Litter Decomposition in Particular Reference to Edaphic Factors

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Abstract

The paper deals with laboratory experiment on decomposition of four different types of lead litter in particular reference to edaphic factor. The four types of leaves revealed different rate of decomposition (mg day^{-1}) under similar edaphic condition reflecting species specificity in the process of decomposition. The statistical analysis showed a positive correlation ($p<0.001$) between weight loss and soil moisture. The relation between the rate of soil respiration and soil moisture has been presented by the expression $Y = 2.533x + 2.297$ and similarly between soil respiration and temperature has been found as $Y = 12.60x - 6.212$.

Introduction

Approximately 100 billion tons of organic matter is produced on the earth by photosynthetic organisms and equivalent amounts is oxidized back to CO_2 and H_2O per year, as a result of the respiratory activity of living organisms and decomposition[1]. Any ecosystem can be characterized by the relationship between- its total rate of production and the rate of decomposition.

In terrestrial ecosystem, a major portion of energy fixed by green plants in form of Net Primary Production is shed as plant litter. It makes its way to the soil decomposition subsystem in the form of dead organic matter of detritus[2]. The detritus is broken down by the combined action of decomposer community resulting into mineralization of essential elements and formation of soil organic matter.

The structural and functional features of any ecosystem can be determined by studying the above two processes. According to Wiegert *et al*[3] dead organic matter establishes a link in energy and nutrient transfer between autotrophic and heterotrophic compartments. Littler decomposition is a very complex and often prolonged process, which is influenced appreciably by the nature of substrate and the characteristic of environment[4]. This process involves intricate relationship between soil inhabiting micro fauna[5-10] and controls recycling of nutrients through mineralization of dead organic matter chelation and microbial recovery in the heterotrophic layer, production of food for a sequence of organisms in the detritus food chain, production of regulatory 'ectocrine' substances[11] and modification of the inert materials of the surface of earth.

The primary determinants of decomposer niches are factors associated with resource quality and the physico-chemical environment The biogeographical scale, the ecosystems, the habitat and the microhabitat all these factors determine the distribution of decomposer organisms. Nutrient concentration is an important selective factor for decomposer. Decomposition of litter in different climatic zone has been presented in Table 1.

The review of literature revealed that no such work has been carried out in this forest rich region of country so far. Keeping the gap of knowledge in background the present project was undertaken as a part of studies on nutrient dynamics in different forest floors. The communication deals with the different aspects of decomposition of litter of four plant species under laboratory condition in particular reference to edaphic factors.

Table 1: Plant litter decomposition in different forests under different climatic zone.

TEMPERATE FOREST			
VEGETATION	Place	Rate of decomposition (%/day)	Author
Oak forest	California, U.S.A.	0.016-0.032	Jenny *et al.*[12]
Pine forest	California, U.S.A.	0.0027-0.0082	Jenny *et al.*[12]
Quercos robor	Roodsea wood, England	0.094	Bocock and Gilbert[13]
Short pine forest	South East Missouri, U.S.A	0.036	Crosby[14]
Quercos alba	Eastern Unifed States	0.107	Shanks and Olson[15]
Oak leaves	Rothamsted, England	0.30	Edwards and Heath[16]

Key words : Litter decomposition, Organic carbon, Soil respiration.

VEGETATION	Place	Rate of decomposition (%/day)	Author
Beach leaves	Rothamsted, England	0.23	Edwards and Heath[16]
Pine forest	Minisota. U.S.A.	0.017	Olson[17]
Pine forest	South Eastrern United State	0.07	Olson[17]
Mixed leaf litter	England	0.027	Heath et al. [18]
Quercos alba	Easteren united State	0.0126	Witkamp and Olson[19]
Quercos robor	Rothamsted, England	0.24	Heath et al.[18]
Quercos alba	Tennessee, U.S.A.	0.15	Witkamp[20]
Morus robra	Tennessee, U.S.A.	0.25	Witkamp[20]
White oak leaves	Brookhaven, U.S.A.	0.18	Woodwell and Marples[21]
		TROPICAL FOREST	
Pre- humic tropical rain forest	Colima, Maxico	0.17	Jenny et al. [12]
Moist subtropical rain forest	Chinechria	0.107	Jenny et al.[12]
Alfalfa leaves	Colombia and Costa Rica	0.31-0.52	Jenny et al.[12]
Mixed rain forest	Belgian corigo	0.90	Laudelout and Meyer[22]
Moist semideciduous ever green forest	Ghana	1.30	Nye[23]
African forest	Africa	1.09	Olson[17]
Colmbian forest	Colombia	0.27	Olson[17]
Pinus roxbergi	India	0.026	Singh and Singh[24]
Shorea robusta	India	0.253	Singh and Singh[24]
Alnus nepalensis	India	0.14	Sharma and Ambast[25]

