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LITTER DEPOSITION, DECOMPOSITION AND NUTRIENT RELEASE DYNAMICS OF SIX YEAR OLD *OCHLANDRA TRAVANCORICA* GAMBLE : AN ENDEMIC REED BAMBOO OF WESTERN GHATS

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Abstract

Ochlandra travancorica Gamble. is a small clump forming reed bamboo species endemic to Western Ghats, naturally distributed in the evergreen and semi-evergreen forests of Kerala. The objective of the present study was to assess the litter production, decomposition and nutrient release dynamics of *O. travancorica*. The litter production and decomposition were studied using the standard litter trap and bag techniques. The total annual litter addition *O. travancorica* was 1.846 t ha^{-1} and it followed a biphasic pattern with a major peak in February 2011 and minor peak in July, 2010. The rate of decomposition in *O. travancorica* was a good fit to exponential decay model suggested by Olson (1963). The decomposition rate constant of *O. travancorica* was 0.014 day^{-1} and the half-life was 49.5 days. The release of nutrients from the decomposing litter was in the order Mg > N > Ca > P > K.

Key words : Decomposition rate constant, litter dynamics, litter bag, litter trap, nutrient release, *Ochlandra travancorica*.

Introduction

Ochlandra travancorica Gamble is a shrubby reed bamboo species endemic to Western Ghats, naturally distributed in the evergreen and semi-evergreen forests of Kerala (Seethalakshmi and Kumar, 1998). Generally, it occurs widely as undergrowth in the low level evergreen and semi evergreen forests. Pure patches which grow as impenetrable thickets are also found along the sides of rivers and streams where other tree species are not allowed to come up. This species prefers diffused light, requires a rainfall of more than 1500 mm, and requires good drainage for proper growth (Asari, 1976). In an environmental point of view, the soil under this species is dark brown, acidic, sandy loam with granular structure, high porosity, good aggregate stability and with high water holding capacity. It is an integral part of rural economy of Kerala from time immemorial and is used for mat and basket making, fishing rods, handicrafts etc. It is an ideal raw material for paper making, bambooply and weaving. Due to its divergent uses, it is identified as one of the priority species for large scale cultivation in India by National Mission on Bamboo Applications and 38 species for international action (Rao and Rao, 1986).

Litterfall plays a significant role in the nutrient cycling of the tropical ecosystems and the rate at which litter falls and subsequently decomposes regulate the energy flow, primary productivity and nutrient cycling in forest ecosystems (Waring and Schlesinger, 1985). The plant litter acts as a temporary sink for nutrients and functions as ‘a slow release nutrient source’ (White, 1988), thereby guaranteeing a permanent contribution of nutrients in to the soil (Cuevas and Medina, 1988). Although, abundant literature on litter dynamics studies are available in tropics, such studies on bamboo forests especially at a plantation level are only few (Sujatha *et al*., 2003; Deb *et al*., 2005; Nath and Das, 2011; Thomas *et al*., 2014). Most of the bamboo species are established in nutrient poor marginal lands worldwide. Hence, understanding the decomposition dynamics of bamboo litter can help to formulate efficient management tools for maintaining productivity of these important plant resources. With the establishment of bamboo missions, considerable attention has been paid to the establishment of large scale plantations of reed

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bamboo and its introduction in the home gardens of Kerala, because of the raw material shortage. The bamboo stand in the present study was established in a progressive farmer field as a block planting. The study throws light on the litter production decomposition and nutrient release dynamics of *O. travancorica* in a farmer's field.

Materials and Methods

Present investigation was carried out at Vilayannur (N 10^{O} 37'58.7" and E 76^{O}30' 54.2''), Palakkad district of Kerala, India from July, 2010 to May, 2011. The rainfall, relative humidity and maximum and minimum temperature of the study site is shown in Fig 1. *O. travancorica* plots were established as block planting in 2005 as part of the Multi-locational Bamboo Species Trial supported by National Mission on Bamboo Applications (Raveendran *et al.*, 2011). As part of the trial, eight bamboo species including *O. travancorica* were established in Randomized Block Design in three replicates at a spacing of 5 m x 5 m with sixteen clumps constituting one replication.

Litterfall of *O. travancorica* was captured using the specially designed litter traps made of bamboo baskets with diameter of 1 m and depth 10 cm placed in the centre of three sample plots. Litter decomposition study was carried out by adopting standard litterbag techniques (Bocock and Gilbert, 1957). The freshly abscised bamboo litter was collected during the peak litter fall period (February-March 2010). Air dried litter mass weighing 30 g was placed in 28 × 23 cm nylon litter bags (2 mm mesh size) and 80 such bags were prepared. Litter bags were placed under the closed canopy of *O. travancorica* on first week of June, 2010. Five samples were retrieved at monthly intervals until 95% decomposition of the litter was observed. The residual material from the monthly retrieved litter bags was separated carefully from the adhering soil particles using a small brush. Litter samples from each bag were oven dried at 70ºC to constant weight.

