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Weight loss and concentration of nutrients during decomposition of leaf litter of *Alnus nepalensis* D. Don in sub-tropical forest of North East India

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ABSTRACT

Weight loss and nutrient (N, P, K) changes with decomposition of alder were examined on two forest stands. Weight loss was faster in the closed forest (K = 2.455) than in the open forest stand (K = 1.854). The weight remaining at the end of 14 months was 5.7 % and 11.5 % in the closed and open stands respectively. An increase in the microflora during summer months and subsequent decrease in the population during winter months was observed on the decomposing litters. The concentrations on N and P were high during June and show marked decrease till the end of the decay process. The concentration of K decreased steadily throughout the experimental period in both forest stands. The absolute weight loss of litter in both cases was correlated negatively with nutrients.

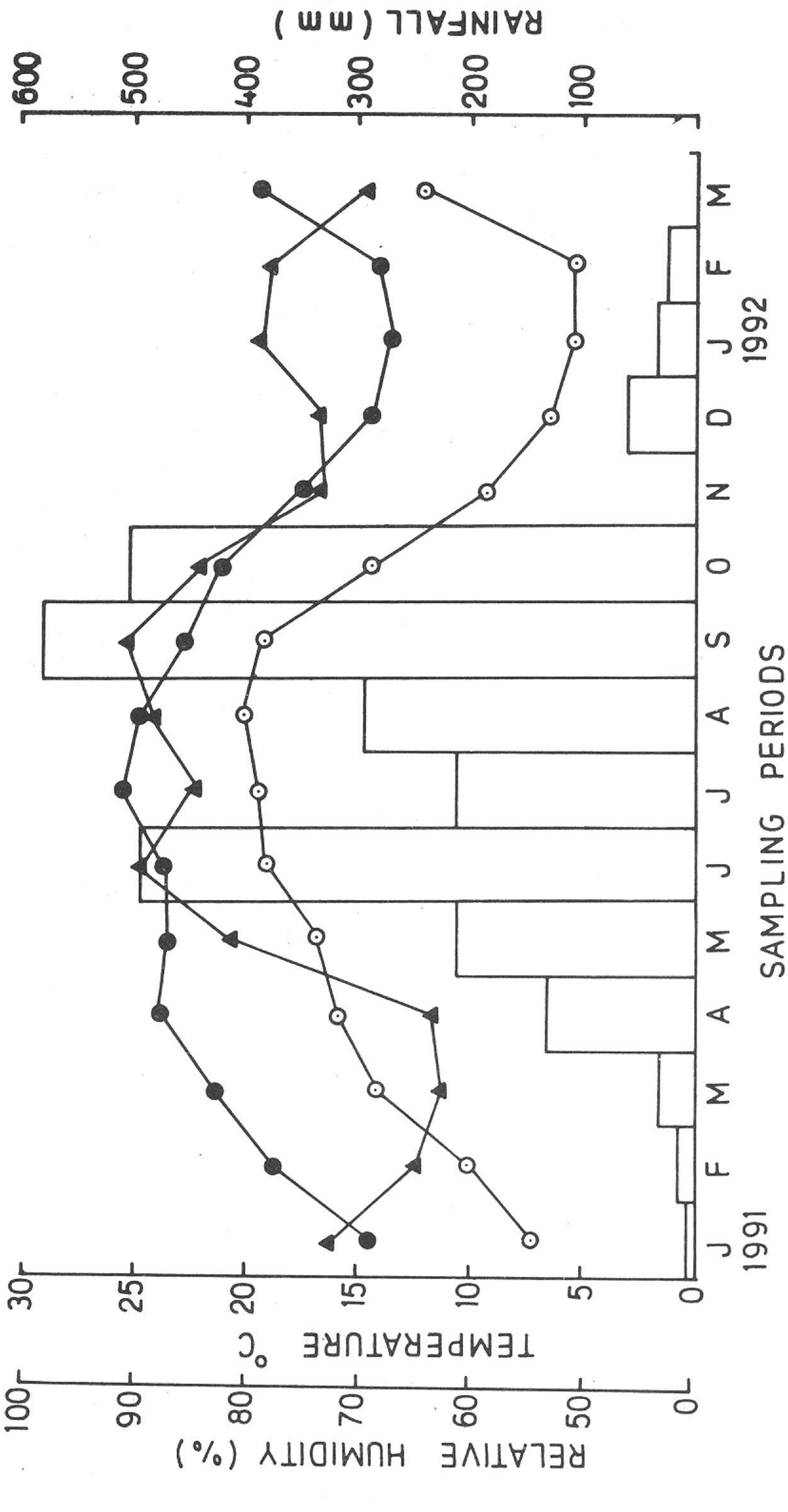
Keywords : Subtropical region, alder, weight loss, microbes, nutrients.

