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Dynamics and elemental composition of litter fall in leguminous tree species of Sub tropical region: A nutrient cycling perspective

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Abstract

Litter fall dynamics have significant importance in nutrient cycling especially the carbon inputs to the soils under the recent climate change scenario. The present study was carried out in sub-tropical region of Pakistan and plant community of tree leguminous species *viz. Dalbergia sissoo* (Shisham); *Albizia lebbeck* (Siris) and *Eucalyptus camaldulensis* (Safaida) were investigated for total litter fall and its elemental composition to be subsequent entry as nutrients into the soil. Litter fall trappers of dimension ($1m^2$) were used for litter fall collection from each tree species. Later nutritional analysis of litter fall was investigated through standard laboratory techniques. The study revealed 4.78, 3.89, 6.37 t $ha^{-1}yr^{-1}$ of litter fall in the shisham, siris and safaida trees respectively. The ANOVA pointed out significant variation ($P<0.001$) in monthly litter fall of each species. Elemental composition analysis revealed that total concentration of C was 42.12; 43.75 and 36 gm kg^{-1} in shisham, siris and safaida respectively. The amount of N was 15.43; 11.11 and 18.25 gm kg^{-1}, while the P composition was 5.6, 8.5 and 2.6 gm kg^{-1} in shisham, siris and safaida respectively· The concentration of K was low as compared to C, N and P in all other species. The results of study are helpful in estimating the amount nutrients entering into the soil and simultaneously have significant role in nutrient cycling in sub-tropical forest forests having composition of these species.

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Introduction

Litter fall characterizes as key biological pathway for element transfer from trees to forest soil. Litter fall production forms the most important part of flux within the forest system by utilization of inorganic matter to the soil (Miller *et al.,* 1979; Maguire, 1994). In an ecosystem most of the nutrients are formed from decomposition of the biomass and entered into the soil (Chapin *et al.,* 2002). Litter fall inputs and litter decomposition represent a large and dynamic portion of the nutrient cycling in forest ecosystem. In addition, the turnover of litter is a major pathway of the nutrient and carbon inputs to forest soils. Significant amounts of organic matter and nutrients in the soils can be transferred during litter decomposition processes (Kim *et al.*, 1997). In the recent past much attention has been paid on the role of the litter fall production as well as inputs of nutrients from the decomposition of the litter fall in soils with special reference to climate change and carbon budgets of different ecosystems (Berg and McClaugherty, 2010; Prescott and Grayston, 2013; Berg and McClaugherty, 2014).

D. sissoo is a tall size leguminous tree and can attain height up to 30 m and have a light canopy. This tree shed their leaves in autumn season. Compound Leaves are leathery, pinnate and alternate. Leaves shedding starts in November and till the end January almost tree canopy becomes open. Whereas, *A. lebbeck* is a medium size tree with fast growth. Canopy of this tree is of umbrella shaped with bark of grayish brown colour. *A. lebbeck* can tolerate drought and frost period. Moist and well drained soils are best for *A.lebbeck* growth. Most of the litterfall occurs in the winter season in the months of January and February. Leaves are mostly bipinnate having a length of 5-15 cm and width 2-3 cm. Each pinna has 6-8 leaflets. Flowers are mostly of white colour giving some fragment (Sheikh, 1993). *E. camaldulensis* can grows to 40-50 meters in height having a smooth white bark. Tree crown is large and dense. The Leaves of *E. camaldulensis* varies from 10-15 cm in length and have almost equal size. It can also be planted in deserts because it can tolerate severe conditions.

All these leguminous species are striving in the sub-tropical forests of Pakistan. Litter fall from dominant species of these forest ecosystems being an important component of nutrient cycling has not been explored previously. To cope with this knowledge gap the present study was designed to investigate the litter fall dynamics and elemental composition in *Eucalyptus camaldulensis*, *D. sissoo* and *A. lebbek using litter fall trapper techniques*. Moreover the information of litter fall and the elemental composition of litter fall will be helpful in determining the rate at which different nutrient at going into the soil after decomposition.

