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NUTRIENT DYNAMICS THROUGH LITTER FALL AND DECOMPOSITION IN BAMBOO AGROFORESTRY SYSTEMS IN HUMID TROPICS OF KARNATAKA, INDIA

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ABSTRACT

Bamboo is hailed as the fastest growing and highest yielding renewable natural resource. Its biological characteristics makes it an ideal economic investment with multiple uses. Also, these characteristics render bamboo a perfect solution for encouraging environmental security through nutrient cycling process. This paper examines nutrient cycling pattern by enhancing the production of litterfall and litter decomposition rate in bamboo (*Dendrocalamus asper*) agroforestry system established in abandoned paddy fields in Kodagu, Karnataka during 2005. A litter decomposition experiment conducted by incubating the known weight of litter samples for the period one year indicated that the mass loss varied significantly and exhibited negative exponential decay pattern. The relative proportion of residual nutrient concentrations remaining in litter at the end of experiment period was highest for N (20.93 %) followed by P (18.81 %) and least was for K (0.51 %). The order of nutrient mineralization was K>P>N. These findings, therefore, provide support for the notion that *D. asper* play a significant role in nutrient conservation under bamboo agroforestry system and considered as a better species for restoring soil fertility status in abandoned paddy fields in humid tropical conditions of Karnataka.

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INTRODUCTION

Agroforestry is an age-old practice to take an advantage of the soil fertility improvement and consists of integration of woody plants with agricultural crops (Yadav *et al.*, 2008). With the advent of modern cultivation practices, the traditional trees (especially slow growing ones) have vanished, hence the recent focus is on raising short rotation species having fast growth with multifarious benefits. Bamboo is one of the ideal economic species that can be utilized in many ways and has more than 1500 documented uses (Tewari, 1992). It has enormous potential for mitigating many social problems facing the world today as it is commonly called "green gold or poor man's timber". The fastest growing nature and its biology considered as a perfect species to replace other slow growing species in agroforestry plantation to mitigate many environmental and social consequences of tropical deforestation (Zhou *et al.*, 2005). As per the FAO report on world forest resources, India is second only to China in genetic resource of bamboo having 125 species in 23 genera (Soderstrom and Ellis, 1988). There are also about 10 exotic species of bamboo, which provide a wide scope for selection of economically and industrially important species suitable for various agroclimatic regions for plantations. *Dendrocalamus asper* is listed as one of the 20 high priority bamboo species identified for international action by both International Network for Bamboo and Rattan (INBAR) and (International Plant Genetic resources Institute) IPGRI (Rao *et al.*, 1998). Itis also considered among the 19 priority bamboo species of India identified by the National Mission on Bamboo Applications (NMBA) (Haridasan and Tewari, 2008) based on the properties testing and assessment of inherent characteristics which are matching with end uses, and is well recognized as most valuable multipurpose species, which is having enormous potential to alleviate many problems, both environmental and social, facing India today. It is one of the giant timber species from Indonesia and cultivated in many parts of South East Asia. The species grows best in rich and heavy soils of the humid regions from the lowlands to 1500 m altitude. It is commercially important in eastern parts of India and widely introduced elsewhere in tropical and subtropical botanic gardens due to its multifarious benefits especially in the rural livelihood. The historical success of the bamboo-based traditional agroforestry system appears to be largely due to the nutrient pumping action of bamboos through slow decomposition of its silica rich litter and greater fine root biomass (Christanty *et al.*, 1997). Hence analysis of litter chemistry, organic matter decay and nutrient release is important for the better understanding of the nutrient cycling, even in bamboo agroforestry systems (Deb *et al.*, 2005).

