LEAF LITTER ADDITION AND NUTRIENT RECYCLING IN TWO CLONES OF RUBBER (*Hevea brasiliensis Muell. Arg.*) IN VELLANIKKARA ESTATE

By

K. N. SUMADHAN

DISSERTATION

Submitted in partial fulfilment of the requirement for the

Post Graduate Diploma in Natural Rubber Production

Faculty of Agriculture
Kerala Agricultural University

DEPARTMENT OF PLANTATION CROPS AND SPICES
KERALA AGRICULTURAL UNIVERSITY
Vellanikkara, Thrissur

1993

ACKNOWLEDGEMENT

I wish to place on record my sincere gratitude to all from whom I received tremendous help in preparing the dissertation.

I am highly grateful to **Dr. P.A. Nazeem**, *Associate Professor, Department of Plantation Crops and Spices, College of Horticulture, Vellanikkara and Major Advisor of the Advisory Committee, for her valuable guidance in the planning and execution of this work, for the advice, sincere criticism and encouragement given throughout the period of investigation and preparation of the dissertation.*

I express my deep sense of gratitude and indebtedness to **Dr. S. Narayanan Potty**, *Joint Director (G&RS), Rubber Research Institute of India, Kottayam-9 for his sincere guidance, timely advice and encouragement for my study and for the immense help for the preparation of the dissertation.*

I am thankful to **Dr. G. Sreekandan Nair**, *Professor and Head, Department of Plantation Crops and Spices, College of Horticulture, Vellanikkara and* **Dr. P.V. Balachandran**, *Associate Professor, College of Horticulture, Vellanikkara for their inspiring guidance and valuable advice for the refinement of the dissertation.*

My sincere thanks are expressed to ***Smt. J. Lalithambika****, I.A.S., Chairperson, Rubber Board and* ***Shri. P.K. Narayanan****, Rubber Production Commissioner, Rubber Board for sanctioning study leave and for providing facilities and financial assistance for completing the course.*

I express my sincere thanks to ***Dr. C.C. Abraham****, Associate Dean, College of Horticulture, Vellanikkara for providing facilities and for his eminent directions for the course and dissertation work.*

I thank Shri. O.K. Ravindran, C/o Peagles, Mannuthy for the neat typing of this manuscript.

I also express my sincere thanks to all the officials and staff of Rubber Research Institute of India, Kottayam and College of Horticulture, Vellanikkara who provided assistance and cooperation for the dissertation.

K.N. SUMADHAN

DECLARATION

I hereby declare that this dissertation entitled ***"Leaf Litter Addition and Nutrient Recycling in Two Clones of Rubber (Hevea brasiliensis Muell. Arg.) in Vellanikkara Estate"*** *submitted to partial fulfilment of the course* ***'Post Graduate Diploma in Natural Rubber Production'*** *of Kerala Agricultural University, is a bonafide record of research work done by me and that the dissertation has not previously formed the basis of the award to me any degree, diploma, associateship, fellowship or other similar title of any University or Society.*

Vellanikkara,
2.8.1993.

K.N. SUMADHAN

CERTIFICATE

Certified that this dissertation ***"Leaf Litter Addition and Nutrient Recycling in Two Clones of Rubber (Hevea brasiliensis Muell. Arg.) in Vellanikkara Estate"*** *is a record of research work done by* ***Sri. K.N. Sumadhan*** *under our guidance and supervision and that it has not previously formed the basis for the award of any degree or diploma to him.*

We, the undersigned members of the committee of ***Sri. K.N. Sumadhan,*** *a candidate for the Post Graduate Diploma in Natural Rubber Production, agree that the dissertation entitled* ***"Leaf Litter Addition and Nutrient Recycling in two clones of rubber (Hevea brasiliensis Muell. Arg.) in Vellanikkara Estate"*** *may be submitted by Sri. K.N. Sumadhan, in partial fulfilment of the requirement of the Diploma.*

Dr. P.A. Nazeem
(Major Advisor)
Associate Professor
Department of Plantation Crops & Spices
College of Horticulture
Vellanikkara

Dr. S. Narayanan Potty
(Co-Chairman)
Joint Director (G&RS)
Rubber Research Institute of India
Kottayam - 686 009

Dr. G. Sreekandan Nair
(Member)
Professor and Head
Department of Plantation Crops & Spices
College of Horticulture
Vellanikkara

Dr. P.V. Balachandran
(Member)
Associate Professor
College of Horticulture
Vellanikkara

CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

1. INTRODUCTION

In man made protected plantations and natural forests, litter addition and nutrient recycling is an important aspect. Litter addition refers to the fall of organic debris from above ground plant parts to the plantation floor and it include leaves, twigs, branches, flowers, fruits and seeds. Among these leaf litter contributes 65 to 92 per cent of the total litter in rubber plantations (Onyibe and Gill, 1992).

Rubber (Hevea brasiliensis) is a deciduous tree which shed leaves well before summer months and is known as wintering. Thus rubber trees annually return organic matter to the soil mainly through leaf shedding during the process of wintering. The organic matter on decomposition releases minerals, humic acid, fulvic acid etc. that favours the humus content of the soil. This process is very much important in nutrient dynamics.

Since man made rubber plantations being a 'closed' ecosystem, the nutrient cycling comprises of cyclic circulation of nutrients between plantation area and rubber plants through the process of nutrient uptake, retention and return to soil. The nutrient cycling in this closed monoculture ecosystem is thus a rather complex system of geological, chemical and biological cycling that the soil organic matter and nutrients are lost and later retained, ensuring continuous productivity of the soil.

The importance of understanding litter dynamics lies not only in the key role that it plays in the carbon and nutrient dynamics of forest ecosytem (Anderson and Swift, 1983) but also in the reduction of splash erosion and surface runoff (Wiersum, 1983). Leaf litter will reduce the moisture loss from the top soil by functioning as a mulch and indirectly increase the microfauna and flora of soil which are beneficial for plant systems. Organic matter helps to increase water holding capacity of the soil and it can also reduce soil temperature.

Numerous studies have been made on litter productivity and nutrient cycling in natural forests and plantations from outside the country (Schweizer, 1939; Shorrocks, 1965a, b; Adams and Attiwill, 1985) as well as from our country (Jasbir Singh and Ramakrishnan, 1982; Malhotra et al., 1987; George and Varghese, 1990a, b; and Negi et al., 1991).

Studies on nutrient recycling in rubber plantations are limited. An attempt is made in the present investigation to quantify the leaf litter addition and nutrient return to the soil and to compare the soil enrichment due to leaf litter in a nine year old rubber plantation comprising of two clones, at Vellanikkara estate of Trichur district.

The result drawn from the present study would be useful in evaluating the nutrient recycling pattern and understanding the clonal variation in litter dynamics.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Leaf litter dynamics and nutrient recycling has been studied and reported in rubber and various other crops from India and abroad. The salient reports are summarised in this chapter.

2.1 Rubber

2.1.1 Leaf litter production

A study on the growth and nutrient content of Hevea brasiliensis varying in age from one year to thirty years has been conducted by Shorrocks (1965a) by weighing the entire tree and analysing samples of roots, trunk, branches and leaves for both major and minor nutrients. He has reported the total dry weight of leaves (Lamina and Petioles) of eight year old RRIM 501 clone to be 12.14 kg and that the weight of annual leaf fall in a mature plantation is likely to vary between 3700 kg and 7700 kg per hectare, these being the amount of leaf found on the trees at any time.

In a comparative study on nutrient recycling under monoculture conditions in the tropical forest ecosystems Premakumari (1987) found that the annual litter fall in a hectare of rubber plantation was 3240 kg. Onyibe and Gill

(1992) have conducted a detailed investigation on litter production and its disappearance in three monoclonal plantations of rubber (RRIM 600, PR 107 and GT I) in Bendel State of Nigeria. The study reports that the leaf litter fall was highest in PR 107 (9604 $\pm$ 25.4 kg ha^{-1} yr^{-1}) followed by GT I (9460 $\pm$ 23.3 kg ha^{-1} yr^{-1}) and RRIM 600 (8902 $\pm$ 23.7 kg ha^{-1} yr^{-1}).

In a preliminary study of leaf litter addition and nutrient recycling in rubber (Hevea brasiliensis) in Vellanikkara Estate, Guruprasad (1992) estimated 4112 kg/ha of leaf litter for the clone RRII 105 during the annual wintering period.

2.1.2 Nutrient return through litter fall

In a study conducted by Schweizer (1939) at the Besoeki Experimental Station, East Jawa, it was reported that the major portion of the nutrients in the leaves have already been translocated just before abscission. From the study Schweizer (1939) estimated a return of 140 kg N, 38 kg P and 40 kg K to the ground per year in a hectare of land with 200 trees by means of shed leaves.

In another study, Shorrocks (1965 b) estimated the nutrient return through leaf litter as 45 to 90 kg N, 3 to 7 kg P, 10 to 20 kg K, 9 to 18 kg Mg and 60 to 120 kg Ca per hectare per year.

According to Tan (1975), leaf litter fall in a well manured mature rubber plantation could return 53 kg/ha of organic leaf litter nitrogen annually to the soil.

Premakumari (1987) also estimated the annual nutrient return through leaf litter in the rubber plantations of Kerala as 48 kg N, 3.7 kg P, 9.7 kg K, 7.3 kg Ca and 6.4 kg Mg per hectare.

In the study on leaf litter addition and nutrient recycling in rubber (Hevea brasiliensis), Guruprasad (1992) estimated the annual nutrient contribution through wintering as 63.3 kg N, 2.64 kg P, 44.0 kg K, 42.32 kg Ca and 8.93 kg Mg.

2.1.3 Nutrient recycling and soil productivity

In a detailed investigation on mineralisation of leaf litter nitrogen and its availability to rubber seedling conducted by Tan and Pushparajah(1985) found that leaf litter of Hevea brasiliensis is having comparatively high C/N ratio (33) and low nitrogen content (1.36 per cent).

