EFFECT OF COVER CROPS ON NUTRIENT DYNAMICS IN THE RUBBER PLANTATIONS

BY

K. PRATHAPAN

THESIS
SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENT FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY
FACULTY OF AGRICULTURE
KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF AGRONOMY
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM

1995

DECLARATION

I hereby declare that this thesis entitled **"Effect of cover crops on nutrient dynamics in the rubber plantations"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

Vellayani,
31-03-1995.

K. Prathapan

CERTIFICATE

This is to certify that the thesis entitled **"Effect of cover crops on nutrient dynamics in the rubber plantations"** is a record of research work done independently by Shri. K. Prathapan under my supervision and guidance and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

Dr. C. Sreedharan,
Chairman, Advisory Committee,
Dean,
Faculty of Agriculture,
Kerala Agricultural University.

Vellayani,
31-03-1995.

APPROVED BY:

CHAIRMAN:

Dr. C. SREEDHARAN

MEMBERS:

1. **Prof. P. CHANDRASEKHARAN**

2. **Dr. N. MOHANAKUMARAN**

3. **Dr. (Mrs.) P. PADMAJA**

4. **Dr. S.N. POTTY**

EXTERNAL EXAMINER:

19/5/95

Dedicated

to

my

family

ACKNOWLEDGEMENT

I express my deep sense of gratitude and indebtedness to Dr. C. Sreedharan, Dean, Faculty of Agriculture, Kerala Agricultural University and Chairman of the Advisory Committee for the guidance, valuable suggestions and constant encouragement throughout the period of this investigation and preparation of the thesis.

I am thankful to Dr. N. Mohanakumaran, Director of Research, Kerala Agricultural University; Dr. S.N. Potty, Director of Research, Indian Cardamom Research Institute, Spices Board; Prof. P. Chandrasekharan, Professor and Head, Department of Agronomy and Dr. P. Padmaja, Professor and Head, Department of Soil Science and Agricultural Chemistry for their valuable guidance and encouragement given as the members of the Advisory Committee.

Thanks are due to Dr. (Mrs.) P. Saraswathy, Head of the Department of Agricultural Statistics for her guidance in statistical analysis and interpretation of data. My thanks are also due to Shri. C.E. Ajithkumar, Junior Programmer for the help rendered in the statistical analysis of the data.

Sincere thanks are also due to Dr. G. Raghavan Pillai and Dr. Muraleedharan Nair, Professors; Dr. V.L. Geethakumari and Dr. Pushpakumari, Associate Professors and Dr. K.R. Sheela, Assistant Professor of the Department of Agronomy for their suggestions and help rendered in the course of the thesis work.

The constant encouragement at various stages of thesis work given by Dr. K.I. Punnoose, Deputy Director, Agronomy/Soils Division, Rubber Research Institute of India is gratefully acknowledged.

My heartfelt gratitude is also due to Late Rev. Arch Bishop Mar Gregorious and the Bethany Estate Management for the facilities provided for the smooth conduct of the Experiments.

I thank Rubber Board for the Extra Ordinary Leave granted and ICAR for the Senior Research Fellowship.

Sincere thanks are due to M/s. Athira Computers, Kesavadasapuram, Trivandrum.

The constant encouragement and moral support given by my wife Sreelu, kids Achu and Pranoy and my parents, are also remembered with gratitude.

31/03/95

K. Prathapan

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INTRODUCTION

1. INTRODUCTION

Rubber tree (*Hevea brasiliensis* MUELL-ARG) is the most important commercial source of natural rubber a product of vital importance obtained from its latex, commonly called the Para rubber. Rubber is grown predominantly in countries like ours, enjoying a tropical climate. This produces 99 per cent of the world's natural rubber (George *et al*. 1980).

In India, commercial cultivation of rubber was started in 1902 first in Kerala. It's cultivation was latter extended to parts of Tamil Nadu, Karnataka and gradually to Andaman and Nicobar islands. It was then introduced to the North-Eastern states and to the states of Andrapradesh, Goa, Maharashtra and Orissa. The area under rubber cultivation in India by the end of 1993-94 was 5.08 lakh ha. and the production of natural rubber during the period 1993-94 was 4.35 lakh tonnes (Rubber Board, 1994).

About 85 per cent of the total area under rubber cultivation is in Kerala and the three south Indian states viz. Kerala, Tamil Nadu and Karnataka jointly account for 92 per cent of the total area (Rubber Board, 1994).

The average yield per hectare of the crop increased from 284 kg ha^{-1} in 1950-51 to 1215 kg ha^{-1} in 1993-94 (Rubber Board, 1994). This has been achieved through the use of high yielding clones and by the adoption of scientific cultivation practices. The production and consumption of natural rubber were increasing simultaneously at a fast rate. However, during the last few years consumption used to overtake domestic production and this necessitated import of natural rubber to the tune of 21,000 tonnes a year (Rubber Board, 1994). Inorder to increase the production, attempts are being made to extend rubber cultivation to more areas in the non-traditional area. It is most important to increase total production by enhancing the production in traditional areas which are ideally suited for rubber cultivation. Increase in production can be achieved by planting high yielding clones as well as by scientific cultivation practices. Among these the latter can be achieved in a shorter period.

The use of cover crops interplanted with the main crop is common practice in tropical plantations, their presence serving to protect the crop and soil from the most extreme climatic conditions. Studies conducted else-where have shown that leguminous ground covers help in better growth of *Hevea* during immature phase and productivity during mature phase through the improvment of soil fertility.

The nutrition to cover crop is an essential agronomic practice for their better growth and improving the soil physical, chemical and biological properties.

The present recommendations for cover crop is 30 kg each of P and K ha^{-1} yr^{-1}. At the same time there is no recommendation to apply N for the covercrop perceivably due to the fact that they are all leguminous crops. However in a tropical situation existing in the most of the southern rubber growing states especially in Kerala the experience is that the initial growth of cover crop in not upto the expected extend and there is scope for increasing the same. This early growth is very important for a cover crop for rendering the soil full coverage at the earliest possible time till the crop is able to fix its own atmospheric Nitrogen. There are experimental evidences available from elsewhere regarding the N nutrition to covercrop (Pushparajah 1977). However under Indian condition so far such evidences are lacking.

The impact of covercrops on the productivity of the rubber soils especially on the physical and biological aspects have not been attempted.

A thorough search of literature also indicated that there are no worthwhile study on the nutrient dynamics and improvement of physical and biological properties of soil through covercropping. Also the literatures are deficient on the improvement of latex flow characteristics and yield of rubber by covercropping. Since the covercropping is a must for rubber plantations and is recommended universally, information on these valuable aspects are absolutely useful especially in a tropical situation where rubber is grown.

Previously covercrops such as Pueraria, Calapagonium, Mimosa and Centrocema were recommended as cover crops in rubber plantations. These covercrops in general had a natural disadvantage where in leaves shed in summer, and eaten by cattle. Another serious disadvantage with these covers are that they wont thrive in mature plantation, when the shade intensity is increased.

Mucuna bracteata is a recent introduction and its adoption as an effective cover in rubber is being extensively practised. This has got the advantage of shade tolerant as well as not being eaten by cattle. Growth is also vigorous and does not shed leaves in summer. Which helps to keep the soil always covered with green mulch.

It is therefore thought worthwhile to investigate the relative merits of growing this introduced cover crop along with an extensively grown *Pueraria* on the physical, chemical and biological properties of soil as well as their comparative impact on the production of natural rubber.

In this circumstances the investigation is undertaken with the following objectives.

1. To assess the effect of cover crops on the nutrient dynamics in *Hevea*.

2. To findout the influence of cover crops on the growth characters, productivity and latex flow characteristics of *Hevea*.

3. To evaluate the impact of cover crop on the physical, chemical and biological properties of soil.

4. To standardise a NPK recommendation for cover crops.

5. To understand the moisture regime in the rhizophere of *Hevea* and cover crops.

6. To study the impact of cover crops on weed growth.

7. And finally to assess the importance of cover crops in maintaining the ecosystem of the rubber plantation.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The use of cover plants interplanted with the main crop is common practice in tropical plantations, their presence serving to protect the crop and soil from the most extreme climatic conditions. In tea and coffee plantations shade trees are provided to protect the plants form excessive heat, and in oil palm, rubber and sisal plantations a ground cover of creeping plants or upright shrub is maintained to protect the soil from insolation, loss of fertility and erosion effects. Studies on the effect of cover crops on nutrient dynamics in rubber plantations are very much limited and all the possible works were reviewed in this chapter.

2.1 Importance of cover crops

Studies conducted else where have shown that leguminous ground covers help in better growth of *Hevea* during the immature phase thus reduces the immaturity period and in attaining higher yield (Watson 1961; Watson *et al*. 1964; Pushparajah and Chellapah *et al*. 1969; Chandapillai 1968; Potty *et al*. 1980; Kothandaraman et.al. 1990 and Prathapan *et al*. 1995).

Nitrogen is one of the important major nutrient both for growth and yield of _Hevea_. The use of legume covers to supply the considerable amount of nitrogen needed and thus enhance the vigor and performance of _Hevea_ (Mainstone 1961; Watson 1961; Pushparajah and Chellappah 1969; Pushparajah and Tan 1976). Generally in addition to nitrogen, levels of phosphorous in leaves of _Hevea_ were enhanced by legume covers. The legume covers enhance soil organic matter (Pushparajah and Chellappah 1969; Watson _et al_. 1964) and improve the soil physical properties and hence rooting (Mainstone 1961; Watson 1961).

Establishment and maintenance of ground cover in rubber plantation is an accepted agro-management practice. Cover crops help in the movement of soil structure and other physical properties (Soong and Yap 1976).

The most widely used leguminous cover crop in India is _Pueraria Phaseoloides_, though others like _Calapagonium mucunoides_, _Centrosema pubesens_ and _Mimosa invisa_ var intermis are also grown on a limited scale (Potty _et al_. 1980). An ideal cover crop should have such characters as fast growth, non-competition with rubber plants, shade tolerance, high nitrogen fixing capacity etc. Pueraria crop is highly palatable to cattle and this nature of the crop results in the indiscriminate removal of the crop from the field. Mucuna bracteata is a recently introduced cover crop. It is a wild and fast growing legume, native to north-eastern India and possesses most of the desirable characters expected of a cover plant. It is not preferred by cattle and tolerant to drought situations also.

Crop cover is widely recognised as being of major importance in reducing the effects of raindrop impact on the soil. By minimising splash erosion, rates of soil detachment are reduced, soil aggregates do not break down so rapidly, aggregate structure is retained, less surface crusting or sealing, infiltration rates remain high and surface runoff is reduced (Morgan 1985).

Leguminous cover also helps in the formation of large size aggregates. It facilitates good soil aeration and better root growth of rubber plants (Krishna Kumar 1989).

Kothandaraman et al. (1990) reported a higher biomass production by Mucuna as compared to Pueraria. They also observed higher shoot/root ratio and higher population of phosphate solubilising micro organisms in soils under _Mucuna_.

Yoon (1967) indicated that the net assimilation rate of the _Pueraria_ was drastically reduced under shade. As a consequence of this, the cover plant was eventually eliminated form its stand by the growing canopy of the rubber plants. Kothandaraman _et al_. (1990) also reported that the _Mucuna_ was tolerant to shade and are not eliminated by growing canopy.

Thus influence of legumes on productivity of rubber has been shown to be not only through its nitrogen return, but also through its influence on the physical and chemical properties of soil. However, there has also been controversy over the economic value of the initial expenditure on establishment and maintanance of a stand of pure legumes with the existing vagaries in the price and availability of nitrogenous fertilizers, the greater use of legume cover becomes essential.

2.2 Effect of cover crop on the organic matter content and soil structure

Most of the soils under plantations, particularly those that have carried one generation of rubber trees and are due for replanting, have low reserves of plant nutrients and organic matter and are of poor structure. As a result of their low permeability to rainfall such soils are susceptible to drought and erosion and cover plants are used in an effort of re-establish satisfactory soil conditions.

Under forestry methods of cover plant control, upright woody plants often develop and their use is sometimes recommended on compacted soils where their strong rooting characteristics help to break up and aerate the soil. Such cover plants are controlled by periodical lopping and considerable amount of material perhaps upto 20 tons per acre, can be returned to the soil in this way. The litter of fallen stems, leaves and loppings, protects the soil against heavy rain but erosion control is not likely to be so good as under a creeping cover plants(Haines 1932).

Most of the cover plants could be expected to improve soil structure but wide variations in their individual effects are found, as discussed by Haines (1933) with a few exceptions. Most grasses do not greatly improve the soil under rubber planting conditions. Their mat of surface roots competes strongly for available moisture and the hard dry conditions observed under grass do not encourage free surface rooting by the rubber tree.

Cover plants, by protecting the soil surface against compaction by heavy rain and by virtue of the binding effects of their roots on soil particles, safeguard and improve soil structure. The organic matter content that they add to the soil as dead leaf, stem and root material, also plays a very large part in the improvement of soil conditions by summation of chemical, physical and biological effects as reported by Bremner (1956).

Watson (1957) reported that the creeping cover plants on the other hand, leguminous or otherwise, exert a marked beneficial effect upon soil structure. The observations seem to show that such cover plants return much more organic matter to the soil as dead leaf and stem material than returned by the grasses. In addition the dead material has a higher nutrient concentration than the grasses. The dense growth of a vigorous creeping cover ensures cool and moist conditions at the soil surface and a loose, permeable top soil layer, with a high organic matter content. Soil erosion under such a cover is low(Page 1939).

Soong and Yap (1976) reported that legumes and natural covers left the soil in much better conditions than grass or Mikania covers, with lower bulk densities and higher pore space resulting in better water infilteration. They also pointed out that the effect of cover plants in improving soil structure depends particularly on the quantity of decomposable organic matter which the covers add to the soil.

Apart from the energy dissipating function, cover crops improve the soil physical structure so that there is increased porosity, infilteration and aggregate stability and consequently reduction in run-off and soil loss. Uriyo (1979) observed that under permanent vegetative cover, infiltration rate was normally greater or equal to the hydraulic conductivity of the soil. In the work reported from Namlongae, Uganda, ten times more run-off ocurred form bare plots than from grass covered plots, and a grass mulch cover was twice as effective than a stone mulch, in terms of run off control. Increased moisture storage capacity of the soil provided by the transpiratory with-drawal of growing crops result in high infiltration rate (Venkatraman, 1978).

Zein et al. (1980) reported high hydraulic conductivity values in the vicinity of the roots of shallow rooted crops. Low bulk density, high porosity and increased soil aggregation were also reported by other workers in grass covered plots (Williams 1963 and Calbrone and Staines 1985).

2.2.1. Effect of cover crops on soil moisture

In Ceylon, however a comparison of the moisture content of soil under clean weeded surface and under a cover of the creeping legume, Centrosema pubescens showed that for the first two years after establishment of the cover there was more moisture in the first six inches of soil under the cover than in the corresponding region of the bare soil, but that the reverse was true for soil below a depth of six inches (Joachim and Kandia 1930).

With the provision of a cover, run-off of rain water can be much reduced but the extra losses of moisture caused by transpiration through the foliage of cover plants can, in turn, be appreciable. Some experiments in Malaysia have shown that the young planting of Centrosema pubescens and Mikania scandens did not significantly reduce the soil moisture content to levels below those found under a bare surface (Belgrave, 1939).

