Proc. Indian natn. Sci. Acad. B47 No. 6. 852–860 (1981)

Biomass and Nutrient Movement through Litter in *Shorea robusta* Gaertn. Plantations in Meghalaya

JASBIR SINGH and P S RAMAKRISHNAN
Department of Botany, School of Life Sciences, North-Eastern Hill University, Shillong 793 014

(Received 16 June 1981; after revision 29 October 1981)

The nutrient in the biomass, litter and its release through litter into the soil were studied in different-aged plantations of *Shorea robusta* Gaertn. in Meghalaya in north-eastern India. The dry weight of individual trees and standing crop biomass increased with age reaching a maximum in a 19-year old stand. The nutrient concentration in different organs like bole, branches and leaves varied and the total quantity increased with the age of the stand. Leaf and wood litter production showed a seasonal pattern with maximum values in dry parts of the year. Maximum litter production of 3 41 t/ha/yr was recorded in a 13-year old stand. Nutrient concentration also varied in the litter depending upon the season with higher levels for N, P and K during the rainy season and lower levels for Ca and Mg at this time. Nutrient quantity released through litter increased with age of the stand.

Key Words: Biomass, Litter production, Nutrient cycling, *Shorea robusta* plantations

Introduction

The geographical pattern of biomass production in major ecosystem types has been summarized by many workers (Rodin & Bazilevitch 1967 and Lieth & Whittaker 1975). The amount of litter production and composition of it in a forest ecosystem is an important aspect of ecosystem function. This is particularly so where the soil is poor in nutrient status due to high rainfall and/or soil characteristics. However, our understanding of tropical and sub-tropical forests is poor. In India, some studies have been done on the biomass and productivity and nutrient cycling in plantations around Varanasi (Misra et al. 1967 and Singh 1968); but no information is available on forests under sub-tropical humid climate of north-eastern India. The present study, therefore, deals with the biomass, standing crop nutrient and its flow through litter fall in *Shorea robusta* Gaertn. plantations at Umtesor (25° 45″ N latitude and 91° 45″ E longitude) at an altitude of 760 m in Meghalaya.

Climate

The climate is typically monsoonic with an annual precipitation of 240 cm, most of which coming in May to September. The rainy season is followed by a mild winter from mid-November to mid-February. March and April are dry summer months preceding rainfall (figure 1).

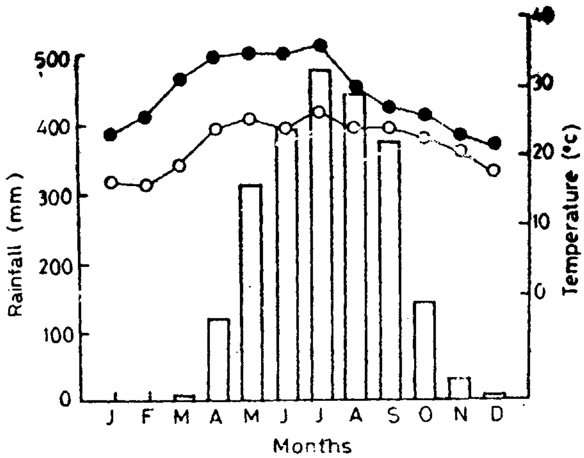


Figure 1 Climate of Umtesor based on the average of two years-1977 and 1978 (data obtained from Department of Silviculture, Government of Meghalaya). Maximum temperature, solid circle; minimum temperature, open circle; rainfall, open triangle.

Methods of Study

Shorea robusta plantations of 9, 11, 13, 15, 17 and 19 years age were selected for various studies. Twenty quadrats of 100 m² were randomly laid in each stand for measurement of density and basal area of trees. DBH was based on the average of all trees within these twenty quadrats. During September 1976, ten randomly selected trees from each stand were felled and their height, branch and leaf number were recorded. Fresh weights of bole, branches and leaves were taken separately. Small composite samples of these components were oven-dried at 80°C and the dry weight computed.

Twenty wooden quadrats of 1 m² each were randomly laid down in each study site and litter collection was done at monthly intervals. The leaf and twig litter was sorted out, oven-dried at 80°C and weighed.