Material and Methods

Freshly fallen leaves collected from plantation around Morhabadi campus of Ranchi University were dried at 85°C for 24 hours in air oven after proper washing. The known weight of dried leaves was kept under amended soil in litter bags. Plastic trays were used for the experiment. At an interval of 30 days the leaves were taken out washed properly and weighed after drying in oven as earlier. The weight loss with respect to original weight was recorded. The edaphic characteristics of experimental soil were analysed at every interval. Organic matter and organic carbon content were determined following rapid titration method[26]. Soil respiration was estimated by alkali absorption method[27]. Soil temperature was measured by thermometer while soil moisture was calculated by oven drying of known weight of soil. The amendment of soil was done by mixing soil, dried and powdered cow dung and water soaked saw dust in 2:1:1 ratio. The amendment was done in order to sustain high decomposer population.

Observation

Out of four types of leaves maximum moisture content was 64% in *Acasia* leaf while minimum in Eucalyptus leaf 56.5%. In the leaves of other two species i.e. *Shorea robusta* and *Dalbergia sissoo* moisture content was found to be 59.0% and 60.0% respectively (Table 2).

Table 3 contains the data on decomposition of leaf of *D. sissoo*. The experiment revealed a gradual decomposition on the basis of cumulative percentage as 28.8%, 44.0%, 47.0%, 61.93%, 71.53% and 81.33% from onset of experiment upto 180 days. The dry weight at different interval and weight loss at different interval have been presented. On the basis of experimental results the rate of decomposition as mg day $^{-1}$ ranged from 15.33 to 7.22 at different intervals. The highest decomposition rate was observed in first interval of sampling and the rate of decomposition gradually decreased. The average rate of decomposition as mg day^{-1} was recorded to be 1.660. The results have been presented in Fig. 1 to 3.

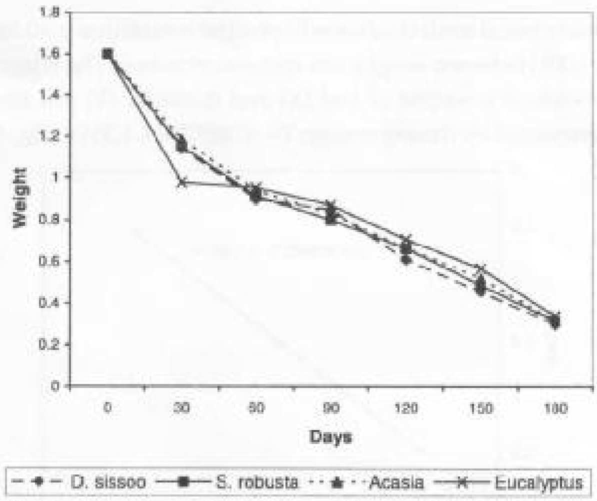

Fig. 1 : Decreasing weight of different leaves at different intervals.

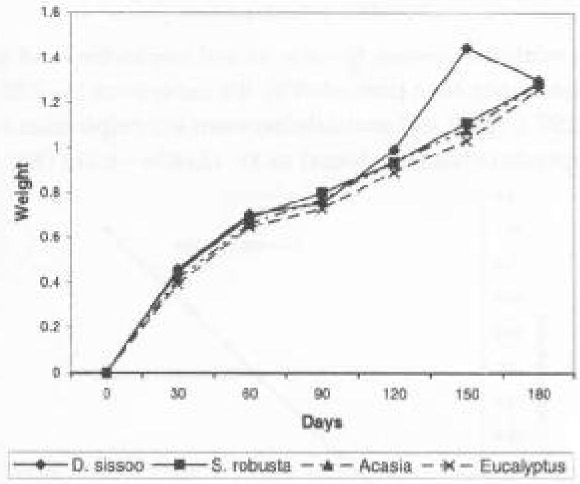

Fig. 2 : The weight loss in different leaves at different intervals.

