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

By

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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

COLLEGE OF HORTICULTURE
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1994

DECLARATION

I hereby declare that this dissertation entitled "**Leaf Litter Addition and Nutrient Recycling in Two Clones of Rubber (*Hevea brasiliensis* Muell. Arg.) at Vellanikkara Estate of Kerala Agricultural University**" 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, **S. Rajan**

14.9.1994.

CERTIFICATE

Certified that the dissertation **"Leaf Litter Addition and Nutrient Recycling in Two Clones of Rubber (<u>Hevea brasiliensis</u> Muell. Arg.) at Vellanikkara Estate of Kerala Agricultural University"** is a record of research work done by **Sri. S. Rajan** 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 of the Committee of **Sri. S. Rajan**, 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 (<u>Hevea brasiliensis</u> Muell. Arg.) at Vellanikkara Estate of Kerala Agricultural University"** may be submitted by Sri. S. Rajan, in partial fulfilment of the requirement of the Diploma.

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INTRODUCTION

INTRODUCTION

Hevea brasiliensis (Para rubber), a native of Amazon rain forests has all the attributes common to forestry species. It is a deciduous tree which shed leaves well before summer months and this process commonly known as 'wintering' is an annual feature in rubber plantations all over the world. After a brief spell, the rubber trees refoliate even under moisture stress, but other species like *Tectona grandis* put up new leaves only after the receipt of regular rains. During wintering, the abscissed leaves form appreciable source of organic material which on decomposition gradually return nutritive elements to the soil.

The organic material added to the soil through the annual leaf fall not only recycles the nutrient elements, but also adds appreciable quantities of biomass. The thick layer of leaf litter provides a layer of mulch which helps in preventing heat build up of soil especially during summer months when there is little canopy cover. The enrichment of soil organic matter through the leaf litter improves the structure of soil, water holding capacity and reduce soil erosion to a limited extent at least till they get decomposed. The beneficial effect of organic matter on soil microflora has been established by many workers.

The pattern of annual leaf fall and the quantity of leaf litter added are highly influenced by the age of the trees, prevailing climatic conditions, canopy density, clones and location.

A wealth of information is available on the pattern of wintering, quantity of biomass added through litter and the nutrient recycling in various tree species, especially of tropical rain forests of India and abroad. However, such attempts are limited in rubber except for the earlier work of Shorrocks (1965a, b); Tan (1975); and a recent one of Oniybe and Gill (1992). Hence a long term study was initiated in 1991-92 in the Vellanikkara rubber estate of Kerala Agricultural University, Trichur to quantify the leaf litter addition and nutrient return to soil (Guruprasad, 1992 and Sumadhan, 1993). The present study is a continuation of the earlier trial with a wider objective of comparing two methods of collection of leaf litter.

The results of the investigation would lead to a better understanding of nutrient dynamics in a nearly closed ecosystem under rubber trees.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Rubber cultivation ensure rapid ground coverage, and also generate biomass approximating to that for humid tropical forests. Furthermore the mature Hevea ecosystem is an efficient nutritionally self-sustaining one (Sivanadyan and Moris, 1993). Many workers from India and abroad have studied leaf litter dynamics and nutrient recycling in various crops which include a few in rubber. In this chapter a brief review of the relevant literature on these aspects is presented.

2.1 Rubber

2.1.1 Leaf litter production

In an elaborate study conducted by Shorrocks (1965a) on the growth and nutrient content of Hevea brasiliensis varying in age from one year to 30 years 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 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 a time.

Premakumari (1987) has observed that the annual litter fall in a rubber plantation was 3240 kg/ha. Onyibe and Gill (1992) in a study conducted in three monoclonal plantations of rubber in Bendel state, Nigeria has reported that the mean annual leaf litter fall was highest in PR 107 (9604 $\pm$ 25.4 kg ha^{-1} yr^{-1}) followed by GT 1 (9460 $\pm$ 23.3 kg ha^{-1} yr^{-1}) and RRIM 600 (8902 $\pm$ 23.7 kg ha^{-1} yr^{-1}). It was also reported that out of the total litter, leaf litter constitutes 74 per cent in PR 107, 92 per cent in GT and 65 per cent in RRIM 600.

In a study conducted by Guruprasad (1992) on leaf litter addition and nutrient recycling in *Hevea brasiliensis* in Vellanikkara Estate, it was estimated that leaf litter for the clone RRII 105 during wintering period was 4112 kg/ha whereas Sumadhan (1993) in a study in the same field has observed that the annual leaf litter fall during wintering period for RRII 105 and RRII 118 were 3926 kg and 2992 kg respectively.

2.1.2 Nutrient return through litter fall

The litter in Hevea ecosystem is seen to contribute appreciable amount of nutrients to be recycled. Schweizer (1939) in a study conducted at the Besoeki Experimental Station, East Jawa, has reported that major portion of the nutrients in the leaves get translocated just before abscission. It was also estimated that 140 kg N, 38 kg P and 40 kg K were returned to a hectare of land annually by way of leaf shedding from 200 rubber trees.

In an elaborate study, Shorrocks (1965b) 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.

Tan (1975) has reported that 53 kg/ha of organic leaf litter N was returned annually to the soil through leaf fall in a well manured mature rubber plantation.

Premakumari (1987) found that the annual nutrient return through leaf litter in the rubber plantation 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 a study conducted by Guruprasad (1992) on leaf litter addition and nutrient recycling in *Hevea brasiliensis*, it was estimated that 63.3 kg N, 2.64 kg P, 44.0 kg K, 42.32 kg Ca and 8.93 kg Mg were the annual contribution through wintering for the clone RRII 105. Sumadhan (1993) in an experiment in the same field has estimated that 68.71 kg N, 4.22 kg P, 48.15 kg K, 52.23 kg Ca and 14.34 kg Mg for the clone RRII 105 and the corresponding figures for the clone

RRII 118 were 44.22 kg N, 2.80 kg P, 28.82 kg K, 49.28 kg Ca and 11.07 kg Mg.

2.1.3 Nutrient recycling and soil productivity

In a detailed study on mineralisation of leaf litter nitrogen and its availability to rubber seedling, 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). In a study by Premakumari (1987), the C/N ratio in rubber plantation at the depth of 0 to 30 cm was 10.

According to Watson (1989), from planting to replanting the rubber plantation presents an environmentally acceptable replacement for the native forest, being a 'closed' ecosystem with a constant cycle of uptake and return of nutrients from and to the soil.

In a study conducted by Krishnakumar *et al*. (1991), the ecological impact of rubber (*Hevea brasiliensis*) plantations in the Siligari Sub-division (Darjeling district) of West Bengal in North-East India, it was observed that the litter accumulation under rubber has been found to be lower than that of teak and natural forest.

2.2 Natural forests and other plantations

2.2.1 Litter production

The amount of litter that accumulates in a forest ecosystem is mainly dependent on the type of vegetation. Robert and Chandler (1943) have reported that about 246.3 lbs/acre of litter (oven dry) was obtained from seven common coniferous species of North East United States. Seth *et al*. (1963) from a study on nutrient cycle and return of nutrients in plantations at 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}.

The annual litter production was reported to be about 5.5 t ha^{-1} yr^{-1} 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}).

Durani *et al*. (1985) in a study compared the annual litter production in different parts of India, and it was observed that sal and teak produce 5.3 t ha^{-1} yr^{-1} of litter and the deciduous forests of Varanasi and Udaipur produce 1.01 to 6.21 t ha^{-1} yr^{-1} and 4.04 t ha^{-1} yr^{-1} respectively.

Ramprasad and Mishra (1985) in a study on litter productivity of dry deciduous teak forest stands of Sagar (Madhya Pradesh) have reported that the total leaf litter production in these forests was 4.959 t ha^{-1} yr^{-1}. It was also reported that higher density values of trees showed high values for their leaf litter and the factors which influenced leaf litter frequency were weight, size, shape and maturity of leaves.

Durani *et al*. (1985) in a study on the litter accumulation in the forest system of the Khandagiri hill of Orissa have reported that the total litter fall was 11.5 t ha^{-1} yr^{-1} and of this 8.03 t ha^{-1} yr^{-1} was leaf litter.

George and Varghese (1990) in a study on the nutrient cycling in *Eucalyptus globulus* plantation of ten year age, observed that 8492 kg ha^{-1} yr^{-1} of litter was produced, of which leaf litter contributed 40 per cent (twig - 38% and bark- 22%).

In a study conducted by Mohankumar and Deepu (1992) in the moist deciduous forests of the Western Ghats (India), the annual litter fall was estimated from 12.18 to 14.43 t ha^{-1}.

While studying the litter fall beneath Bruguiera gymnorrhiza in Mangrove forests of South Andamans, Dagar and Sharma (1993) have observed that leaf material contributed 68 to 73 per cent of the total litter dry weight.

Shajivaz and Abraham (1994) in a study on litter production in forest ecosystems of Kallar and Palode, Kerala have observed that leaves contributed 76 per cent of the total litter fall.

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. The mineral constituents of the fresh leaves also showed such variation, eventhough their contents were much higher than the corresponding figures for the freshly fallen leaves.

In a study conducted by Venkataramanan and Chinnamony (1978) in shola forests of Nilgiris it was reported that litter added annually was 2121 kg/ha, and its nutrient content works out to 23.1 kg N, 1.3 kg P, 11 kg K, 34 kg Ca and 5 kg Mg.

The nutrients returned through leaf litter of eucalyptus hybrid plantation in Coimbatore, Tamil Nadu, have been estimated by George (1979) as 150 kg K, 40.2 kg Ca, 29.8 kg N, 5 kg Mg and 1.6 kg P.

According to Protector et al. (1983) the element concentration in the litter fall differed greatly between each forest types. The concentration of all elements except calcium from litter fall was below or within the ranges reported for other tropical forests.

In a comparative study of the nutrient return between eucalyptus and shola in Nilgiris in Tamil Nadu, Venketaraman et al. (1983) have reported that leaf litter of shola contained a higher percentage of nutrients especially N, P, Ca and organic matter than that of eucalyptus. They also studied the return of nutrients by the leaf litter in blue gum (Eucalyptus globulus) and observed that the litter of blue gum contained the highest amount of N (1.4 to 1.9%) followed by Ca (0.83 to 1.10%), K (0.14 to 0.32%) and Mg (0.07 to 0.19 %).

Singh *et al*. (1984) have reported that different species of Conifers in Himachal Pradesh contained calcium as the most important base in all the species. The status of nutrients in the litter was in the decreasing order of Ca, N, P and Na. The litter of conifers release more N and P than eucalyptus. They are also of the view that P concentration in litter will be significantly higher in Alpine forests consisting of *Eucalyptus pauciflora* and *Eucalyptus delegatensis*.

In Eucalyptus hybrid plantation of East Dehradun division in Uttar Pradesh, George (1986) had observed that the nutrient content in leaves were of the order of 41, 5, 37, 6 and 9 kg/ha/yr of N, P, K, Ca and Mg respectively.

George and Varghese (1990) in a study on the nutrient cycling in *Eucalyptus globulus* plantation, it was observed that on an annual basis, the total return of nitrogen was 58 kg/ha followed by potassium 40 kg/ha and phosphorus 4.6 kg/ha.