According to Premakumari (1987) the C/N ratio in rubber plantation at the depth of 0 to 30 cm was 10. Watson (1989) reported that the rubber plantation presents an environmentally acceptable replacement for the native forest, being a 'closed' ecosystem with constant cycle of uptake and return of nutrients from and to the soil.

According to Krishnakumar et al. (1991) the litter accumulation under rubber has been found to be lower than that of teak and natural forest and it could be attributed to a faster rate of decomposition under a high moisture regime and a higher content of P, K and Mg than teak.

Onyibe and Gill (1992) have reported that the turnover time of leaf litter of three clones RRIM 600, GT I and PR 107 at Nigeria were 0.7 year, 0.5 year and 0.6 year respectively.

2.2 Natural forests and other plantations

2.2.1 Leaf litter production

Seth et al. (1963) from a study on nutrient cycle and return of nutrients in plantations and New Forest Research Institute, Dehradun reported that Tectona grandis produced about 5328.81 kg, Shorea robusta 5018.04 kg, Pinus roxburghii 7039.92 kg, Araucaria cunninghami 5904.35 kg and Dendrocalamus strictus 3209.29 kg of litter ha^{-1} yr^{-1}.

Premakumari quoted that the annual litter production was estimated to be about 4 tons/ha in a 65 year old Pinus halepensis forest (Rapp, 1967) and 4062.5 kg/ha in Quercus ilex and Quercus coccifera (Rapp and Lossaint, 1967).

Venkataramanan and Chinnamany (1978) reported in the preliminary studies on the chemical composition and total quantity of the leaf litter in the wet (montane) temperate evergreen forests (sholas) of the Nilgiris annually to be 2121 kg/ha of litter.

The annual litter production was reported to be about 7799 kg/ha and 4884 kg/ha in Loblolly and Long leaf pine in coastal south Carolina (Gresham, 1982) and only 5500 kg/ha annually in the 50 year old humid tropical forest of Meghalaya in India (Jasbir Singh and Ramakrishnan, 1982).

Venkataramanan *et al*. (1983) have reported that *Eucalyptus globulus* (Blue gum) in Nilgiris in Tamil Nadu add annually 1935 kg/ha of leaf litter.

In a comparative study of the annual litter production in four prominent Coniferous species, Singh *et al*. (1984) have observed that annual litter production was maximum in *Picea smithiana* (10.91 kg ha^{-1} yr^{-1}) followed by *Cedrus deodara* (9.12 kg ha^{-1} yr^{-1}), *Abies pindrow* (6.89 kg ha^{-1} yr^{-1}) and *Pinus wallichiana* (2.38 kg ha^{-1} yr^{-1}).

A comparison of the annual litter production in different parts of India made by Durani *et al*. (1985) indicate that Sal and Teak produce 5.3 tons ha^{-1} yr^{-1} of litter and the deciduous forest of Varanasi and Udaipur produce 1.01 to 6.21 ton ha^{-1} yr^{-1} and 4.04 ton ha^{-1} yr^{-1} respectively.

Ramprasad and Mishra (1985) conducted studies on litter productivity of natural dry deciduous teak forest of Sagar (M.P.) and has reported that total annual leaf litter production in these forests worked out to be 4.959 tons/ha. The study also reports that higher density values of trees showed higher values for their leaf litter and other factors which influence leaf litter frequency are weight, size, shape and maturity of leaves.

2.2.2 Nutrient return

Seth *et al*. (1963) have described the annual return of nutrients through leaf fall in a mixed plantation at New Forest in Dehradun. The figures in percentage range from 0.56 to 1.05 for N, 0.15 to 0.28 for P, 0.42 to 0.56 for K, 0.66 to 2.85 for Ca and 0.08 to 0.29 for Mg.

Rapp (1967) has estimated the annual nutrient contribution through litter fall by *Quercus sps*. as 33 kg N, 5 kg P, 5 kg K, 41 kg Ca, and 5 kg Mg per hectare.

In a research study on mineral cycling in deciduous forests (principally Oak wood), Duvigneaud and Smet (1970) have reported that the young leaves are always richer in N, P and K and poorer in Ca than mature leaves. During active growth N, P and K content steadily decrease but remain constant when leaves are completely developed. During the autumnal yellowing N, P and K, decrease (leaching, shift to the tree branches, bole and roots), but Ca content increases. Through out the leaf development, Mg level remains constant.

According to the study conducted by Venkataramanan and Chinnamany (1978) in shola forests of Nilgiris annually add 2121 kg/ha of litter which by way of nutrients works out to 23.1 kg N, 1.3 kg P, 11 kg K, 34 kg Ca and 5 kg Mg per hectare.

Singh *et al*. (1984) have reported the nutrients released through annual litter fall in four Coniferous species. The enrichment of the soil due to leaf litter addition was the maximum by Ca followed by N,P and K. In Eucalyptus hybrid plantation of East Dehradun Division in U.P., George (1986) had observed the nutrient content in leaves was in the order of 41, 5, 37, 6 and 9 kg ha^{-1} yr^{-1} of N, P, K, Ca and Mg respectively. George and Varghese (1991) have estimated the annual nutrient return through leaf litter in *Eucalyptus globulus* plantations of 10 year old, grown in the Nilgiri South Forest Division of Tamil Nadu as 28 kg/ha N, 2.7 kg/ha P and 20 kg/ha K.

According to Tandon _et al_. (1991) the annual nutrient return through leaf litter in poplar plantation (_Populus deltoides_) was estimated on per hectare basis as 20.28 kg N, 0.57 kg P, 5.50 kg K, 31.11 kg Ca and 1.89 kg Mg.

2.2.3 Nutrient recycling and soil productivity

Remezov (1959) has shown that as a plantation matures, the rate of nutrient uptake decreases and is accompanied by a corresponding reduction in litter fall.

Balagopalan and Jose (1982) have pointed out that the organic matter content was decreased with the depth of soil, in areas where leaf litter was deposited.

Venkataramanan _et al_. (1983) have suggested that the recycling of nutrients in the _Eucalyptus globulus_ plantation in Nilgiris, keep the land under high fertility status with a rich top soil and dense vegetation. They have also reported that the status of organic carbon, total N, exchangeable Ca and exchangeable K were very high in 0 to 15 cm soil layer as compared to 30 to 60 cm soil depth.

According to Adams and Attiwill (1985) litter fall is the major path way for return of N, P, Ca and usually Mg to the soil. In general nutrient turnover was related to the rate of organic matter turnover.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present study is a part of a long term observation initiated to quantify the leaf litter addition and nutrient recycling in rubber plantations. The investigation started in 1991-92 season in the clone RRII 105 planted in Vellanikkara Estate of Kerala Agricultural University was continued. In order to collect additional information the observation was extended to RRII 118 planted in the same field. Both the clones RRII 105 and RRII 118 were planted in the year 1983. The experimental site was almost flat.

3.1 Selection of trees

Three trees each of the clone RRII 105 and RRII 118 were selected from plots of similar spacing of 4.85 m x 4.85 m and having uniform growth. All the three trees selected were from a single row ensuring that there are no vacant points all around.

3.2 Collection of leaf litter

In order to prevent the entry of leaf litter from the neighbouring trees and also to check the fallen leaves being blown away by wind, the three trees were isolated from others by providing a closely woven nylon net around the selected trees as a whole, upto a height of 13 metres from the ground level. The bottom of the net was also fixed to the ground by strong pegs. The net was provided, sufficiently earlier to the commencement of wintering.

After fixing the nets, the whole area inside the net was cleared off the grasses, left over leaf litter, branches and pods. The left over leaf litter, pods and branches after the last year collection of litter present in the net already provided for the clone RRII 105 site was collected separately and dry weight quantified. Wintering commenced by 15th November 1992 in RRII 105 and by 23rd November 1992 in RRII 118. Anyhow first collection started on 21st November 1992 and continued at fortnightly intervals till the wintering was over by 27.2.1993.

3.3 Quantification of the litter collected

Leaf litter was collected separately for each clone and weighed in the common balance to get the fresh weight on the collection day itself. Samples of 500 gram were taken from each collection and were oven dried till constant weight was obtained. Both the fresh and dry weight were recorded separately for the leaf lamina and petiole. Based on these figures, the moisture percentage, dry matter percentage and lamina petiole ratio were computed. The total leaf litter addition was worked out and expressed in terms of kg/ha taking into consideration the actual density of trees (366/ha) in the experimental plot. Branches and twigs fallen during wintering season were also collected separately and quantified as air dried weight.

3.4 Chemical analysis of leaf litter

The quantities of the major mineral nutrients added through leaf litter were found out by analysing the composite samples taken from all the fortnightly collections. Analysis for nitrogen, phosphorus, potassium, calcium and magnesium was done at Rubber Research Institute of India at Kottayam. N, P and K were analysed by using Auto analyser and Ca and Mg by using Atomic Absorption Spectrophotometer following the procedure prescribed in the "Laboratory Manual of Rubber Research Institute of India" (Karthikakutty Amma, 1989).

3.5 Chemical analysis of soil

In order to find out the variations in mineral nutrient status, soil samples were collected from the leaf litter removed area (inside the net) and leaf litter deposited area (outside the net) at three depths of 0 to 15 cm, 15 to 30 cm and 30 to 60 cm. Soil samples were analysed for the available elements following the methods suggested by Jackson (1973). Analysis for organic carbon was done by Walkley and

Black method and available P by Bray and Krutz method. Available K was estimated by flame photometric method and available magnesium was analysed by Atomic Absorption Spectrophotometry at Rubber Research Institute of India.

3.6 Leaf area index

Leaf area of 50 leaves (150 leaflets) at mature stage for each clone was measured using leaf area meter. Leaf area index for each clone was computed using these values. The corresponding dry weight for the same sample of leaves were recorded to relate the leaf area with the dry weight.