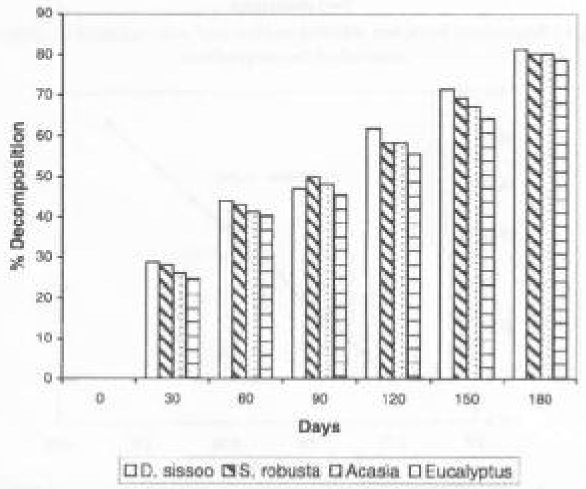

Fig. 3 : Rate of decomposition of different types of leaves (%) at different intervals.

The statistical analysis showed a positive correlation ($r = 0.930$, $p < 0.001$) between weight loss and soil moisture. The relation between weight (X) and duration (Y) has been represented by the expression $Y = -0.0066x + 1.629$ (Fig. -4).

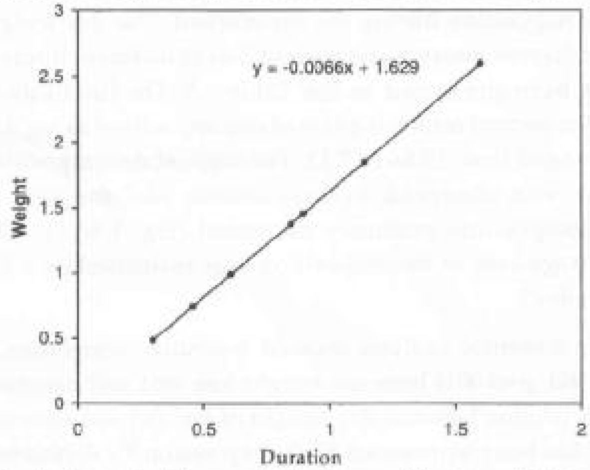

Fig. 4 : Regression between weight of leaves of *D. sissoo* and different interval of decomposition.

A gradual decomposition litter of *S. robusta* on the basis of cumulative percentage was found as 28.1%, 43.0%, 50.0%, 58.4%, 69.46% and 80.3% from onset of experiment upto 180 days. The rate of decomposition as mg day^{-1} ranged from 14.96 to 7.13. Similar to *D. sissoo* leaf the highest decomposition rate was observed in first month and the rate of decomposition gradually decreased. The results on weight of leaves at different intervals weight loss and percentage of decomposition have been presented in Fig. 1 to 3.

The statistical analysis showed a positive correlation ($r = 0.915$, $p < 0.001$) between weight loss and soil moisture. The relation between dry weight of leaf (X) and duration (Y) has been represented by the expression $Y = -0.00646x + 1.6222$ (Fig. 5).

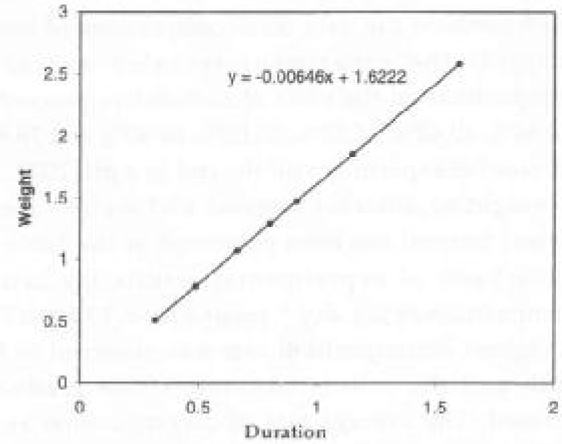

Fig. 5 : Regression between weight of leaves of *S. robusta* and different interval of decomposition.

