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Microbial decomposition of pineapple (*Ananas comosus* L.) litters

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ABSTRACT

Microbial decomposition of pineapple litter (leaf and root) was studied under field conditions. Using OLSON's (1963) exponential decay model it was found that time required for 95% of the leaf and root litters to decompose was 1911 and 2576 days respectively. The present study demonstrated that the leaf litter decomposed more rapidly than that of roots. Dry winter season (300/400 days) with low moisture and temperature did not enhance for a fast litter decomposition while on the other hand the rainy summer season (120/420 days) was most suitable for a high rate of litter breakdown. In general, the leaf litter contained higher concentration of N and K while P content was higher in root litter. The concentrations of all elements increased during the early phase of decomposition which was followed by a drop during the middle phase of decomposition and a slight increase during the last phase of decomposition.

KEY WORDS: microbial population, fungi, bacteria, rate of litters breakdown.

RÉSUMÉ

La décomposition de la litière d'ananas (feuilles et racines) a été étudiée en condition naturelle. En utilisant le modèle de décomposition exponentiel d'OLSON (1963), on évalue le temps nécessaire à décomposer 95% de la litière de feuilles et de racines respectivement à 1911 et 2576 jours. L'étude montre que les feuilles se décomposent plus rapidement que les racines. La saison hivernale sèche (300/420 jours), avec des humidités et des températures basses, n'augmente pas la décomposition. Par contre la saison des pluies estivales (120/420 jours) était responsable d'un taux de décomposition élevé. En général les teneurs en N et K sont plus élevées dans la litière foliaire, celle en P dans la litière radiculaire. Les concentrations augmentent pour tous les éléments durant les stades initiaux de la décomposition. Puis elles diminuent pour augmenter à nouveau, mais légèrement, dans le matériel en fin de décomposition.

MOTS CLÉS : populations microbiennes, champignons, bactéries, taux de décomposition.

1. INTRODUCTION

Litter decomposition is an important part in the nutrient cycles. Results of the several studies demonstrated that approximately 70% of the annual uptake of

macronutrients (C, N, P, K, Ca and Mg) are returned via litterfall (DUVIGNEAUD & DESMET, 1970). Decomposition of the chemically complex organic part of the plant litter takes place in several steps. The soluble and some of the solid polymer carbohydrates are degraded first and the remainder, which is made up of polymer carbohydrates and lignin decomposes later and at a lower rate (BERG & STAAF, 1980).

The climatic conditions and nature of soil environment were found to be the most important factors which significantly influence the rate of decomposition (SINGH & GUPTA, 1977; MEENTEMEYER, 1978). A number of workers noted that higher moisture content and temperature enhance the rate of litter breakdown (WITKAMP, 1966; CHRISTENSEN, 1986; MOORE, 1986; ORSBORNE & MACAULEY, 1988). Substrate quality, particularly the chemical composition of the decomposing material, has also long been considered as a critical factor in determining the rate of decay (SINGH & GUPTA, 1977). Nitrogen and lignin are the major substrate quality components controlling the rate of decomposition (STAAF & BERG, 1982; BERG & WESSEN, 1984; BERG & STAAF, 1987; UPADHYAY, 1988; LAISHRAM & YADAVA, 1988).

Most of the studies regarding litter decomposition are generally confined to the forest and agricultural crop residues (MISHRA, 1979; DAS, 1980; JAWSON & ELLIOTT, 1986; WESSEN & BERG, 1986). Pineappele is the most important commercial cash crop of north-eastern region of India. This region produced approximately 50,000 t pineapple fruits annually. A large amount (approx. 2,000 kg/ha) of litter is added each year to the pineapple plantation soil by the death of old leaves (TIWARI, 1988).

2. MATERIAL AND METHODS

2.1. STUDY SITE (LOCATION)

The present study was conducted at Pineapple Research Station Nayabunglow (25°44″N latitude, 91°53″E longitude, altitude 800 m) in the East Khasi Hill district of Meghalaya, 30 km north of Shillong, India.