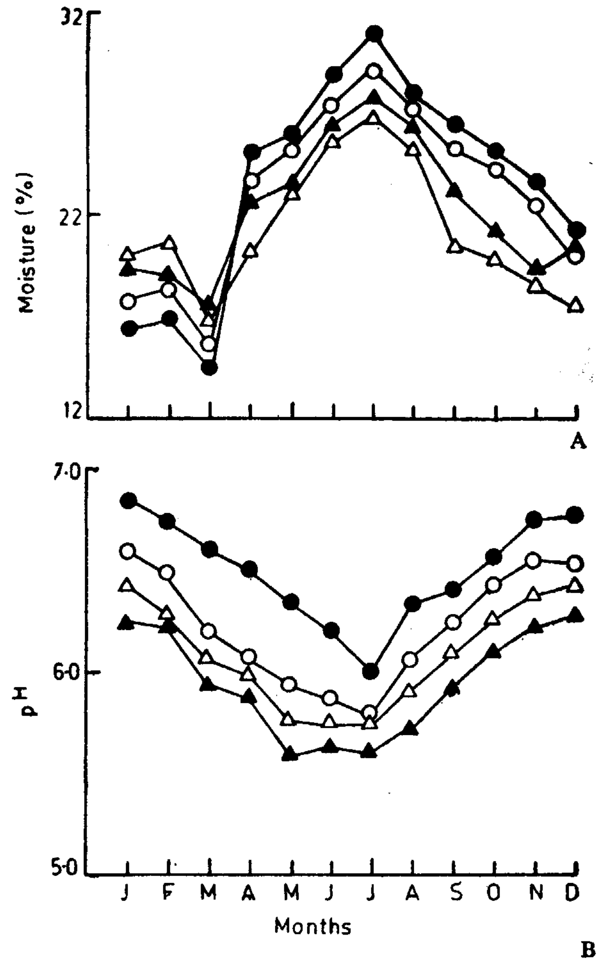
Monthly soil sampling was done in a 19-year-old plantation from 0–10, 10–40, 40–70 and 70–100 cm depths. In other plantations, the soil analysis data presented are only for the 0–10 cm layer in the month of September. All the analyses are based on three replicates. *p*H of the soil was determined in a soil-water suspension of 1:5 using *p*H meter. Total nitrogen, organic carbon, available phosphorus and exchangeable cations were analysed by standard procedures (Jackson 1958 and Allen 1974). Thus, soil carbon was determined by the Walkley-Black method and total nitrogen by the Kjeldahl's method. Calcium and magnesium were analysed by the EDTA titrations while potassium was estimated by flame emission method, after extracting the exchangeable cations with 1N ammonium acetate solution at *p*H 7. Available phosphorus was extracted with Bray-Cruz solution and estimated colorimetrically by the molebdenum-blue method.

The dried plant components and litter were ground into powder, passed through a 20-mesh sieve and analysed for various elements using standard procedures (Allen 1974).

Results and Discussion

Soil

Soil is dark brown in surface layers turning from light red to deep red at depths below 40 cm. In a 19-year-old plantation (figure 2) which is typical of the pattern of fluctuation in chemistry of the soil with depth and with season, *p*H was lower ($P = < 0.05$) during the monsoon season, reaching a minimal value in July and was higher during the drier months. *p*H declined with depth ($P = < 0.05$) within a range of 6.5 to 5.9. The concentration of all the nutrients in the soil also showed higher values ($P = < 0.05$) during the monsoon season compared to the drier part of the year and

