Geo-Eco-Trop, 1982, 6 (1) 33-44

LITTERFALL PATTERN IN A SUB-TROPICAL EVERGREEN MONTANE FOREST IN NORTH-EAST INDIA

Apports de matière organique à la litière en forêt montagnarde sempervirente subtropicale dans le N.E. de l'Inde

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RESUME

Les apports organiques totaux à la litière atteigent 8,95 t.ha^{-1}.an^{-1} dans une forêt montagnarde sempervirente subtropicale à Shillong, dans le N.E. de l'Inde. Le matériel a été trié en cinq catégories, à savoir feuilles, rameaux, fleurs, fruits et divers; cette dernière catégorie comprend les fragments de feuilles, l'écorce, etc ... Ces catégories contribuent respectivement pour 63, 16, 3, 6 et 12 % des apports organiques à la litière. La chute de cette matière organique s'observe tout au long de l'année, mais un maximum distinct se situe en mars. La quantité de matière organique qui tombe pendant les mois secs (novembre à avril) est environ trois fois supérieure à celle observée pendant la partie humide de l'année. La durée moyenne de vie des feuilles a été estimée à une valeur de l'ordre de vingt mois pour la forêt étudiée.

ABSTRACT

Total aboveground litterfall in a sub-tropical evergreen montane forest at Shillong (1900 m) averaged 8.95 t.ha^{-1}.yr^{-1}; leaves, twigs, flowers and fruits contributed 63 %, 16 %, 3 % and 6 % respectively. Other miscellaneous litter fraction consisting of fragments of leaf tissue, bark, etc ... accounted for 12 % of the total annual litterfall. Litterfall occurred throughout the year, but with a distinct peak in the months of March. The rate of litterfall in the drier part of the year (November to April) was approximately thrice the rate during the wetter part of the year. Mean leaf-life was estimated to be an average of twenty months for the forest.

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INTRODUCTION

The importance of litter production in the forest ecosystem has long been recognized; therefore this is one of the aspects that has received much attention (BRAY & GORHAM, 1964; JENSEN, 1974; JORDAN & MURPHY, 1978). While most of the studies on litter production have been done on temperate forests, tropical and sub-tropical forest ecosystems have also received some attention (JENNY *et al.*, 1949; LAUDELOT & MEYER, 1954; MALAISSE *et al.*, 1975; NYE, 1961; CORNFORTH, 1971; HAINS & FOSTER, 1977; KLINGE, 1977; KLINGE & RODRIGUES, 1968; KUNKEL-WESTPHAL & KUNKEL, 1979; SINGH, 1980). However, the data available on tropical and sub-tropical montane forests are few and scattered. A few important studies on the montane forests of the tropical and sub-tropical belt are those of JENNY *et al.* (1949) in Colombia (1630 m), EDWARDS (1977) at New Guinea (2400 - 2500 m), SAXENA *et al.* (1978) at Nainital, India (1950 - 2200 m) and TANNER (1980) at Jamaica (1500 m).

The present study on litter production pattern of a sub-tropical montane forest at an elevation of 1900 m near Shillong concerns that of a mixed evergreen sacred forest grove. This sacred grove has been maintained by the local Khasi tribe with least disturbance as they believe that their sylvan deities live here and therefore this represents a relict climax community of this area which otherwise is highly disturbed due to slash and burn agriculture (RAMAKRISHNAN & TOKY, 1978) which is a prevalent form of agricultural pratice of the region. Majority of the trees of this forest, although evergreen, are strongly seasonal in their phenology. This study on the seasonal pattern of litterfall is, therefore, of considerable interest from phenological and production ecological points of view.

METHODS OF STUDY

The study area, climate and vegetation have been described elsewhere (BOOJH & RAMAKRISHNAN, 1981).

Litter was collected from 12 randomly placed 1 m^2 permanent quadrats, demarcated by wooden frames with a permanently fixed nylon mesh at a height of about 15 cm from the ground which permitted drainage of water without any litter loss. Litter sampling was done at monthly intervals during drier months and at fornightly intervals during the rainy season. The collection material was classified according to the tree

species and the individual fractions of litter and was oven dried at 85° C to a constant weight. Leaf litter was separated into 12 major tree species and all other species were considered under the mixed leaf category. Flowers, fruits and twigs were considered jointly for all the species. Unidentifiable plant litter other than those considered above were grouped into miscellaneous category.

The average leaf-life of the forest as a whole was based on 12 important tree species in the forest, on the basis of periodic observations of identified leaves on a number of individuals.