INTRODUCTION

Alnus nepalensis D. Don is an important tree in the Eastern Himalaya. It is fast growing, highly efficient in biological nitrogen fixation, and colonizes denuded habitats, freshly exposed soils and rocky and eroded slopes in the subtropical to temperate belts of the Himalaya (Sharma, 1988).

The litter decomposition and nutrient cycling in subtropical forests of North East India are interesting because in such forests the decomposition is rapid, soils are highly leached and so the bulk of the nutrients occur in the plant litter. The release of nutrients from decomposing litter is known to be quantitatively one of the most important processes for nutrient cycling in forest ecosystems (Anderson & Macfadyen, 1976). Studies on the dynamics of nutrient release from litter yielded differing results between nutrients even for litters of one species (Blair, 1988; Laskowski *et al*, 1993). Nevertheless from the abundant literature some general patterns can be distinguished which differ between nutrients. In most temperate zone forest ecosystems, the dynamic of nitrogen and phosphorus in decomposing litter exhibit similar patterns, which may be predictable : at low initial concentration there is an increase in the amount, followed by a release (Berg & Staaf, 1987).

Intensive studies on litter dynamics in forest ecosystems have been carried out in many parts of the world, especially in temperate zones


RAINFALL (mm)
600
500
400
300
200
100
TEMPERATURE °C
30
25
20
15
10
5
0
RELATIVE HUMIDITY (%)
100
90
80
70
60
50
0
J F M A M J J A S O N D J F M
1991
1992
SAMPLING PERIODS

(Anderson & Swift, 1983) but only limited on this aspect are available from the subtropical forest. Although large scale planting with alder tree species began several decades ago, to date only little is known about the litter dynamics and nutrient cycling in forest plantation in Meghalaya, Shillong. It is against this background that the present study was undertaken with following objectives : (1) to evaluate the rate of microbial decomposition of alder on two forest stands, (2) to quantify changes in the concentration of N, P and K during decay processes, (3) to quantify the population of fungi and bacteria in decomposing litter. Experiments were conducted under similar climatic and edaphic field conditions but dissimilar understorey vegetation to ascertain whether relative differences in litter decomposition are similar under the two adjacent different forest stands of alder.

MATERIALS AND METHODS

Study sites : The study was conducted at Upper Shillong, 6.5 km away from Shillong, the capital of Meghalaya, North East India, located at in attitude of 1600 m (MSL) between 25° 34′ N and 91°57′ E. Two forest stands dominated by alder tree (*Alnus nepalensis* D. Don) were selected at the same latitude. Both faced the eastern side of the hill with undulated slope and were about 600 m apart from each other. Each of the the two sites chosen was subdivided into closed and open forest stands depending upon the biotic disturbance in term of tree falling. The sites are closely comparable, the functional differences are attributed to their tree density. The closed forest comprised of 42 years old alder plantation being the original undisturbed stand and the other one the young open cleared forest stand of 23 years old along with a few tree stumps of *Pinus kesiya* and *Myrica esculenta* exposed to disturbances each as cutting twigs and collection of wood for fuel by the local inhabitants. Tree densities per hectare were 1180 and 383 in closed and open stands, respectively.

The predominant understorey vegetation of closed forest stand was dominated by *Rubus ellipticus, Osbeckia crinata, Cassia mimosoides, Hedychium aurentiacum* and *Eupatorium adenoporum.* While the open forest stand was dominated by herbaceous weedy species *Ageratum conizoides, Lantana camara, Artimesia nilagirica* and *Eupatorium riperum*.

The study area is red loamy with fine silt and gravel constituting the major fraction (Sand 54 %, Silt 25.9 % and Clay 20 %) and acidic in reaction.

Climate : The climate of the area is subtropical monsoonic type largely controlled and influenced by the Himalayan hill ranges. The annual rainfall at Shillong varied from 0.1 mm to 2539 mm and most rainfall occurred between June and October. Minimum & maxi mum temperature recorded during the study period were 5.5°C & 25°C respectively. The average humidity ranged from 64.5 to 90 % (Fig. 1).

