MICROBES FOR BETTER LIVING
MICON – 94 & 35th AMI Conference 9 – 12, Nov. 1994

BIODEGRADATION OF FOREST AND AGROWASTES IN A SOCIAL FORESTRY ECOSYSTEM

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Abstract

The biodegradation of forest and agricultural residues was studied in a social forestry ecosystem. The results showed that the fungi colonizing the waste materials in the early and intermediate stages played a major role in biodegradation. Weight loss of the plant materials showed significant positive correlation with soil moisture, litter moisture, fungal population and number of fungal species. The fertility of the soil was increased by this decomposition process.

Keywords : Biodegradation, Litter, Nylon net bag technique, Mean relative decomposition (MRD).

Introduction

The agroresidues and plant materials are the major sources of soil organic matter. The release of nutrients from litter and humus is a fundamental process in the soil ecosystem. The humus derived from the aromatic polymeric compounds of plants, animals and organisms act as stability agents and are directly involved in the fertility of soil. The varied types of leaf litter accumulating in the farm sector as well as crop residues and wastes are to be degraded quickly and converted into manures for application to soil for increasing crop productivity. Decomposition in terrestrial and aquatic environments of biogenic or synthetic organic material to inorganic products (mineralization) is predominantly accomplished by microbes. Many different kinds of organisms are involved in the degradation of various agro and plant residues, but it is mainly the task for fungi, as bacteria have only a limited capability of degradation. Hence, in the present study, a trial was carried out to identify the fungal species, which could effectively degrade the forest and agricultural wastes in a social forestry ecosystem.

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Materials and Methods

Study Area

Man-made social forestry located within Bharathiar University Campus (Tamil Nadu, India) at the foot of Western Ghats (lat — 11° 58 S : long 76° 93 E ; elevation 426 ± 50M, MSL) was selected for the present study. The forest is a monoculture system having four years old *Cassia siamia* Lam trees. The soil surface is completely covered by *Cympopogan* sp. The type of soil is sandy loam with neutral pH and low organic content. The climate is typically monosonic, characterized by three seasons, *viz.*, warm and moist rainy season (July to October), cool and dry winter season (November to February) and dry and hot summer season (March to June). Data on maximum and minimum temperature, total rainfall and relative humidity prevailed during the study period are presented in Table 1.

Table 1. Climatologial Data for the Study Period

Study period	Average maximum temperature (°C)	Average minimum temperature (°C)	Rainfall (mm)	Relative humidity (%)
June	32.8	23.8	21.9	75
July	31.1	23.2	30.5	71
August	31.9	22.8	20.9	78
September	32.5	21.0	24.3	83
October	30.5	22.3	154.5	89
November	28.5	21.1	248.7	89
December	29.2	20.0	NA	91

NA—Data not available

Fungal Biodegradation

Samples

The freshly fallen leaves of pongamia (*Pongamia glabara* L.), eucalyptus (*Eucalyptus globulus*, Labill.) and teak (*Tectona grandis* L.) and the agrowastes, paddy straw and coir pith were selected for biodegradation studies. The nylon net bag technique (Adhikari and Tiwari, 1991) was followed to assess the biodegradation process. The samples were dried under sunlight and 5g of dried samples were placed in nylon net bags (20 × 20 cm size, with 2mm^2 sieve) and buried at a depth of 4–6 cm in the forest floor at different places. The litter bags were collected at regular monthly intervals from each sampling site. Soil particles were carefully removed and the litter was stored in sterilized polyethylene bags until use. The soil around the litter bags were collected aseptically in sterilized polyethylene bags.

Isolation of Mycoflora from Plant Materials

Mycoflora were isolated from the plant materials by the method of Adhikari and Tiwari (1991).

Isolation of Soil Mycoflora

Soil mycoflora were isolated by dilution plate technique (Norman James and Sutherland, 1939).

Percentage frequency and abundance of the mycoflora were calculated (Udaiyan, 1981). Weight loss, moisture content, mean relative decomposition and rate of degradation of the plant materials were estimated by the methods proposed by Adhikari and Tiwari (1991).

