125.63	1	3.8	0.0416	0.0907	0.1272
N	25.00	1	12.5	0.0226	0.0493	0.0691
P	5.36	5	7.7	0.0034	0.0074	0.0103
K	10.53	1	6.9	0.0097	0.0211	0.0296

cent; highest nutrient contents were observed in soil samples amended with *Thelephora sp.* pretreated and earthworm decomposed vegetable wastes.

Though amendment of soil with agrowaste compost increased the soil fertility, the level of increase is lower when compared to vegetable waste compost amendment (Table 4 a,b). Here, the carbon content was increased by 11.8 to 470.6 per cent; nitrogen and phosphorus contents were not increased significantly; potassium content was increased by 4.6 to 47.7 per cent (significant at 1 % level); C/N ratio was increased by 11.2 to 323.5 per cent. Here again, the *Thelephora sp.* pretreated and earthworm decomposed agro wastes were found to be good soil additives as manure.

The coir pith compost amendment significantly increased (1.0% level) the carbon and phosphorus contents and decreased the potassium content of the soil; but the nitrogen content was not significantly altered. However, the increase in soil nutrient content was very low when compared to the compost of vegetable waste and agrowaste. In coir pith amended soil samples, increase of 35.3 to 464.7 per cent carbon and 16.7 to 83.3 per cent phosphorus were observed; potassium content was decreased by 21.5 to 41.5 per cent; the C/N ratio was increased by 10.3-747.1 per cent. In coir pith also, *Thelephora sp.* pretreatment with earthworm decomposition was found to be effective in preparation of compost from coir pith.

Composting is the process of converting organic residues of plant and animal origin into manure, rich in humus and plant nutrients. It is largely a microbiological process based upon the activities of a host of bacteria, actinomycetes and fungi. All kinds of organic residues amenable to the enzymatic activities of the microorganisms can be converted into compost by providing optimum conditions for biodegradation.

The main constituents of plant residues are the carbonaceous compounds such as cellulose, hemicellulose and lignin; nitrogenous constituents (proteins) occur to a lesser extent. Protein, cellulose and hemicellulose decompose easily. Lignin, a complex aromatic polymer, is resistant to microbial attack to a considerable extent. Most components of lignin reach the finally produced humus in the compost (Neelakantan *et al.*, 1974, Wani and Shinde, 1977; Lynch *et al.*, 1981). Kalekar *et al.* (1976) reported that compostable organic materials are naturally inhabited by large number of heterotrophic microorganisms, which bring about satisfactory decomposition under appropriate environmental conditions. Dash *et al.* (1979) reported that earthworm grazing on the soil microflora enhanced microflora growth by preventing senescence.

Kononova (1966) and Stevenson (1982) reported

Table 3a. Nutrients content of vermicompost from coir pith
(Control - C: 2.065; N: 0.14g/kg; P:0.05g/kg; K: 0.31g/kg; C/N: 147.1%)