RESULTS AND DISCUSSION

4. RESULTS AND DISCUSSION

The study comprised of evaluating the pattern of wintering, quantity of leaf litter added, nutrient addition through leaf litter, soil fertility as influenced by leaf litter and the leaf area index for the two clones RRII 105 and RRII 118.

4.1 Pattern of wintering

During the period of study, wintering started first in RRII 105 by the 15th of November 1992 and continued upto 20th February 1993 (Table 1, Fig.1) whereas in RRII 118 wintering started late by one week and continued till 27th February 1993 (Table 2, Fig.1). The rate of leaf fall in RRII 105 gradually increased by second fortnight of November and reached the maximum during the second fortnight of January and decreased later. But in RRII 118 the rate of leaf fall was very slow initially, then increased and reached the peak during the first fortnight of February and it suddenly stopped.

In the case of RRII 105 maximum leaf fall took place during the month of January whereas in RRII 118 the maximum leaf fall was in February. In a study on litter dynamics in three clones of rubber in Nigeria, Onyibe and Gill (1992) observed more or less the same trend. A report from RRII (1980) reveals that rubber tree winters during December-February in South India. It also reports that wintering may be either complete or partial depending upon the clone, age of plants, seasonal factors and location. Report made by Orimoyegun (1985) also confirm this result.

Onyibe and Gill (1992) reported more than eighty percentage of the leaf litter fall during the months of February 1988 and January 1989, which corresponded to the driest months of study and suggested that the peak of leaf fall my be greately related to a period of water stress. The observations of present study is also in agreement with the above mentioned studies on pattern of wintering.

4.2 Quantity of leaf litter added

The leaf litter addition at fortnightly intervals during the wintering period is presented in Tables 1, 2 and in Fig.1. The cumulative figures of litter addition is also presented in Tables 3, 4 and Fig. 2.

The average litter fall per tree for RRII 105 clone was 10.73 kg (oven dry weight) whereas in RRII 118 it was only 8.18 kg. Based on these figures the dry leaf litter was estimated by considering the actual stand of 366 trees/ha and

Table 1. Quantity of leaf litter collected at fortnightly interval from three selected trees of RRII 105

Date of collection	Dry weight of leaf litter (kg)		
	Lamina	Petiole	Total
21.11.92	0.158	0.028	0.186
05.12.92	1.551	0.247	1.798
19.12.92	3.445	0.621	4.066
02.01.93	4.808	0.949	5.757
16.01.93	5.005	0.945	5.950
30.01.93	8.898	1.216	10.114
13.02.93	2.620	0.407	3.027
20.02.93	1.063	0.219	1.282
Total	27.548	4.632	32.180
Mean (per tree)	9.183	1.544	10.727

Table 2. Quantity of leaf litter collected at fortnightly interval from three selected trees of RRII 118

Date of collection	Dry weight of leaf litter (kg)		
	Lamina	Petiole	Total
21.11.92	Nil	--	--
05.12.92	0.882	0.110	0.992
19.12.92	1.608	0.240	1.848
02.01.93	1.777	0.253	2.030
16.01.93	1.797	0.257	2.054
30.01.93	5.943	0.837	6.780
13.02.93	7.980	1.596	9.576
27.02.93	1.040	0.207	1.247
Total	21.027	3.500	24.527
Mean (per tree)	7.009	1.167	8.176

Fig.1 Estimated quantity of leaf litter at fortnightly intervals for the clones RRII 105 and RRII 118 (kg/ha)

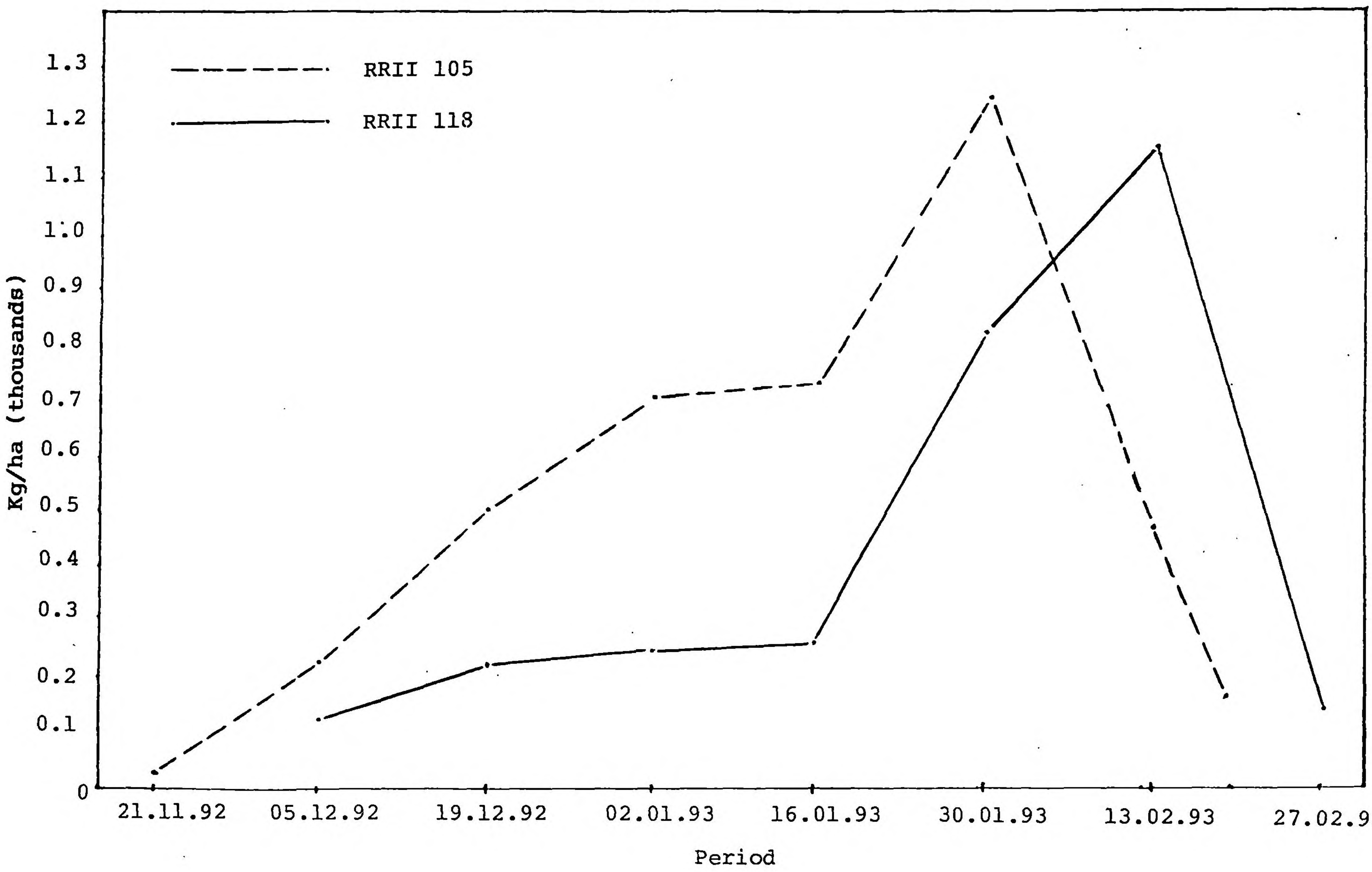


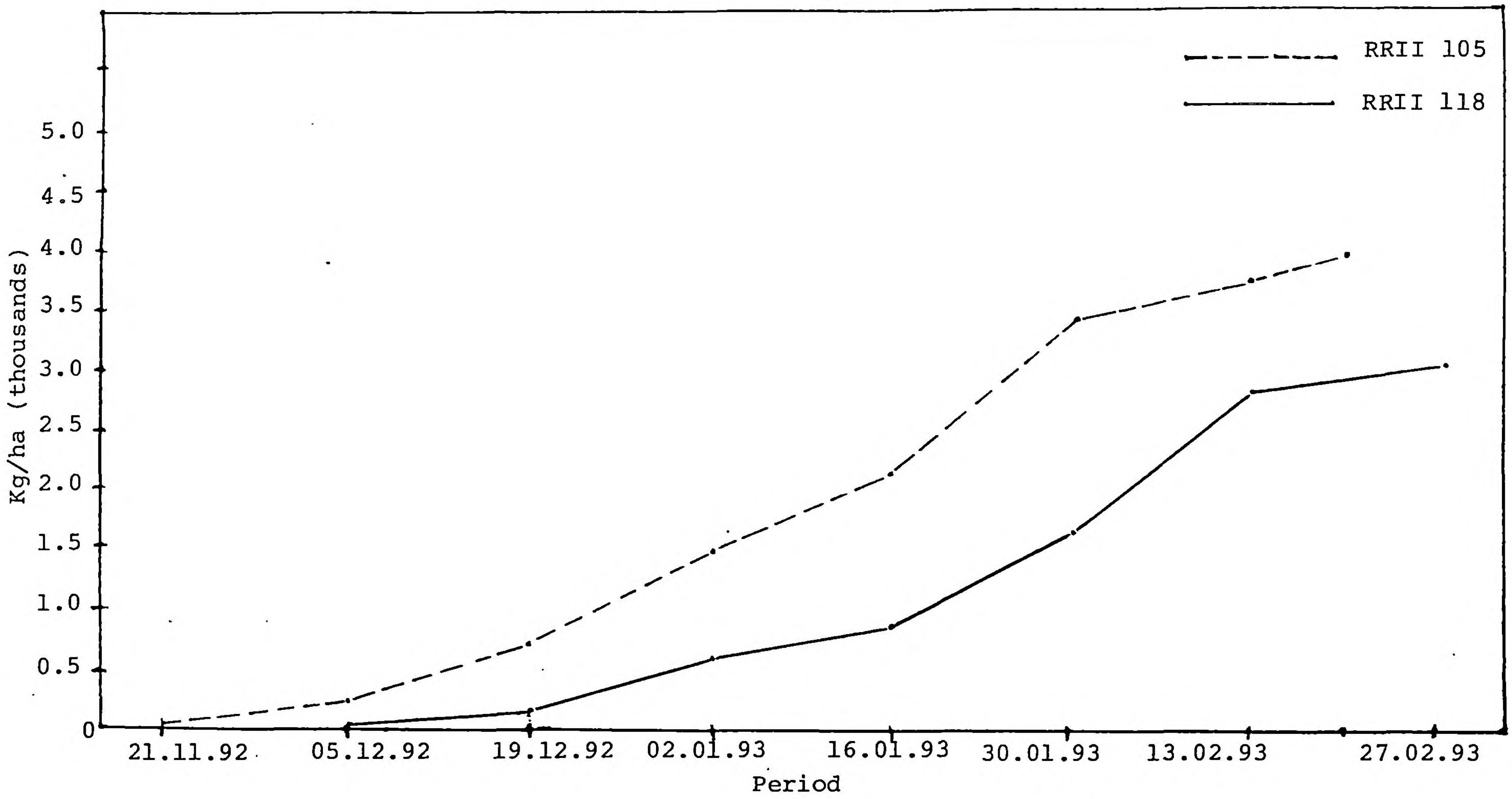
Table 3. Cumulative addition of leaf litter at fortnightly intervals for the clone RRII 105

