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# QUANTIFICATION OF ROLE OF EARTHWORMS IN DECOMPOSER SUBSYSTEM IN LABORATORY EXPERIMENT

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## ABSTRACT

The impact of presence and absence of earthworms during decomposition of amended litter of *Shorea robusta* in laboratory experiment, in particular reference to some edaphic factors, has been studied. The investigation revealed statistically significant ($p < 0.05$) increase in the rate of decomposition (mg dry wt./day) as well as soil respiration (mg $CO_2$/g soil) with earthworms over without earthworms. 0.52 mg dry wt./day litter decomposed more due to presence of earthworms. The value of decomposition constant 'K', which is an index of the effectiveness of decomposer community, was higher with earthworms (1.975) than without earthworm (1.625). The statistical analysis revealed a negative correlation between decomposition and duration. The relationship between soil respiration and soil moisture was found to be $y = 17.413x - 0.1149$, $r = 0.907$ ($p < 0.001$) and $y = 2.534x + 2.298$, $r = 0.987$ ($p < 0.001$) in experiment without and with earthworms respectively. Similarly the relationship between soil respiration and temperature has been represented by the expression $y = 0.536x - 12.243$, $r = 0.914$ ($p < 0.001$) and $y = 0.078x + 0.542$, $r = 0.989$ ($p < 0.001$) in experiment without and with earthworms.

## INTRODUCTION

The functioning of any ecosystem can be recognised as occurring within three distinct subsystems - the plant subsystem, herbivore subsystem and the decomposer subsystem. The integrity of the ecosystem is maintained by the transfer of matter and energy (Swift et al. 1979). While the herbivore and decomposition subsystem depend and thrive on the annual gain of energy and matter by plant subsystem, i.e., net primary production, the plant subsystem in turn is dependant on the decomposer subsystem for its raw materials. The decomposer subsystem performs two major functions, i.e., mineralization of essential elements and formation of soil organic matter. The structural and functional features of any ecosystem can, thus, be determined by studying the above two processes of production and decomposition. According to Wiegert & Evans (1964) dead organic matter establishes a link in energy and nutrient transfer between autotrophic and heterotrophic compartments.

Photosynthetic organisms produce every year approximately 100 billion tons of organic matter on the earth, and almost an equivalent amount is oxidized back to $CO_2$ and $H_2O$ during the same time period as a result of the respiratory activity of living organisms through decomposition (Vallentyne 1960).

In terrestrial ecosystems, a sizable portion of energy, fixed by green plants in form of NPP, is shed as plant litter. It makes its way to the soil decomposition subsystem in the form of dead organic matter of detritus (Odum 1971). This dead organic matter originating from plant litter plays a major role in determining the structure and function of an ecosystem by acting as an energy source for the heterotrophic organisms and a nutrient reservoir for the intrasystem cycling (Macfadyen 1963).

Litter decomposition is a complex and often prolonged process, which is influenced appreciably by the nature of substrate and the characteristic of the environment (Satchell 1971). This process involves intricate relationship between soil inhabiting microflora and fauna (Macfadyen 1963, Behera

1980, Dash et al. 1984). The involvement of various organisms in the decomposition of plant litter has been well documented by Dickinson & Pugh (1974).

Studies on plant litter decomposition have been extensively reviewed by various workers. Working on temperate forests soil, Witkamp (1966) emphasized that temperature is the controlling factor affecting annual respiration cycle. Besides temperature, moisture is also an important parameter regulating soil metabolism process. Parkinson & Coups (1963) reported positive effect of moisture on soil respiration of podzolic soils. Soil animals contribute to the breakdown of litter in many ways (Edward et al. 1963). They disintegrate plant and animal tissues and make them more easily invadable to microorganisms. Role of soil animals in the process of decomposition has been evaluated by many workers (Crossley & Hoglend 1962, Edwards & Heath 1963, Satchell & Lowe 1967, Edward et al. 1970, Zlotin 1970, Anderson 1973, Wood 1976).

In India, aspect of soil metabolism has been investigated by few workers. Singh & Ambasht (1980) have studied the decomposition rate of litter in a teak forest near Varanasi and have reported that litter decomposition depends on moisture. Upadhyaya & Singh (1985) have made a detailed investigation of soil reparation while investigating organic matter turnover in Indian tropical grassland soil. Behera & Padi (1980) have made carbon budget study in a tropical grassland using soil respiration and primary production data. Rajvanshi & Gupta (1980) in their detailed investigation on soil respiration in a tropical (*Dalbergia sissoo*) forest ecosystem pointed out that the seasonal variation in the soil respiration was mostly attributable to changes in temperature and soil moisture.

