

FOLIAR DYNAMICS AND NUTRIENT RETRANSLOCATION IN AN AGE SERIES PLANTATION OF *TECTONA GRANDIS* RAISED IN MOIST DECIDUOUS FOREST REGION, NORTHERN INDIA

KAUSHALENDRA KUMAR JHA*

Introduction

The renewable resource of plants also referred as to phytomass or biomass, is the result of utilization of conventional source of solar energy by the foliage system of plants. This is only possible due to biochemical reactions in metabolically active leaves, which, on one hand, help to conserve nutrients within standing crop through redistribution, and, on the other hand, prevents loss of it through leaf fall. These active leaves continue to drive nutrients up to a maximum till maturity, thereafter, nutrient contents often decline to a minimum as a result of senescence caused by retranslocation (Stachurski and Zimka, 1975).

Retranslocation of nutrients before abscission of leaves depends upon many factors e.g., plant growth forms, stature associated with age, and site characteristics (Charley and Richards, 1983). Fraction of mass of all nutrients that are retranslocated from leaves during senescence decreased with increasing stand age (Bargali, 1990; Lodhiyal, 1990). Many workers (Olsen, 1948; Lindgren *et al.*, 1977; Tilton, 1977; Ostman and Weaver, 1982) have reported that nutrients differ in the extent of their retranslocation from senescing leaves. Eickmeir (1979) has further reported that in plants adapted to

infertile sites greater proportional loss of nutrients occur at senescence than those adapted to fertile sites. Furthermore, it has also been suggested by a few workers (Beadle, 1966; Monk, 1966; Hagg, 1974; Chapin, 1980) that the species with long lived leaves occupy nutrient poor sites and those with short lived leaves occupy nutrient rich sites.

Teak naturally grows in moist and nutrient rich regions of its native countries. It has been successfully introduced in high rainfall and fertile area of several tropical countries (Weaver, 1993; Tanaka *et al.*, 1998). In India it is well adapted to certain dry and fairly nutrient poor sites. It is a deciduous species having 8-10 months leaf longevity. It is initially fast growing and develops crown at early age. The species has attracted investors for early harvesting at 15 to 30 years (Tewari, 1992; Jha and Singh, 1999).

The present investigation is aimed at understanding following aspects in a chronosequence of young teak plantations raised in moist deciduous forest region :

- (i) Patterns of leaf mass changes and leaf area expansion,
- (ii) Seasonal variation in foliar nutrient concentration
- (iii) Amount of nutrients through retranslocation, and

* Presently : CCF, Regional Manager, Production, U.P. Forest Corpn., Lucknow (U.P.).

- (iv) Effect of age on foliar and nutrient dynamics

Material and Methods

Study site : An age series teak plantations of 1, 5, 11, 18, 24 and 30 year age were situated at the base of the Himalayas in Kumaun region of Uttaranchal, India. Geographical location of the study site is 29°3' - 29°12' North Latitudes and 79°20' - 79°23' East Longitudes. The altitudinal range is 230 - 280 m amsl. Plantation size varied from 15 to 97 ha, and sample plots size from 1200 to 2900 m². Spacing of the plantations averaged 4 m by 2.5 m. Plantations were raised and managed according to standard silvicultural practices prescribed for the region which included thinning to remove dead, dying, diseased, suppressed and badly formed trees at the age of 10 years (Prakash and Khanna, 1979). The natural vegetation, presently highly altered, was originally "Alluvial Savannah Woodland - type 3/IS1, with some pockets of moist Tarai Sal - type 3c/C2c" (Champion and Seth, 1968). The low-density forest areas were clear felled and converted into plantations of exotics like Poplar, Eucalyptus, Teak and other miscellaneous species.