It was evident that more moisture was lost by transpiration from the cover plant than was conserved by the surface mulch it produced, however during the second two years of the experiment the mulch under the cover plants develop to such an extent that eventually more moisture was found at all levels down to twenty four inches under the cover plants, than under the bare surface. These findings have been confirmed by Watson (1957).

In newly planted rubber plantations, the top soil in the planting row will tend to be dry and that the reserves of water in the sub soil are likely to suffer depletion by lateral diffusion into the drying subsoil under the inter row covered area. Both factors will contribute drought susceptibility of the planting row and are strong arguments in favour of mulching being carried out around the young rubber trees. After the first or the second year of growth, rubber roots spreading under the cover plants will be able to take full advantage of the water conserving properties of the mature cover and its litter mulch, Watson (1957).

Pushpadas et al. (1976) reported that the cover crop serves as mulch and reduces evaporation from the soil, and on the other hand it depletes available moisture from the soil, through transpiration. The net effects on soil moisture thus depends on evaporation or transpiration whichever is dominant. They also compared the moisture percentages in the slashed Mucuna sp plots with bare soil and with unslashed plots. The moisture percentages in the slashed plots were maintained at higher levels and also for a longer duration, as compared to unslashed and bare soil plots.

Kothandaraman et al. (1990) observed that the soil moisture during summer months in the Mucuna bracteata and Pueraria phaseoloides grown plots were higher compared to grass cover. They also noted that the thick mulch provided by Mucuna bracteata and its deeprooted nature and the difference in evapo-transpiration have contributed to higher soil moisture at the 0-30cm depth.

In a study on moisture retention of soil, Krishna Kumar et al. (1990) revealed that the soil moisture retention capacity at -0.033 Mpa was highest in the profile under legume cover than under natural cover. Their study also highlighted that the legume cover could modify the soil moisture energy relationship by changing the desorption pattern.

2.3. Nutrition and fertilizer use in cover crops

Pushparajah (1977) reported that for the efficient growth of cover crop "starter doses" of nutrients are essential. This starter dose of N,P,K and Mg helped for a speedier ground cover growth and vigour.

Yogaratnam et al. (1984) reported that phosphate application to covers led to better tree girth than that was applied to the trees. It also showed higher leaf P values at the end of 6 years from planting. This increased leaf P concentration also help to improve girth and percentage of tappability of trees at the end of 6 years.

Suresh (1992) observed that raising of cover crops coupled with fertilizer application resulted in higher content of available 'P'. Also he opined that the crop residues of the cover plants recycling enhanced the 'P' supplying power of the soil.

2.3.1. Effect of cover crops on the soil nutrient status

Soil nutrients will be lost from an area if the rubber trees of the first generation are cleared off the land at replanting (Page 1939) and nutrients will be lost in the latex taken off the site. Over the life of one generation of rubber trees, the various losses of nutrients are evidently sufficient to lower the soil nutrient status to the point where application of complete fertilizers are essential to produce satisfactory growth in the second generation of Hevea. Cover plants are used to offset soil deterioration, particularly with a view to the maintenance of soil structure and prevention of soil erosion and they can play an important part in the soil nutrient cycle (Broughton 1977).

Competition between cover crops are necessarily harmful over a long term period, as the nutrients taken up by the cover plant and rendered unavailable to the rubber tree in the first instance are eventually returned to the soil as dead plant material and will become available for uptake by either the rubber tree or cover plant roots. Such action will minimise the leaching of decaying plant material, their eventual availability to the rubber tree may be increased (De Ceus 1941).

Watson (1957) reported that cover plants can affect the soil nitrogen status by interfering with nitrification processes in the soil and symbiotically fixing atmospheric nitrogen.

Leguminous creepers have been shown to mobilise greater quantities of nitrogen, phosphorus and calcium than the other experimental covers during the first two years after planting. Since the litter under these leguminous covers has a low C/N ratio it would be expected to mineralise rapidly with its nutrient content becoming quickly available again for uptake by <u>Hevea</u> or cover crops (Watson, 1961).

A marked decrease in vigour coupled with a net return of nutrients to the soil by all covers took place, much higher levels of nitrogen, potassium, calcium and magnesium being returned form legumes. This was particularly so for nitrogen. Nitrogen return to the soil from legume covers between the third and fifth year after planting totalled 214.5 kg acre^{-1}, with 88.3 kg acre^{-1} nitrogen still held in the green material and litter of the standing cover at the end of fourth year (Watson et.al 1964a).

Watson <u>et al</u>. (1964) reported that the exchangeable potassium content and pH value of 0-6 inch soil under legumes were significantly lower than those under <u>Mikania</u> and there was a tendency for the exchangeable magnesium under legumes to be lower than that under grass and <u>Mikania</u>. They also reported that when fertilizers were applied to covers the phosphorous and exchangeable cation status of the 0-6 inch soil layer tended to be higher than where fertiizer was applied to the tree rows but this effect was only significant for total and available phosphorous. There was a tendency in the legume treatments for a similar effect on phosphorous occur in the 12-18 inch soil layer indicating that some downward movement of the applied phosphate may have occured, perhaps by direct leaching through the soil, or by transport via the cover plants.

Kothandaraman *et al*. (1987) studied on the growth pattern, nodulation and nitrogen fixation by *Mucuna bracteata* and confirmed that the soil fertility improvement is done by the cover crops.

Mathew *et al*. (1989) reported that most of the soil responded to P applications especially when soil P was low. Response was greater when the tree was being tapped on virgin panel than on renewed panel. Chances of response to 'P' were greater when there was legume ground cover.

Kothandaraman *et al*. (1990) compared the efficiency of *Mucuna bracteata* with *Pueraria phaseoloides* and growth of *Hevea* and reported that organic carbon content was increased with cover crops. There was an increase in total nitrogen under *Pueraria phaseoloides* which is due to its better decomposition as evidenced by the narrow C:N ratio.

2.4. Effect of cover crops on biological properties of soil

Watson (1957) reported that the bacteria of the genus Rhizobium found in the root nodules of leguminous cover crops and could modify the soil nitrogen status by absorbing nitrogen from the soil, hence minimising the loss of soil nitrate by leaching.

Kothandaraman et al. (1987, 1990) opined that the counts of total bacteria, fungi and actinomycetes were higher in soils under Mucuna bracteata. They also reported that the Beijerinkia the non symbiotic nitrogen fixing bacteria and phosphate solubilising micro-organisms were found to be higher, in the legume cover cropped area.

2.5. Root development of Hevea and cover crops

Watson et al. (1964) observed that the vigorous development of roots of Hevea took place under the legume cover and such developments were evidently favoured by the heavy mulch of dead leaves that built up under the cover crop.

While studying the nature, extent and distribution of the root systems of different cover plants Chandapillai (1968) observed a more shallow rooting pattern for Pueraria in the form of network of fibrous roots of early decomposable nature. The dry weight of the roots of a three months old individual plant was reported to be 3.22g and the mean dry weight of shoot was 1.11g. He also observed a reduction in the horizontal spread and vertical penetration of roots of the creeping covers at the twelve month sampling compared to the six-month sampling.

Deep penetration of the roots of the cover plants reportedly increased the fertility of the surface soil by extracting nutrients from the deeper layers and depositing them on the surface in the organic matter of their litter (Wycherley, 1963). This effect is increased by the recommended plantation practice of periodical slashing of the vigorously growing cover crops.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

Field experiments were carried out to study the effect of cover crops on the nutrient dynamics in rubber plantations. There were three field experiments and were conducted at Bethany Estate, Mukkampala, Kanyakumari District from February 1991 to October 1993. They were:

I. The effect of cover crops on nutrient dynamics in the immature rubber plantation

II. The effect of cover crop on nutrient dynamics in the mature area and

III. Microplot study of cover crops alone

3.1. Materials

3.1.1. Site Characteristics

Bethany Estate is situated at 8° 20' 27" North latitude, 77° 21' 22" East longitude and at an altitude of 105m above mean sea level.

1.2. Climate

The area enjoys a typical tropical climate. Monthly average values of important meteorological parameters observed during the period of experiments are furnished in Appendix I.

The maximum temperature varied between 29.8°C and 35.1°C with a highest daily maximum of 37.9°C in April in all three years. With regard to the minimum temperature in the first year, lowest value of 18.2°C was recorded in January and the highest of 23.6°C in April. These values were 17.9°C, 18.5°C and 24.0°C, 22.7°C respectively in January and June during the second and third year. The lowest minimum was 17.9°C in January 1992. The most humid month recorded was June with average humidity above 85 per cent and January with most dry in all the three years. In 1991, a total of 2084 mm. of rain was received through 121 rainy days. The corresponding values for 1992 and 1993 were 2128,2154mm and 124,119 days respectively. In all the three years June received the highest rainfall and its was 780,665,715 mm..

The south west monsoon peak was observed in June in all the three years with a value of 780 mm in the first year and 665, 715 mm in the second and third year respectively. The north east monsoon peak was observed in November in all the three years with a value of 264 mm in the first year and 322,248 mm in the second and third year respectively.

3.1.3. Soil characteristics

The soils of the experimental areas were shallow, well drained, moderately acidic oxisol with a sandy clay loam surface texture. Morphological feature of a typical profile of the experimental site are presented below :

Location	:	Bethany Estate, Mukkampala, Kanyakumari District
Vegetation	:	Heavily infested with weeds such as <u>Pennisetum</u> <u>polystachyon</u>, <u>Brachiaria</u> <u>mutica</u>, <u>Chromolaena</u> <u>odorata</u> and <u>Mimosa</u> <u>pudica</u>
Parental Material	:	Weathered Gneiss
Topography	:	Undulating
Drainage	:	Well drained with moderate permeability
Ground water table	:	Deep > 22m.

Horizon	Depth (cm)	Description
AP	0-30.0	Yellowish red (5YR 4/6 moist) gravelly loam; moderate medium, subangular blocky; friable, slightly sticky and slightly plastic; common, medium, distinct, mottles; few fine distinct iron; roots abundant, permeability rapid, gradually smooth boundary.
B_{21}	30.0-60.0	Yellowish red (5YR 4/6 moist) gravelly clay; medium moderate, subangular blocky; wet sticky and plastic; few medium distinct mottles; roots few, permeability moderately rapid diffused wavy boundary
B_{22}	60.0-90.0	Red (2.5YR 4/6) and strong brown (7.5YR 5/8) mottles plenty, initial stages of laterisation, low permeability

3.1.3.1. Physical and Chemical characteristics

The physical and chemical characteristics of the soils are given in Table 1 and 2.

3.1.4. Nature and cropping History

The experimental sites I and III were new areas, lying fallow during the previous years. The experimental site II was mature area under standing rubber trees with RRII 105 (Rubber Research Institute of India) of 8 years old, planted at a spacing of 5 x 5 m.

3.1.5. Crops

3.1.5.1 Experiment I

Rubber : Clone RRII 105 of one year old planting.

Cover crops

1. Pueraria phaseoloides Benth.

2. Mucuna bracteata D.C

Table 1. Physical properties and mechanical composition of soil from the experimental site

Soil depth, cm	Bulk density g cc^{-1}	Particle density g cc^{-1}	Total porocity per cent	Mechanical composition				Textural class
				Coarse	Fine	Silt	Clay	
0-30	1.21	2.44	46.90	28.91	7.34	6.88	56.90	Clay
30-60	1.19	2.41	49.75	19.76	4.72	4.90	70.62	Clay

Table 2. Chemical composition of soil from the experimental site

Orgainic carbon per cent	Available nutrients (kg ha^{-1})					pH
	N	P	K	Ca	Mg	
1.07	227	21	122	242	121	4.4

3.1.5.2. Experimant II

Rubber : Clone RRII 105 of 8 years old trees under tapping.

Cover Crop : Mucuna bracteata D.C alone

3.1.5.3. Experiment III

Microplot study of cover crops alone with

1. Pueraria phaseoloides Benth. and

2. Mucuna bracteata D.C.

3.1.6. Season

All the three experiments were started from February 1991 at three locations in Bethany Estate, Mukkampala, Kanyakumari District of Tamil Nadu and continued upto October 1993.

3.1.7. Fertilizers

In all the three experiments rubber trees received the fertilizers as per the recommendations of the Rubber

Research Institute of India and the cover crops were manured as per the treatments. For Kanyakumari District, the fertilizer mixture recommended by the RRII for immature trees are 12:12:6 NPK mixture and the year wise quantities are given below

Year of planting	Months after planting	Time of application	Dose per tree	Dose per ha.
I year	9 months	April-May	380g.	170kg
II year	15 months	Sept-Oct	380g.	170kg
	21 months	April-May	480g.	215kg
III year	27 months	Sept-Oct	480g.	215kg

For mature trees under tapping 10:10:10 NPK fertilizer mixture were applied and the quantities are given below

		Dose per tree	Dose per ha
Every year	April-May	335g.	150kg
	Sept-Oct	335g.	150kg

Fertilizers with the following grades were used for all the experiments

Urea	:	46 per cent	N
Mossoorie Rock Phosphate	:	20 per cent	P_2O_5
Muriate of Potash	:	60 per cent	K_2O

3.2. Methods

3.2.1. Experiment I

I year old RRII 105 rubber plants

Cover crops :

1. <u>Pueraria phaseoloides</u>
2. <u>Mucuna bracteata</u>

Design (5 x 2) + 1 RBD (5 levels x 2 covercrops) + absolute control

Replications.: 3

Net plot 4 x 3 = 12 trees $plot^{-1}$ 20 x 15 m^2

Gross plot 6 x 5 = 30 trees $plot^{-1}$ 30 x 25 m^2

Layout plan is given in Fig.1.

3.2.1.1. Treatments

C_1F_0 – Rubber + Cover Crop (1) + F_0

Fig. 1. Lay out plan of the Experiment I

R I	R II	R III
C_1F_0	C_2F_1	C_1F_0
C_2F_2	Control	C_2F_3
C_1F_1	C_1F_1	C_1F_2
Control	C_2F_0	C_1F_3
C_2F_0	C_2F_2	C_2F_1
C_1F_2	C_1F_3	C_1F_1
C_2F_4	C_2F_3	C_2F_2
C_1F_3	C_1F_0	C_1F_4
C_2F_3	C_1F_4	Control
C_2F_1	C_2F_4	C_2F_0
C_1F_4	C_1F_2	C_2F_4

25 m

30 m

C_1 : *Pueraria phaseoloides*

C_2 : *Mucuna bracteata*

C_1F_1	–	Rubber + Cover Crop (1) + F_1
C_1F_2	–	Rubber + Cover Crop (1) + F_2
C_1F_3	–	Rubber + Cover Crop (1) + F_3
C_1F_4	–	Rubber + Cover Crop (1) + F_4
C_2F_0	–	Rubber + Cover Crop (2) + F_0
C_2F_1	–	Rubber + Cover Crop (2) + F_1
C_2F_2	–	Rubber + Cover Crop (2) + F_2
C_2F_3	–	Rubber + Cover Crop (2) + F_3
C_2F_4	–	Rubber + Cover Crop (2) + F_4
C	–	Control (immature rubber alone)

Levels of fertilizers to cover crops ($kg\ ha^{-1}$)

	N	P	K
F_0	0	0	0
F_1	0	30	30
F_2	10	30	30
F_3	0	60	60
F_4	10	60	60

3.2.1.2. Planting and spacing

Rubber plants and cover crops were planted/sown as follows

i) Rubber

One year old plants of RRII 105 which is popular among the planters were planted at 420 field budded plant points per hectare. Rubber trees were planted at a spacing of 5 x 5 m^2 during 1990 June. Common border rows were left in all plots.

ii) Cover crops

<u>Pueraria sp</u> was sown on the raised beds in the middle of the four rubber trees at the rate of 4.5kg. seeds ha^{-1}, <u>Mucuna bracteata</u> were raised in poly bags and planted in the field. Both the cover crops were sown on the same day.