Review of literature reveals that studies on the litter decomposition and soil metabolism with special role of macrofaunal decomposer organisms are limited to the works of very few workers, both in India and abroad. The present investigation is, thus, an attempt to evaluate the litter decomposition and soil related metabolism ($CO_2$ evolution), both in presence and absence of earthworms, in controlled laboratory conditions to evaluate their impact on the process of decomposition.

## MATERIALS AND METHODS

**Litter Collection:** Freshly fallen leaves, collected from plantation around Morhabadi campus of Ranchi University, were kept in polythene bags in the month of July, 2005. The leaves were properly washed and dried at 85°C for 24 hours in air oven.

**Litter bag preparation:** The litter bag technique of Gupta & Singh (1981) was used for studying litter decomposition rates. The litter bags were prepared by placing 1.6 g of litter into 2mm mesh 20 × 20 cm nylon wire netting cloth bags. The open side of the litter bag was stapled after placing the material. One-half of the prepared bags with litter were placed under amended soil without earthworms and the other half in soil with earthworms. Plastic trays were used for the experiment.

**Method of study:** At an interval of 30 days the litter bags were taken out, washed properly and weighed after drying in oven. The edaphic characteristics of experimental soil were analysed at every interval.

**Weight loss:** The weight loss with respect to original weight, both in control (i.e., without earthworm) and with earthworms, was recorded.

**$CO_2$ Evolution**: Organic matter and organic carbon contents were determined following rapid titration method. Soil respiration was estimated by alkali absorption method (Witkamp 1966).

**Temperature and other physical parameters:** 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.

## RESULTS

Dry weight of litter during different intervals of decomposition starting from 0 days to 180 days has been presented in Table 1 and Fig. 1. Increase in loss of litter mass, an index of decomposition, was observed with time. Within a period of 180 days the dry weight of litter decreased from 1.6 g to 0.315 g in control (i.e., without earthworms) and 0.222 g with earthworms with a cumulative percent loss of 80.3, and 86.14 % respectively (Fig. 2, Table 2).

The average daily rate of litter weight loss has been presented in Table 3. The rate of loss varied from 14.967, 7.967, 3.733, 4.467, 5.9, and 5.767 mg/day at the interval of 30 days, 60 days, 90 days, 120 days 150 days and 180 days respectively in the control. The corresponding values in experiment with earthworms varied from 15.73, 9.433, 4.5, 5.633, 4.8, 5.833 mg/day respectively during the same interval of time. The average rate of decomposition in mg/day was calculated to be 7.14 in the control experiment and 7.66 with earthworms.

Two-way analysis of variance revealed that the difference in the litter loss between different intervals and between two sets of experiments were statistically significant $F1 = 421.35$, $p < 0.001$; $F2 = 17.680$, $p < 0.05$ (Table 4).

Analysis of coefficient of correlation between weight loss and duration showed a negative co-relation; $r = -0.973$ in set without earthworms and $r = -0.9713$ with earthworms. The relation between dry weight of leaf ($x$) and duration ($y$) has been represented by the expression $y = -0.00646x + 0.0143$ for control and $y = -0.00702x + 0.014$ with earthworms.

Table 1: Monthly litter weight loss (dry weight) during different intervals of decomposition.

| Interval in days | Weight after interval (g) Without Earthworm | With Earthworm |
|---|---|---|
| 0 | 1.600 | 1.060 |
| 30 | 1.150 | 1.128 |
| 60 | 0.912 | 0.845 |
| 90 | 0.800 | 0.710 |
| 120 | 0.665 | 0.541 |
| 150 | 0.488 | 0.397 |
| 180 | 0.315 | 0.222 |

Table 2: Cumulative weight loss in % of litter during different intervals of decomposition.

| Interval in days | % Decomposed Without Earthworm | With Earthworm |
|---|---|---|
| 0 | 0 | 0 |
| 30 | 28.10 | 29.50 |
| 60 | 43.00 | 47.21 |
| 90 | 50.00 | 55.64 |
| 120 | 58.40 | 66.21 |
| 150 | 69.46 | 75.21 |
| 180 | 80.30 | 86.14 |

Table 3: Average daily rate of litter decomposition during different intervals of decomposition.

| Interval in days | Average daily rate of decomposition<br>Without Earthworm | <br>With Earthworm |
|---|---|---|
| 0 | 0 | 0 |
| 30 | 14.967 | 15.73 |
| 60 | 7.967 | 9.433 |
| 90 | 3.733 | 4.500 |
| 120 | 4.467 | 5.633 |
| 150 | 5.900 | 4.800 |
| 180 | 5.767 | 5.833 |
| **Av. rate of decomposition** | **7.14 mg/day** | **7.66mg/day~** ~ |