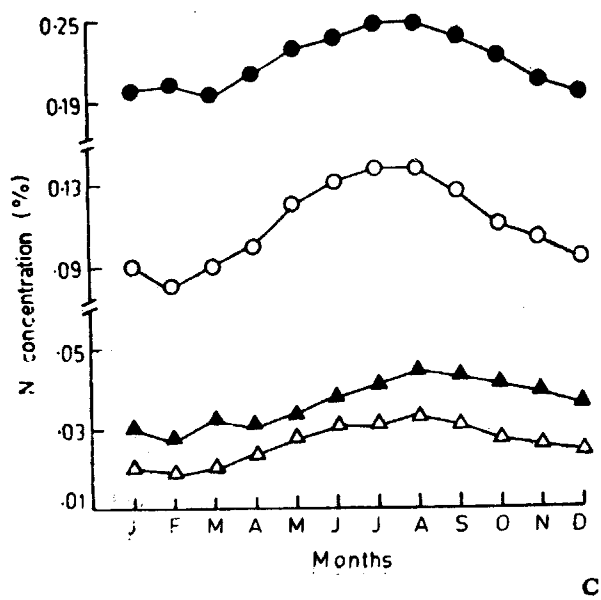


also decreased with depth ($P = < 0.05$). This seasonal fluctuation was less pronounced with depth. Such a seasonal pattern in *p*H and nutrient fluctuation could be related to the fast decomposition of the litter during the rainy season, which increases acidity and releases nutrients from the litter. Amongst the cations, this seasonal pattern was more marked for potassium. Since addition of nutrients to the soil is also due to throughfall and since potassium is considered to be more susceptible to this (Tukey et al. 1958 and Nye 1961), this may explain such a pronounced pattern for this element.

Since the monthly and profile pattern for soil characteristics was the same for all the plantations, the soil analysis data presented here (table 1) are from a depth of 0–10 cm in the month of September. *p*H, organic carbon and all the nutrients also increased ($P = < 0.05$) with the age of the stand.

Biomass and its nutrients

The number of trees/ha decreased with age due to natural thinning only. While basal area, height, DBH and leaf area per tree



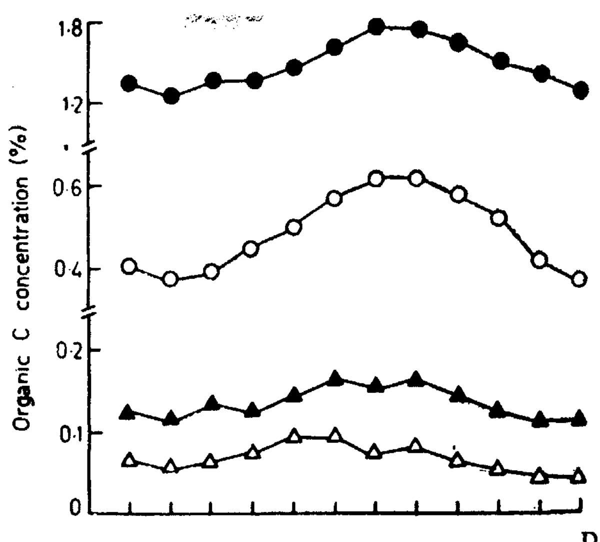
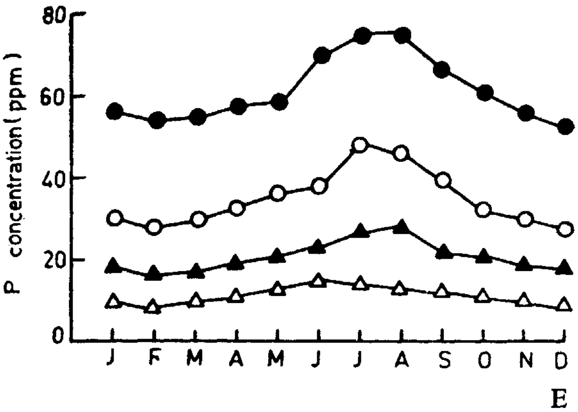


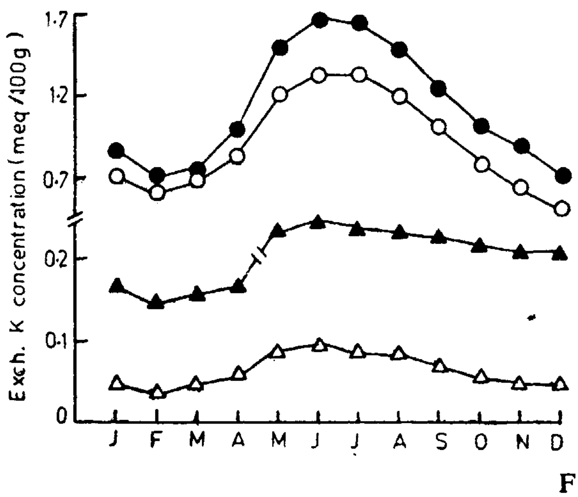
Figure 2 Monthly and depthwise variation in concentration of (A) soil moisture; (B) *p*H; (C) organic carbon; (D) total nitrogen

