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A quantitative study of the forest floor, litter fall and nutrient return in an oak-conifer forest in Himalaya

I. — *Composition and dynamics of forest floor*

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SUMMARY

The present study, which deals with the dynamics of forest floor in a mixed oak-conifer forest at Naini Tal in Kumaun Himalaya, indicated yearlong occurrence of two distinct litter materials, besides the herbaceous vegetation, on the forest floor: (*a*) the uppermost layer of fresh leaf litter and (*b*) partially decomposed material which sometimes assumed a multilayered structure depending upon the kind of overhead species and season. The greatest amount of fresh litter was contributed by one of the most dominant species on this site, viz., *Quercus floribunda*. The peak values of fresh litter and partially decomposed material occurred in the period April-May and in May, respectively. The relative contribution of partially decomposed material to the total forest floor remained greatest in all the months. The herbaceous vegetation on the forest floor reflected maximum biomass in September with total annual net production of 108.9 $g.m^{-2}$. The total calculated annual input of litter was 612.63 $g.m^{-2}$. About 72 % of the forest floor was replaced each year with a consequent turnover time of 1.4 years.

KEY-WORDS: *Himalaya - Upland forest - Herbaceous production - Litter structure - Litter production.*

RÉSUMÉ

Cette étude traite de la dynamique du tapis herbacé et de la litière dans une forêt mixte à chênes et à conifères de Naini Tal dans l'Himalaya de Kumaon. La litière est formée (*a*) de feuilles fraîchement tombées (strate supérieure) et (*b*) de matériaux plus ou moins décomposés se répartissant parfois en plusieurs strates inférieures selon la saison et la composition du peuplement dominant. *Quercus floribunda*, une des especes dominantes, fournit la plus grande partie de la litière. La litière fraîche ou partiellement décomposée, atteint une valeur maximale en avril-mai. Quel que soit le mois, il y a toujours plus de litière altérée que de litière fraîche. Le maximum de biomasse herbacée est atteint en septembre et la production nette est de 108,9 $g.m^{-2}.a^{-1}$. La production annuelle de litière est de 612,63 $g.m^2$. Environ 72 % de la biomasse végétale au niveau du sol (tapis herbacé et litière) se trouvent renouvelés chaque année (renouvellement complet en 1,4 an).

MOTS-CLÉS : *Himalaya - Forêt d'altitude - Strate herbacée - Litière - Structure - Production.*

INTRODUCTION

The Himalayan chain of mountains harbours a great variety of forest types ranging from tropical dry deciduous forest in the foothills to alpine scrub forests near the timber line (CHAMPION & SETH, 1968). Among these, the Himalayan moist temperate forests, extending from 1 500 to 3 000 m in the western and central Himalaya, are characterized by extensive pure and mixed oak-conifer forests. However, increasing biotic pressure within this zone in recent years has caused extensive deforestation which in turn has augmented massive soil erosion in the hills and floods in the plains consequent to silting of rivers. This has necessitated a rational and scientific management of the Himalayan forests which can be achieved only after a thorough understanding of the structure and function of these ecosystems. Unfortunately there is a conspicuous lack of data on the quantitative ecology of Himalayan forests. The present study successively examines the composition and structure of the forest floor, litter fall and consequent nutrient return in a mixed oak-conifer forest.

The forest floor has been defined by the third International Congress of Soil Science (HEIBERG, 1937) as the whole of the organic material on the soil surface. This includes the floor vegetation and litter in different stages of decomposition. MEDWECKA-KORNAS (1971) defined litter as the material lying on the soil surface and composed of dead plants and shed organs (excluding standing dead material). According to ROCHOW (1974), litter consists of dead or drying leaves, twigs, branches, bark, flowers and fruits and other debris that constitute part of the forest ecosystem. The organic-matter present on the forest floor plays a major role in determining ecosystem structure and function, and represents an energy source for heterotrophic organisms, a nutrient reservoir for intrasystem cycling and a regulatory factor influencing forest hydrology (LANG, 1974; CHAPMAN *et al.*, 1975). ASHTON (1975) argued that the litter on forest floor represents an important stage in the cycle of habitat conservation, and ASHTON & MACAULEY (1973) have emphasized the role of forest floor in forest reproduction.

The first paper of the series deals with the composition and dynamics of the forest floor, while the subsequent paper quantifies the litter fall and nutrient return to the forest floor.