To determine the initial litter chemistry and chemistry of litter retrieved at each sampling period, litter samples were ground in a Wiley mill for analysis. Total carbon was estimated using Euro vector (EA 3000) CHNS Elementar analyser and nitrogen and phosphorus was estimated using Continuous Flow Analyzer (Skalar San++). Potassium was estimated using a flame photometer (ELICO) and calcium and magnesium were estimated using an Atomic Absorption Spectrophotometer (VARIAN) (Jackson, 1973). Mass loss over time was computed using the negative exponential decay model (Olson, 1963); *X/X*0=e-k*t* where, X is the litter mass at time t, X0 the initial litter weight, e is the base of natural logarithm and k is the decomposition rate constant. The time required for 50% (t_{50}) and 99 per cent (t_{99}) decay was calculated as $t_{50} = 0.693/k$ and $t_{99} = 5/k$.

Nutrient remaining in the litter was calculated using the formula.

$$N = \left(\frac{C}{C_0}\right) \times \left(\frac{D_M}{D_{M0}}\right) \times 100$$

Where, *N* is percentage of nutrient remaining in the litter. *C* is the concentration of the element in litter at the time of sampling; C_0 is the concentration of element in the initial litter kept for decomposition; D_M is the mass of dry matter at the time of sampling and D_{M0} is the mass of initial dry matter kept for decomposition (Bockheim *et al.*, 1991). The % nutrient release from the litter mass was calculated as 100 - *N*.

The data were subjected to one-way analysis of variance in SPSS 17 for windows and treatment means were compared using least significant difference (lsd) as necessary. Correlation and regression analysis also were carried out in SPSS 17. Litter decay constant was calculated using MS-Excel 2007.

Results and Discussion

Litter deposition

The total litterfall of *O. travancorica* from June 2010 to May 2011 was 1.846 t ha^{-1} spread throughout the year with significant monthly variations (p=0.01). The litter deposition followed a bimodal pattern with a major peak during February and a minor peak during July (fig. 2). Profound seasonal variation was observed in litter deposition with rainy season recording the lowest litterfall. The minor peak of litterfall was observed in July. More than 70 % of the litterfall *in O travancorica* occurred during November to March. *S*easonal variation in litter accumulation pattern similar to our study has been observed in many studies (Ndakara, 2011 and Thomas *et al*., 2014). They reported an increase in monthly litter production during the dry season and a lower litter production in the wet season. Litter production of *O. travancorica* was correlated with climatic factors like monthly rainfall (r = -0.72, p = 0.01) and maximum temperature (r = -0.67, p = 0.01).

Quantification of litter production is important while estimating nutrient turnover, C and N fluxes and C and N pools in ecosystems. The observed litter production of *O. travancorica* was on the extreme low end of the spectrum for similar vegetation types and climates. For instance, the litter production in the moist topical forests is reported to be 2 to 11 t ha^{-1} Proctor (1987). Even otherwise, litter deposition of *O. travancorica* was lower compared to that of most tropical and sub-tropical bamboo species (Upadhyaya *et al*., 2008). However, litter deposition in the present study was greater than that reported for *Dendrocalamus strictus* (Joshi *et al*., 1991) and *Arundinaria racemosa* (Upadhyaya *et al*., 2008). But it was comparable to that of the same genus, *O. setigera* (1.981 t ha^{-1}).

The proximate composition of litter revealed that the major share of total litterfall of *O. travancorica* was contributed by leaves (95.34±0.72%) followed by branches (2.90±0.33%) and culm sheaths (1.76±0.41%). The annual inputs of nutrients to the soil via litter deposition (t ha^{-1}) estimated using the litter production and nutrient concentration in *O. travancorica* were in the rank order K (0.03)>N (0.02) = P (0.02) > Ca (0.01) >Mg (0.002).

Litter decomposition

Weight loss of litter on dry weight basis during litter decomposition of *O. travancorica* (fig. 3) depicted an initial rapid loss followed by slower rate towards the end. Hence, a negative exponential model $y = e^{-kt}$ was fitted to the mass loss data. The rate of decomposition was a good fit to exponential decay model suggested by Olson (1963). The regression model that depicted the progression of litter decomposition was $y = 150.92e^{-0.014t.}$ (R^2 = 0.98). Decomposition rate constant was 0.014 g day^{-1}, the half-life was 49.5 days and days taken for 99% decomposition was 357.1.