For preparation of soil samples for analysis and for determination of soil pH, EC % and moisture content, the methods proposed by Jackson (1967) were followed. Organic carbon content, was estimated by the colorimetric method of Sims and Haley (1971) and available nitrogen by Subbiah and Asija (1956) methods. Available phosphorus and potassium contents were estimated by the methods of Olsen *et al.* (1954) and Jackson (1967), respectively. Soil cellulase activity was estimated by Pancholy and Rice (1973) method.

Results and Discussion

In the forest soil, fungal population ranged from 23.07 to 88.80 × 10^3/g soil and number of fungal species ranged from 4 to 8. In plant materials, *P. glabara* had a fungal population of 12.00 to 47.50 × 10^3 ; *E. globulus* had 0.50 to 83.00 × 10^3 and *T. grandis* had 9.00 to 38.30 × 10^3. Paddy straw had a population of 9.85 to 56.00 and coir pith 14.83 to 62.83 × 10^3 (Table 2).

The data on frequency and abundance of the fungal species reveal that fungi commonly occurring in soil were *Aspergillus fumigatus, A. lateralis, A. niger, A. oryzae* and *A. terreus* ; frequently occurring species were *A. awamori, A. ustus* and *A. versicolor* and rarely occurring species were *Penicillium citrinum, A. flavipes*, and *A. flavus* (Table 3). In plant materials, 11 species were isolated from *P. glabara*, 12 from *E. globulus*, 7 from *T. grandis*, 17 from paddy straw and 12 from coir pith. Among these species, *A, awamori, A. flavipes, A. niger, A. proliferans, A. pulverulentus, A. ustus* and *A. versicolor* occurred as early colonizers. *A flavus, A. terrus, Drechslera halodes, Mucor racemosus, P. citrinum*, and *Rhizopus stolonifer* were intermediate colonizers. *A. lateralis* was a late colonizer. *A. fumigatus* and *A. oryzae* were the resident fungi (Table 4).

The mean relative decomposition (MRD) of the substrates was maximum in the initial period and got reduced with prolonged incubation (Fig. 1). It showed that the early fungal colonizers were very active on these substrates and readily degraded some of the

Table 2. Distribution of Fungi in Soil and Plant Materials

Incubation period (days)	Plant material											
	Soli		P.G		E.G		T.G		P.S		C.P	
	P(× 10^3)	N	P(× 10^3)	N	P(× 10^3)	N	P(× 10^3)	N	P(× 10^3)	N	P(× 10^3)	N
0	23.07	6	20.00	6	9.00	5	9.00	5	9.85	5	14.83	6
30	44.53	8	47.50	5	0.50	1	36.30	4	18.30	8	62.83	5
60	46.80	8	16.00	6	1.25	2	26.83	2	28.50	9	44.65	8
90	51.20	5	12.00	4	22.00	6	23.83	3	22.33	9	34.33	5
120	88.80	4	13.00	3	77.50	1	35.20	4	56.00	2	20.00	4
150	65.30	5	20.50	3	83.00	1	45.00	3	27.75	4	22.00	2
180	49.80	5	ND	ND	25.75	5	27.50	6	ND	ND	30.25	5

Values are mean of six replicates.
P.G. = *P. glabara* ; E.G = *E. globulus* ; T.G = *T. grandis*
P.S. = Paddy straw ; CP = Coir pith
P = Population ; N = Number of fungal species isolated
ND = Not detected