Incubation	Fungus					Worm					FW *					FW **				
Period (days)	C %	N g/kg	P g/kg	K g/kg	C/N	C %	N g/kg	P g/kg	K g/kg	C/N	C %	N g/kg	P g/kg	K g/kg	C/N	C %	N g/kg	P g/kg	K g/kg	C/N
F. lividus																				
45	1.92	0.14	0.03	0.23	137.1	1.90	0.14	0.05	0.24	135.7	1.90	0.14	0.05	0.26	135.7	1.92	0.14	0.03	0.26	137.1
60	2.11	0.14	0.05	0.23	150.7	2.04	0.14	0.05	0.22	145.7	2.09	0.14	0.06	0.25	149.3	1.92	0.14	0.05	0.26	137.1
75	2.14	0.28	0.05	0.20	76.40	2.14	0.28	0.04	0.21	76.40	2.14	0.28	0.05	0.20	76.40	2.18	0.28	0.05	0.23	77.90
90	2.16	0.28	0.05	0.19	77.10	2.11	0.28	0.04	0.19	76.40	2.09	0.42	0.05	0.17	49.80	2.18	0.28	0.05	0.18	77.90
105	2.18	0.28	0.05	0.15	77.80	2.09	0.28	0.04	0.11	74.60	2.04	0.28	0.05	0.16	72.90	2.11	0.28	0.06	0.16	75.40
Thelephora sp.																				
45	1.87	0.14	0.04	0.24	133.6	1.92	0.14	0.05	0.25	137.1	1.92	0.14	0.05	0.25	137.0	1.87	0.14	0.04	0.28	133.6
60	2.14	0.14	0.05	0.24	152.9	2.11	0.14	0.04	0.24	150.7	2.04	0.14	0.05	0.24	145.7	1.92	0.14	0.05	0.27	137.1
75	2.18	0.28	0.05	0.20	77.90	2.11	0.14	0.04	0.22	150.7	2.11	0.28	0.05	0.21	75.40	2.16	0.28	0.05	0.24	77.10
90	2.14	0.28	0.05	0.17	76.40	2.19	0.28	0.04	0.18	78.20	1.99	0.28	0.06	0.18	71.10	2.16	0.28	0.05	0.20	77.10
105	2.09	0.28	0.04	0.11	74.60	2.07	0.28	0.04	0.16	73.90	1.90	0.28	0.05	0.14	67.90	2.06	0.28	0.05	0.16	73.60
T. versicolor																				
45	1.90	0.28	0.02	0.24	67.90	1.94	0.28	0.06	0.24	69.30	1.94	0.14	0.05	0.24	138.6	1.90	0.14	0.04	0.27	135.7
60	2.14	0.28	0.06	0.24	76.40	2.14	0.28	0.08	0.23	76.40	2.14	0.14	0.06	0.24	152.9	1.92	0.14	0.06	0.26	137.1
75	2.09	0.28	0.05	0.24	74.60	2.14	0.28	0.05	0.24	76.40	2.16	0.28	0.06	0.19	77.10	2.18	0.28	0.05	0.24	77.90
90	2.09	0.42	0.05	0.17	49.80	2.09	0.28	0.04	0.19	74.60	2.02	0.28	0.05	0.17	72.10	2.16	0.28	0.05	0.18	77.10
105	2.06	0.42	0.05	0.16	49.00	2.11	0.28	0.04	0.15	75.40	1.94	0.28	0.05	0.15	69.30	2.09	0.28	0.05	0.17	74.60

FW * Fungus and worm inoculated at same time
FW ** Worm inoculated after one month
Values are mean of five replicates

Table 3b. Statistical analysis of the data presented in table 3 a.

Nutrient component	F value	Level of significance (%)	CV (%)	SED	LSD 5%	LSD 1%
A. Among treatments						
F. lividus						
C	NS	NS	4.7	0.0613	0.1280	0.1746
N	1.43	NS	37.4	0.0503	0.1049	0.1431
P	NS	NS	20.8	0.0063	0.0132	0.0180
K	7.08	1	17.8	0.0254	0.0530	0.0723
Thelephora sp.						
C	NS	NS	4.9	0.0639	0.1333	0.1818
N	1.40	NS	34.2	0.0436	0.0910	0.1241
P	1.09	NS	17.3	0.0052	0.0109	0.0148
K	6.02	1	18.8	0.0272	0.0567	0.0774
T. versicolor						
C	NS	NS	4.6	0.0595	0.1242	0.1694
N	7.45	1	24.8	0.0378	0.0789	0.1076
P	NS	NS	25.5	0.0082	0.0171	0.0233
K	7.07	1	16.6	0.0242	0.0504	0.0688
B. Among fungi						
C	1.01	NS	11.1	0.1661	0.3619	0.5073
N	11.46	1	14.6	0.0220	0.0479	0.0671
P	2347.71	1	4.7	0.0038	0.0083	0.1170
K	71.14	1	5.2	0.0086	0.0187	0.0263