3.2.2. Experiment II

8 years old RRII 105 Rubber trees.

Cover crop : *Mucuna bracteata* alone

Design (5 x 1) + 1 RBD
(Five levels x one cover crop) + one absolute control

Replications : 4

Gross plot 5 x 4 = 20 trees $plot^{-1}$ 25 x 20 m^2

Net plot 4 x 3 = 12 trees $plot^{-1}$ 20 x 15 m^2

Layout plan of the experiment is given in Fig. 2.

3.2.2.1. Treatments

F_0 – Rubber + Cover crop + F_0

F_1 – Rubber + Cover crop + F_1

F_2 – Rubber + Cover crop + F_2

F_3 – Rubber + Cover crop + F_3

F_4 – Rubber + Cover crop + F_4

C – Control (mature rubber alone)

Levels of fertilizers to cover crop (kg ha^{-1})

	N	P	K
F_0	0	0	0
F_1	0	30	30
F_2	10	30	30
F_3	0	60	60
F_4	10	60	60

Fig. 2. Lay out plan of the Experiment II

R I	R II	R III	R IV
F_0	F_4	F_2	F_1
F_2	F_0	F_4	F_3
Control	F_1	F_3	Control
F_1	F_2	F_0	F_4
F_3	F_3	Control	F_2
F_4	Control	F_1	F_0

20m

25m

3.2.2.2. Planting and spacing

i. Rubber

In this experiment the rubber trees are of the age of eight years old polybag plants and tapping is going on from the seventh year onwards. The trees were planted at 5 x 5 m^2 spacing with 420 trees per hectare.

ii. Cover crop

<u>Mucuna</u> <u>bracteata</u> alone was grown and maintained in this experiment. Mucuna seeds were planted in poly bags and planted in between rows of rubber trees.

3.2.2.3. Cultural operation

The fertilizers as per the recommendation to the mature tree were applied every year in two equal split doses. The first dose given in May (Pre-monsoon) and second in September (Post-monsoon) (Rubber Board 1994). The pre-monsoon application was done after the receipt of a few showers, but before the onset of regular south-west monsoon.

The post-monsoon application was done after the south-west monsoon, but before the onset of north-east monsoon when a relatively brief rainfree period was available. Both applications were done when there was adequate moisture in the soil. The fertilizer was broadcasted in rectangular patches in between rows of trees, each patch serving four trees, after clearing the leaf litter on the ground. The fertilizer was then lightly forked into the soil and the leaf litter was put back to cover the fertilizer applied patches (Ananth 1966 and Rubber Board, 1994).

At the experimental area incidence of Powdery mildew (Oidium heveae) disease occured and was controlled by sulphur dusting as a prophylatic measure.

Tapping was done third daily on half spiral system. The tapping panels were protected with polyethylene rain guards to facilitate tapping during rainy season. During the period of this experiment tapping was being done on the first side of virgin bark.

3.2.3. Experiment III

In this experiment the cover crops namely Puraria phaseoloides and Mucuna bracteata were grown in 10 microplots each of 2.5 x 2m size with normal fertilizer recommendation of 0:30:30 kg ha^{-1} (Rubber Board 1994)

Layout plan is given in Fig. 3

3.2.4. Establishment of cover crop

All the three experiments were grown with cover crops. The experiments I and III were grown with *Pueraria phaseoloides* and *Mucuna bracteata*, and the II experiment was grown with *Mucuna bracteata* alone.

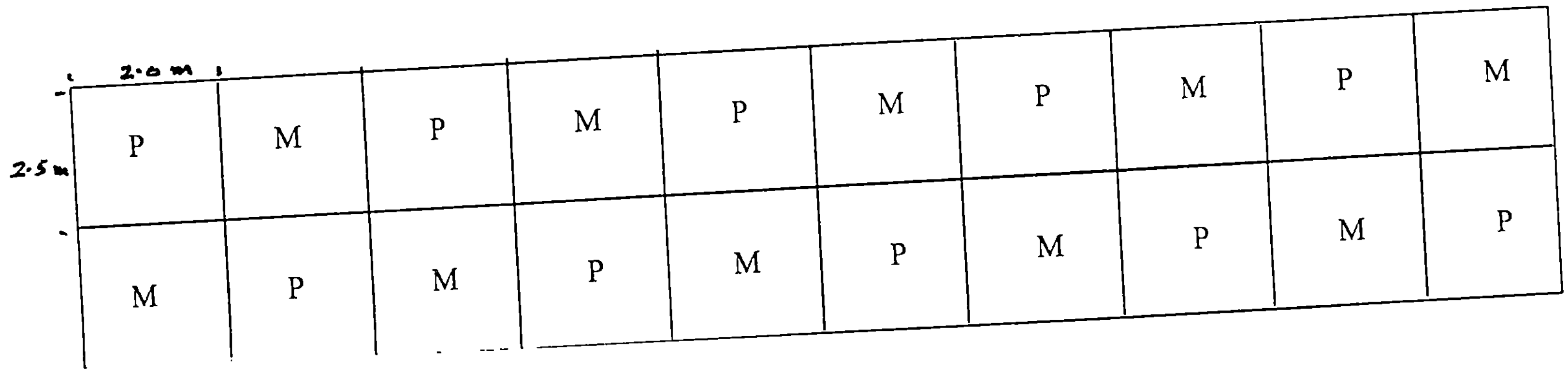
3.2.4.1. Sowing of cover crops

The concentrated sulphuric acid treated seeds were mixed with equal quantity of rock phosphare and sown in between the plant rows during January. The patches or strips where the seeds were sown were clean-weeded and forked well. The germinated seeds were sown. Pueraria seeds were sown in the field and Mucuna seeds were sown in poly bag. As the suceeding months were drier months life saving irrigation was given for the germinated cover crop seedlings. The Mucuna seedlings were transplanted during the Ist week of April before the pre-monsoon showers.

3.2.4.2. Manuring of cover crops

As per the treatments fertilizers were broad casted along the strips where the cover crops were planted, in two

Fig. 3. Lay out plan of the Experiment III



P : *Pueraria phaseoloides*

M : *Mucuna bracteata*

equal instalments. The first instalment of fertilizers were applied one month after sowing and the second two months after the first application during the first two years of establishment of the cover crops(Rubber Board 1994).

3.2.4.3. Control of cover crops

Excess growth of cover crops were regulated by slashing around the base of the rubber plants.

3.2.5. Observations

3.2.5.1. Experiment I

3.2.5.1.1. Rubber

The following biometric observations were recorded for measuring the growth rate of rubber.

3.2.5.1.2. Plant height

The plant height was recorded in meter following the method described by Dissanayake and Mithrasena (1986). Plant height is measured from the point of bud union to the growing tip of the topmost whorl.

3.2.5.1.3. Girth

The plant girth was recorded in cm following the method explained by Owen *et al*. (1957). The girth was measured at 150cm above the bud union around the trunk of the plant. From these data the girth increment for the period July 1991 to July 1993 was worked out.

3.2.5.1.4. Weeds

The dry matter production of weeds in the treatment plots were recorded by the method explained by Burnside and Wicks (1965) using a quadrate at random in four places outside the net plot area. The weeds removed were ovendried and weight recorded in kg ha^{-1}. This was recorded at six months interval.

3.2.5.2. Cover crops

3.2.5.2.1. Biomass production

The biomass production of cover crops were estimated at six months interval using a quadrate at random in four places outside the net plot area and the material was dried and weighed, and is expressed in t ha^{-1}.

3.2.5.2.2. Nodule count and nodule weight

The number of healthy nodules were counted per plant at 40th day after planting and the fresh weight of nodules were worked out and expressed in g.

3.2.5.3. Soil

3.2.5.3.1. Physical characteristics

The following physical characteristics of the soil at two depths namely 0-30 and 30-60 cm from the treatment plots were determined at the initial and final stage of the experiment.

3.2.5.3.1.1. Bulk density

Bulk density measurements were made on core samples obtained by a soil core sampler (Lutz 1947). It was expressed in $g.cc^{-1}$.

3.2.5.3.1.2. **Total pore space**

Total pore space distrubution was determined by the following equation and expressed in percentage.

$$\% \text{ Total pore space} = \frac{1 - \text{bulk density}}{\text{particle density}} \times 100$$

3.2.5.3.1.3. **Aggregate analysis**

This was measured by the wet-sieving method described by Russell (1949) on an apparatus modified by Low (1954). The state of aggregation or the percentage weight of aggregates in a given weight of soil was calculated for the soil samples.

3.2.5.3.1.4. **Water retention capacity**

Water holding capacity at 0.3 bar and 15 bar were detemined using pressure plate apparatus and expressed in percentage.

3.2.5.3.1.5. Soil moisture content

The soil moisture content in all the treatments were recorded gravimetrically at two depths namely 0-30 and 30-60 cm during the summer months of January, February, March and April of 1991, 1992 and 1993 and were expressed in percentage.

3.2.5.4. Chemical analysis

3.2.5.4.1. Soil analysis

Soil samples were collected form each of the treatment plots in September 1991, 1992 and in 1993, just after the experiment was completed. Soil was collected from 0-30 cm depth just prior to the post monsoon fertilizer application of the respective year.

3.2.5.4.2. Organic carbon , Soil N, P, K, Ca and Mg.

Organic C was determined by the dichromate-sulphuric acid digestion method (Walkely and Black, 1934). The available nitrogen was estimated by the Alkaline permanganate method (Subbiah and Asija 1956). For the determination of available

P, the soil was extracted with Bray no. 2 (Bray and Kurtz, 1945) reagent and the concentration of P in solution was measured in a UV spectrophotometer after developing colour using chloromolynbdic acid-stanus chloride reduction method (Hesse, 1971). The soil was extracted using Morgan's reagent and available K was determined by flame photometric method (Jackson, 1973). Available Ca and Mg were determined from the same extract using a GBC Double Beam atomic absorption spectrophotometer Model no. 902. The organic carbon content was worked out as percentage and those of available N,P,K,Ca and Mg as Kg ha^{-1}.

3.2.5.4.3. Leaf analysis

Leaf samples were collected from each treatment plot in September (Shorrocks, 1965, Gugha et al. 1971 and Lu and He, 1982). 1991, 1992 and 1993. Three trees were selected from each treatment plot for leaf sampling in Experiment II. Three healthy disease free twings from each tree were collected (Shorrocks 1961 and Lu and He, 1982). From each twig the lowermost matured whorl was selected. In the experiment I the mature leaves at the top second whorl were selected. For cover crops matured leaves were collected. The leaf lets were separated and the petioles were cut and removed and the leaf laminae secured. The leaves thus obtained were dried in an oven at 70°C for three days and powdered in grinder.

Nitrogen was determined by micro Kjeldhal method (Piper, 1950). Phosphorous was detemined by Molybdenum blue method in a spectrophotometer (Jackson, 1973). Potassium was determined in a flame photometer (Jackson, 1973) Both Ca and Mg concentration were read in a GBC Double Beam atomic absorption spectrophotometer model no. 902. The nutrient contents were expressed as percentage. The leaf analysis of cover crops were done at six months interval.

3.2.5.4.4. Biological properties

The general microbial count was taken following the method of Timonin (1940) and phosphate solublisers by that of Sperber (1958). The count of total bacteria, fungi and phosphate solublising micro organisms were also undertaken and all the counts were expressed as x 10^4 g^{-1} of dry soil.

3.2.6. Experiment II

3.2.6.1. Rubber

3.2.6.1.1. Yield

The latex collected in the collecting shells after tapping was coagulated in situ using one per cent acetic acid. The cup lumps from the individual trees were collected on metal hooks, air dried for a week in shade and there after dried in a smoke house for 25 days. After complete drying the lumps were weighed, yield was similarly recorded every month (Owen et al. 1957). Yield recording was continued for a period for six months at the end of the experiment. From these data the mean yield was worked out as initial yield and final yield and expressed as g $tree^{-1}$ $tapping^{-1}$.

3.2.6.1.2. Girth

In order to guage the growth rate, the girth of trees were recorded (Dissanayake and Mithrasena 1986) in July 91 and July 93. The measurement of girth was done at a height of 150 cm from the bud union every time (Owen et al. 1957) From these data the girth increment for the period from July 1991 to July 1993 were worked out.

The thickness of the virgin bark and that of the renewed bark which was tapped two years ago were recorded July 1993 using a Schliper bark measuring guage (De Jonge 1957).

3.2.6.1.3. Leaf litter

The dry weight of the leaf that fell on the ground during the annual leaf fall in February was recorded during 1991, 1992 and 1993. For this, four patches were selected at random by throwing a $1m^2$ quadrat and the dry weight was computed as t ha^{-1} (Rubber Research Institute of Malaya, 1972).

3.2.6.1.4. Latex flow characteristics

The characters connected with the flow of latex were recorded three times viz. July 1992, Oct 1992 and April 1993 corresponding to the wet, moderately wet and dry seasons in one year cycle. Two trees were selected, from each net plot for the recording of observation when the trees were tapped the latex obtained in the initial 5 minutes was separately collected and the volume measured. This is referred to as the initial volume. After about 2-3 hours the dripping of latex was complete, the entire volume of latex including the initial volume was measured for each tree and this is referred to as total volume (Milford _et al_. 1969).

The initial flow rate was worked out as initial 5 minutes volume. This is expressed in ml. Another parameter called 'Plugging index' was computed form the initial flow rate and total volume and is an index of duration of latex flow after tapping. (Milford _et al_. 1969 and Paardekooper and Samosorn, 1969).

$$\text{Plugging index} = \frac{\text{Initial flow rate}}{\text{Total volume}} \times 100$$

The dry rubber content of latex was also determined three times simultaneously with the recording of the flow characters described above. When the flow of latex was over and dripping of latex ceased the latex obtained form the recording trees was pooled and 10ml. of it was transferred into a weighed 50ml. beaker and the weighed along with the latex was determined. The latex thus transferred was diluted with 20 ml. water and coagulated by adding about 1 ml. of one per cent acetic acid. The next day the coagulated lump of rubber was washed in water, made into a thin film and dried in an oven at about 85^0C until constant weight was obtained (Rubber Research Institute of Malaysia 1973). The weight of the dry rubber and that of the fresh content of latex is computed as

$$\frac{\text{Weight of dry rubber}}{\text{Weight of fresh latex}} \times 100$$

3.2.6.2. Cover crops

a. Biomass production of cover crops were recorded as explained in Experiment I

b. Nodule count and fresh weight of nodules per plant were also recorded as mentioned in Experiment I at 40th day after planting

3.2.6.3. Soil

Physical, chemical and biological properties were worked out as narrated under Experiment I

3.2.6.4. **Weeds**

The dry weight of weeds in the treatment plots were also recorded as explained in Experiment I at six months interval.

