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Full Length Research Paper

Litter decomposition dynamics associated with cashew nut plantation in coastal habitat of Orissa, India

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Being a key process in nutrient and carbon cycling in coastal ecosystems, decomposition of litter in coastal sand dunes of Orissa was studied in relation to abiotic and biotic factors. Microbial isolation was performed using standard procedures and decomposition of leaf litter was studied using litter bag technique. Higher microbial populations were encountered in soil with cashew plantations compared to barren sand dunes, corresponding with the fluctuation of prevailing temperature and moisture. Micro-fungi of both soils showed a positive correlation with soil moisture but were negatively correlated with soil temperature. A total of 129 species of fungi belonging to 68 genera were enumerated of which sand dune with cashew plantation had a share of 45 genera, 114 spp. and barren sand dune contributed 51 genera and 112 spp. Sand dune without vegetation revealed 32 restricted spp. while *Anacardium* plantation soil revealed 34 spp. *Trichoderma, Aspergillus* and *Penicillium* are predominant occurrence and have been found to be effective decomposers in the present study. Rates of litter loss and carbon dioxide output followed the same trends as the fungal numbers. Shannon- Wiener index and richness were higher in soil with *Anacardium* plantation than the barren sand dune. Maximum fungal population density was observed in the rainy season followed by winter and summer months. The rate of decomposition was controlled by rainfall, soil temperature, soil moisture, relative humidity and fungal count of soil. This research will help in monitoring the isolation, successful introduction and management of decomposing fungi and their importance in ecosystem service could be a valuable tool for understanding the long term effects of changes in soil condition of the forest floors in coastal sand dunes of Orissa, India.

Key words: Decomposition rate, diversity indices, fungi, abiotic factors, soil respiration.

INTRODUCTION

Orissa, one of the eastern coastal states of India has 480 km long barren coast line of sand dunes. Presently, monoculture plantations of *Casuarina equisetifolia* L. in the outer belt and *Anacardium occidentale* L. in the inner belt have been created along coastline to prevent wind blast and erosion of sand dunes. Although, it has solved the problem to some extent, but the litter decomposition dynamics of *Anacardium* species is yet to be studied. Plant litter decomposition is considered as complex and important factor in controlling both vegetation structure (Liu et al., 2004) and ecosystem function (Xiong and Nilsson, 1999). In particular, litter decomposition plays an

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important role in nutrient cycling and organic matter turnover within ecosystems (Smith and Bradford, 2003) and is important determinant for maintaining the biosphere; it also performs unique and indispensable activities on which larger organisms including humans depend.

However, the rate of decomposition is influenced by environmental factors and also by physico-chemical properties of leaves of the species studied and decomposing organisms present in the soil (Vesterdal, 1999; Wedderburn and Carter, 1999; Smith and Bradford, 2003). Detritus decomposition also encompasses interactions among many types of organisms and environmental variables (Reshi and Tyub, 2006), each effecting quality of the litter as a substrate for the subsequent decomposers (Berg et al., 2003). Such an understanding has been largely obtained from litter decomposition studies of natural forests and grasslands (Malaisse et al., 1975; Swift et al., 1981; Bargali et al., 1993; Joshi et al., 1993; Singh et al., 1993; Gartner and Cardon, 2004; Singh et al., 2004; Tyub and Reshi, 2008). Not withstanding this importance, very few attempts have been made to study the decomposition of manmade ecosystems in coastal sand dunes (Panda, 2010).

Hence, the present study examines the decomposition rate using litter bag technique in coastal sand dunes of Orissa, India. Besides, relationship between litter mass loss and biotic and abiotic factors such as microbial community structure and different groups of microbes, the effects of plantation on occurrence, distribution, diversity and succession of micro flora, soil respiration rate, soil temperature and soil moisture, were worked out for better understanding and management of the important process of litter decomposition in coastal sand dunes.

MATERIALS AND METHODS

The study site covered 65km of coastline along the Bay of Bengal at 6 to 8 m elevation above mean sea level in Ganjam district of Orissa with geographical position of 19°15'N and 84°50'E. The climate of the region is monsoonic and maritime. Air temperature ranges from 37°C in summer to 13°C in winter with an annual average rainfall of approximately 130 cm. The soil structure is coarse and varies from very fine sand (0.05 cm) to small pebbles (1.5 cm). The soil profile is aeolin and geogentic in character (Panda, 1998). The height of the planted *A. occidentale* trees ranged from 2.57 m to 3.28 m with diameter from 16.8 to 21.2 cm at breast height. The planted stand age was 6 to 8 years old with an average density of 700 trees/ha.