Date of collection	Dry weight of leaf litter from selected 3 trees (kg)	Dry weight of leaf litter kg/ha (estimated)
21.11.92	0.186	22.692
05.12.92	1.984	242.048
19.12.92	6.050	738.100
02.01.93	11.807	1440.454
16.01.93	17.757	2166.354
30.01.93	27.871	3400.262
13.02.93	30.898	3769.556
20.02.93	32.180	3925.960

Table 4. Cumulative addition of leaf litter at fortnightly intervals for the clone RRII 118

Date of collection	Dry weight of leaf litter from selected 3 trees (kg)	Dry weight of leaf litter kg/ha (estimate)
05.12.92	0.992	121.024
19.12.92	2.840	346.480
02.01.93	4.870	594.140
16.01.93	6.924	844.728
30.01.93	13.704	1671.888
13.02.93	23.280	2840.160
27.02.93	24.527	2992.294

Fig.2 Cumulative addition of leaf litter for the clones RRII 105 and RRII 118 (kg/ha)



it worked out to 3925.96 kg and 2992.29 kg respectively for RRII 105 and RRII 118 (Tables 5 and 6). Out of the total leaf litter added in RRII 105, leaf lamina constituted 3360.86 kg and petioles 565.10 kg (Table 5). The leaf lamina of RRII 105 accounted for about 85.6 percentage of total leaf litter.

In the case of RRII 118, the leaf lamina constituted 2565.29 kg/ha and petioles 427.00 kg/ha (Table 6). Leaf lamina of RRII 118 contibuted 85.7 percentage of the total leaf litter added. In both the clones petiole lamina ratio was worked out to be 1:6. This value is in agreement with the observations of Shorrocks (1965 a).

Studying the leaf litter fall amongst monocultural crops, Singh (1968) recorded an exceptionally high value of 17,300 kg ha^{-1} yr^{-1} for Tectona grandis in India. However lower values of leaf litter fall in monocultural crops have been reported by Egunjobi and Onweluzo (1979) for Pinus caribeae (5988 kg ha^{-1} yr^{-1}), Venkataramanan et al. (1983) in Eucalyptus globulus (1935 kg/ha); Rajvanshi and Gupta (1985) for Dalbergia sisso (4750 kg ha^{-1} yr^{-1}).

In a study in the same field conducted by Guruprasad (1992) the annual leaf litter fall during wintering season of last year for RRII 105 was 4112 kg ha^{-1} yr^{-1}. The present study also showed a similar value of 3925 kg ha^{-1} yr^{-1} for the

Table 5. Estimated quantity of leaf litter at fortnightly intervals per ha for the clone RRII 105

Date of Collection	Fresh weight (kg)			Dry weight (kg)		
	Lamina	Petiole	Total	Lamina	Petiole	Total
21.11.92	22.448	5.612	28.060	19.276	3.416	22.692
05.12.92	224.529	36.551	261.080	189.222	30.134	219.356
19.12.92	490.367	73.273	563.640	420.290	75.762	496.052
02.01.93	609.730	123.490	733.220	586.576	115.778	702.354
16.01.93	760.574	195.906	956.480	610.610	115.290	725.900
30.01.93	1214.889	205.191	1420.080	1085.556	148.352	1233.908
13.02.93	332.427	67.733	400.160	319.640	49.654	369.294
20.02.93	147.687	21.893	169.580	129.686	26.718	156.404
Total	3802.651	729.649	4532.300	3360.856	565.104	3925.960

Table 6. Estimated quantity of leaf litter at fortnightly intervals per ha for the clone RRII 118

Date of Collection	Fresh weight (kg)			Dry weight (kg)		
	Lamina	Petiole	Total	Lamina	Petiole	Total
21.11.92			Wintering not started			
05.12.92	131.382	16.230	147.620	107.604	13.420	121.024
19.12.92	234.569	21.631	256.200	196.176	29.280	225.456
02.01.93	229.177	40.443	269.620	216.794	30.866	247.660
16.01.93	222.040	31.720	253.760	219.234	31.354	250.588
30.01.93	918.373	173.527	1091.900	725.046	102.114	827.160
13.02.93	912.943	213.117	1126.060	973.560	194.712	1168.272
27.02.93	150.233	30.327	180.560	126.880	25.254	152.134
Total	2798.717	527.003	3325.720	2565.294	427.000	2992.294

same clone where as RRII 118 is having a comparatively lower quantity of leaf litter of 2992 kg ha^{-1} yr^{-1}. The marginal decrease in leaf litter of RRII 105 is slightly in deviation from the expectation as leaf litter should have been marginally higher as the tree advances in age. However incidence of abnormal leaf fall due to phytophthora infection might have been slightly more this year which could have reduced leaf density. Appreciably lower accumulation of leaf litter in RRII 118 also could be attributed to the same reason, since this clone is reported to be more susceptiable to abnormal leaf fall.

The observation of Premakumari (1987) with an estimation of 3240 kg ha^{-1} yr^{-1} of annual litter fall in rubber plantations in the tropical conditions of Kerala is a mean of present estimates of RRII 105 and RRII 118. It is also comparable with Tectona grandis which produced 5.3 tons ha^{-1} yr^{-1} (Seth et al., 1963) and is also within the range of 1.01 to 6.21 tons ha^{-1} yr^{-1} as reported by Singh (1968) in the deciduous forest of Varanasi and Udaipur. An estimate of 4.04 tons ha^{-1} yr^{-1} in the same forest reported by Garg and Vyas (1975) is almost same as in the present study.

In a recent investigation conducted in three monoclonal rubber plantation in Bendel state of Nigeria by Onyibe and Gill (1992) a mean annual leaf litter fall of

9604 ± 25.4 , 9460 ± 23.3 and 8902 ± 23.7 kg ha^{-1} yr^{-1} in clones PR 107, GT 1 and RRIM 600 respectively were reported. It is a higher value when compared with the present results. The variability may be mainly due to the age and also due to climate, density of planting, clone, maintenance as reported by Orimoyegun (1985).

On comparison the results showed that RRII 105 is more efficient (31 per cent) than RRII 118 in leaf litter production. Yield data are not available in the present study for making possible correlations with the leaf litter addition. This can be tried in further studies.

4.3 Nutrient status of leaves and litter

4.3.1 Nutrient status of leaves retained on the tree while wintering

The percentage composition of N, P, K, Ca and Mg in leaves prior to wintering, middle of wintering, and by the end of wintering were analysed separately and tabulated in the Tables 7 and 8. The leaf samples were collected from a tree of each clone having partial wintering.

A close study of the values in Tables 7 and 8 reveals that among the five major nutrients, N, P and K showed a gradual increase in concentration till the middle of wintering

Table 7. Chemical composition of leaf samples of RRII 105 having partial wintering

Date of collection	Description of leaf sample	Percentage of nutrients in lamina				
		N	P	K	Ca	Mg
10.11.92	Sample collected before wintering	3.07	0.29	1.12	1.25	0.50
02.01.93	Sample collected in the middle of wintering	3.33	0.31	1.28	1.32	0.40
20.02.93	Sample collected at the end of wintering	2.60	0.18	0.98	1.34	0.39

Table 8. Chemical composition of leaf samples of RRII 118 having partial wintering

Date of collection	Description of leaf sample	Percentage of nutrients in lamina				
		N	P	K	Ca	Mg
10.11.92	Sample collected before wintering	3.05	0.29	1.30	1.52	0.42
02.01.93	Sample collected in the middle of wintering	3.15	0.29	1.32	1.96	0.46
27.02.93	Sample collected at the end of wintering	2.40	0.19	0.80	2.18	0.56

and later decreased as the wintering was complete. This pattern was similar in both the clones. But Ca concentration increased with the progress of wintering in both clones. The magnesium content was decreased in RRII 105 and showed a little increase in RRII 118 as the wintering progresses. This change in foliar nutrient level might be due to the mobilisation of nutrients in the plant. By January (middle of wintering) refoliation starts and the nutrient reserves would be mobilised to the foliage and would be reflected initially on the existing mature foliage also.

4.3.2 Nutrient status of leaf litter

Chemical status of major nutrients like N, P, K, Ca and Mg in the leaf litter of each clone collected fortnightly is given in Tables 9 and 10. The changes in the percentage content of the above nutrients in the different collections is depicted in Fig.3 and 4.

