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Decomposition of Different Litter Fractions in Agroforestry System of Central India

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ABSTRACT

Albiziaprocera is the native and most common agri silvicultural /agrosilvopastutal tree species of Semi-arid regions of Central India. This study focused on litter decomposition and subsequent nutrient release (N, P, K) from litter fall under six-year old A. procera in agroforestry system. The average weight loss from different fractions of litter of A. procera, pod litter shows maximum decay followed by leaves and petiole Pod litter got the maximum decay rate coefficient indicate faster rate of its decomposition. For 95 percent decay leaf, petiole and pod litter decomposed faster under A. procera + crop. Decomposition of A. procera litter is positively correlated with N, P and hemicellulose concentration of litter and negatively correlated with lignin, C/N ratio, and lignin/N ratio. Nutrient release from litter of A. procera followed the trend: K > N > P and was found higher from pod followed by leaves and petiole. The added nutrients may contribute to the sustainability of soil fertility, which is becoming an important phenomenon for agroforestry practices.

Introduction

Agroforestry is an ideal scientific approach for eco-restoration of degraded lands and sustainable resource management (Tripathi *et al.*, 2009), in which litter fall is one of the main natural physiological phenomenon in trees having enormous implications in nutrient recycling, soil biodiversity, soil reclamation, allelopathy and yield of understory crops in agroforestry. It is a fundamental process in nutrient cycling and it is the main means of transfer of organic matter and mineral elements from the vegetation to the soil surface (Regina *et al.*, 1999). Litter accumulation on the topsoil depends on several factors i.e. plant species, climate, land use types, decomposers population and their activities (Fernandes *et al.*, 1997) and their decomposition process is influenced by a number of factors such as microclimate, mainly temperature and humidity, litter quality, soil nutrient content and the qualitative and quantitative compositions of decomposer communities (Anderson and Swift 1983, Dawoe *et al.*, 2010). The choice of the tree species for agroforestry is influenced by knowledge of the species performance and their economic and environmental benefits. It is understood that quality or the initial chemical characteristics of litter played great role in the process of decomposition (Swift *et al.*, 1979). Nevertheless, the decomposition of litter in agroforestry system differs from that of in the natural forest and in the agricultural system, because of differences in the types and quality of organic inputs (Mafongoya *et al.,* 1998). A balance between litter deposition and decomposition regulates the accumulation of organic matter within an ecosystem (Singh *et al.,* 2004). Over all, the product of litterfall decomposition is facilitating the formation of soil organic matter and return nutrient into soil (Odiwe and Muoghalu, 2003; Xuluc-Tolosa *et al.,* 2003). Magnitude of soil enrichment depends upon the amount of litter fall and quality of the litter added. Both higher amount and quality of litter added in the system adds more nutrients and vice versa (Yadav *et al.,* 2008). This paper discusses litter dynamics to with reference to decomposition and nutrient cycling patterns in agroforestry systems in Bundelkhand, central India.

Materials and Methods

Study site and plant material

The study was conducted in six year old *A. procera* based agroforestry system at research farm of National Research Centre for Agroforestry, Jhansi, Uttar Pradesh, India. The experimental field is situated at 25^0 27’ North latitude and 78^0 35’ East longitudes, 271 m asl in the semi-arid region of the Central Indian Plateau. Average annual rainfall of the region is 806 mm, about 80% of which occurs between June to September with intermittent dry spells. The mean monthly temperature is generally high, with high degree of variation between a maximum 39.8°C in May and June and minimum temperature of 5.8°C in December and January. In summer, temperature occasionally reached up to 48°C. The mean monthly evaporation in the region is highest in April-June (9.40-15.2mm) and it ranges from 1.90-6.00 mm during other months of the year. During 2006, total rainfall received was 375.20 mm spread over 30 rainy days. During 2007 total rainfall received was 554.8 mm spread over 40 rainy days. The soil in the experimental field is Parwa representing inter-mixed black and red soil group of Bundelkhand region (U.P.), India, falling under the soil order *Alfisol*. It is medium in texture, moisture retentive and workability, prone to crust whenever drought spell exceeds 2-3 weeks even under mild evaporation situation.

The experiment field was established as agri silviculture (crop + tree) system with *Albizia procera* as the tree fractions. *A. procera* was planted in at spacing of 8m x 4m in plot size of 576 m^{-2} (18 trees plot-1) with three replications. In the established experiment, following pruning regimes were maintained for the studies on decomposition of litter fall: Under *A. procera* blackgram – mustard crop sequence were taken as intercrop. In Kharif season (Black gram) the trails were fertilized with 20kg /ha N, 40 Kg/ha P and in rabi season (mustered) 60 Kg/ha N, 40 Kg/ha P and 40 Kg/ha K were applied. Inter crop black gram is rainfed in both pruning regime, therefore mustard is irrigated twice a year (1st at flowering and 2nd at siliquae formation).