This information will also be helpful for efficient management of these forests. The specific objective of the study are: a) To determine the monthly dynamics of leaf litter fall in three dominant tree leguminous species *D. sissoo; E.camaldulensis* and *A.lebbeck* b) To determine the C,N. P and K nutrients composition in the leaf litter of each tree species.

Materials and methods

Study site

The study was conducted in sub-tropical forest of Jhatoky (Zafarwal) in district Narowal of Province Punjab. It is situated at 32° 21'0 N 74° 54'0 E with an elevation of 268 m. It is spreaded over an area of 205.176 ha. From production point of view the main species of this region are *D.sissoo; while E. camaldulensis* and *A.lebbeck* are the other associated species. Zafarwal Tehsil is agricultural area with forestry since the Indus Valley Civilization. The climate is warm in Zafarwal. Mean annual temperature of Zafarwal is 26° C and mean annual rainfall is about 820 mm.

Study design

Litter fall collection

Overall, 10 litter fall trappers were randomly installed under each species canopy. The litter fall traps were made up of nylon net (mesh size will be of 1 mm). These were placed one meter above ground, so that bottom of the trap could not touch the ground biomass. Litter was collected on monthly basis.

Below the trap all material was removed on regularly basis. At the end of every month litter was collected from July 2015 to June 2016. Every month trappers were checked for any damage and repaired subsequently. In damaged litter traps litter was rejected. After collection all the litter was separated into branches, leaves, twigs and legumes. The branches (<2 cm in thickness) falling or hitting litter traps were not included in the weight.

Elemental composition analysis

After collection and separation the collected samples were washed softly to remove dirt by distilled water. Each sample was then oven dried at 65°C for 48 hours till a constant weight achieved. The collected litter was crushed and crumbled to make powder in plant grinder. After grinding samples were stored in a polythene bag to avoid moisture interruption. About 10 grams of grinded samples were taken for elemental analysis.

Analysis of total Nitrogen (N)

As nitrogen is the main constituent of amino acids. Plants need it for their growth and development. Total nitrogen content in the plant dry matter varies from 1 – 5 %. The famous Kjeldahl Nitrogen (without catalyst) method was used in this study to determine nitrogen content in plant samples. Calculation for N was carried out using following formula (Ryan *et al.,* 1999):

$$\text{Nitrogen \%} = \frac{(V - B1) \times N \times V2 \times 14.01 \times 100}{Wt1 \times V3 \times 1000}$$

Analysis of total Phosphorus (P)

Phosphorus content in plants usually varies in the range 0.1 – 0.5 % of the dry matter. In plant sample, total phosphorus can be estimated by wet digestion or dry ashing. Both of these methods are reasonable.

Dry ash method is simpler easier and non-hazardous and economical as compared to other. However, Wet digestion method was used in this study to estimate total P content in plant samples. The following formula was used for calculation of total P (Ryan *et al.*, 1999)

$$\text{Phosphorus in ppm} = \text{P in ppm} \times \frac{V1}{Wt} \times \frac{100}{V2} \times \frac{1}{1000}$$

Analysis of total Potassium (K)

Total potassium in plant samples varies in a range from 0.5 – 5.0 %. Dry ashing is the procedure used in this study to fine out the K concentrations in plant samples. Ashing is not suitable because it leads to loss of volatile K. Calculations were made by using following formula (Ryan *et al.,* 1999):

$$\text{Potassium in ppm} = \text{K in ppm} \times \frac{V1}{Wt}$$

Analysis of total Carbon (C)

To find out the carbon content in each sample, ash percentage was estimated. For this purpose five grams of digested samples were taken into pre-weighted china dish. These dishes were then placed in muffle furnace at a temperature of 500 °C for 2-4 hours. This procedure converted these samples to ash which is mineral content of the sample. China dish residues were weighed and percentages of ash contents were estimated by percentage formula. The carbon content of each sample was calculated by given formula (Ryan *et al.*, 1999).

$$\text{Carbon \%} = \frac{100 - \text{Ash \%}}{1.8}$$

Statistical analysis

After collection of data on monthly litter fall, regression analysis was carried out to determine the trend of litter fall in each species . Moreover a regression model was built to determine the total amount of litter fall (t ha^{-1} yr^{-1}) under each species canopy. Coefficient of determination (R^2) was also calculated. All the statistical analysis was carried out on SPSS ver. 20 and figures were made on sigma plot ver. 12.5.