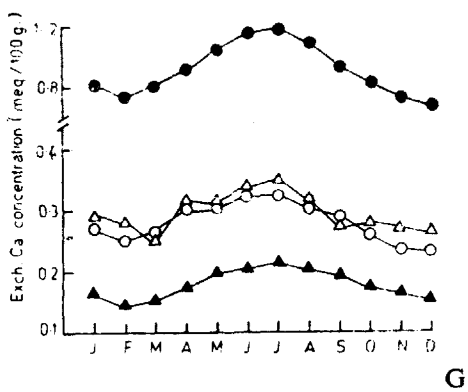
increased with the age of the stand, leaf area/ha reached a maximum at 13 years, declined sharply at 15 and 17 years and again increased at 19 years. This pattern seems to be more due to density of the trees which declined sharply with age (table 2).

With the age of the stand, the dry matter build up in bole, branches and leaves increased ($P = < 0.001$). The allocation to the bole, which was 53% of the total in the 9 year old stand, went up to 87% in a 19 year stand. Though leaf biomass per tree increased, the percentage allocation decreased from 34% in a 9 year old plantation to 7% in a 19 year old one (table 3).

The standing crop biomass/ha increased with stand age. However, the green biomass/ha increased up to 13 years, subsequently decreased in 15 and 17 year old stands and then again increased in a 19 year old stand ($P = < 0.01$). On the other hand, the non-green biomass/ha, increased ($P = < 0.05$) with stand age, as a consequence of which the non-green/green ratio increased with the age and levelled off in 17 and 19 years old plantations (table 4). The low biomass production recorded for this study site compared to that at Varanasi (Misra et al. 1967 and







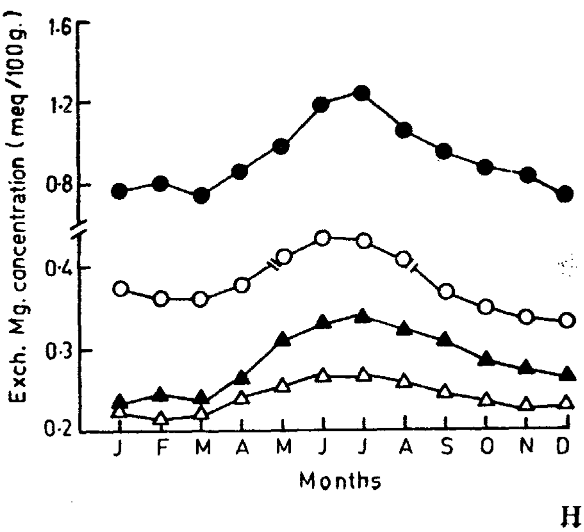


Figure 2 Monthly and depthwise variation in concentration of (E) available phosphorus (F) exchangeable potassium; (G) Exchangeable calcium; (H) Exchangeable magnesium in soil of a 19-year-old plantation.
0–10 cm, solid circle; 10–40 cm, open circle; 40–70 cm, solid triangle; 70–100 cm, open triangle

Table 1 *Soil analysis data for* S. robusta *plantations (9–17 yr old stands)*

Stand age (years)	pH	Organic Carbon (%)	Total Nitrogen (%)	Available Phosphorus (ppm)	Cations (m eq. %)		
					Potassium	Calcium	Magnesium
9	6.1±0.2	1.2±0.2	0.15±0.02	42±5.2	0.82±0.14	0.70±0.05	0.74±0.10
11	6.1±0.1	1.3±0.1	0.18±0 02	51±6.1	0.92±0.12	0.82±0.10	0.82±0.09
13	6.5±0.1	1.5±0.1	0.21±0.04	62±6.4	1.10±0.02	0.95±0.08	0.94±0.09
15	6.7±0 2	1.5±0 2	0.24±0.03	60±7.1	0.95±0.12	0.95±0.07	0.90±0.11
17	6.8±0.3	1.7±0.1	0.25±0.02	63±8.1	1.12±0.10	0.90±0.06	1 22±0.8

Table 2 *Stand characteristics of S. robusta plantations of different age (with S E values)*

