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LITTER PRODUCTION, DECOMPOSITION AND NUTRIENT RELEASE OF WOODY TREE SPECIES IN DHANAULTI REGION OF TEMPERATE FOREST IN GARHWAL HIMALAYA

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Abstract

The study has been carried out in Dhanaulity region of temperate forest of Garhwal Himalaya to understand litter production, their decomposition and concentration of nutrients release by leaf litter at different altitudes. The results indicate that the litter production with altitude in each season reduced in order of Lower>middle>upper altitudes, while in each altitudes the seasonal litter production reduced in order of summer>rainy>winter. The value of decomposition constant (k) was reduced as 0.511, 0.438 and 0.256 at lower, upper, middle altitude respectively. The concentration of nutrients seasonally (irrespective altitude), potassium reduced from summer (0.92%), rainy (0.90%) and winter (0.84%) however, phosphorus shown reverse trend with potassium as summer (0.104%), rainy (0.108%) and winter (0.203%) whereas nitrogen was highest in rainy (1.13%) followed by winter (1.11%) and summer (1.01%). The nutrient concentration with altitude (irrespective season), potassium increased with increasing altitudes, whereas, phosphorus and nitrogen have not shown any trend with altitude.

Keywords: Himalaya, Forest floor, Nutrient elements, NPK.

Özet

Bu çalışma Garhwal Himalaya'nın Dhanaulity bölgesindeki ılıman kuşak ormanlarındaki ölü örtü birikimi, ölü örtü ayrışması ve böylece ölü örtüden besin maddelerinin salımı miktarlarını belirlemek amacıyla yapılmıştır. Araştırma sonuçları, ölü örtü miktarları en yüksekten en düşüğe doğru alt>orta>üst yükseltilerde olduğu ve herbir yükselti basamağında yaz>yağmurlu mevsim>kış sıralamasına göre oluştuğu tespit edilmiştir. Ayrışma sabiti (k) alt, üst ve orta yükseltilerde sırasıyla 0.511, 0.438 ve 0.256 şeklinde değişmiştir. Yükseltiye bağlı olmaksızın potasyum yaz>yağmurlu mevsim>kış (sırasıyla %0.92, 0.90 ve 0.84), fosfor potasyumun tersine kış>yağmurlu mevsim>yaz (%0.203, 0.108, 0.104) şeklinde bir değişim göstermiş, azot ise mevsimlere göre yağmurlu mevsim>kış>yaz (%1.13, 1.11 ve 1.01) bir seyir izlemiştir. Mevsimlere bağlı kalmaksızın bakıldığında ise potasyum yükselti arttıkça artış göstermiş, fosfor ve azot ise yükseltiye bağlı belirgin bir değişim göstermemiştir.

Anahtar Kelimeler: Himalay, Ölü örtü, Besin elementleri, NPK.

INTRODUCTION

Litter production and nutrient cycle in terrestrial ecosystem plays an important role in turnover of nutrient and maintenance of soil fertility and productivity. The accumulation and decomposition of plant litter has been considered as complex and important factor in controlling both vegetation structure and ecosystem function (Grime, 1979). Organic matter in the mineral soil is composed of close physical and chemical relationship with the mineral function of the soil.

Litter fall on the forest floor occurs in the form of leaves, twigs, fruits, bark and small branches. The interactive and sequential process of litter fall, its decomposition and subsequent mineralization are essential in substaining a dynamic ecosystem. Litter of forest floor minimizes the soil erosion, runoff and increases the percolation rates as well as nutrient taken up by the tree which is held in the green foliage. A sub-sequential amount of nutrient taken up by the aboveground component of the tree is returned to the soil through litter fall. .

Litter decomposition plays a crucial role in the nutrient budget of forest ecosystems where vegetation depends mainly on the recycling of nutrients contained in the plant detritus. During this process plant nutrients become available for recycling within the ecosystem. Litter decomposition is influenced by environmental factors and also by physico-chemical properties of the parts such as stem wood, leaves, root, etc. of the species studied and decomposer organisms present in the soil. Woody debris in the form of standing dead trees, fallen boles, large branches and roots is abundant in many forest ecosystems, and plays an important ecological role in the recycling of nutrients within the forest. This woody debris also reduces soil erosion, acts as a reservoir for nutrient and water storage, seed bed for plant establishment, and a habitat for fungi, bacteria, arthropods and a variety of vertebrates.

Decomposition of leaf litter is a major source of nutrients in forest ecosystems. As leaves are broken down by insect and microbial decomposers, organically-bound nutrients are released as free ions to the soil solution which are then available for uptake by plants.

Decomposition of coniferous forest is very slow. Slow rate of decay can result in the accumulation of large nutrients stocks on the soil horizons (Melillo et al., 1982). Forest release of nutrient from a forest may help an assemblage of different types of communities in the ecosystem. The rate of litter decomposition is determined by nature or plant and microclimatic conditions. The decomposer substratum performs two major functions i.e., the mineralization of essential elements and formation of soil organic matter.