2.2. CLIMATE

The south-west monsoon and north-east winter winds influence the climate of the area. Data on average rainfall, temperature and relative humidity are given in figure 1. The climate is quite wet (annual rainfall, 2,000-2,300 mm). The months from May to September represent wet season, although occasional showers are received during November to March. June and July are the wettest months. The year can be divided into four seasons: (i) Spring (March to April), (ii) Summer (May to September), (iii) Autumn (October to November) and (iv) Winter (December to February). The spring season is characterised by occasional showers and gradual increase in temperature over that in the preceding winter months. The spring is followed by the summer during which season strong winds blow up to May and abundant rainfall is received until September. The retreat of Monsoon and fall in temperature herald the advent of autumn which is followed by cold winter season lasting from December to February. This period is characterised by low temperature, negligible rain and short photoperiod. Clear days during winter are usually followed by frosty nights.

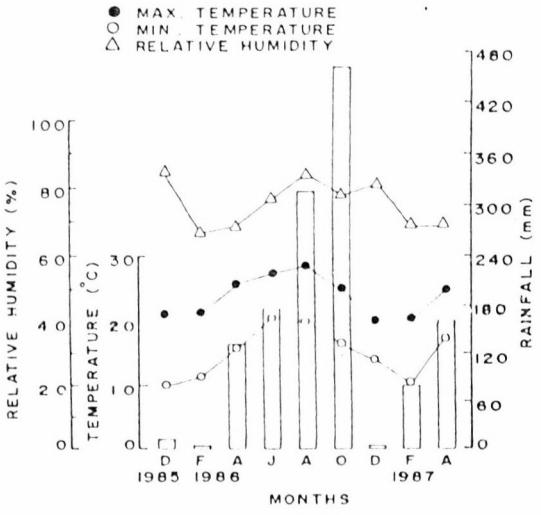

FIG. 1. – Monthly variation in rainfall (histogram) maximum temperature, minimum temperature and relative humidity of the study area.

2.3. SOIL CHARACTERIZATION

The Shillong plateau embracing the Garo, Khasi and Jaintia Hills of Meghalaya is made up largely of pre-cambrian rocks acutely folded and steeply dipping, with an overturned fringe of mesozoic and tertiary sediments. The rock distribution in the plateau reveals that the core of plateau is an ancient mass of gneiss much intruded by a coarse granite (PASCOE, 1950). Sandstones, limestones and conglomerates with subordinate clays superimposed over these rocks also occur in the Shillong plateau (ZIMBA, 1977). The soil of study site is red sandy loam (sand 66.61%, silt 14.6%, clay 18.8%) and acidic in nature. Organic carbon (1.7%) and total nitrogen (0.60%) of the soils are rather low.

2.4. RATE OF LITTER BREAKDOWN

Progressive weight loss of leaf and root litters was followed from December, 1985 to June, 1987 by nylon mesh bag technique (BOCOCK *et al.*, 1960) for determination of litter decomposition. Roots and freshly fallen leaves of pineapple were collected. Leaf and root litters were air dried and homogenized. Three replicates, 10 g air dried weight each, from stock litter samples were oven dried at 60°C to determine a correction factor for estimating the initial oven dry weight of litter in bags. 10 g (oven dried weight) of homogenized leaf and root litter samples were kept in 1 mm nylon mesh bags (20 × 20 cm in size) and thereafter, open end was stiched. Nylon bags of 1 mm mesh size were chosen to minimize drop out of litters and activities of soil mesofauna. The bags with the leaf litter were spread randomly on the soil surface and covered with additional mixed litter from the field on December 15, 1985. The bags contained root litter were buried in the soil (5.0 cm deep). At each sampling period, a random sample of five bags (each from leaf and root litters) were removed and brought into laboratory. For the determination of weight loss and chemical analysis (N, P and K) the residual litter of three bags were oven dried at 60°C for 48 hours. Thereafter adhering soil particles were carefully removed from the litters by brushing and the oven dry weight of the litters was recorded.

2.5. Chemical analysis and changes in the nutrient contents N, P and K of the decomposing litters

Nicely cleaned (from any adhering soil particles) litter samples of leaf and root were powdered separately with the help of electric grinder and sieved (through 0.2 mm). The powder thus prepared was used for the estimations of nutrient contents of decomposing leaf and root litters. The total nitrogen was determined in litter samples by the semi-microkjeldahl method (Allen, 1974). Phosphorus and potassium content in litter samples were determined by wet tri-acid digestion procedure as suggested by Allen (1974).