RESULTS AND DISCUSSION

Leaf-life

The mean leaf-life value of about 20 months for the important trees in the forest suggests the generally evergreen physiognomy of the forest. The leaves of *Cinnamomum impressinervum*, *Machilus kingii*, *Quercus dealbata* and *Q. paniculata* which are dominant species in the forest were retained for periods greater than two years. The deciduous species like *Litsea sebifera* and *Schima khasiana* showed an average leaf-life of one year only. *Acer laevigatum*, *Lindera pulcherima* and *Manglitia insignis* fall in between these two extremes (Tab. I).

Species	Average leaf-life (months)
Acer laevigatum	14
Cinnamomum impressinervum	26
Elaeocarpus pyriformis	18
Lindera pulcherima	15
Litsea sebifera	12
Machilus kingii	28
Manglitia insignis	16
Quercus dealbata	30
Q. paniculata	30
Rhododendron arboreum	20
Schima khasiana	12
Symplocos crataegoides	18
Total	20

Tab. I : Mean leaf-life of some important tree species.

Litterfall

The total annual litterfall in the forest worked out to 8.96 t. $ha^{-1}.yr^{-1}$. A major fraction of this was represented by leaf, followed by twigs, miscellaneous litter, fruits and flowers (Tab. II). The specieswise contribution of leaf litter was highest for *Quercus dealbata* an important overstorey species followed by *Symplocos crataegoides* a dominant of the understorey (Appendix).

Litter fractions	Amount (t/ha/yr) ± S.E.	% of the total litter
Leaves	5.68 ± 0.56	63.4
Twigs	1.45 ± 0.18	16.2
Fruits	0.50 ± 0.08	5.6
Flowers	0.27 ± 0.06	3.1
Miscellaneous	1.05 ± 0.11	11.7
Total	8.96 ± 0.72	100

Tab. II : Annual contribution by different litter fractions.

Comparisons with other montane tropical/sub-tropical forests

In any comparison of litter production it is important to consider the highly variable nature of litterfall in space and time. The results presented here showed that the standard error of the mean was usually less than 10 % of the mean for the major litter fractions as well as total litter (Tab. III). Since a similar degree of variability was also

Litter	Amount t/ha/yr	Range	S.D.	S.E. (%)
Leaves	5.68	2.94 - 8.70	1.95	9.94
Twigs	1.45	0.60 - 2.44	0.63	12.48
Fruits	0.50	0.16 - 1.07	0.27	15.35
Flowers	0.27	0.02 - 0.74	0.20	21.08
Miscellaneous	1.05	0.60 - 1.69	0.37	10.06
Total	8.96	2.66 -13.32	2.50	8.08

Tab. III : Accuracy of measurements for litter and litter fractions.

found by many other workers (KLINGE & RODRIGUES, 1968; BRASSEL *et al.*, 1980; TANNER, 1980), these values can be considered as reliably representative and it may be relevant to the comparisons of the estimates of

FOREST TYPE	ALTITUDE	LITTER FRACTION				AUTHOR
		Leaves	Bark & Twigs	Fruits & Flowers	Total	
Lowland forests						
Semi-evergreen young secondary forest, Zaïre	300	-	-	-	12.3	LAUDELOT & MEYER (1954)
Semi-evergreen secondary forest, Ghana	150	7.0	3.5	-	10.5	NYE (1961)
Mature secondary forest, Panama	137	5.83	2.30	1.23	11.10	HAINS & FOSTER (1977)
Montane forests						
Colombia	1630	-	-	-	10.1	JENNY *et al.* (1949)
Central site of radiation study, Puerto Rico	460	4.8	-	-	-	WIEGERT (1970)
New Guineae	2400-2500	6.35*	1.20**	-	7.55	EDWARDS (1977)
Nainital, India	1950-2200	-	-	-	5.5	SAXENA *et al.* (1979)
Tropical Australia	680-820	-	-	-	9.25	BRASSEL *et al.* (1980)
Jamaica						
- Gap forest	1550	5.5	0.9	-	6.4	TANNER (1980)
- Mor ridge forest		4.9	1.7	-	6.6	
- Mull ridge forest		5.6	0.2	-	5.8	
- Wet selope forest		4.4	1.2	-	5.6	
Shillong, India	1900	5.67	2.50	0.78	8.96	Present study

Tab. IV : The annual litter production in some tropical and sub-tropical forests of the world (values in $t.ha^{-1}$).
* Leaves and other material; ** Woody material.

litterfall from studies of other tropical and sub-tropical montane forests shown in table IV. The annual litterfall recorded in the present study is comparable to the data of others. A comparison with lowland tropical forests, however, indicates that these have generally higher litter production than those obtained in montane forests of higher elevations.

