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# Leaf litter decomposition and nutrient release in reed bamboo (*Ochlandra travancorica*)

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**Abstract**—Recently, considerable attention has been paid to the establishment of large scale plantations of reed bamboo *(Ochlandra travancorica* Benth) and its introduction in the home gardens of Kerala, India. As in forest ecosystems, the decomposition and nutrient release of leaf litter are supposed to play an important role in the nutrition of bamboo stands. The mass loss of reed bamboo was studied using a litter bag in a predominantly reed growing area at Vazhachal situated in the southern Western Ghats of India. Two sites, one in a pure reed patch and the other in a teak plantation with reed under growth, were selected. Results of the study indicated that the exponential model proposed by Olson [1] was the best fitting model to work out the annual decomposition rate constant of reed leaf litter. These rate constants varied from 0.234 at Site 1 to 0.229 at Site II and were not different between the two sites. The time for 50% decomposition was three months and that of 95% was 13 months. The decomposition rate was highest in July and it was strongly and positively correlated with rainfall and soil moisture. Release of nutrients from the leaf litter varied with the type of element, and the nutrient mobility from decomposing reed leaf litter was in the order K > N > Mg > Ca > P.

*Key words*: Ochlandra travancorica; leaf litter decomposition; nutrient release.

## INTRODUCTION

Reed bamboo (*Ochlandra sp*) is a tufted reed-like gregarious bamboo confined only to the moist tropical forests of India and Sri Lanka, despite the wide distribution of various other genera of bamboo in the world [2]. Among eight species of *Ochlandra* reported in the Kerala part of the Western Ghats [3], *Ochlandra travancorica* Benth is the most common and widespread species. It occurs widely as an undergrowth in low level evergreen and semi-evergreen forests. Pure patches of reed, which grow as impenetrable thickets, are also found along the sides of rivers and streams [2]. Removal of upper canopy through deforestation has resulted in

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the rapid multiplication and vigorous growth of this species forming extensive reed patches. It prefers diffused light and requires a rainfall of more than 1500 mm and good drainage [4]. It was noticed that it flourished well in areas with an annual rainfall from about 3050 to 3810 mm and a temperature between 18 and 35°C [5]. The culm, which is the main yield from the plant, forms the major raw material for paper and pulp industries of the State. Apart from this, it serves the livelihood of a large number of people engaged in reed cutting and various cottage industries (handicrafts, flute-making, basket-weaving, mat-making etc.). The significant role of reed bamboo in controlling soil erosion is also well established [6].

The soils on which *Ochlandra travancorica* Benth is distributed are mainly Ultisols and Alfisols [7]. Thomas and Sujatha [6] reported that physical properties of soils are improved greatly by reed colonisation. It is also found to be an ideal species for growing under older teak plantations [8] of Kerala and also for improving the health of degrading lateritic soils [9].

Leaf litter, the main component of detritus in both natural forests and forest plantations, plays a major role in determining the structure and function of the ecosystem by acting as an energy source for heterotrophic organisms and a nutrient reservoir for intra-system cycling [10]. The decomposition rate of leaf depends on the nature of the substrate and the characteristics of the environment [11]. The availability of nutrients, which are released during decomposition, for plant uptake depends upon the re-absorption and re-translocation of the nutrient before leaf fall and subsequently on decomposition and mineralisation of the organic matter. Even though studies on this line are plentiful in various natural forests and plantations [10, 12–14], very few are reported in bamboo [15] and none in reed bamboo. Since reed occurs naturally as pure reed patch and also as undergrowth, this study mainly focuses on the rate of decomposition and nutrient release pattern of reed leaf litter in both these types of vegetations which do not differ in geology and climate.

## STUDY AREA AND METHOD

### *Study area*

The study of *in situ* reed leaf litter decomposition was carried out at two selected sites in Vazhachal located at 500 m above mean sea level. Since the study aimed at delineating geographical factors influencing the decomposition, care was taken to select sites with the same elevation and topography but differing only in vegetation. The first site selected was a pure reed patch while the other was a teak forest with reed. At both sites, the canopy was almost closed. The terrains were moderately sloping, the first site facing towards north and the other towards west.