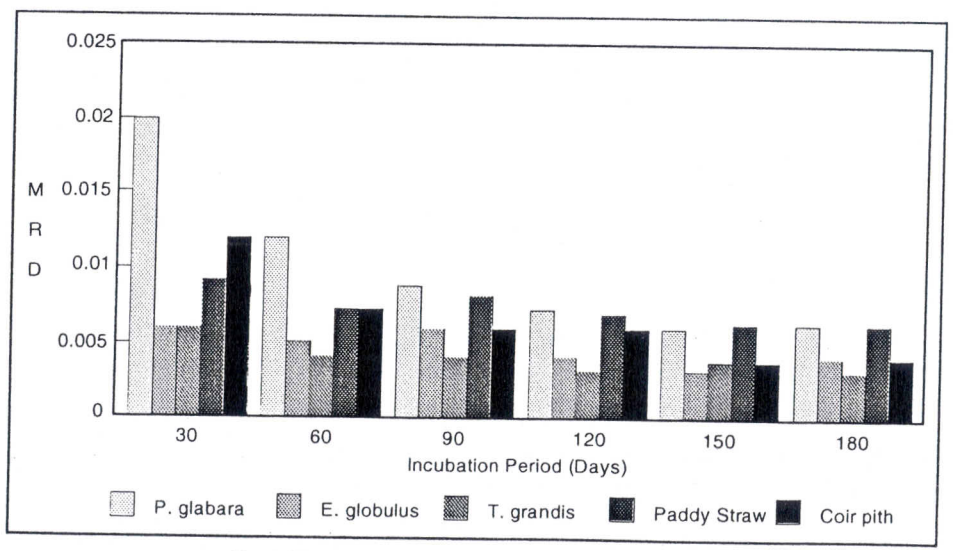

Fig. 1. Mean relative decomposition of plant materials.

Table 3. Frequency and Abundance of Fungal Species in the Soil Sample of the Study Area

Fungal species	Incubation period (days)													
	0		30		60		90		120		150		180	
	F	A	F	A	F	A	F	A	F	A	F	A	F	A
1. *Aspergillus awamori*	55.6 (F)	13.8 (3)	100 (D)	40.5 (5)	22.0 (O)	2.0 (1)	—	—	—	—	—	—	—	—
2. *A. flavipes*	—	—	—	—	11.1 (R)	2.5 (1)	77.8 (C)	21.4 (4)	—	—	—	—	—	—
3. *A. flavus*	—	—	—	—	11.1 (R)	2.5 (1)	—	—	—	—	—	—	—	—
4. *A. fumigatus*	77.8 (C)	28.5 (5-)	100 (D)	21.1 (4)	33.3 (D)	4.5 (2)	22.2 (O)	2.0 1	33.3 (O)	4.9 (2)	50 (F)	5.1 (2)	100 (D)	13.5 (3)
5. *A. lateralis*	—	—	33.3 (O)	4.6 (2)	—	—	22.2 (O)	1.0 (1)	33.3 (O)	1.6 (1)	50 (F)	3.1 (2)	83.3 (D)	7.6 (2)
6. *A. niger*	22.2 (O)	1.5 (1)	100 (D)	22.1 (4)	—	—	33.3 (O)	7.7 (2)	—	—	—	—	83.3 (D)	8.1 (3)
7. *A. oryzae*	—	—	—	—	66.7 (C)	33.8 (5)	100 (D)	71.9 (5)	100 (D)	91.8 (5)	100 (D)	74.2 (5)	100 (D)	66.5 (5)
8. *A. terreus*	44.4 (F)	4.6 (2)	77.8 (C)	7.1 (2)	66.7 (C)	19.7 (4)	—	—	66.7 (C)	1.6 (1)	75 (C)	13.4 (3)	100 (D)	4.3 (2)
9. *A. ustus*	44.4 (F)	5.4 (2)	22.2 (O)	1.0 (1)	100 (D)	23.3 (4)	—	—	—	—	—	—	—	—
10. *A. yersicolor*	55.6 (F)	23.1 (4)	33.3 (O)	3.6 (2)	—		—	—	—	—	25 (O)	4.1 (2)	—	—
11. *Pencillium citrinum*	—	—	—	—	55.6 (F)	7.1 (2)	—	—	—	—	—	—	—	—

F – Frequency; A – Abundance
(D) – Dominant ; (O) – Occasional
(C) – Common ; (R) – Rare
(F) – Frequent Numbers in the parentheses—class value

biochemical components of the substrates, especially the simple sugars and carbohydrates (Udaiyan, 1981). This might be the reason for high MRD of the plant materials in the initial period of decomposition. In *P. glabara*, a steep decrease was observed in the MRD, but in other plant materials, the decrease was gradual revealing that the fungi appearing in the latter stages had a potential role in decomposition.