The value of leaf litter is similarly within the range of reported value (6 to 10.4 $t.ha^{-1}.yr^{-1}$, Tab. IV). The higher proportion of leaf fraction in the litter, reported in the present study is also in conformity with the results of others (BRAY & GORHAM, 1964; RODIN & BRAZILEVICH, 1967).

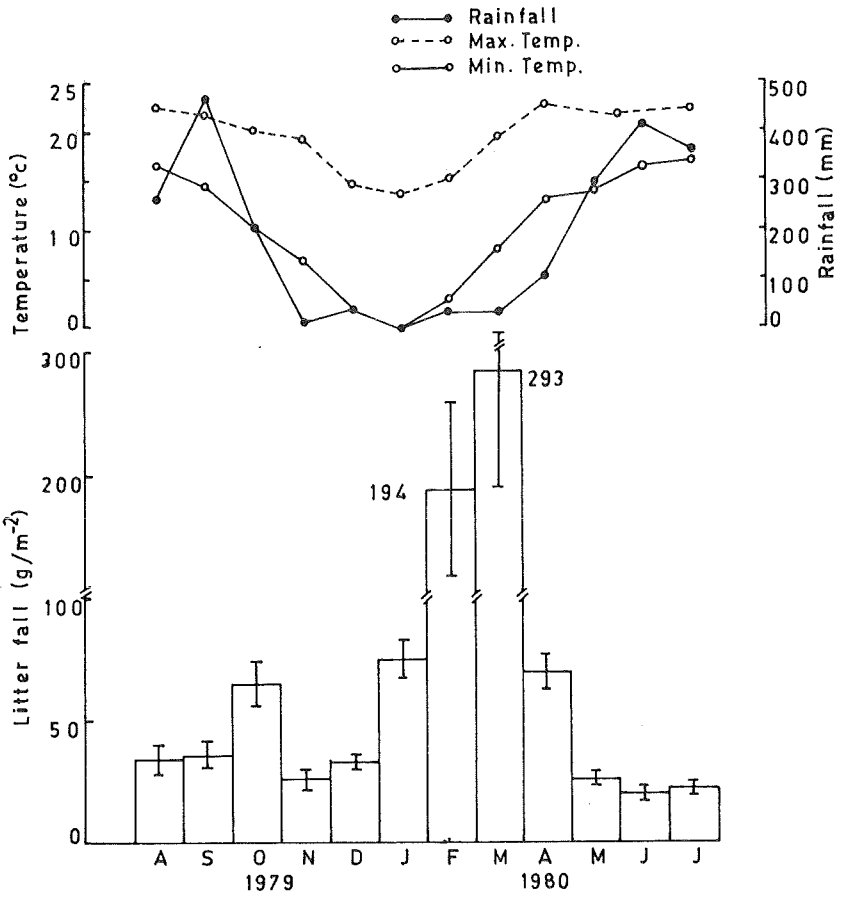

Fig. 1 : Temporal distribution of litterfall, temperature and rainfall in Upper Shillong montane forest. Vertical lines are standard errors of the mean values.

Seasonality of litterfall

Litter fell throughout the year with a marked seasonal distribution. It was less during May to December and was maximum during January to April, with a distinct seasonal peak in the month of March. Another minor peak was seen in the month of October. These periods of maximum leaf shedding corresponded well with the dry periods of the warm season (Fig. 1). Litter production during the dry months was 3 times more than that during the wet period and the rate of fall was also equally high (Tab. V). The seasonal pattern of fall of litter fractions is shown in figure 2. This was similar to the pattern observed for total litterfall. However, maximum flower and fruit litter was found to be in the month of April. The seasonal pattern of leaf litterfall for individual species also followed a more or less similar general trend (Appendix).

Period	Amount of litterfall t/ha/yr	Rate of litterfall g/day
Dry (181 days)	6.92 (77)	3.82
Wet (184 days)	2.04 (23)	1.11
Total	8.96 (100)	2.45

Tab. V : The seasonality of litterfall in Upper Shillong Forest during 1979-1980; values in parentheses are % of the total in each column.