2.6. The counting of platable microorganisms

Dilution plate method (Waksman, 1922) was used to count the numbers of fungi and bacteria associated with litters. 1 g of litters (leaf and root) were suspended in 100 ml sterile distilled water and then shaken on horizontal shaker (120 throws min^{-1} and 1.5 cm displacement) to form a homogeneous suspension. Further 10^{-3} and 10^{-4} dilutions were obtained by adding sterile distilled water. 10^{-3} and 10^{-4} dilutions were used for the determination of fungal and bacterial populations respectively. 0.5 ml of 10^{-3} and 10^{-4} dilutions was inoculated separately into each of three replicate petridishes. 20 ml sterilized and cooled (45°C) Martin's (1950) rose bengal agar [dextrose, 10.0 g; peptone, 5.0 g; KH_2PO_4, 1.0 g; $MgSO_4$; $7H_2O$; 0.5 g; rose bengal (1%) 3.3 ml; agar, 20.0 g; distilled water 1,000 ml; streptomycin, 30.0 mg]. Nutrient agar (peptone, 5.0 g; NaCl, 8.0 g; beef extract, 3.0 g; agar, 15.0 g; distilled water, 1,000 ml) medium (Johnson & Curl, 1972) were poured separately into each petridishes for the estimation of fungal an bacterial populations respectively. The petridishes were rotated clockwise and anticlockwise to get a homogeneous distribution of the suspension into the medium. They were incubated at 25 ± 1°C for fungi and 30 ± 1°C for bacteria. The fungal and bacterial colonies were counted after 3 days and 1 day of incubation periods respectively.

2.7. Determination of moisture content and pH of the litters

The usual oven-drying method was adapted for determination of moisture content of the litter. 10 g (small pieces) litter samples were kept at 60°C for 24 hours in a hot air oven in triplicate. The dried samples were weighed and the moisture content (%) was calculated. For pH measurement of the litters, an electric digital pH meter was used. Samples were shaken in distilled water in a ratio of 1 : 5 (w/w) and the pH of the supernatant liquid was measured after 1 hour.

2.8. Determination of decomposition parameters

Weight loss is most reliable criterion for estimating plant litter decomposition in terrestrial ecosystems. Olson's (1963) exponential decay model assumes that for any amount of material at any time there is a constant fractional loss $Wt = Wo^{-Kt}$ . . . (1). Where Wo is the initial weight, wt, is the weight at time t and k is the rate constant or rate coefficient (per day). Values of K can be calculated by using the equations, $\text{Log}_e (\%R/100)/t = -K$ . . . (2) or $K = (\text{Log}_e 100 - \text{Log}_e \%R)t$ . . . (3). Where R is the weight remaining after time t. Using above equations the time required for 50% loss or biological half life (0.693/K) and the time required for loss of 95% of the initial weight or 95% life (3/K) were calculated.

3. RESULTS

3.1. Moisture content and pH of the litters

Percentage moisture content of decomposing leaf litter at samplings varied between 3 and 64% while root litter showed a range between 0.2 and 48% (table 1).

pH of leaf litter ranged between 5.0 and 6.58. Root litter showed a range of pH between 5.07 and 7.15.

TABLE I. — *pH and % moisture content of decomposing litters of pineapple.* ± = *standard deviation.*

Sampling dates	Period (days)	Leaf		Root	
		pH	Moisture content (%)	pH	Moisture content (%)
15.12.85	Initial	6.28 ± .03	3 ± .41	7.11 ± .07	0.2 ± .11
15.2.86	60	6.13 ± .01	5 ± .27	7.07 ± .03	14 ± .11
15.4.86	120	5.31 ± .08	9 ± .10	5.62 ± .09	23 ± .09
15.6.86	180	5.91 ± .09	46 ± .02	5.61 ± .03	24 ± .02
15.8.86	240	6.31 ± .04	64 ± .002	5.85 ± .04	45 ± .005
15.10.86	300	6.58 ± .06	47 ± .02	7.15 ± .07	48 ± .006
15.12.86	360	6.41 ± .01	7 ± .003	6.00 ± .03	11 ± .02
15.2.87	420	5.20 ± .03	29 ± .02	5.49 ± .02	44 ± .15
15.4.87	480	5.17 ± .08	35 ± .003	5.21 ± .02	36 ± .003
15.6.87	540	5.00 ± .05	34 ± .05	5.07 ± .04	34 ± .04