Tandon *et al*. (1991) reported the annual nutrient addition through leaf litter in poplar plantation (*Populus deltoides*) was estimated on per hectare basis as 20.28 kg N, 0.57 kg P, 5.5 kg K, 31.11 kg Ca and 1.89 kg Mg.

In a study conducted by George and Varghese (1992) on nutrient cycling in *Tectona grandis* plantation in Coimbatore

Forest Division having a stand of 750 trees/ha it was observed that the return of various nutrients amounts to 201 kg N, 14 kg P and 84 kg K.

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.

According to Weetman (1962), N became the limiting factor for tree growth in forest ecosystem because it was largely immobilized in the materials accumulated on the forest floor.

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.

In a study conducted by Adams and Attiwill (1985) litter fall was the major pathway 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.

From a study on the nutrient uptake and reclycing in eucalyptus hybrid plantation, George (1986) has observed that the maximum retention was found to be for P and Ca eventhough the maximum uptake was for N and Ca.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present study is the continuation of the study which was started in 1991-92 season to quantify the leaf litter addition and nutrient recycling in rubber plantation in the Vellanikkara Estate of Kerala Agricultural University. First observation in 1991-92 was exclusively on the clone RRII 105 and in 1992-93, the clone RRII 118 was also brought under observation. In the present study, two different methods for litter collection were adopted for the same clones. The rubber trees planted in 1983 in the same field whére the previous studies were undertaken were used. The Vellanikkara estate lies 10°-13' N latitude and 76°-13' E longitude and is 40.29 m from mean sea level. The terrain of the site is almost flat.

3.1. Selection of trees

Three trees of uniform growth in a line, with similar spacing of 4.85 m x 4.85 m and having no vacant points in and around were selected for all the plots.

3.2 Protection for drift of leaf litter and collection of litter

A group of three trees, separately for each of the clone RRII 105 and RRII 118 were well protected by closely woven nylon net upto a height of 14 metres from the ground level in order to prevent the entry of litter from the neighbouring trees and also to prevent the leaves fallen under the tree canopy from being blown away by the wind. The bottom portion of the nets were fixed to the ground by proper pegging

Similarly, two sets of three trees each for the two clones RRII 105 and RRII 118 were protected by fencing at 15 cm height along the centre of the planting rows on all the four sides to find out whether the costly and cumbersome method of providing nets can be avoided

Fixing of nets and fencing were provided by the second week of November i.e., sufficiently earlier to the commencement of wintering. The floor of the selected area was cleared off the grasses, fallen leaves, pods, branches etc.

Wintering commenced on 23rd November, 1993 for the clone RRII 105 and on 25th November, 1993 for the clone RRII 118. The first collection of litter started on 27th November, 1993 and continued till the end of wintering at fortnightly intervals.

3.3 Quantification of the litter collected

Fresh weight of the leaf and twig litter were taken separately. From each collection, samples of 500 g of leaf litter were oven dried till the constant weights were obtained. From the fresh weight and oven dried weight of leaves, the moisture percentage and dry matter percentage were computed. Taking into account the actual density of 366/ha of rubber trees in the experimental plot and as per the 1:6 petiole lamina proportion reported earlier (Sumadhan, 1993), the total lamina and petiole litter addition were estimated. So also the twig litter collected were air dried and weighed and the total twig litter addition was estimated at the rate of 366/ha.

3.4 Chemical analysis of leaf litter

Composite samples of oven dried lamina and petiole were analysed at Rubber Research Institute of India, Kottayam and the nutrient addition through leaf litter were quantified. Nitrogen, phosphorus and potassium 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

The variations in mineral nutrient status of the soil were observed by analysis of soil samples at three depths of 0 to 15 cm, 15 to 30 cm and 30 to 60 cm, collected from the leaf litter removed area (inside the net) and leaf litter deposited area (outside the net). The soil samples were analysed for organic carbon, available P_2O_5, K_2O and MgO following the methods suggested by Jackson (1973). Analysis for organic carbon percentage was done by Walkley and Black method and available P by Bray and Kurtz method. Available K was estimated by flame photometric method and available magnesium analysed by Atomic Absorption Spectrophotometer at the Rubber Research Institute of India.

3.6 Leaf area index

The oven dried weight of 60 leaves (180 leaflets) at mature stage was recorded. The leaf area of individual leaf was recorded using the leaf area meter. Leaf area index was computed based on the formula.

$$\text{Leaf area index} = \frac{\text{Total leaf area}}{\text{Total ground area}}$$

3.7 Weather parameters

Meteorological data for the period, recorded at the observatory, Kerala Agricultural University, Vellanikkara were utilised for the study. Parameters like temperature, rainfall, wind velocity and relative humidity were considered.

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

Evaluation of 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 through two different methods were studied. The mature trees (11 year old) maintained at the Rubber Estate of Kerala Agricultural University, Vellanikakra were utilised for the study.

4.1 Pattern of wintering

The pattern of wintering for the clones RRII 105 and RRII 118 for the year 1993-94 is presented in Tables 1 and 2 and depicted in Figures 1 and 2. The wintering commenced by the 23rd of November for the clone RRII 105 and continued upto 12th February, 1994 whereas in the clone RRII 118 wintering started on the 25th of November and continued till 17th February, 1994. In RRII 105, rate of leaf fall was observed to increase gradually and the maximum leaf fall was in the first fortnight of January 1994. But in the clone RRII 118 rate of fall was slow initially and a slight hike was observed during the first fortnight of January 1994 and the maximum leaf fall was observed in the first fortnight of February 1994 and completed all on a sudden in the same manner. In both the clones the entire leaves were shed.

Table 1. Addition of leaf litter (Lamina + Petiole) per hectare for the clones RRII 105 and RRII 118 under 'netted' condition

Date of collection	RRII 105		RRII 118	
	Fresh wt. in kg	Dry wt. in kg	Fresh wt in kg	dry wt. in kg
27.11.93	357.460	330.420	225.700	215.914
11.12.93	320.250	305.280	172.630	166.465
24.12.93	634.400	471.490	308.660	242.823
08.01.94	1505.480	1470.902	651.148	619.385
22.01.94	1249.280	1136.364	719.800	654.049
05.02.94	939.300	895.645	1617.282	1516.748
19.02.94	488.000	344.168	1620.282	1169.214
Total	5488.170	4954.297	5315.502	4584.558

Table 2. Addition of leaf litter (Lamina + Petiole) per hectare for the clones RRII 105 and RRII 118 under 'fenced' condition

Date of collection	RRII 105		RRII 118	
	Fresh wt. in kg	Dry wt. in kg	Fresh wt in kg	dry wt. in kg
27.11.93	106.140	89.768	64.660	60.388
11.12.93	211.060	201.662	124.440	119.478
24.12.93	383.080	263.644	124.440	82.733
08.01.94	1054.080	996.404	326.960	311.119
22.01.94	622.200	575.865	419.680	394.421
05.02.94	483.120	463.245	512.400	491.713
19.02.94	231.800	146.269	424.560	275.327
Total	3091.480	2736.857	1997.140	1734.946

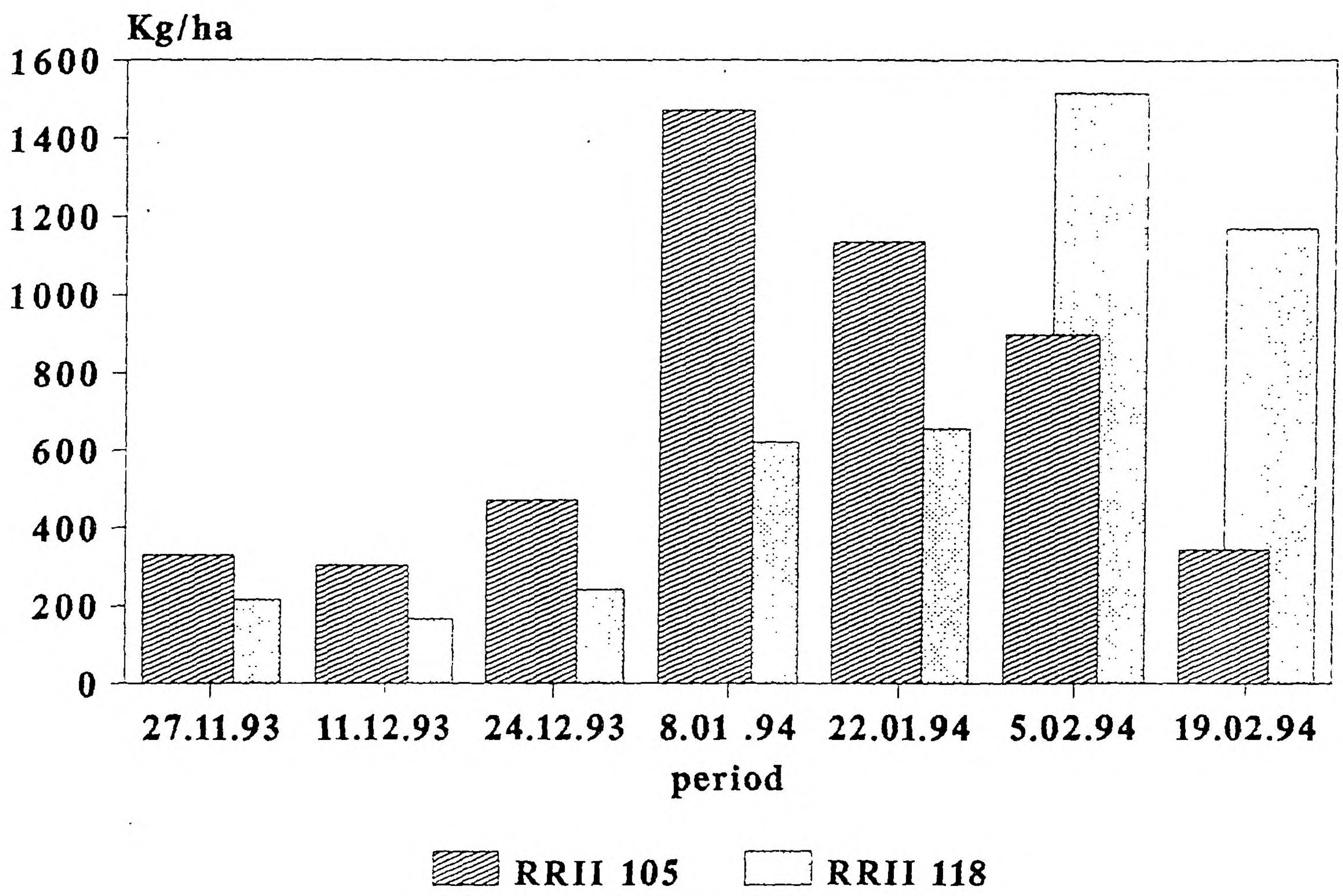

FIG.1. ADDITION OF LEAF LITTER AT FORTNIGHTLY INTERVALS FOR THE CLONES RRII 105 AND RRII 118 UNDER 'NETTED' CONDITION (KG/HA)