Results

Monthly litter fall

Amount of litterfall of *D.sissoo, A. lebbeck* and *Eucalyptus camaldulensis* varied every month (Fig.1, 2and 3). The study revealed 4.78, 3.89, 6.37 t ha^{-1} yr^{-1} of litter fall in the shisham, siris and safaida trees respectively.

The litter collected from *D. sissoo* and *A.lebbeck* from July to January showed a continuous increasing trend. While trend for *E. camaldulensis* was almost steady as compared to other species. For shisham, maximum litter fall (0.99 t ha^{-1}) occurs in the month of January followed by in December (0.64 t ha^{-1}). About 0.44 t ha^{-1} and 0.35 t ha^{-1} of litter fall was assessed in November and October respectively. About 2.42 t ha^{-1} litter fall was occurred in the months of October to January which is about 50.606 % of the total litter fall. Maximum litter fall for shisham was occurred in the month of January (0.99 t ha^{-1}) which is 20.702 % of the total annual litter fall. Lowest litter fall was occurred on the month of June (0.10 t ha^{-1}) and July (0.110 t ha^{-1}) respectively which is about 4.39 % of the total litter fall followed by May (0.115 t ha^{-1}) respectively as shown in Fig 1.

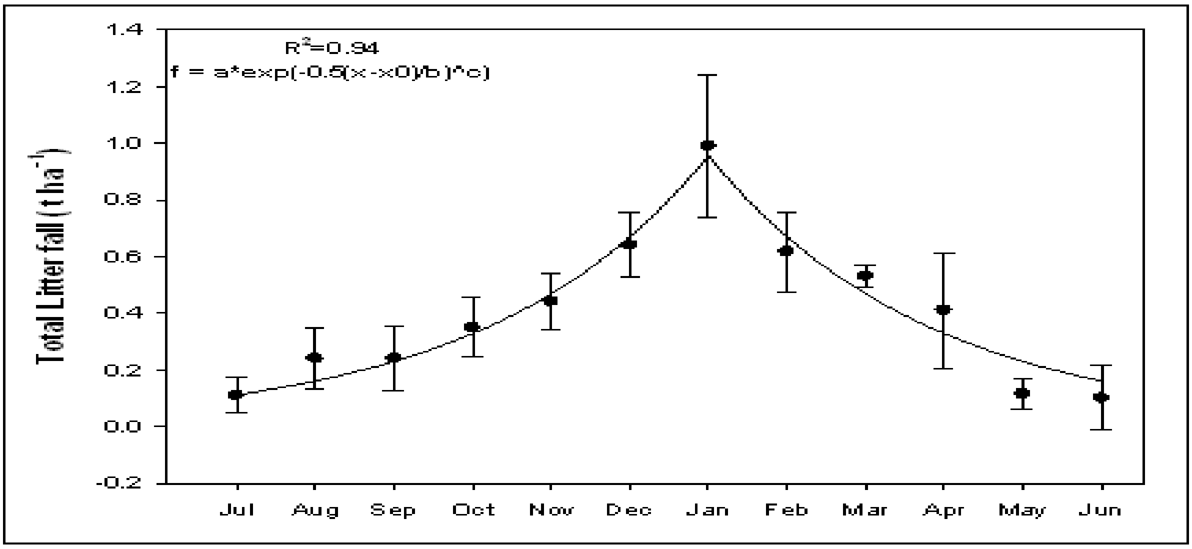

Fig. 1. Monthly litter fall (t ha^{-1}) from *Dalbergia sissoo* canopy.

Regression equation shows a sigmoidal relationship for shisham litter fall (R^2= 0.94). For sirs, maximum litter fall (0.67 t ha^{-1}) occurs in the month of January which is about 17.22 % of the total annual litter fall. Lowest litter fall was occurred on the month of June (0.10 t ha^{-1}) and July (0.12 t ha^{-1}) respectively which is about 5.65 % of the total litter fall followed by May (0.13 t ha^{-1}) respectively as shown in Fig 2.