3.2. RATE OF LITTER BREAKDOWN

Initially, the litters decomposed with a slow rate. An increase in the rate of litter breakdown was noted during the 120-360 days period (fig. 2). From the figure 2, it is evident that generally leaf litter decomposed more rapidly as compared to the root litter. At the end of experiment (540 days), 86% of the leaf litter was decomposed while for roots, 76.5% of the original weight was lost from the litter bags. Using OLSON's (1963) exponential decay model it was found that the time required for the leaf and root litters to reach 95% decomposition was 1911 and 2576 days respectively (table II). Generally, the rate of litter breakdown in the case of two litter types followed almost similar trend of variation with time (fig. 2).

3.3. FUNGAL FLORA ASSOCIATED WITH LITTERS

Initially, lower number of fungal counts was recorded from both the litters (fig. 3). Thereafter, an increase in fungal population was observed up to the period of 180 days in both the litters. Fungal population dropped to a low level during the period between 240-300 days which was followed by an increase up to 480 days and a drop was recorded towards the end of the study. Generally, leaf litter showed higher fungal population in comparison to the root litter. Two peaks in fungal population were recorded one at the 180 days and another at 480 days sampling period in the case of leaf litter. While in the case of root litter the peaks were recorded at 240 and 420 days. During the period of decomposition minimum fungal population was recorded at 300 days sampling period in both the cases (fig. 3). Generally, more or less similar trend of temporal variation was found in both the litters.

Qualitatively fungal flora of both the litters did not differ much. Generally, most of the fungi isolated were recovered from both the cases. *Aspergillus nidulans*, *Cladosporium herbarum*, *Curvularia maculans*, and *Penicillium javanicum* were of

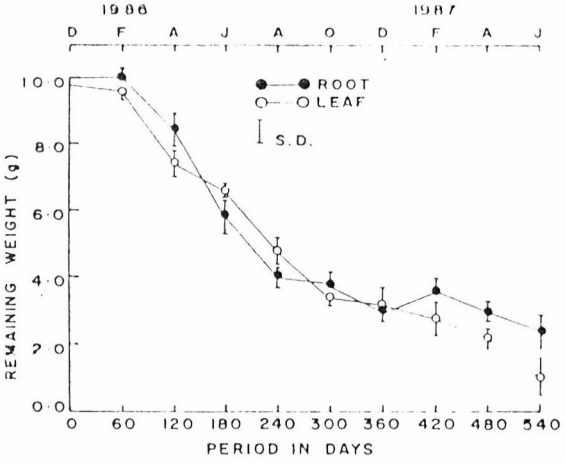

FIG. 2. — Remaining weight of the pineapple leaf and root litters after different periods of decomposition.

TABLE II. *Decay constant (K), Half life and 95% life (percentage weight remaining Vs. time in days) values for pineapple leaf and root litters decomposition under field condition.*

Litter types	K (per day)	Half life (50%) (days)	95% life (days)
Leaf	0.0015698	441.45	1,911.07
Root	0.0011646	595.07	2,575.99

rare occurrence. *Cladosporium herbarum* was restricted to the decomposing leaf litter and *Aspergillus nidulans*, *Curvularia maculans* and *Penicillium javanicum* were found restricted to the root litter.

3.4. BACTERIAL POPULATION ASSOCIATED WITH LITTERS

Initially, root litter showed higher bacterial population than the leaf litter (fig. 4). During early period of the decomposition bacterial population increased in both cases and thereafter it depleted to a low level at 360 days sampling period. Bacterial population again increased at 420 and 480 days sampling periods which dropped to a low level at the last sampling period (fig. 4). Two peaks in bacterial population were noted; one at 120/180 days and another at the 480 days. Similar trend of temporal variation in bacterial population was recorded in both the litters.