The contents of table- 5 depict the data on decomposition of leaf of *Acasia*. The cumulative percentage as 26.0%, 41.33%, 48.13%, 58.4%, 67.40% and 80.20% from onset of experiment upto 180 days were the extent of decomposition during the experiment. The dry weight at different interval and weight loss at different interval has been presented in the Table - 5. On the basis of experimental results the rate of decomposition as mg day $^{-1}$ ranged from 13.86 to 7.12. The highest decomposition rate was observed in first month and the rate of decomposition gradually decreased (Fig. 1 to 3). The average rate of decomposition was estimated as 1.755 mg day^{-1}.

The statistical analysis showed a positive correlation ($r = 0.983$, $p < 0.001$) between weight loss and soil moisture. The relation between dry weight of leaf (X) and duration (Y) has been represented by the expression Y= -0.00649x + 1.6434 (Fig. 6).

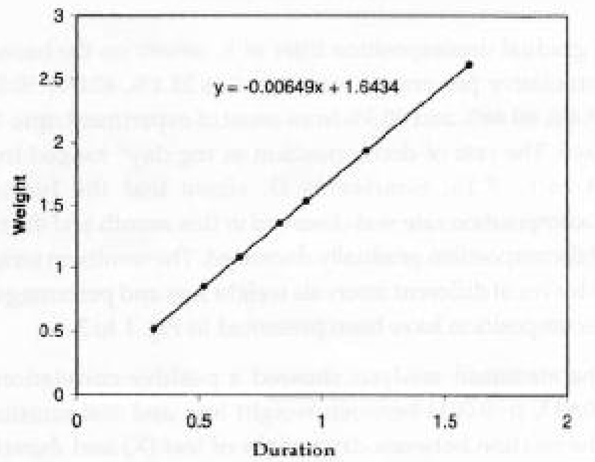

Fig. 6 : Regression between weight of leaves of *Acasia* and different interval of decomposition.

Table 6 contains the data on decomposition of leaf of *Eucalyptus* the experiment revealed a gradual decomposition on the basis of cumulative percentage as 24.60%, 40.40%, 45.60%, 55.80%, 64.40% and 78.80% from onset of experiment till the end in April 2003. The dry weight at different interval and weight loss at different interval has been presented in the Table - 6. On the basis of experimental results the rate of decomposition as mg day $^{-1}$ ranged from 13.10 to 7.00. The highest decomposition rate was observed in first month and the rate of decomposition gradually decreased. The average rate of decomposition as mg day $^{-1}$ was recorded to be 1.883. The results have been presented in Fig.1 to 3.

The statistical analysis showed a positive correlation ($r = 0.985$, $p < 0.001$) between weight loss and soil moisture. The relation between dry weight of leaf (X) and duration (Y) has been represented by the expression Y= -0.00577x + 1.5514 (Fig. 7).

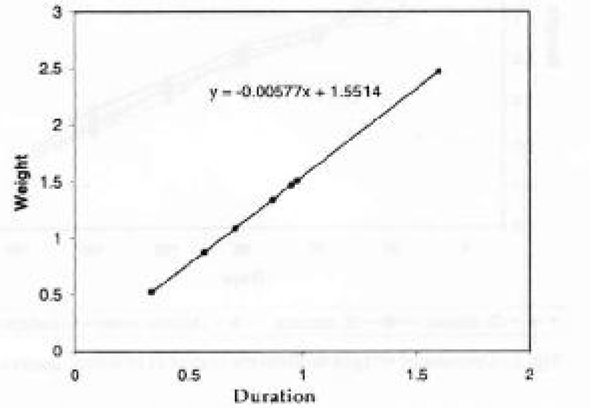

Fig. 7 : Regression between weight of leaves of *Eucalyptus* and different interval of decomposition.

The relation between the rate of soil respiration and soil moisture has been presented by the expression Y= 2.533 x + 2.297 (Fig. 8) and similarly between soil respiration and temperature has been found as Y= 12.605x – 6.212 (Fig. 9).