DESCRIPTION OF THE STUDY AREA AND METHODS

Location

The study site is located at Naini Tal (29°24′ N lat. and 79°28′ E long.) in a protected reserve forest at an altitude of 2.050 m on north-west aspect. The soil is residual, originating from krol limestone.

Climate

The mean maximum temperature at Naini Tal varies from 10.3° C in January to 27.7° C in May and the mean minimum from 3.6° C in January to 16.9° C in June. The average monthly rainfall ranges from 6.8 mm (November) to 804.3 mm (July) with the total annual being 2,821.6 mm. Based on the climatic va[illegible] the year is divisible into three seasons, viz., summer (April to the first fortnight of June), rainy (second fortnight of June to September), and winter (November to February). The months of March and October constitute transition periods, respectively, between winter and summer, and between rainy and winter seasons. The ombrothermic diagram (fig. 1) indicates that the rainy season is flanked with a warm and a cool dry period. The area is markedly affected by summer monsoon, arrival of which heralds the onset of the rainy season in the later part of June, and its retreat by the end of September coincides with lowering of temperature and gradual advent of the winter season. Infrequent winter showers occur during December-February due to the low pressure troughs in the westerlies which sweep over the ranges at that time. During this period there also occurs light snow fall and hailstorms although their frequency is very irregular.

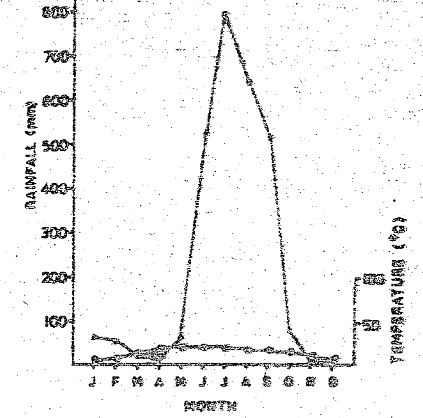

FIG. 1. — Ombrothermic diagram for Naini Tal based on five year data, 1970-1975.

Methods

The phytosociological analysis of the woody community was done through point centred quarter method (COTTAM & CURTIS, 1956) by taking 150 points or 600 quarters distributed randomly within an area of about 2 ha.

The forest floor was categorised into two main components, viz., herbaceous vegetation and litter. Litter was further categorised into: fresh tree leaf litter (by species, viz., *Aesculus indica*, *Cedrus deodara*, *Cupressus torulosa*, *Ilex dipyrena*, *Quercus floribunda*, *Quercus leucotrichophora* and *Fraxinus micrantha*), partially decomposed leaf-litter, woody litter (including fruits), and miscellaneous litter (consisting of the material belonging to other than the above mentioned categories). The herbaceous vegetation was categorised into live and standing dead shoots.

The data on forest floor components were collected by using 50 × 50 cm harvest plots. A total of ten random quadrats were sampled on each sampling date at one month interval, beginning January 14, 1977 to December 14, 1977. In each quadrat all the live and standing dead herbaceous vegetation was first harvested at ground level. The harvested material was placed in numbered polyethylene bags. The material on forest floor left after harvesting the herbaceous vegetation was collected in separate bags by categories as mentioned above.

The data were analysed through analysis of variance following SNEDECOR & COCHRAN (1968).

RESULTS

TREE VEGETATION

Table I includes data on the structure of woody community. In all, the forest consisted of 16 tree elements, out of which 9 were conifers and 7 broad-leaf species. Three species, viz., *Aesculus indica*, *Lyonia ovalifolia* and *Fraxinus micrantha*, are of deciduous nature, the rest (including the two oaks, *Quercus floribunda* and *Q. leucotrichophora*) being evergreen. *Cupressus torulosa* followed by *Q. floribunda* had maximum total basal cover in this forest. However, the maximum mean basal area per tree was exhibited by *Pinus roxburghii*, while the minimum was recorded for *Cunninghamia lanceolata*. Although, the mean basal area of *Q. floribunda* was much lower compared to *C. torulosa*, because of its higher relative density and frequency it assumed an importance value index (IVI) almost similar to that of *C. torulosa*. Other important species, in terms of IVI, were *A. indica*, *Q. leucotrichophora*, *Cedrus deodara* and *Ilex dipyrena*. The total tree density was 13.45 per 100 m^2 and the total basal cover was 5,339.8 cm^2 per 100 m^2.