that a number of exoenzymes, secreted by the soil organisms, catalyse the hydrolytic degradation process of the litter polymers, but catalyse also a number of condensation reactions in the soil water phase leading to the formation of complex humic substances, which in addition to the lignin derived polyphenols and quinones also contain amino compounds, polysaccharide units and phosphorylated sites. These substrates were further acted upon by the earthworms to form nutrient rich manure. Mackay *et al.* (1982) have speculated that earthworms would appear to stimulate phosphorous uptake from organic matter by redistribution and by increasing phosphatase activity. Similarly, earthworms can affect the cycling of nitrogen. Barley and Jennings (1959) showed that 6.4 per cent of the non-available nitrogen ingested by growing *Allolobophora caliginosa* was excreted in casts in plant available form. The available nitrogen in the worms occur as ammonium nitrogen, nitrate nitrogen and as other soluble nitrogen; 96 per cent of nitrogen in fresh casts is present as NH_4 and rapid nitrification occurred following cast production, finally improving the soil fertility (Parle, 1963).

By shifting fine particles from coarser particles, earthworms prepare a good media that promote microbial activity essential for the fertility of most of the soil (Hayes, 1983). Syers and Springett (1983) have shown that worms chemically influence the nutrients in the soil by direct enzyme action on organic matter in the intestine, metabolise the organic materials and release the metabolic products into the soil, particularly nitrogen. The increase in nitrogen content in worm casts is attributed to thorough mixing of the organic material by the digestive secretions (Lindquist, 1941; Lunt and Jacobson, 1944; Barley and Jennings, 1959). Singh *et al.* (1999) reported that worm castings have more organic matter, phosphate, copper, zinc, iron manganese and low pH than that of the soils; obviously, these casts contribute to the value of the compost (Barley and Jennings, 1959; Parle, 1963; Mackay *et al.*, 1982; Bano *et al.*, 1984). The present study revealed that the pretreatment of lignocellulosic wastes by white rot fungi before earthworm composting will improve the level of degradation and the fertilizer value of the compost.

REFERENCES

Abdulnasser, N. H., Heltny S. M., and Elgammal, A. A., 1997. Fonnation of enzymes by biodegradation of agricultural wastes with white-rot fungi. Polym. Degrad. Stabil. 55, 249-255.

Baca, M.T., Fornasier, F and de Nobili, M. 1992. Mineralization and humification pathways in two composting processes applied to cotton wastes.

Table 4a. Effect of compost amendment on soil fertility
(Control - C: 0.34 ; N:0.03; P: 0.06; K: 0.65; C/N: 113.33)

Substrate/	Fungus					Worm					FW *					FW**				
Fungus	C %	N g/kg	P g/kg	K g/kg	C/N	C %	N g/kg	P g/kg	K g/kg	C/N	C %	N g/kg	P g/kg	K g/kg	C/N	C %	N g/kg	P g/kg	K g/kg	C/N
Vegetable waste																				
F. lividus	0.91	0.04	0.20	1.09	227	0.96	0.04	0.20	1.12	240	1.08	0.07	0.18	1.34	154	1.90	0.04	0.20	1.09	475
	167.	33	233	67	100	182	33	233	72	111	217	133	200	106	36	459	33	233	67	319
Thelephora sp.	0.84	0.03	0.20	1.19	280	0.98	0.04	0.19	1.02	245	1.10	0.04	0.17	1.22	275	1.92	0.04	0.20	1.20	480
	147	00	233	83	147	188	33	216	57	116	223	33	183	88	142	464	33	233	84	323
T. versicolor	0.96	0.03	0.21	1.21	320	1.03	0.03	0.19	1.21	343	1.34	0.03	0.18	1.36	446	1.94	0.04	0.21	1.20	485
	182	00	250	86	182	202	00	216	86	202	294	00	200	109	293	470	33	250	85	328
Agro waste																				
F. lividus	0.50	0.03	0.08	0.68	166	0.43	0.04	0.08	0.80	107	0.41	0.07	0.11	0.82	58.6	1.94	0.07	0.08	0.78	277
	47	00	33	5	47	27	33	33	23	6	21	133	83	26	-48	470	133	83	20	144
Thelephora sp.	0.55	0.04	0.08	0.70	137	0.46	0.04	0.08	0.90	115	0.38	0.07	0.13	0.91	54.3	1.90	0.04	0.08	0.86	475
	62	33	33	8	21	35	33	33	39	2	12	133	117	40	-52	458	33	83	32	319
T. versicolor	0.38	0.03	0.09	0.72	126	0.43	0.03	0.08	0.93	143	0.43	0.04	0.13	0.96	107	1.92	0.04	0.09	0.89	480
	12	00	50	11	11	27	00	33	43	26	26	33	117	48	-6	464	33	50	37	324
Coir pith																				
F. lividus	0.48	0.03	0.11	0.43	160	0.53	0.03	0.06	0.46	176.7	0.72	0.03	0.08	0.52	240	1.87	0.03	0.11	0.47	623
	41	00	83	-34	41	56	00	00	-29	55	112	00	33	-20	112	450	00	83	-28	450
Thelephora sp.	0.46	0.03	0.11	0.46	153	0.50	0.04	0.05	0.38	125.0	0.67	0.03	0.08	0.41	223	1.92	0.01	0.11	0.49	960
	35	00	83	-29	35	47	33	-17	-42	10	97	00	33	-36	97	405	-67	83	-25	747
T. versicolor	0.46	0.03	0.11	0.48	153	0.55	0.03	0.05	0.47	183.3	0.74	0.04	0.08	0.48	185	1.92	0.01	0.11	0.51	960
	35	00	83	-26	35	68	00	-17	-28	62	118	33	33	-26	63	465	-67	83	-22	747