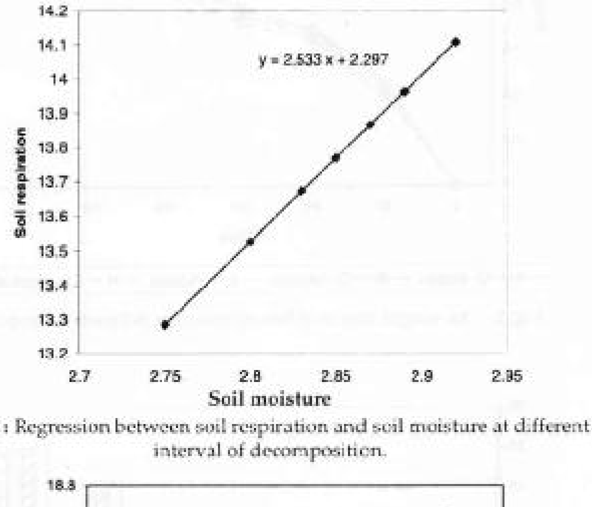

Fig. 8 : Regression between soil respiration and soil moisture at different interval of decomposition.

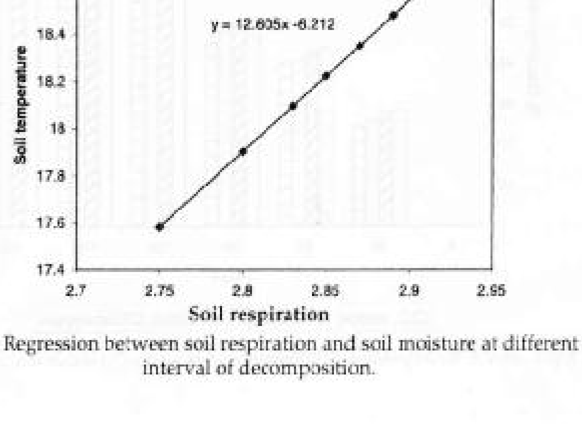

Fig. 9 : Regression between soil respiration and soil moisture at different interval of decomposition.

Table 2: Moisture content of leaves (n=3).

S.No.	Leaf of species	Original weight	Const. Dry weight	% Moisture
1.	*Shorea robusta*	2.3 ± 0.021	1.357 ± 0.022	59.0
2.	*Dalbergia sissoo*	2.4 ± 0.031	1.44 ± 0.031	60.0
3.	*Acasia*	2.5 ± 0.027	1.60 ± 0.033	64.0
4.	*Eucalyptus*	2.5 ± 0.072	1.412 ± 0.028	56.5

Table 3: Decomposition of leaves of *Dalbergia sissoo* (initial weight= 1.6 g).

Interval in days	Weight after interval (g)	Weight loss (g)	% Decomposed	Decomposition constant k
0	1.6	0	0	
30	1.139	0.461	28.8	
60	0.896	0.704	44.0	
90	0.848	0.752	47.0	
120	0.610	0.990	61.93	
150	0.456	1.144	71.53	
180	0.299	1.301	81.33	0.279
Average rate of decomposition = 1.661 mg day^{-1}				

Table 4: Decomposition of leaves of *Shorea robusta* (initial weight = 1.6 g)

Interval in days	Weight after interval (g)	Weight loss (g)	% Decomposed	Decomposition constant k
0	1.6	0	0	
30	1.150	0.449	28.1	
60	0.912	0.688	43.0	
90	0.80	0.80	50.0	
120	0.665	0.934	58.4	
150	0.488	1.111	69.46	
180	0.315	1.284	80.3	1.625
Average rate of decomposition = 1.750 mg day^{-1}				

Table 5: Decompositon of leaves of *Acasia* (initial weight = 1.6 g)

Interval in days	Weight after interval (g)	Weight loss (g)	% Decomposed	Decomposition constant k
30	1.184	0.416	26.0	
60	0.938	0.661	41.33	
90	0.829	0.770	48.13	
120	0.665	0.934	58.40	
150	0.521	1.078	67.40	
180	0.316	1.283	80.20	0.220
Average rate of decomposition = 1.755 mg day^{-1}				

Table 6: Decomposition of leaves of *Eucalyptus* (initial weight = 1.6 g)

Interval in days	Weight after interval (g)	Weight loss (g)	% Decomposed	Decomposition constant k
30	0.977	0.393	24.60	
60	0.953	0.646	40.40	
90	0.870	0.729	45.60	
120	0.707	0.892	55.80	
150	0.569	1.030	64.40	
180	0.339	1.260	78.80	0.238
Average rate of decomposition = 1.883 mg day^{-1}				

Table 7: Different physico-chemical parameters of the experimental soil.