TABLE I

Analysis of tree layer of mixed oak-conifer forest at Naini Tal (only trees ≧ 31.5 cm cbh are considered in this table).

Species	Density (plants 100 m^{-2})	Mean basal area ($cm^2.tree^{-1}$)	Total basal cover ($cm^2.100 m^{-2}$)	Relative dominance (%)	Relative density (%)	Relative frequency (%)	Importance value index (IVI)
Cupressus torulosa D. Don.	2.80	793.6	2,222.2	41.6	20.8	19.6	82.0
Quercus floribunda Rehder	4.53	231.7	1,049.7	19.7	33.6	28.3	81.6
Aesculus indica Colebr.	1.43	315.9	451.8	8.5	10.6	11.3	30.4
Quercus leucotrichophora A. camus	1.26	327.2	412.3	7.7	9.4	11.3	28.5
Cedrus deodara Roxb.	0.98	527.7	517.2	9.7	7.3	8.6	25.6
Ilex dipyrena Wall.	0.87	254.0	221.0	4.2	6.5	9.5	20.2
Ilex odorata Buch. Ham.	0.54	276.0	149.0	2.8	4.0	3.6	10.4
Abies pindrow Royle.	0.54	151.0	81.5	1.5	4.0	2.7	8.2
Pinus wallichiana Jackson	0.13	556.4	72.3	1.4	1.0	1.2	3.6
Picea smithiana Wall.	0.10	431.3	43.1	0.8	0.8	0.9	2.5
Lyonia ovalifolia Wall.	0.13	261.7	34.0	0.6	1.0	0.9	2.5
Cryptomeria japonica Linn.	0.04	937.3	37.5	0.7	0.3	0.6	1.6
Fraxinus micrantha Lingelsh.	0.04	267.8	10.7	0.2	0.3	0.6	1.1
Pinus roxburghii Sarg.	0.02	1,127.0	22.5	0.4	0.2	0.3	0.9
Taxus baccata Linn.	0.02	623.5	12.5	0.2	0.2	0.3	0.7
Cunninghamia lanceolata Hook.	0.02	127.0	2.5	0.1	0.2	0.3	0.6

HERBACEOUS VEGETATION

The peak biomass of live shoots occurred in September and the lowest in January (fig. 2). The analysis of variance indicated significant differences in the biomass for different months ($P < 0.001$).

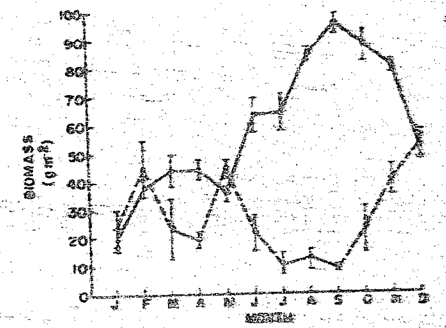

FIG. 2. — Variation in the biomass of live (solid line) and standing dead shoots (broken line) on the forest floor.

The rather rapid increase in the biomass during the period May-September was due to a fast growth of herbaceous vegetation triggered by warm temperatures and accentuated rainfall in that period. September marked the end of growth period as temperature and moisture started declining and as a result the herbaceous plants began to die. The decline in the biomass after September resulted from death and shattering of annual plants following maturity. The bulk of live biomass was thus transferred to the standing dead compartment during September-December.

The trend of changes in the biomass of dead shoots, for the greater part, was reverse to that of live shoots: the accumulation of dead shoots was most rapid during the period September-December (fig. 2). The small peaks in February and May perhaps reflect respectively, winter mortality and hydric deficiency of April. The differences in the biomass for different months were statistically significant ($P < 0.001$).

The net above-ground primary production (*ANP*) of herbaceous vegetation was calculated as:

$$ANP = \sum_{i=1}^{n} \Delta LS + \sum_{i=1}^{n} \Delta DS$$

where *LS* is positive increment in biomass of live shoots and *DS* is the positive increment in biomass of dead shoots summed over same sampling intervals (n). The estimate came to 108.9 $g.m^{-2}$. This method was argued by Singh et al. ([illegible]) to be among the best for estimating *ANP* from harvest data.

LITTER LAYERS

Due to perpetual leaf-fall in this mixed oak-conifer forest the litter layer varied in thickness throughout the year. The total thickness ranged from 2 to 5 cm in winter and summer, and 1 to 3 cm in rainy season.