However, studies on litter dynamics of tree species and its contribution to nutrient status in the soil in Dhanaulti area of Tehri Garhwal, Uttarakhand, India, have not been conducted so far; therefore, present study was undertaken with the objective of understanding Seasonal pattern of litter production, decomposition and nutrient release of woody tree species in selected forest along altitudinal gradient.

MATERIALS AND METHODS

Location and climate of study area

The present study was carried out on litter production decomposition and nutrients concentration of litter release at three different altitudes of woody tree species forest near Dhanaulti in Garhwal Himalaya of Uttarakhand. Dhanaulti is located in the Garhwal Hills between 30' 45^{o} N and 78' 25^{o} E, at an altitude of 2286m. The forests have thick trees covers of *Cedrus deodara, Quercus leucotrichophora, Rhododendron arboreum Pinus roxburghii,* etc. The moist *Cedrus deodara* Deodar forest (Type – 12/C_1C; Champion and Seth 1968) is found between altitudes 1750-2150 m a.s.l. *Cedrus deodara* is mainly observed in pure patches, while few scattered individuals of other associated species such as *Quercus leucotrichophora, Pinus wallichiana, Cupressus torulosa* and *Rhododendron arboreum* are also found.

Three sites were selected for the present study (Figure.1) at three different altitudes i.e., upper, middle and lower (Table 1). Soils of Dhanaulti area belongs to mollisols and Satengal to inceptisols. All these polypedons are members of fine sandy loam, mixed, messic family. These soils, developed from different parent materials are in equilibrium with geogenic factors. All pedogenic processes are active in the study area. The soils are generally acidic in nature with pH values increasing with the depths.

The temperature in this area is cool throughout the year. The summer months are cool. The winters here are not very freezing but provide a misty view of distant mountains. The summer temperatures range from 31^{0}C to 7.5^{0}C while the winter temperature ranges from 7^{0}C to 1^{0}C. The meteorological data of the study area is given in Figure.2.