Interval in days	CO_2 ($mgCO_2/g$)	Organic carbon (mg/g)	Organic matter (mg/g)	Soil temperature (°C)	Soil moisture (mg/g)	$CaCO_3$ %
0	2.750	8.06	13.895	28.5	0.18	1.5
30	2.800	8.18	14.102	28.9	0.20	1.5
60	2.830	8.24	14.205	29.6	0.21	1.5
90	2.850	8.48	14.619	29.8	0.22	1.8
120	2.870	8.54	14.722	29.9	0.22	1.8
150	2.890	9.12	15.722	30.2	0.23	1.8
180	2.920	9.37	16.136	30.6	0.25	2.0

Discussion

The decomposition of pant litter is one of the most crucial stages in the biogeochemical cycle of an ecosystem[28]. Decomposition includes the breakdown of litter and transfer of organic matter and nutrients to the soil. Temperature, moisture, composition of the decomposer community and residence quality are some of the most important factors that influence decomposition rates[29-30]. The relative importance of regulating factors may differ for temperate and tropical forests. The rate of decomposition in the tropics is higher than in the temperate zone. The difference may be due to temperature and water content of the litter[31].

Decomposition and soil respiration are the two major inter-dependent processes of consequence to detritus ecology. Soil respiration is a useful parameter for studying soil biological activity, carbon cycling and energy flow in an ecosystem and is also considered as an important index of the decomposition subsystem[32].

As evident by figures the percentage of litter mass remaining in the bags at each sampling interval decreased linearly with time. The rate of disappearance observed in this study in the initial stage was mainly due to loss of soluble and easily decomposable compounds, through either leaching (or) assimilation and catabolism by decomposer.

The rate of decomposition was different between species. Berg and Ekbohn observed that species with high nitrogen content disappeared at grater rates. During decomposition carbon is used as an energy source by decomposers, while nitrogen is assimilated in to cell-proteins and other compounds[32]. Nutrient release from decomposing leaf litter is greater for nutrient-rich broad-leaved species[33]. Plant materials with high nitrogen content, such as nitrogen fixing legumes, can decompose and release nitrogen quickly.

Datta Munshi *et al.*[34] also reported that the fast disappearance rate of litter might be due to accelerated growth of microbial population as well as their activities to decompose the material in presence of sufficient moisture and optimum temperature. The higher rate of decomposition of litter per day (Table 8) during the present study supports this view. The ideal condition of laboratory and amended soil to habour high microbial population have resulted into considerably high rate of decomposition.

Table 8: A comparative account of the weight loss rate of plant litter in different tropical forests of India.

Litter	Forest type (percent per day)	Weight loss rate	Author
Diospyros melanoxylon leaf	Tropical deciduous forest of Vindhyan region	0.19	Singh[41]
Buchanania lanzans leaf	Tropical deciduous forest of Vindhyan region	0.19	Singh[41]
Quercus clauca leaf	Himalayan forest	0.274	Singh and Singh[24]
Pinus roxburghii leaf	Himalayan forest	0.126	Singh and Singh[24]
Shorea robusta leaf	Himalayan forest	0.253	Singh and Singh[24]
Alnus nepalensis leaf	Himalayan forest	0.14	Sharma and Ambasht[25]
Dalbergia sissoo leaf litter	Dry deciduous forest	0.254	Rajvanshi and Gupta[26]
Mixed herbaceous leaf litter	Dry deciduous forest	0.234	Rajvanshi and Gupta[26]
Dalbergia sissoo twig litter	Dry deciduous forest	0.228	Rajvanshi and Gupta[26]
Dalbergia sissoo leaf litter	Laboratory experiment	0.387	Present study
Shorea robusta leaf	Laboratory experiment	0.382	Present study
Acasia leaf	Laboratory experiment	0.381	Present study
Eucalyptus	Laboratory experiment	0.375	Present study

Tanner stated that 27-96% of decomposition depends on the types of humus and nitrogen and phosphorus contents of the leaves. The nitrogen content of plant material have been stated to be an important controlling factor in the rate of decomposition.

In a study conducted by Sundaravalli *et al.* CO_2 evolution rates ranged from 61-73 to 1026.20 mg CO_2 m^{-2} hr^{-1} in the plantation and 56.12 to 1001.74 mg CO_2 m^{-2} hr^{-1} in the grazing land. The maximum rate occurred during the rainy season in November, and the minimum in March. On both the sites CO_2 evolution rates were positively correlated with soil moisture content ($r = 0.4$, $P<0.05$).