JORGENSEN (1975) maintained that three main factors limit litter production - temperature, water and nutrient availability. At the present study site the temperature and rainfall variables are quite seasonal which cause large seasonal fluctuations in the fall pattern. The rate of litterfall was also almost 3 times higher during dry season compared to that during wet period. Such a pattern of coincidence of litterfall with the dry season was also reported by others (NYE, 1961; KLINGE & RODRIGUES, 1968; MALAISSE *et al.*, 1975; SINGH, 1980; TANNER, 1980) which is related to water stress (WHITMORE, 1975). While the litterfall pattern generally coincided with phenological events in the forest (BOOJH & RAMAKRISHNAN, 1981) fruit fall was maximum during April though majority of the species produced mature fruits in the preceding October. This is due to heavy fall of fruits of *Litsea* and *Lindera* during the month of April which contributed to the fruit litter.

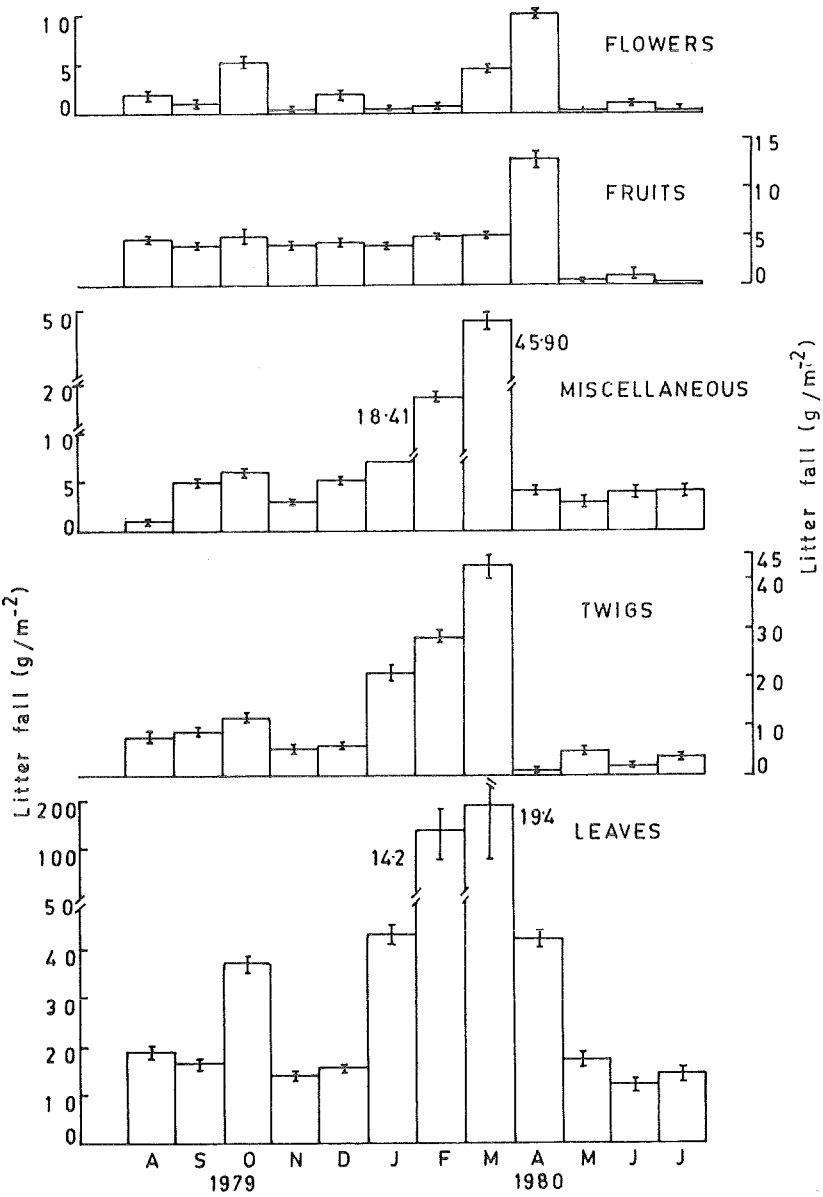

Fig. 2 : Seasonal pattern of fall of litter fractions in the Upper Shillong montane forest. Vertical lines are standard errors of the mean values.

ACKNOWLEDGEMENTS

This research work was financed by the Department of Science and Technology, Government of India. R. BOOJH acknowledges the Council of Scientific and Industrial Research, New Delhi also for the award of Junior Research Fellowship during the preparation of this paper. We are grateful to Dr. V. MEENTEMEYER, University of Georgia, Athens (U.S.A.) for critically going through the manuscript.