A two phase pattern of litter decomposition comprising an initial rapid phase followed by a slower phase was obtained in the present study. Whereas, a three phase decomposition pattern (initial slow phase, intermediate fast phase and terminal slow phase) in litter incubated long before rainy season (Sujatha *et al*., 2003). During litter decomposition, mass loss rates were higher during the initial periods (during southwest monsoon), due to the rapid multiplication and intense activity of microbes as a result most of the easily decomposable substances are lost from the system. The initial faster mass loss might be associated with the release of easily decomposable materials which resulted in accumulation of relatively decay resistant materials remain in the litterbags and consequently a decrease in mass loss during the following months was observed.

The monthly decomposition rate constant of *O. travancorica* (0.42) was higher compared to *Ochlandra setigera* (0.23) at Nilambur (Thomas *et al*., 2014) and *O. travancorica* (0.23) in Vazhachal, the southern Western Ghats of India (Sujatha *et al*., 2003). Compared to farmers' field situations, the decomposition rates were found to be slow under natural habitats. The decay rate constants in tropical plantations are reported to range between 0.11-2.00 (O'connell and Sankaran, 1997). The *k* values worked out at the end of the decomposition in the present study corroborate with this range. Initial chemistry of the litter mass of *O. travancorica* is depicted in the table 1. Data on initial litter chemistry indicated that carbon was the major component followed by nitrogen and the nutrient in least quantity was Mg. The ratios of carbon to N, P and K also varied and the C: N ratio was as low as 26.16. But a higher C: P and C: K was observed. Initial N (Meentemeyer and Berg, 1986) and lower C: N ratio (Swift *et al.*, 1979) have been well correlated with the weight loss. The C:N ratio upto 20: 1 indicate a high mineralisation and subsequent nutrient release. Wider C:N ratio are reported to slow the decomposition rate. The slow decomposition rate of *O. travancorica* in the present study might be due to higher initial C:N ratio.

Nutrient release

In order to estimate the nutrient release from the decomposing litter mass, the concentration of nutrients (N, P, K, Ca and Mg) in the decomposing litter samples was estimated at monthly intervals. The data on concentration of litter mass retrieved at monthly intervals indicated significant variation (p=0.01) and in general, the nutrient concentration decreased towards the end of decomposition (fig. 4). The average nitrogen concentration in the decomposing litter mass varied from 0.75 to 2.04%. Initial N concentration was 1.09% and the highest N concentration was observed during January 2011 (2.04%) at 240 days. With some exceptions, the N concentration of litter mass increased till 240 days after incubation (January, 2011) indicating nutrient accumulation and thereafter N content decreased. The increase in N concentration is associated with microbial fixation of atmospheric N_2 inputs from external sources like throughfall and microbial immobilization (Laskowski *et al.*, 1995). Whereas, such a pattern in terms of increase or decrease in concentration was not observe in P concentration during litter decomposition. However, an initial decrease in P was observed and the P content ranged from 0.918 to 0.105% during the different periods of incubation. Literature indicates that the concentration of P in decomposing litter mass sometimes decreases or increases or remains constant during decomposition. This is a characteristic of the leaf litter quality and the site, namely whether P is limited (Moore *et al*., 2006). Our results are inconsistent with those of Sujatha *et al.* (2003) for *O. travancorica* where an increase in P concentration

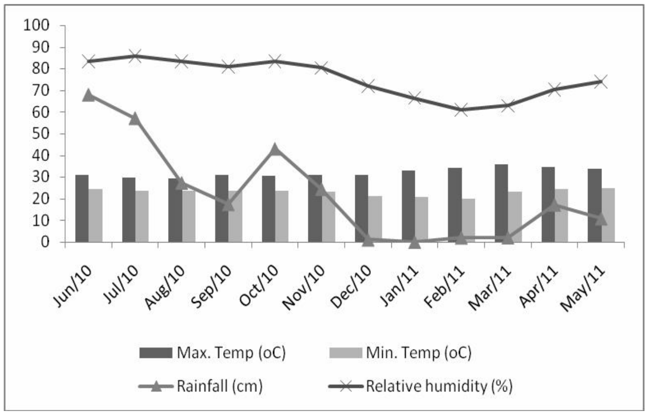

Fig. 1 : Change in monthly rainfall, relative humidity and maximum and minimum temperatures during the course of study.