Parameters	Stand age (year)					
	9	11	13	15	17	19
Tree/ha	8440±6.392	7920±1.403	6630±9.757	4280±10.906	4310±14.335	4620±11.334
Basal area/tree (cm²)	1 22±1.023	4.02±1.610	12.58±1.522	18.75±1.257	33 38±1.731	38.48±2 097
Basal area (m²/ha)	1.03	3.18	8.35	8.03	14.38	17.78
Height (m)	1 90±0.225	3.71±0.421	5.57±0.471	6.44±0.512	7.62±0.585	8.35±0.651
Avg. DBH (cm)	1 02±0.333	2.02±0.850	4.00±0.573	5.02±0.690	6.05±0.840	7.00±1.156
Leaf area/tree (m²)	0.912±0.916	5.678±2.803	10.58±4.101	11.36±3.101	9.775±3.841	12.362±2.073
Leaf/area (m²/ha)	7697.28	44969.76	70172.58	48620.80	42130.25	57103.20

Table 3 *Compartmentalization of biomass (kg/tree) in different stands of* S. robusta *(with S E values)*

Stand age (years)	DBH (cm)	Plant components			Total
		Bole	Branches	leaves	
9	1.02	0.115±0.02	0.028±0.004	0.074±0.017	0.217
11	2.02	0 708±0.072	0.162±0.014	0.359±0.03	1.229
13	4.00	3.06 ±0.246	0.225±0.027	0.5̈4±0.035	3.857
15	5.42	5.985±0.561	0.592±0.184	0 600±0.055	7.176
17	6.05	8.229±0.433	0.434±0 055	0.695±0.14	9.358
19	7.00	11.17±1.428	0.631±0.154	0.942±0.081	12.744

Table 4 *Proportion of green and non-green bio mass in different stands of* S robusta *(with S E values)*

Variables	Age (years)					
	9	11	13	15	17	19
Standing crop biomass (t/ha)	1.82±0.21	9.73±0.98	23.47±1.88	30.71±3.01	40.71±3.78	58.88±3.99
Green biomass (t/ha)	0.62±0.06	2.85±0.02	3.65±0 41	2.57±0.30	2.99±0.31	4.35±0·36
Non-green biomass (t/ha)	1.20±0.08	6.88±0.40	19.82±0 98	28.41±1.99	37 72±3.00	54.53±3 89
Non-green/green ratio	1.94	2 41	5.43	10.96	12.62	12.54

Sharma 1976) may be related to the poor quality of the highly leached lateritic soil in the present case.

The concentration of all the elements was more in leaves compared to branches and bole (table 5). However, the concentration of calcium was generally higher in the bole and in a 19-year-old stand it was more than double compared to leaves. Such a trend in accumulation of calcium was also recorded by others (Greenland & Kowal 1960 and Woodwell et al. 1975).

The nutrient content in the living biomass increased with the age of the stand. The amount of calcium followed by nitrogen was maximum in all stands (table 6). The nitrogen and phosphorus in the living biomass is comparable to that recorded by Ovington (1959) and Cole et al. (1975) for temperate forests though they are much lower than that recorded for tropical forests in Ghana (Greenland & Kowal 1960) and other *Shorea robusta* stands in Varanasi (Singh 1968).

Table 5 *Concentration of elements (mean values) in bole, branches and leaves of* S. robusta *in different stands*

Stand age (years)	Components	Concentration (%)				
		N	P	K	Ca	Mg
9	bole	0.64	0.04	0.16	1.03	0.18
	branches	0.83	0.06	0.39	0 51	0.20
	leaves	1.41	0.13	1.76	1.31	0.46
11	bole	0.58	0 05	0.18	1.10	0.20
	branches	0 80	0.06	0.38	0.61	0.28
	leaves	1.46	0.13	0.72	1.41	0 46
13	bole	0.53	0.06	0.19	1.13	0.02
	branches	0.75	0.07	0.36	0 30	0.28
	leaves	1.50	0.15	0.65	1.18	0.40
15	bole	0.50	0.06	0.20	1.17	0.22
	branches	0.71	0.07	0 32	0.74	0.25
	leaves	1.57	0.16	0.60	1.50	0.42
17	bole	0.46	0.07	0.21	1.20	0.24
	branches	0.69	0.08	0.30	0.79	0.26
	leaves	1.60	0.18	0 57	1.53	0.44
19	bole	0.41	0.07	0.21	1.20	0.25
	branches	0.66	0 09	0.26	0.81	0 27
	leaves	1.68	0.54	1.60	0.56	1.60

The litter and its nutrients

The monthly variation in leaf litter fall in a 19-year-old stand, which is typical of others also, showed a maximum in the dry period of the year with a peak in March (figure 3a) and is obviously related to moisture stress (Nye 1961 and Whitmore 1975).