Regression equation shows a sigmoidal relationship for shisham litter fall (R^2= 0.92). For safaida, maximum litter fall (0.79 t ha^{-1}) occurs in the month of January which is about 12.42 % of the total annual litter fall. Lowest litter fall was occurred on the month of July (0.41 t ha^{-1}) and August (0.41 t ha^{-1}) respectively followed by May (0.42 t ha^{-1}) respectively as shown in Fig 3. Regression equation shows a sigmoidal relationship for shisham litter fall (R^2= 0.95). The study revealed that a significant relationship ($p<0.005$) was found in litter production.

Elemental composition

Composition of N, P, K and C in litter fall

Study assumed that in *D. sissoo,* the amount of C, N, P and K concentrations were varied up to 42.125 gm kg^{-1}, 15.43 gm kg^{-1}, 5.6 gm kg^{-1} and 0.1495 gm kg^{-1} respectively (Fig. 4).

The amount of C, N, P and K concentrations were varied up to 43.75 gm kg^{-1}, 11.1055 gm kg^{-1}, 8.49 gm kg^{-1} and 0.17 gm kg^{-1} respectively in *A.lebbeck*. While in *E. camaldulensis* litter, the amount of C, N, P and K concentrations were varied up to 36 gm kg^{-1}, 18.25 gm kg^{-1}, 2.6 gm kg^{-1} and 0.176 gm kg^{-1} respectively. Amount of K concentration was very low as compared to the C, N and P. Annual P mineralization rate was positively correlated with litter mass loss. Nutrient release pattern follow a decreased trend in this way i.e C > N > P > K.

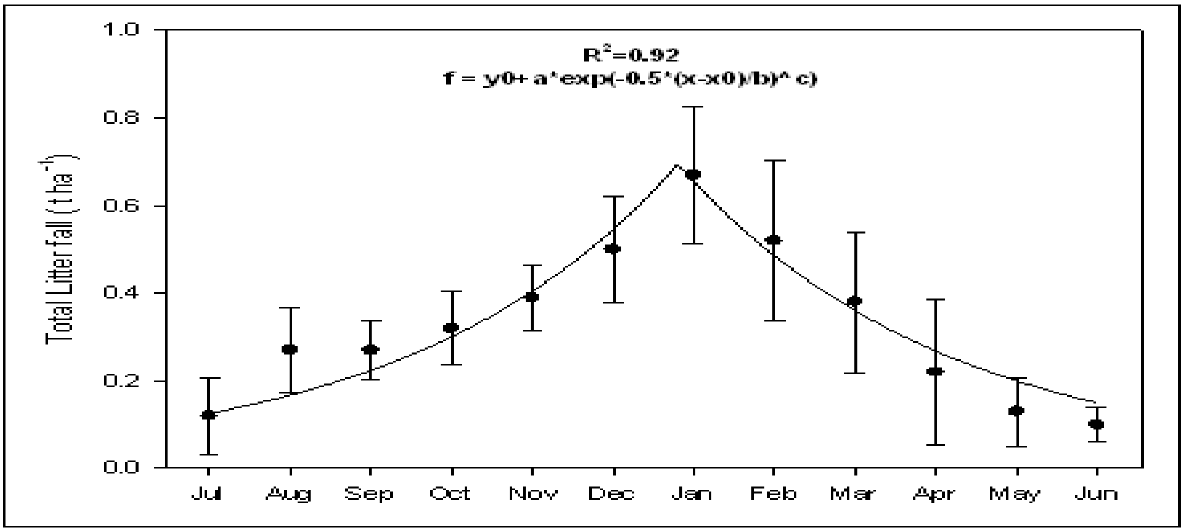

Fig. 2. Monthly litter fall (t ha-1) from *Albizia lebbeck* canopy.