Some of the unproductive uplands and coastal sand dunes in this region were extensively covered by *C. equisetifolia* and Cashew (*A. occidentale*) plants. Cashew plantation at the inner belt of the site covered an area about 1500 h extending 4 to 5 km with a width of 250 to 450 m including *Casuarina* plantation of 30 to 40 rows covering 15 to 20 m along the coast of the sea (in the outer belt of the site) that form a shelter belt cum wind break vegetation. *A. occidentale* is one of the most popular farm forestry trees in the coastal lands of Orissa.

Two sites each of about one hectare were selected for the present investigation for a period of two years. First site was with 6 to 8 years old plantation of *A. occidentale* without any undergrowth and the second site was a big patch of sand dune situated adjacent to *Anacardium* plantation comprising few grasses only. Soil samples in triplicate were collected randomly from two sites in sterilized test tubes at monthly intervals by inserting sterile glass tubes at selected point at a depth of 0.3 cm for microbial analysis. Each tube was allowed to contain 10 to 15 g soil and stoppered tightly.

Samples were brought to the laboratory in sterilized polythene packets along with identification tags in sealed condition. The samples were temporarily stored in an ice chest prior to isolation of microbes. The fungi were isolated by dilution plate (Waksman, 1927) and soil plate (Warcup, 1950) techniques using potato dextrose agar medium. Fungi were identified according to Sarabhoy (1983). Soil moisture was measured by oven dry method and soil temperature by using a soil thermometer. Soil metabolism was studied by the alkali absorption method (Witcamp, 1966). Litter bag technique was used to measure decomposition of leaf litter. Freshly collected litter (only leaves) weighing 40 g were taken in nylon cloth bags (25 × 25 cm, 0.25 mm mesh size) and were placed in the field at both sites. Total of 80 bags were placed in the study plots at each site of which three bags were removed at monthly intervals. The bags were carefully tapered to remove adhering soil particles. Its contents were oven dried at 80ºC and weighed. Rates of litter loss were determined by the percent remaining of the original. The dry weight of litter on successive sampling dates was used to study the kinetics of litter decay using single negative exponential model (Olson, 1963):

$$(M_0/M_t) = e^{-kt}$$

Where, M_0 is the initial mass of the litter and M_t is the litter mass remaining at time (t days), k represents the rate constant at which litter is disappearing.

Data analysis

The following indices of diversity were calculated based on species level identification (Krebs, 1989; Ludwig and Reynolds, 1988).

Shannon –Wiener index $H = -\sum_{i=0}^{s} Pi \ln Pi$

Where Pi is the proportion of the individual found in the i^{th} species, ln denotes natural logarithm and H is the Shannon –Wiener index.

Simpson's index $D = \sum_{i=0}^{s} (Pi)^2$

Where Pi is the proportion of the individual found in the i^{th} species and D Simpson's index.

Evenness index (E) = $H/\ln S$

Where H is the Shannon –Wiener index of diversity, S total number of species and ln is the natural logarithm.

Jacquard's index $S_{ab} = S_{AB} / (S_A+S_B - S_{AB})$

Where S_{AB} is the number of species shared by two locations (A and B), S_A the total number of species in location A and S_B the total number of species in location B. S_{ab} is the extent of similarity between the species in location A and B.

Table 1. Decomposition of litter with biotic and abiotic variables (Mean± standard error) in coastal habitat of Orissa.