The total rainfall received during the study period was 4340 mm (Fig. 3) with maximum recorded during June (1140 mm). The rainfall received during March and December was negligible. March, April and May are the hottest months with an average temperature of 29.4°C to 32.2°C.

The soils of the study areas were Ustic haplohumult [7]. They were well drained, loose with sandy loam texture and acid in reaction. The soil surface at both sites was mostly covered with litter (2 cm thick), which was under varying degree of decomposition.

### *Method*

This study was carried out by adopting the litter bag technique [16]. For this, freshly fallen reed leaf litter was collected from the two selected reed growing sites at Vazhachal. These litter bags were brought to the laboratory, air dried and made free of adhering materials. A known weight (25 g) of litter was packed in a nylon bag of size $25 \times 25$ cm and mesh size 5 mm. At each selected site, twelve bags were placed on the soil surface around a clump of reed bamboo at the bottom, middle and top of the slope to avoid the influence of topography. Thus, there were 36 ($12 \times 3$) bags at one site and a total of 72 bags at both the sites. These bags were covered with reed leaf litter to avoid disturbance from man and wild animals. Three samples (each representing bottom, middle and top of the slope) were drawn from each site on the 4th day of every month starting from February for a period of one year. After removing the adhering soil particles these bags were taken to the laboratory, made free of foreign materials, oven dried at 70°C to constant weight, powdered and used for nutrient analysis. Soil samples (0–15 cm) for moisture determination were also collected from these sites during the monthly withdrawal of litter bags. For more accuracy, three soil samples were collected along with one litter bag. Thus there were nine soil samples per site for moisture determination.

## LABORATORY ANALYSIS

### *Soil samples*

The soil samples collected in stainless steel boxes from the field for moisture determination were weighed for initial wet weight in the laboratory. They were oven dried for constant weight at 105°C and the loss in weight was used to determine the moisture percentage.

### *Litter sample*

The plant nutrients, namely, N, P and K in the litter samples were determined [17]. Ca and Mg were determined by following EDTA titrimetry [18].

### *Statistical analysis*

To find out the best model to work out the decomposition rate constant, the data were subjected to curve fit. Among the 25 models tried, based on the value of high

$R^2$ (0.9970) and residual analysis the best fitting curve was selected. The model selected was

$$x/x_o = e^{-kt},$$

where $x$ is the weight remaining at time $t$, $x_o$ is the original weight, e is the base of natural logarithms, $k$ is the decay rate coefficient and $t$ is time.

This was in line with the model proposed by Olson [1]. The same model was used to compute the time required for 50% and 95% decomposition. The significance of difference between decay rates in the two study sites was assessed by comparing regression coefficient using Student's $t$-test. Correlation between various parameters related to litter decomposition was also worked out [19].

## RESULTS AND DISCUSSION

### *Soil moisture status*

Considering the importance of soil moisture in the degradation of leaf litter, soil samples for moisture determination were also collected along with the monthly withdrawal of leaf litter bags. At site I, the variation in soil moisture was in the range from 11.2 to 28.3% and at site II it was from 10.4 to 32.8% (Fig. 2). The variation in the content of soil moisture at both the sites followed a similar pattern. This may be due to the similar climatic and soil conditions prevailing at both sites. In reed growing tracts, the litter layer acts as a mulch on the soil surface and thereby prevents evaporation to a great extent. Moreover, the closed canopy of reed also gives an added effect to lessen the soil moisture loss. As expected, higher soil moisture was observed in rainy months. This was further supported by a highly significant and positive correlation between soil moisture content and the amount of rainfall received ($r = 0.6550^{**}$).