3.2.7. **Experiment III**

In the experiment III the observations are recorded from 10 plants within each microplot area.

3.2.7.1. **Biomass production**

The biomass production of cover crops was estimated using a quadrate at random in four places as explained in Experiment I and II and expressed in t ha^{-1}

3.2.7.2. **Nodulation count and fresh weight per plant**

Nodule count and fresh weight of nodule per plant were recorded as explained in Experiment I and II.

3.2.7.3. **Soil**

Physical chemical and biological properties of the soil were worked out as explained in Experiment I and the values were recorded.

3.2.7.4. Leaf analysis

Leaf samples collected at six months interval were analysed for N, P, K, Ca, Mg as per the methods explained in the Experiment I.

Weeds

3.2.7.5. DMP of weeds

The DMP of weeds were worked out as per the technique explained in Experiment I and the values were recorded at six months interval.

3.2.8. Statistical analysis

The data collected were analysed statistically by applying the technique of Randomised block design in Experiment I, Factorial RBD in Experiment II and in Experiment III the mean values were compared with Experiment I and II. The data were analysed as per the procedure described by Panse and Sukatme (1985), where ever the results were significant. Critical difference (least significant difference) and standard error of means were worked out for the probability level of 0.05.

RESULTS AND DISCUSSION

4. RESULTS AND DISCUSSION

In order to study the effect of cover crops on soil nutrients, physico-chemical properties, biological changes on soil, as well as growth and yield of rubber, three situations representing immature phase (one year old), mature phase (8 year old) and an open area were selected. The various observations recorded were statistically analysed. The important results are presented and discussed.

4.1 Effect of cover crops and their nutrition on immature rubber

4.1.1 Growth characters

4.1.1.1 Girth increment

The girth increment for the two years period 1991-93 for the immature rubber is presented in Table 3. It is observed that all the treatments with cover crops were significantly superior to the absolute control, where there was no cover crop. Among the levels of fertilizers to cover crops the levels F_4 and F_2 were significantly superior to F_1 and F_0. The level F_3 was on par with F_1. F_0 was significantly inferior to all other levels. There was no significant difference between the cover crops and also no significant difference in the interaction effect.

Growing of cover crops even without any fertilizer gave more girth increment than plots without any cover crops, thereby showing the distinct advantage of cover crops alone. The cover crops in general has increased the girth but individually there is no significant different between them. This shows that there is no distinct superiority of one over the other in increasing the growth attribute (Fig. 4).

Application of fertilizer to cover crops have further increased the girth increment over F_0 as evidenced from the treatments. The highest level of fertilizers have recorded the maximum girth. However, this is on part with fertilizer level F_2 thereby indicating the sufficiency of the later level. This shows that fertilizer application beyond 10:30:30 is not of any specific advantage.

Growing of cover crops has increased the girth probably due to the increase in absorption of N, P and K by the plants grown with cover crops. This is substantiated in

Table 3. Effect of covercrops and their nutrition on the girth increment (cm) 1991-93

	F0	F1	F2	F3	F4	Mean C
C1	5.87	7.10	8.00	7.57	8.17	7.340
C2	5.90	7.23	8.10	7.83	8.27	7.47
Mean F	5.88	7.17	8.05	7.70	8.22	

Mean of control 3.333

CDt 1.462 t : treatment

CDf 1.034 f : fertilizer levels

CD tr vs ct 1.08 tr. vs ct: treated (vs) control

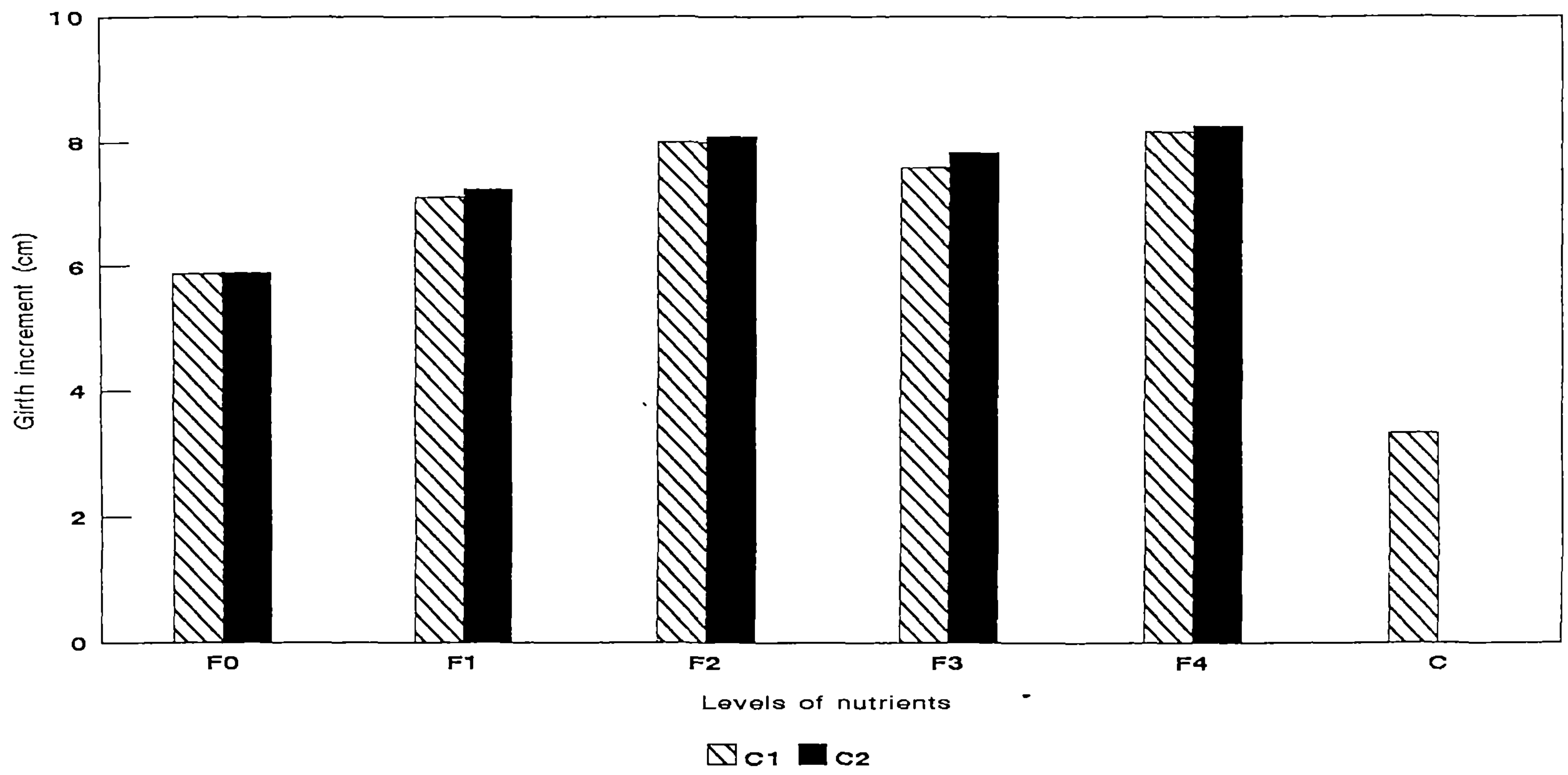
Table 4. Effect of covercrops and their nutrition on the height increment (m) 1991-93

	F0	F1	F2	F3	F4	Mean C
C1	2.05	2.10	2.20	2.10	2.28	2.15
C2	2.07	2.15	2.18	2.15	2.28	2.17
Mean F	2.06	2.13	2.19	2.13	2.28	

Mean of control 0.677

CD tr vs ct 0.514

Fig. 4. Effect of cover crops and their nutrition on the girth increment (cm) 1991-1993



the Table 3. The girth increment is directly related with the major leaf nutrients namely N, P and K. The leaf nutrient contents of the rubber leaves were found significantly higher in plots where cover crops were grown. Similar results were reported by Wycherley (1969), Yogaratnam *et al*. (1984) and Punnoose (1993).

Application of fertilizer was found to be of additional benefit as for the girth increment is concerned. It is seen from the table that growing cover crops have increased the girth from 3.33 to 5.88 cm and the girth was further enhanced to 8.05 cm in the fertilizer treatment receiving 10:30:30. This finding is in line with the findings of Pushparajah (1977).

The application of N to cover crops has benefited the girth increment inspite of the medium content of soil N. (Table 2). This would have resulted in more absorption of 'N' by rubber plants as evidenced by higher content of leaf N (Table 11). The nodule count of cover crop have also shown an appreciable increase in nodule count in the plots receiving initial dose of nitrogen. This could have helped the rubber plant to absorb more Nitrogen especially in the first year. The beneficial effect of N in increasing the cell size and photosynthetic rate of rubber plant were reported by Brady (1988). Own _et al_. (1957), Bolton (1964), Kalam _et al_. (1980) and Potty _et al_. (1980) also reported high girth increment from higher level of application of N.

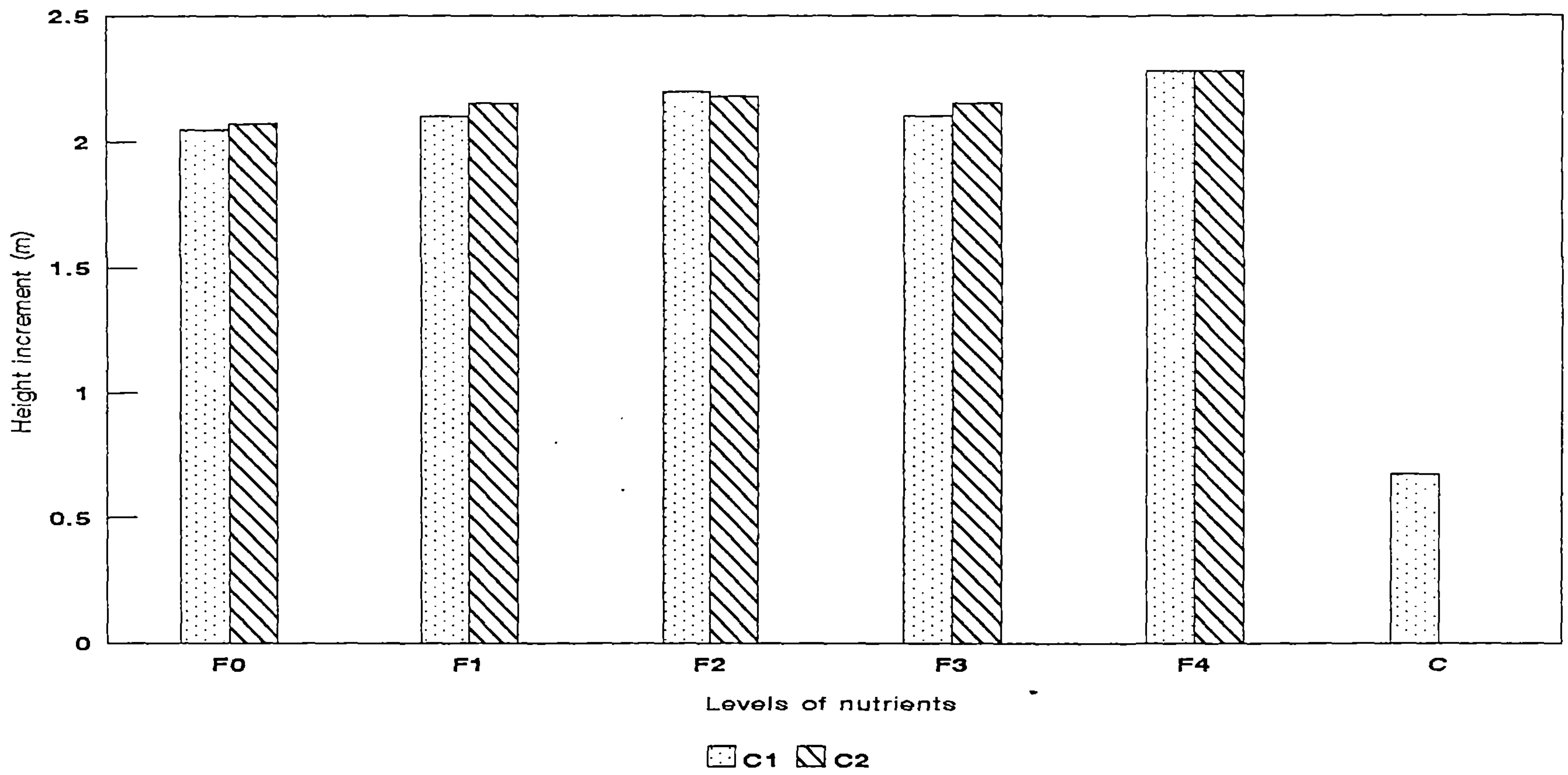
Application of 'P' to cover crop has given higher girth increment. Phosphorus being an essential constituent of ADP, ATP and several organic compounds in the plant, might have promoted the metabolises of the trees and improved the growth (Sutcliff and Baker 1974).

It is seen that application of K to cover crop improved the girth increment of rubber tree through increased leaf production as biomass of cover crop and this must have enriched the soil with K. Potassium being essential for chlorophyll development and photosynthesis its application might have helped in enhanced girth increment (Brady 1988).

4.1.1.2 Height increment

The height increment for the two years period 1991-1993 for the immature rubber is presented in Table 4. It is

Fig. 5. Effect of cover crops and their nutrition on the height increment (m) 1991-1993



seen from the table that all the treatments with cover crops were significantly superior to the absolute control. There was no significant difference between the cover crops as well between the levels of fertilizer to cover crops on the height increment. It is also noted that there was no significant difference in the interaction effect. However, there was a marked increase by growing cover crop alone without fertilizer which is significant over the treatment with no fertilizer and nocover. It is also seen that increase in the fertilizer level has enhanced the height eventhough not statistically significant. (Fig. 5).

From the above results it is evident that growing cover crops, even without any fertilizer gave more height increment than plots without any cover crops thereby highlighting the distinct advantage of cover crop alone.

4.1.2 Soil nutrient status

The effect of cover crops and their nutrition on soil organic carbon and available P, K, Ca and Mg are presented and discussed.