The data presented in Tables 9 and 10 and Figures 3 and 4 is more or less agreeable with earlier mentioned facts in Tables 7 and 8. A gradual decrease of nutrient concentration in the leaf litter was observed in the case of N, P and K in both the clones, whereas gradual increase was noticed in nutrient concentration of Ca and Mg. Schweizer (1939) quoted by Dijkman (1951) observed that the leaves just before

Table 9. Chemical composition of leaf litter of RRII 105 at fortnightly intervals

Date of collection	N%	P%	K%	Ca%	Mg%
21.11.92	2.47	0.21	1.20	0.96	0.31
05.12.92	2.45	0.20	1.22	0.98	0.32
19.12.92	2.08	0.16	1.34	1.23	0.30
02.01.93	2.74	0.18	1.56	0.90	0.30
16.01.93	1.36	0.08	1.12	1.30	0.32
30.01.93	1.32	0.06	1.04	1.65	0.46
13.02.93	1.36	0.06	1.26	1.44	0.37
20.02.93	1.30	0.06	1.26	1.49	0.39
Average	1.88	0.13	1.23	1.24	0.35

Table 10. Chemical composition of leaf litter of RRII 118 at fortnightly intervals

Date of collection	N%	P%	K%	Ca%	Mg%
05.12.92	2.20	0.14	1.14	1.21	0.29
19.12.92	1.89	0.16	1.06	1.43	0.35
02.01.93	1.92	0.15	1.16	1.52	0.29
16.01.93	1.67	0.12	1.14	1.33	0.27
30.01.93	1.30	0.07	1.06	1.51	0.28
13.02.93	1.36	0.06	0.80	1.88	0.47
27.02.93	1.13	0.06	0.80	2.00	0.48
Average	1.64	0.11	1.02	1.55	0.35

Fig.3 Chemical composition of leaf litter at fortnightly intervals for the clone RRII 105

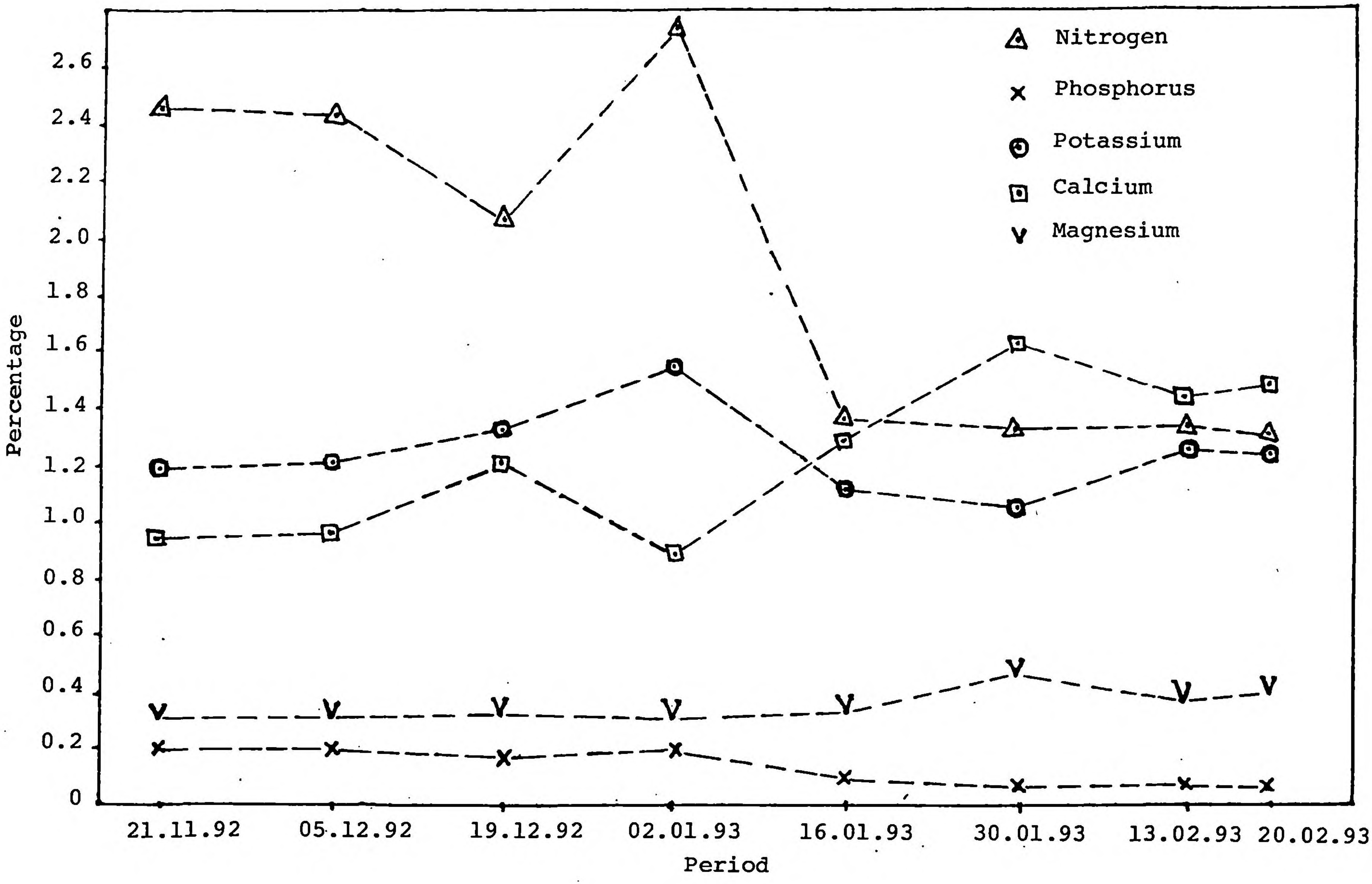
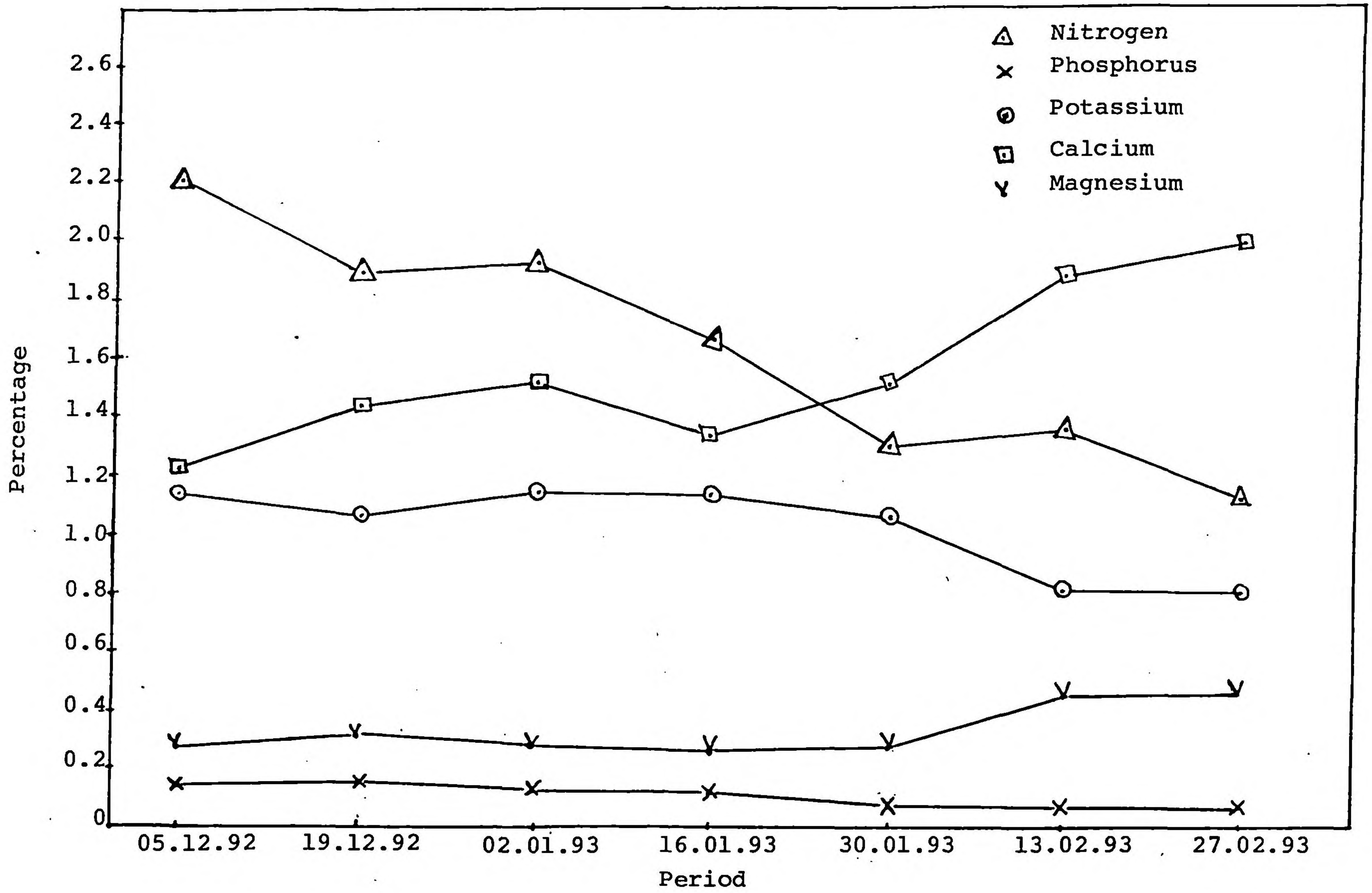


Fig.4 Chemical composition of leaf litter at fortnightly intervals for the clone RRII 118



abscission contained 140 kg N, 38 kg P, 40 kg K per ha/yr eventhough a major portion of nutrients get translocated by the time of wintering. Guruprasad (1992) also reported that the elements like N, P and K get translocated as the wintering progresses. The observations in the present study are also in conformity with the earlier findings.