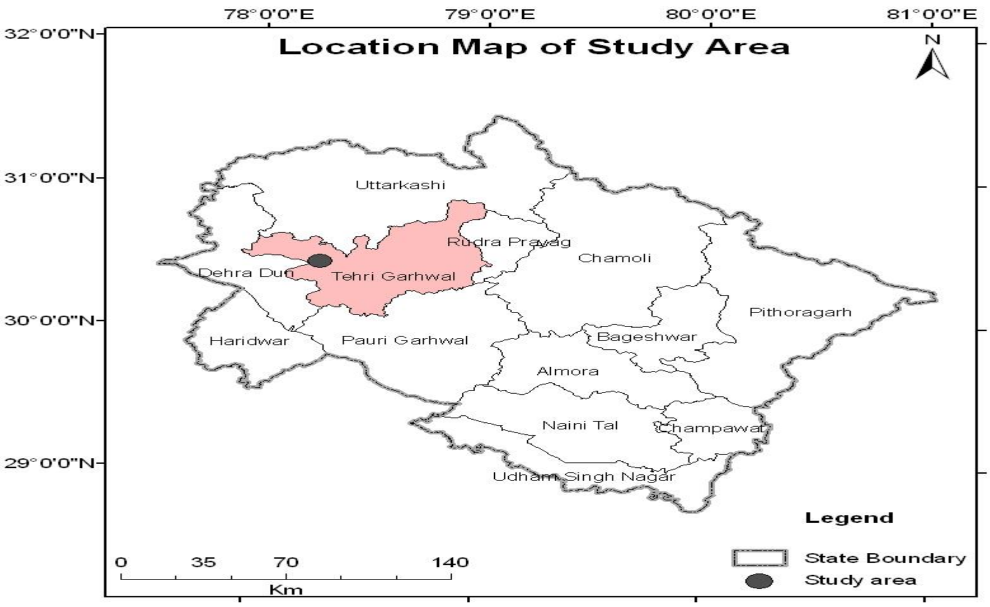


Figure.1 Location map of the study area in Uttarakhan

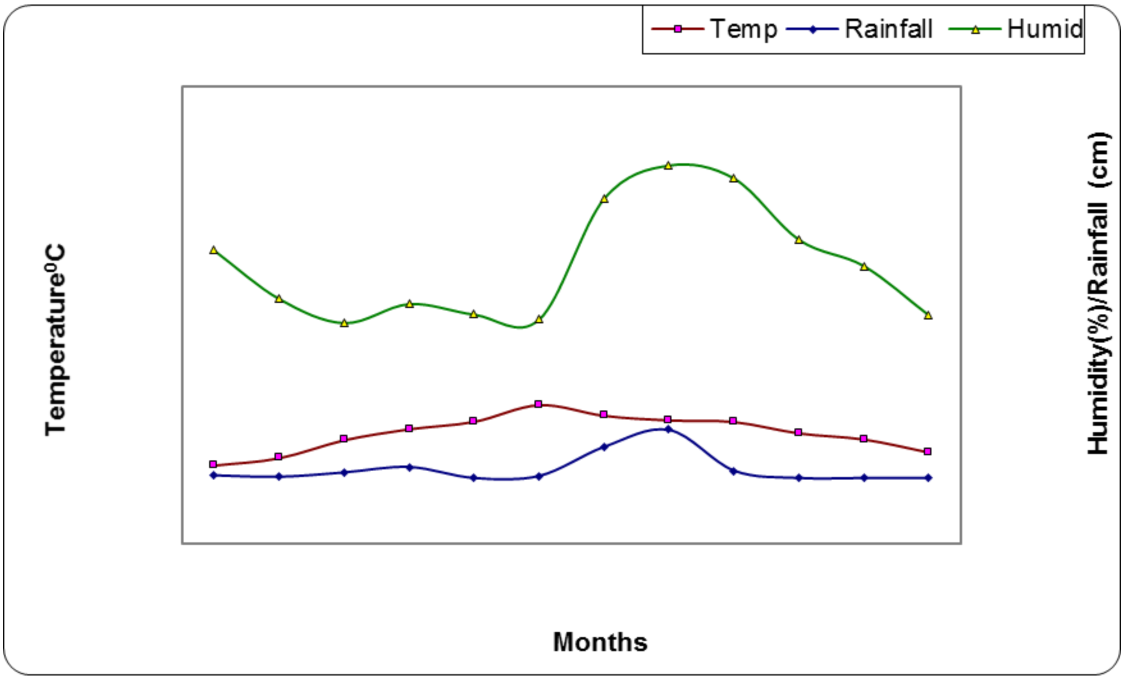


Figure.2 Meteorological data of the study area.

Table: 1. Details of the study area

Location	Altitude	Georeference	Elevation (m asl)	Aspect
Dhanaulti	Upper	N30°24'434"; E078°17'894"	2350	North west
	Middle	N30°25'209"; E078°17'867"	2200	North west
	Lower	N30°25'336"; E078°17'811"	2050	North

Methodology adopted

Litter Production

Litter production was assessed by collecting litterfall using 1m x 1m size litter trap at 20 cm high above the ground at three different altitudes. Litter was collected seasonally i.e., summer, rainy and winter. Each season was considered four months and exact after interval of 4 month of a period of 120 days the litter samples were collected and same procedure was repeated for 8 months (240 days) and 12 months (360 days).

. The collected litter was brought to the laboratory for further analysis. Dry weight of litter was determined by drying to a constant weight at 80^{0}C. The seasonal value of litter production for each altitude was worked out on a unit area basis (t ha^{-1}).

Litter decomposition and chemical analysis

The rate of decomposition was estimated using standard litter-bag techniques (Bocock and Gilbert, 1957), wherein known weight of dried leaf litter samples as per availability of collected samples were placed in nylon-mesh bags (1mm) and placed on the forest floor. Total nine samples were established in each altitude and same repeated for other altitudes. At a regular interval i.e., 120, 240, 360 days 3 samples were collected from each altitude and the process repeated further for each altitude and seasons. The procedure was repeated only for a period of one year.

The selected samples of litter bags were brought to the laboratory and cleaned off foreign material if any, and oven dried in paper bag to a constant weight. After drying the litter mass each bag was weighed individually. The model for constant potential weight loss (Olson, 1963) was represented by the following equation. $X/Xo \equiv e^{-kt}$ where X is the weight remaining at time t, Xo the original mass, 'e' the base of natural logarithm, k the decay rate coefficient, and t the time. Half-life periods of decomposing litter samples were estimated from k values using the standard equations (Bockhiem et al., 1991). Analysis of litter sample was carried out by using standard analytical methods. Nitrogen was estimated by Kjeldahl, method. Phosphorus and potassium were determined by Molybdate-blue and Flame Photometer methods respectively.

RESULTS

Litter production

The seasonal litter production of leaf litter in different altitudes is given in Table-2. In summer season the highest litter production (4.42±0.12 t ha^{-1}) was in lower altitude and the lowest (3.57±0.27 t ha^{-1}) in upper altitude. In rainy season the maximum litter production was in lower altitude (3.02±0.47 t ha^{-1}) and minimum in upper altitude (2.34±0.51 t ha^{-1}). In winter season the highest litter production was observed in lower altitude (2.23±0.52 t ha^{-1}) and lowest in upper altitude (2.12±0.16 t ha^{-1}). Irrespective of altitude the annual litter production was observed maximum in summer season (4.42±0.12 t ha^{-1}) followed by rainy (2.75±0.35 t ha^{-1}) and winter (2.19±0.059 t ha^{-1}) seasons (LSD at 5%: 0.37, 0.26 and 0.14, respectively) (Table 2).