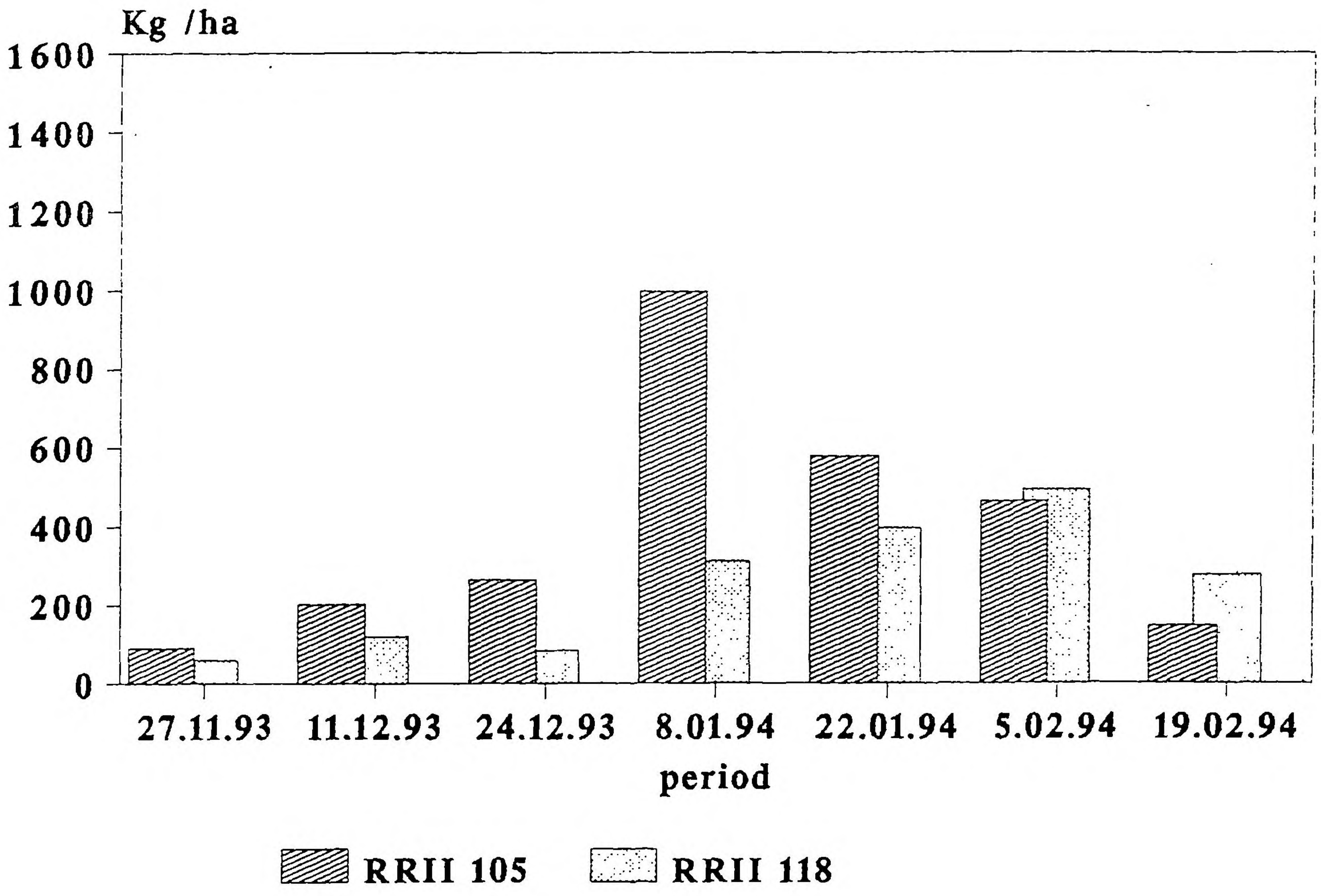

FIG.2. ADDITION OF LEAF LITTER AT FORTNIGHTLY INTERVALS FOR THE CLONES RRII 105 AND RRII 118 UNDER 'FENCED' CONDITION (KG/HA)

From the meteorological data collected for the area (Annexure 1 and 2) it was observed that the wind velocity ranged between 5 km/hr and 13.2 km/hr in the month of November 1993 and was more towards the end of the month. It was during this period that wintering started in the Vellanikkara area. So also the wind velocity was the maximum during the period from third week of December 1993 to fourth week of January 1994 and it ranged between 4.2 km/hr and 23.3 km/hr and the rate of leaf fall during this period was more in both the clones. The wind velocity ranged between 9.2 to 9.9 km/hr during the period from 4th February to 8th February 1994 and during this period the rate of leaf fall was seen increased considerably, especially for the clone RRII 118. The above observations show that wind velocity has a direct influence on the rate of leaf fall.

As per the previous studies conducted in the same locality, it was reported that wintering started by 14th December 1991 and continued till 2nd March, 1992 (Guruprasad, 1992). According to Sumadhan (1993) wintering started in the area on 15th November 1992 and continued upto the end of February 1993 . He also observed clonal variation for the pattern of wintering. Thus, data collected for the last three years indicate that wintering for the clones RRII 105 and RRII

118 in Vellanikkara area is spread over a period of about three to four months from November-December to February-March.

A report from RRII (1980) reveals that wintering in rubber tree is during December-January in South India and wintering may be either complete or partial depending upon the clone, age of plants, seasonal factors and location. In a study conducted by Oniyibe and Gill (1992) in three monoclonal plantations of rubber in Nigeria, it was reported that the bulk of the leaf litter was shed in the driest months of January and February and suggested that the peak leaf fall may be greatly related to water stress. In the present study also a similar pattern, but spread over for three to four months is observed in the leaf fall. Under Indian conditions, the period of leaf fall do not coincide with the dry months, but coincides with periods of low relative humidity, high wind velocity and periods of maximum maturity for the foliage.

Singh et al. (1993) observed litter fall throughout the year in the tropical moist deciduous forest of the Western Ghats with the maximum fall during January and February. In a study conducted by Shajivaz and Abraham (1994) in forest ecosystems of Kallar and Palode in Kerala heavy leaf shedding in deciduous trees was reported to begin in the mid December attaining maximum in the month of February.

The observations of present study is in agreement with the above mentioned reports with respect to the pattern of wintering, confirming the deciduous nature of para rubber.

4.2 Quantity of litter added during wintering

The total litter added during the period was quantified as twig and leaf parts separately. The quantity of leaf litter added at fortnightly intervals during the defoliation period is presented in Tables 1,2 and in Fig.1 and 2. The cumulative figures for litter addition was worked out and presented in Tables 3 and 4 and Figures 3 and 4.

During the period between the completion of wintering in the previous year and commencement of wintering this year, the quantity of leaf litter produced was estimated as 615.700 kg and 419.216 kg (oven dry weight) respectively for the clones RRII 105 and RRII 118. This would be an arbitrary data since much of the fallen leaves would have decomposed during the severe monsoon in the intervening period.

The dry leaf litter collected for RRII 105 during the wintering period was estimated at 4954.297 kg (oven dry weight) whereas in RRII 118 clone it was only 4584.558 kg (Table 1) in the area where canopy was protected with net. Out of the total leaf litter added in RRII 105, leaf lamina constituted around 4246 kg and petioles 708 kg as per the 1:6

Table 3. Cumulative addition of leaf litter at fortnightly intervals for the clones RRII 105 and RRII 118 in the collection in the 'netted' area

Date of collection	RRII 105 Clone kg/ha	RRII 118 Clone kg/ha
27.11.93	330.420	215.914
11.12.93	635.700	382.379
24.12.93	1107.190	625.202
08.01.94	2578.092	1244.587
22.01.94	3714.456	1898.636
05.02.94	4610.101	3415.384
19.02.94	4954.297	4584.558

Table 4. Cumulative addition of leaf litter at fortnightly intervals for the clones RRII 105 and RRII 118 in the collection in the 'fenced' area

Date of collection	RRII 105 Clone kg/ha	RRII 118 Clone kg/ha
27.11.93	89.768	60.388
11.12.93	291.430	179.866
24.12.93	555.074	262.599
08.01.94	1551.478	573.718
22.01.94	2127.343	968.139
05.02.94	2590.588	1459.852
19.02.94	2736.857	1734.946