Nutrient cycling is a key process in any ecosystems, which provides substantial benefit to the environmental quality by cyclic transfer of various nutrients within different components of ecosystem and includes processes such as weathering of minerals, activities of soil biota, and other transformations occurring at different levels on diversified sphere of the earth (Jordan, 1985). Leaf litter is also considered to be an important temporary sink for various nutrients (White *et al.*, 1988) and later acts as an input-output system for nutrients (Das and Ramakrishnan, 1985), and finally functions as a 'slow-release' nutrient source in forest ecosystems (Jamaludheen and Kumar, 1999). Litter decomposition and nutrient mineralization presents an important source of nutrients for primary production in terrestrial ecosystems (Wenyao *et al.,* 2000). It is concluded that, bamboo plantations make an efficient use of nutrients through internal cycling and conserve nutrients by accumulation in phytomass and immobilization in the decomposing leaf mass (Das and Chaturvedi, 2006). Yet, there are hardly few studies to substantiate the unsighted myth on bamboo ecosystem that, it acts as sink for nutrients due to its fast growing nature than source by playing a major role in nutrient dynamics (Christanty *et al.,* 1997). Although there have been several studies on litter dynamics in tropical trees and forest ecosystems in India, however information on litter decomposition and mineralization in bamboo plantations are limited for better management of plantations and to predict the effect of such land use systems on soil environment. The fundamental hypothesis of this paper is that, do the bamboo species play a significant role in nutrient cycling process in an agroforestry system? The principal focus of the paper is to validate the present hypothesis by estimating the quantity of litter fall, decomposition and the chemistry of both. Thus the objective of the present study was to determine the rates of litter production, decomposition rate and nutrient mineralization pattern in *Dendrocalamus asper* in agroforestry system.

MATERIALS AND METHODS

Study area and general features of the experimental site

The study was conducted in a bamboo-based agroforestry system established during September 2005 in Thithimathi, Kodagu district, Karnataka, India. The average area of the experimental site was 1600 m^2. The experimental design was laid out in 5x5 m spacing with four replication considering 16 plants for each replicate block of total 64 plants, having bamboo (*Dendrocalamus asper*) as main crop and medicinally important species called sappanwood (*Caesalpinia sappan*) as an intercrop. The planting design followed was quincunx method with four bamboo plants at the corner of the square and a sappanwood at the centre. The locations selected for the present investigation fall within a latitude of 12°13′ 44. 67" N and the longitude of 76°00′ 51.21" E. The altitude of the site was 851 m a.m.s.l with a mean annual rainfall was 1396.46 mm. The study site falls under tropical humid climate with April-May being hottest and December-January the coldest periods, with maximum rainfall during June-August. The year is divisible into three distinct seasons such as summer (March-June), rainy (July-October) and winter (November-February). Weather data of the study site for the study period are presented in Figure 1.The experimental area was vacant or abandoned paddy field situated inside the coffee plantation (TATA Balamani coffee estate). The paddy soil was clayey black colour with neutral pH (7.41) and low SOC (0.44 %). The content of major nutrients was 94.76, 6.23 and 279.47 kg ha^{-1} of N, P and K respectively.

Litter collection and decomposition

Freshly fallen and senescent leaves were collected during the peak period of litterfall (January to March, 2009) by installing circular traps around the bamboo clump randomly (Jamaludheen and Kumar, 1999; Shanmughavel *et al.*, 2000). These traps were designed such that litter would be retained in the containers, once it is trapped and the litter within or outside the trap would not get intermixed either by the wind or small animals or undergo loss from decay due to collection of water within them. The collected litter was air dried for five days under laboratory condition. The mass litter was separated into two components such as leaf and twig litter. The standard litter bag technique was employed for characterising litter decomposition dynamics (Jamaludheen and Kumar, 1999; Shanmughavel *et al.*, 2000). Twenty grams of leaf litter, twig litter and filter paper (control) samples were put into nylon mesh bags (dimensions: 20x20 cm: 2 mm mesh size). Sixty such bags were prepared for the period of fifteen months for each litter component considering four bags (replication) at monthly interval. The total of 180 bags were kept for each species in each location (Total 180 = 4 replication × 3 litter type including control × 15 months). The bags were then placed in the litter layer of the experimental plantations during June 2009 in litter wise strips, to facilitate easy retrieval. At monthly intervals, four bags from each litter component including control were carefully retrieved from the soil (12 bags) and returned to the laboratory. The bags were gently rinsed with water to remove the soil and other extraneous materials. The residual litter mass removed from the bags were oven dry at 80°C and weighed after excluding the fine roots and macro arthropods penetrating the mesh.