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	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Total
Acer Laevigatum	-	-	-	0.2 ±0.2	0.6 ±0.5	5.2 ±1.6	8.9 ±3.9	1.9 ±0.6	0.5 ±0.4	0.1 ±0.05	0.1 ±0.1	0.05 ±0.03	17.5 (3.1)
Cinnamomum impressinervum	0.3 ±0.1	0.1 ±0.1	0.4 ±0.2	0.1 ±0.1	0.4 ±0.2	0.6 ±0.4	4.0 ±1.9	14.8 ±2.4	0.5 ±0.2	1.3 ±0.1	0.4 ±0.2	0.4 ±0.2	23.3 (4.1)
Elaeocarpus lancifolius	-	1.4 ±0.8	0.5 ±0.3	0.9 ±0.4	0.3 ±0.2	0.5 ±0.3	13.6 ±5.3	16.2 ±4.6	4.2 ±2.5	1.5 ±0.9	0.3 ±0.2	0.9 ±0.5	40.2 (7.1)
Lindera pulcherima	0.4 ±0.3	0.4 ±0.2	0.5 ±0.3	0.4 ±0.2	0.4 ±0.2	3.2 ±1.3	7.8 ±3.3	7.7 ±4.3	0.7 ±0.3	0.6 ±0.3	0.8 ±0.3	0.9 ±0.3	23.9 (4.2)
Litsea sebifera	-	-	0.4 ±0.2	0.4 ±0.3	0.3 ±0.2	0.7 ±0.4	3.5 ±2.5	1.0 ±0.8	1.4 ±0.9	1.2 ±1.0	0.1 ±0.1	1.1 ±0.9	10.0 (1.8)
Machilus kingii	1.0 ±0.8	0.3 ±0.1	2.5 ±0.9	0.2 ±0.1	0.3 ±0.1	0.6 ±0.2	2.3 ±1.6	4.6 ±1.8	1.5 ±0.7	0.7 ±0.3	0.1 ±0.1	0.5 ±0.2	15.0 (2.6)
Manglitia insignis	0.7 ±0.4	0.8 ±0.7	3.2 ±1.4	1.3 ±0.5	0.6 ±0.3	1.4 ±0.6	5.7 ±2.3	14.2 ±7.9	1.7 ±0.9	0.4 ±0.3	0.6 ±0.4	0.2 ±0.2	30.9 (5.4)

	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Total
Quercus dealbata	4.4 ±1.4	2.5 ±1.0	2.0 ±0.9	1.1 ±0.5	1.4 ±0.7	2.5 ±1.2	18.9 ±9.8	45.5 ±17.9	10.7 ±6.0	2.6 ±0.8	2.3 ±0.6	3.0 ±1.7	96.9 (17.1)
Q. paniculata	- -	0.2 ±0.2	4.1 ±4.1	1.0 ±0.4	0.8 ±0.4	3.9 ±1.4	14.2 ±5.6	19.2 ±7.4	4.6 ±2.7	3.1 ±1.8	0.6 ±0.4	0.8 ±0.5	52.4 (9.2)
Rhododendron arboreum	0.9 ±0.8	1.7 ±1.7	0.8 ±0.4	1.7 ±1.3	0.4 ±0.1	1.0 ±1.0	2.5 ±2.5	5.7 ±5.7	0.4 ±0.3	0.3 ±0.3	0.2 ±0.2	0.9 ±0.9	16.5 (2.9)
Schima khasiana	0.4 ±0.3	0.7 ±0.4	6.3 ±4.0	0.6 ±0.4	2.4 ±0.9	7.8 ±4.0	6.7 ±3.4	1.3 ±0.7	0.3 ±0.2	0.3 ±0.2	0.5 ±0.4	0.4 ±0.2	27.7 (4.9)
Symplocos crataegoides	3.4 ±1.1	2.5 ±0.7	1.5 ±1.1	2.3 ±1.3	1.5 ±0.6	5.1 ±1.9	18.9 ±5.5	21.6 ±7.1	6.4 ±2.2	1.9 ±0.7	1.0 ±0.2	1.1 ±0.5	67.2 (11.8)
Others	7.8 ±0.9	5.7 ±0.8	15.1 ±7.2	3.9 ±0.5	6.2 ±1.1	10.0 ±1.2	34.5 ±9.3	50.7 ±20.6	9.4 ±0.9	4.6 ±0.8	5.2 ±0.8	4.3 ±0.7	141.1 (25.4)
Total	19.3 ±2.7	16.5 ±2.7	37.2 ±7.7	14.1 ±2.1	15.5 ±1.8	42.6 ±4.1	141.9 ±26.6	194.3 ±42.6	42.2 ±5.0	17.4 ±1.9	12.3 ±1.8	14.4 ±2.4	567.58 (100)

Appendix : Monthly variation of leaf litter (g m^{-2} yr^{-1}) in different tree species (± S.E. of the mean and values in parentheses are % of the total).