BIOMASS PRODUCTION AND NUTRIENT BUDGETING OF *HEVEA BRASILIENSIS* IN SOUTH INDIA

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Submitted: 19 February 2002 Accepted: 30 December 2004

Karthikakuttyamma, M., Satisha, G.C., Suresh, P.R. and Aiyer, R.S. (2004). Biomass production and nutrient budgeting of *Hevea brasiliensis* in South India. *Natural Rubber Research*, 17(2) : 108-114.

The biomass accumulation and total nutrient content in twenty year old rubber (*Hevea brasiliensis*) trees was quantified by weighing the entire tree by destructive sampling and analysing the nutrient content in different parts of the tree. The balance sheet of nutrients for a planting cycle was worked out, and comparison was drawn between rubber (after three cycles) and forest ecosystems for nutrient reserve and depletion in soils. The branches and trunk accounted for 80 per cent and the roots comprised about 15 per cent of the total dry matter on whole plant basis. The concentration of nitrogen in the leaf and bark exceeded that in the branches and trunk, while calcium concentration in the bark was greater than that in the wood / leaf by factors ranging from five to forty times. In general, major portion of nutrients was accumulated in the branches and trunk and was in the order of Ca > N > K > Mg > P. Balance sheet of nutrients indicated that a substantial amount of all the nutrients was removed through biomass and there was a calcium deficit. The depletion of potassium and calcium at 60 cm depth was considerably higher in rubber cultivated soils compared to forest soils. The 'R' factor (per cent of cultivation within the cycle of fallowing and cropping) worked out for rubber plantation in South India was 12.5 per cent, which makes it an agro-forestry ecosystem closely resembling the rain forest.

Key words: Biomass, *Hevea brasiliensis*, Nutrient balance, Nutrient depletion, uptake.

INTRODUCTION

In the commercial cultivation of rubber (*Hevea brasiliensis*), trees are cut down and removed after the completion of the economic life span of 30-32 years and the area is replanted. The removal of massive amounts of biomass through timber results in significant recycling of nutrients. Rubber plants take 4 to 5 years for canopy closure and grow to full sized trees in 15 to 20 years. The biomass accumulation and total nutrient content of the plant in its growth cycle is a basic requirement for assessment of nutritional requirement. However, information in this regard is scanty. Some workers (Watson, 1964; Shorrocks, 1965b) have assessed the nutrient cycle of rubber plantation with reference to soil nutrient content. These data were utilized to formulate recommendations for manuring, particularly of mature rubber. The present investigation attempts to quantify the amount of biomass accumulation by mature *Hevea* plants and the nutrients removed due to felling and clearing of trees. The balance sheet was prepared considering addition and removal of nutrients for a planting cycle. A compara-

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tive study of the depletion of nutrients in soil was also made for a rubber plantation (after 3 cycles) and a natural forest.

MATERIALS AND METHODS

Two trees with growth comparable to mean growth of the trees in a twenty year old plantation of clone RRII 105 at Central Experiment Station, Chethackal, Kerala, were destructively sampled. Trees in which there was a clear distinction between the main stem and the branching system above the fork were selected thus enabling a standard trunk to be sampled on both the trees. Trees were uprooted and divided into five morphological units *viz.* (1) roots – the tap root and the lateral roots, (2) the trunk including the collar or union – the main branches being cut off from the trunk at the fork, (3) twigs – representing the current year's branch growth, (4) branches – all remaining old branches, and (5) leaves – consisting of laminae and petioles. The relative distribution of total dry matter in various plant was estimated and expressed as percentage. The nitrogen, phosphorus, potassium, calcium and magnesium content were determined in all plant samples by following the standard procedures. In order to estimate the nutrients added, the quantity of fertilizer added as per the recommendation of Rubber Research Institute of India, was worked out. The quantities of major nutrients removed through biomass during felling and clearing of trees were also worked out. In order to relate the depletion of soil nutrients observed on the basis of the balance sheet, a comparative study was made between a rubber plantation of third planting cycle and forest soils up to 60 cm depth.