Chemistry of litter

The oven dried litter (leaf and twig litter) samples retrieved at different intervals of months were ground in a Willey-mill and passed through a 0.5 mm sieve before chemical analysis. The samples were analysed for total nitrogen (N) by CHN analyzer (LECO - Model number: 630-100-300). Total phosphorus (P) and potassium (K) were estimated after digesting the samples with acids by following diacid digestion method (Perchloric acid and Nitric acid) (Allen, 1989). Phosphorus was determined by Vanado-molybdo phosphoric yellow colour method and potassium was by Flame photometry method (Allen, 1989).

Statistical analyses and calculations

The residual litter mass remaining in the litter bags and their corresponding nutrient concentrations were also analysed. The residual moss loss over time was computed using the negative exponential decay model (Olson, 1963) represented by the equation $X/X_o = e^{(-kt)}$. Where, 'X_o' is the initial dry weight in gram, 'X' is the dry weight remaining at the end of the sampling interval (gram), '*e*' is the base of natural logarithm, 'k' is the decay rate coefficient and 't'is the time interval in months.The time required to achieve 50 % (t_{50}) and 99 % (t_{99}) decay was calculated as $t_{50} = 0.693/k$ and $t_{99} = 5/k$ (Bockheim *et al.,* 1991). The total stock of nutrients in litter was calculated by multiplying the concentration (%) with that of dry matter. However, the per cent nutrient remaining in the litter bag was investigated by the formula; Nutrient remaining (%) = $(C/C_o) \times (X/X_o) \times 100$ (Jamaludheen and Kumar, 1999). Where, 'C' is the concentration of element in the leaf litter at the time of sampling, 'C_o' is the concentration of the initial litter kept for decomposition, 'X' is the mass of dry matter at time of sampling and 'X_o' is the initial dry matter of the litter sample kept for decomposition.

RESULTS AND DISCUSSION

Litter decomposition and its nutrient dynamics

The total litter fall at fourth year after the plantation was 31.90 Mg ha^{-1}. Important finding of the present study was the seasonal variation in litter production, which showed distinct peak during winter season for leaf litter and during the mid of rainy season for twig litter production. In the bamboo plantation, leaf litterfall was markedly seasonal. Peak production of litterfall was concentrated during the cool-dry period (November-February). This could be possibly related to a combination of decreased temperature and lowered soil moisture during that time which induces natural senescence (Tripathi and Singh, 1995; Sundarapandian and Swamy, 1999; Jamaludheen and Kumar, 1999).The mean contribution of major nutrients from the litterfall was 1.83 % of nitrogen, 4.36 % of phosphorous and 1.59 % of potassium.These results are in general agreement with those observed in *Eucalyptus species* (George and Varghese, 1990). The residual litter mass declined exponentially with time for both the litter component and filter paper also (Fig. 2), which may be due to favourable high rainfall and temperature in the humid tropics (Shanmughavel *et al.*, 2000). The mass remaining at the end of the study period was more in twig (12.63 %) followed by leaf litter (4.53 %) and least in control (2.03 %). The decay rate constant (-*k* month^{-1}) was 0.4822 for control (R^2= 0.9433), 0.381 for leaf litter (R^2=0.9789) and 0.2654 for twig litter (R^2=0.944) (Table 1). The litter had an initial rapid phase of decomposition followed by a slower phase, which may reflect the decay of easily decomposable tissues and readily meneralizable elements (Kumar and Deepu, 1992; Sundarapandian and Swamy, 1999; Tripathi and Singh, 1995) and relatively slower decay rates in later stages may be attributable to the accumulation of more resistant or stable constituents in the residual litter mass (Sundarapandian and Swamy, 1999). The nutrient turnover rates are partly depends on chemical composition of the litter. Decomposition of litter includes the three stages like leaching, accumulation and release (Kumar and Deepu, 1992). The nutrient concentration was highly variable and the residual composition remaining after one year of decomposition was highest for N (20.93 %) followed by P (18.81 %) and least was for K (0.50 %) respectively (Fig. 3). The rate of release pattern for N and P was characterised by initial rapid and subsequent slow release phase. However, the rate of K release was exhibited negative exponential pattern (Jamaludheen and Kumar, 1999). The order of mineralization of remaining residual nutrient