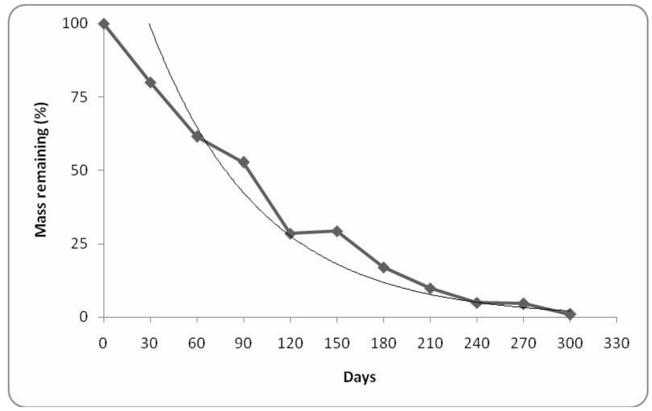

Fig. 3 : Litter decomposition of *Ochlandra travancorica* (Thicker line represents the actual weight loss and thinner line denote predicted weight loss based on an exponential model).

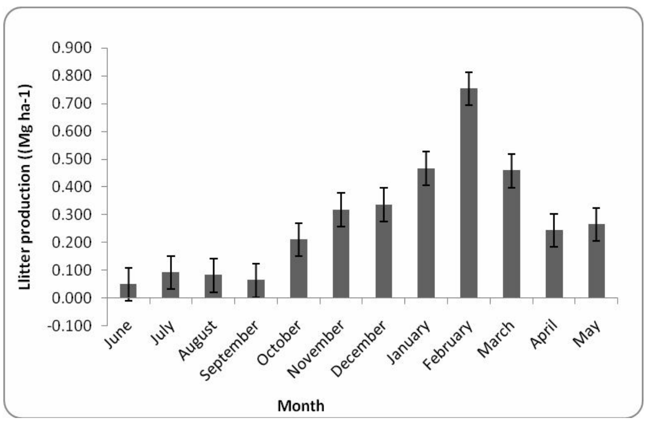

Fig. 2 : Litter production of *Ochlandra travancorica* from June 2010- May 2011.

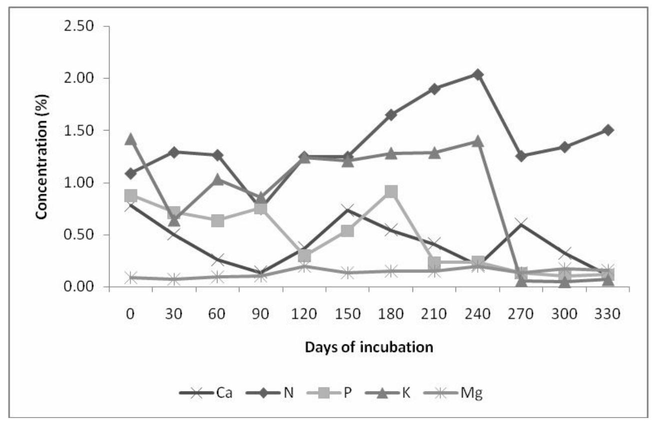

Fig. 4 : Nutrient concentrations in the monthly retrieved litter samples of *Ochlandra travancorica*.

Table 1 : Initial litter chemistry of *Ochlandra travancorica*.

Nutrients	Value
Nitrogen (%)	1.088±0.164
Phosphorus (%)	0.879±0.073
Potassium (%)	1.420±0.111
Calcium (%)	0.782±0.023
Magnesium (%)	0.088±0.001
Carbon (%)	27.63±3.61
C: N ratio	26.15±7.70
C: P ratio	31.76±6.44
C: K ratio	19.67±4.17

was recorded during decomposition. The initial K concentration in the litter mass was 1.42% which almost halved within 30 days of incubation indicating a faster release. Thereafter, the concentration steadily increased till 240 days and at that time, K concentration was almost equal to initial concentration and then a sudden decline was observed in the K concentration of the litter mass. Attiwill (1968) reported K as the most mobile element in the litter 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. Meanwhile, the Ca concentration in the litter mass ranged from 0.782 to 0.113% during incubation. A steady decrease in Ca concentration was observed till 90 days indicating the release and it was followed by accumulation phase till 150 days. Again, a Ca accumulation was observed followed by the release phase. Attiwill (1968) reported that the loss of calcium from decomposing litter was slow due to its importance as a structural component. The concentration magnesium in decomposing litter mass varied from 0.195 to 0.069% at different stages of incubation. The initial concentration of Mg was 0.088% which declined at the end of June (30 days), steadily increased to reach peak value at 120 days (0.195%). It decreased to 0.134% at 210 days after incubation and steadily increased to reach 0.194% in January 2011(240 days). Thereafter, the Mg content of litter declined. Many

Table 2 : Exponential regression equations for nutrient release during litter decomposition of *Ochlandra travancorica* and the nutrient release constants.