Climate of this region is subtropical and monsoon type with long dry (8 months) and short wet seasons. Winter extends from November to mid-March. December and January are the coolest months. Summer stretches from mid-March to June. June is the hottest month. Another conspicuous season is rainy season that, invariably, starts in later half of June and lasts, generally, up to September. Mean monthly temperature ranges from 14.4°C to 31.3°C and annual average rainfall is

1593 mm. Distribution of average total rain in different seasons are approximately 83%, 3% and 14% in rainy, winter and summer season, respectively. Average humidity is 65%. Soil of this part of Kumaun Himalayas is typic hapludoll and fine loamy in texture (Kumar and Sharma, 1990). Soil pH and EC ranged from 6.30 to 7.64 and from 0.030 to 0.172 mhos cm⁻¹, respectively. Soil Organic Carbon and Nitrogen (N) ranged between 0.48 to 1.83 and 0.042 to 0.158 %, respectively, across sites and soil depth upto 60 cm (Jha and Singh, 1999).

Methods : To study the leaf mass change, leaf area expansion and nutrient content in the leaves through the foliage-growing season at different age, leaf collection was made along with the phenological observation. Fifty leaves were plucked randomly from lower, middle and upper canopy of a marked tree from each site. This was done in all the foliage-bearing months of the study period (April 1992 to March 1993). These foliage samples were packed in polyethylene bags and brought to the laboratory for further study. First of all they were measured to find out green weight of fifty leaves. Next step was to calculate the area of leaves. This was done by spreading each leaf on graph sheet and drawing its silhouette on it. The squares falling inside leaf boundary were counted to find out the area of the leaf. Afterwards these leaves were oven dried at 80°C and weighed again and again to find out constant dry weight.

Leaf area index (LAI) was calculated as the amount of leaf area per unit ground area. Leaf area was found out from leaf mass using specific leaf area, the ratio of fresh foliage surface area to unit dry foliage mass (Bond-Lamberty *et al.*, 2002).

Nitrogen and phosphorus (P) were chosen due to their importance in the functioning of photosynthesis in the leaves and their easy resorption (Larcher, 1995). For estimation of the nutrient concentration leaf samples of April, September, November and December were selected to represent summer, rainy, autumn and winter season, respectively. Leaf samples of all the six stands were pooled season-wise since there was no significant difference in nutrient concentration across the studied age group of the stands. These sub-samples were mixed thoroughly and crushed properly. Afterwards they were powdered with the help of domestic mixer-cum-grinder. Thus prepared composite samples representing various seasons were stored for chemical analyses. Nitrogen was estimated by micro-kjeldahl method as in Jackson (1958) and P by phosphomolybdic blue method as in Singh and Singh (1991).

Nutrient mass (content) of the leaves was calculated as the product obtained by multiplying dry mass of leaves of different stands and seasons with corresponding nutrient concentration.

Percentage retranslocation was calculated as per below mentioned formula (Rahman and Singh, 1987) :

$$\% \text{ retranslocation} = \frac{\{(\text{nutrient mass in leaf at steady state} - \text{nutrient mass in leaf at abscission}) \times 100\}}{(\text{nutrient mass in leaf at steady state})}$$

In the above computation through fall leaching was not taken into account because senescence in teak does not occur during rains. Also the concentration of N and P is not affected since they are in organic forms in the leaves while nutrient loss due to leaching is usually related to

organic forms (Chapin, 1980). In this regards finding of Chapin and Kedrowski (1983) that less than 0.6% N and P is lost through leaching is also important in the sense that leaching magnitude is very low.

Total retranslocation of nutrients was assessed by multiplying annual foliage biomass production (by harvest method, part of another study) with average foliage nutrient concentration and the result again multiplied by corresponding per cent nutrient retranslocation.