In the samples collected during early January, concentrations of certain nutrients were increased marginally. A similar observation was also reported by Guruprasad (1992) and hence a closer study to analyse the situation is needed. However the relatively higher nutrient level in January might be due to the commencement of refoliation, as discussed earlier.

It was also observed that the nutrient concentration in the leaf litter of both the clones varied considerably. The average nutrient concentration of each clone was in the decreasing order of N>Ca>K>Mg>P. All the major nutrients studied except Ca were higher in RRII 105 than in RRII 118 (Tables 9 and 10).

Higher percentage of Ca in leaf litter was reported by Duvigneaud and Smet (1970) in Oak Forests of Belgium, Venkataramanan and Chinnamony (1978) in temperate evergreen forests of Nilgiris, Singh (1984) in Eucalyptus of smith plantations (U.P.), Tandon et al. (1991) in Poplars of Tarai region of U.P. and Guruprasad (1992) in the clone RRII 105 of Vellanikkara Estate. The higher percentage of calcium accumulation in the leaf litter may be due to the low mobility of Ca within the plant system.

4.3.3 Total nutrients added to soil through litter addition

The quantity of nutrients added (N, P, K, Ca and Mg) to the soil through leaf litter is presented in Tables 11, 12 and 13 and are depicted in Fig.5. Among the five major nutrients there was maximum return of N followed by Ca and K in RRII 105. Whereas in RRII 118 maximum return was for Ca, followed by N and K. The return of P was minimum in both the clones.

The values observed for N, P, Ca and Mg for the clone RRII 105 are almost within the range of values reported by Shorrocks (1965 b) in Rubber Plantations of Malaysia. But the addition of K is almost double in the present study as reported by Guruprasad (1992) and it may be due to the higher availability in the soil and luxury consumption of this particular element by the plant.

Tan (1975) reported that 53 kg N per hectare is returned to the soil annually through litter fall in a well maintained mature plantation. Premakumari (1987) estimated a

Table 11. Addition of nutrients through leaf litter during wintering from three selected trees of RRII 105

Date of collection	Nutrients released (grams)				
	N	P	K	Ca	Mg
21.11.92	4.59	0.39	2.23	1.78	0.57
05.12.92	44.05	3.60	22.00	17.62	5.75
19.12.92	84.57	6.51	54.48	50.01	12.19
02.01.93	157.74	10.36	89.81	51.81	17.27
16.01.93	80.92	4.76	66.64	77.35	19.04
30.01.93	133.50	6.07	105.19	166.88	46.52
13.02.93	41.17	1.82	38.14	43.58	11.19
20 02.93	16.66	0.76	16.15	19.10	5.00
Total	563.20	34.57	394.64	428.13	117.52
Mean (per tree)	187.73	11.52	131.55	142.71	39.17

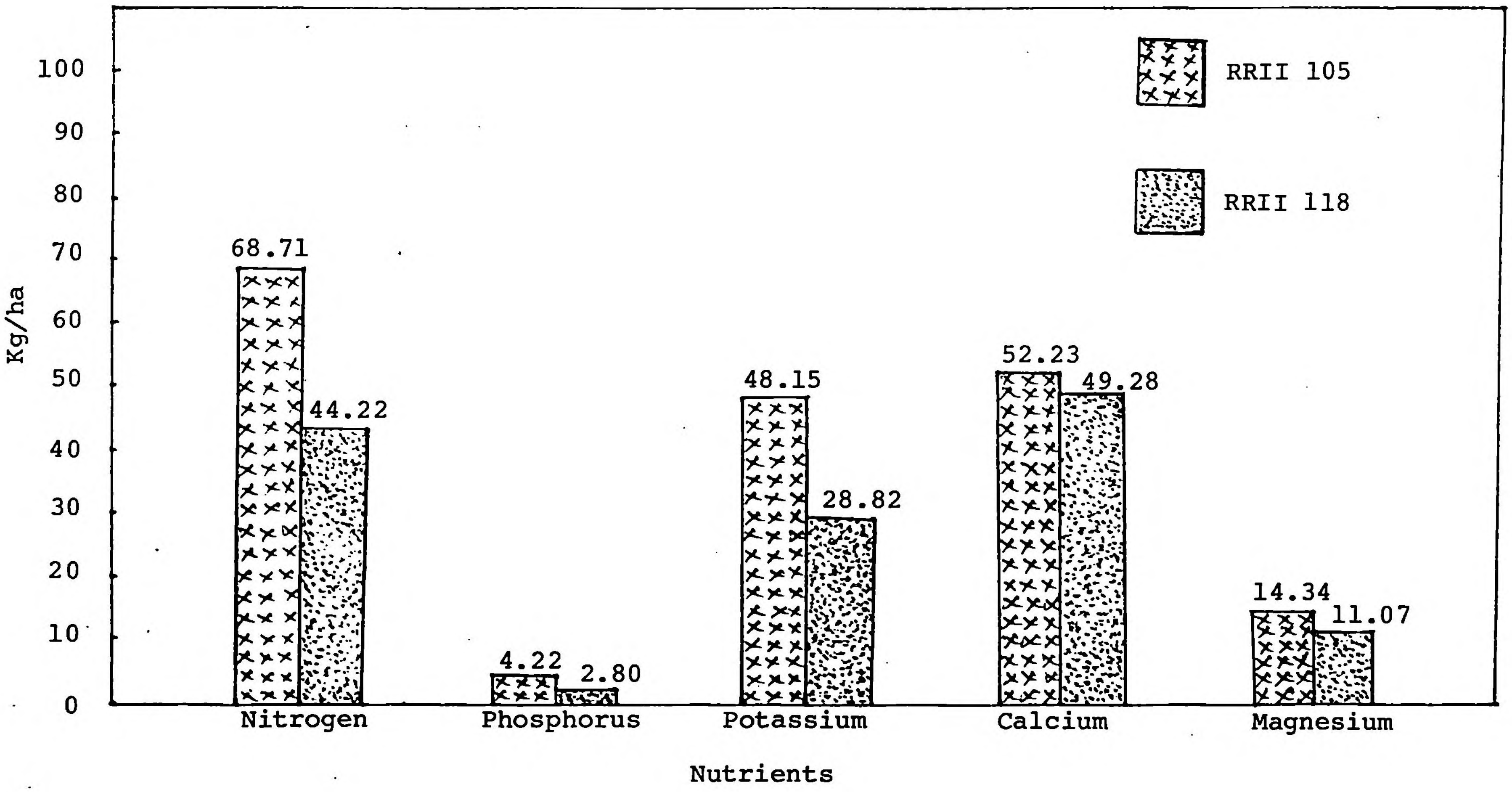
Table 12. Addition of nutrients through leaf litter during wintering from three selected trees of RRII 118

Date of collection	Nutrients released (grams) N	P	K	Ca	Mg
05.12.92	21.82	1.38	11.30	12.00	2.87
19.12.92	34.92	2.95	19.58	26.42	6.46
02.01.93	38.97	3.04	23.54	30.85	5.88
16.01.93	34.30	2.46	23.41	27.31	5.54
30.01.93	88.14	4.74	71.86	102.37	18.98
13.02.93	130.23	7.66	76.60	180.02	45.00
27 02.93	14.09	0.74	9.97	24.94	5.98
Total	362.47	22.97	236.26	403.91	90.71
Mean (per tree)	120.82	7.66	78.75	134.64	30.24

Table 13. Addition of nutrients through leaf litter during wintering for the clones RRII 105 and RRII 118

Nutrients	Estimated quantity (in kg) on per hectare basis	
	RRII 105	RRII 118
Nitrogen	68.71	44.22
Phosphorus	4.22	2.80
Potassium	48.15	28.82
Calcium	52.23	49.28
Magnesium	14.34	11.07

Fig.5 Addition of nutrients through leaf litter during wintering for the clones RRII 105 and RRII 118 (on per ha basis)



quantity of 48.5 kg N ha^{-1} yr^{-1} in the rubber plantation of Kerala andisalmost similar to the present result observed for RRII 118.

Comparison of the valuesgiven in Table 13 showed that there is considerable clonal variation in the nutrient status of the leaf litter. Return of N through the leaf litter of RRII 105 was almost double as compared with that of RRII 118. This is because of the higher quantity of leaf litter added in the clone RRII 105 rather than the higher foliar nitrogen level.

4.4 Soil fertility as influenced by leaf litter

Soil samples taken from the litter removed plot (inside the net) and litter deposited areas (outside the net) were analysed and tabulated in the Tables 14 and 15 for the clones RRII 105 and RRII 118 respectively. In a close study of Tables 14 and 15 the percentage of organic carbon, available P, available K and available Mg were found to decrease with the depth of soil. But available Mg was found to be high in 30 to 60 cm soil depth. It may due to the high magnesium content present in the subsoil, released during the soil genesis.

According to Pritchett (1979) the concentration of potassium and magnesium generally decreased from the surface litter to that of lower humus layer. This observation is found agreeable with the present study. In another study conducted by Venkataramanan et al. (1983) it was found that the level of organic carbon, total nitrogen and exchangeable potassium were very high in 0 to 15 cm soil layer as compared to 30 to 60 cm soil depth in the Eucalyptus globulus plantation in Nilgiris. It is also in conformity with the results obtained in the present study.

It is too early to compare the soil fertility status influenced by leaf litter in clone RRII 118, because the investigation started in 1992 November only and so soil samples were not analysed after the experiment. According to Onyibe and Gill (1992) the turn over time of leaf litter of rubber trees at Nigeria varies from 0.5 years to 0.7 years.

A comparative study of soil analysis data of litter removed plot and litter deposited area of RRII 105 obtained before the experiment (Table 14) showed a marked increase in the organic carbon content in the soil of the litter deposited area, whereas the increase was not much pronounced in other major nutrients. The decrease of nutrients due to rhizosphere activity was more pronounced in litter removed plot. This fact was again studied from the soil analysis datas obtained from the same plots after the experiment (Table 16).