### *Mass loss during decomposition*

Monthly mass loss (g/month) from decomposing reed leaf litter was determined from the difference between the mass remaining in litter bags in each month and the initial fresh weight. From the values of monthly loss, the mean monthly loss in each site for a period of one year was accounted. The values pertaining to the periodical disappearance of litter (Fig. 1) indicated that the total mass loss increased with increase in time, but the monthly loss was not uniform over different months, which might be due to the difference in rainfall recorded over different months. The mean monthly loss at Site I ranged from 0.74–6.0 g and at Site II it was 0.24–5.77 g. At both sites, mean mass loss was comparatively low during January, February and March. The slow process of decomposition observed during these months is attributed to the low rainfall received during that time. In April, there was a sudden increase in the mass loss of decaying leaf litter, thought to be due

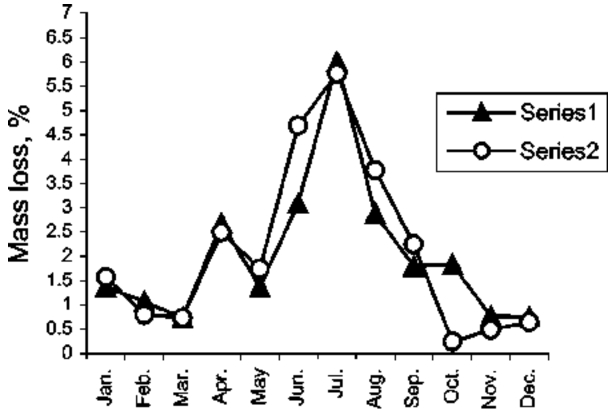


**Figure 1.** Mass loss during decomposition of reed leaf litter.

**Table 1.**
Decomposition parameters of reed leaf litter

| Plot | Annual decomposition rate constant (K) | Time required for 50% (half-life) decomposition | Time required for 95% decomposition |
|---|---|---|---|
| I | 0.23395 ($R^2 = 0.90$)** | 3 months | 13 months |
| II | 0.22868 ($R^2 = 0.92$)** | 3 months | 13 months |

to the few showers that occurred during that period. After that, with the onset of monsoon showers in June, there was a sudden uplift in the decaying processes and consequent mass loss. At both sites, maximum disappearance of mass was in July, and during the following months the mass loss was decreasing. The reported studies indicate that temperature and moisture are critical environment factors for high rates of decomposition. During the rainy season, due to the rapid multiplication and intense activity of microbes, most of the easily decomposable substances are lost from the system. As a result, relatively more resistant materials remain in the litter bags and this caused a decrease of mass loss during the following months.

The $K$ values (annual decomposition rate constants) determined using the selected model at Site I and Site II were 0.234 and 0.229 respectively (Table 1). The $R^2$ values indicated that the contribution of independent variable (months) in the total variation of $Y$ (mass loss) was 90% at Site I and 92% at Site II. The time required for 50% (half life) and 95% decomposition were found to be the same for both sites, the 50% decomposition within three months and a decay of 95% was anticipated within a time span of 13 months.

A comparative study of decomposition rate constants at the two sites yielded no statistically significant difference. This may be because of the similar climatic condition prevailing in the study sites. Even though the vegetation was different, the closed canopy of reed at both sites might have offered similar microclimatic

**Table 2.**
Correlation matrix between various parameters related to decomposition of reed leaf litter

| Soil moisture | Soil moisture | Mass loss | Rainfall |
|---|---|---|---|
| | 1.0000 | | |
| Mass loss | 0.2922 | 1.0000 | |
| Rainfall | 0.6550** | 0.6080** | 1.0000 |

**Table 3.**
Decomposition rate constants of various moist deciduous species

| Name of species | Decomp-<br>osition<br>rate constant (k) | Reference |
|---|---|---|
| *Tectona grandis* | 0.32 | [12] |
| *Pterocarpus marsupium* | 0.44 | [12] |
| *Dillenia pentagyna* | 0.35 | [12] |
| *Xylia xylocarpus* | 0.33 | [12] |
| *Grewia tiliaefolia* | 0.34 | [12] |
| *Terminalia paniculata* | 0.29 | [12] |
| *Albizia falcataria* | 0.14 | [14] |