Experimental design : Freshly fallen litter of alder (*Alnus nepalensis* D. Don) was collected in December 1990 and air dried. The nylon litter bags (Bocock *et al,* 1960) of 20 × 20 cm (mesh size = 1 mm) were used to assess the microbes (fungi and bacteria) and the rate of litter decomposition. 10 g air dried alder litter was placed in January 1991 in each litter bag. The Bags containing leaf litter were spread randomly on the respective forest floors. The collection of litter bags was done at monthly interval. At each sampling time, six litter bags were collected aseptically in sterilized polythene bags from both the study sites and were brought to the laboratory. Three replicates bags each recovered for the determination of weight loss. The samples were oven dried at 60°C after which adhering soil particles were carefully removed from the litter by brushing and the oven dry weight of the litter was recorded. The decay constant (k) was calculated using Olson's (1963) decay model. The remaining bags were used for the assessment of the number of microbes, pH and moisture content of the litter.

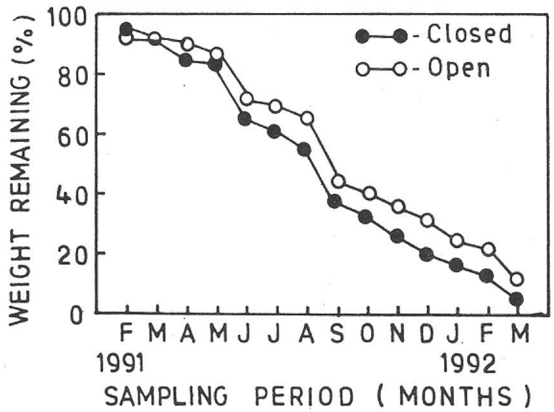
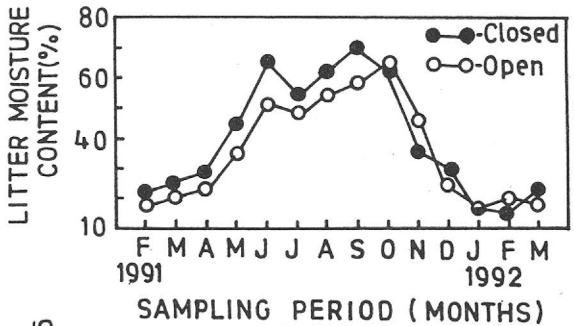


Fig. 2.



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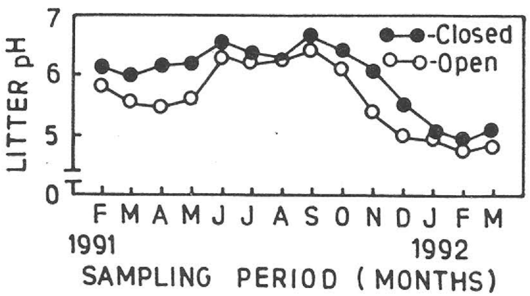

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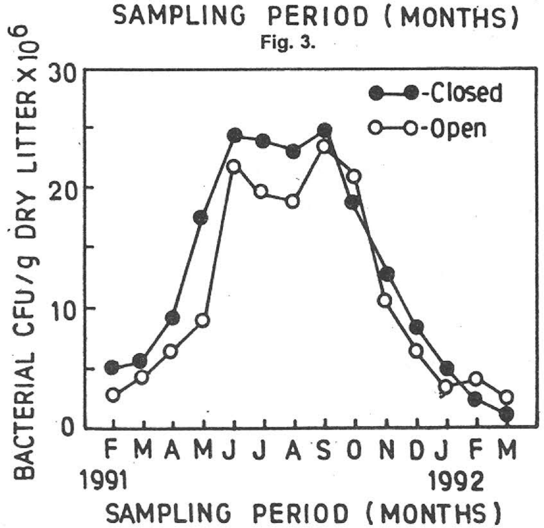


Fig. 5.

Fig. 2. Percentage of original dry weight of alder litters remaining after different time intervals at two forest stands.

Fig. 3 Monthly variation in moisture content of alder litter at two different stands.

Fig. 4. Monthly variation in pH alder leaf litter at two forest stands.

Fig. 5 Monthly variation in bacterial colony forming unit (CFU) of decomposing leaf litter of alder.