The superficial layer was comprised of fresh leaf litter. Beneath this layer was the fragmented and partially decomposed litter. The layering in the partially decomposed stratum depended upon the overhead species and season (fig. 3). In general, the number of layers in this stratum varied from 1 (in areas dominated by broad-leaf species in winter) to 3 (rainy season).

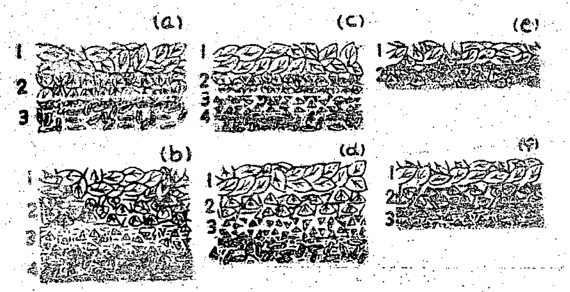

FIG. 3. — Diagrammic representation of the seasonal variation in litter layers. The upper diagrams represent areas dominated only by broad-leaf species and the lower diagrams represent areas where broad-leaf species are intimately mixed with conifers. The fresh leaf litter makes the topmost layer in each diagram.

(a) and (b) = summer season; (c) and (d) = rainy season; (e) and (f) = winter season.

The description of the layering of partially decomposed matter is as follows:

(a) Out of the two layers of partially decomposed material, the upper one was derived from fragmenting effect of rain and hailstorms on the fresh litter and the lower one was comprised of partly decayed material.

(b) Three layers were apparent: the fragmented broad leaves mixed with half decayed coniferous litter was flanked above by fragmented broad leaves and below by partially decayed broad leaves.

(c) Three layers were present: the upper layer consisting of discoloured and somewhat threshed leaves, the second layer of fragmented, thin, papery and yellow coloured pieces of litter with black spots. The lowermost consisted of small black moisturized pieces of litter.

(d) Three layers were apparent: the upper most layer consisted of discoloured and weathered litter (mostly broad leaves) and the middle layer consisted of more fragmented broad leaf litter. The lowermost layer was composed of dark coloured coniferous litter mixed with pieces of broad leaves.

(e) There was only one layer of partially decomposed material.

(f) The upper layer was composed of partially decayed broad-leaf litter and the lower layer of partially decomposed conifer litter.

LITTER BIOMASS

Fresh leaf litter

The maximum standing crop was recorded during April-May and the minimum in September (fig. 4). The fluctuations in the values reflected the varied pattern of leaf-fall in different species; analysis of variance showed significant differences in fresh litter biomass in different months ($P < 0.001$).

Table II includes the standing crop values for fresh leaf litter of the 7 important tree species. The greatest amount of fresh litter was contributed by *Q. floribunda* with peak values in April-May. *Q. leucotrichophora* exhibited greatest contribution to fresh leaf litter in the period March-May, while *A. indica* and *F. micrantha* did so during August-November. *C. deodara*, *C. torulosa* and *I. dipyrena* did not show any marked seasonality. The variance analysis indicated significant differences in the quantities of fresh leaf-litter due to species and due to months ($P < 0.001$). In addition, the species x month interaction was also significant ($P < 0.001$) indicating a differential time pattern of litter deposition by different species.

TABLE II

Variation in biomass of fresh leaf-litter of different tree species ($gm^{-2} \pm 1$ SE).