Results

The features of the plantations under present study are given in Table 1. In these plantations leaf bud sprouting was observed in the month of April. But there was a delay of at least two to three weeks in 11 and 24 year old plantations. It was also observed in these two stands that leaf shedding completed in December, earlier by around two weeks, as compared to other stands. Right from the day of appearance leaves started expanding till the month of September when maximum leaf area was recorded in all the plantations. Afterwards there was non-linear decreasing trend (Table 2). Range of maximum leaf area was between 538 cm² leaf⁻¹ (30 years) to 847 cm² leaf⁻¹ (11 years). Average leaf area through the stands varied from 376 cm² leaf⁻¹ (24 years) to 473 cm² leaf⁻¹ (11 years). The oldest plantation of the chronosequence (30 years) had lower average leaf area as compared to younger plantations (5, 11, 18 years). Across all the months and plantations it varied between 60 cm² leaf⁻¹ (April) and 701 cm² leaf⁻¹ (September). However, the expansion period was around 20 weeks in all the stands under study.

Table 1*Characteristics of Teak stands under study*

Age (yrs)	Location	Density (tree ha ⁻¹)	Av. DBH (cm)	Av. height (m)	Basal Area (m ² ha ⁻¹)
1	Tanda	1183	3.33	3.90	1.20
5	Lamachaur	1728	7.63	9.12	5.92
11	Tanda	376	20.40	16.98	10.57
18	Lamachaur	512	19.04	16.81	12.83
24	Gadgadia	273	24.43	19.37	16.33
30	Lamachaur	323	29.96	23.57	18.52
Average		732 (591)	17.46 (10.12)	14.95 (7.17)	10.90 (6.48)

Figures in parenthesis are standard deviation.

Table 2*Leaf area (cm² leaf⁻¹) of selected Teak stands in different months*

Months	1 yr	5 yrs	11 yrs	18 yrs	24 yrs	30 yrs	Average
April	84	57	-	56	-	45	60 (17)
May	108	193	197	206	168	98	162 (47)
June	359	348	361	430	276	438	369 (60)
July	492	466	595	499	466	530	508 (49)
August	470	688	619	627	358	769	588(150)
September	546	820	847	820	636	538	701(144)
October	533	669	410	348	332	365	443(132)
November	525	404	350	682	406	534	483(122)
December	446	313	405	415	365	424	395 (48)
January	468	570	-	423	-	422	471 (70)
February	-	-	-	-	-	-	
March	-	-	-	-	-	-	
Average	403 (170)	453 (238)	473 (203)	450 (224)	376 (138)	416 (213)	

Figures in parenthesis are standard deviation.

During the growth of leaves two phases of development were very distinct: (i) increase in leaf mass accompanying leaf

expansion and (ii) decline in leaf mass along with leaf area reduction. Phyto-mass kept increasing up to September

and thence onward there was irregular decrease (Table 3). This trend was almost similar to that of leaf area. However, range of maximum phytomass was between 5.0 g leaf⁻¹ (30 year) to 7.3 g leaf⁻¹ (1 year). Average phytomass through the stands varied from 3.3 g leaf⁻¹ (11 years) to 5.0 g leaf⁻¹ (1 year). Across all the months and plantations it varied between 1.5 g leaf⁻¹ (April) and 5.8 g leaf⁻¹ (September).

Leaf mass loss (LML) before senescence was recorded in the range of 11.84 and 48.00% (Table 4), lowest being in 1 year and highest in 11 year plantation. This loss indicated non-linear relationship with age. Similar relationship was shown by LAI versus age. LAI of the studied

plantations varied from 1.49 (1 year) to 7.6 (11 years).

There was significant change in per cent nutrient concentration of leaves through the seasons (Table 5). In the summer season when the leaves were youngest N and P concentration were highest. Concentration of nitrogen kept on decreasing in the seasons to be followed. During winter, which was the senescence period, N concentration was lowest. Phosphorus was also lower in following seasons but trend was non-linear. Average nutrient content of leaf was minimum in summer season in both the cases (N and P), as contrary to the nutrient concentration. It was highest in rainy season in the case of N and in autumn in

Table 3

Leaf mass (g leaf⁻¹) of selected teak stands in different months.