Table: 2. Seasonal pattern of litter production (t ha^{-1}) in different altitudes

Altitude	Summer	Rainy	Winter
Upper	3.57±0.27	2.34±0.51	2.12±0.16
Middle	4.26±0.94	2.86±0.71	2.22±0.02
Lower	4.42±0.12	3.02±0.47	2.23±0.52
LSD at 5%	0.37	0.26	0.11

Litter decomposition

Table-3 shows litter decomposition rate (k) for the study site in different altitudes. The value of decomposition constant (k) was significantly high (P<0.01) in lower altitude (0.511) followed by upper (0.438) and middle (0.256) altitudes. Various factors are responsible for the different rates of litter decomposition such as quality of litter, temperature and moisture on which the microbial activity depends. Regular rainfall on litter gradually increases the moisture level on the top.

Table: 3. Decomposition constant (k) and half life ($t_{0.50}$) for weight loss of leaf litter from different altitude

Altitude	k	Std. Err.	R^2	Adj R^2	$t_{0.50}$
Upper	0.438	0.0004	0.9022	0.8140	585.7
Middle	0.256	0.0001	0.9022	0.8140	1047.3
Lower	0.511	0.0002	0.9590	0.9197	485.6

Nutrient release from litter

Winter season

Seasonal value of percent nutrient concentration is given in Table-4. Among the nutrients nitrogen was maximum (1.302±0.194%; P<0.01) in middle altitude and minimum (0.996±0.002%) in the upper altitude. The phosphorus has not shown any trend with altitude, which was maximum (0.336±0.428 %) in lower altitude and minimum (0.126±0.046 %) in upper altitude (P<0.05). The maximum (1.037±0.025 %) and minimum (0.64±0.106 %) values of potassium were observed in upper and middle altitudes respectively (P<0.01).

Summer season

The value of nitrogen percent (1.127±0.047%; P<0.05) 0in upper, middle. The highest (0.114±0.027 %) and lowest (0.086±0.009 %) values (P<0.01) of phosphorus were observed in middle and lower altitudes respectively, however, potassium was maximum (1.075±0.386 %) in upper altitude and minimum (0.675±0.222%) (P<0.01) in the lower altitude (Table 4).

Table: 4.Seasonal percent (%) nutrient concentration of leaf litter in different altitude

Altitude	Season								
	Rainy			Winter			Summer		
	N	P	K	N	P	K	N	P	K
Upper altitude	1.143[a] ±0.040	0.117[x] ±0.005	1.067[p] ±0.416	0.996[b] ±0.002	0.149[y] ±0.013	1.037[q] ±0.025	1.127[a] ±0.047	0.113[x] ±0.006	1.075[p] ±0.386
Middle altitude	1.297[a] ±0.265	0.122[x] ±0.028	0.907[p] ±0.311	1.302[a] ±0.194	0.126[x] ±0.046	0.64[q] ±0.106	0.966[b] ±0.319	0.114[y] ±0.027	1.015[p] ±0.463
Lower altitude	0.975[b] ±0.021	0.085[x] ±0.012	0.733[p] ±0.231	1.032[c] ±0.040	0.336[y] ±0.428	0.847[q] ±0.136	0.953[b] ±0.044	0.086[x] ±0.009	0.675[r] ±0.222

n = 5; ±SE. In each altitude and for each nutrient, the values with similar letters across season are not significantly different at P <0.05.

Rainy season

The highest (1.297±0.265 %) value of nitrogen was in the middle altitude and lowest (0.975±0.021%) in lower altitude. The phosphorus was maximum (0.122±0.028 %) in middle altitude and minimum (0.085±0.012 %) in the lower altitude. The exchangeable potassium was maximum (1.067±0.416 %) in upper altitude and minimum (0.733±0.231 %) in the lower altitude (Table 4).

DISCUSSION AND CONCLUSION

Litter production

Season-wise litter production

In all the forest sites of Dhanaulti, the maximum (4.09 t ha^{-1}) litter production was observed in summer season followed by rainy (2.75 t ha^{-1}) and winter seasons (2.19 t ha^{-1}) The seasonal pattern of litter fall may be attributed to difference in climatic factors, such as temperature and moisture and intrinsic genetic factors (Jamaludheen and Kumar, 1999). Several workers (Sundarapandian and Swamy, 1991) have reported peaks litter fall mass in spring, summer and autumn in tropical climates. The peak litter fall in summer may be associated with physiological leaf senescence and this rhythm fits with similar studies of evergreen broadleaved forests (Lin et al., 1999; Yang et al., 2004). In present study the litterfall production has shown negative relationship with altitude. Zhou (2006) also reported decreasing trend of litterfall with increasing elevation. The significant negative relationships between elevation and litterfall productions suggest that small changes in temperature may result in significant changes in reproductive allocation.