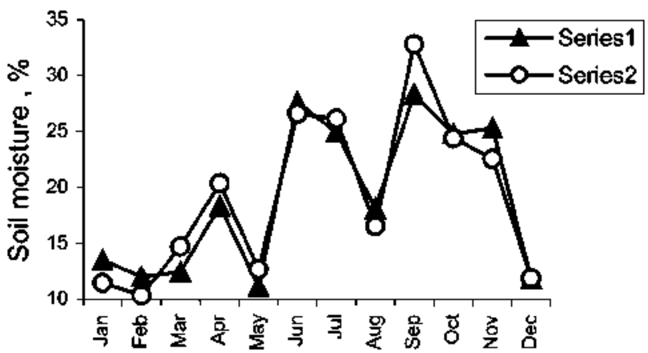


**Figure 2.** Soil moisture status in reed growing tracts at Vazhachal.

conditions. The rate of decomposition of reed leaf litter in general was slightly lower when compared to different moist deciduous species (Table 3).

A relatively low decomposition rate constant obtained in the present study in spite of higher content of N in the litter is assumed to be due to the change in the time of placement of leaf litter in the field. Since mass loss was strongly and positively correlated (Table 2) with rainfall ($r = 0.6080^{**}$) ($^{**}$ means significant at 1% level), the decomposition would have been much quicker if the litter bags were placed just before the monsoon showers. Hence it is hoped that the decomposition rate constant of reed leaf litter can be raised to a certain extent if the time of placement of litter bags is extended to June, just after the onset of monsoon showers.

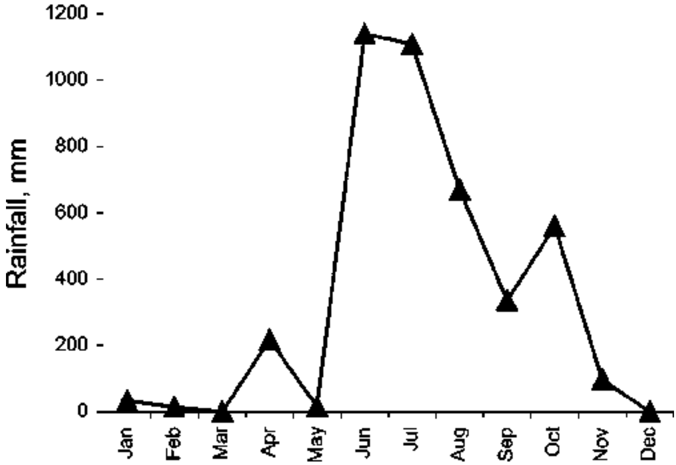


**Figure 3.** Rainfall distribution during the year '94 at Vazhachal.

Apart from the climatic factor, the faunal diversity and their decomposing ability also influence the rate of decomposition. A high diversity (16 classes) of faunal groups, the majority having a significant role in the decomposing process, was noted in this soil. The dominant faunal groups occurring in the reed growing soils were Isopoda, Chilopoda, Acarina, Collembola, Isoptera and Oligochaeta. All these groups except Chilopoda help in the degradation of litter and enrich the soil with highly fertile humus [20].

*Nutrient release*

The fresh leaf litter of reed contained highest amount of N (1.98%) followed by K (0.46%), Ca (0.16%), Mg (0.12%) and P (0.085%) (Fig. 4). During decomposition of this litter, along with mass removal, differential changes occur in the concentration and absolute content of these nutrients. The releasing pattern of these nutrients from the decompositing litter are discussed in the following paragraphs.