Months	1 yr	5 yrs	11 yrs	18 yrs	24 yrs	30 yrs	Average
April	2.4	0.9	-	1.7	-	0.8	1.5 (0.7)
May	1.3	1.9	2.7	2.4	1.6	1.0	1.8 (0.7)
June	3.1	2.5	2.5	3.0	2.2	2.0	2.6 (0.4)
July	5.7	5.2	3.5	4.1	4.3	4.3	4.5 (0.8)
August	5.2	4.0	3.2	4.4	3.0	6.1	4.3 (1.2)
September	7.3	5.8	5.5	5.8	5.6	5.0	5.8 (0.8)
October	5.5	5.4	2.8	3.1	3.1	3.8	4.0 (1.2)
November	7.0	4.0	3.4	6.7	6.0	7.0	5.7 (1.6)
December	6.4	5.4	2.9	3.6	3.8	4.8	4.5 (1.3)
January	6.4	5.0	-	4.2	-	4.6	5.1 (1.0)
February	-	-	-	-	-	-	-
March	-	-	-	-	-	-	-
Average	5.0 (2.0)	4.0 (1.7)	3.3 (0.9)	3.9 (1.5)	3.7 (1.5)	3.9 (2.0)	

Figures in parenthesis are standard deviation.

Table 4

Leaf biomass, per cent LML, LAI, and retranslocation of Teak plantations at different age.

Stand Age (yrs)	Leaf Biomass (kg ha ⁻¹)	LML (%)	LAI	Retranslocation			
				% N	% P	Total N	Total P
1	1784	11.84	1.49	32.3	3.7	8.7	0.10
5	6308	30.55	7.14	41.0	20.6	39.1	2.08
11	5303	48.00	7.60	59.9	36.8	48.0	3.12
18	5147	37.08	5.93	52.4	43.5	40.7	3.58
24	3310	33.33	3.36	48.6	33.4	24.3	1.75
30	5723	24.09	6.10	37.6	26.9	32.5	2.46
Average	4595 (1706)	30.81 (12.21)	5.27 (2.36)	45.3 (10.2)	27.5 (14.0)	32.2 (14.0)	2.18 (1.22)

Figures in parenthesis are standard deviation.

Table 5

Nutrient concentration and nutrient content in Teak leaves

Season/ Month	Nutrient concentration (%)		Nutrient content (g leaf ⁻¹)	
	N	P	N	P
Summer (April)	2.29	0.24	3.435	0.360
Rains (September)	1.78	0.14	10.324	0.812
Autumn (November)	1.51	0.16	8.607	0.912
Winter (December)	1.37	0.17	6.165	0.765

the case of P. Afterwards it declined in winter season, the period of senescence.

Of all the stands range of per cent retranslocation of N was 32.3-59.9% and P was 3.7-43.5% (Table 4). One year plantation had lowest percent retranslocation of N and P. The highest per cent retranslocation of N was in 11 year and P in 18 year old plantation. Average per cent retranslocation was 45.3% (N) and 27.5% (P). The range of annual retranslocation of nutrient was 8.7-

48.0 kg ha⁻¹ yr⁻¹ for N and 0.10-3.5 kg ha⁻¹ yr⁻¹ for P. Average annual retranslocation across the stands was 32.21 kg ha⁻¹ yr⁻¹ and 2.18 kg ha⁻¹ yr⁻¹ in N and P, respectively.

Linear regression results are computed in Table 6. Retranslocation values for N and P were regressed on a few foliage parameters like, leaf weight, leaf area, LML and LAI. These equations were not significant (>5%). Nitrogen and P values of retranslocation along with LML

Table 6*Linear regression relation between different parameters related to retranslocation*