Table 5. Effect of covercrops and their nutrition on the soil organic carbon % 1991

F	0	1	2	3	4	Mean C
C1	1.003	0.990	1.010	1.000	1.050	1.011
C2	1.017	1.000	1.000	1.020	1.040	1.027
Mean F	1.010	0.995	1.035	1.010	1.045	

Mean of control 0.677

CD tr vs ct 0.247

Table 5a. Soil organic carbon % 1992

F	0	1	2	3	4	Mean C
C1	1.020	1.043	1.117	1.040	1.170	1.078
C2	1.053	1.080	1.213	1.060	1.253	1.132
Mean F	1.037	1.062	1.165	1.050	1.212	

Mean of control 0.673

CD tr vs ct 0.232

Table 5b. Soil organic carbon % 1993

F	0	1	2	3	4	Mean C
C1	1.063	1.093	1.173	1.097	1.250	1.135
C2	1.103	1.120	1.283	1.127	1.367	1.200
Mean F	1.083	1.107	1.228	1.112	1.308	

Mean of control 0.687

CD tr vs ct 0.236

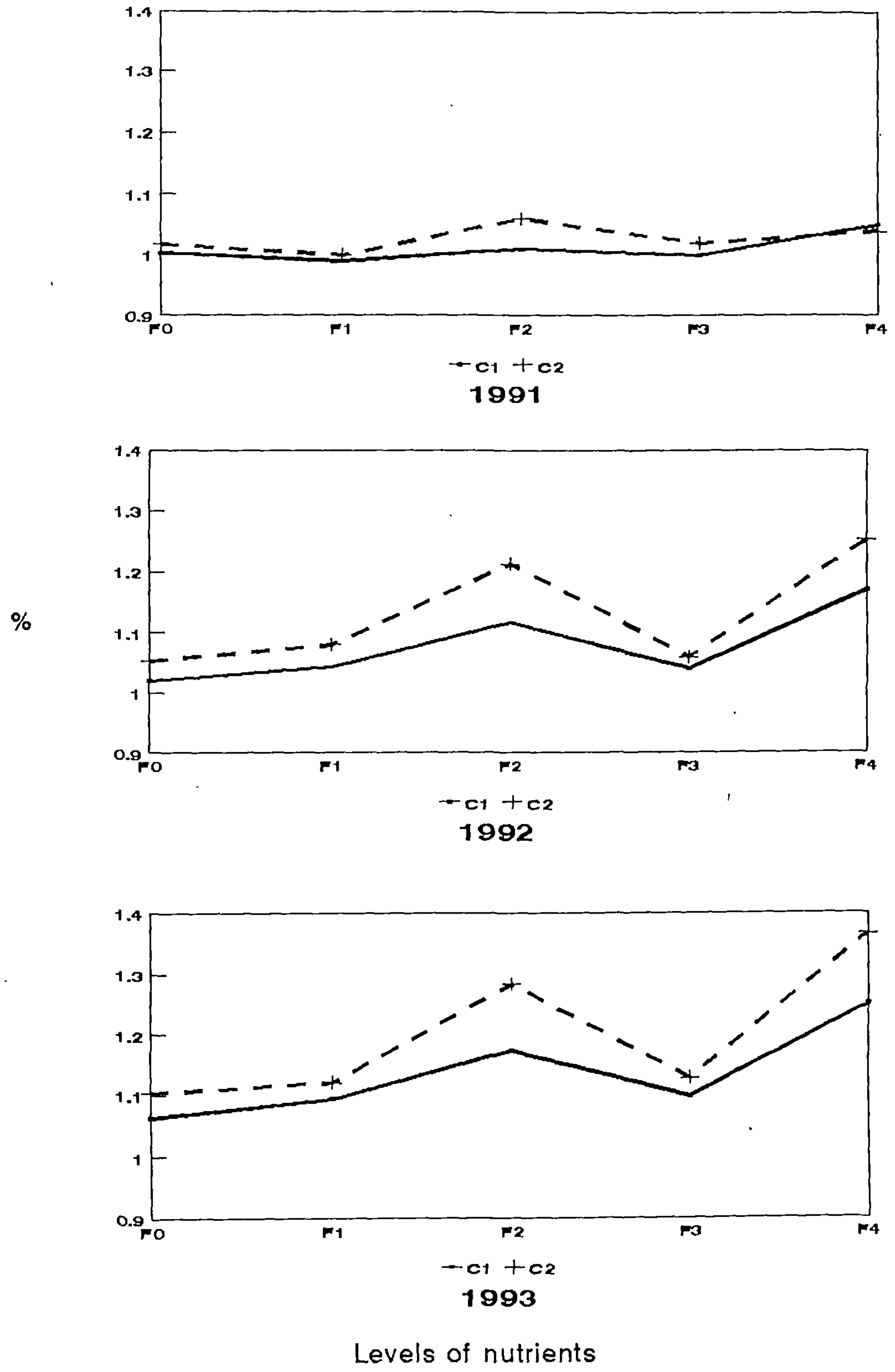
4.1.2.1. Organic carbon

The results obtained from the three years observations are presented in Table 5-5b. Growing of cover crops have significantly increased the organic carbon content over the absolute control plots in all the three years of observations. Among the cover crops there was no significant difference on the organic carbon content. The levels of fertilizer applied to cover crops also did not show significant difference. (Fig. 6).

In the covercropped treatment plots the dead litter materials deposited on the surface of soil got decomposed and the soil organic carbon content might have increased in due course when compared to plots without cover crops. The results also showed that there was an incremental increase of organic carbon by growing cover crops. These findings are in corroborative with the observations of Watson (1961), Watson et al. (1964), Broughton (1977) and Punnoose (1993).

It is also seen that addition of all nutrients helped in the gradual building and enrichment of soil organic carbon when mineral nutrients are in adequate quantity in

Fig. 6. Effect of cover crops and their nutrition on soil organic carbon (%) 1991-1993



soil there will be better conservation of organic carbon of soil. (Stevenson, 1964 and Brady, 1988). The gradual building of organic carbon in soil could be the result of continuous addition of leaf litter from cover crop.

4.1.2.2. Available N

The available N content in the different years of observations are presented in Table 6-6c. The cover cropped plots recorded significantly higher available N content than the control plots during all the three years of observations.

There was no significant difference noted between the cover crops on the soil available N. The levels of fertilizer to cover crops have increased the available N content significantly. The level F_4 has recorded the highest value of available N content and was on par with F_2 during 1992 Sept. The levels F_1 and F_0 were significantly inferior to F_4 and F_2 during all the three years observations. (Fig. 7).

Table 6. Effect of covercrops and its nutrion on the soil available N Kg ha^{-1} 1991 initial

F	0	1	2	3	4	Mean C
C1	183.73	187.50	172.70	174.93	171.87	178.05
C2	172.37	173.87	191.97	186.13	170.36	178.94
Mean F	178.05	180.68	182.08	180.53	171.12	

Mean of control 109.300

CD tr vs ct 37.41

Table 6a. Soil available N Kg ha^{-1} 1991 Sept.

F	0	1	2	3	4	Mean C
C1	195.70	212.40	236.97	224.40	245.27	222.95
C2	182.33	198.70	217.40	207.40	227.93	206.77
Mean F	189.02	205.55	227.92	215.90	236.60	

Mean of control 111.47

CD tr vs ct 37.69

Table 6b. Soil available N Kg ha^{-1} 1992 Sept.

	0	1	2	3	4	Mean C
C1	211.57	228.73	283.70	243.63	315.93	256.713
C2	205.60	228.10	269.57	253.53	301.97	251.753
Mean F	208.58	228.417	276.63	248.58	308.95	

Mean of control 118.100

CDt 55.209

CDf 39.038

CD tr vs ct 40.940

Table 6c. Soil available N Kg ha^{-1} 1993 Sept.

	0	1	2	3	4	Mean C
C1	222.53	244.57	309.73	263.13	254.53	278.90
C2	218.60	244.83	305.87	269.33	248.50	277.340
Mean F	220.567	214.700	307.800	266.233	351.30	

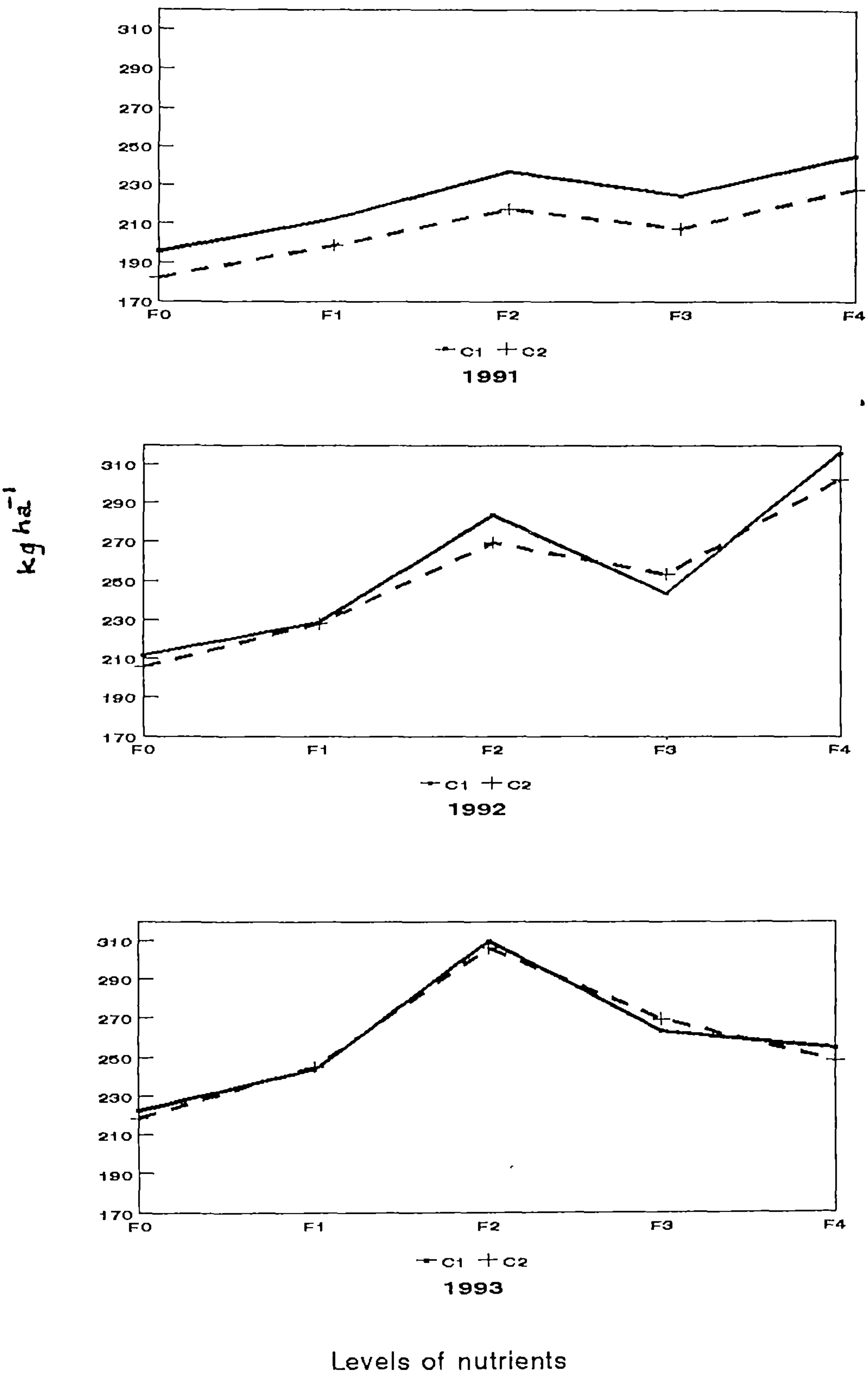
Mean of control 160.02

CDt 54.078

CDf 38.238

CD tr vs ct 40.110

Fig. 7. Effect of cover crops and their nutrition on soil available Nitrogen (kg ha^{-1}) 1991 - 1993



The increase in available N content of soil in the cover croppped plots over the control plots were mainly due to the presence of thick dead litter mulch on th soil surface. This thick mulching improved the soil organic carbon, soil moisture, soil physical properties and soil microbial population (Tables 5, 17-20 and 35) thus enhanced the available N content. Similar findings was also reported by Kothandaraman et al. (1990).

4.1.2.3. Available P

The available P content in the different years of observation are presented in Table 7-7b. The cover cropped plots recorded significantly higher available P content than the control plots during all the three years of observation.

There was also appreciable increase in P content in plots grown with Mucuna over Pueraria and the increase is significant for the last two years. The levels of fertilizer applied to cover crops also increased the available P content significantly. The level F_4 has recorded the highest value and was on par with F_2 alone during 1993. The levels F_1 and F_0 were significantly inferior to F_4 and F_2. (Fig. 8).

Table 7. Effect of covercrops and their nutrition on the soil available P Kg ha^{-1} 1991

F	0	1	2	3	4	Mean C
C1	15.05	15.28	15.70	15.42	15.20	15.33
C2	15.50	16.48	15.22	15.68	16.50	15.88
Mean F	15.28	15.88	15.46	15.55	15.85	

Mean of control 9.97

CD tr vs ct 3.332

Table 7a. Soil available P Kg ha^{-1} 1992

F	0	1	2	3	4	Mean C
C1	15.53	17.05	20.12	18.15	20.03	18.18
C2	16.82	20.70	22.27	21.03	24.53	21.07
Mean F	16.18	18.18	21.19	19.59	22.28	

Mean of control 9.70

CD t 4.08

CDc 1.967

CDf 3.111

CD tr vs ct 3.263

Table 7b. Soil available P Kg ha^{-1} 1993

F	0	1	2	3	4	Mean C
C1	17.48	22.98	26.55	23.38	27.65	23.61
C2	19.72	26.02	29.90	26.77	31.77	26.83
Mean F	18.60	24.50	28.23	25.08	29.71	

Mean of control 11.40

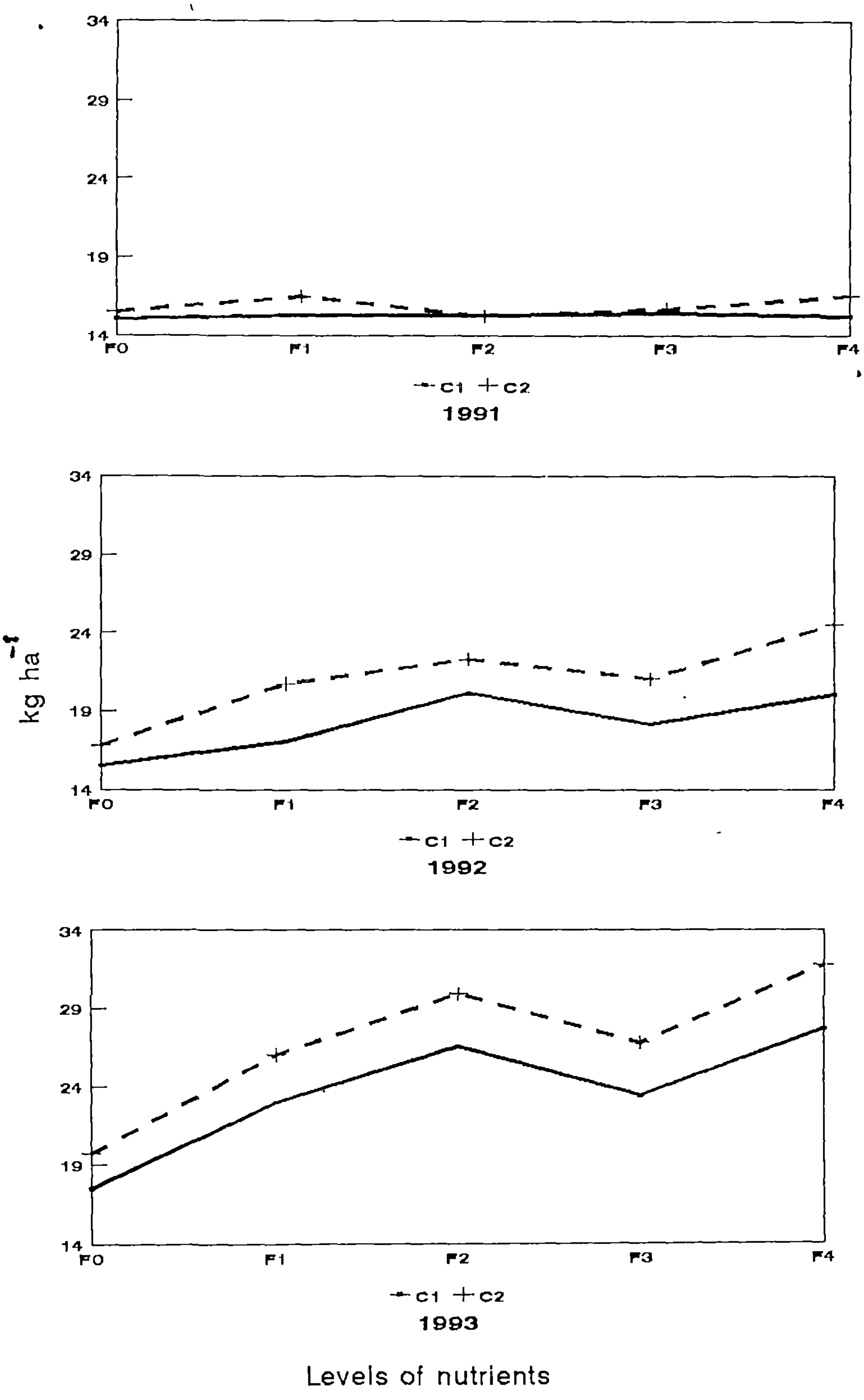
CD tr 5.213

CDc 2.331

CDf 3.686

CD tr vs ct 3.686

Fig. 8. Effect of cover crops and their nutrition on soil available Phosphorus (kg ha^{-1}) 1991-1993