Isolation and counting of platable microorganisms : The dilution plate technique (Parkinson *et al*, 1971) was employed to count the most important groups of the litter microflora. The litter was cleaned, air dried, cut into pieces of 1.0 cm and then powdered with a sterilized pestal and mortar. One gram of powdered litter was added into 250 ml conical flask, containing 100 ml of sterilized distilled water and then shaken for 20 minutes on horizontal shaker. A minimum of 10^{-4} dilution was used to isolate bacteria and 10^{-3} for fungi. 0.5 ml of litter suspension from suitable dilution was spread into each sterilized petriplates containing 20 ml of cooled solidified Rose Bengal Agar (Martin, 1950) and Nutrient Agar (Difco Manual, 1953) media for fungi and bacteria respectively. They were incubated at 25 ± 10°C for fungi and 30 ± 10°C for bacteria. The colony forming unit (CFU) of fungi and bacteria were counted after 7 days and 24 hours of incubation respectively. From this data the average number of microorganisms per gram of oven dry weight of litter was computed.

Litter pH and moisture content : The pH of litter in litter water suspension (1 : 5, W/v was determined with a digital pH meter (Systronics, India). The litter moisture content was measured by oven drying at 60° for 48 hours.

Chemical analysis of litter : For the chemical analysis the litter samples were oven dried (60°C), powdered and sieved (0.2 mm). Total N was determined by micro Kjeldahl procedure (Allen, 1974). After an acid wet oxidation in $HNO_3 + H_2SO_4 + HClO_4$, analysis was performed for phosphorus by the sulphomalybdic acid method (Jackson, 1967) and potassium by flame photometric (Systronics - 121, India) procedure.

Statistical analysis : Correlations were calculated between fungal and bacterial counts and litter physico-chemical factors using Karl Pearson's Coefficient (Zar, 1974).

RESULTS

Weight loss from alder leaf litter was faster in the closed forest (K = 2.455) than in the open forest stand (K = 1.854). Relative weight loss rates were highest during the summer months (June and September) and minimum during winter months in both stands. The weight remaining at the end of 14 months was 5.7 % and 11.5 % in the closed and open stands respectively (Fig. 2). A significant negative correlation ($P < 0.55$) between time (days) and log of per cent weight remaining was obtained in both stands.

At the closed forest, the moisture content of litter varied from 15 to 70 % and at open forest, from 16 to 64 %. (Fig. 3). At the closed forest, the litter was less acidic (pH 5.0 - 6.75) than at the open forest (pH 4.6 - 6.4). During the winter months the litter was more acidic than during the rainy season (Fig. 4).

Initially, low bacterial counts were recorded from both alder stands. From May onwards they increased consistently attained a peak in June with a slight decrease in July and August but exhibited a second peak in September in both cases. Their numbers decreased towards the end of the decomposition (Fig. 5). Quantitatively the bacterial community was more numerous than the fungal community. Bacteria showed a significant positive correlation with moisture content, climatic factors, nutrients and litter pH (Table 1).

Fungal counts exhibited a more or less similar trend in the monthly variation in both forest stands. However, higher numbers of fungi were associated with leaf litters in the closed forest as compared to the open one. The fungal count was low in the fresh litter and increased with the progress of litter decay. Maximum numbers of fungi were recorded in June, after which the population decreased until August. There was a slight increase in September and thereafter their numbers decreased towards the

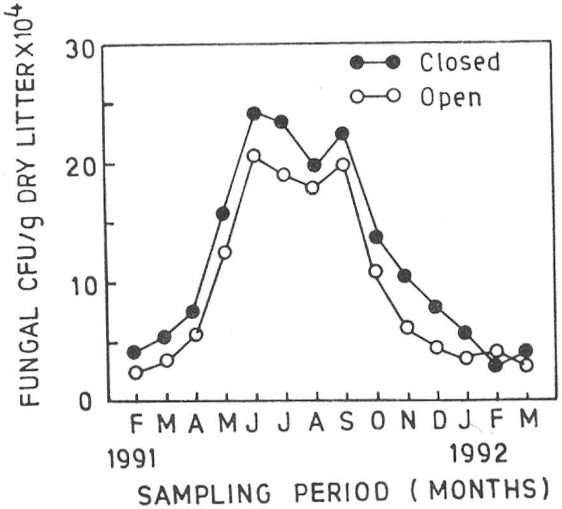
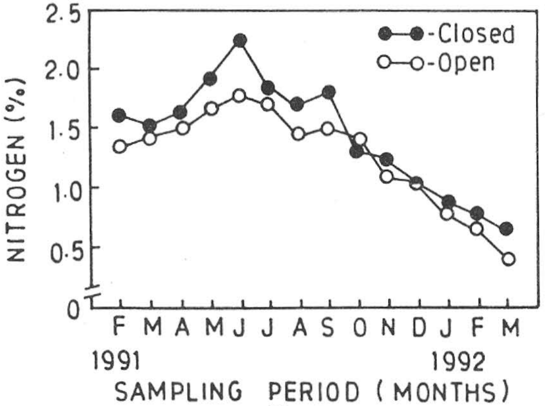


Fig. 6.