*Nitrogen.* During decomposition of reed leaf litter, the concentration (Fig. 5) and percentage (Fig. 4) of N in the remaining mass was found to show variable trends at both sites. During the early three months of decomposition, it declined, which might be due to its loss through leaching, accelerated by the few showers that occurred during this period. This reduction was found to vary from 3.5 to 4.0% of its original content. But the following months showed an accumulation phase and this was continued up to the month of September. During this time the percentage increase reached even up to 60.6% of its initial content. This is almost certainly due to the intense immobilization activity of microbes including N fixing ones during these most favourable climatic conditions coupled with the rapid decomposition of organic matter compared with the release of N. A similar rise in the concentration of

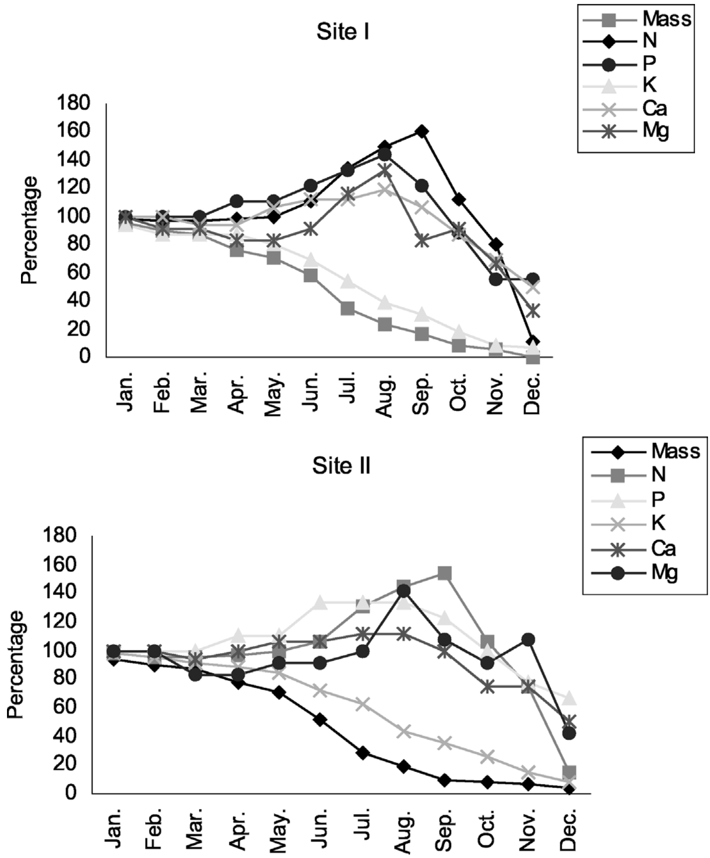


**Figure 4.** Relationship between mass and nutrient remaining in the decomposing reed leaf litter.

N during decomposition was also observed by several other workers [21, 22]. After September, it again decreased, and at the end of a one-year period, the content of N was reduced to 0.22% at Site I and 0.30% at Site II. Thus, the results in general indicated that 84.8 to 88.9% of N was released from reed leaf litter within 12 months of decomposition.

The data on the absolute content (determined by multiplying the nutrient concentration and the mass remaining at each month) of N (Fig. 6) showed a gradual decrease with increase in time of decomposition . This is explained by the relatively higher mass loss compared to the change in the concentration of nutrient with increase in time. The nitrogen release estimated based on the absolute content was 99.7% at Site I and 99.4% at Site II.

*Phosphorus.* The concentration (Fig. 5) and percentage (Fig. 4) of P in the remaining mass of decomposing litter remained similar during the first four months at both the sites studied, revealing a very slow release of this nutrient. But after the onset of monsoon showers, there was a sudden increase in the P content of