The increase in the available P content of soil in the cover cropped area over the control plots was mainly due to the presence of thick dead litter mulch on the soil surface. This thick mulch improved the soil moisture content (Tables 17-20) and soil physical properties (Tables 21-30). This thick dead litter mulch also improved the soil by increased activity of microbes like bacteria and phosphate solubilisers (Table 35). Similar finding was also reported by Kothandaraman et al. (1990).

The increase in the available P content of soil with F_4 level was notable. It is only a direct effect of application of P fertilizer. Similar increases in P content of soil were reported by Bolton (1960), Pushpadas et al. (1972) Pushparajah (1984) and Punnoose (1993) in rubber growing soils.

4.1.2.4. Available K

The available K content of soil in different years of observation, are presented in Table 8. The plots grown with cover crops recorded significantly increased available K. content over the control plots. There was no significant

Table 8. Effect of covercrops and their nutrition on the soil available K(Kg ha^{-1})1991

F	0	1	2	3	4	Mean C
C1	118.52	121.23	120.32	122.58	119.98	120.427
C2	119.37	118.32	122.05	125.92	119.83	121.097
Mean F	118.94	119.78	121.25	124.25	119.66	

Mean of control 80.20

CD tr (vs) Ct 26.66

Table 8a. Available K(Kg ha^{-1})1992

F	0	1	2	3	4	Mean C
C1	138.73	136.32	123.37	131.80	130.85	132.213
C2	139.92	139.93	124.82	132.72	133.18	134.115
Mean F	139.33	138.13	124.09	132.26	132.02	

Mean of control 94.43

CD tr (vs) ct 31.509

Table 8b. Soil available K(Kg ha^{-1})1993

F	0	1	2	3	4	Mean C
C1	160.60	165.22	134.88	147.20	134.97	148.57
C2	161.68	165.85	137.63	146.87	134.57	149.320
Mean F	161.14	165.53	136.26	147.03	134.76	

Mean of control 107.73

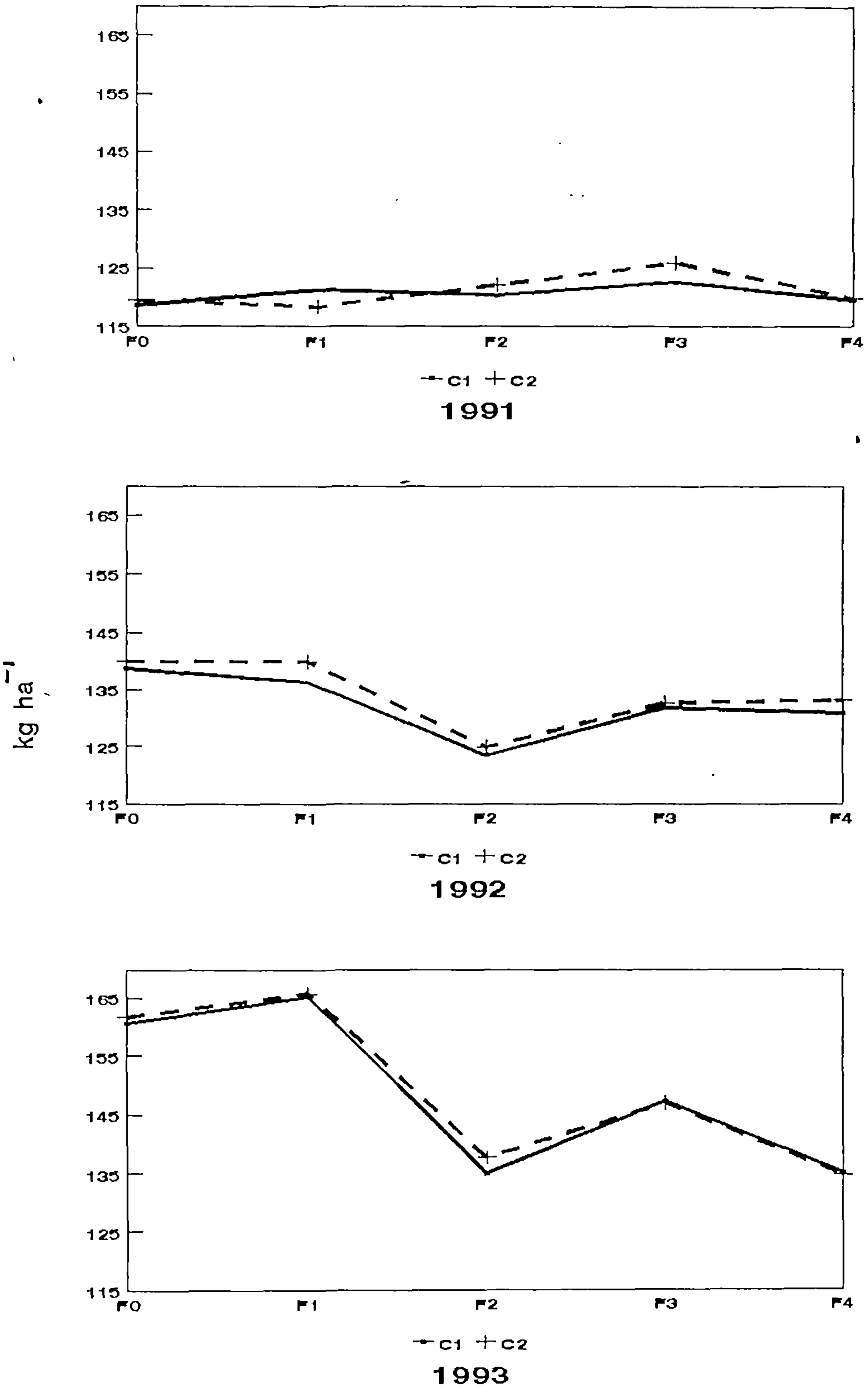
CD tr (vs) Ct 35.770

difference noticed between the levels of fertilizers for each cover crops as well as between the cover crops. (Fig. 8).

The increase in the available K content of soil in the cover cropped treatment is mainly attributed to the addition of cover crop litter in to the soil which contains lot of K. This is all the more evidenced by the increase in the quantity of the available soil K from 91 to 1993. There was also a corresponding increase in the available K through the biomass as the growth of the cover crop is progressively increased due to the age (Table 31). The rain water interception and preventing soil erosion by the live cover crop also might have contributed to higher available soil K. These findings are in corroborative with that of Watson (1961), Shorrocks (1965), Russell (1983) and Pushparajah (1984).

The increase in the available K content of soil showed a negative effect when an extra dose of 10 kg nitrogen was added (Table 8b). These findings are in corroborative with that of Watson (1961), Shorrocks (1965) and Russell (1983).

Fig. 9. Effect of cover crops and their nutrition on soil available Potassium (kg ha^{-1}) 1991-1993



Levels of nutrients

The increase in the available K content of soil showed a negative effect on extra dose of 10 kg nitrogen was added (Table 8b). This application of nitrogen and reduction of available K content might be due to the following reasons.

Higher concentration of NH_4^+ ions especially in the lower layers would have replaced K^+ ions from the exchange sites brining more of K into the solution from where they were lost by leaching (Tisdale et al. 1985). Moreover the higher growth associated with application of N to cover crop have increased the plant uptake of K (Table 31f) thus reducing its level in the soil (Table 8b).

4.1.2.5. Available Ca

The available Ca content of soil is presented in Table 9. The cover crop grown plots were significantly superior than the absolute control on the available Ca content. There was no significant difference found between the levels of fertilizers to cover crops as well as between the cover crops. (Fig. 9).

The increased Ca content of soil in the cover cropped plots than the absolute control is mainly due

Table 9. Effect of covercrops and their nutrition on the soil available Ca Kg ha^{-1} 1991

F	0	1	2	3	4	Mean C
C1	172.08	175.43	169.63	174.67	169.62	172.69
C2	172.33	170.40	172.28	176.73	180.47	174.44
Mean F	117.35	172.92	175.90	175.70	175.04	
				Mean of control		117.35

CD tr (vs) ct 38.66

Table 9a. Soil available Ca Kg ha^{-1} 1992

F	0	1	2	3	4	Mean C
C1	202.08	235.43	219.63	274.70	271.23	240.62
C2	204.00	236.37	222.55	277.32	273.55	242.76
Mean F	203.04	235.90	221.09	276.01	272.39	
				Mean of control		130.73

CD tr 57.310

CDf 40.52

CD tr (vs) ct 42.50

Table 9b. Soil available Ca Kg ha^{-1} 1993

F	0	1	2	3	4	Mean C
C1	227.13	270.43	264.63	314.93	311.27	277.680
C2	228.78	273.87	267.45	317.27	314.07	280.287
Mean F	227.958	272.150	266.042	311.667	312.667	
				Mean of control		168.50

CD tr (vs) ct 51.305

CDf 44.30

to the addition of increased leaf litter materials to the soil. The leaf litter materials contain 0.75 to 1.00% of Ca and is recycled into the soil.

There was also a build up of Ca in the soil with addition of P over the years. This could be due to the continuous application of rock phosphate (Bolton 1960, Pushparajah 1966, and Punnoose, 1993).

4.1.2.6. Available Mg

The soil available Mg content is presented in Table 10. The cover croped plots were significantly superior to the absolute control on the available Mg content. Among the levels of fertilizers to cover crops as well between the cover crops there was no significant difference recorded.

The increased Mg content of soil in the cover cropped treatments over the absolute control is mainly due to the addition of leaf litter and root materials to the soil. The cower crop leaf litter contains 0.25 to 0.45% of Mg and

Table 10. Effect of covercrops and their nutrition on the soil available Mg ha^{-1} 1991

F	0	1	2	3	4	Mean C
C1	105.12	107.18	105.90	99.83	101.35	103.88
C2	107.22	109.40	108.00	102.03	102.80	106.220
Mean F	106.17	108.29	106.95	101.03	102.80	
				Mean of control		66.75

CD tr (vs) Ct 22.41

Table 10a. Soil available Mg ha^{-1} 1992

F	0	1	2	3	4	Mean C
C1	124.37	143.42	153.33	146.72	140.52	141.67
C2	126.35	145.28	154.17	148.37	143.27	143.49
Mean F	125.36	144.35	153.75	147.54	141.89	
				Mean of control		80.05

CD tr (vs) Ct 32.36

Table 10b. Soil available Mg ha^{-1} 1993

F	0	1	2	3	4	Mean C
C1	145.95	165.17	167.88	167.60	168.37	162.893
C2	147.40	165.22	160.27	153.53	158.70	157.023
Mean F	146.425	165.900	164.080	160.573	163.53	
				Mean of control		86.98

CD tr (vs) Ct 28.968

is recycled into the soil. Also the root nodules which are rich in Mg added into the soil. These findings are in accordance with the work of Watson (1961).

Application of K beyond 30 kg level had a negative effect on the Mg content of soil. Application of K increased the concentration of K^+ ions which might have replaced. More of Mg^{++} ions from the exchange sites into the soil solution and they were subsequently lost by leaching (Tisdale et al. 1985). Also more, of Mg was probably removed by the rubber and cover crops when growth and biomass were improved by application of N and K.

4.1.3. Effect of cover crops and their nutrition on the Hevea leaf nutrient contents.

The results of major nutrients N, P, K, Ca and Mg content of Hevea leaves are presented and discussed below.