3.5. NITROGEN

Initially, leaf litter showed the higher nitrogen concentration than the root litter (table III). In the beginning of the decomposing the nitrogen content of the litters decreased which was followed by an increase. Two peaks in nitrogen content

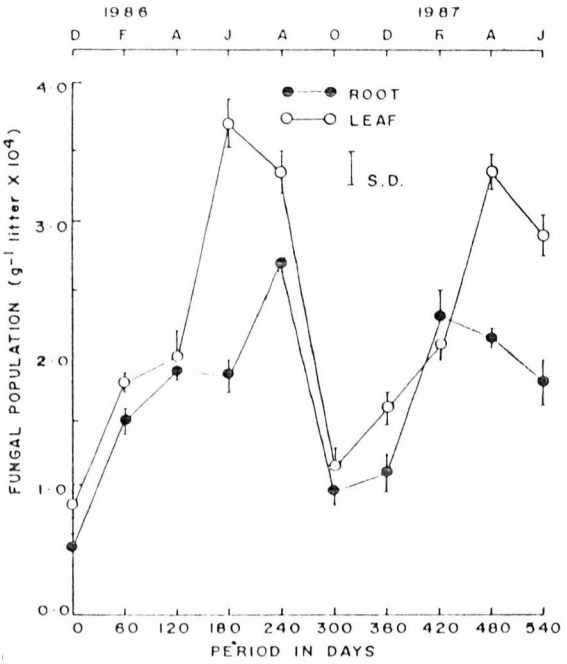

FIG. 3. — Fungal population associated with litters during various periods of decomposition.

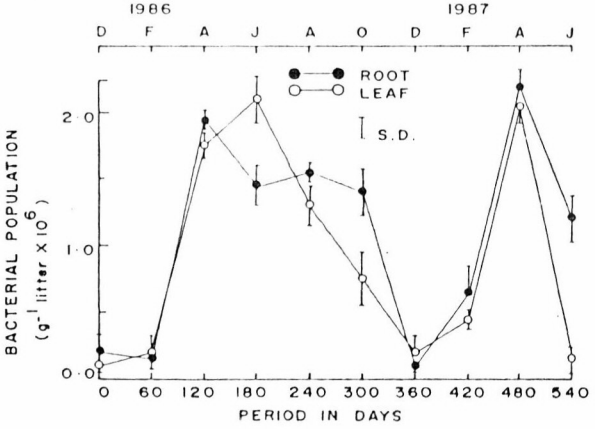

FIG. 4. — Bacterial population associated with litters during various periods of decomposition.

were recorded; one at 120 days and another at the 480 days in both the litters studied.

3.6. Phosphorus

Higher phosphorus was recorded from the decomposing root litters at early stage of decomposition (table III). Drop in phosphorus was noted after the initial sampling in both cases. Increase in phosphorus was noted at 360 days.

3.7. Potassium

During the early period of decomposition leaf litter contained more potassium than the root litter (table III). Generally, leaf litter contained higher potassium than the root litter.

Table III. — *N, P and K contents of decomposing pineapple (leaf and root) litter.* ± = *standard deviation.*

Sampling dates	Period (days)	Leaf			Root		
		N (%)	P (%)	K (%)	N (%)	P (%)	K (%)
15.12.85	Initial	1.8 ± .3	0.09 ± .01	1.0 ± .2	1.2 ± .2	0.15 ± .03	0.7 ± .1
15.2.86	60	1.0 ± .1	0.08 ± .02	0.8 ± .02	1.3 ± .5	0.14 ± .05	0.5 ± .1
15.4.86	120	1.9 ± .4	0.07 ± .01	1.6 ± .4	1.5 ± .3	0.04 ± .01	0.3 ± .1
15.6.86	180	1.0 ± .2	0.5 ± .02	1.5 ± .3	1.1 ± .4	0.08 ± .02	0.7 ± .2
15.8.86	240	0.9 ± .3	0.11 ± .04	0.7 ± .4	0.8 ± .3	0.07 ± .03	0.6 ± .2
15.10.86	300	0.7 ± .4	0.14 ± .01	0.5 ± .3	0.4 ± .2	0.04 ± .01	0.4 ± .1
15.12.86	360	0.6 ± .2	0.11 ± .02	0.9 ± .4	1.2 ± .5	0.07 ± .01	0.5 ± .2
15.2.87	420	1.5 ± .6	0.02 ± .01	0.7 ± .3	1.9 ± .1	0.08 ± .02	0.6 ± .3
15.4.87	480	2.2 ± .8	0.09 ± .02	1.4 ± .5	2.0 ± .2	0.13 ± .03	0.9 ± .1
15.6.87	540	1.7 ± .5	0.10 ± .03	0.9 ± .2	1.5 ± .1	0.11 ± .02	0.5 ± .2

DISCUSSION

The low rate of litter breakdown during the early period might be due to low moisture and temperature conditions. Rapid rate of decomposition of litters was noted between 120-300 days (rainy summer) which might be attributed to the higher moisture and microbial population at the same time (Nagy & Macauley, 1982; Moore, 1986). During winter (360-420 days) the rate of litter breakdown decreased which may be ascribed to the lowering of temperature and low microbial population which also resulted into lower mocrobial activity. Shukla (1976) and Harper and Lynch (1981) also recorded slow rate of decomposition in the field conditions during low temperature conditions. The decomposition of litters in field was faster during the periods when moisture and temperature were higher (fig. 1).