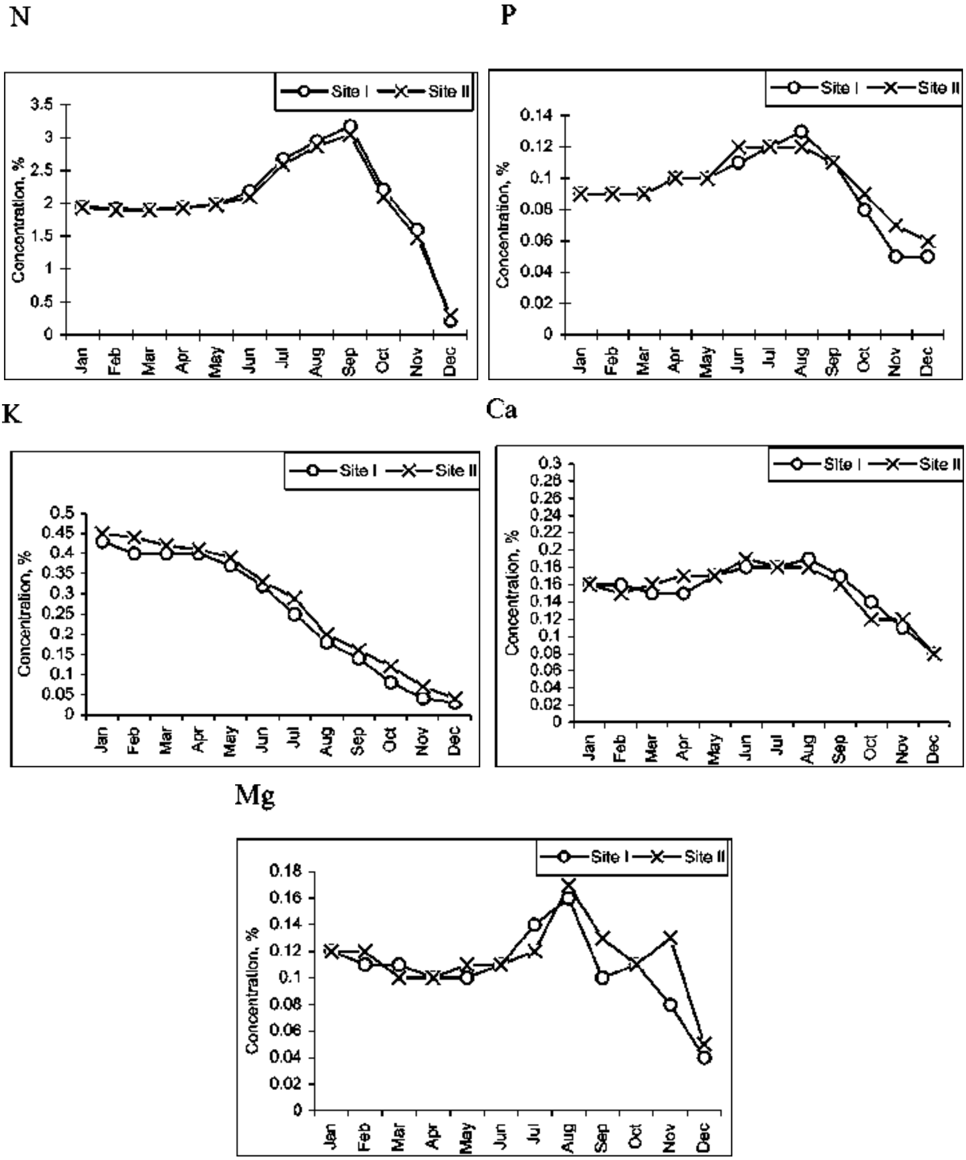


**Figure 5.** Nutrient concentration in the remaining mass of reed leaf litter during decomposition.

litter mass, which might be the contribution from the mycelial growth of fungus that multiplied during this time. The rapid disappearance of litter mass caused by the intense decomposition activity also might have caused the rise in the nutrient concentration. This increase was recorded up to 44.4 and 33.3% at Sites I and II, respectively. But after that, it decreased and in the month of December the percentage of P in the remaining mass varied from 55.6–66.7 of its original content (Fig. 4). The data in general showed that the release of P from reed leaf litter