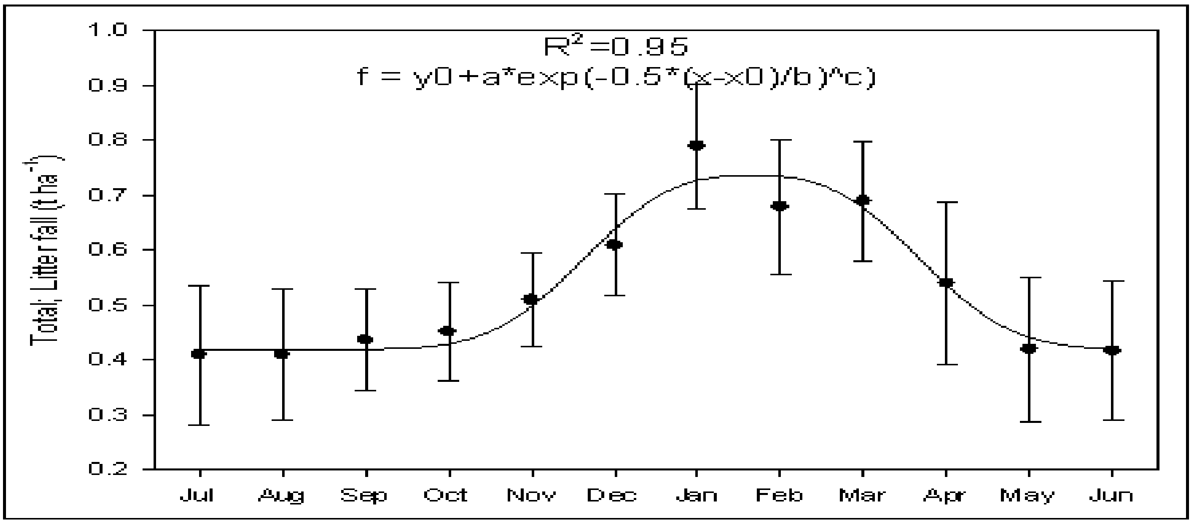

Fig. 3. Monthly litterfall (t ha^{-1}) from *Eucalyptus camaldulensis* canopy.

Discussion

About 65-70 % of the total litterfall production was assessed in this cool and dry season for *Dalbergia sissoo* due to cool and dry conditions because there was low availability of water and soil moisture due to which plant species shed their leaves. Drier

soil conditions also increase the rate of litterfall. Drier soil conditions also increase the rate of litterfall. As litter fall mass varies in different stands by time which describes a complex interaction between a-biotic and biotic factors (Lawrence, 2005; Polyakova and Billor, 2007; Scherer- Lorenzen *et al.*, 2007). A study by Singh *et al.*, 1999 revealed that amount litter fall in Shisham varies up to 3120 ± 340 kg ha^{-1} yr^{-1} i.e. 3.12 t ha^{-1} yr^{-1} which is consistent with our study.

The variation in litter fall may be due to many factors such as crown size, morphology of leaves and size (Mahmood and Hoque 2008). A study by Hasanuzzaman *et al.*, 2014 stated that *M. azadirachta* had maximum rate of litter fall (553 gm $week^{-1}$) as compared to *S. macrophylla* (525 gm $week^{-1}$) which showed significant differences i.e. $p < 0.05$.

The past research has identified that nutrients that are added in the soil may passes through decomposition process of the leaf litter (Mahmood and Hoque, 2008). It was revealed that amount of nitrogen concentration varies up to 36.5 kg ha^{-1} yr-1 while that amount of phosphorus concentration varies up to 1.4 kg ha^{-1} yr^{-1}.

Studies revealed that both results are very closely related to each other. While in another study, estimated carbon concentration was about 42.9 % through litter fall in *D. sissoo* (Singh *et al.,* 1999). A study by Hasanuzzaman *et al.*, 2014 stated that in *M. azadirachta* had maximum nitrogen concentration (13 mg g-1) followed by *E. camaldulensis* (8.70 mg g-1) while amount of phosphorus concentration was estimated in *A. indica* followed by *A. saman* (8.56 mg g^{-1}), amount of potassium was maximum in litterfall of *A. indica* (43.61 mg g^{-1}) and potassium in *E. camaldulensis* was found to be 37.23 mg g^{-1}. A study by Lin *et al.*, 2012 estimated that the average monthly concentration of N, P and K in *Acacia montana* litter fall were 13.63, 0.88 and 4.49 g kg^{-1} while those of *F. hodginsii* litter fall were 8.79, 0.54 and 3.26 g kg^{-1} respectively.