Litter production increased markedly ($P = < 0.01$) with increasing age up to 13 years and was not significantly different in

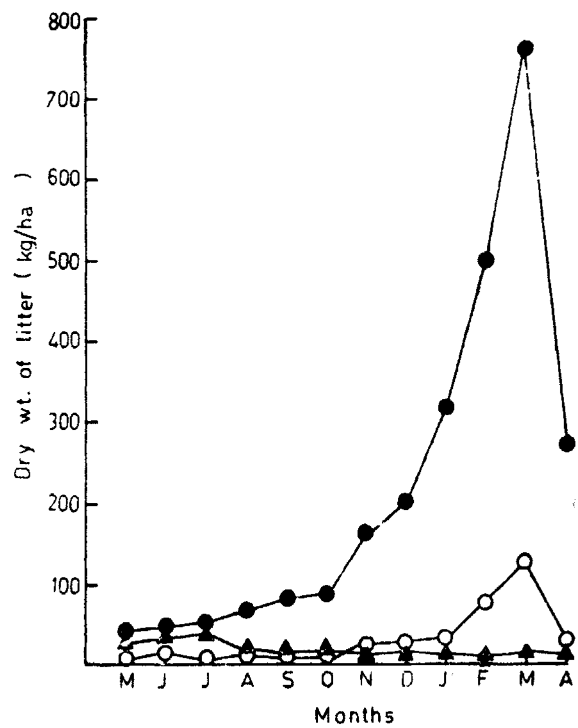


Figure 3a Monthly litter production in a 19 year old *S. robusta* plantation. Leaf litter of *S. robusta*, solid circle; other species, open circle; wood litter, solid triangle

Table 6 *Standing crop nutrients (kg/ha) in different stands of* S. robusta *(with S E values)*

Nutrient elements	Stand age (years)					
	9	11	13	15	17	19
Calcium	19.39±1.9	109.60±6.6	284.27±10.1	356.92±11.8	473.73±15.5	712.56±12.9
Nitrogen	16.98±1.8	84 29±6.8	175.04±10.0	186.37±12.6	223.84±18.1	303.95±22.2
Potassium	7.55±0.4	33.75±2.2	68.40±2.0	74.74±3.3	97.16±6.2	130.46±9.9
Magnesium	5.09±0.14	26.17±2.3	61.39±14.4	73.47±14.9	95.29±8.7	156.92±18.8
Phosphorus	1.34±0.1	8.52±0.5	18.84±1.8	21.25±1.9	31.72±2.4	471.02±3.0

older fallows (figure 3b). The litter production here was lower than that reported for *Shorea robusta* at Varanasi (Singh 1968).

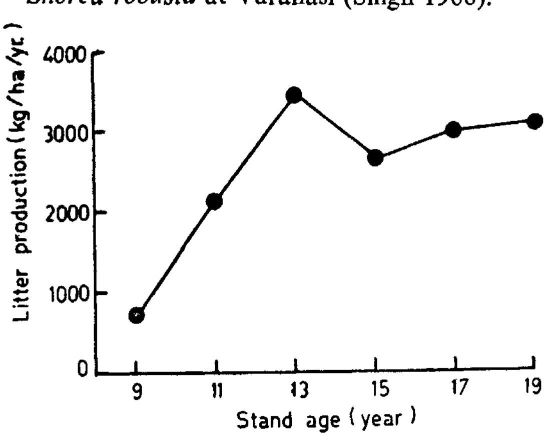


Figure 3b Litter production in different stands of *S. robusta*

The monthly variation in nutrient concentration in the litter given in figure 3c is typical of the pattern for other stands too. Nitrogen, phosphorus and potassium had lower concentrations in the litter during the rainy season compared to the dry period of the year. This may be due to leaching of these nutrients during the monsoon as also observed by Nye and Greenland (1960) and Carlisle et al. (1966). Calcium and magnesium, however, showed a reverse pattern with high concentrations during the rainy season, though not so pronounced; such a pattern was also noted in the wood litter (figure 3d).