On comparison of Tables 14 and 16 it is found that the percentage of organic carbon, available phosphorus, available potassium and available magnesium contents were low in litter removed plot of RRII 105. This decrease is due to the continued activity of rhizosphere and other losses in the absence of soil enrichment through leaf litter addition. The latter was checked by the removal of leaf litter at fortnightly intervals. The difference was maximum in 0 to 15 cm depth and the minimum in 30 to 60 cm, because the feeding roots of rubber tree is more concentrated in surface layer of soil.

In another comparison of soil analysis data of leaf litter deposited areas, given in Tables 14 and 16 showed a considerable increase of organic carbon content at depth of 0 to 15 cms soil, after the experiment. Whereas the other nutrients showed a marginal increase only. It is due to the decomposition of the leaf litter added. A little decrease of nutrients were noticed in the soil depth of 15 to 30 cm and it may be due to the uptake of nutrients by the trees.

A comparison of last year soil analysis (top soil 0 to 30 cm) reproduced in Table 17 and the corresponding present data given in Table 16 reveals the depletion of organic carbon and major nutrients except available P in the soil of the

Table 14. Data of soil chemical analysis of RRII 105 plot before starting the experiment (November 1992)

Part No.	Sample description	Depth of soil	Percentage of organic carbon	Available P (mg/100 g)	Available K (mg/100 g)	Available Mg (mg/100 g)
A	Soil sample from leaf litter removed area (inside the net)	0 to 15 cms	0.799	0.80	3.63	2.82
		15 to 30 cms	0.651	0.60	2.75	2.96
		Mean (0 to 30 cms)	(0.725)	(0.70)	(3.19)	(2.89)
		30 to 60 cms	0.562	0.50	2.50	4.48
B	Soil sample from leaf litter deposited area (outside the net)	0 to 15 cms	1.240	0.88	4.82	4.23
		15 to 30 cms	0.932	0.55	3.94	2.25
		Mean (0 to 30 cms)	(1.086)	(0.68)	(4.38)	(3.10)
		30 to 60 cms	0.620	0.50	2.75	4.49

Table 15. Data of Soil chemical analysis of RRII 118 plot before starting the experiment (November 1992)

Part No.	Description	Soil sample No.	Depth of soil	Percentage of organic carbon	Available P (mg/100g)	Available K (mg/100g)	Available Mg (mg/100g)
A	Soil sample from leaf litter removed area (inside the net)	1	0 to 15 cm	0.920	0.6	5.5	4.32
		2	15 to 30 cm	0.969	0.5	4.88	3.60
		3	30 to 60 cm	0.920	0.5	3.0	4.40
B	Soil sample from leaf litter deposited area (outside the net)	4	0 to 15 cm	0.920	0.6	5.0	4.0
		5	15 to 30 cm	0.681	0.3	5.63	4.0
		6	30 to 60 cm	0.622	0.3	3.25	4.48

Table 16. Data of soil chemical analysis of RRII 105 plot after the experiment is over (March 1993)

Part No.	Sample description	Depth of soil	Percentage of organic carbon	Available P (mg/100 g)	Available K (mg/100 g)	Available Mg (mg/100 g)
A	Soil sample from leaf litter removed area (inside the net)	0 to 15 cm	0.689	0.72	3.02	2.36
		15 to 30 cm	0.648	0.53	2.41	2.70
		Mean (0 to 30 cm)	(0.668)	(0.62)	(2.72)	(2.53)
		30 to 60 cm	0.562	0.51	2.49	4.37
B	Soil sample from leaf litter deposited area (outside the net)	0 to 15 cm	1.401	0.89	4.89	4.26
		15 to 30 cm	0.942	0.54	3.90	3.23
		Mean (0 to 30 cm)	(1.172)	(0.72)	(4.40)	(3.75)
		30 to 60 cm	0.619	0.52	2.81	4.48

Table 17. Data of soil chemical analysis of RRII 105 (March - 1992)*

Soil sample No.	Description of sample	Percentage of organic carbon	Available P (mg/100 g)	Available K (mg/100 g)	Available Mg (mg/100 g)
A.	Top soil sample from litter removed area (0 to 30 cm)	1.39	0.59	4.21	2.66
B.	Top soil sample from the litter deposited area (0 to 30 cm)	1.21	0.53	4.87	4.30

* Data reproduced from Guruprasad (1992)

litter removed plot. The slight increase of available P may be due to the release of fixed P and its low uptake. The decrease of other nutrients was already discussed earlier. When the organic carbon and nutrient status of litter deposited areas of present study (Table 16) was compared with that of last year (Table 17) a little decrease in organic carbon and available potassium in the top soil (0 to 30 cm) was observed. However, with respect to P and Mg an increase was noticed. The decrease of nutrient may be due to the high rate of uptake by the rhizosphere and the plant uptake of available P and available Mg may be low.

4.5. Leaf area index

Leaf area index was computed for the clones RRII 105 and RRII 118 (Table 18) from a sample of fifty dried leaves (150 leaflets). It was observed that RRII 105 is having a higher leaf area index than RRII 118. It is only due to the higher quantity of leaf rather than the unit leaf area. This would reflect in the photosynthetic efficiency and biomass production of the clones. The high leaf area index would be one of the important factor that contributes to higher litter addition and yield potential for the clone RRII 105.

Table 18. Leaf area index for the clones RRII 105 and RRII 118

Parameters	RRII 105	RRII 118
Unit leaf area (3 leaflets)	196.00 cm^2	208.30 cm^2
Unit leaf dry weight	43.00 gm	44.00 gm
Leaf area per gram dry weight	216.27 cm^2	236.70 cm^2
Leaf litter added per hectare (dry weight of lamina)	3360.86 kg	2565.29 kg
Leaf area per hectare	72685.23 m^2	60720.51 m^2
Leaf area index	7.27	6.07

SUMMARY

5. SUMMARY

The present study is a part of a long term observation to quantify the leaf litter addition and to compare the nutrient recycling in different clones of rubber in the Vellanikkara estate of Kerala Agricultural University.

During the year under study the pattern of wintering was studied for two clones namely, RRII 105 and RRII 118. The wintering started earlier in RRII 105 and it was delayed by one week in RRII 118. The wintering started by 15th November 1992 and it continued upto 27th February 1993. It was complete in both the clones. The rate of defoliation in RRII 105 was found to gradually increase from 2nd fortnight of November and reached the maximum by the 2nd fortnight of January 1993; whereas in RRII 118 wintering was late and started slowly and then showed sudden increase during January and reached the maximum in the 1st fortnight of February 1993.

During the defoliation period, total leaf litter production (dry weight) was estimated to be 3925 kg ha^{-1} yr^{-1} and 2992 kg ha^{-1} yr^{-1} for the clones RRII 105 and RRII 118 respectively.

The nutrients contributed through the leaf litter of RRII 105 worked out on per hectare basis. accounted for

69 kg N, 4 kg P, 48 kg K, 52 kg Ca and 14 kg Mg, whereas leaf litter of RRII 118 contributed 44 kg N, 3 kg P, 29 kg K, 49 kg Ca and 11 kg Mg. The clone RRII 105 was found to contribute more nutrients to the soil through leaf litter addition than RRII 118.

During the study, a gradual decline in the levels of N, P and K was noticed in the leaves of both the clones during wintering period and this might be due to the shift of these nutrients to the other parts. But such a trend was not observed in the case of Ca and Mg. Nutrient levels of leaf litter collected at fortnightly intervals, showed a sudden increase in N, P and K levels in the 2nd fortnight of December and this shift was more conspicuous. This may be due to the mobilisation of stored nutrients to the activated shoot tips just before the commencement of refoliation.

An attempt was made to study the nutrient dynamics through leaf litter addition in the plots of RRII 105 and it was observed that the rate of depletion of nutrients was higher in the litter removed area than the litter deposited area. The depletion of nutrients was more pronounced in 0 to 30 cm of soil depth compared to 30 to 60 cm and it may be due to the active functioning of surface feeding roots of rubber.

In the leaf deposited area the rate of depletion of nutrients were minimum because the nutrient removal would be almost compensated by the release of nutrients from the decomposed litter added to the soil. It is too early to quantify the nutrient dynamics in the present study.

Leaf area index for the clones RRII 105 and RRII 118 were also worked out to be 7.27 and 6.07 respectively. This variation would reflect in the photosynthetic efficiency and biomass production.

REFERENCES

REFERENCES

Adams, M.A. and Attiwill, P.M. (1985). Nutrient cycling and Nitrogen mineralization on the forest of S.E. Australia. <u>Plant and Soil</u>, 92: 319-339.

*Anderson, J.M. and Swift, M.J. (1983). Decomposition in the tropical forests. In <u>The Tropical Rainforest. Ecology and Management</u>. (Eds.) S.L. Sutton, T.C. Whitemore and A.C. Chadwick, Black Wells, Scientific Publication, Oxford.

Balagopalan, M. and Jose, A.I. (1982). Distribution of organic carbon and form of Nitrogen in soil under Mahogany and Teak. <u>Agri</u>. <u>Res</u>. <u>J</u>. <u>Kerala</u>, 20: 16-21.

*Dijkman (1951). Fertilizing and Soil Management <u>Hevea</u>. <u>Thirty years of research in the Far East</u> Univ. of Miami Press, Florida : 17-41.

Durani, P.K., Rout, D.K. and Asma Begum (1985). Estimates of litter accumulation in the forest system of Khandariri Hill <u>Indian</u> <u>Forestor</u>, III (7): 554-561.

*Duvigneaud, P. and De Smet (1970). Biological nutrients in temperate deciduous forests. <u>Analysis of Temperate forest ecosystem</u>. Ed. Reichie, D.E. Springer-Verlag, Berlin : 199-225.