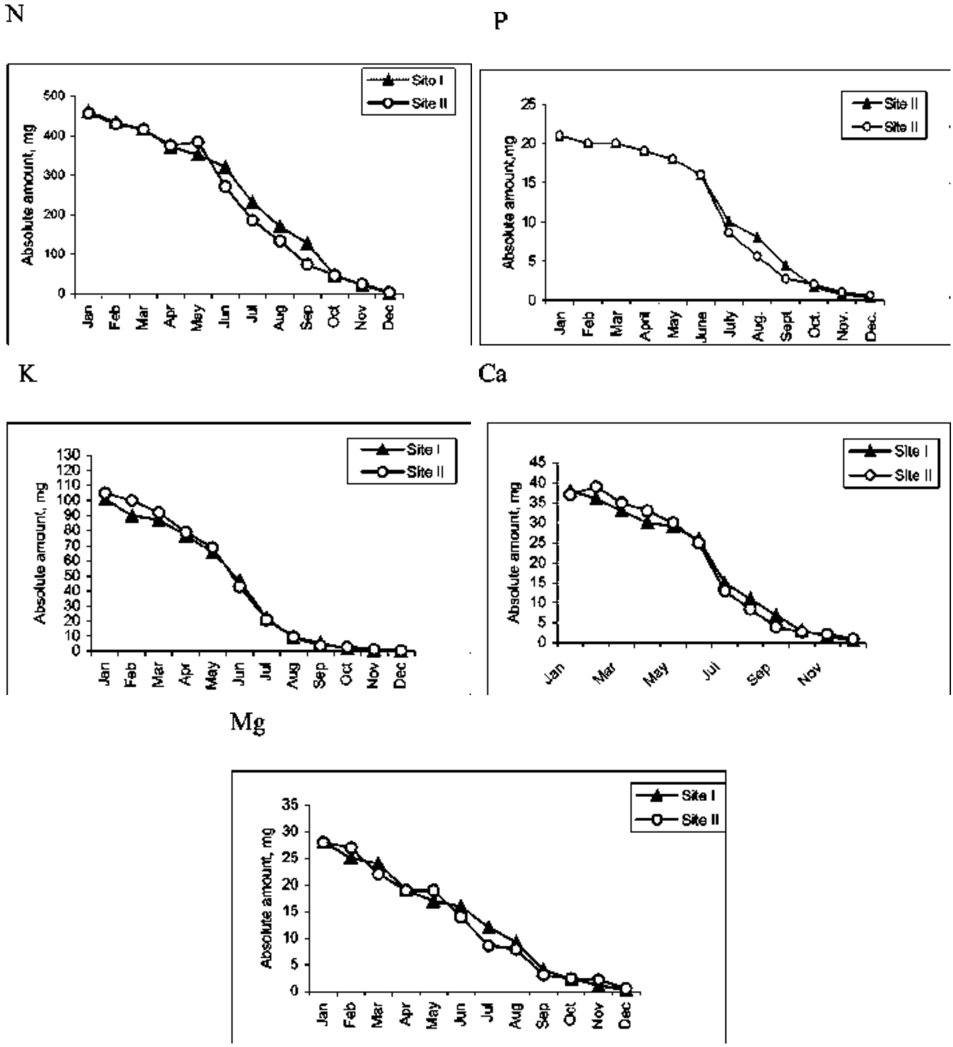


**Figure 6.** Absolute content of nutrients in the remaining mass of reed leaf litter during decomposition.

occurred only in the later stages of decomposition. But Srivastava *et al.* [23] reported uniform return of P from the decomposing leaf litter in Sholas. The slow release of P from the reed leaf litter here may be due to its immobile nature. A similar release pattern of P was also observed by Bockheim and Jepsen [24] in north-western Wisconsin and by Bahuguna *et al.* [25]) in *Shorea robusta* and *Eucalyptus camaldulensis* in India. As in the case of N, the absolute content of P (Fig. 6) also showed a gradual decrease with increase in time of decomposition; the reasoning applied to N is applicable here also. Based on the absolute content, the total release of P was 98.7% at Site I and 97.4% at Site II.