Table 4: Summary of *t*-test for $CO_2$ evolution and weight loss of amended leaf litter.

| ~ | F1 | F2 | P1 | P2 |
|---|---|---|---|---|
| $CO_2$ Evolution | $1.648^{NS}$ | 31.758** | 0.2795 | 0.00133 |
| Weight Loss | 421.35*** | 17.680** | 1.32E-07 | 0.00565 |

The anova value is significantly different at $^{NS}$ $p > 0.05$; ** $p < 0.05$; ***$p < 0.001$ level of significance using two way anova test, F1 = F value between months, F2 = F value between the two experimental conditions i.e., without and with earthworms.

Table 5: Correlation analysis between soil respiration ($CO_2$ evolution) and soil moisture during the period of decomposition.

| Without Earthworm | With Earthworm |
|---|---|
| r = 0.907 | r = 0.987 |
| a = -0.1149 | a = 2.298 |
| b = 17.413 | b = 2.534 |

Table 6: Correlation analysis between soil respiration ($CO_2$ evolution) and soil temperature during the period of decomposition.

| Without Earthworm | With Earthworm |
|---|---|
| r = 0.914 | r = 0.989 |
| a = -12.243 | a = 0.542 |
| b = 0.536 | b = 0.078 |

Table 7: Different physiochemical parameters of the experimental soil.

| Interval in days ~ | $CO_2$ (mgCO2/g)<br>Without Earthworm | <br>With Earthworm | Organic carbon (mg/g)<br>Without Earthworm | <br>With Earthworm | Organic matter (mg/g)<br>Without Earthworm | <br>With Earthworm | Soil temp. (°C) | Soil moisture (mg/g) |
|---|---|---|---|---|---|---|---|---|
| 00 | 2.75 | 2.75 | 8.06 | 8.06 | 13.895 | 13.895 | 28.5 | 0.18 |
| 30 | 2.80 | 3.5 | 8.18 | 10.25 | 14.102 | 17.67 | 28.9 | 0.20 |
| 60 | 2.83 | 3.68 | 8.24 | 10.78 | 14.205 | 18.54 | 29.6 | 0.21 |
| 90 | 2.85 | 3.79 | 8.48 | 10.93 | 14.619 | 18.79 | 29.8 | 0.22 |
| 120 | 2.87 | 3.82 | 8.54 | 11.36 | 14.722 | 19.54 | 29.9 | 0.22 |
| 150 | 2.89 | 3.96 | 9.12 | 11.64 | 15.722 | 20.02 | 30.2 | 0.23 |
| 180 | 2.92 | 3.99 | 9.37 | 12.80 | 16.136 | 27.75 | 30.6 | 0.25 |

Table 8: Decomposition constant (K), half life (0.693/K) and 95% life (3/K) of litter samples in the experimental study site.

| | Without Earthworm | With Earthworm |
|---|---|---|
| K | 1.625 | 1.975 |
| 0.693/K | 0.426 | 0.351 |
| 3/K | 1.846 | 1.519 |

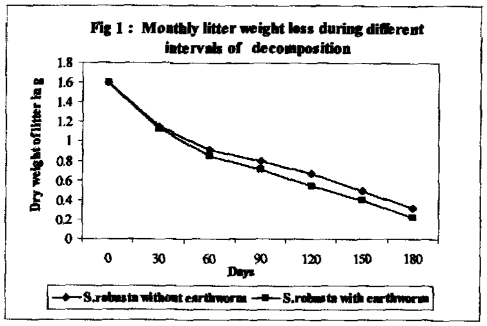
Fig 1 : Monthly litter weight loss during different intervals of decomposition

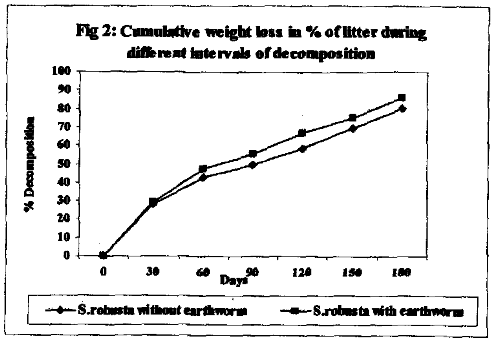
Fig 2: Cumulative weight loss in % of litter during different intervals of decomposition