RESULTS AND DISCUSSION

Biomass production

The fresh and dry weights and percentage dry matter in various parts of the twenty year old rubber trees are given in Table 1. The dry matter varied from 24 kg in twigs to 593 kg in branches. The highest percentage of dry matter was noticed in the trunk (59%) followed by roots (53%). The branches and the trunk together accounted for nearly 80 per cent and the roots about 15 per cent of the total dry matter per tree.

Table 1. **Biomass of different parts of twenty year old *H. brasiliensis* tree**

Plant part	Fresh weight (kg)	Dry weight (kg)	Dry matter (%)	Share of dry matter (%)
Leaf	135	52	39	4
Twigs	104	24	23	2
Branches	1301	593	45	46
Trunk	747	444	59	34
Roots	353	188	53	14
Total	2647	1303	49	100

Nutrient composition

The concentration of nutrients in various parts of the tree is presented in Table 2. Leaves contained higher concentration of nitrogen (3.65%) followed by bark of the main trunk (3.38%). The main trunk had the least concentration of N (0.42%) followed by the tap roots and the side roots (0.74%).

The maximum phosphorus (P) content was observed in leaves (0.27%) while minimum was noticed in petioles (0.04%). In the root system, the tap root contained 0.11 per cent and smaller roots contained 0.09 per cent P. Among the bark on different parts, the main trunk bark contained maximum P concentration (0.1%).

Potassium (K) also registered high

Table 2. **Concentration of nutrients in different parts of twenty year old *H. brasiliensis* tree**

Plant part	Total nutrient content (%)				
	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium
Leaves	3.65	0.27	1.40	1.04	0.41
Petioles	0.83	0.04	0.88	2.18	0.29
Twigs	2.09	0.13	0.72	0.28	0.11
Branches	0.60	0.06	0.64	1.45	0.14
Main trunk	0.42	0.06	0.22	0.84	0.15
Tap root	0.81	0.11	0.94	1.29	0.31
Side roots	0.97	0.09	0.88	1.83	0.38
Bark					
Tap root	1.12	0.09	1.06	1.87	0.49
Lateral roots	1.08	0.09	1.72	2.22	0.46
Branches	0.83	0.05	0.96	3.22	0.27
Main trunk	3.38	0.10	1.16	4.00	0.48

concentration in leaves (1.40%). Of the above ground parts, main trunk contained the lowest K concentration (0.22%). Of the various roots, the tap root contained 0.94 per cent K. Comparatively high concentration of K was present in the bark from all the parts.

Bark of main trunk contained the maximum calcium (Ca) (4.00%) followed by bark of branches (3.22%) and lateral roots (2.22%). Calcium concentration in the bark exceeded that in the wood by factors ranging from five to forty times. As in the case of Ca, magnesium (Mg) content in the bark was higher than those of the wood, the highest being in bark of tap root and the lowest (0.11%) in the twigs. Leaves contained 0.41 per cent Mg. Similar results have also been reported by Shorrocks (1965a).

Uptake of nutrients

The uptake of nutrients (g/tree) by various parts of the rubber tree is shown in Fig. 1. The major share of nutrients accumulation was in branches followed by trunk. The total uptake of calcium was found to be highest (1.5%) considering the whole plant