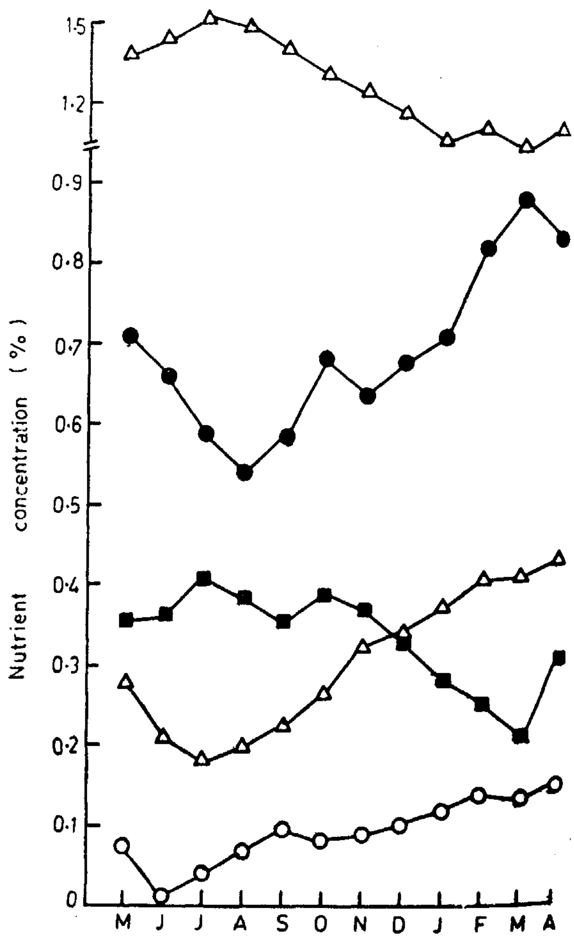


Figure 3c Monthly variation in concentration of different nutrients in leaf litter of a 19 year old *S. robusta* plantation. N, solid circle; P, open circle; K, solid triangle; Ca, open triangle; Mg, solid rectangle

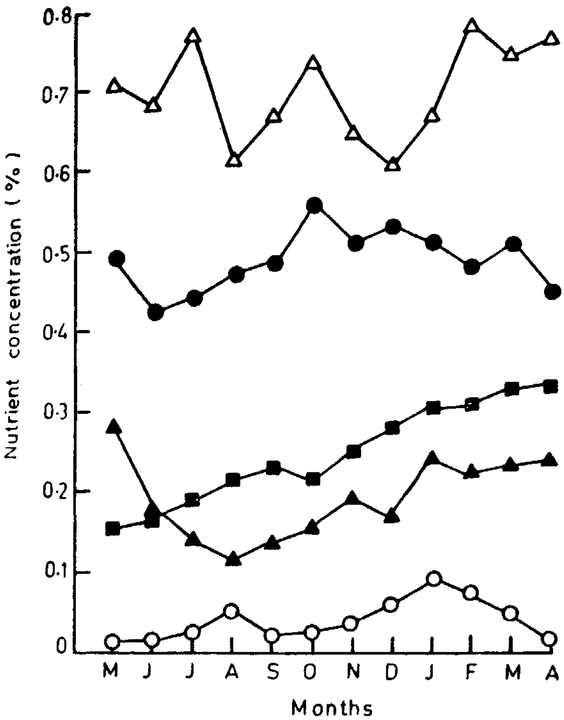


Figure 3d Monthly variation in concentration of different nutrients in wood litter of a 19 year old *S. robusta* plantation. N, solid circle; P, open circle; K, solid triangle; Ca, open triangle; Mg, solid rectangle

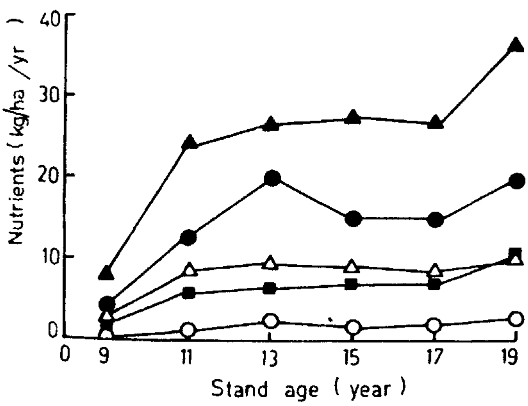


Figure 3e Total amount of nutrient elements in *S. robusta* plantation. N, solid circle; P, open circle; K, solid triangle