X axis	Y axis	Intercept	Slope	R ²
LML (%)	N (kg ha ⁻¹)	-4.708	1.125	0.832 ^{NS}
	P (kg ha ⁻¹)	-0.351	0.082	0.679 ^{NS}
LAI	N (kg ha ⁻¹)	2.043	5.293	0.691 ^{NS}
	P (kg ha ⁻¹)	-0.046	0.423	0.673 ^{NS}
Leaf weight (g)	N (kg ha ⁻¹)	110.022	-20.184	0.572 ^{NS}
	P (kg ha ⁻¹)	9.101	-1.743	0.650 ^{NS}
Leaf area (cm ²)	N (kg ha ⁻¹)	-115.160	0.338	0.668 ^{NS}
	P (kg ha ⁻¹)	-6.995	0.021	0.407 ^{NS}
	Leaf weight (g)	6.782	-0.006	0.166 ^{NS}
Age (year)	N (kg ha ⁻¹)	42.958	0.161	0.031 ^{NS}
	P (kg ha ⁻¹)	16.690	0.729	0.336 ^{NS}
	LML (%)	27.499	0.223	0.042 ^{NS}
	LAI	4.748	0.035	0.028 ^{NS}
BA (m ²)	N (kg ha ⁻¹)	26.865	0.283	0.014 ^{NS}
	P (kg ha ⁻¹)	1.001	0.108	0.334 ^{NS}

NS : Not significant

and LAI were also regressed on age and basal area (BA) of the stands. These parameters were also found not significant (>5%).

Discussion

Growing pattern of leaf in present study is similar to that of typical dry deciduous trees. After complete leaflessness in the end of winter season leaf bud sprouting started in late spring or early summer. Leaves gained mass rapidly during rainy season and started losing it during autumn. Leaf bud sprouting time (April-May) and leaf shedding time (November-January) recorded during the study period matched closely to the earlier report of Tewari (1992), Sudheendra-

kumar *et al.* (1993) and Anon. (1992) in teak and Ralhan and Singh (1987) in a few deciduous as well as evergreen species. This pattern of leaf mass dynamics is also comparable to typical northern temperate trees (Kozłowski and Kellel, 1966; Tilton, 1977). Leaf mass gain period was almost synchronous to the leaf expansion period. Twenty weeks leaf expansion period in teak is different from the report of Ralhan and Singh (1987) in certain high altitude deciduous subcanopy and shrubs species. In the case of latter maximum expansion period was 6 weeks. This huge difference could possibly be due to entirely different locality factors at two different regimes and different species-specific requirements.

Regina *et al.* (2001) have reported that the vegetative cycle of deciduous forests leaves is subject to three stages of development: rapid growth, maturation and senescence. In present study also these phases were apparent. However, out of four phases of leaf development : (i) Increase in leaf mass accompanying leaf expansion, (ii) Increase in leaf mass after expansion is completed, (iii) Leaf mass steady state and (iv) Decline in leaf mass) reported by Ralhan and Singh (1987); two phases: (i) increase in leaf mass after expansion and (ii) leaf mass steady state, were not distinguishable in present study. Nevertheless, presence of steady state leaf mass can not be ruled out since the gap between two observations was of 4 weeks and it is likely possible that steady state period may have been of shorter span and would have fallen in this gap. This may further be corroborated with the fact that leaf mass steady state varies from few to several weeks (Ralhan and Singh, 1987).

The oldest plantation of the chronosequence studied (30 years) had lower average leaf area as compared to younger plantations (5, 11, 18 years). The leaf area decline in the oldest stands was reported earlier in boreal black spruce (Bond-Lamberty *et al.*, 2002) and other forest chronosequence studies (Ryan *et al.*, 1997).

Range of Teak LAI 1.49 to 7.6 recorded in present study is comparable to Black spruce LAI [Bond-Lamberty (2002) 1.1-7.5]. This is also closer to the LAI of temperate and boreal Aspen, Jack pine and Black spruce (Woods *et al.* 1991; Chen *et al.*, 1997). It is likely possible that LAI should have positive relationship with canopy closure. But the stand having lower LAI (3.36 in 24 year stand) had almost

closed canopy while the stand having higher LAI (7.6 in 11 years stand) had substantial opening in the canopy (unpublished data). This suggests that high LAI value do not necessarily imply canopy closure. This result is also supported by earlier findings of Bond-Lamberty (2002).