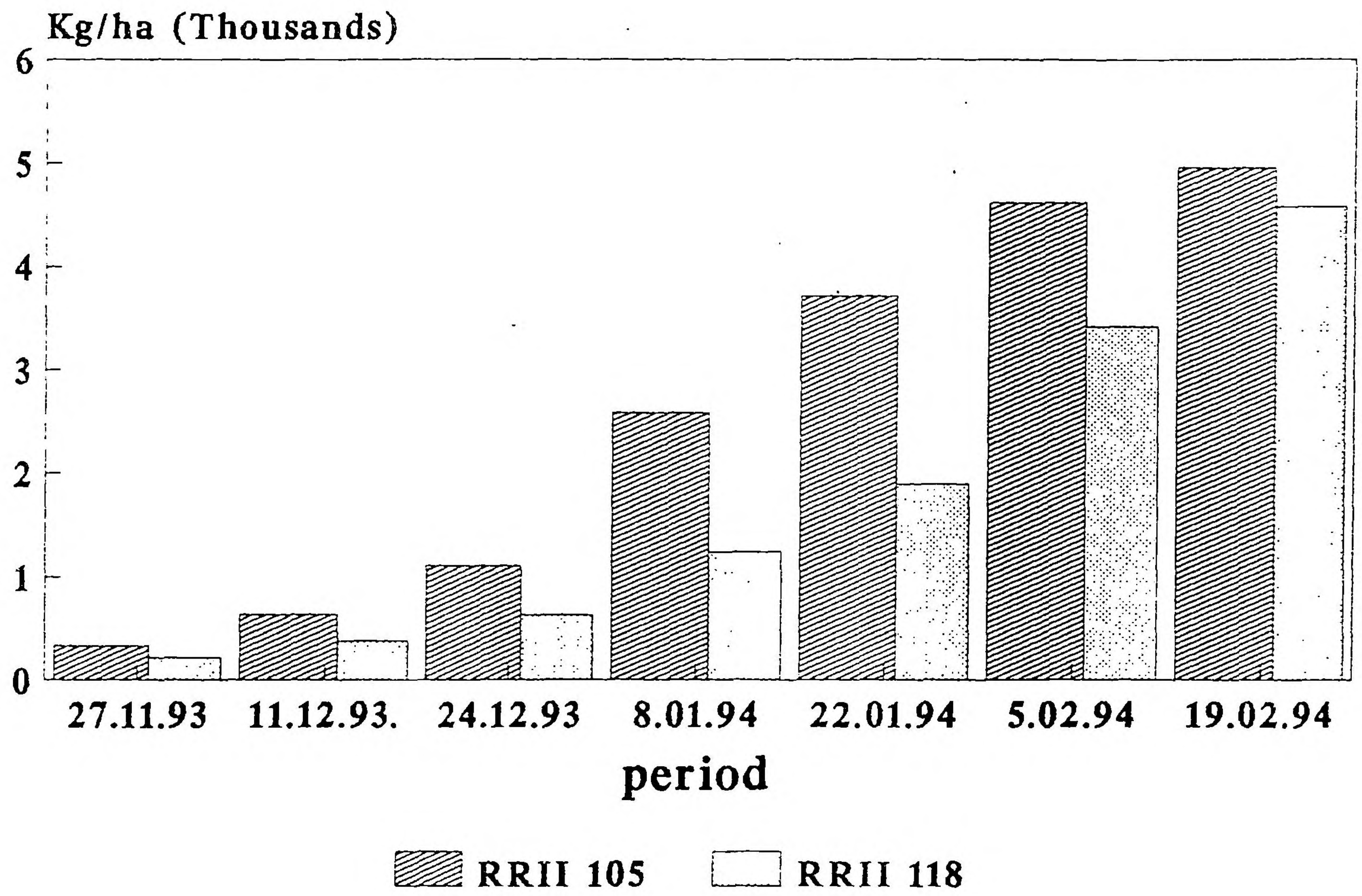

FIG.3. CUMULATIVE ADDITION OF LEAF LITTER (KG/HA) FOR THE CLONES RRII 105 AND RRII 118 IN THE 'NETTED' CONDITION

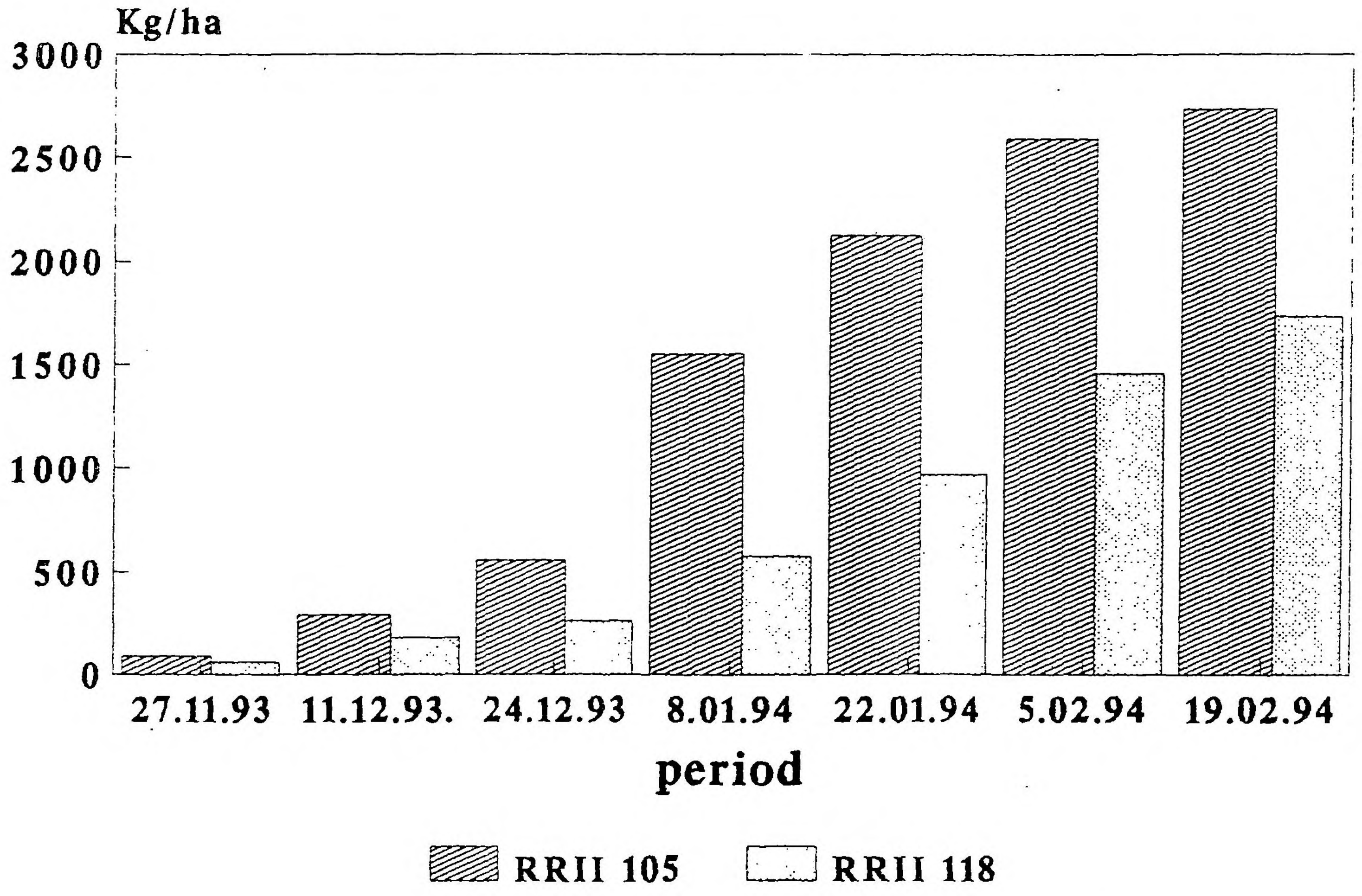

FIG.4. CUMULATIVE ADDITION OF LEAF LITTER (KG/HA) FOR THE CLONES RRII 105 AND RRII 118 IN THE 'FENCED' CONDITION

proportion reported earlier (Sumadhan, 1993). The corresponding figures for RRII 118 would be 3930 kg and 655 kg respectively. The same trend was observed for the trees in which the leaf litter was conserved for collection by fencing (Table 2). However the quantity of litter collected by this method was significantly low as compared to those trees in which the whole canopy was protected with net (Tables 5 and 6). The total litter collected for fenced area was only 55 per cent of the quantity collected in the net area for the clone RRII 105 and it was only about 38 per cent for the clone RRII 118. The high wind velocity during the wintering period would cause leaf drift and this made the fencing method ineffective for litter collection.

The twig litter fall in the wintering period in the net area for RRII 105 was 791 kg and that for RRII 118 was 652 kg (Table 7). The corresponding figures for RRII 105 and RRII 118 in the fenced area were 233 kg and 360 kg respectively (Table 8). The twigs fallen is not likely to contribute to the nutrient status since much of it would be collected and used as fire wood.

In the previous study in the same field the annual leaf litter fall during wintering season of 1991-92 for the clone RRII 105 in the net area was reported to be 4112 kg ha^{-1} (Guruprasad, 1992). Sumadhan (1993) observed the annual

Table 5. Comparison of leaf litter (Lamina + Petiole) in the 'netted' area and 'fenced' area of clone RRII 105

Date of collection	Weight of leaf litter per hectare in the net area (Dry wt.)	Weight of leaf litter per hectare in the fenced area (Dry wt.)	Percentage of leaf litter obtained in the fenced area (when compared to that of net area)
27.11.93	330.420	89.768	27.17
11.12.93	305.280	201.662	66.06
24.12.93	471.490	263.644	55.92
08.01.94	1470.902	996.404	67.74
22.01.94	1136.364	575.865	50.68
05.02.94	895.645	463.245	51.72
19.02.94	344.168	146.269	42.50
Total	4954.269	2736.857	55.24 (Average)

Table 6. Comparison of leaf litter (Lamina + Petiole) in the the 'netted' area and 'fenced' area of clone RRII 118

Date of collection	Weight of leaf litter per hectare in the net area (Dry wt.)	Weight of leaf litter per hectare in the fenced area (Dry wt.)	Percentage of leaf litter obtained in the fenced area (when compared to that of net area)
27.11.93	215.914	60.388	27.97
11.12.93	166.465	119.478	71.77
24.12.93	242.823	82.733	34.07
08.01.94	619.385	311.119	50.23
22.01.94	654.049	394.421	60.30
05.02.94	1516.748	491.713	32.42
19.02.94	1169.214	275.327	23.55
Total	4584.598	1735.179	37.80 (Average)

Table 7. Addition of twig litter for the clones RRII 105 and RRII 118 under 'netted' condition

Date of collection	RRII 105 Clone		RRII 118 Clone	
	Per tree in kg	Per hect in kg	Per tree in kg	Per hect in kg
27.11.93	0.136	49.776	0.206	75.396
11.12.93	0.285	104.310	0.472	172.752
24.12.93	0.413	151.158	0.273	99.918
08.01.94	0.220	80.52	0.427	156.282
22.01.94	0.107	39.162	0.133	48.678
05.02.94	0.933	341.478	0.100	36.600
19.02.94	0.200	24.156	0.057	62.220
Total		790.56		651.846

Table 8. Addition of twig litter for the clones RRII 105 and RRII 118 under 'fenced' condition

Date of collection	RRII 105 Clone		RRII 118 Clone	
	Per tree in kg	Per hect in kg	Per tree in kg	Per hect in kg
27.11.93	0.125	45.750	0.127	46.482
11.12.93	0.142	51.972	0.183	66.978
24.12.93	0.113	41.358	0.260	95.160
08.01.94	0.080	29.280	0.087	31.842
22.01.94	0.060	21.960	0.107	39.162
05.02.94	0.067	24.522	0.060	21.960
19.02.94	0.050	18.300	0.053	58.560
Total		233.142		360.144

leaf litter fall during wintering season of 1992-93 for RRII 105 as 3925.960 kg and that of RRII 118 as 2992.294 kg. The litter collected during the present study was found to be substantially higher than the previous year.

Seth et al. (1963) has estimated the annual litter fall in Tectona grandis at 5300 ha^{-1} yr^{-1}. Singh (1968) has reported that the annual litter ranges from 1010 to 6210 kg ha^{-1} yr^{-1} in the deciduous forest of Varanasi and Udaipur. Garg and Vyas (1975) have estimated the litter at 4.04 ha^{-1} yr^{-1} in the same forest. Reports 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 show lower values of leaf litter fall in monocultural crops.

Premakumari (1987) has estimated the annual litter fall in rubber plantations in the tropical conditions of Kerala as 3240 kg ha^{-1} yr^{-1}. In a study by Onyibe and Gill (1992) in three monoclonal rubber plantation in Bendel State of Nigeria, a mean annual leaf litter addition of 9604 $\pm$ 25.4, 9460 $\pm$ 23.3, 8902 $\pm$ 23.7 kg/ha/yr in clone PR 107, GT and RRII 600 respectively were reported. The values reported from Nigeria are significantly higher than the observed values in the present investigation and this might be a reflection of prevailing agroclimatic condition and difference in canopy size.

George and Varghese (1992) have reported that in Tectona grandis plantation in Coimbatore Forest Division (Age-20 years, Density-750 trees/ha), the total litter amounted to 10.6 t/ha yr^{-1} of which 94.6 per cent was constituted by leaf litter and the rest by non-leaf litter. The planting density and genotype would definitely influence the biomass production and is expressed in terms of leaf litter also. Similar observations has been reported by various other workers (Mohankumar and Deepu, 1992; Singh et al., 1993; Pandit, 1993; Omkarsingh et al., 1993; Joshi, 1993).

The results of the present study are comparable to that of the previous reports from the same experimental plot and also the quantity of leaf fall reported from Malaysia. The present study showed little higher value when compared to the previous studies presumably due to effective spraying done just before the onset of monsoon and also the tree advances in age. But values reported by Oniybe and Gill (1992) from Nigeria seem to be very high compared to the present reports. The variability may be due to the optimum agro-climatic conditions prevailing in Nigeria, age of trees, density of planting, clone used, maintenance etc. The results show that RRII 105 is more efficient (about 9%) than RRII 118 in leaf litter addition which can be due to the tolerance of this clone to abnormal leaf fall disease.