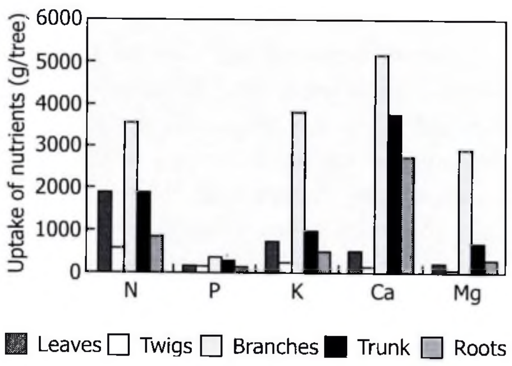

Fig. 1. Uptake of nutrients

while that of nitrogen (1.2%) and potassium (0.8%) were next in order. Calcium being a constituent of cell wall and potassium, a nutrient with regular function in the plant metabolic activities, their concentrations were generally higher than that of the other nutrients. Shorrocks (1965a) reported large-scale deposition of calcium in the trunk and branch bark, which probably is not needed fully for growth of the plant. It appears that the role of this nutrient has to be studied in detail not only because of its large uptake, but also on account of soil fertility considerations. In general, all the cationic and anionic nutrients except nitrogen are fixed in the trunk and do not contribute much to the soil pool through the annual litter recycle. These results suggest that a large proportion of nutrients are immobilized within the trunk, roots and main branches, whilst smaller proportions return to the soil through the annual defoliation (wintering), seed and branch fall, and rain wash. Nevertheless, the uptake and accumulation of nutrients by the tree is the major process in the growth cycle of rubber, although in the early years of planting the uptake of nutrients by the vigorous leguminous cover plants, growing in the almost open conditions, can exceed that by the tree.

Balance sheet of nutrients

In order to get a clear picture of the nutritional balance of each plantation cycle, the quantities of different nutrients removed by clear felling of plants has been quantified and presented in Table 3. For quantification of nutrient removal, twigs, branches and trunk were only accounted because it is assumed that leaves and roots of the plants are not removed from the site and are thus recycled. On an average one hectare of land at the later stages of plantation contains approximately 300 trees and hence the quantities of nutrients are expressed as per hectare of land. The data in Table 3 reveal that the nutrient removal is highest for Ca followed by N and K. The removal of P was only 210 kg while for Mg it was 5 times that of P. Tapping of the trees also results in the removal of nutrients through latex. The outflow of nutrients as latex over a period of 20 years is also significant though it is less than the outflow through timber. The estimated removal of nutrients through latex is presented in Table 4. The maximum removal is for N (300 kg/ha) followed by K (180 kg/ha). These results are in agreement with earlier reports (Beaufils, 1954; Krishnakumar and Potty, 1992).

In order to work out the balance sheet of nutrients of one plantation cycle, the quantities applied through fertilizer and the amount of nitrogen fixed by the leguminous

Table 3. **Nutrient loss during felling and removal of rubber trees**

Parts removed from field	Nitrogen (g/tree)	Phosphorus (g/tree)	Potassium (g/tree)	Calcium (g/tree)	Magnesium (g/tree)
Twigs	508	73	175	68	27
Branches	3558	356	3795	5159	2906
Main trunk	1876	268	983	3751	670
Total (per tree)	5942	697	4953	8975	3602
Total (kg/ha*)	1800	210	1500	2700	1050

* for 300 trees

Table 4. **Balance sheet of nutrients (kg/ha) for *H. brasiliensis* in one plantation cycle**

Nutrient	Addition	Removal		Total	Deficit / surplus
		Latex	Timber		
Nitrogen	1345	300	1800	2100	-755
Phosphorus	467	90	210	300	+167
Potassium	797	180	1500	1680	-883
Calcium	1530	90	2700	2790	-1260
Magnesium	195	90	1050	1140	-945

cover crops raised in the plantation were considered besides the quantities of nutrients removed through latex and biomass during felling and removal of trees. As it is not possible to evaluate the precise amount of nitrogen fixed by the legume cover symbiotically the conservative estimate of 300 kg N per hectare (Watson, 1964) was adopted for the present study. Regarding the amount of nitrogen fixed non-symbiotically, although some workers have estimated as much as 40 kg per hectare per annum, it appears that 6 kg per hectare per annum as estimated by Allison (1955) is more reasonable.

A perusal of the balance sheet of nutrients (Table 4) reveals that a substantial amount of all the nutrients except P are removed through biomass. The highest deficit was noticed for Ca (1260 kg/ha) followed by Mg (945 kg/ha). Similar results have been reported by Shorrocks (1965b).