4.1.3.1. Hevea leaf N content

The results obtained for the period from 1991 to 1993 are presented in Tables 11-11b. It is observed that there was significant difference between the mean of

Table 11. Effect of covercrops and their nutrition on the Hevea leaf N % 1991

F	0	1	2	3	4	Mean C
C1	3.104	3.111	3.125	3.159	3.176	3.135
C2	3.114	3.186	3.121	3.308	3.117	3.169
Mean F	3.109	3.149	3.123	3.234	3.147	

Mean of control 2.137

CD tr (vs) ct 0.706

Table 11a. Hevea leaf N % 1992

F	0	1	2	3	4	Mean C
C1	3.202	3.213	3.331	3.288	3.377	3.282
C2	3.311	3.386	3.418	3.398	3.461	3.395
Mean F	3.257	3.299	3.375	3.343	3.419	

Mean of control 2.175

CD tr (vs) Ct 0.719

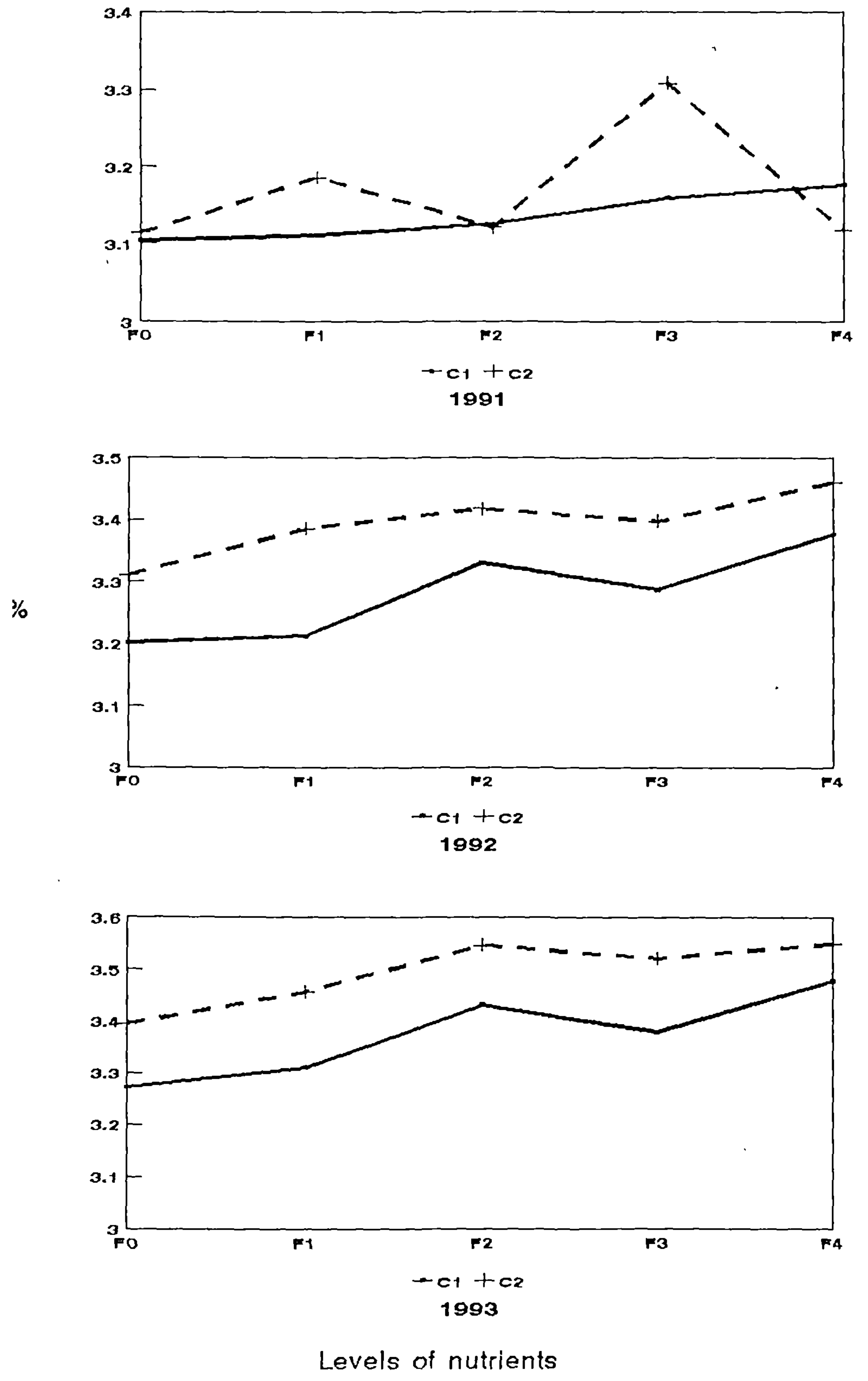
Table 11b. Hevea leaf N % 1993

F	0	1	2	3	4	Mean C
C1	3.273	3.311	3.432	3.380	3.478	3.375
C2	3.396	3.457	3.547	3.522	3.550	3.494
Mean F	3.335	3.384	3.490	3.451	3.514	

Mean of control 2.192

CD tr (vs) Ct 0.725

Fig. 10. Effect of cover crops and their nutrition on the Hevea leaf Nitrogen (%) 1991-1993



treatments and control plots. The former recorded significantly higher leaf N content. It may be seen from the table on organic carbon content was more in the treatment plots with cover crop than that of absolute control. Among the levels of fertilizer, there is no significant difference. (Fig. 10). This would have influenced the nitrogen content of Hevea under cover cropped situation. All the benefits associated with cover crop such as moisture availability, lack of weed competition and faster mineralisation would have contributed to higher leaf nitrogen content of Hevea. These findings are in line with the works of Watson (1961), Watson et al. (1964) and Pushparajah (1977).

4.1.3.2. Hevea leaf P content

The results of Hevea leaf P obtained for the period from 1991 to 1993 are presented in Table 12-12b. It is seen from the table that there was a significant difference between the treatments and control plot. The plots with cover crops recorded significantly higher leaf P content than the control plots. It is also observed that there was no significant difference between the cover crops as well as between the levels of fertilizers. There was no interaction effect found. (Fig. 11).

Table 12. Effect of covercrops and their nutrition on the Hevea leaf P % 1991

F	0	1	2	3	4	Mean C
C1	0.226	0.236	0.243	0.251	0.266	0.244
C2	0.230	0.246	0.254	0.267	0.273	0.254
Mean F	0.228	0.241	0.249	0.259	0.270	

Mean of control 0.135

CD tr (vs) Ct 0.045

Table 12a. Hevea leaf P % 1992

F	0	1	2	3	4	Mean C
C1	0.228	0.237	0.244	0.259	0.260	0.246
C2	0.237	0.249	0.258	0.274	0.280	0.260
Mean F	0.233	0.243	0.251	0.267	0.270	

Mean of control 0.146

CD tr (vs) Ct 0.048

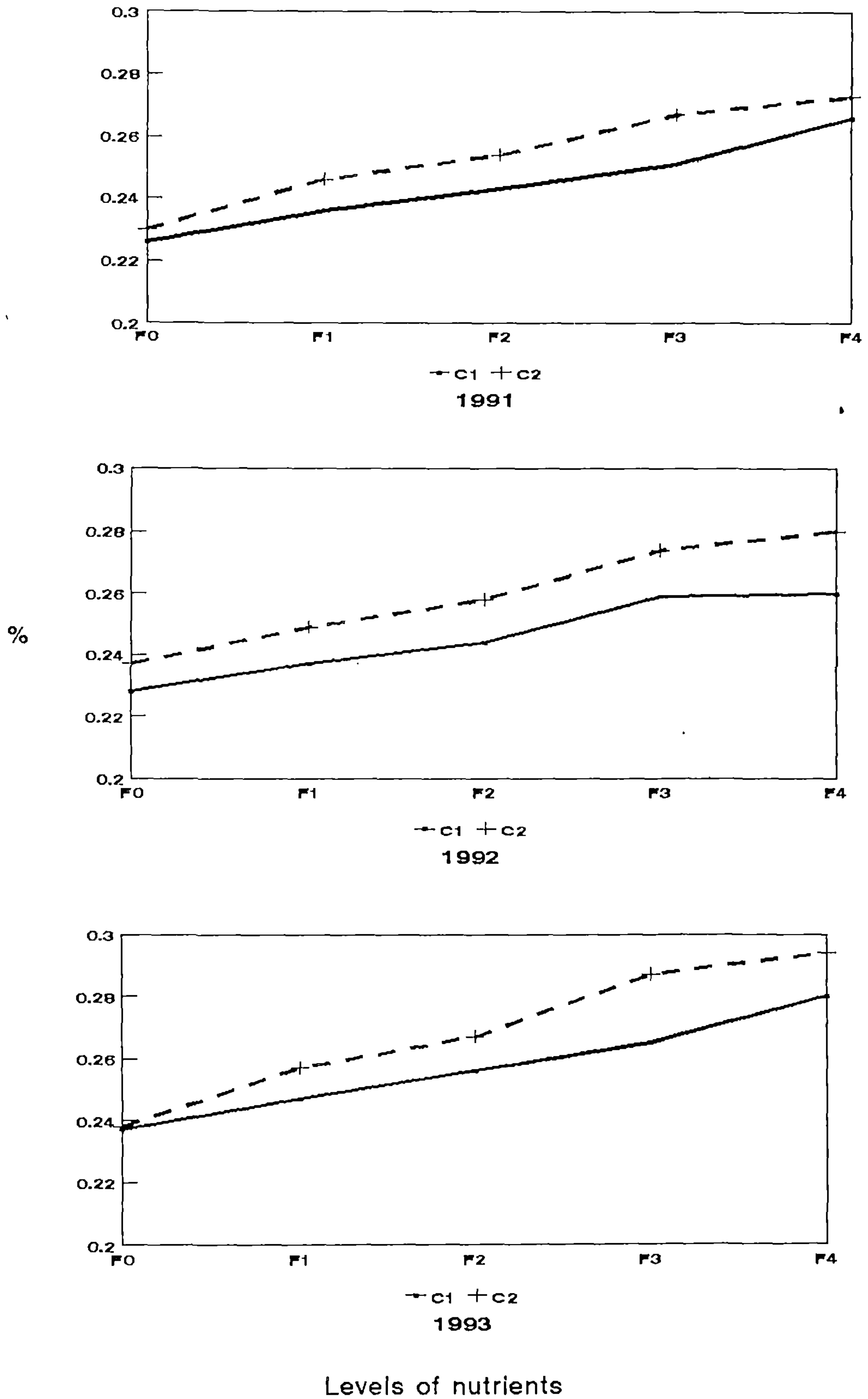
Table 12b. Hevea leaf P % 1993

F	0	1	2	3	4	Mean C
C1	0.287	0.247	0.256	0.265	0.280	0.263
C2	0.238	0.257	0.267	0.287	0.294	0.269
Mean F	0.253	0.252	0.262	0.276	0.284	

Mean of control 0.151

CD tr (vs) Ct 0.056

Fig. 11. Effect of cover crops and their nutrition on the Hevea leaf Phosphorus(%) 1991-1993



All the three years of sampling, the *Hevea* leaf P content in the cover cropped plots were higher due to the increased available P content of the soil, this was through the increased population of phosphate solubilizing microorganisms in the soil (Table 35). The increased leaf P could be attained through the enhanced mineralisation process and increased uptake of P from Soil along with N are K for the growth and other plant metabolism. This finding is in accordance with the works of Watson (1961) and Kothandaraman *et al*. (1990).

The high soil P status might have helped in better absorption of P resulting in higher P content of *Hevea* leaves in the cover cropped treatments. Shorrocks (1962), Pushpadas *et al*. (1978), Yogaratnam *et al*. (1984) and Punnoose (1993) also reported that application of P improved the leaf P content of *Hevea*.

4.1.3.3. *Hevea* leaf K content

The *Hevea* leaf K content for the period from 1991 to 1993 are presented in Tables 13-13b. It is noted from the table that there was significant differences between the treatments and control plot. The treatment plots with

Table 13. Effect of covercrops and their nutrition on the Hevea leaf K % 1991

F	0	1	2	3	4	Mean C
C1	1.265	1.293	1.316	1.345	1.456	1.335
C2	1.268	1.301	1.320	1.348	1.459	1.339
Mean F	1.266	1.297	1.318	1.346	1.457	

Mean of control 0.806

CD tr (vs) Ct 0.265

Table 13a. Hevea leaf K % 1992

F	0	1	2	3	4	Mean C
C1	1.269	1.297	1.321	1.350	1.461	1.340
C2	1.274	1.306	1.325	1.353	1.452	1.342
Mean F	1.272	1.302	1.323	1.352	1.457	

Mean of control 1.341

CD tr (vs) Ct 0.266

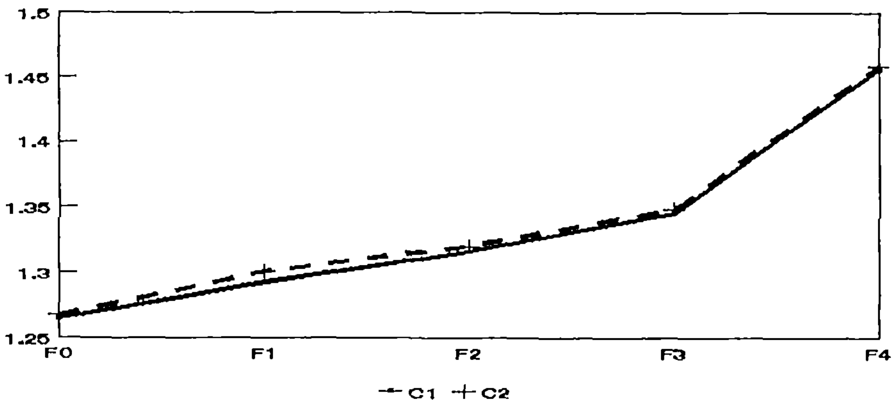
Table 13b. Hevea leaf K % 1993

F	0	1	2	3	4	Mean C
C1	1.271	1.303	1.325	1.353	1.466	1.344
C2	1.277	1.311	1.329	1.357	1.469	1.349
Mean F	1.274	1.307	1.327	1.355	1.468	

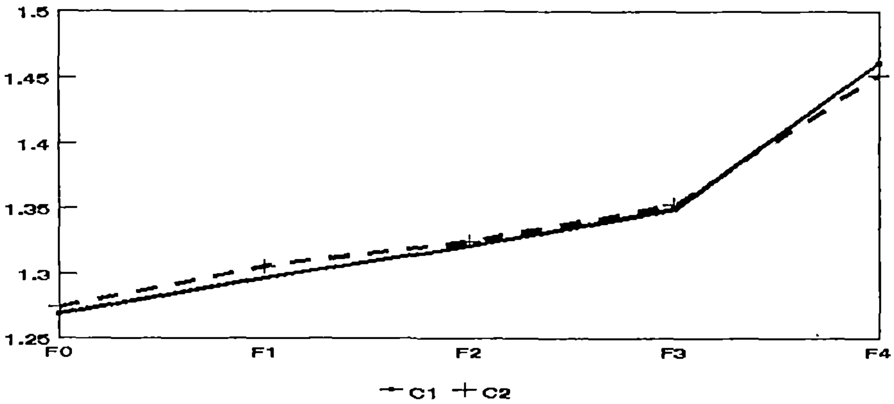
Mean of control 0.810

CD tr (vs) Ct 0.267

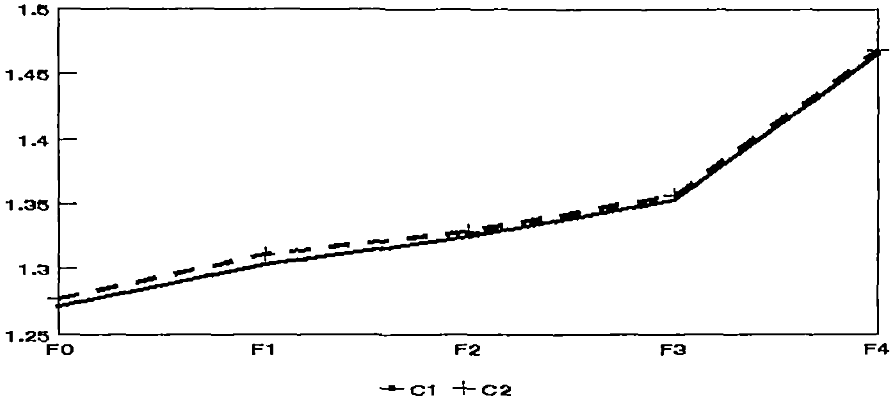
Fig. 12. Effect of cover crops and their nutrition on the Hevea leaf Potassium (%) 1991-1993



1991



1992



1993

Levels of nutrients

cover crop recorded significantly higher leaf K content than the absolute control. There was no significant difference between cover crops as well as between the levels of fertilizers to cover crops. It is also noted that there was no interaction effect. (Fig. 12).

The increased K content of <u>Hevea</u> leaf in the cover cropped treatment over the absolute control is mainly due to the presence of higher quantity of available K which was obtained through the decomposed dead litter addition and the K from rainfall interception by cover crops. Moreover the higher growth associated with application of N enhanced to cover crop would have increased the plant uptake of K thus increasing its level in leaf. This finding is in line with the work of Watson (1961), Russel (1983) and Punnoose (1993).