4.3 Nutrient composition of leaf litter

The samples of leaf petiole and lamina were analysed separately for the elements N, P, K, Ca and Mg and are presented in Tables 9 and 10. The variation in the level of nutrients at different stages of wintering is depicted in Fig.5, 6, 7 and 8.

On analysis of the leaf litter it was found that the mean levels of N and Mg were relatively more in the leaf lamina in both the clones studied. The P content was relatively the same in both the lamina and petiole whereas K and Ca did not follow a regular pattern (Tables 9 and 10).

In the clone RRII 105, the litter sample collected on 24.12.93 recorded high levels of N, P and K. This might be because of the presence of high amount of green leaves present in the samples collected during that time. Such distinct variation was not observed in the litter collected for the clone RRII 118.

The percentage of nutrients observed are comparable to that of the earlier studies in the same field by Guruprasad (1992) and Sumadhan (1993). But clonal variation was observed

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

Date of collection		N%	P%	K%	Ca%	Mg%
27.11.93	Lamina	1.26	0.06	0.62	1.36	0.21
	Petiole	1.08	0.05	0.76	1.22	0.15
11.12.93	Lamina	1.41	0.04	1.54	1.27	0.14
	Petiole	1.09	0.07	0.86	1.22	0.22
24.12.93	Lamina	2.95	0.14	1.34	0.97	0.18
	Petiole	1.75	0.10	1.46	1.19	0.15
08.01.94	Lamina	1.58	0.03	1.26	1.23	0.15
	Petiole	0.80	0.04	1.34	1.03	0.12
22.01.94	Lamina	1.31	0.03	0.92	1.08	0.33
	Petiole	0.63	0.03	1.24	1.13	0.20
05.02.94	Lamina	1.12	0.03	1.26	1.17	0.33
	Petiole	0.88	0.04	0.94	1.59	0.21
19.02.94	Lamina	1.88	0.03	1.08	1.45	0.41
	Petiole	0.77	0.03	1.26	1.54	0.30
Mean	Lamina	1.64	0.05	1.15	1.22	0.25
	Petiole	1.00	0.05	1.12	1.27	0.19

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

Date of collection		N%	P%	K%	Ca%	Mg%
27.11.93	Lamina	1.38	0.10	1.08	1.39	0.15
	Petiole	1.44	0.08	1.58	1.53	0.20
11.12.93	Lamina	1.77	0.08	0.88	1.37	0.14
	Petiole	2.82	0.06	0.86	1.70	0.11
24.12.93	Lamina	2.56	0.10	0.88	1.14	0.15
	Petiole	1.54	0.10	1.30	1.26	0.14
08.01.94	Lamina	2.05	0.08	1.00	2.35	0.17
	Petiole	1.32	0.07	1.14	1.65	0.09
22.01.94	Lamina	1.08	0.03	0.86	1.54	0.15
	Petiole	1.10	0.05	1.40	1.29	0.11
05.02.94	Lamina	1.17	0.03	1.04	1.71	0.20
	Petiole	0.87	0.03	1.06	1.77	0.17
19.02.94	Lamina	1.15	0.03	0.64	1.89	0.30
	Petiole	0.74	0.02	1.10	1.44	0.09
Mean	Lamina	1.59	0.06	0.91	1.63	0.18
	Petiole	1.40	0.06	1.21	1.52	0.13