Variable	Soil type	Rainy 1st Yr	Winter 1st Yr	Summer 1st Yr	Rainy 2nd Yr	Winter 2nd Yr	Summer 2nd Yr
Litter loss (g)	Soil A	1.96 ± 0.67	1.26 ± 0.4	0.59 ± 0.45	1.78 ± 0.41	0.81 ± 0.21	0.47 ± 0.05
	Soil B	0.92 ± 0.25	0.68 ± 0.07	0.37 ± 0.03	0.78 ± 0.15	0.69 ± 0.11	0.34 ± 0.045
% weight remaining	Soil A	90.9 ± 4.07	70.9 ± 1.4	63.9 ± 0.9	52.6 ± 3.4	38.6 ± 1.2	32.95 ± 0.74
	Soil B	95.5 ± 1.8	86.2 ± 1.0	81.6 ± 0.58	76.2 ± 1.45	67.8 ± 0.95	63.3 ± 0.49
K value x10^{-5}	Soil A	178 ± 0.001	139 ± 0.0008	76 ± 0.001	279 ± 0.001	165 ± 0.0003	116 ± 0.0001
	Soil B	79 ± 0.0005	63 ± 0.0001	38 ± 0.002	83 ± 0.0003	81 ± 0.0002	40 ± 0.0001
Fungal numbers (cfu/g dry soil)	Soil A	74 ± 9.7	73 ± 4.0	53 ± 5.1	72 ± 8.5	69 ± 1.5	50 ± 4.0
	Soil B	61.5 ± 7.5	57.5 ± 5.7	43.5 ± 5.0	61 ± 5.8	57.5 ± 6.3	40.3 ± 5.1
Soil temperature(℃)	Soil A	30.4 ± 0.65	26.5 ± 0.62	32.5 ± 1.64	30.5 ± 0.8	27.1 ± 0.72	33.5 ± 1.41
	Soil B	34 ± 0.5	32.2 ± 0.19	36.4 ± 1.5	33.3 ± 0.52	32 ± 0.15	36.9 ± 1.8
Soil moisture (%)	Soil A	2.1 ± 0.56	1.14 ± 0.54	0.72 ± 0.18	2.05 ± 0.42	0.89 ± 0.28	0.68 ± 0.16
	Soil B	1.17 ± 0.21	0.62 ± 0.17	0.2 ± 0.035	1.3 ± 0.27	0.61 ± 0.14	0.29 ± 0.1
Relative humidity (%)	Soil A	82 ± 1.48	77.3 ± 2.06	72.8 ± 3.8	86.8 ± 1.1	77.8 ± 1.5	62.5 ± 3.06
	Soil B	79.3 ± 1.5	67.3 ± 3.5	71.3 ± 2.8	82.5 ± 2.9	70 ± 1.8	55.3 ± 1.7
Rainfall(mm)	Soil A	190.3 ± 67	111.1 ± 151	36.4 ± 29.7	195 ± 96.3	87.93 ± 124	20.6 ± 12.9
	Soil B	190.3 ± 67	111.1 ± 151	36.4 ± 29.7	195 ± 96.3	87.93 ± 124	20.6 ± 12.9
Respiration (mg of CO_2 m^{-2} hr^{-1})	Soil A	218 ± 13	163 ± 14	155 ± 14	230 ± 7.5	206 ± 3.8	139 ± 16.5
	Soil B	135 ± 12.5	106 ± 18.5	85 ± 2.5	123 ± 10.0	127 ± 5.5	90 ± 7.4

Richness index (Margalef, 1963) $R = S-1/\ln N$

Where S is the total number of species and N is the sampling number.

RESULTS AND DISCUSSION

Because of the similar process of succession, coastal sandy belts throughout the globe are structurally similar.But they differ in several functional properties like biomass production, cycling of matter, productivity, litter fall, and litter decomposition. Coastal sandy soils have poor structural stability, low microbial community and poor nutrient holding capacity (Parrotta, 1999; Sall et al., 2003). Organic matter decomposition is the main source of ecosystem energy in these soils and plays a major role on soil plant relationship (Lavelle and Spain, 2001; Diallo et al., 2005). Soil moisture and total fungal numbers were significantly higher in site A than in site B (Table 1). Micro fungi of both soils show positive correlation with soil moisture but are negatively correlated with soil temperature (Soil A moisture $r=+0.767$ $p < 0.001$, temperature $r= -0.643$ $p < 0.001$; Soil B moisture $r=+0.822$ $p < 0.001$; temperature $r= -0.737$ $p < 0.001$). Plantations are often linked to a strong increase of soil microorganisms of the sand dunes (Manlay et al., 2000; Panda, 2009). The qualitative and quantitative differences of microbial populations at two sites indicate that surface vegetation as well as abiotic factors influences micro fungal inhabitants of the soil.

The result of the present study revealed that the mass loss of litter occurred exponentially with time. During present investigation striking differences in decomposition rate was recorded between the two soil types. Maximum decomposition was at Cashew plantation and minimum at sand dunes (Table 1). Maximum decomposition has been recorded during rainy followed by winter and summer months both in plantations and sand dunes (Pant and Tiwari, 1992; Manlay et al., 2004). The high rate of decomposition in rainy season attributed to the suitable moisture, rainfall and micro-fungal population. Similar observations have also been made earlier

Table 2. Pearson's correlation matrix of litter loss (g) with different biotic and abiotic variable in coastal habitat of Orissa.