Litter bag incubation, decomposition and nutrient analysis

Freshly fallen/ sense cent litter (leaves, petiole and pods) of *Albizia procera* were collected from field during March/ April 2006 and oven dried at 72°C till constant weight. The standard litterbag technique (Anderson & Ingram, 1989) was employed for characterizing litter decomposition dynamics. Samples of 5.0 g of each fractions of the tree were transferred to nylon mesh bags (20x20 cm, 2 mm mesh size). The bags [432(2x3x3x24)] were randomly kept on the soil surface below respective pruning wise tree canopies on 1st June 2006 in experimental field. Each month, 3 litter bags for each litter fractions of *A. procera* were collected from the floor of the different land sues. The litter samples thus drawn were washed under a fine jet of water using a fine mesh screen to remove all the adhered soil particles, dried at 72°C to constant weight, weighed and ground in a Wiley Mill to pass through a 1mm mesh screen. Samples were analyzed for N, P and K analysis. Soil samples were also drawn beneath litterbags quarterly to evaluate extent of enrichment in soil fertility subsequent to decomposition of the litter.

Data analysis

To evaluate nutrient release pattern, nutrient remaining in the decomposing litter were estimated by equation (Bockhelm *et al.*, 1991)

% Nutrient remaining = $(C/C_0) \times (DM/DM_0) \times 10^2$

Where,

C = Concentration of nutrient element in decomposition litter at the time of sampling

C_0 = Concentration of nutrient element at the beginning of the study

DM = Mass of dry matter at the time of sampling

DM_0 = Initial dry matter of the biomass kept for decomposition

The decay rate coefficient (k) of the decomposing litter of different fractions for the entire study period was calculated through the negative exponential decay model of Olson (1963) as represented by the equation:

$X / X_0 = e^{-kt}$

Further, following Olson (1963), the time required for 50 (half-life) % weight losses was estimated from k values using the equation:

$t_{50} = \ln (0.5) / -k = -0.693 / -k$

Similarly, time taken for 95% decay can be estimated as follows

$t_{0.95} = 2.9957/k$

The effect of land use of *Albizia procera* on decomposition, nutrient dynamics and cumulative impact on soil properties was tested by means of ANOVA using the General Linear Model of SYSTAT Ver.9 (SYSTAT Inc. 1998).

Results and Discussion

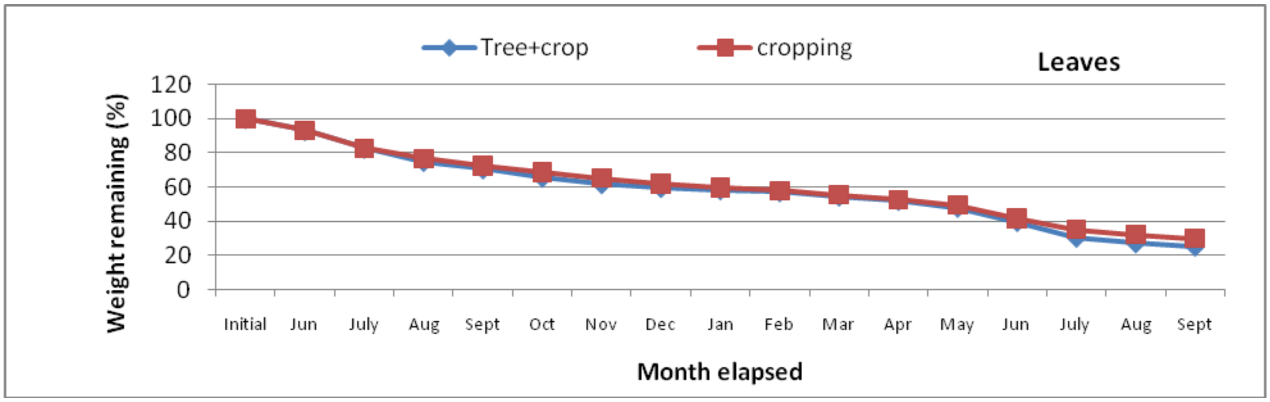
Decomposition and decomposition coefficient (k)