*Egunjobi, J. K. and Onweluzo, B.S. (1979). Litterfall, mineral turnover and litter accumulation in *Pinus caribeae* L. Stands at Ibadan Nigeria. *Biotropica* 11: 251-255.

*Garg, R.K. and Vyas, L.N. (1975). Litter production in deciduous forest near Udaipur, (South Rajasthan), *Indian Tropical Ecological Systems*: 131-135.

*George, M. (1986). "Nutrient uptake and cycling in a young Eucalyptus hybrid plantation". *Mysore. Forest* 22: 19-26.

George, M. and Varghese, G. (1990a). Nutrient cycling in *Eucalyptus globulus* plantation I. organic matter production, nutrient accumulation in standing crop and nutrients removal through harvest. *Indian Forester*, 116 (1): 42-48.

George, M. and Varghese, G. (1990b). Nutrient cycling in *Eucalyptus globulus* plantation II. Litter production and nutrients return. *Indian Forester*, 116 (12): 932-968.

George, M. and Varghese, G. (1991). Nutrient cycling in *Eucalyptus globulus* plantation III. Nutrients retained, returned, uptake and nutrient cycling. *Indian Forester*, 117 (2): 110-116.

*Gresham, C.A. (1982). Litter fall pattern in mature loblolly and long leaf pine status in coastal South California. Forest Science 28: 223-231.

Guruprasad, M.K. (1992). Leaf litter addition and nutrient recycling in Rubber (Hevea brasiliensis Muell. Arg.) in Vellanikkara Estate. P.G. Diploma Dissertation, Department of Plantation Crops and Spices, Kerala Agri. Uty., Vellanikkara.

Jackson, M.L. (1973). Soil chemical analysis. Prentice Hall of India (P) Ltd., New Delhi.

Jasbir Singh and Ramakrishnan, P.S. (1982). "Structure and Function of a Subtropical humid forest of Meghalaya" II. Litter dynamics and nutrient cycling. Proc. Indian Aca. Sci. 91: 255-268.

Karthikakutty Amma, M. (1989). Plant and Soil Analysis. Laboratory Manual, Rubber Research Institute of India, Kottayam.

Krishnakumar, A.K., Chandra Gupta, R., Sinha, R.R., Sethuraj, M.R., Potty, S.N., Thomas Eappen and Krishna Das (1991). Ecological impact of Rubber (Hevea brasiliensis) Plantation in North East India. 2. Soil properties and biomass recycling. Indian J. Nat. Rubb. Res. 4 (2): 134-141.

Malhotra, P.P., Tandon, V.N. and Pramod Kumar (1987). Distribution of Nutrients and their return through litter fall in an age series of Pinus patula schl. and cham. Plantation in Nilgiris. Indian Forester, 113 (5): 323-332.

Negi, J.D.S., Sharma, D.C. and Lepcha, S.T.S. (1991). Biomass and nutrient accumulation (inventories) in shrub land ecosystems of Garhaval. Indian Forester, 117 (8): 635-641.

Onyibe, H.I. and Gill, L.S. (1992). Litter production and disappearance in three clones of Rubber J. Pln. Crops 20 (1): 22-31.

* Orimoyegun, S.O. (1985). Nitrogen return through litter fall in an Obeche (Triplochiton scleroxylon K.Schum) Plantation ecosystem in Nigeria. J. Trop. For. Res., 1: 63-74.

Premakumari, S. (1987). Nutrient recycling under monoculture conditions in the tropical forest ecosystems. M.Sc. Thesis., Kerala Agrl. Uty., Vellayani.

Pritchett, W.L. (1979). Properties and management of forest soils. C. John Wiley & Sons, New York: 62-69.

* Rajvanshi, R. and Gupta, S.R. (1985). Biomass productivity and litterfall in a tropical Dalbergia sisso Roxb. forest. J. Tree Science 4: 73-78.

Ramprasad and Mishra, G.P. (1985). Litter productivity of dry deciduous teak forest stands of Sagar (Madhya Pradesh). Indian Forester, 111 (6): 359-367.

*Rapp, M. (1967). Litter production and contribution to the soil of mineral elements and Nitrogen in Pinus halepensis forest, Oecolpl 2: 325-328.

*Rapp, M. and Lossaint, P. (1967). Organic matter and mineral elements returned to the soil under Quercus ilex and Quercus coccifera in Southern France Trans. Comf. Mediterranean Soils, Madrid 1966: 269-275.

*Remezov, N.P. (1959). The method of studying the biological cycle of elements in forests. Pochroredenie, 1: 71-79.

Rubber Research Institute of India (1980). The rubber tree (Hevea brasiliensis Muell. Arg,) Hand book of Natural Rubber production in India. Ed. P.N. Radhakrishna Pillai, p.25.

*Schweizer, J. (1939). Over de functic vanhet blad bij het cultuurgewas gedurende een vegetatie period. De Bergcult 13: 1628-1641.

Seth, S.K., Kaul, O.N. and Gupta, A.C. (1963). Some observations on nutrition cycle and return of nutrients in plantations at new forest. Indian Forester, 89 (2): 90-98.

Shorrocks, V.M. (1965a). Mineral Nutrition growth and nutrient cycle of Hevea brasiliensis I. growth and nutrient content. J. Rubb. Res. Inst. Malaya. 19 (1): 32-47.

Shorrocks, V.M. (1965b). Mineral Nutrition, Growth and nutrient cycle of Hevea brasiliensis II. Nutrient cycle and fertilizer requirements. J. Rubb. Res. Inst. Malaya. 19 (1): 48-61.

Singh, K.P. (1968). Litter production and nutrient turn over in deciduous forests of Varanasi. Proc. Symp. Recent Advanced Trop. Ecol. 655-665.

Singh, R.P. (1984). Nutrient cycle in Eucalyptus tereticoris Smith plantations, Indian Forester, 110 (1): 76-85.

Singh, R.P., Mathur, H.N. and Gupta, M.K. (1984). Litter production and release of nutrients in coniferous forest of Himachal Pradesh. Indian Forester, 110 (10): 1014-1022.

*Tan, K.H. (1975). Hevea leaf litter fall and chemical changes during litter decomposition. Proc. Third Asian Soil Conf., Kuala Lumpur, 1975: 147.

Tan. K.H. and Pushparajah (1985). Studies on nitrogen in Malasian Soils. V. Mineralisation of leaf litter nitrogen and its availability to rubber seedlings. J. Rubb. Res. Inst. Malaysia, 33 (1): 26-36.

Tandon, V.N., Pandey, M.C., Rawat, H.S. and Sharma, D.C. (1991). Organic productivity and mineral cycling in palntations of Populus deltoides in Tarai region of Uttar Pradesh. Indian Forester, 117 (8): 596-608.

Venkataramanan, C. and Chinnamony, S. (1978). A preliminary note on the return of nutrient by the leaf litter of wet (montane) temperate evergreen Shola Forests of Nilgiris. Indian Forester, 104 (6): 450-456.

Venkataramanan, C., Haldorai, B., Samraj, P., Nalatwadmath, S.K.and Henry, C. (1983). Return of nutrients by leaf litter of blue gum (Eucalyptus globulus) plantation in Nilgiris in Tamil Nadu. Indian Forester, 109 (6): 370-377.

Watson, G.A. (1989). Nutrition, Rubber Ed. C.C. Webster, and W.J. Baulkwill, Longman Scientific and technical, N.Y. 291-348.

*Wiersum, K.F. (1983). Effect of various vegetation layers in an *Acacia auriculiformis* forest plantation on surface erosion in Java, Indonesia. Soil Erosion and conservation, Eds. S.A. EI-Swaify, W.C. Moldenhauer and A.LO. Soil Conservation Society of America, Ankeny, pp. 79-89.

* (Original not seen)

LEAF LITTER ADDITION AND NUTRIENT RECYCLING IN TWO CLONES OF RUBBER (*Hevea brasiliensis Muell. Arg.*) IN VELLANIKKARA ESTATE

By

K. N. SUMADHAN

ABSTRACT OF THE DISSERTATION

Submitted in partial fulfilment of the requirement for the

Post Graduate Diploma in Natural Rubber Production

Faculty of Agriculture
Kerala Agricultural University

DEPARTMENT OF PLANTATION CROPS AND SPICES
KERALA AGRICULTURAL UNIVERSITY
Vellanikkara, Thrissur

1993

ABSTRACT

The pattern of wintering, rate of litter fall, nutrient return through leaf litter and soil fertility status were investigated in two clones of rubber in Vellanikkara Estate of Kerala Agricultural University. The wintering started by mid November and was earlier in RRII 105 than in RRII 118 and ended by last week of February. The peak period of defoliation for RRII 105 was in the 2nd fortnight of January, whereas for RRII 118 it was maximum in the 1st fortnight of February. The total leaf litter production by RRII 105 and RRII 118 was estimated to be 3926 kg and 2992 kg ha^{-1} yr^{-1} respectively. The recycling of major nutrients through leaf litter was higher in RRII 105 (N: 69 kg/ha, P: 4 kg/ha, K: 48 kg/ha, Ca: 52 kg/ha and Mg: 14 kg/ha) than in RRII 118 (N: 44 kg/ha, P: 3 kg/ha, K: 29 kg/ha, Ca: 49 kg/ha and Mg: 11 kg/ha). In both the clones the percentage of N, P and K retained in the leaf litter was found to be increased suddenly by the end of December and then decreased till the end of wintering. The rate of depletion of nutrients in the litter removed area was higher than the litter deposited area. The nutrient depletion was not much pronounced in litter deposited area since the nutrient removal for crop growth might be compensated by the nutrients released from the litter on decomposition. The rate of depletion was high in 0 to

15 cm depth of the soil and was negligible in 30 to 60 cm depth. Leaf area index was estimated to be 7.27 and 6.07 for the clones RRII 105 and RRII 118 respectively. The higher leaf area index would be the major contributing factor for the increased litter production and better yield potential exhibited by the clone RRII 105.