Non-canopy form (1 year stand having LAI 1.49) recorded lower retranslocation than the canopy forms (5, 11, 18, 24, 30 years having LAI 3.36-7.6). This has consistency with the report of Charley and Richards (1983) that growth form of the tree is correlated to retranslocation. Observation of Miller (1986, 1989) also goes in favour of present study to the extent that retranslocation of nutrients is not important during early phase of stand growth but attains significance later. Ralhan and Singh (1987) have also reported retranslocation difference among canopy, subcanopy and shrub forms in different forests. However, among canopy stands in present study no significant trend was observed on account of crown size and age difference.

In the summer season when the leaves were youngest N and P concentration were highest. In the following seasons this concentration was lower. In the neighbouring locality of present study Ralhan and Singh (1987) have also recorded declining N and P concentration from initial peak. In a highly contrasting locality (Southern Europe) and entirely different species (*Castanea sativa*) Regina *et al.* (2001) have reported similar results. Reduction in concentration of N and P from initial stage of leaf development (summer) to leaf maturity (rainy season) suggested utilisation of nutrients for structural building of foliage while reduction in content of nutrients from

mature stage (rainy season/autumn) to senescence/abscission period (winter) indicated retranslocation for conservation of nutrients for future use. Ackerly and Bazzaz (1995) and Hickosaka (1996) have also suggested that retranslocation may occur throughout the life of a leaf but a major pulse of retranslocation normally occurs shortly before leaf abscission. The nutrient retranslocation strategy before abscission is meant for its redeployment in developing tissue such as leaves and seeds or storage for later use by the woody tissues (Wright and Westoby, 2003).

Average per cent retranslocation N (45.3%) and P (27.5%) in present study was lower than the general hypothesis of 50% retranslocation of nutrients before abscission (Erickson, 1994; Aerts, 1996). However, present report falls in the retranslocation range (Table 7) reported for different natural and artificial ecosystems (6-77% N and 23-81% P), forest types (6-69% N and 23-76% P) and plantations (31-77% N and 26-81% P). It is interesting to note that estimation of N (53-65%) and P (50-58%) resorption in teak stands by Karmacharya (1989) is almost

Table 7

Values of retranslocation per cent recorded in different forests and plantation stands

S.N.	Ecosystems	N	P	Source
1	Dry tropical forest, India	(67)	(5)	Singh and Singh (1991)
2	Dry subtropical forest, Puerto Rico	65	-	Lugo and Murphy (1986)
3	Moist tropical forest,	6-58	23-69	Vitousek and Sanford (1986)
4	Mixed hardwood forest	51	61	Ryan and Boreman (1982)
5	Subalpine conifer forest	54	59	Turner and Singer (1976)
6	Chestnut Oak forest	76-80	61-65	Ostman and Weaver (1982)
7	Poplar plantation, India	64.2	46.6	Lodhiyal (1990)
8	Eucalypt plantation, India	(30.4)	(25.9)	Bargali <i>et al.</i> (1992)
9	Teak plantation, India (Moist Deciduous)	(29.9) 45.4	(2.18) 27.5	Present study
10	Teak plantation, India (Dry Deciduous)	53-65	50-58	Karmacharya (1989)
11	Douglas fir	61-69	50-58	Parkinson (1984)
12	Douglas fir	36-42	46-63	Turner (1975)
13	Loblolly pine plantation	45	66	Switzer and Nelson (1974)
14	Loblolly pine	52	47	Wells and Metz (1963)
15	Scott pine stand	69	81	Malkonen (1974)
16	Scott pine	77	-	Stachurski and Zimka (1975)
17	Hornbeam	37-64	-	Stachurski and Zimka (1975)
18	Eastern cottonwood plantation	74	76	Baker and Blackman (1977)
19	<i>Eucalyptus globulus</i>	31-51	26-45	Saur <i>et al.</i> (2000)

Figures in parentheses are total retranslocation ($\text{kg ha}^{-1} \text{ yr}^{-1}$).