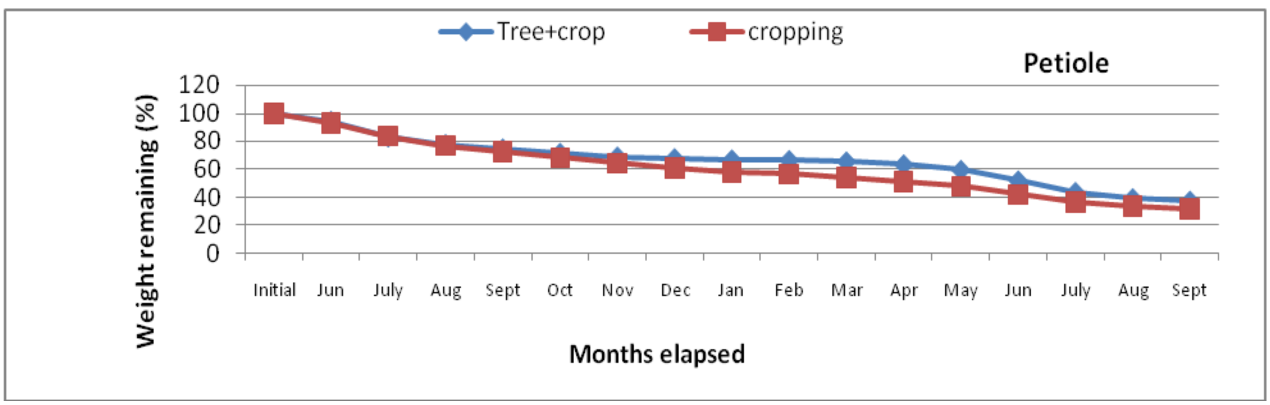
Decomposition of *A. procera* litter is positively correlated with N, P and hemicellulose concentration of litter and negatively correlated with lignin, C/N ratio, and lignin/N ratio (Table 1). The average weight loss from different fractions of litter (Fig. 1) of *A. procera* was higher in first four months due to the peak season of rainfall (from June to September). Pod litter got the maximum decay rate coefficient indicate faster rate of its decomposition (Table 2). For 95 percent decay leaf litter and fruit litter decomposed faster under *A. procera* + crop, while petiole litter was decomposed faster under cropping.

Nutrient release

The nutrient release pattern of N, P and K are represented for each litter fractions in figure 2. N release data evident that *A. procera* pod litter released N at faster rate followed by leaf and petiole. Across fractions of decomposing litter, *A. procera* litter under *A. procera* + crop released maximum N. P release was found more than 95 % in decomposing leaf litter under both land use. K release data evident that mineralization of K was maximum from *A. procera* pod litter followed by leaf and petiole. Across fractions of decomposing litter, under *A. procera* + crop released maximum K, except for petiole litter under which cropping released maximum K. Nutrient release from litter of *A. procera* followed the trend: K > N > P and was found higher from pod followed by leaves and petiole.

Fig.1 Per cent weight loss of different litter fractions of *A. procera* under different land use