FW* Fungus and worm inoculated at same time
FW** Worm inoculated after one month
Values in italics are per cent increase (+) or decrease (-) over control

Table 4b. Statistical analysis of the data presented in table 4 a.

Nutrient component	F value	Level of significance(%)	CV (%)	SED	LSD 5%	LSD 1%
A. Among treatments						
Vegetable waste						
C	184.91	1	6.8	0.0593	0.1321	0.1879
N	1.03	NS	29.3	0.0089	0.0199	0.0283
P	239.07	1	4.1	0.0056	0.0124	0.0177
K	40.95	1	6.3	0.0554	0.1235	0.1756
Agricultural waste						
C	752.81	1	5.9	0.0348	0.0775	0.1102
N	3.11	NS	29.5	0.0101	0.0225	0.0320
P	1.03	NS	137.9	0.1509	0.3362	0.4780
K	13.82	1	6.5	0.0423	0.0942	0.1339
Coir pith						
C	2027.87	1	3.1	0.0200	0.0446	0.0634
N	2.39	NS	27.0	0.0063	0.0141	0.0200
P	80.87	1	6.2	0.0042	0.0094	0.0134
K	16.53	1	7.3	0.0298	0.0664	0.0945
B. Among fungi						
C	5.19	5	33.4	0.1340	0.2920	0.4093
N	3.36	NS	25.3	0.0064	0.0139	0.0195
P	4.19	5	48.4	0.0918	0.0918	0.1286
K	98.64	1	7.9	0.0440	0.0959	0.1344

Journal of Fennentation and Bioengineering 74, 179-184.

.Bakshi, B. K., 1971. Indian polyporaceae -on trees and timbers, Indian Council for Agricultural Research (ICAR) publications, New Delhi, p. 80-81.

Bano, K., Kale and R. D., Gajanan, G. N., 1984. Culturing ofearthwonns, *Eudrilus engeniae* for cast production: Assesment of 'wonn cast' as bio-fertilizer. Proc. Nat. Symp. Soil Pest Soil organism, (ed.Singh,J.), B.H.U. Varanasi.

Barley, K. P and Jennings, A. C., 1959. Earthwonns and Soil fertility. III. The influence of earthwoms on the availability of nitrogen. Australian Forest Agricultural Research 10,364-370.

Bhardwaj, K. K. R and Gaur, A. C., 1985. Recycling of organic wastes. Palampur, India: project coordinating unit (Microbiology), Himachal pradesh, Krishi Vishvavidyalaya.

Darwin, C., 1881. The fonnation of vegetable mould through the action of wonns with observations on their habits, Murray, London, pp. 298.

Dash, M. C., Senapati, B. K and Behara, N., 1979. Microfungi associated with decomposition of earthworm tissue in a pasture soil. Biological Bulletin India 1, 21-23.