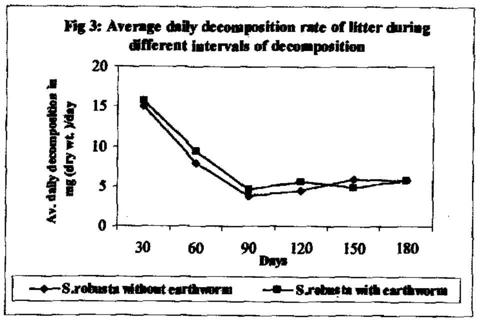
Fig 3: Average daily decomposition rate of litter during different intervals of decomposition

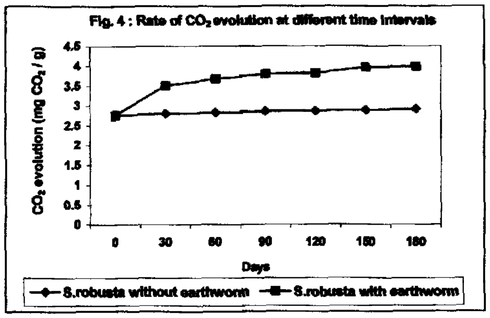
Fig. 4 : Rate of $CO_2$ evolution at different time intervals

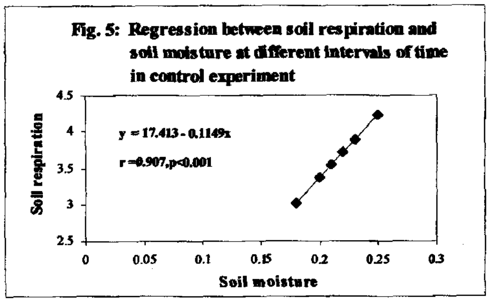
Fig. 5: Regression between soil respiration and soil moisture at different intervals of time in control experiment

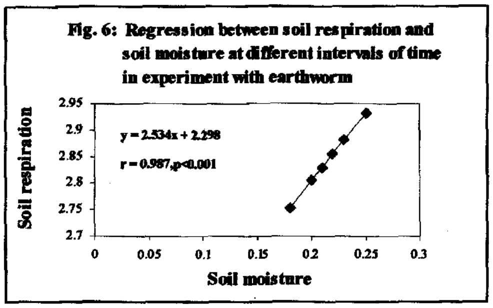
Fig. 6: Regression between soil respiration and soil moisture at different intervals of time in experiment with earthworm

Rate of $CO_2$ evolution (mg $CO_2$/g or soil respiration) and its variation in control and with earworms have been represented in Fig. 5. In the control the amount of $CO_2$ evolution ranged from 2.75 mg$CO_2$/g to 2.92 mg$CO_2$/g during the experimental period. The corresponding values for the set with earthworms was 2.75 mg$CO_2$/g to 3.99 mg$CO_2$/g. The soil respiration was more in set with earthworms in comparison to the control without earthworms. Further, the value of soil respiration showed a gradual increase with time in both the cases.

Soil respiration rates of both the experiments, i.e., with and without earthworms, at different intervals were subjected to analysis of variance (Table 4). The analysis revealed that there was significant difference in variation of soil respiration rate in the two experimental sets ($F = 31.758$; $p < 0.05$). However, the difference between days was not significant ($F = 1.684$; $p < 0.05$).

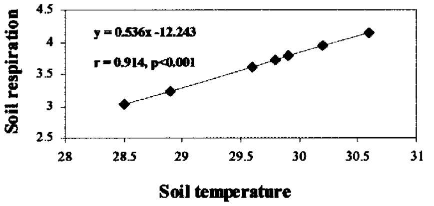

**Fig. 7 : Regression between soil respiration and soil temperature at different intervals of time in control experiment**

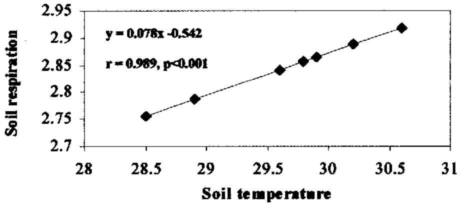

**Fig. 8: Regression between soil respiration and soil temperature at different intervals of time in experiment with earthworm**

The study of correlation between soil respiration and soil moisture revealed ($r = 0.907$, $p < 0.001$ in control experiment and $r = 0.987$, $p < 0.001$ in experiment with earthworms) a significant positive correlation (Table 5, Figs. 5 and 6). Further, the study between temperature and soil respiration also revealed a positive a significant correlation ($r = 0.914$; $p < 0.001$ in control experiment and $r = 0.989$; $p < 0.001$ in experiment with earthworms) (Table 6, Figs. 7 and 8).