Nutrient	Exponential Regression Equation	Coefficient of determination (R^2)	k ($month^{-1}$)	t_{50} (days)	t_{99} (days)
N	$y = 219.57e^{-0.3824x}$	0.88	0.382	54.4	392.3
P	$y = 333.76e^{-0.6191x}$	0.89	0.619	33.6	242.3
K	$y = 399.93e^{-0.6464x}$	0.75	0.646	32.2	232.1
Ca	$y = 127.66e^{-0.44x}$	0.81	0.440	47.3	340.9
Mg	$y = 208.71e^{-0.3457x}$	0.85	0.346	60.1	433.9

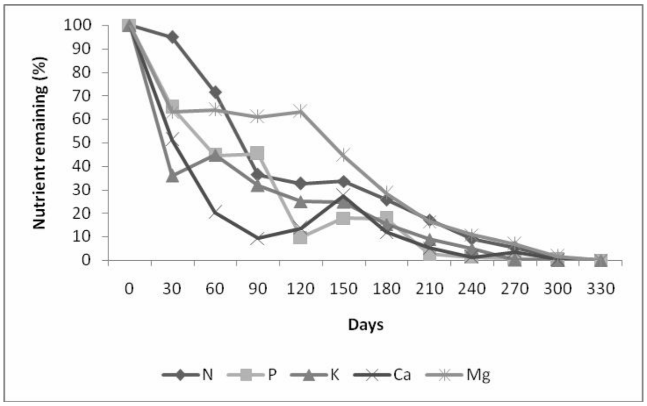

Fig. 5 : The percentage of nutrient in the remaining litter mass of *Ochlandra travancorica*.

authors reported Mg dynamics in decomposing litter similar to the two-phase pattern recorded in our study (initial leaching phase and late immobilization phase (Laskowski and Berg, 1993). Magnesium is not a structural material and exists mainly in solution in plant cells and thus leached out from litter in the initial phase of decomposition.

The percentage of nutrient in the remaining litter of bamboo species at different stages of incubation is given in fig. 5. Figure 5 depicts that the nitrogen remaining at 30 days after incubation was 94.89%, which implied that only 5.11% N release occurred in June. However, the highest release of N occurred at 90 days after incubation (35.17%) and which was followed by that at 60 days (23.42%). There was a slight accumulation phase at 150 days after incubation (0.83%). More than half of the N was released from the litter mass during 30-90 days. In general, the release of N was continuous. Compared to N, the P release was faster, the phosphorus remaining in litter mass at 30 days after incubation was 65.10% which implied that 34.9% of P release occurred in June. The highest release of P occurred at 120 days after incubation (35.61%) and which was followed that at 60 days (23.42%). There were two P accumulation phases at 90 (0.77%) and 150 days after incubation (8.16%). At the end of 30 days 64% of K release occurred. There was three slight K accumulation phases at 60, 120 and 180 days after incubation otherwise the nutrient release was continuous. Meanwhile, after 30 days, 48.71% of Ca was released from the litter mass. There were three Ca accumulation phases at 120, 150 and 270 days after incubation. More than 80% of the Ca release occurred during initial two months. Similarly, a higher release (37.07%) of the Mg occurred at 30 days after incubation. There were two Mg accumulation phases at 60 and 120 days after incubation where 0.89 and 2.23% Mg accumulated in litter. The release of Ca and Mg was faster compared to other nutrients. Three sequential phases occur during mineralisation of nutrients from decomposing plant residues *viz*. An initial phase when leaching and nutrient release predominate, the net immobilization phase during which nutrients are imported in to residues by microbe, and a net release phase when nutrient mass decreases (Staaf and Berg, 1982). However, not all these phases occur for all nutrients and all types of litter.

Nutrient release rates were all rapid in the early stages of decomposition but slowed later. Hence, a negative exponential model was fitted ($y = e^{-kt}$). The relation between time and the rate of nutrient release was analyzed using regression analysis. The exponential regressions equation used to describe mass loss through time were significant ($p = 0.01$). The equations are given in table 2.

The nutrient release from the decomposing litter mass was in the order Mg > N > Ca > P > K. Meanwhile, the nutrient mobility from decomposing O. *travancorica* leaf litter from natural forests of Vazhachal, Thrissur, Kerala was in the order K > N > Mg > Ca > P. Whereas, the nutrient release from the decomposing litter mass was in rank order N = Mg > K = Ca > P (Thomas *et al*., 2014). Both reported P as the least mobile element during the litter decomposition.

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