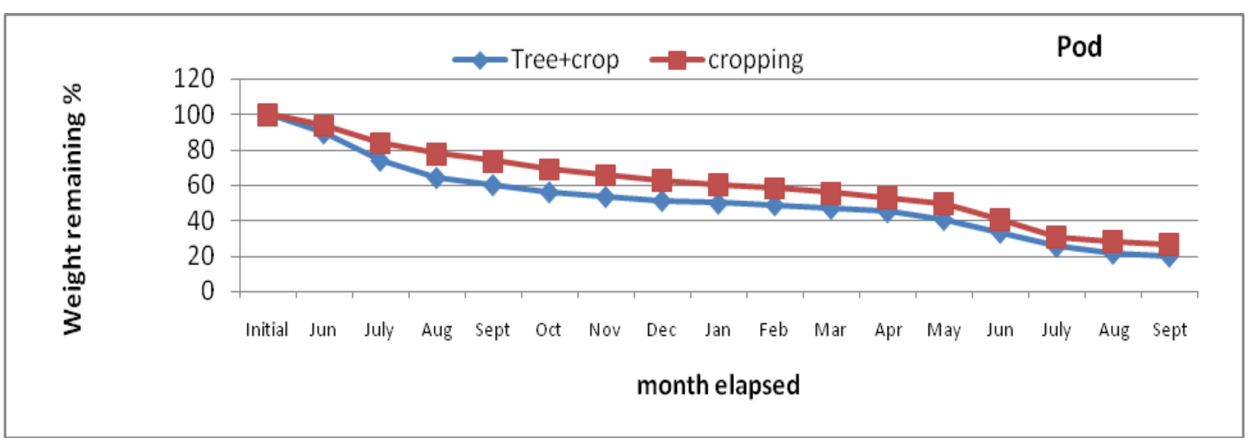
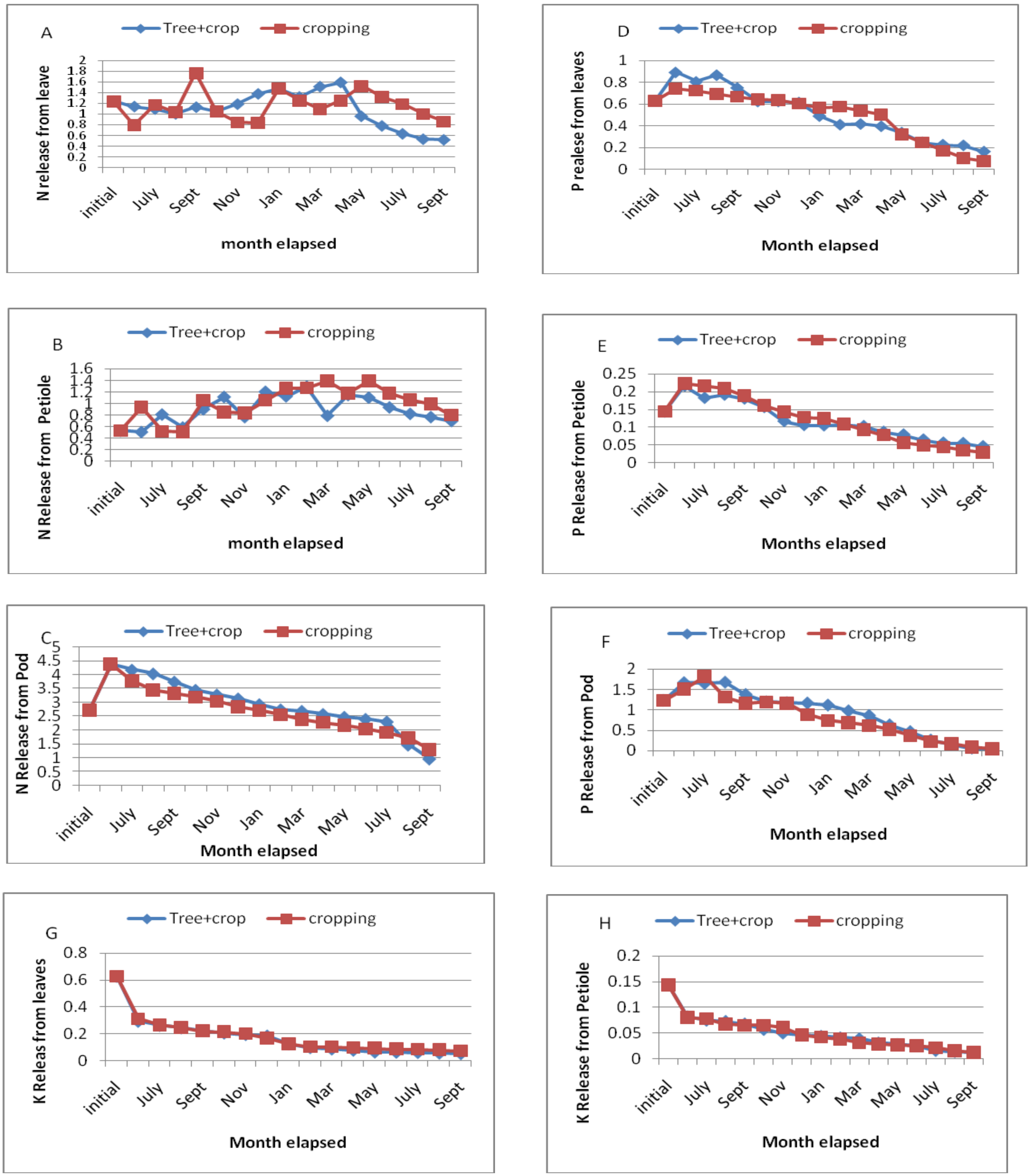


Fig.2 Nutrient release from decomposing litter fractions of *A. procera* under different land use