## DISCUSSION

Litter decomposition is a complex and often a prolonged process and subsystem performs two major functions, *viz.,* mineralisation of essential elements and formation of soil organic matter. According to Wiegert & Evans (1964) this dead organic matter establishes a link in energy and nutrient transfer between autotrophic and heterotrophic compartments. The process of decomposition is mainly influenced appreciably by temperature, moisture, residual quality and most importantly by the composition of decomposer community (Stott et al. 1986).

The decomposer organisms vary from minute bacteria and fungi to large invertebrates like earthworms and termites. They can be classified into primary decomposers (microbes) and secondary decomposers (invertebrates). They can be again classified into microflora and microfauna etc. The microfauna is composed of protozoans, nematodes, rotifers etc., while the macrofauna comprises of large litter feeding arthropods, molluscans and large earthworms. Bacteria and fungi are the main decomposers of primary resources because it is within this group that the depolymerising enzymes such as cellulases, protease and oxidoreductase are found.

The decomposition (stabilization) of organic matter by biological action has been taking place in nature since life first appeared on this planet while parameters like temperature and moisture remaining uncontrolled. In recent times, man has attempted to control the process of decomposition by manipulating the involvement of soil organisms and directly utilizing the process for sanitary recycling and reclamation of organic waste material.

The comparative account of weight loss of plant litter during decomposition in control experiment and experiment with involvement of earthworms shows that the loss of weight of litter was from 1.6 g to 0.315g in control and to 0.222 g in with earthworms. The variation in the weight loss rate of the two samples, observed in this study, can be ascribed to the high microbial activity due to presence of earthworm in the experimental sample, while the conditions of soil moisture and temperature remaining the same in both the set-ups.

The higher percentage of decomposition (86.14%) with earthworms as compared to the control (80.3%) can be attributed to the presence of earthworms in the former. Similarly, the average daily rate of decomposition was found to be higher with earthworms (7.66 mg/day) in comparison to the control (7.14 mg/day) from which it can concluded that an excess of 0.52 mg/day/1.6g (dry weight) of litter was decomposed by virtue of the presence of earthworms as compared to the control. However, monthly variation in the rate of decomposition exhibited a clear trend. While the decomposition rate is maximum in the initial intervals, being 14.967mg in the control and 15.73mg with earthworms, it got reduced to 5.767mg in the control and 5.833mg with earthworms by end of the experiment (180 days).

From the weight loss data decomposition constant ‘K’ was calculated by the following equation.

$K = (\ln X_t/X_o)/t$ (Olson 1963)

Where, K = Decomposition constant

$X_o$ = Initial dry weight of litter

$X_t$ = Final dry weight of litter after time interval ‘t’

The above equation of Olson (1963) also allows the calculation for half life (0.693/K) and 95% life (3/K) of litter during the decomposition. The values of ‘K’, half life and 95% life of different litter samples at different sites have been presented in (Table 8). Among the two experimental sets, values of ‘K’ for litter samples were observed to be maximum in the experiment with earthworms as compared to the control. According to Olson (1963) the decomposition constant ‘K’ can be interpreted as an index of the effectiveness of decomposer community in an ecosystem. As per Swift et al. (1979), ‘K’ is a good measure of organic turnover in an ecosystem. Therefore, higher value of ‘K’ in the experiment with earthworms reflects relatively better organic turnover because of the presence of earthworms, which enhance decomposer activity. Because of this, value of half life and 95% life of litter samples were observed to be minimum with earthworms.

Relatively higher rate of soil respiration in experimental condition with earthworms can be ascribed to the role of earthworms in enhancing decomposition activity. While the amount of $CO_2$ (mg/g) released increased 2.750 to 2.920 in experiment without earthworms within a time interval of 180 days, the corresponding values in the experiment with earthworms ranged from 2.750 to 3.99.

The soil $CO_2$ output from the soil system is directly or indirectly governed by the by moisture and temperature (Singh & Gupta 1981). In the present investigation, significant positive correlation of soil moisture with $CO_2$ evolution agrees with the views of the above worker.

Soil respiration is considered to be an index of soil organismal activity as well as decomposition process (Witkamp 1966, Singh & Gupta 1977). Therefore, weight loss rate of litter during the period of decomposition should bear a positive relationship with the soil respiration rate. Singh & Ambasht (1980) observed positive relationship between the weight loss and soil respiration rate during the decomposition of litter in various tropical ecosystems in India. In the present study the positive relationship between weight loss and soil respiration rate is, therefore, an agreement with their observations.

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