Variable	Soil type	Soil temperature	Soil moisture	Fungal Number	Relative Humidity	Rainfall	Respiration	K value
Litter loss	Soil A	-0.223	+0.913***	+ 0.837***	+0.573**	+0.518**	+ 0.544**	+0.865***
	Soil B	-0.555**	+858**	+0.882***	+0.412*	+0.605**	+0.837***	+0.952***

Significant level at * $P<0.05$, **$P<0.01$, *** $P<0.001$

(Singh and Joshi, 1982; Osborne and Maucauley, 1988; Okeke and Omaliko, 1992; Wedderburn and Carter, 1999; Sarjubala and Yadav, 2007). Much lower rate of decomposition during summer may be due to paucity of soil water and low microbial load resulting from low rainfall (Austin and Vitosek, 2000). The mass remaining in litter bags decreased with time in both the sites. In case of soil with *Anacardium* plantation, percent mass remaining was 32.95% (Table 1) and in case of sand dune it was 63.3% (Table 1). Percent weight remaining of two sites differed significantly (t test 2.59< p 0.05). The correlation matrix between loss of leaf litter in gram and measured biotic and abiotic variables during different months was significantly correlated with fungal numbers, rainfall, soil moisture, soil respiration rate, k value and relative humidity but negatively correlated with temperature (Table 2).

A distinct pattern of fungal community structure was observed in both the samples during the study period. A total of 129 species of fungi belonging to 68 genera were enumerated of which sand dune with Cashew plantation had a share of 45 genera, 114 spp. and barren sand dune contributed 51 genera and 112 spp. Sand dune without vegetation revealed 32 restricted spp. while *Anacardium* plantation soil revealed 34 spp. Eighty fungal species were detected common to site without vegetation or with *Anacardium* plantation. The percentage composition and rank abundances of different fungal species fluctuated in both the soil types (Table 3). *Trichoderma, Aspergillus* and *Penicillium* are predominant occurrence and have been found to beeffective decomposers in the present study. Such an observation draws support from the studies of Chapin et al. (2002), Osono and Takeda (2002), and Panda (2010). They stated that fungi are the main ecosystem engineers of terrestrial dead plant material and the same holds true for the present observation as well because the rate of decomposition correlates well with total number of colony forming units. Other studies also revealed predominance of these fungi in various Indian soils (Rai and Kumar, 1988; Panda et al., 2007, 2008).

The extent of decomposition (% weight remaining) in the present study (Figure 1) is significantly lower than that reported previously (Pandey, 1986; Mamtaz et al., 1991; Singh et al., 1993; Panda 2010). It is because of low microbial load of the soil (Table 1). The value of k (Table 1) determined in the present study is in well agreement with Das and Ramakrishna (1985). Shannon's diversity index is reasonably high correspondingly the dominance value is low (Table 4). The D value and H value in soil A indicates many species with maximum diversity. The evenness index varies from 0.869 to 0.881 an indication that species were fairly evenly distributed. The soil A, have the highest species richness where as soil B shows lowest richness (Table 4). Mycoflora of plantation soil was found to be richer than the soil without plantation (Similarity index value 0.55). Many studies have reported an increase in rate of weight loss in relation to temperature soil/air, soil moisture, microbial load and rainfall (Gupta and Lekha, 1989; Pant and Tiwari, 1992; Cortez, 1998; Neher, 1999; present study) but none had paid heed the importance of relative humidity during decomposition process. However, in the present study significant correlation between litter loss and relative humidity indicates its role in decomposition process. Carbon dioxide output (Table 1) showed similar trends of fluctuation that closely followed those of the fungal numbers (Soil A r=+ 0.599 $p<0.01$; Soil B r= + 0.861 $p<0.001$) and rate of decomposition (Soil A r=+ 0.544 $p<0.01$; Soil B r= + 0.837 $p<0.001$). It is similar to the findings of Behera and Pati (1986), Panda et al. (1996) and Panda (2010). The slow rate of carbon dioxide evolution and decomposition at site A might be due to low moisture, high temperature and with low microbial population in comparison to site B.