closer to the general hypothesis but conspicuously higher than the results of present study. The reason for this contrasting variation in the same species may be possibly the differences in locality factors of two regimes, former being the relatively nutrient poor dry area while latter the nutrient rich moist one. This is consistent with the earlier observation that species of infertile sites show greater proportional retranslocation of N, P, and K than the species adapted to fertile sites (Specht and Groves, 1966; Small, 1972; Thomas and Grigal, 1976; Chapin *et al.*, 1980). Comparison of these two findings in teak also supports the hypothesis of Fife and Nambiar (1997) and Nambiar and Fife (1987) that nutrient retranslocation is not only a mechanism associated with low fertility soil but also occurs copiously in trees on fertile soils.

As compared to the present study N and P retranslocation percentage in dry tropical forests, India (Singh and Singh, 1991) and dry subtropical forests, Puerto Rico (Lugo and Murphy, 1986) is higher but this is well within the range reported by Vitousek and Sanford (1986) in moist tropical forests. This is also comparable to the earlier findings of Bargali *et al.* (1992) in *Eucalyptus* hybrid growing in the same locality of present study. However, *Populus deltoides* also growing in same climate showed higher retranslocation (Lodhiyal, 1990). This is an indication that only edapho-climatic factors do not control retranslocation of nutrient. It is possibly governed by the requirement of a particular species. Radloff (2000) has also suggested that tree species is the main determinant of retranslocation.

Leaf mass loss (LML) and nutrient retranslocation found directly proportional to each other is in consonance with Ralhan

and Singh (1987) who found positive correlation between LML and nutrient removal from leaves. Chapin and Kedrowski (1983) have same results in the case of N and P for a wide range of species. Assuming that leaf mass loss is a measure of the total quantity of material retranslocated from leaves, they suggested that over all phloem transport rate may influence N and P retranslocation. LML percentage also showed positive correlation with chronosequence LAI (exception 30 year stand) of present study.

Lower percentage loss of leaf mass (29%) in teak stands is indicative of infertile sites as also suggested by Chapin and Kedrowski (1983). However, loss of mass is greater in present study (29%) as compared to deciduous species of temperate region (18%) as reported by Chapin and Kedrowski (1983). Present values fall within the range (21-34%) reported by Ralhan and Singh (1987) in the case of deciduous subcanopy trees and shrubs of submontane evergreen forests.

The relationship between age of the stands and retranslocation amount of N and P in present study was not consistent. This finding did not support the earlier report of Bargali (1990) and Lodhiyal (1990) working in the same locality on chronosequence plantations of *Eucalyptus* hybrid and *Populus deltoides*, respectively. They found negative relationship between these two parameters. It is likely possible that not only one but also interaction of multiple parameters influence nutrient retranslocation. In this regard suggestion of Ralhan and Singh (1987) and Nambiar and Fife (1991) could be taken in to account that climate (soil and environmental factors), growth form, and eco-physiology of the species, etc. play significant role in determining the nutrient retranslocation.

SUMMARY

Foliar dynamics strongly influences the nutrient pool in general and retranslocation enables plants to conserve and reuse nutrients in particular. Therefore, to have the understanding of such functions, patterns of monthly leaf mass changes and leaf area expansion, and annual nutrient retranslocation were studied in 1, 5, 11, 18, 24 and 30 years old teak plantations of moist deciduous forest region at the base of the Himalayas (29°3'-29°12' N and 79°20'-79°23' E). In these stands leaves kept on expanding and gaining mass from April to September. Leaf area and leaf mass varied between 376-473 cm² leaf⁻¹ and 3.3-5.0 g leaf⁻¹, respectively. Leaf area index (LAI) ranged from 1.49 to 7.6. Concentration of nitrogen (N) and phosphorus (P) was highest in summer while it was lowest in winter. Nevertheless, nutrient content of leaves was minimum in summer and maximum in rainy season or autumn. Average percent retranslocation values were 45.6 % (N), and 27.51 % (P) and average annual retranslocation were 29.957 kg ha⁻¹ yr⁻¹, and 2.186 kg ha⁻¹ yr⁻¹, respectively. Non-canopy stand (1 year) showed minimum retranslocation of both N and P. Although the retranslocation of N and P and leaf mass loss (LML) was prominent in all the stands regression relationship of N and P retranslocation with certain parameters like, LML, LAI, leaf area, leaf weight, stand age and basal area were not found significant (>5%). Nevertheless, the retranslocation data suggested that teak growing in tropical moist region is moderately efficient in nutrient conserving mechanism.