In present study the total annual litter fall production ranged between (8.03±0.74) to (9.68±1.11 t ha^{-1}). Rodin and Bazilevick (1967) in USSR, observed range of litterfall production from 7.0 to 10.0 t ha^{-1} in Coniferous forest. Rana et al. (1989) reported the litterfall production value of 17.3 t ha^{-1} for chir-pine forest of India. Chhabra and Dadhwal (2004) observed the litterfall production in many forests i.e., tropical evergreen (6.89±0.75 t ha^{-1}), tropical moist deciduous forest (8.93±0.64 t ha^{-1}), mangrove and swamp (8.52±0.94 t ha^{-1}), tropical dry deciduous (5.97±0.69 t ha^{-1}), tropical evergreen (7.52±1.55 t ha^{-1}), sub-tropical montane (6.70±0.72 t ha^{-1}) and montane temperate (5.66±0.24 t ha^{-1}). Devi et al. (2010) reported the annual litter fall of 7.35 t ha^{-1} in tropical forest of Northeast India.

These reported values show fluctuation above and below the values of present study because litter production varies according to habit of the tree species, its age and local environmental condition (Hawkins et al., 1990; Szott and Kass, 1993). Data on litter production indicates that major portion was contributed by leaf and similar findings have also been reported (Sundarpandian and Swamy, 1999).

Seasonal fluctuations like climatic variables, exposure, soil moisture and wind velocity etc. affect variation in litterfall (Chaturvedi and Singh, 1987). Bray and Gorham (1964) found that annual litter fall production increased rapidly during stand development until canopy closer, and then remained relatively constant over a long period of time before decrease in old stands.

Litter decomposition

In the present study average decomposition (irrespective altitude and season) constant (k) was 0.402. Jenny et al. (1949) reported the decomposition rate of 0.584-1.17 for oak and 0.986-2.99 for pine forest between in USA. Similarly in USA, Witkamp (1966) reported k value of 0.015 for *Quercus alba* forest. Swift et al. (1979) reported k value of 0.21, 0.77 and 6.0 for boreal, temperate deciduous and tropical forests respectively. Pandey (1979) reported the values of decomposition rate (k) of 0.158 for *Cedrus deodarda*, 0.193 for *Quercus leucotrichophora* and 0.139 for *Cupressus torulosa* forest. Upadhyay (1984) reported the decomposition rate of 0.253 for *Quercus leucotrichophora*, 0.274 for *Quercus glauca* and 0.126 for *Pinus roxburghii* forests. Pant et al. (1992) reported the decomposition rate of 2.52 in Kumaon Himalaya for *Quercus leucotrichophora* forest. Pandey et al. (1993) reported the value of k as 1.35 for *Pinus roxburghii* forest in India. Singh et al. (1993) reported the decomposition rate value of 0.025 for *Tectona grandis* forest and

0.30-0.94 for *Eucalyptus* forest. Kumar et al. (2003) reported the k value of 3.33 for a deciduous forest in India. Kaushal et al. (2012) reported the value of k as 0.026 for *Toona ciliata* forest in India.

In present study the rate of decomposition was fast during rainy season and slow in winter season because weight loss was highest in rainy season. Tripathi et al. (2009) also reported litter decomposition was fast during rainy season and slow during winter season. Bala et al. reported (2010) slow rate of decomposition (k=0.1508) in *Eucalyptus* forest.

Pant and Tiwari, 1992 reported maximum decomposition during rainy season followed by winter and summer months in plantations and sand dunes areas. Many other workers (Wedderburn and Carter, 1999; Sarjubala and Yadav, 2007) also observed high rate of decomposition in rainy season because of suitable moisture, rainfall and micro-fungal population.

Decomposition essentially results in a change of state of a resource under the influence of a number of biological and abiotic factors. Initially, decomposition rate in this study was increasing with days. This could mean that different species have different rates of decomposition as reported by Muoghalu et al. (1994) and Temel (2003). High rate of decomposition recorded at the early stage and around July and August may be attributed to less moisture content in the soil, leading to high aeration, causing the aerobic organism to be active. Frioretto et al. (1998) suggested that microbial activity could be limited by litter moisture content.

Increasing decay rate indicates a faster early decomposition while increasing limit value indicates a higher fraction of slowly decomposable litter. During the decomposition of leaf litter, a vast array of chemical, physical and biological agents act upon litter constituents changing their compositions and concentrations (Berg and McClaugherty 2008).

Kumar et al. (2010) reported the faster rate of litter weight loss of during rainy season, as compared to winter was obvious in the present study. This may be attributed to prevailing locality factors. Many studies have reported an increase in rate of weight loss in relation to temperature soil/air, soil moisture, microbial load and rainfall (Gupta and Lekha, 1989; Pant and Tiwari, 1992) but none had paid heed to the importance of relative humidity during decomposition process.