Evolution of CO_2 from the soil peaking up during the rainy season as a result of favourable soil moisture and optimum temperatures providing a suitable micro-climate for increased microbial activity and root decomposition, enhancing CO_2 output from the soil have been reported[35]. Similar seasonal effects on soil respiration have been reported in several studies[36]. During summer month, low soil moisture and higher temperature cause desiccation of the soil which adversely affect soil metabolism. The positive relationship between CO_2 emission and soil moisture in the present study supports the observations of other researchers[36]. The respiration rates observed in this study are also positively correlated with decomposition rates, since the moisture content and temperature were regulated in the laboratory at an optimal condition.

Differences in edaphic conditions, amount of plant cover, substrate quality of overlying litter and physical conditions of forest floor litter under similar climatic conditions also alter the CO_2 evolution rates[37-38]. No such factors have been influencing the rate of decomposition during the study as it was laboratory experiment free from such pressure.

Relatively higher rate of decomposition and also the soil respiration in experimental soil can be ascribed to optimal soil conditions and rich organic matter with high microbial activity. As the experimental soil is artificial one the high organic content as cow dung and saw dust support very high microbial biomass which help in the process of decomposition.

The soil CO_2 output from the soil system is directly or indirectly governed by moisture and temperature[32].

Although moisture favourably affects the soil respiration rate, excess soil moisture may lead to depression of CO_2. In the present investigation, significant positive correlation of soil moisture with CO_2 evolution ($r = 9.87$, $p<0.001$) agree with the views of the above worker.

Soil respiration is considered to be an index of soil organismal activity as well as decomposition process[20,32,39]. Therefore, weight loss rate of litter during the period of decomposition should bear a positive relationship with the soil respiration rate. Positive relationship between the weight loss and soil respiration rate during the decomposition of litter in various tropical ecosystem in India has been reported. In the present study the positive relationship between weight loss and soil respiration rate has been observed. Therefore it is an agreement with their observations.

In the present study the weight loss rate of leaf litter varied considerably as in observation (Table 3 & 4). These rates of weight loss were observed to be comparable with that of other litter types in different Indian tropical forests[24-25].

The monthly variation is the weight loss rate of the different samples observed in this study can be explained on the basis of fluctuations of soil moisture and temperature. Monthly weight loss rate of litter samples exhibited a positive relationship with monthly soil moisture value. It may be concluded that in the Indian tropical ecosystem, the process of decomposition is more governed by the soil moisture regimes than the soil temperature. The present work was done in the laboratory hence the conditions were made ideal and moisture regime was always in optimal condition while variation in temperature was due to seasonal changes. Maximum weight loss of litter can be explained on the basis of better soil conditions and comparatively high microbial biomass.

From the weight loss data decomposition constant 'k' was calculated following the equation[17]

$$k = \ln \frac{X_t / t}{X_0}$$

Where k = decomposition constant

X_0 = initial dry weight of litter

X_t = final dry weight of litter after time interval 't'

The above equation of Olson[17] also allows the calculation for half life (0.0693/k) and 95% life (3/k) of litter during the decomposition. The values of 'k' half-life and 95% life of different litter samples have been estimated. According to Olson[17], the decomposition constant 'k' can be interpreted as an index of the effectiveness of decomposer community in an ecosystem. As per Swift *et al.*[40] 'k' is a good measure of organic turnover in an ecosystem. The higher value of 'k' during the present experiment reflects relatively better organic turnover because of relatively more efficient decomposer activity.

Different rates of decomposition was observed during the present study for the four types of leaves taken for study when the nature of soil, moisture content and temperature profile was nearly the same for all the experimental sets. This gives an idea that the species specificity of the leaves also influences the rate of decomposition. Many authors have advocated the leaf structure, shape and size etc. to influence the rate of decomposition. The chemical composition of the leaf and anatomical details are also important factor to influence the rate of decomposition.

The major causative biotic component of soil i.e. microbial biomass is dependent upon the organic matter content and suitability of environmental variable such as temperature and moisture, which are responsible for the process of decomposition and thereby enriching the soil with nutrients and organic matter.

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