In general, the decomposition of root litter was slower than the leaf litter. Saini (1987) also reported the slower rate of root litter decomposition than the leaf litter. Similar results were also reported in case of barley (Broadbent & Nakashima, 1971) and maize root litters (Dkhar, 1983). Leaf litter decomposed

more rapidly than the root litter which may be ascribed to the losses of polysacchrides from the leaf which are generally higher in amount in the leaves. SMITH (1966) and DKHAR (1983) also reported the similar results.

Initially, population of bacteria and fungi associated with the decomposing litters was higher which may be attributed to the colonization of new substrate. Microbial population (fungi and bacteria) of leaf and root litters increased to their maximum levels at the 120 and 480 days when moisture content was higher which probably helped in the rapid growth of the microorganisms. It is envisaged that release of soluble nutrients from the litter coupled with favourable moisture and temperature conditions played an important role in the growth of microflora on the litter. The population of bacteria and fungi after reaching at the peak declined sharply to a low level (figs. 3, 4). This drop may be due to a significantly drop in moisture content and temperature at the same period. Exhaustion of soluble nutrients from the decomposing litters at the same time may also be the reason for the drop in microbial population (BARUAH, 1983; DKHAR, 1983). DAS (1980), BARUAH (1983) and DKHAR (1983) also suggested the similar reason for the drop in microbial population associated with decomposing litters. HOLM & JENSEN (1972) reported that microbial population on decomposing litter was affected more by the changing weather condition. Higher fungal population associated with leaf litter (fig. 3) may also be due to the higher surface area of the leaf as it provides better chances for microbial colonization.

Qualitatively fungal flora of decomposing leaf and root litters did not differ much. CALDWELL (1963) also found the similar results. Very little difference in the species composition of fungal flora of leaf and root litters suggests that most of the fungi are non-selective and they can utilize a wide variety of substrate. BANGAR *et al.* (1979) reported that *Trichoderma viride* and *Penicillium* sp. were the important cellulose degrading fungi. These fungi were also isolated in the present investigation. Summer flora was found to be dominated by *Penicillium* and *Aspergillus* sp.

The increase in the nitrogen content during the later phase of decomposition may be attributed to the immobilization of nitrogen to the microbial biomass (SAITO, 1957; GILBERT & BOCOCK, 1960; IVERSON, 1973; SUBERKROPP *et al.*, 1976; DAS, 1980). The low nitrogen content from decomposing litters observed initially (table III) may be ascribed to the rapid breakdown of nitrogenous compounds thereby releasing nitrogen from the litter (BURGES, 1967). SHUKLA and SINGH (1984) reported that low moisture condition was not found suitable for the leaching of the nutrients from the decomposing litters. They further, suggested that during the on set of rains the litters were exposed to the attack of the microorganisms. The soluble carbohydrates protective layers of wax and cutin, etc. were washed away during rainy season and this resulted into increased leaching of the minearals (N, P and K). This may be the reason for the low contents of the minerals (N, P and K) recorded from the decomposing leaf and root litters as most part of these minerals leached into the soil during rainy season (180-300 days).

Changes in weather condition may be responsible for the temporal variation in microbial population associated with the litters (PUGH, 1958; WITKAMP, 1963; HOLM & JENSEN, 1972). DAS (1980) reported that favourable moisture, temperature and intensive activity of soil fauna which exposed the litter surface for microbial colonization may be the reason for the gradual increase in the microbial population.

Results of the present study demonstrate that environemental conditions (moisture, temperature) and microbial population (fungi and bacteria) are the main factors which influence the rate of litters (leaf and root) decomposition. Dry season with low moisture and temperature was not suited for the litter decomposition while on the other hand rainy summer season was most suitable for the rapid rate of litter breakdown.

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