The comparative study of depletion / reserve of nutrients for rubber (after 3 cycles) and forest soils at 60 cm depth (Table 5) indicated that rubber cultivated soils were deficient in N, K, Ca and Mg, whereas P was sufficient. This has been corroborated by the findings that in all the zones studied, the soils of rubber plantation in the third cycle contained higher contents of total P when compared with nearby forest soils. The highest depletion was noticed for nitrogen and the lowest for magnesium. This may be because rubber plantation in its third planting cycle was considered for the comparison and such changes might have taken place over a period of approximately 60 to 90 years and thus any urgent requirement to replace nutrients is not considered to exist. In replanted rubber, the soil nutrient reserves are likely to be depleted at the time of replanting and nutrient deficiencies could be expected as the second generation of rubber draws further from the soil nutrient reserves. Hence, replenishment of soil nutrients may be necessary where soil nutrient reserves are low. Moreover, to ensure satisfactory establishment of the young rubber, it is advisable to apply adequate doses of fertilizers.

Rubber as an agro-forestry crop : an evaluation by 'R' factor

One of the most useful ways for linking production with soil condition in tropical areas is through the 'R' factor (Young

Table 5. **Total quantity of nutrients (kg/ha) contained in 60 cm depth of soil under forest and rubber (after 3 cycles)**

Nutrient	Ecosystem	Nilambur	Chemoni	Vithura	Mundakayam	Mean	Difference
Nitrogen	Rubber	12520	15090	13600	10920	13020	-5810
	Forest	15840	26000	18000	15480	18830	
Phosphorus	Rubber	3304	7224	5656	7648	5958	+1825
	Forest	2800	4204	3224	6304	4133	
Potassium	Rubber	4400	5600	7600	22400	10000	-2160
	Forest	10800	12800	12000	25200	12160	
Calcium	Rubber	8400	7200	7200	6800	9200	-2900
	Forest	16000	11200	11600	9600	12100	
Magnesium	Rubber	800	800	800	1200	900	-300
	Forest	1200	1600	800	1200	1200	

and Wright, 1979; Young, 1989). R factor is the percent of cultivation within the total cycle of fallowing and cropping and it is expressed as

$$R\,(\%) = \frac{\text{Years under cultivation}}{\text{Years under cultivation + Fallow}} \times 100$$

An R value of 5 per cent indicates cultivation only once in 20 years while 100 per cent means cultivation during every year. The R value may also vary depending on the levels of inputs for various soil types. R value for ferralsols under rain forest for low, intermediate and high levels of input are 15, 35 and 70 per cent respectively (Young and Wright, 1979).

For the rubber plantation ecosystem, a cycle of nearly 32 years includes first year for clearing of land and planting, and the next five years for canopy establishment. During the second year a leguminous cover crop is introduced and its establishment takes about three years. Hence, out of six years of the initial period of plantation cycle, land can be considered to be under cultivation for three years and the remaining three years under fallow. Once the canopy is established, the rubber plantation resembles a fallow system for nearly 25 years after which one year may be devoted for slaughter tapping and logging before replanting the second cycle. Thus there are four years of cultivation and 28 years fallow, giving an R value of 12.5 per cent.

Similarly, the R value for the second and third cycles will also be around 12.5 per cent. Considering rubber as a tree crop under agro-forestry plantation, with intermediate range of management, the R value expected is 35 per cent. However, the R value under the rubber cultivation situations in South India is only 12.5 per cent, which makes it an agro-forestry ecosystem closely resembling the rain forest. Nair *et al.* (1999) came to similar conclusions by comparing monoculture plantations with multistrate agro-forestry systems under similar climatic conditions.

ACKNOWLEDGEMENT

The authors gratefully acknowledge Dr. A.K. Krishnakumar, Rubber Production Commissioner, Rubber Board, Kottayam, Kerala, India and Dr. V.K. Venugopal, Professor and Head, College of Agriculture, Vellayani, Kerala, India, for their valuable suggestions and encouragement. Authors also thank Dr. C. Kuruvilla Jacob, Deputy Director, Plant Pathology Division, RRII, for giving permission to uproot the trees maintained by him, for this study.

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