Month	*Quercus floribunda*	*Quercus leucotrichophora*	*Ilex dipyrena*	*Cedrus deodara*	*Cupressus torulosa*	*Aesculus indica*	*Fraxinus micrantha*
January	17.27 ± 3.07	0.76 ± 0.76	2.28 ± 1.09	0.88 ± 0.37	2.51 ± 1.19	—	—
February	15.28 ± 2.87	2.88 ± 1.27	2.88 ± 1.27	3.24 ± 1.54	1.08 ± 0.65	—	—
March	17.00 ± 3.32	8.20 ± 2.70	1.80 ± 1.21	2.28 ± 1.22	1.96 ± 1.01	—	—
April	70.32 ± 8.89	11.20 ± 4.90	1.26 ± 0.69	2.94 ± 1.44	11.23 ± 6.77	1.92 ± 1.32	0.96 ± 0.96
May	69.95 ± 7.49	9.29 ± 4.95	1.04 ± 0.78	2.13 ± 1.47	2.62 ± 1.46	0.78 ± 0.33	0.53 ± 0.26
June	25.28 ± 11.55	2.18 ± 0.61	—	2.86 ± 0.88	0.92 ± 0.41	0.50 ± 0.50	0.30 ± 0.30
July	7.96 ± 4.46	2.62 ± 1.47	—	3.79 ± 2.02	3.50 ± 1.31	13.84 ± 7.90	2.22 ± 1.92
August	2.15 ± 1.09	1.69 ± 1.02	1.96 ± 1.96	0.92 ± 0.60	0.62 ± 0.42	—	—
September	2.29 ± 0.75	0.44 ± 0.24	0.52 ± 0.36	0.57 ± 0.47	0.49 ± 0.35	7.34 ± 2.28	1.55 ± 1.98
October	6.68 ± 2.09	0.60 ± 0.40	0.41 ± 0.32	3.11 ± 1.61	1.64 ± 0.77	13.64 ± 4.92	3.23 ± 2.16
November	3.65 ± 1.73	0.98 ± 0.39	0.28 ± 0.28	0.30 ± 0.12	1.08 ± 0.63	—	—
December	3.21 ± 1.22	1.31 ± 0.50	1.48 ± 0.99	0.99 ± 0.34	2.87 ± 0.98	—	—

Partially decomposed litter

The mean biomass indicated an increasing trend from January to May (fig. 4). Subsequently, a decreasing trend was evident till September in which month the relatively lowest amount of partially decomposed material was encountered. The greater amounts of partially decomposed litter in May-July were preceded by the peak in April-May in fresh leaf litter. The lower amounts in subsequent months were perhaps due to lower inputs from fresh litter compartment and greater disappearance of old litter. However, an analysis of variance indicated no significant difference in the amounts during the different months. This may indicate that in general, the quantity of organic matter in this compartment remains somewhat stable throughout the year; a balance being achieved in the rates of input of fresh litter and decomposition of the old litter. The larger variability in the data would indicate a marked spatial heterogeneity due to uneven topography (affecting differential accumulations due to wind action) and heterogenous nature of the stand (*i. e.*, microareas dominated by broad-leaved species and others by a mixture of broad-leaved and conifer species).

Miscellaneous litter

The miscellaneous litter consisted of litter of tree species other than those mentioned in table II, herbaceous litter and litter from mosses and ferns. The biomass of miscellaneous litter peaked in October (fig. 4). The relatively greater amounts during August to November reflect a transfer of live and dead herbaceous plants

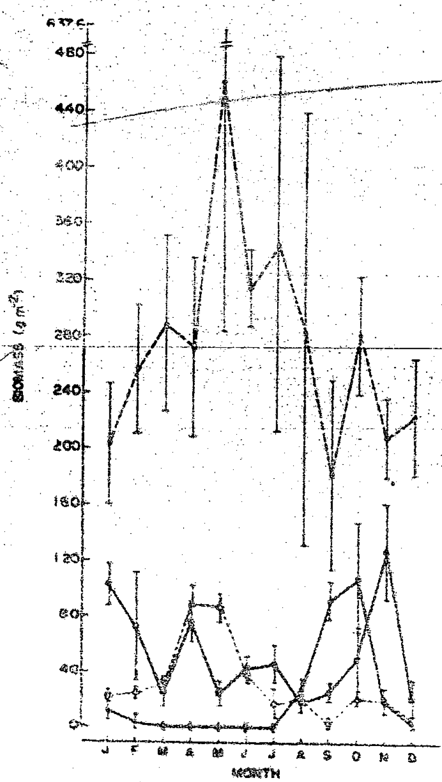

FIG. 4. — Variation in the biomass of fresh (open circles with broken line), partially decomposed (solid circles with broken line), woody (solid squares), and miscellaneous (solid circles with solid line) litter on the forest floor (bars = ± 1 SE).

into this compartment. Additionally, September-October constitute the period of peak litter fall for epiphytic ferns and mosses, and also fern and mosses present on the forest floor. Analysis of variance indicated that the differences in the biomass of miscellaneous litter in different months were significant ($P < 0.001$).

Woody litter

The values fluctuated markedly and no distinct seasonality was apparent (fig. 4). However, the greatest value was observed in November which coincided with massive fruit fall in *C. deodara* and *C. torulosa*. The analysis of variance showed significant differences in the amount in different months ($P < 0.001$).