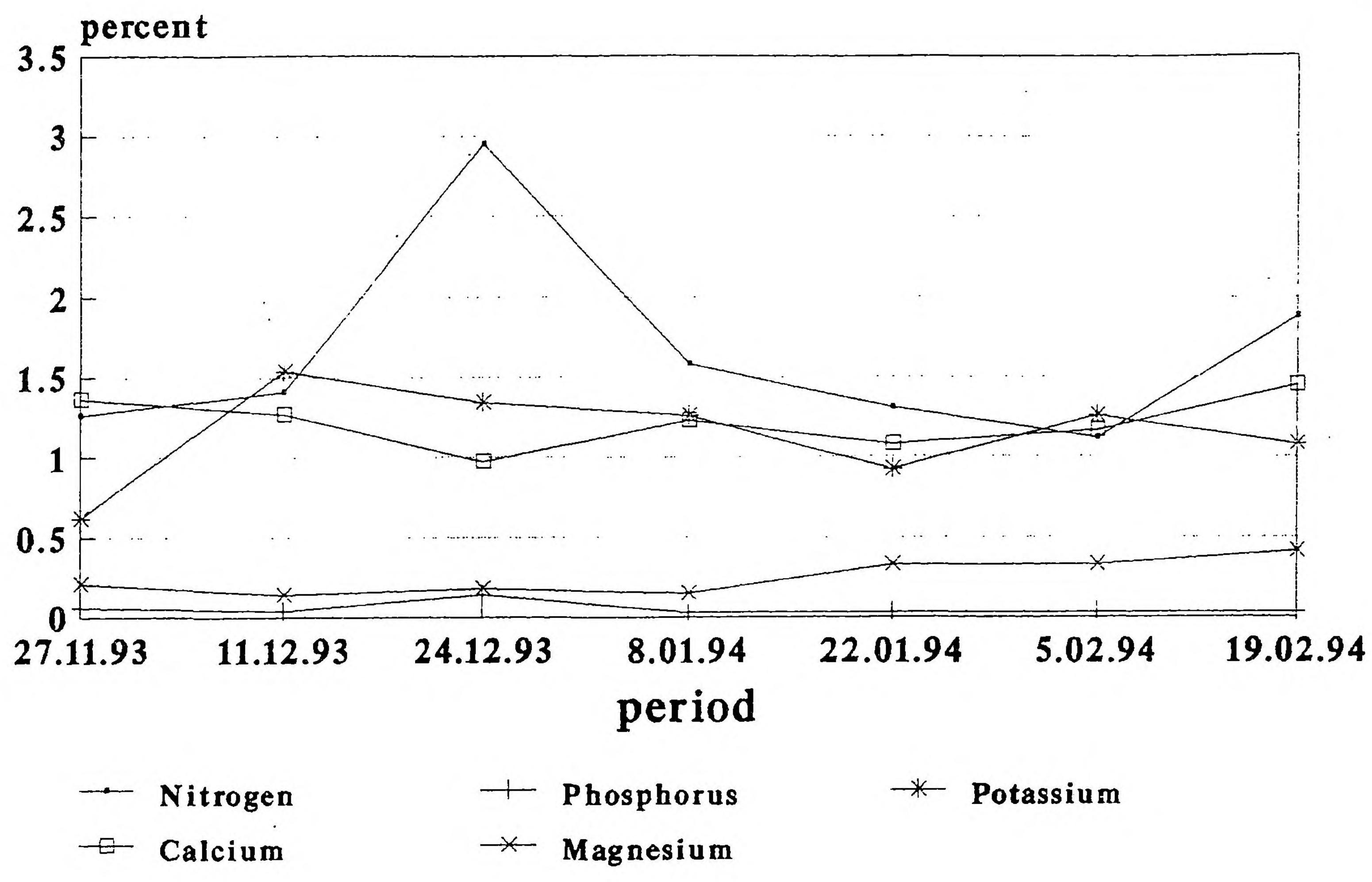

FIG.5. CHEMICAL COMPOSITION OF LEAF LITTER (LEAF LAMINA) AT FORTNIGHTLY INTERVALS FOR THE CLONE RRII 105

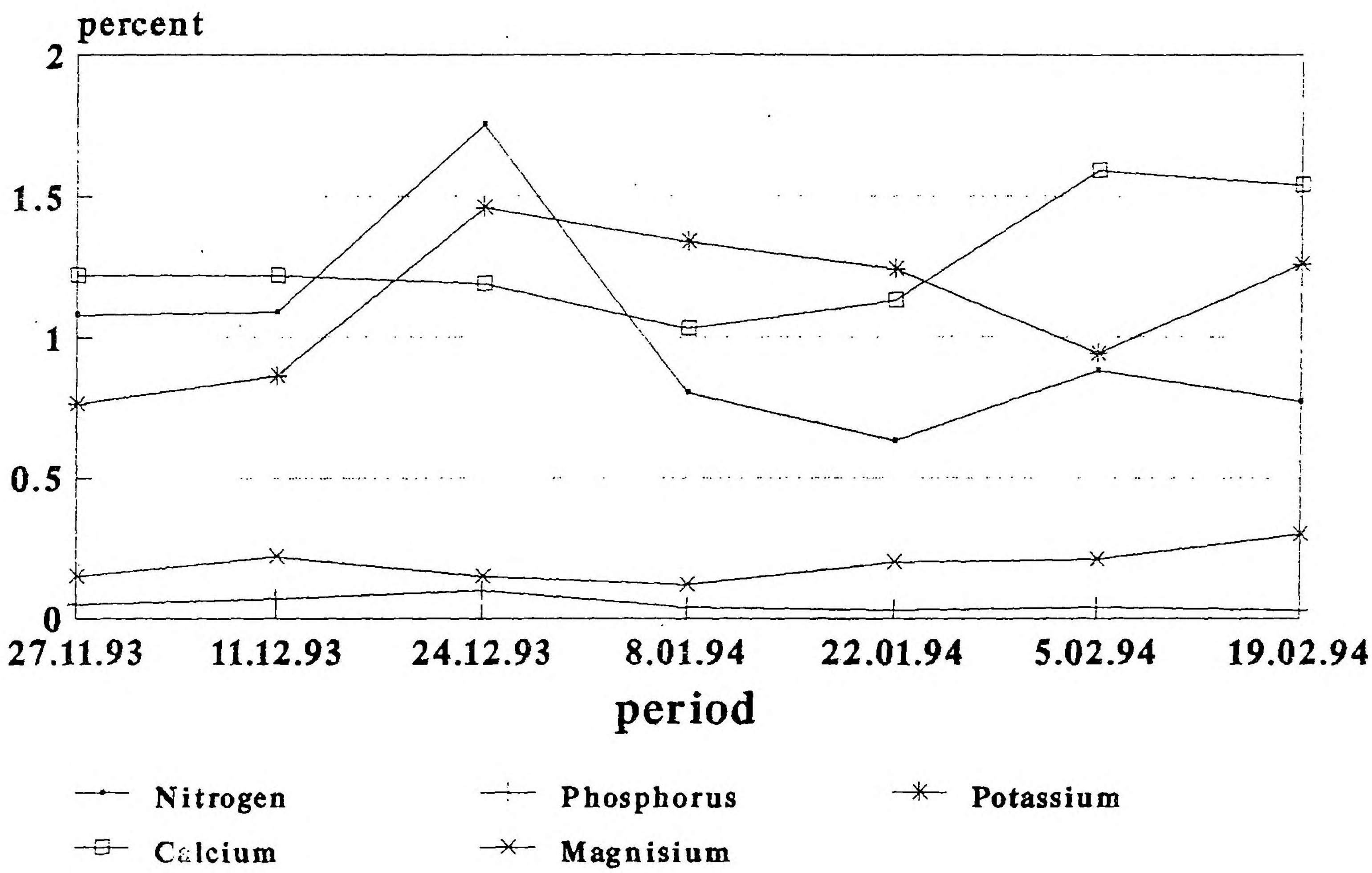

FIG.6. CHEMICAL COMPOSITION OF LEAF LITTER (LEAF PETIOLE) AT FORTNIGHTLY INTERVALS FOR THE CLONE RRII 105

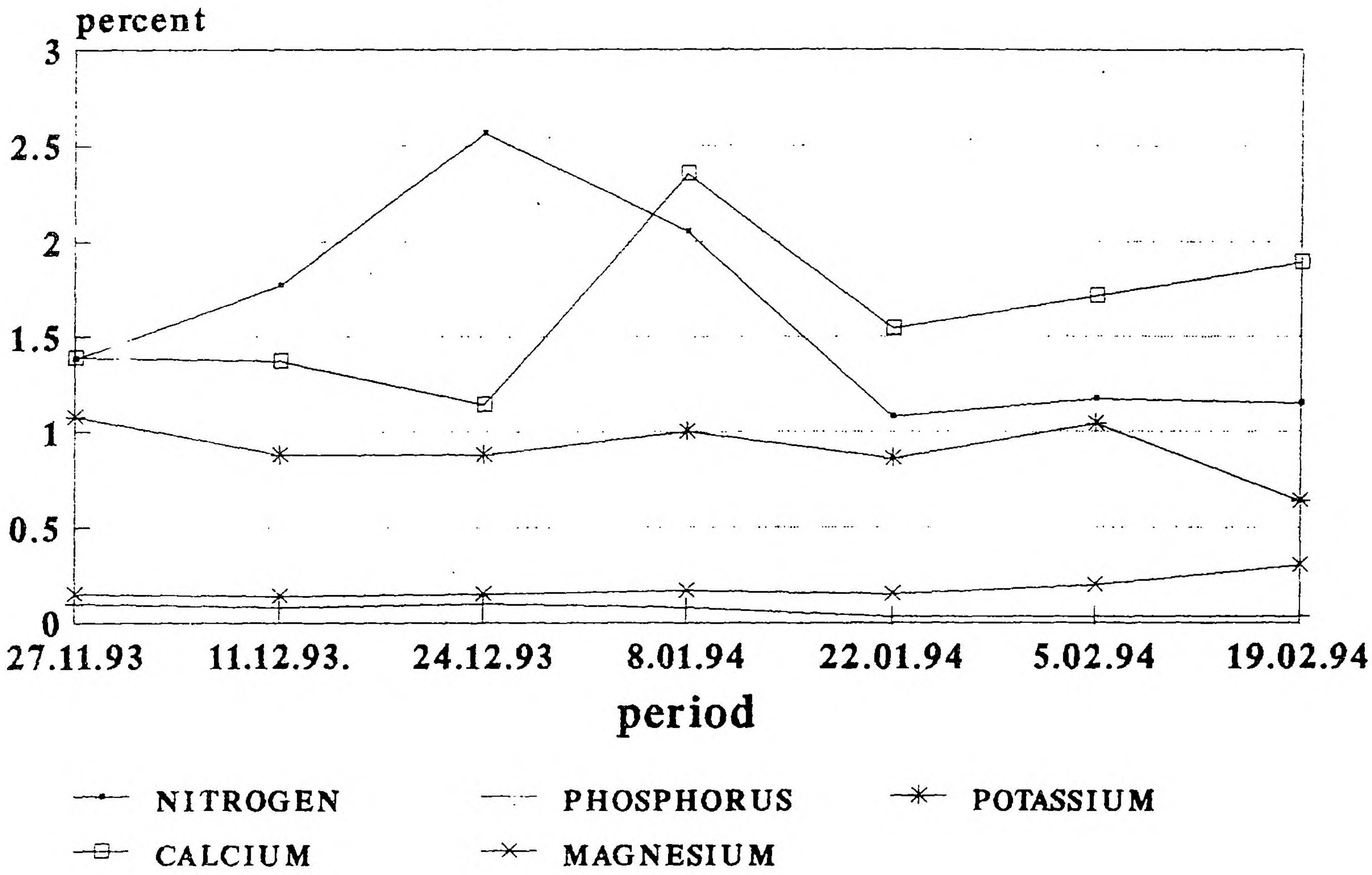

FIG.7. CHEMICAL COMPOSITION OF LEAF LITTER (LEAF LAMINA) AT FORTNIGHTLY INTERVALS FOR THE CLONE RRII 118

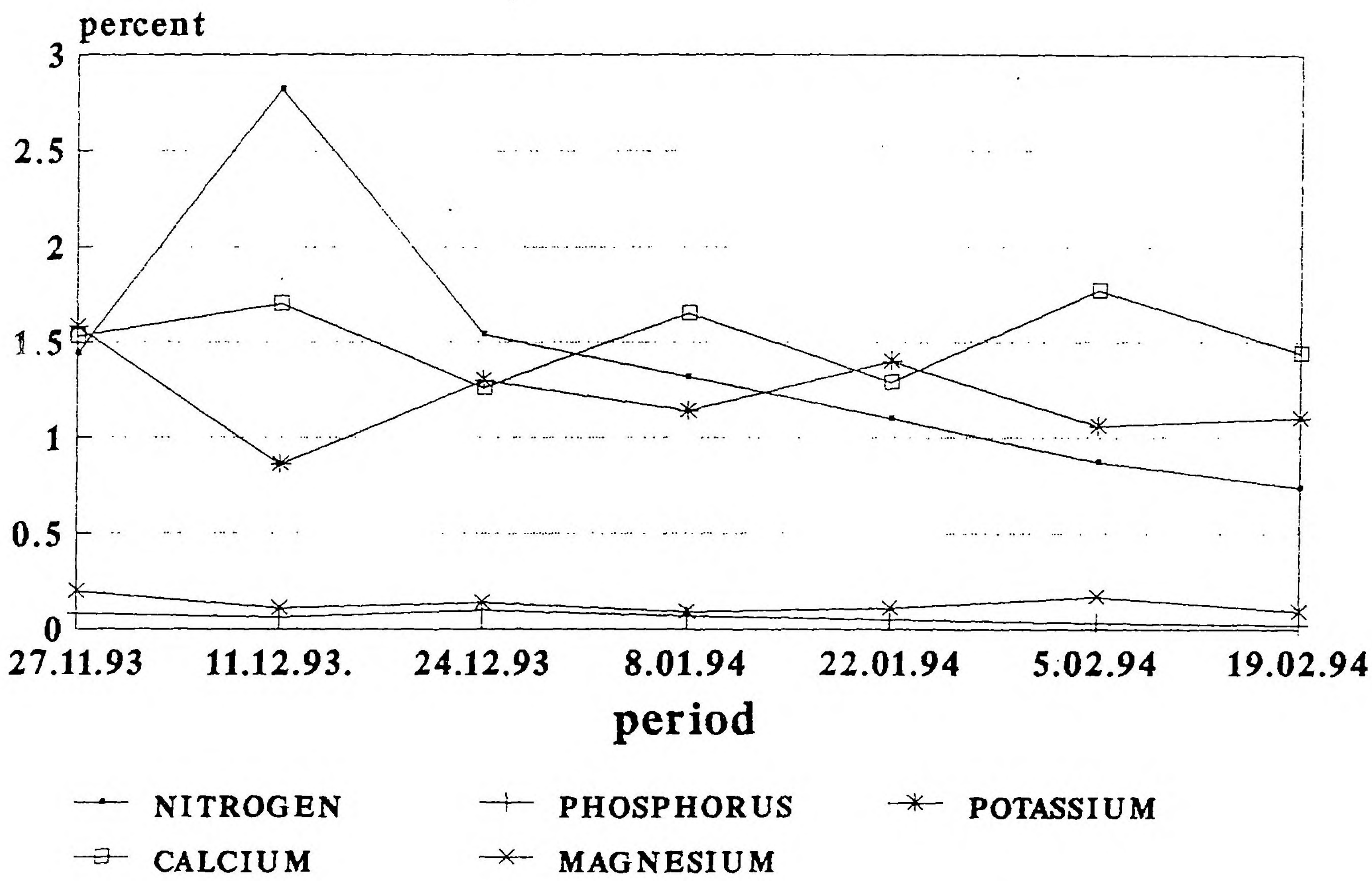

FIG.8. CHEMICAL COMPOSITION OF LEAF LITTER (LEAF PETIOLE) AT FORTNIGHTLY INTERVALS FOR THE CLONE RRII 118

for the nutrient concentration in the leaf litter of both the clones during the period 1993-94 and this is in conformity with the earlier reports. The average nutrient concentration in the leaf litter collected for the clone RRII 105 was in the order of N>Ca>K>Mg>P whereas for the clone RRII 118 it was in the order of Ca>N>K>Mg>P. The level of Ca was relatively more in the leaf litter collected for the clone RRII 118. Large uptake of calcium by rubber has been demonstrated by Shorrocks (1965). Though not externally applied, the plant is reported to accumulate large amount of calcium in the trunk, branches and leaves and it is possible that not all of that taken up is truly essential for the growth of the tree.

Higher percentage of calcium in the leaf litter has been reported by Duvigneaud and Smet (1970) in oak forests of Belgium, in temperate evergreen Shola forests of Nilgiris (Venkataramanan and Chinnamony, 1978) in coniferous forests of Himachal Pradesh (Singh _et al._, 1984), in eucalyptus plantation of Uttar Pradesh (Singh, 1984), in poplars of Tarai region of Uttar Pradesh (Tandon _et al._, 1991). Relatively high Ca level in the leaf litter has been reported in the earlier experiments in the same locality (Guruprasad, 1992 and Sumadhan, 1993). Better accumulation of calcium by the clone RRII 118 obtained in the present study is in agreement with the reports made by Sumadhan (1993).

4.4 Total nutrients added to soil through leaf litter addition

The quantity of nutrient added (N, P, K, Ca and Mg) to the soil through leaf litter is worked out and presented in Tables 11, 12 and 13 and are depicted in Fig.9.