The results of our study in coastal sand dunes of Orissa demonstrate the importance of plant litter decomposition and soil microorganisms in controlling the biological soil properties. The present investigation clearly brings out that the plantation significantly influences the rate of decomposition in coastal sand dunes and soil fungi are the dominant decomposers. Besides, soil moisture and relative humidity are the important predictors of the decomposition of *A. occidentale* litter. Thus, vegetation cover of the sand dunes should be protected for proper management of the biodiversity in Orissan coastal belts. This research will help in monitoring and management of decomposing fungi and their importance in ecosystem service could be a valuable tool for understanding the long-term effects of changes in soil condition of the forest floors in coastal sand dunes of Orissa, India.

Table 3. Percentage contribution and ranks of some dominant fungi isolated from coastal habitat of Orissa.

Fungi	Soil with *Anacardium* plantation(Soil A)			Soil without vegetation(Soil B)		
	No. of colony	%	Rank	No. of colony	%	Rank
Absidia butleri	45	5.32	4	14	1.99	21
A. glauca	23	2.72	10	-	-	-
A. spinosa	17	2.01	20	-	-	-
Alternaria alternata	-	-	-	13	1.85	22
Aspergillus awamori	57	6.74	1	56	7.98	1
A. flavus	24	2.84	9	24	3.2	8
A. fonsecaceus	21	2.48	11	-	-	-
A. fumigatus	25	2.96	8	28	3.99	6
A. luchuensis	18	2.13	16	18	2.56	14
A. niger	49	5.79	3	43	6.12	2
A. terreus	16	1.89	21	19	2.71	13
Chaetomium homopilatum	14	1.66	25	22	3.13	10
C.murorum	13	1.54	27	-	-	-
Cladosporium cladosporoides	20	2.36	12	18	2.56	15
C. oxysporum	16	1.89	22	15	2.14	19
Curvularia eragrostidis	-	-	-	27	3.85	7
C. lunata	15	1.77	23	17	2.42	16
C.pallescens	-	-	-	12	1.71	23
Drechslera australiensis	-	-	-	16	2.28	17
Fusarium species	20	2.36	13	16	2.28	18
Mucor species	13	1.66	26	-	-	-
Penicillium citrinum	44	5.2	5	30	4.27	4
P.javanicum	32	3.78	7	39	5.56	3
P.minio-leuteum	19	2.25	15	22	3.13	11
P. nigricans	18	2.13	17	11	1.57	24
P. oxalicum	15	1.77	24	20	2.85	12
P. rubrum	18	2.13	18	15	2.14	20
P.rugulosum	19	2.25	14	-	-	-
P. verruculosum	52	6.15	2	30	4.27	5
Rhizopus nigricans	18	2.13	19	-	-	-
Trichoderma viride	44	5.2	6	23	3.28	9

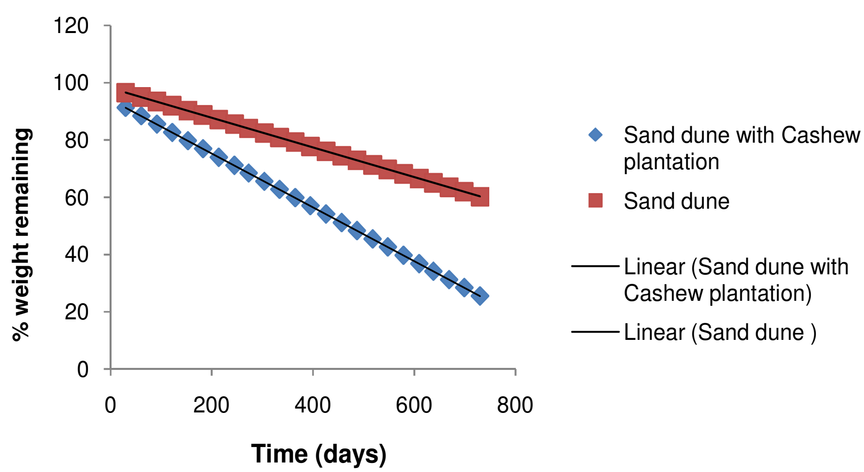

Figure 1. Percentage weight remaining with time (days) in coastal habitat of Orissa.

Table 4. Dominance, diversity, evenness and richness indices of fungi in coastal habitat of Orissa.

Sites	D	1-D	H	E	R
Site without vegetation	0.0323	0.968	3.718	0.881	21.08
Site with *Anacardium* plantation	0.032	0.968	3.744	0.869	23.28

D= Simpson dominance index, H= Shannon diversity index, E= Evenness, R= Richness.

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