उत्तरी भारत के आर्द्र पर्णपाती वन क्षेत्रों में उगाए जा रहे आयु-संश्रेणी टेक्टोना ग्रांडिस रोपवन में पर्ण गतिकी और पोषाहारों का पुनर्स्थानान्तरण

कोशलेन्द्र कुमार झा

सारांश

पत्तियों की गतिकी पोषाहार संचयन पर सामान्यतः और पुनर्स्थान्तरण विशेषतः पेड़-पौधों द्वारा उनका संरक्षण करने और पोषाहारों को पुनः उपयोग करने पर बहुत प्रभाव डालते हैं। इसीलिए ऐसे कार्यों की जानकारी पाने को पत्तियों के पुंज में होने वाले मासिक परिवर्तनों की सज्जा और पर्णक्षेत्र के विस्तार और वार्षिक पोषाहार पुनर्स्थान्तरण का अध्ययन हिमालय की तलहटी में स्थित (29°3'-29°12' उत्तर और 79°20'-79°23' पूर्व) आर्द्र पर्णपाती वन क्षेत्रों में लगे हुए 1, 5, 11, 18, 24 और 30 वर्षीय सागौन रोपवनों का अध्ययन किया गया। इन संनिधियों में पत्तियां अप्रैल से सितम्बर तक निरन्तर विस्तार और पुंजवर्धन करती रही। पर्ण क्षेत्रफल और पर्णपुंज में क्रमशः 376-473 सेमी²/पर्ण और 3.3-5.0 ग्राम/पर्ण की घटबढ़ रहती पाई गई। पर्ण क्षेत्रफल निर्देशांक 1.49 से लगाकर 7.6 तक रहा। नाइट्रोजन और फास्फोरस का संकेन्द्रण गर्मियों में अधिकतम और सर्दियों में न्यूनतम पाया गया। तथापि, पत्तियों का पोषाहार तत्व गर्मियों में न्यूनतम और बरसात अथवा शिशिर (पतझड़ वाला मौसम) में अधिकतम निकला। औसत प्रतिशत पुनर्स्थान्तरण अर्थात् 45.6 % (नाइट्रोजन) और 27.51 % (फास्फोरस) की तथा उनका औसत वार्षिक पुनर्स्थान्तरण क्रमशः 29.957 किग्रा/हेक्टे०/वर्ष और 2.186 किग्रा/हेक्टे०/वर्ष रहा। वितान रहित संनिधि (1 वर्ष की) में नाइट्रोजन और फास्फोरस दोनों पुनर्स्थान्तरण न्यूनतम दिखाई पड़ा। हांलाकि नाइट्रोजन और फास्फोरस का पुनर्स्थान्तरण तथा पर्णपुंज में हुई कमी संनिधियों में दिखाई पड़े नाइट्रोजन और फास्फोरस पुनर्स्थान्तरण के कतिपय परिमाणों जैसे पर्णपुंज में हुई कमी, पर्णक्षेत्रफल निर्देशांक पत्तियों का भार, संनिधि की उम्र और आधारित क्षेत्रफल के साथ प्रतीपायन सम्बन्ध सार्थक (> 5%) रहते नहीं पाए गए। तथापि, पुनर्स्थान्तरण आंकड़े यह सुझाते हैं कि उष्णदेशीय आर्द्र क्षेत्रों में सागौन को उगाना पोषाहार संरक्षण की यन्त्रक्रिया दृष्टि से मध्यमतः कार्यक्षम रहता है।

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