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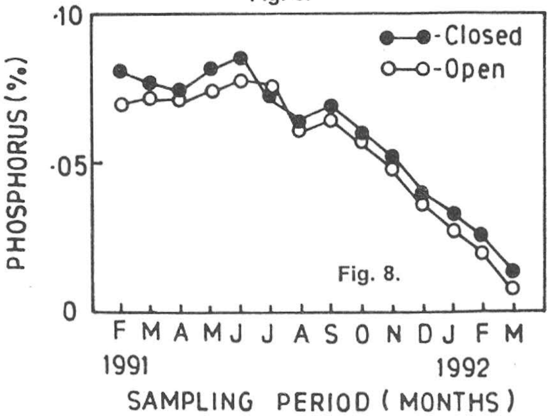

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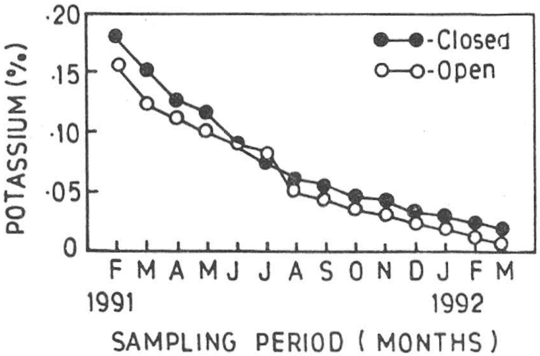

Fig. 9.

Fig. 6. Monthly variation in fungal forming unit (CFU) of decomposing leaf litter of alder.
Fig. 7. Monthly variation in total nitrogen content at two forest stands of alder leaf litter.
Fig. 8. Monthly variation in phosphorus content of two forest stands of alder leaf litter.
Fig. 9. Monthly variation in Potassium content at two forest stands of alder leaf litter.

Table 1. Correlation coefficient (r) for pH, moisture content, total nitrogen, phosphorus, potassium and fungal and bacterial counts of decomposing *Alnus nepalensis* leaf litter.

Source of variation	Df	Bacterial Counts		Fungal Counts	
		Open	Closed	Open	Closed
litter pH	12	0.889**	0.827**	0.857**	0.783**
Moisture content	12	0.960**	0.955**	0.826**	0.931**
Total nitrogen	12	0.632*	0.771**	0.688**	0.765
Phosphorus	12	0.474	0.575*	0.536*	0.537*
Potassium	12	– 0.124	– 0.042	– 0.034	– 0.075
Rainfall	12	0.910**	0.838**	0.824**	0.821**
Temperature	12	0.658*	0.746**	0.762**	0.744**
Humidity	12	0.828**	0.823**	0.853**	0.832**
Weight remaining	12	0.078	0.201	0.216	0.164

*, ** $P < 0.25$ and 0.01 respectively, Df = degree of freedom

Table 2. Correlation coefficient (r) for moisture content, total nitrogen, phosphorus, potassium and fungi and bacterial counts of decomposing Alnus nepalensis leaf litter.

Source of variation	Dr	Weight loss	
		Open	Closed
Fungi	12	– 0.216	– 0.164
Bacteria	12	– 0.078	– 0.201
Moisture content	12	0.015	– 0.145
Total Nitrogen	12	– 0.785**	– 0.731**
Phosphorus	12	– 0.894**	– 0.895**
Potassium	12	– 0.947**	– 0.953**
Rainfall	12	– 0.125	– 0.101
Humidity	12	0.194	0.241
Temperature	12	– 0.596*	– 0.564*

*, ** $P < 0.25$ and 0.01 respectively, Df = degree of freedom

end of the decomposition (Fig. 6). The fungal counts in both forest stands showed a significant positive correlation with climatic factors, nutrients, litter moisture and pH (Table 1).

Changes in nitrogen concentration over time were similar at both the forest stands. The general pattern was an increase in nitrogen concentration up to the month of June with a decline slightly in July and August and a slight increased in September, then followed by a subsequent decrease till the end of the decay process (Fig. 7). The concentration of phosphorus exhibited a similar trend which ranged from .02 % to .09% in closed forest and .01% to .07% in case of open forest. The maximum value of available phosphorus was obtained in May-June in both forest stands, and then was gradually released along with decomposition of litter (Fig. 8). The concentration of potassium decreased steadily throughout the experiment period in both forest stands. (Fig. 9).