The quantity of nutrients added through leaf litter in both the clones is computed and presented in Tables 11 and 12. It is interesting to note that the maximum contribution of N, K and Ca coincided with the peak wintering period for both the clones i.e., in the litter collected during the first week of January for the clone RRII 105 and first week of February for the clone RRII 118. The nutrient status of the litter collected during this period did not show any significance (Tables 9 and 10) and hence the better contribution of these elements is strictly due to the high quantity of litter added during that period. With respect to the contribution of P through leaf litter it was observed that the litter collected prior to the peak wintering period (two to four weeks) contributed the maximum P to the soil whereas in the case of Mg, the litter sample collected after the peak wintering period accounted the maximum. In spite of the high litter content added at the peak wintering period, the better contribution of P and Mg during other periods was found to be

Table 11. Addition of nutrients through leaf litter from RRII 105 clone (kg/ha)

Date of collection		N	P	K	Ca	Mg
27.11.93	Lamina	3.568	0.170	1.756	3.851	0.595
	Petiole	0.510	0.024	0.359	0.576	0.071
Total	Lamina & Petiole	4.078	0.194	2.115	4.427	0.666
11.12.93	Lamina	3.689	0.105	4.030	3.323	0.366
	Petiole	0.476	0.030	0.375	0.533	0.096
Total	Lamina & Petiole	4.165	0.135	4.405	3.856	0.462
24.12.93	Lamina	11.921	0.566	5.414	3.919	0.727
	Petiole	1.179	0.067	0.984	0.802	0.101
Total	Lamina & Petiole	13.100	0.633	6.398	4.721	0.828
08.01.94	Lamina	19.920	0.378	15.886	15.508	1.891
	Petiole	1.681	0.084	2.815	2.164	0.252
Total	Lamina & Petiole	21.601	0.462	18.701	17.672	2.143
22.01.94	Lamina	12.758	0.292	8.959	10.518	3.214
	Petiole	1.023	0.049	2.015	1.836	0.325
Total	Lamina & Petiole	13.781	0.341	10.974	12.354	3.539
05.02.94	Lamina	8.597	0.230	9.671	8.980	2.533
	Petiole	1.127	0.051	1.204	2.036	0.269
Total	Lamina & Petiole	9.724	0.281	10.875	11.016	2.802
19.02.94	Lamina	5.546	0.088	3.185	4.277	1.209
	Petiole	0.379	0.015	0.620	0.758	0.148
Total	Lamina & Petiole	5.925	0.103	3.805	5.035	1.357
Grand total		72.374	2.149	57.273	59.081	11.797

Table 12. Addition of nutrients through leaf litter from RRII 118 clone (kg/ha)

Date of collection		N	P	K	Ca	Mg
27.11.93	Lamina	2.554	0.185	1.999	2.573	0.278
	Petiole	0.443	0.024	0.486	0.471	0.062
Total	Lamina & Petiole	2.997	0.209	2.485	3.044	0.340
11.12.93	Lamina	2.526	0.114	1.256	1.955	0.200
	Petiole	0.671	0.014	0.205	0.405	0.026
Total	Lamina & Petiole	3.197	0.128	1.461	2.360	0.226
24.12.93	Lamina	5.327	0.208	1.831	2.372	0.312
	Petiole	0.534	0.035	0.451	0.437	0.048
Total	Lamina & Petiole	5.861	0.243	2.282	2.809	0.360
08.01.94	Lamina	10.886	0.425	5.310	12.478	0.903
	Petiole	1.168	0.062	1.009	1.460	0.079
Total	Lamina & Petiole	12.054	0.487	6.319	13.938	0.982
22.01.94	Lamina	6.054	0.168	4.821	8.633	0.841
	Petiole	1.027	0.047	1.307	1.204	0.103
Total	Lamina & Petiole	7.081	0.215	6.128	9.837	0.944
05.02.94	Lamina	15.211	0.390	13.521	22.232	2.600
	Petiole	1.885	0.065	2.297	3.836	0.368
Total	Lamina & Petiole	17.096	0.455	15.818	26.068	2.968
19.02.94	Lamina	11.525	0.301	6.414	18.942	3.007
	Petiole	1.236	0.033	1.837	2.405	0.150
Total	Lamina & Petiole	12.761	0.334	8.251	21.347	3.157
Grand total		61.047	2.071	42.744	79.403	8.997

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

Nutrients	Estimated quantity (in kg) on per hectare basis	
	RRII 105	RRII 118
Nitrogen	72.374	61.047
Phosphorus	2.149	2.071
Potassium	57.273	42.744
Calcium	59.081	79.403
Magnesium	11.797	8.977

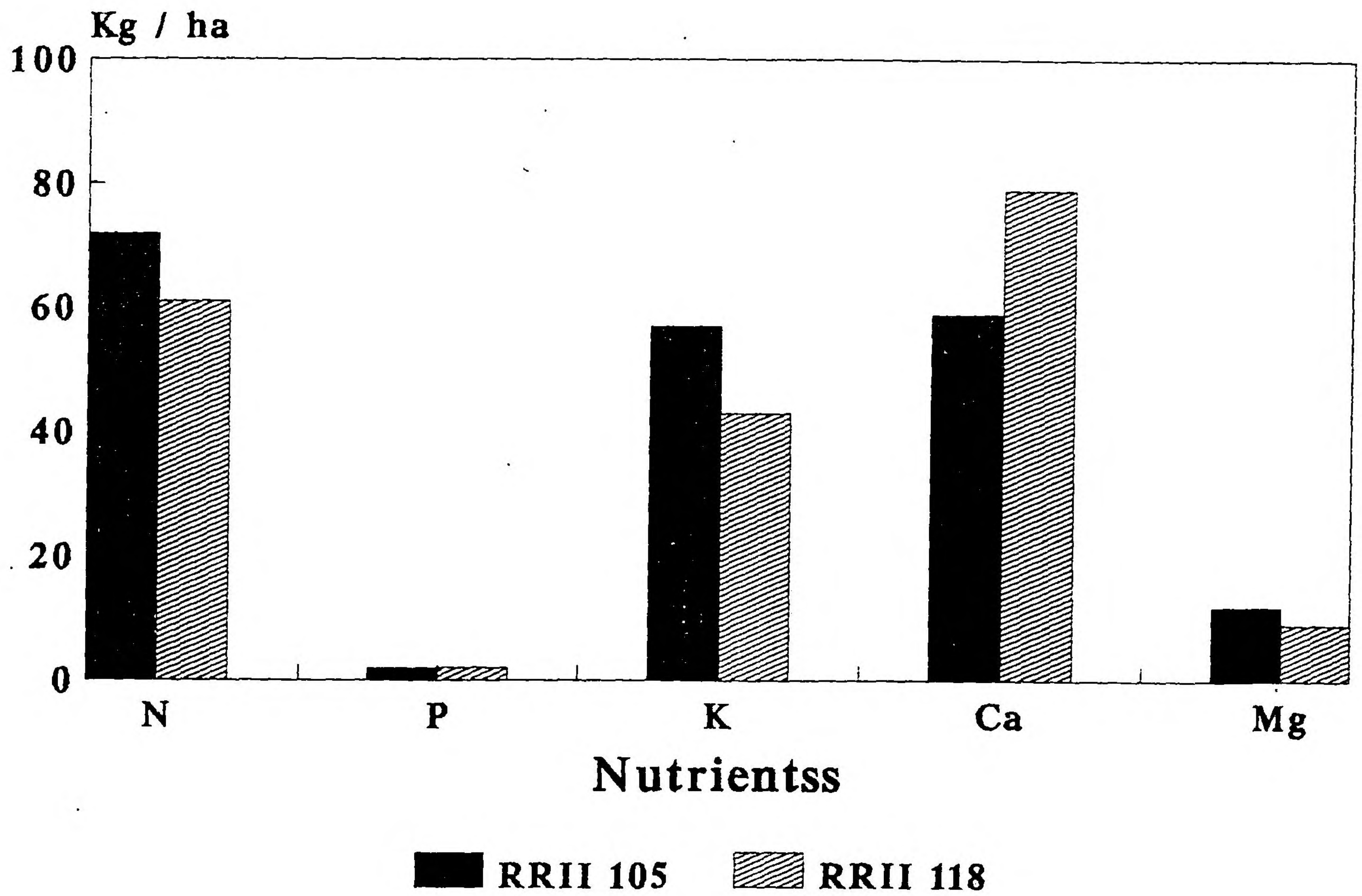

FIG.9. ADDITION OF NUTRIENTS THROUGH LEAF LITTER DURING WINTERING FOR THE CLONES RRII 105 AND RRII 118 (ON PER HECTARE BASIS)

due to better foliar level of these elements during those periods (Tables 9 and 10).

The total return of nutrients during the wintering period was relatively high for the clone RRII 105 except for calcium. The maximum return in RRII 105 was in the order N>Ca>K>Mg>P whereas in RRII 118 it was Ca>N>K>Mg>P. In both the clones the return of P was the minimum.

In the present study ~~present study~~ it is observed that in RRII 118, K and N have substantially increased whereas Mg addition decreased when compared to that reported by Sumadhan (1993).

The quantities worked out for the clone RRII 105 were 72 kg N, 59 kg Ca, 57 kg K, 12 kg Mg and 2 kg P. The corresponding figures for the clone RRII 118 were 79 kg Ca, 61 kg N, 43 kg K, 9 kg Mg and 2 kg P. Compared to the previous report in the same field the nutrients added back to soil through litter was found to be relatively more for the elements N, K and Ca whereas Mg and P added back were slightly less. The increase in the quantity of litter added this year contributed to relatively high feed back of the major elements N and Ca.

4.5 Soil fertility as influenced by leaf litter

Soil samples taken from the plots from which litter was removed (inside the net) and litter deposited areas (outside the net) were analysed for organic carbon (index for N) P_2O_5, K_2O and MgO. The results obtained are presented in Tables 14 and 15.

Comparison of soil fertility levels for the two clones showed that the organic carbon status of the top (0-15 cm) layer of soil in the area from where the litter was removed was relatively low as compared to the nearby area where the litter was allowed to get incorporated into the soil (Tables 14 and 15). The litter removal during the wintering period for the last three years might have greatly reduced the organic carbon level in the soil. The magnesium level in the soil was also found to get reduced in the litter removed area, the reduction being more conspicuous in the upper layer of the soil (Tables 14D, 15D). In the top-layer the magnesium status was 2.15 mg/100 g in the litter removed areas whereas it was 31.5 mg/100 g in the area when the litter was not removed. A similar trend was noticed for phosphorous and potassium also, but the difference was less conspicuous. In the deeper layers the changes in nutrient status were not very consistent.

This could be explained based on the fact that the

Table 14. Nutrient status of the soil at different depths in the litter added (outside the net) and litter removed area (inside the net) for the clone RRII 105

A. Percentage of organic carbon

Depth of soil	Before experiment						After experiment					
	0-15		15-30		30-60		0-15		15-30		30-60	
Period	Net area	Out side	Net area	Out side	Net area	Out side	Net area	Out side	Net area	Out side	Net area	Out side
1992-93	0.80	1.24	0.65	0.93	0.56	0.62	0.69	1.40	0.65	0.94	0.56	0.62
1993-94	1.62	2.10	1.18	1.83	0.73	1.51	1.14	1.45	1.02	1.28	1.08	0.94

B. Available P_2O_5 mg/100 g soil

Depth of soil	Before experiment						After experiment					
	0-15		15-30		30-60		0-15		15-30		30-60	
Period	Net area	Out side	Net area	Out side	Net area	Out side	Net area	Out side	Net area	Out side	Net area	Out side
1992-93	0.80	0.88	0.60	0.55	0.50	0.50	0.72	0.89	0.53	0.54	0.51	0.52
1993-94	0.20	0.80	0.30	0.40	0.10	0.20	1.10	2.00	0.60	0.70	0.80	0.60

C. Available K_2O mg/100 g soil

Depth of soil	Before experiment						After experiment					
	0-15		15-30		30-60		0-15		15-30		30-60	
Period	Net area	Out side	Net area	Out side	Net area	Out side	Net area	Out side	Net area	Out side	Net area	Out side
1992-93	3.63	4.82	2.75	3.94	2.50	2.75	3.02	4.89	2.41	3.90	2.49	2.81
1993-94	4.75	8.75	6.25	6.75	5.25	9.00	8.00	8.50	6.38	10.00	6.00	9.12

D. Available MgO mg/100 g soil

Depth of soil	Before experiment						After experiment					
	0-15		15-30		30-60		0-15		15-30		30-60	
Period	Net area	Out side	Net area	Out side	Net area	Out side	Net area	Out side	Net area	Out side	Net area	Out side
1992-93	2.82	4.23	2.96	2.25	4.48	4.49	2.36	4.26	2.70	3.23	4.37	4.48
1993-94	7.00	9.00	5.00	6.00	6.00	7.00	2.15	3.15	2.23	2.46	2.46	2.85