CALCULATED INPUT OF LITTER

From the time-series data on the biomass of litter of different categories the annual input of litter was calculated as follows (SINGH & YADAVA, 1974; SIMS & SINGH, 1978).—

The significant positive increments in the biomass within the year were summed. Thus, in the fresh litter component a positive increment of 64.8 $g.m^{-2}$ resulted between January and April, and another increment of 19.8 $g.m^{-2}$ occurred during September and October. As a result a total of 84.6 $g.m^{-2}$ of fresh leaf-litter was added. In the case of partially decomposed litter the difference between the biomass in May and January amounted to 257.9 $g.m^{-2}$. This positive increment was concomitant with positive increase in the biomass of fresh leaf-litter; thus this calculation did not result in any double addition. In miscellaneous litter the biomass values between July and October samplings were significantly different and thus an accumulation of 108.1 $g.m^{-2}$ of litter from miscellaneous sources occurred.

This miscellaneous litter also consisted of litter from herbaceous vegetation. The share of herbaceous litter can be calculated through the balance sheet approach as below:

(1) (*ANP*, 108.87 + initial live biomass, 19.50) − (live biomass at the end, 51.05) = transfer to standing dead shoots (77.32).

(2) (Transfer to standing dead, 77.32 + initial standing dead biomass, 22.90) − (standing dead biomass at the end, 51.19) = litter production (49.03).

Thus out of the total input of 108.07 $g.m^{-2}$ as miscellaneous litter, 49.03 $g.m^{-2}$ was due to herbaceous vegetation.

The increments in the biomass of woody litter were significant during the intervals, March-April and August-November, yielding a value of 162.06 $g.m^{-2}$. The total calculated input of litter thus amounted to 84.60 + 257.90 + 108.07 + 162.06 = 612.63 $g.m^{-2}$. These estimates suffer from the fact that the amount which disappeared during the sampling intervals could not be taken into account.

DISCUSSION

The present study revealed yearlong occurrence of two distinct litter materials, besides the herbaceous vegetation, on the forest floor: (*a*) the upper most layer of fresh leaf litter and (*b*) partially decomposed material which sometimes assumed a multilayered structure depending upon the kind of overhead species and season.

HEATWOLE (1961) has classified litter layer into three different classes: class I, consisting of curled leaves with large interstitial spaces; class II, consisting of leaves lying flat upon each other with small interstitial spaces; and class III, consisting chiefly of woody objects not forming a continuous carpet on the forest floor. On the present study site litter of all the above three classes were represented. Class I was comprised of the leaf litter of *A. indica* and *F. micrantha*, and class II was represented by the leaf litter of *Q. floribunda*, *Q. leucotrichophora*, *C. deodara* and *C. torulosa*. The class II could be further classified into "thick" type and "needle" type (HEATWOLE 1961). The leaf litter of *Q. floribunda* and *Q. leucotrichophora* fall under "thick" type while that of *C. deodara* and *C. torulosa* fall under "needle" type. In *I. dipyrena* and *I. odorata* the leaf litter was thick but not leathery. In class III, woody litter of solid and undecayed nature was present.

PANDEYA *et al.* (1968) stated that in temperate conditions there are three distinct layers: (1) litter (*L* or Aoo horizon) layer consisting of plant or animal remains unaltered, (2) *F* layer consisting of partially decomposed organic matter, and (3) *H* layer comprised of well decomposed amorphous organic matter. In contrast, the "floor" in tropical forests is short lived and the *F* layer gets mineralized either in a year or two. This cycle in deciduous forests begins with the formation of *L* layer and ends with its complete biologic degradation (ASHTON, 1975). In the present forest the black, amorphous humus layer described for many temperate forests was not present. The finely divided particulate detritus either remains dispersed with the lower most litter layer or gets rapidly incorporated into the soil due to intense earthworm activity.

The relative contribution of different components to the total forest floor varied markedly in different months (table III). However, the percent contribution of partially decomposed material remained greatest in all the months. Next to partially decomposed material, the biomass of live shoots executed the highest percentages in most of the months. The mean year-long biomass of live herbs was 59 $g.m^{-2}$ and that of dead shoots 26 $g.m^{-2}$, giving a total of 85 $g.m^{-2}$. This value is greater than the values reported for herb biomass in oak-forests in Minnesota (39.6 $g.m^{-2}$; REINERS, 1972) and in oak-forest at Missourie (17.5 $g.m^{-2}$; ROCHOW, 1974). In April and May, the fresh leaf litter showed greatest contribution. This period coincided with massive litter-fall in oaks.