Chemical analysis of litter

Nitrogen (N)

In present study the value of nitrogen (irrespective altitude and season) was 1.008 %. **Singh et al. (1993)** reported the values of nitrogen as 1.8% in *Litsea deccanensis* forest and 1.5 % in *Dalbergia sissoo* forest in India. Arunachalam et al. (1998) reported the values of nitrogen 0.89% for *Q.dealbata* and 0.73% for *Q. griffithii* forest of India. Devi et al. (2009) reported the value of nitrogen as 1.02% for *Quercus serrata* forest of northeast India. Tripathi et al. (2009) reported the nitrogen values for *Citrus reticulata* (1.85%), *Alnus napalansis* (1.91%) and *Pinus cassia* (1.18%) for different forests in Meghalaya. Patra et al. (2012) reported the values of nitrogen for different forest types i.e., tropical dry miscellaneous open forest (N=1.20%), closed miscellaneous forest (N=1.38%), open sal forest (N =1.72%) and closed sal forest (N=0.93%).

Chemical composition of litter, which changes with type of plant community, influences structure and activity of microbial communities inhabiting soils (Kutsch and Dilly, 1999), and biological and physicochemical properties of top soil (Heal and Dighton, 1986). Knowledge of litter production is important when estimating nutrient turnover, C and N fluxes, and C and N pools in different ecosystems. Release of nutrients not only depends upon litter composition but also upon soil type, microbial communities and soil properties (Kutsch and Dilly, 1999; Scholes and Walker, 1993). Lower content of highly mobile nitrogen might be due to leaching with rain water, and lower Mg content in leaf litter possibly reflected the chlorophyll decay which confirms findings by Kava'ova and Acek, (2003). More nitrogen is returned through litter fall than any other element in this study, which was similarly observed by other studies (Muoghalu et al., 1993; Hermansah et al., 2002). Generally, tropical forests have higher concentration of nitrogen than comparable temperate forests due to higher concentration of this element in leaf litter. Fluxes of nitrogen associated with leaf fall are an important component of the internal N cycle of a forest ecosystem. Reich et al. (1992) and Aerts (1996) suggest that they are determined largely by the physiological and anatomical characters of the main tree species. The concentration of plant nutrients in litterfall is important because it influences both the rate of decomposition and the amount of nutrient released to the soil during such decomposition. Therefore, the quality of litterfall, particularly N was probably affected by the concentration of N in the soil and also due to the nature of the tree which is a leguminous plant capable of fixing nitrogen. The nutrient flux within the study site had nitrogen with highest flux and this may be presumably due to the tree species, a leguminous plant.

Phosphorus (P)

In present study the value of phosphorous (irrespective altitude and season) was 0.139%. Singh et al. (1993) reported the values of phosphorus amounting to 0.16% in *Litsea deccanensis* forest and 0.04 % in *Dalbergia sissoo* forest in India. Arunachalam et al. (1998) reported the values of phosphorus 0.06% for *Q. dealbata* and 0.05% for *Q. griffithii* forest of India. Tripathi et al. (2009) reported the values of phosphorus in different forests i.e., *Citrus reticulata* (0.22%), *Alnus napalansis* (0.22%) and *Pinus cassia* (0.096) in Meghalaya. Patra et al. (2012) reported the phosphorus values in different forest types i.e., tropical dry miscellaneous open forest (P=0.17%), closed miscellaneous forest (P=0.36%), open sal forest (P =0.34%) and closed sal forest (P=0.27%).

Variation in concentrations of nutrient elements reflected the seasonal trend in the amount of litter fall and the concentration of elements in the litter as observed by Muoghalu et al. (1993). Potassium, phosphorus and Mg had their maximum concentrations in the dry season, although Klinge and Rodrigues (1968) recorded a high concentration of phosphorus and potassium in litter in the wet season.

Potassium (K)

In present study the value of potassium (irrespective altitude and season) was 0.888%. Singh et al. (1993) reported the values of potassium amounting to 0.8% in *Litsea deccanensis* forest and 0.7 % in *Dalbergia sissoo* forest in India. Tripathi et al. (2009) reported the values of potassium in different forests i.e., *Citrus reticulata* (1.58%), *Alnus napalansis* (1.71%) and *Pinus cassia* (0.97%) in Meghalaya. Patra et al. (2012) reported the values of potassium in different forest types i.e., tropical dry miscellaneous open forest (K=0.29%), closed miscellaneous forest (K=0.40%), open sal forest (K =0.32%) and closed sal forest (k=0.35%).