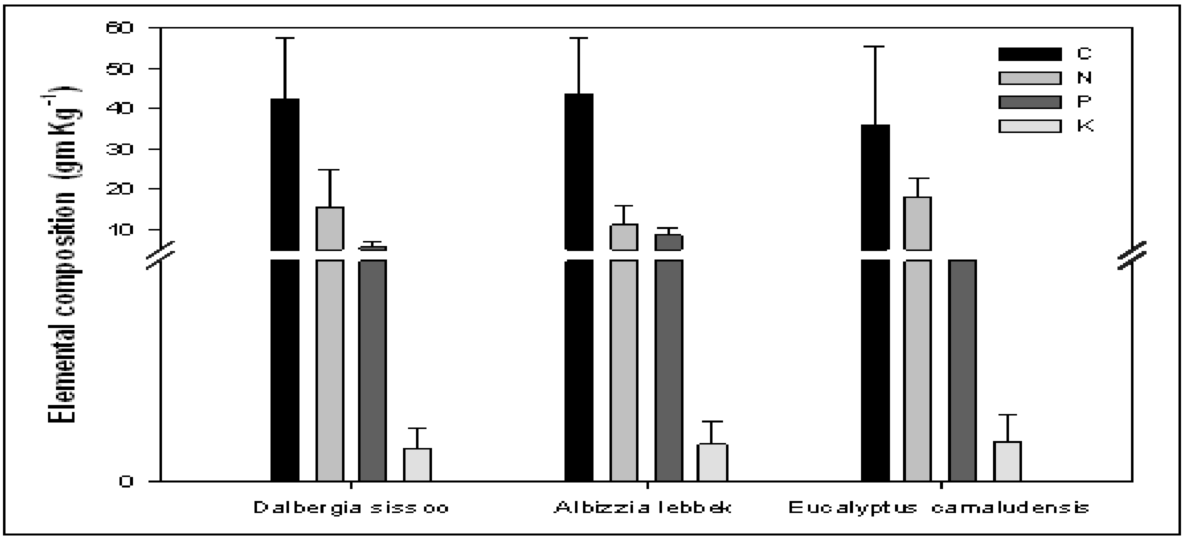

Fig. 4. Elemental composition (C, N, P & K; gm kg-1)) in litter fall of *Dalbergia sissoo, Albizia lebbeck and Eucalyptus camaldulensis*.

About 2.8 to 7 t ha^{-1} yr^{-1} litter production in Sal mixed forest was estimated in India and annual amount of N and P was 31 to 67 and 0.9 to 2.3 kg ha^{-1} yr^{-1} respectively (Sharma *et al.,* (1990 a,b). About 1 to 6.2 t ha^{-1} yr^{-1} litter production in deciduous forest (India) was estimated and annual amount of N and P was 18 to 54 and 0.2 to 28 kg ha^{-1} yr^{-1} respectively (Singh 1968).

Conclusion

In any forest ecosystem, litter plays a significant role in production and nutrient cycling. The total amount of leaf litter fall was 4.78, 3.89, 6.37 t ha^{-1} yr^{-1} in the shisham, siris and safaida trees respectively. Elemental composition analysis revealed that total concentration of C was 42.12; 43.75 and 36 gm kg^{-1} in shisham, siris and safaida respectively. The amount of N was 15.43; 11.11 and 18.25 gm kg^{-1}, while the P composition was 5.6, 8.5 and 2.6 gm kg^{-1} in shisham, siris and safaida respectively. Total concentration of K was 0.1495; 0.17 and 0.176 gm kg^{-1} in shisham, siris and safaida respectively. The basic information generated in this study are helpful for understanding the nutrient going into the soil when the litter fall decomposed in these forests ecosystem. This can be helpful in efficient management of these forests in future.

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