Soil temperature in the study area ranged between 31.43 and 38.44°C. It did not show much variability. Similarly, there was not much variation in the soil pH. Electrical conductivity

Table 4. Frequency and Abundance of Fungal Species in Litter Samples

Fungal species	Litter/Incubation period (Days)				
	P. glabara	*E. globulus*	*T. grandis*	Paddy straw	Coir pith
1. *Aspergillus* awamori	O(D,3);90 (D,4)	O(D,3); 90(O,2)	O(D,5); 90(D,2)	O(D,4); 30(D,3); 90(D,3)	30(D,4); (90C,4)
2. *A. carneus*	—	90(D,5)	—	90(C,1);150(F,1)	90(D,5)
3. *A. flavipes*	—	—	—	30(D,2)	—
4. *A. flavus*	—	90(O,1)	—	60(D,3);120(D,1)	30(D,5); 60(D,4)
5. *A. fumigatus*	O(D,5); 30(D,2) 60(D,4)90(D,2); 150(D,3)	O(D,5); 180(D,5)	O(C,5); 30(D,2); 180(D,2)	O(D,5); 30(D,3); 60 (D,5); 90 (0,2); 150(F,4) 90(D,3)	O(D,5); 30(D,3); 90 (D,5); 120 (D,4);120(D,4); 150 (D,3);180(D,3)
6. *A. lateralis*	90(D,2);120(D,3) 150(D,3)	90(D,4);180(D,3)	90(D,2);120(D,1) 180(D,5)	60(D,4); 90(D,3); 150(F,3)	60(D,1);120(D,3) 180(D,3)
7. *A. nidulans*	—	—	—	90(D,2)	—
8. *A. niger*	O(O,1)	—	—	60(C,2)	30(O,1);90(O,2)
9. *A. oryzae*	30(D,5);60(D,5) 120(D,5); 150(D,5)	60(D,5);90(D,5) 120(D,5);150(D,5) 180(D,5)	30(D,5);60(D,5) 90(D,5);120(D,5) 150(D,5);180(D,3)	30(D,5);60(D,3), 120(D,5) ; 150(D,5)	30(D,5); 60(D,3); 120,150(D,5); 180(D,3)
10. *A. pruliferans*	—	—	—	O(O,1)	—
11. *A. pulverulentus*	O(C,1)	O(C,2)	—	90(C,2)	—
12. *A. terreus*	60(D,3);120(D,2)	180(D,5)	O(O,1);120(F,1); 150(F,2);180(F,2)	30(D,3);60(D,3); 90(D,1)	O(O,1);60(D,4); 120 (D,3); 180(D,2)
13. *A. ustus*	O(D,3);30(D,2)	O(D,4);180 (D,5)	O(C,3);30(D,1); 18O*F,5) 60(D,3)	O(D,3); 30(D,3);	O(D,2); 30(D,3) 60(D.2); 180(D,5)
14. *A. versicolor*	O(C,3);30(O,1) 60(D,2)	O(D,5)	O(C,4);150(D,4); 180(F,1)	O(C,4); 30(D,4)	O(C,4); 30(D,1) 60(D,2)
15. *Dreshslera halodes*	—	—	—	—	90(C,4)
16. *Mucor racemosus*	90(C,3)	—	—	90(D,5)	—
17. *Neurospora* sp.	60(F,1)	60(D,5)	—	60(C,1)	60(O,1)
18. *Rhizopus stolonifer*	—	30(D,5)	—	30(D,1); 60(O,1)	—

Frequency : D – Dominant; C – Common; F – Frequent; O – Occasional; R – Rare.
Numbers in parantheses — Abundance, class value.

Table .5. Correction Coefficient (r) between Weight Loss of Plant Materials and Various Abiotic and Biotic Factors

Variable (x)	Plant material/correlation coefficient (r)				
	P. glabara	*E. globulus*	*T. grandis*	Paddy straw	Coir pith
Soil temperature	0.29	0.27	0.24	0.31	0.23
Soil pH	0.21	0.25	0.41	0.32	0.29
Soil moisture	0.54*	0.64*	0.57*	0.71*	0.65*
Soil cellulase activity	0.17	0.05	0.27	0.11	0.07
Litter moisture	0.86*	0.70*	0.75*	0.68*	0.85*
Fungal population	0.16	0.57*	0.61*	0.71*	0.03*
Number of fungal species	0.51*	0.58*	0.69*	0.77*	0.59*

*Significance at 1% level ; others not significant.