The maximum concentration of these elements was in the dry season. High potassium content could be due to lack of rainfall during these months. Potassium is easily leached from leaves and litter by rain water (Egunjobi, 1971; Egunjobi and Fasehun 1972). The amount of nutrient flux corresponded with the dry weight of litter produced. This is in accordance with the observation by Frioretto et al. (1998) that microbial activity can be limited by litter moisture content. However, where there is high concentration of aerobic organism, nutrient release through decomposition will still continue because these organisms are active when there is high aeration. The result indicated higher rate of P, K and N release. Similar trend has been observed by Singh (1980) in the humid tropical forest. This rapid release could be attributed to the rapid loss of water soluble compounds. Potassium and phosphorus are usually constituents of metabolites enzyme system of the plant sap. Early immobilization of N and P and subsequent decrease in concentration following mass loss has been found in other studies (Sharma and Ambasht, 1987; Palm and Sanchez, 1990).

The nutrient accumulation could also be from falling litter, precipitation, through fall, stem flow, the soil substrate, and from the growth of fungal hyphae (Swift et al., 1979). High rate of nitrogen release from the leaf litter of *Leucaena* could be attributed to the influence of soil microarthropods. The sudden increase in nutrient remains at the end of the studies for nitrogen could indicate that soil N was being immobilized by the decomposing organism (Alfred and O'sullivan 2001).

Generally, the net accumulation of nutrient remaining at the end of the study may also suggest that some microorganisms acting on the resource fed, died and decomposed on the litter, thus, increasing the nutrient quality. In decomposing litter, the chemical component may be regarded in a certain sequence, reflecting a succession of micro-organisms with different saprotrophic abilities (McClaugherty and Berg, 1987; Temel, 2003). Frankland (1992) and Cox et al. (2001) attributed litter decomposition and release of N, P, K, Ca and Mg to the influence of microarthropods and earthworms. Decomposition is important because plant production depends on the recycling of nutrients within the system; recycling depends on the decomposition of organic matter and release of the nutrient it contains. It has long been recognized that soil fauna affects decomposition mainly through the combination of substrates, and influencing microbial activity (Tian et al., 1998). The results agree with other workers' conclusion that litter decomposition rate is more related to litter quality than to environmental conditions (Facelli and Pickett, 1991; De Santo et al., 1993, Temel, 2003).

The variation in nitrogen % due to seasons is not significant i.e., the seasonal effect on nitrogen of decomposed litters is insignificant. However it may be seen, that nitrogen % increases from summer to rainy season and decreased from rainy season to winter (Figure-3).

The variation in nitrogen % with altitudes is highly significant ($P<0.01$). It is highest (1.196 %) in the lower altitude and reduced with altitude where minimum (0.962 %) value was reported in the upper altitude (Figure-4).

The variation in potassium due to seasons is not significant i.e., there is no seasonal effect on potassium of decomposed litters. However it may be seen that potassium decreases after summer and was reported minimum in winter (Figure-5). The variation in K with altitudes is highly significant. It is highest (1.156 %) in the lower altitude and lowest (0.632) in the upper altitude (Figure-6). This shows that with increase in altitude the potassium percent in litter decreases.

The variation in phosphorus % due to seasons is not significant i.e., the seasonal effect on phosphorus of decomposed litters is insignificant. The variation in phosphorus with altitudes is not significant. It is highest (0.175 %) in the middle altitude and minimum (0.09 %) in the upper altitude (Figure-7).