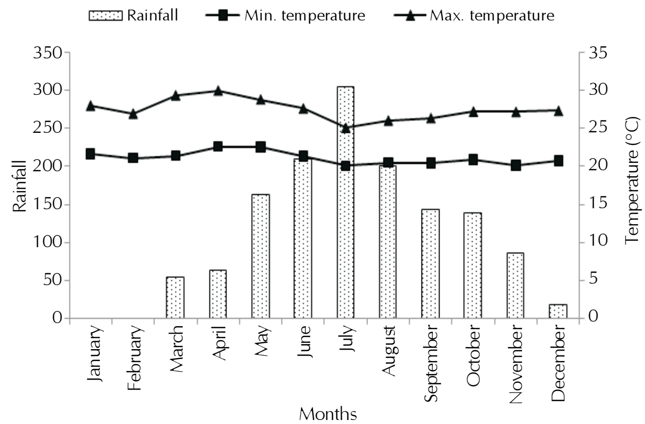

Figure 1: Temperature and precipitation data of the study period

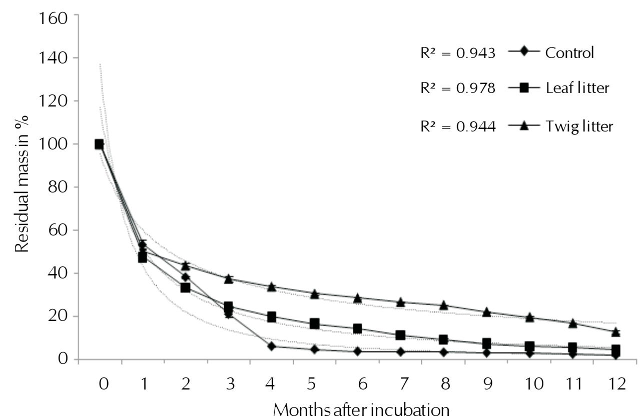

Figure 2: Mass remaining after the decomposition of litter in *D. asper*. Solid line denotes cumulative weight loss, while broken line denotes predicted weight loss based on exponential model

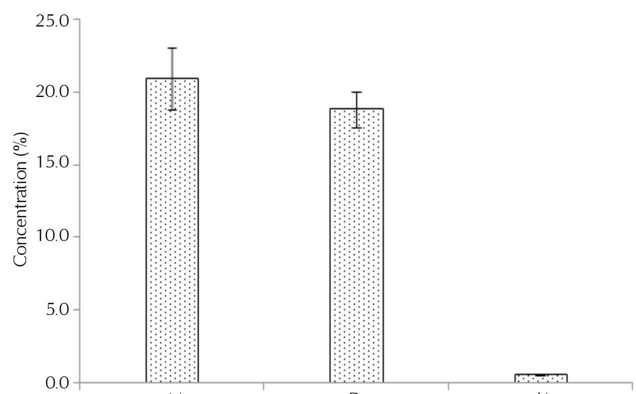

Figure 3: Residual nutrient concentrations remaining after one year of decomposition

Table 1: Mass of remaining litter (percent of the initial mass), the instantaneous decay constant (k) for mass, the time required for 50% (t_{50}) and 99% (t_{99}) mass loss and R^2 value at the end of the decomposition study

Decay Parameter	Kodagu Filter paper (Control)	Leaf litter	Twig litter
Mass remaining % at the end	2.03	4.53	12.63
Decomposition rate constant (-*k* month^{-1})	0.4822	0.3810	0.2654
t_{50} (months)	1.44	1.82	2.61
t_{99} (months)	10.37	13.12	18.84
R^2 value	0.9433	0.9789	0.9440

concentration was K>P>N. In contrast to N and P, K is not bound as a structural component in plants and is highly water soluble (LickensGosz and Bormann, 1973; Bahuguna *et al.*, 1990). Litter decay favours the process of nutrient mineralization, which intern helps in enriching the soil fertility.

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