Table 6. Properties of the Soil Sample of the Study Area

Incubation period (days)	Temperature (°C)	pH	E C (us)	Soil moisture (%)	Orange carbon (%)	N Kg/hect	P Kg/hect	K Kg/hect	Soil cellulase activity mg glucose/g soil/d.
0	35.42	7.46	32.6	3.83	0.08	160.22	10.37	169.2	0.047
	+1.40	+0.06	+2.8	+0.21	+0.0	+11.74	+4.50	+0.02	
30	44.80	7.33	53.8	2.72	0.22	177.33	15.18	326.4	0.070
	+1.50	+0.04	+4.8	+0.81	+0.0	+9.33	+1.70	+0.01	
60	33.23	7.56	77.7	6.09	0.13	186.22	18.51	460.8	0.095
	+1.26	+0.06	+4.5	+0.14	+0.02	+23.02	+1.70	+0.05	
90	36.30	7.61	62.7	5.74	0.12	199.10	19.26	369.6	0.088
	+0.78	+0.09	+10.9	+0.17	+0.03	+25.70	+2.56	+0.01	
120	32.89	7.46	132.8	8.38	0.18	196.00	18.90	383.4	0.050
	+0.95	+0.10	+43.0	+0.12	+0.05	+0.0	+3.33	+0.01	
150	31.43	7.47	90.4	5.43	0.11	217.00	19.20	398.1	0.044
	+0.81	+0.06	+4.4	+0.24	+0.01	+9.89	+0.0	+0.01	
180	38.44	7.58	85.3	5.63	0.13	219.00	18.50	420.5	0.053
	+0.80	+0.02	+3.2	+0.16	+0.01	+9.89	+1.60	+0.05	

Values are mean of three replicates
+ standard deviation.

(FC) of the soil ranged between 32.6 and 132.8 us. Soil moisture content ranged from 2.72 to 8.38%. Janson and Berg, (1985) stated that soil moisture and temperature could augument the litter decomposition. O'Connell (1990) reported a positive correlation between litter moisture and microbial activity. Adhikari; and Tiwari (1991) reported a statistically significant relationship with weight loss of *Quercus* litter and litter moisture, temperature, carbondioxide evolution and fungal population, but soil moisture and soil pH did not have any significant relationship. In the present study (Table 5), the weight loss yielded statistically significant relationship with litter moisture (r = 0.68 to 0.86). Fungal population had *r* values of 0.57, 0.61 and 0.71 in *E. globulus, T. grandis* and paddy straw, respectively. But, in coir pith and *P. glabara* leaf, it was very low (0.03 and 0.06, respectively). Soil moisture had r values of 0.47 to 0.71. The statistical analysis showed that weight loss could be correlated to litter moisture, fungal population, number of fungal species and soil moisture. The other abiotic and biotic factors, soil temperature, pH and soil cellulase activity did not have much correlation with decomposition of plant materials. Eventhough Donelly *et al.* (1990) and Adhikari and Tiwari (1991) reported significant correlation between soil temperature and weight loss, in the present study, there was not much variation in the soil temperature (Table 6) throughout the study period. So, it might not have significant effect on weight loss. Similarly, since most of the fungi recorded in thte present study were sugar fungi, which could utilize mostly the simple sugars, the soil cellulase activity might be very low to influence the biodegradation of the plant materials.

Organic carbon content was increased by three folds in the first 30 days. It might be due to effective breakdown of plant materials as evinced by the high MRD values (Fig. 1), observed during the period. In later stages, it was slightly decreased by the fungal utilization. Nitrogen, phosphorus and potassium contents of the soil were also increased by fungal degradation (Table 6). Similar observations were made by Omar *et al.* (1970) and El-Hussein, *et al.* (1980). Swift *et al.* (1981) reported that decomposition of plant litter in the soil increased the soil fertility by increasing the soil organic matter content and by regenerating the nutrients. They have also reported that decomposition of litter resulted in accumulation of a reservoir of Ca, Mg, N, P and K in soil.

The present study revealed that the early and intermediate colonizing fungi played a main role in the decomposition of plant material. The rate of decomposition is dependent upon soil moisture, litter moisture, fungal population and the number of fungal species. This decomposition process could increase the soil fertility.

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