Fig. 3.Variation in nitrogen % in litter due to changing seasons

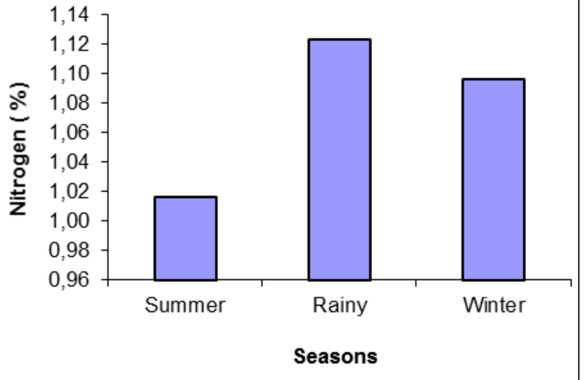
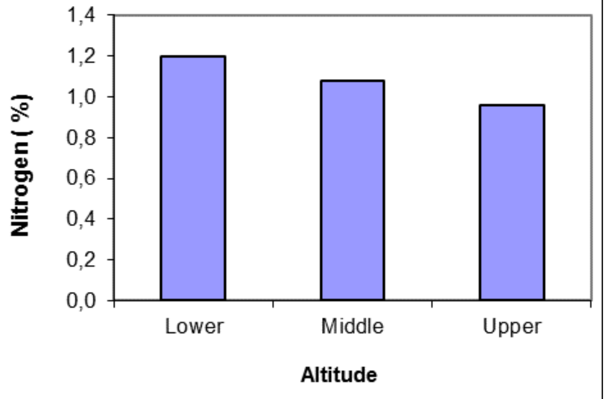
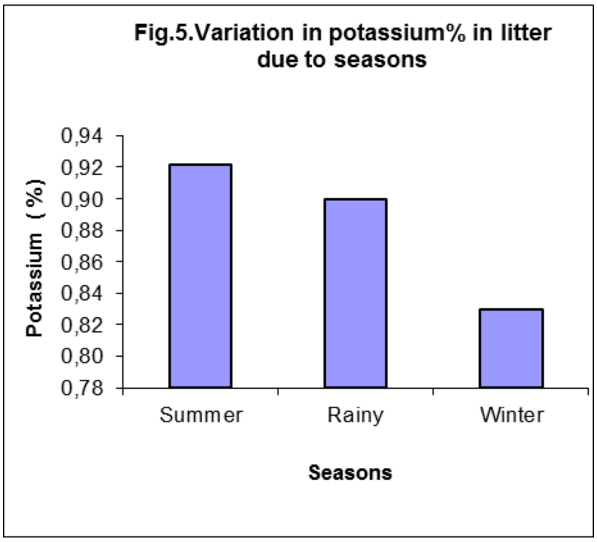
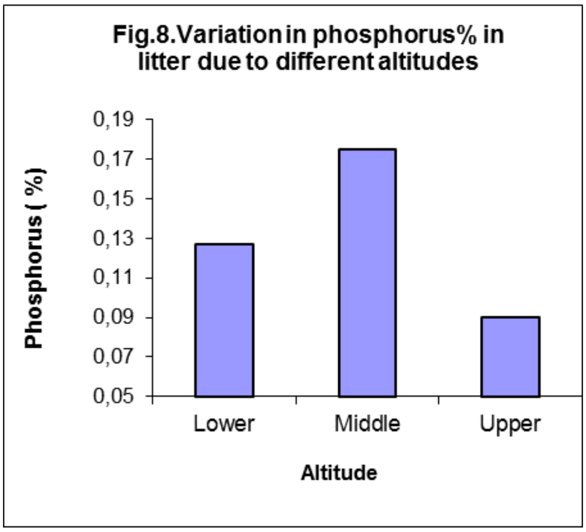
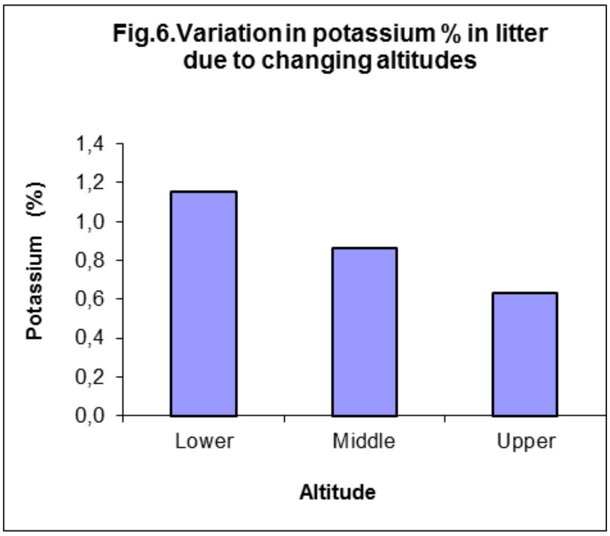


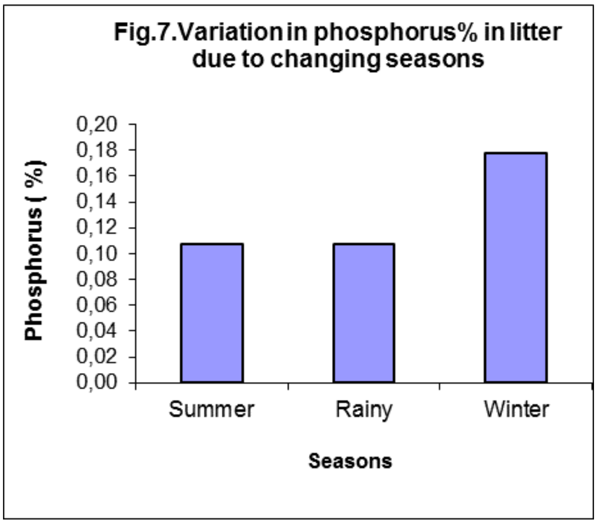
Fig.4 Variation in nitrogen % in litter due to changing altitudes











The annual return of nutrient irrespective of altitude was observed in order of N>K>P. The concentration of nitrogen was in order of middle altitude>upper altitude>lower altitude. Similarly the concentration of phosphorus was in order of lower altitude>upper altitude>middle altitude and the concentration of potassium was in order of upper altitude >middle altitude>lower altitude.

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