Edwards, C. A and Lofty, J. R., 1972. Biology of earthworm, Chapman and Hall Ltd., London. pp. 282.

Gilbertson, R. L and Ryvarden, L., 1986. North American polypores. Oslo: Fungi flora, vol. 1, 433p

Hayes, M. H. B., 1983. Darwin's vegetable mould and some modern concepts of humus structure and soil aggregation. In: "Earth worm Ecology from Darwin to vermiculture" (ed., Satchell, J.E). Chapman and Hall. London, 19-33.

Jackson, M. L., 1967. Soil chemical analysis. Prentise Hall of India private Ltd., New Delhi, p.485.

Kalekar, A.R., Bangar, G.S., Patil, P.L. and More, B.B. 1976. A study on decomposition of various organic materials as affected by different fungi. *Journal of Maharashtra Agricultural University*, 1 : 116-119.

Kononova, M. M., 1966. Soil organic matter. Pergamon press, Oxford.

Kirk, T. K and Farell, R.L., 1987. Enzymatic combustion; the microbial degradation of lignin. Annual Revenue Microbiology 41, 465-505.

Lindquist, B., 1941. Investigations on the significance of some scandinavian earthworms in decompostion of leaf litter and the structure of mull soil. Suensk. Skogs. U. Foren. Tidskr 9, 179-242.

Lunt, H. A and Jacobson, M. G. M., 1944. The chemical composition of earthworm casts. *Soil Science* 58, 367-375.

Lynch, I .M., Slater, J. H and Harper, S. H. T., 1981. Cellulase activities of some aerobic microorganisms isolated from soil. *Journal of General Microbiology* 127, 231-239.

Mackay, A. D., Syers, J. K and Springett J. A., Gregg, P. E. H., 1982. Plant availability of phosphorus in superphosphate and a phosphate rock as influenced by earthworms. *Soil. Biology and Biochemistry* 14, 281-287.

Muthukumar, G and Mahadevan, A., 1983. Microbial degradation of lignin. *Journal of Scientific and Industrial Research* 42, 518-528.

Neelakantan, S., Mishra, M. M., Bhardwaj, S. K and Vyas, S. R., 1974. Qualitative microbiological changes during decomoposition of plant material in a sandy sierozem. *Soil Folia Microbiologica* 19, 55-58.

Olsen, S. R., Cole, C. V., Watonabe, F. S and Dean, D. A., 1954. Estimation of available phosphorus in soil by extraction with sodium bicarbonate, *USDA Cire, P.* 939.

Parle, J. N., 1963. A microbiological study of earthworm casts. Journal of General Microbiology 31, 13-22.

Roy Watling, 1971. Basiodiomycetes: Homobasidiomycetidae. In: Methods in Microbiology, V.4. (ed. Booth, C.). Academic press, London and New York, 219.

Sims, R. and Haley, A., 1971. Simplified colorimetric determination of soil-organic matter. *Soil Science* 112, 137-141.

Singh, S. M., Chandra, R., Yadav, P and Juneja, R., 1999. Studies on vermicastings: Biofertilizer for augumenting agricultural diversity and better environment In: Modem trends in environmental pollution and ecoplanning, (ed. Arvind Kumar), p. 144-148.

Stevenson, F. J., 1982. Humus chemistry: Genesis, composition, reactions.Wiley, New York.

Subbiah, B. V and Asija, G. L., 1956. A rapid procedure for estimation of available nitrogen in soils. Current Science 25, 259-262.

Syers, J. K and Springett, J.A. 1983. Earthworm ecology in grassland soils. In: Earthworm Ecology from Darwin to vermiculture, (ed. Satchell JE), Chapman and Hall, London. pp. 495.

Tuomela, M., Vikman, M., Hatakka, A and Itavaara, M., 2000. Biodegradation of lignin in a compost environment: a review. Bioresource Technology 72, 169-183.

Wani, S. P and Shinde, P. A., 1977. Studies on biological decomposition of wheat straw. I: Screening of wheat straw decomposing microorganisms in *in vitro*, plant and soil 47, 13-16.

—***—