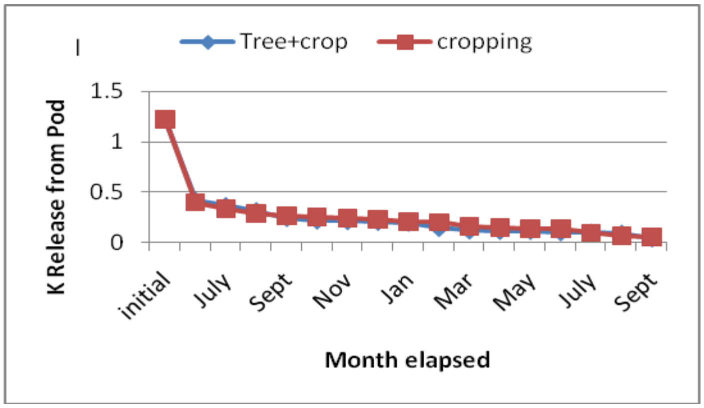


Table.1 Pearson correlation coefficient between *A. procera* litter substrate quality and decomposition constant averaged across the different land use

Quality parameters	Leaves k	Petiole k	Pods k
C	0.029	-0.154	0.141
N	0.483**	0.404*	0.383*
P	0.041	0.425*	0.371*
Lignin	-0.192	-0.334	-0.399
C/N	-0.052	-0.369*	-0.367
Lignin/N	-0.494**	-0.327	-0.154
ADF	-0.346	-0.113	-0.386*
Cellulose	-0.398*	0.0120	-0.151
Hemi cellulose	0.484**	0.125	0.292
L/LC	0.127	-0.246	-0.241
C/P	-0.031	-0.430*	-0.325

* Significant at P < 0.05, ** P < 0.01

Table.2 Decomposition parameters of different fractions of litter biomass of *A. procera*

Decay parameters	Land uses	
	***A. procera* + crop**	**Cropping**
	Leaves	
Decay constant	0.0028	0.0026
t_{50} (days)	247	273
t_{95} (days)	1068	1180
t_{99} (days)	1780	1967
	Petiole	
Decay constant	0.0020	0.0024
t_{50} (days)	344	292
t_{95} (days)	1490	1265
t_{99} (days)	2483	2108
	Pod	
Decay constant	0.0034	0.0028
t_{50} (days)	206	251
t_{95} (days)	893	1085
t_{99} (days)	1489	1809

Initial substrate quality

Substrate (litter/biomass) quality, quantity and quality of decomposer organisms are the primary determinants of any biomass decay rates (Swift *et al.,* 1979). In this study, the differences in rates of decomposition of different fractions of litter and biomass of *A. procera* under different land uses and pruning regimes could be related to differences in substrate (litter) quality and variations in microenvironment beneath *A. procera* in cropping. The higher concentration of N and lower C/N ratio in the biomass of *A. procera* was probably responsible for its faster decomposition and lower concentration of N in the petiole of *A. procera* brought slower rate of decomposition. A positive effect of N concentration on decomposition was also reported by several workers (Melillo *et al.*, 1982; Pandey and Singh, 1982; Sandhu *et al.*, 1990; Shukla *et al.*, 1990, Das and Chaturvedi, 2003 and Yadav *et al.*, 2008).

Litter decomposition

During biomass and litter decomposition, nutrients may endure three sequential stages (i) initial release stage in which leaching predominate (ii) the net immobilization stage in which nutrients are imported in the residual litter mass, and (iii) the net release stage in which an absolute decrease in the nutrient concentration occurs in the residual litter mass (Staff and Berg, 1982). In the present study, increase in N and P concentration of decomposing different fractions of litter of *A. procera* under different land uses and pruning regimes could be ascribed to microbial immobilization (Joergensen and Meyer, 1990 and Das and Chaturvedi, 2003) and the second phase of decrease to the mineralization of the nutrients from the decomposing litter. Tripathi *et al.,* (2009) reported that litter decomposition was fast during rainy season and slow during winter season.

Total nutrient release from decaying litter

Nutrient release from litter fractions of followed the trend: K>N>P and found higher in pod followed by leaves and petiole. Comparatively higher initial concentration of N, P, K in the pod litter *A. procera* followed by leaves litter indicated that capabilities of the pod and leaf litter to re-translocated these nutrients were lower during the senescence litter (Hossain *et al.*, 2011, Berg and laskowski 2006). The faster decreasing K concentration from all fractions of litter was observed as it is a non-structural element and highly mobile to be the most leachable action during the decomposition of litter (Marschner 1995, Guo and Sims 2002 and Tisdale *et al.*, 1993). N structurally bound with cell wall and leaf contained comparatively lower concentration of P (Hossain *et al.*, 2011, Defelice 1993 and Mayer *et al.*, 1973). During decomposition, increase concentration of nutrients (N, P, K) at different stages of decomposition was attributed to microbial or non-microbial immobilization in the residual litter while litter act as a surface for fungi or heterotrophic organism. (Hossain *et al.*, 2011, Lin *et al.*, 2007 and Mahmood *et al.*, 2014)

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