The total quantity of nutrients—returned to the soil through litter—increased with the age of the stand ($P = < 0.01$) which is related with litter production. The quantity of different nutrients added through litter in a 19-year-old plantation, was lower than that for other tropical forests (Golley et al. 1975 and Ewel 1976) and for *Shorea robusta* plantations in north-western India (Seth et al. 1963).

A comparison of our results with those available for *Shorea robusta* plantations in the north-western India suggests that the living biomass, litter production and nutrient capital observed by us in these two compartments, are generally lower. This is related to the poor nutrient status of the highly leached lateritic soils on which these plantations were done in the present case. More detailed studies on plantations of *Shorea robusta* and other tree species in the north-east are called for in order to evaluate the forestry practices in this region.

Acknowledgements

The help given by Mr O P Toky and Mr K G Saxena in the preparation of this manuscript is acknowledged. One of us (J S) was the recipient of a junior research fellowship from the North-Eastern Hill University.

References

Allen S E 1974 *Chemical analysis of Ecological Materials* (Oxford: Blackwell Scientific Publications)

Carlisle A, Brown A H E and White E J 1966 Litter fall, leaf production and the effects of defoliation by *Tortrix viridana* in a sessile oak (*Quercus petraea*) Woodland; *J. Ecol.* **51** 65–85

Cole D W, Turner J and Gessel S P 1975 Element cycling in Douglas-fir ecosystems of the Pacific north west: A comparative examination; Paper presented at *12th Int. Bot. Congr. Leningrad*, USSR, Mimeo 12 pp

Ewel J J 1976 Litter fall and leaf decomposition in a tropical forest succession in eastern Guatemala; *J. Ecol.* **64** 293–308

Golley F B, McGinnis J T, Clement R G, Child G I and Duever M J 1975 *Mineral Cycling in a Tropical Moist Forest Ecosystem* (Athens: University of Georgia Press)

Greenland D H and Kowal J M C 1960 Nutrient content of moist tropical forest of Ghana; *Pl. Soil* **12** 154–174

Jackson M L 1958 *Soil Chemical Analysis* (New Jersey: Prentice Hall)

Leith H and Whittaker R H 1975 *Primary Productivity of the Biosphere* (New York : Springer-Verlag)

Misra R, Singh J S and Singh K P 1967 Preliminary observation on the production of dry matter by sal (*Shorea robusta* Gaertn.); *Trop. Ecol.* **8** 94–104

Nye P H 1961 Organic matter and nutrient cycles under moist tropical forest; *Pl. Soil* **8** 336–346

Ovington J D 1959 The circulation of minerals in plantations of *Pinus sylvestris* L.; *Ann. Bot.* **23** 229–239

Rodin L E and Bazilevich N I 1967 *Production and Mineral Cycling in Terrestrial Vegetation* (Edinburgh: Oliver and Boyd)

Seth S K, Kaul O N and Gupta A C 1963 Some observations on nutrient cycle and return of nutrients in plantations at New Forests; *Indian For.* **89** 90–98

Sharma V K 1976 Biomass estimation of *Shorea robusta* and *Buckanania lanzen* by regression technique in natural deciduous forest; in *OSLO Biomass Studies* 131–142 ed. H E Young, Orono Meine

Singh K P 1968 Litter production and nutrient turnover in deciduous forests of Varanasi; *Proc. Symp. Trop. Ecology*. pp 655–665 eds. F B Golley & P M Golley (Athens: Georgia)

Tukey H B Jr, Tukey H B and Wittuier S H 1958 Loss of nutrients by foliage leaching as determined by radioisotopes; *Proc. Amer. Soc. Hortic. Sci.* 71 496–506

Whitmore T C 1975 *Tropical Rainforests of the Far East*. (London: Oxford University Press)

Woodwell G M, Whittaker R H and Houghton R A 1975 Nutrient concentrations in plants in the Brookhaven oak-pine forest; *Ecology* **56** 318–332