Table 15. Nutrient status of the soil at different depths in the litter added (outside the net) and litter removed area (inside the net) for the clone RRII 118

A. Percentage of organic carbon

Depth of soil	Before experiment						After experiment					
	0-15		15-30		30-60		0-15		15-30		30-60	
Period	Net area	Out side	Net area	Out side	Net area	Out side	Net area	Out side	Net area	Out side	Net area	Out side
1992-93	0.92	0.92	0.97	0.68	0.92	0.62						
1993-94	1.51	2.37	1.24	1.83	1.13	1.13	1.65	2.02	1.34	1.48	1.25	1.43

B. Available P_2O_5 mg/100 g soil

Depth of soil	Before experiment						After experiment					
	0-15		15-30		30-60		0-15		15-30		30-60	
Period	Net area	Out side	Net area	Out side	Net area	Out side	Net area	Out side	Net area	Out side	Net area	Out side
1992-93	0.60	0.60	0.50	0.30	0.50	0.30						
1993-94	0.20	0.40	0.10	0.20	0.10	0.20	0.60	0.90	0.40	0.70	0.50	0.70

C. Available K_2O mg/100 g soil

Depth of soil	Before experiment						After experiment					
	0-15		15-30		30-60		0-15		15-30		30-60	
Period	Net area	Out side	Net area	Out side	Net area	Out side	Net area	Out side	Net area	Out side	Net area	Out side
1992-93	5.50	5.00	4.90	5.63	3.00	3.25						
1993-94	7.00	8.75	6.13	7.50	4.75	14.75	6.50	8.00	3.25	7.00	5.38	6.25

D. Available MgO mg/100 g soil

Depth of soil	Before experiment						After experiment					
	0-15		15-30		30-60		0-15		15-30		30-60	
Period	Net area	Out side	Net area	Out side	Net area	Out side	Net area	Out side	Net area	Out side	Net area	Out side
1992-93	4.32	4.00	3.60	4.00	4.40	4.48						
1993-94	7.50	8.00	5.20	9.00	5.20	8.00	3.08	4.61	2.85	1.77	2.46	3.08

litter incorporated during the previous years would have contributed to the better nutrient level at deeper layers. Further, the concentration of feeding roots in the surface layer favour nutrient depletion at faster rate from this layer.

In the previous reports for the same experiment (Sumadhan, 1993), the percentage of organic carbon, available P and K were found to decrease with the depth of soil. Such a pattern was not observed in the present study. However, the nutrient depletion in the top soil from where the litter was removed was conspicuous in the earlier studies also (Sumadhan, 1993).

4.6 Leaf area index

A sample of 60 oven dried leaves (180 leaflets) each for the clone RRII 105 and RRII 118 (Table 16) were used to compute the leaf area index of each clone. On computation it was observed that RRII 105 had a higher leaf area index than RRII 118 and this may be due to higher quantity of leaves rather than greater area for individual leaf. By the leaf area index, the photosynthetic efficiency and biomass production of the clones are brought to limelight. High leaf area index recorded for RRII 105 indicate its better photosynthetic efficiency and thus high yield potential.

Table 16. Leaf area index for the clones RRII 105 and RRII 118

Parameters	RRII 105	RRII 118
Leaf area per gram dry weight	157.67 cm^2	140.67 cm^2
Leaf litter added per hectare (Lamina only)	4246.54 kg	3929.60 kg
Leaf area per hectare	64454.9104 m^2	55277.96454 m^2
Leaf area index	6.44	5.53

SUMMARY

SUMMARY

The present study deals with the quantification of leaf litter addition and nutrient recycling in two clones of rubber in the Vellanikkara Estate of Kerala Agricultural University, Trichur. Two different methods of collection were adopted for litter collection in both the clones RRII 105 and RRII 118. Wintering was found to start on 23rd November, 1993 for clone RRII 105 and continued till 12th February, 1994 whereas in RRII 118 wintering started by 25th November, 1993 and continued till 17th February, 1994. Peak leaf fall was noticed in the month of January for RRII 105 whereas it was in the month of February in the case of RRII 118. Thus clonal variation do exist for the wintering pattern.

The total leaf litter production was estimated to be 4954.297 kg for RRII 105 and 4584.558 kg for RRII 118. The nutrients contributed through leaf litter during wintering in the clone RRII 105 were 72 kg N, 2 kg P, 57 kg K, 59 kg Ca and 12 kg Mg whereas for the clone RRII 118 it was 61 kg N, 2 kg P, 43 kg K, 79 kg Ca and 9 kg Mg. The clone RRII 105 contributed more litter as well as nutrients than the clone RRII 118.

Contrary to the previous years the nutrient levels in the leaf litter did not follow a regular pattern during the wintering period. The presence of green leaves shed due to high wind velocity resulted in an increased level of nutrients in some collections. It was also observed that the contribution of N, K and Ca were more during the wintering period whereas P was more prior to peak wintering and Mg was more after peak wintering.

Comparison of nutrient status in soil samples collected from the area enclosed by net and outside sites showed that removal of leaf litter resulted in relatively lower levels of soil nutrients in the top soil. The leaf area worked out during the study was 6.44 for the clone RRII 105 and 5.53 for clone RRII 118.

The study also revealed that enclosing the trees with net is the best method to quantify the leaf litter addition. The expensive and cumbersome procedure of providing nets cannot be replaced by collecting the leaf litter from a marked area provided with 15 cm high fencing. The leaf litter accumulated in the fenced area was always less and varied from 27 to 71 per cent of the quantity of litter collected by providing net to cover the canopy all around the trees.

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ANNEXURES

ANNEXURE-1

Meteorological data for the period from March, 1993 to February 1994 (at weekly intervals) recorded at Vellanikkara

Period	Mean temperature Maximum (0°C)	Mean temperature Minimum (0°C)	Rainfall (mm)	Wind (km/hr)	Relative humidity (range) (%)
1993 March 5-11	34.4	23.0	Nil	8.1	27-73
12-18	35.1	23.9	Nil	5.3	53-85
19-25	35.3	24.3	Nil	5.0	50-84
26-1st April	35.4	24.1	Nil	5.3	52-83
April 2-8	36.3	23.9	2.2	5.1	54-80
9-15	34.5	24.4	25.3	4.8	56-84
16-22	35.5	25.7	Nil	5.0	54-83
23-29	36.6	26.0	4.6	4.8	55-84
30-6th May	35.3	25.7	3.0	5.0	55-84
May 7-13	35.4	25.9	1.4	5.8	56-82
14-20	34.1	23.8	31.9	4.8	65-86
21-27	34.5	24.4	6.0	4.4	62-88
28-3rd June	32.8	24.0	103.8	4.7	69-90

Contd.

Period	Mean temperature Maximum (0°C)	Mean temperature Minimum (0°C)	Rainfall (mm)	Wind (km/hr)	Relative humidity (range) (%)
June 4-10	29.6	23.3	236.6	4.5	80-95
11-17	29.2	23.8	237.9	4.5	81-95
18-24	30.4	24.5	85.5	4.5	73-94
25-1st July	29.2	23.6	186.4	4.2	82-94
July 2-8	28.6	22.7	158.9	4.2	78-95
9-15	28.7	22.6	167.8	4.0	83-92
16-22	28.9	22.9	128.1	4.7	76-94
23-29	28.0	23.1	101.0	4.6	80-94
30-5th August	29.1	23.7	94.4	6.5	76-95
August 6-12	29.9	23.5	54.9	4.4	75-95
13-19	29.2	23.1	66.3	3.7	78-93
20-26	29.8	23.2	61.9	4.3	74-96
27-2nd September	29.8	23.5	31.6	5.0	73-95
September 3-9	29.4	23.0	23.7	3.8	75-93
10-16	30.7	23.1	11.5	3.5	69-93
17-23	31.7	23.4	23.2	3.8	63-94
24-30	31.0	23.2	14.9	3.6	65-91

Contd.

Period	Mean temperature Maximum (0°C)	Minimum	Rainfall (mm)	Wind (km/hr)	Relative humidity (range) (%)
October					
1-7	28.8	24.4	149.8	3.5	82-93
8-14	29.3	23.2	151.5	3.2	78-95
15-21	31.2	23.2	102.7	3.2	74-90
22-28	31.9	23.5	83.4	3.0	72-92
29-4th	32.5	24.2	3.2	6.2	63-80
November					
5-11	30.4	23.9	58.3	8.3	70-84
12-18	31.8	23.0	12.7	3.9	66-91
19-25	31.8	23.1	1.2	6.5	54-72
26-2nd December	31.4	24.3	0.8	11.5	60-77
December					
3-9	31.2	22.7	17.0	6.1	62-84
10-16	32.5	21.9	Nil	9.0	47-75
17-23	31.0	23.8	1.0	12.8	59-75
24-31	31.6	23.5	Nil	12.8	47-72
January					
1-7	32.6	23.6	Nil	13.2	44-69
8-14	32.2	22.7	Nil	12.6	43-73
15-21	33.6	23.7	19.4	6.0	49-83
22-28	32.8	22.0	Nil	13.3	32-65
29-4th February	33.9	21.0	Nil	6.1	37-81

Contd.

Period	Mean temperature		Rainfall	Wind	Relative humidity (range)
	Maximum	Minimum	(mm)	(km/hr)	(%)
	(0°C)				
February					
5-11	34.6	23.8	Nil	7.0	43-77
12-18	34.4	23.1	1.7	5.0	45-86
19-25	35.7	23.0	Nil	5.3	36-83

* Humiditypercentage at 0700 hours Local Mean Time and 1400 hours local mean time

ANNEXURE-2

Daily wind velocity (km/hr) recorded at Vellanikkara during the wintering period

Date	November 1993	December 1993	January 1994	February 1994
1	6.8	13.0	13.0	3.8
2	8.1	14.3	14.2	4.1
3	2.7	8.5	12.5	6.3
4	6.7	6.1	13.9	9.9
5	4.6	3.4	9.8	7.4
6	10.2	3.9	12.5	9.5
7	13.9	4.4	16.6	9.7
8	10.0	7.9	17.9	9.2
9	2.8	8.8	17.7	5.9
10	6.9	5.2	16.0	3.7
11	10.0	9.4	14.5	3.6
12	5.8	6.8	10.3	4.8
13	3.2	9.2	6.5	4.1
14	5.0	8.3	5.4	4.0
15	4.1	11.5	5.4	4.4
16	3.8	13.0	4.2	3.5
17	2.5	12.9	3.3	5.6
18	2.6	16.7	4.6	8.6

Date	November 1993	December 1993	January 1994	February 1994
19	3.2	14.5	5.8	2.3
20	5.0	8.7	8.4	7.0
21	5.1	7.8	10.6	6.0
22	7.4	11.8	12.0	5.4
23	8.0	17.5	11.3	5.0
24	8.1	23.3	16.5	4.5
25	8.9	15.8	15.0	6.6
26	7.4	16.4	14.3	8.2
27	8.0	13.7	12.8	9.3
28	12.0	9.3	11.4	9.2
29	13.2	10.0	9.7	-
30	12.5	7.7	4.0	-
31	-	8.8	4.7	-