TABLE III

Variation in proportion of various forest floor components in different months (% of total biomass for each month).

Categories	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov	Dec.
Live shoots....	5.06	8.6	10.7	9.0	5.4	13.2	13.2	18.8	23.3	15.2	16.0	14.1
Dead shoots...	5.9	10.1	5.6	1.9	6.8	4.5	2.1	2.7	2.0	3.9	8.1	14.1
Fresh litter....	6.15	5.6	7.6	17.9	13.3	8.0	3.8	5.2	0.9	4.0	4.6	2.6
Partially decomposed litter...	52.8	58.1	69.9	55.3	70.4	64.9	71.2	63.7	44.5	49.0	41.5	62.0
Woody litter...	26.9	16.7	6.1	15.6	3.9	9.1	9.5	4.2	6.6	8.9	25.6	5.8
Miscellaneous litter........	3.2	0.9	0.2	0.2	0.1	0.3	0.2	5.4	22.8	18.9	4.1	1.4

When an analysis of variance was performed taking into account all the forest floor categories (*i. e.* live and dead shoots, fresh litter, partially decomposed litter, woody litter and miscellaneous litter), the differences due to categories were significant ($P < 0.001$) but the differences due to months became non-significant indicating that the total floor biomass, within limits, remains almost constant throughout the year. However, the category x month interaction was significant ($P < 0.001$) indicating differential time pattern for individual categories.

A cross section of average litter biomass values for certain tropical and temperate forests is given in table IV. It is evident that the litter biomass of the present forest corresponds with the lower limit of the range of values for temperate forests and with the upper limit of the range for tropical forests. MADGE (1965) has earlier reviewed some of the litter accumulation data; the values ranged from 170 to

TABLE IV

Litter accumulation in certain forests.

Vegetation type	Average litter biomass ($g.m^{-2}$)	Author(s)
Tropical regions:		
Broad-leaved rain forest.	450.0	JENNY *et al.* (1949), JENSEN (1974).
Mixed rain forest.	430.0	LAUDELOUT & MEYER (1954), WILLIAMS & GRAY (1974).
Moist semideciduous moist evergreen forest.	222.0	NYE (1961), GREENLAND & KOWAL (1960).
Mixed dry lowland forest.	170.0-245.0	MADGE (1965).
Moist evergreen forest.	304	HOPKINS (1966).
Moist deciduous forest.	104-239	HOPKINS (1966).
Tropical deciduous forest.	147.5	SINGH & MISRA (1978).
Evergreen rain forest	100-400	BERNHARD-REVERSAT (1972), BERNHARD (1970).
Temperate regions:		
Oak-pine forest.	1,595	WOODWELL & MARPLES (1968).
Oak-forest.	956	MONK *et al.* (1970).
Oak-forest.	1,260	REINERS & REINERS (1970).
Mature oak-forest in Belgium.	530.0	DUVIGNEAUD & DENAEYER-DE-SMET (1970).
Cryptomeria forest.	777.0-1,500.0	HARADA *et al.* (1972).
Mixed oak-forest.	873	LANG (1974).
Sub-alpine coniferous forest.	5,352.0	TURNER & SINGER (1976).
Present study:		
Mixed oak-conifer forest.	466.4	—

1,470 g.m^{-2} within the tropical zone and from 360 to 3,998 g.m^{-2} in the temperate region.

The turnover rate (K) for the litter on the forest floor was calculated following the method of JENNY *et al.* (1949) and OLSON (1963) as follows:

$$K = \frac{A}{A + F},$$

where A is the annual increment of litter (*i. e.* calculated input of litter to the forest floor) and F is the residual biomass of forest floor. In the present study K has been obtained by taking the minimum total floor biomass as F. Turnover time was calculated as $t = 1/K$.

These calculations indicated that about 72 % of the forest floor is replaced each year with a consequent turnover time of 1.4 years. Thus the forest floor of the present mixed oak-conifer forest is characterised by a high replacement rate and would appear to be quite dynamic.

Thus the absence of the black, amorphous humus layer, a considerable amount of herbaceous vegetation, litter biomass data, and a high turnover rate of the litter layer sets the forest apart from true temperate forests. It may be recalled that the Naini Tal region latitudinally lies in the tropical belt experiencing monsoon effects, although it represents temperate conditions (low temperatures, light snow fall, oak-conifer forests, etc.) altitudinally.

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