*Potassium.* The data pertaining to the concentration (Fig. 5) and percentage (Fig. 4) of K in the remaining mass of reed leaf litter revealed that the loss in K occurred at all stages of decomposition, but it was more pronounced during rainy months. Both the sites showed similar pattern of release of this nutrient. The loss in general was found to be 10.9 to 13.0% before the onset of monsoon showers, 45.6 to 47.9% during the rainy season and 32.6–34.8% after the rainy season. Attiwill [26] found it was the most mobile element, and this explains the rapid release of this nutrient. In contrast to N and P, K is not bound as a structural component in plants and is highly water soluble [27]. The present study indicated that almost 91.3 to 93.5% of K was released within a time span of one year.

But these results are not in agreement with the results reported by Bahuguna *et al.* [25] wherein they could observe an increase of K concentration during the later stages of decomposition in *Shorea robusta*. The heavy rainfall prevailing during the later stages of decomposition might have removed this most immobile element from reed residue and this explains the low value recorded in the present study. Similar decrease of K and its close successive correlation with the loss in total organic matter in *Eucalyptus globulus* has been reported [28].

The data on the absolute content of K (Fig. 6) showed a gradual decrease of this nutrient with increase in time of decomposition and the maximum release was recorded during July. At the end of the one-year period, the total release of K was 99.8% at Site I and 99.7% at Site II.

*Calcium.* The content of Ca in the original litter sample was not affected much during the early months of decomposition (Fig. 5). But after the onset of monsoon showers, due to the faster rate of multiplication of soil fauna together with the rapid disappearance of litter mass, the content of Ca in the remaining litter mass was elevated to the maximum of 0.19% producing an immobilization increase to 18.8% (Fig. 4). After that, starting from September a gradual decline of this nutrient was noticed. However, within a time span of one year, the total loss accounted for was only 50% of its original content at both the sites studied.

According to Burges [29], Ca was retained within the litter until the major breakdown of cell wall tissue occurred. Attiwill [26] could observe only very little leaching of Ca, which he attributed to the immobility of the element. The results of the present study indicated that release of Ca from decomposing reed leaf litter occurred very slowly and the major loss was noticed during last months of decomposition. As revealed in Fig. 6, a total of about 99% of Ca was lost from the decomposing litter.

*Magnesium.* As in the case of K, a gradual decline in the concentration of Mg was observed at both the sites during the first four months (Fig. 5). This reduction was computed as only 20% of its initial content. Even though the values showed some immobilization trends during the monsoon period, the data showed some fluctuation towards the last months of decomposition. It was estimated that a total release of 58.3 to 66.7% of Mg occurred within a time span of 12 months. Bockheim and Jepsen [24] could observe a gradual release of Mg in decomposing jack pine and northern pine oak leaf litter. But in bamboo timber stands of China, Fu Maoyi *et al.* [15] reported an increase in the content of Mg with successive decomposition of leaf litter. This leads to the conclusion that the heavy rainfall obtained in the present study site might have helped to remove this nutrient from the system to a certain extent.

As in the case of other nutrients, the absolute content of Mg (Fig. 6) also showed a gradual decrease with increase in time of decomposition. The total loss was 99.0% at Site I and 98.0% at Site II within a period of 12 months.

The results of the study revealed that, in general, the release of various elements at successive stages of decomposition varied with type of element. From the relationship between percentage mass remaining and percentage nutrient remaining (Fig. 4), the nutrient mobility from decomposing reed leaf litter was in the order K > N > Mg > Ca > P.

## CONCLUSION

The above study revealed that the decomposition rate constants of reed leaf litter varied from 0.234 at Site 1 to 0.229 at Site II in a humid tropical climate and it did not vary significantly between pure reed patch and as undergrowth in teak. Mass loss during decomposition was highly influenced by rainfall. The time required for 50% and 95% decomposition was 3 and 13 months respectively. The nutrient mobility from decomposing reed leaf litter was in the order K > N > Mg > Ca > P.

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