DISCUSSION

The significant correlations with moisture content of litters and an unfavourable environmental conditions caused by low rainfall and temperature explains the low counts of fungi and bacteria during the initial phase of litter decomposition which are known to affect microbial growth and an increased counts in rainy months (Orsborne & Macauley, 1988; Kshattriya *et al,* 1994). The improvement of moisture levels, moderation of temperature and higher relative humidity favoured the maximum build up of the microbial counts in the rainy season (Alexander, 1977; Sankaran, 1993). A gradual depletion in nutrient coupled with less favourable climatic conditions were the reason for a reduction in the numbers of fungi and bacteria during winter months and during the advanced stage of decay process (Adedeji, 1986; Sankaran, 1993).

The higher microbial counts in closed forest than in the open forest were ascribed to the changed microhabited of the two stands (Webster, 1957). The destruction of forest also affected the distribution of microorganisms by introducing microclimatic changes (Kshattriya *et al.*, 1994).

High rate of litter decomposition in closed forest than open was probably a result of more suitable microclimatic conditions in the forest (Taylor *et al.,* 1991). Moreover in closed forest, microbial population, litter moisture content and nutrients were relatively more abundant than in open forest. All these factors may favour faster decomposition of litter. It is reported that the higher the concentration of minerals the faster the rate of weight loss (Berg & Staaf., 1980). The differential decomposition rate might be due to physical nature of plant material (Bhatt *et al*, 1985), difference in pH, moisture content, substrate quality and temperature which ultimately governed the distribution of microflora (Swift *et al.*, 1979; Howard & Howard, 1980).

The loss in weight of the litter was highest during the summer months. High temperatures are known to have favourable effects on the rate of decomposition (Van Cleave, 1971; Weight & Mc Ginnis, 1975). But a negative relationship occurred between temperature and the rate of weight loss of alder litter (Table 2). The initial high leaching of saluting chemical components from the litter might also have contributed to the sharp decline in weights of litter during the summer months (Shukla *et al.*, 1990). Recent research indicates that bacterial metabolism, rather than leaching is responsible for the greatest part of mass loss (Mc Claugherty, 1983; Parsons *et al.,* 1990).

The behaviour of N and P during decomposition were similar to each other but different from K. It is characterized by the same initial immobilization and a released phase in later stage of decomposition as reported in most other forest ecosystems Christensen, 1985; Mitchell *et al*, 1986). Nutrients may be released from litter by leaching or by mineralization (Swift *et al*, 1979). A decline in nitrogen during later parts of rainy months corresponding to a leaching or rapid decay phase (Berg and Staaf, 1981; Prescott *et al*, 1993). The increase in the nitrogen content in the beginning may be due to a demand for nitrogen by heterotrophs in which the N gets immobilized during decomposition (Lousier and Parkinson, 1978). It has been established that increase in relative concentrations may be explained in part by microbial incorporation of nutrients released from litter as Carbon is mineralized (Blair, 1988).

Phosphorus was immobilized at the initial stage of decomposition and then decrease rapidly as decay proceed. Rapid loss of P has been observed for some litter types in some ecosystem (Lousier & Parkinson, 1978; Edmunds, 1979; Rusterd & Cronan, 1988; Upadhyay *et al*., 1989). While immobilization for shorter or longer periods has been observed in others (Berg *et al.,* 1987; Stohlgren, 1988). The tendency for P to be retained less strongly than N is usually taken to indicate that P is not limiting to decomposer organism (Berg & Staaf, 1981). The rapid release of K early in decomposition is a commonly observed phenomenon. Potassium has high mobility as it is not associated with structural materials and need not mineralize to be released from organic substrate (Sharma & Ambasht, 1987) and is subject to removal by physical leaching (Waring & Schlesinger, 1985). Therefore K release is not strongly dependent on biotic activity (Alexander, 1977; Blair, 1988).

CONCLUSIONS

The study provides further proof that microflora can produce different rate of weight loss under similar environmental conditions and the correlation analysis revealed that climatic factors and litter moisture were the most important regulating the microbial counts. It can also be inferred that rate of decomposition is highly influenced by both abiotic and biotic factors and the enhanced microbial population in turn can be used as a tool to increase the rate of decomposition and ultimately quick return of nutrients to the sites.

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