4.1.3.4. <u>Hevea</u> leaf Ca content

The <u>Hevea</u> leaf Ca content for the sampling period were presented in Tables 14-14b. The treatments with cover crops were significantly higher in Ca content than the absolute control. It is observed that there was no significant difference obtained between either the levels of fertilizers or between the cover crops.

Table 14. Effect of covercrops and their nutrition on the Hevea leaf Ca % 1991

F	0	1	2	3	4	Mean C
C1	0.403	0.463	0.487	0.477	0.500	0.465
C2	0.433	0.477	0.510	0.480	0.520	0.486
Mean F	0.423	0.470	0.498	0.475	0.510	

Mean of control 0.217

CD tr (vs) Ct 0.073

Table 14a. Hevea leaf Ca % 1992

F	0	1	2	3	4	Mean C
C1	0.450	0.490	0.523	0.510	0.553	0.507
C2	0.480	0.540	0.540	0.510	0.560	0.526
Mean F	0.465	0.515	0.537	0.510	0.557	

Mean of control 0.243

CD tr (vs) Ct 0.081

Table 14b. Hevea leaf Ca % 1993

F	0	1	2	3	4	Mean C
C1	0.483	0.520	0.560	0.560	0.617	0.548
C2	0.513	0.523	0.597	0.577	0.633	0.579
Mean F	0.498	0.547	0.578	0.568	0.625	

Mean of control 0.273

CD tr (vs) Ct 0.093

The increased leaf Ca content is due to the increased quantum addition of dead leaf and twig litter materials into the soil. This addition of Ca into the soil might have helped in better absorption of Ca resulting in higher Ca content in leaf of Hevea. This finding is in line with the work of Watson (1961) and Pushparajah (1966).

4.1.3.5. Hevea leaf Mg content

The Hevea leaf Mg content during the experiments were presented in Tables 15-15b. The treatments with cover crops were significantly superior than the absolute control on the leaf Mg content. There was no significant difference between the levels of fertilizers. It was noted that there was no significant difference between the cover crops.

The increased Mg content of Hevea leaf in the cover cropped treatment plots are mainly due to the addition of dead leaf, stem and root litter of cover crops which are good source of Mg. This added litter enhanced the mineralisation process and imported the uptake of Mg by Hevea. The N, P, K addition gradually, improved the uptake of Mg by Hevea as well as cover crops also. Similar findings were reported by Watson (1961) and Punnoose (1993).

Table 15. Effect of covercrops and their nutrition on the Hevea leaf Mg % 1991

F	0	1	2	3	4	Mean C
C1	0.252	0.254	0.225	0.259	0.260	0.256
C2	0.252	0.255	0.257	0.262	0.265	0.258
Mean F	0.252	0.255	0.256	0.260	0.262	

Mean of control 0.164

CD tr (vs) Ct 0.054

Table 15a. Hevea leaf Mg % 1992

F	0	1	2	3	4	Mean C
C1	0.254	0.255	0.258	0.263	0.270	0.260
C2	0.256	0.261	0.263	0.267	0.271	0.263
Mean F	0.255	0.258	0.260	0.265	0.271	

Mean of control 0.166

CD tr (vs) Ct 0.055

Table 15b. Hevea leaf Mg % 1993

F	0	1	2	3	4	Mean C
C1	0.253	0.255	0.258	0.261	0.267	0.259
C2	0.255	0.258	0.259	0.261	0.269	0.260
Mean F	0.254	0.256	0.258	0.261	0.268	

Mean of control 0.165

CD tr (vs) Ct 0.055

4.1.4. Effect of cover crops and their nutrition on Weed Dry Matter Production (DMP)

The quantity of weed drymatter produced in Kg ha^{-1} in the experiment is analysed and the same is presented and discussed below. The recording of week DMP were under taken at six monthly interval.

It is also seen from the Tables 16-16d that during the first year of the experiment there was no significant difference noted in the weed DMP between the treatments and absolute control. There was significant difference from April 1992 to October 1993 between the treatments and absolute control on the weed DMP during all the recordings. There was no significant difference found between the cover crops. However in the case of fertilizer treatments there was a drastic reduction in weed DMP when the level of fertilizers were increased. This reduction was significant in April 1993. (Fig. 13).

During the first year of the experiment the cover crops were just establishing in the treatment plots, that might be the reason for not showing any significant

Table 16. Effect of covercrops and their nutrition on weed dry matter Kg ha^{-1} Oct. 1991

F	0	1	2	3	4	Mean C
C1	1168.3	870.0	687.6	775.0	556.0	811.40
C2	1196.7	915.0	628.3	810.0	589.3	827.867
Mean F	1182.5	892.0	658.0	792.5	572.7	

Mean of control 1200.00

CDf 402.050

Table 16a. Weed dry matter Kg ha^{-1} April 1992

F	0	1	2	3	4	Mean C
C1	945.0	668.3	476.7	616.7	453.00	632.00
C2	825.0	605.0	413.3	53.30	396.0	554.67
Mean F	885.0	636.7	445.0	575.0	475.0	

Mean of control 1073.33

CD tr (vs) Ct 371.230

Table 16b. Weed dry matter Kg ha^{-1} Oct. 1992

F	0	1	2	3	4	Mean C
C1	1156.7	871.7	683.3	818.3	655.0	837.00
C2	1021.7	798.3	618.3	730.0	555.0	744.67
Mean F	1089.2	835.0	650.8	774.2	605.0	

Mean of control 1285.00

CD tr (vs) Ct 405.230

Table 16c. Weed dry matter Kg ha^{-1} April 1993

F	0	1	2	3	4	Mean C
C1	978.3	688.3	476.6	568.3	451.7	632.7
C2	813.3	588.3	368.3	401.7	360.0	506.3
Mean F	895.8	638.3	422.5	485.0	405.8	

Mean of control 990.00

CD tr (vs) Ct 339.800

CDf 323.983

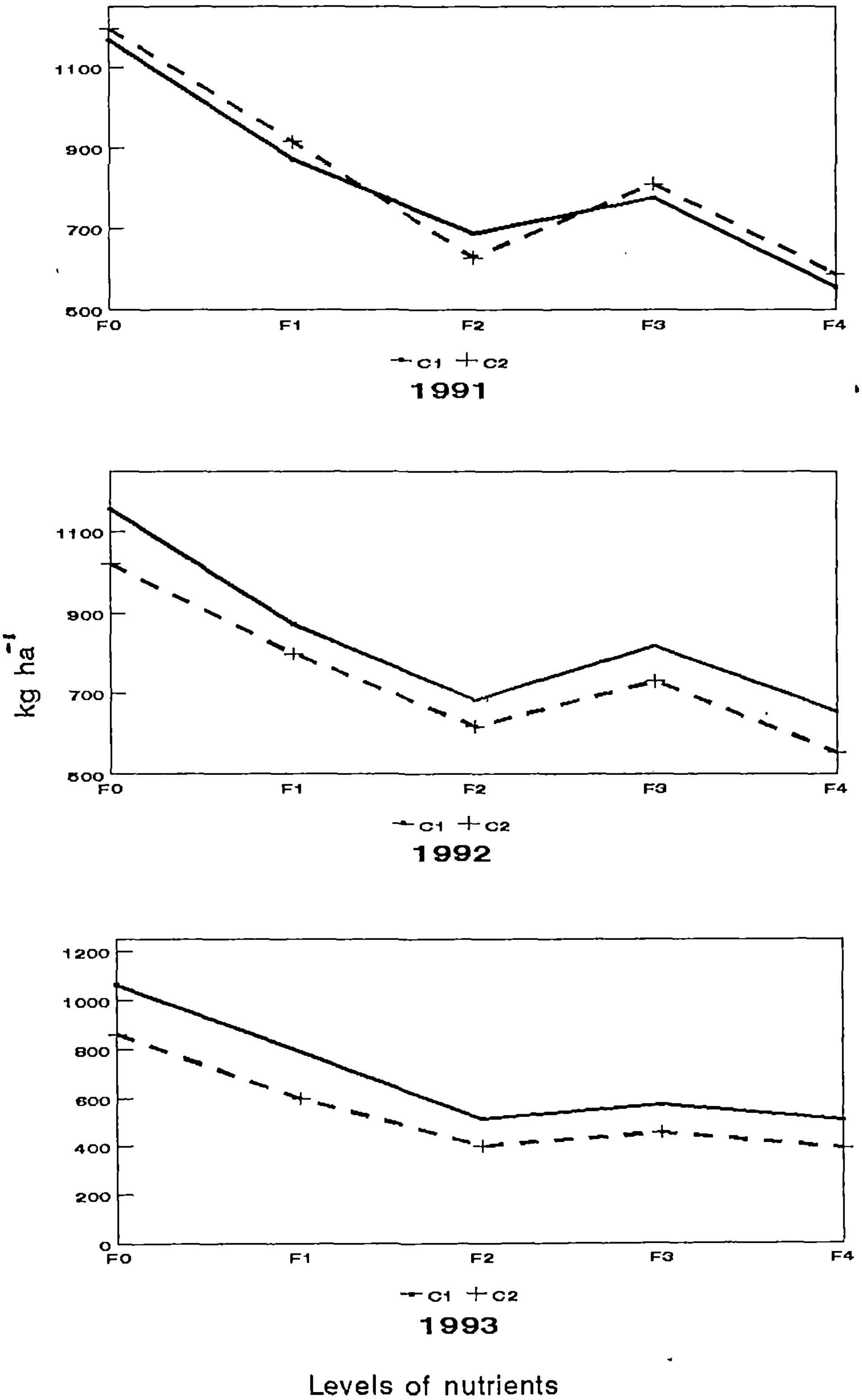
Table 16d. Weed dry matter Kg ha^{-1} Oct. 1993

F	0	1	2	3	4	Mean C
C1	1061.7	790.0	515.0	573.3	458.3	689.6
C2	858.3	598.3	401.6	456.6	393.3	541.7
Mean F	960.0	694.2	515.0	515.0	450.8	

Mean of control 1208.3

CD tr (vs) Ct 413.352

Fig. 13. Effect of cover crops and their nutrition on weed DMP (kg ha^{-1}) 1991-1993



difference between the absolute control and cover crop grown plots on the weed DMP. From April 1992 there was a significant reduction on the weed DMP between the absolute control and cover crop grown plots. From April 1992 there was significant reduction of weed DMP in the treatment plots over absolute control. This might be due to the smothering effect of cover crops on the weed growth in the cover crops grown treatments. These findings are in accordance with the observations of Potty et al. (1980) and Kothandaraman et al. (1987).

When the three observations in October are examined, it can be seen that the control plots have recorded almost same quantity of DMP of weeds, where as the treatment plots (cover cropped plots) there was a drastic reduction in on in the DMP as the time is passed. The same trend is also seen between the observations during April 92 and April 1993, wherein the reduction in DMP is nearly 50%. This is attributed to the distinct beneficial effect of cover crops in the reduction of weed growth.

In the first year of the establishment, the cover crop Mucuna had a tentancy to grow very slowly and those plot with that cover crop recorded highest weed DMP during October 1991. Afterwards it has grown profusely and suppressed the weed growth and recorded least quantity of weed DMP. This finding is corroborative with the work of Kothandaraman *et al*. (1990).

It may further seen that there is also appreciable difference noticed in the weed DMP between the seasons. The April month coincided with summer season and the cover cropped plots recorded comparatively reduced DMP than that of wet season in October. This is due to the smothering effect of the cover crop on weed growth. The competition for moisture also must have reduced the weed population since the cover crops are of robust nature.

4.1.5. Effect of cover crops and their nutrition of soil mositure

The soil moisture content for summer months viz., January, February, March and April of 1992 and 1993 were estimated, analysed and discussed below.

From the Tables 17-20c it is seen that during the I year, top soil (0-30 cm depth of soil) soil moisture in the

Table 17. Effect of covercrops and their nutrition on the soil moisture % at 0-30 cm (Jan. 1992)

F	0	1	2	3	4	Mean C
C1	15.25	15.10	15.98	15.16	15.10	15.50
C2	15.57	16.77	17.16	16.98	18.07	17.01
Mean F	15.908	15.933	16.567	15.82	17.040	

Mean of control 8.033

CD tr (vs) ctrl 2.66

Table 17a. Soil moisture % at 0-30 cm (Feb. 1992)

F	0	1	2	3	4	Mean C
C1	14.15	14.27	14.97	14.17	15.47	14.60
C2	15.20	15.58	16.57	15.32	17.77	16.09
Mean F	14.675	14.93	15.77	14.74	16.620	

Mean of control 7.333

CD tr (vs) ct 2.44

CDc 1.47

Table 17b. Soil moisture % at 0-30 cm (March 1992)

F	0	1	2	3	4	Mean C
C1	12.30	13.33	14.38	13.30	14.97	13.657
C2	13.13	13.95	15.91	14.27	17.03	14.760
Mean F	12.717	13.39	15.15	13.78	16.00	

Mean of control 6.366

CD tr (vs) ct 2.177

CDc 1.076

CDf 2.018

Table 17c. Soil moisture % at 0-30 cm (April 1992)

F	0	1	2	3	4	Mean C
C1	11.45	12.20	13.43	12.37	13.93	12.677
C2	12.13	12.58	14.97	13.27	16.18	13.827
Mean F	11.39	12.39	14.20	12.82	15.06	

Mean of control 5.48

CD tr (vs) ct 1.817

CD tr 2.451

CDc 1.096

CDf 1.733

Table 18. Soil moisture % at 30-60 cm (Jan, 1992)

F	0	1	2	3	4	Mean C
C1	16.53	16.42	16.62	16.17	17.43	16.63
C2	17.57	17.78	18.17	17.50	19.08	18.02
Mean F	17.05	17.10	17.39	16.83	18.260	

Mean of control 9.017

CD tr (vs) ct 2.987

CDc 1.287

Table 18a. Soil moisture % at 30-60 cm (Feb. 1992)

F	0	1	2	3	4	Mean C
C1	15.30	15.42	15.98	15.22	16.63	15.710
C2	16.48	16.73	17.73	16.47	18.93	17.270
Mean F	15.89	16.075	16.858	15.842	17.783	

Mean of control 8.617

CD tr (vs) ct 2.747

CDc 1.460

Table 18b. Soil moisture % at 30-60 cm (March 1992)

F	0	1	2	3	4	Mean C
C1	13.177	14.10	15.33	13.85	15.60	14.410
C2	14.55	14.45	16.80	15.13	18.05	15.797
Mean F	13.858	14.28	16.07	14.49	16.83	

Mean of control 7.266

CD tr (vs) ct 2.431

CDc 1.287

CDf 2.217

Table 18c. Soil moisture % at 30-60 cm (April 1992)

F	0	1	2	3	4	Mean C
C1	12.45	13.25	14.46	13.37	15.28	13.76
C2	13.18	13.70	15.43	14.25	17.43	14.80
Mean F	12.817	13.47	14.95	13.81	16.36	

Mean of control 6.2

CD tr (vs) ct 2.177

CDc 1.017

CDf 2.076

cover cropped plots were more than the absolute control. Fertilizer application also increased the moisture content and the combined effect of both is more pronounced and significant. As the period of observation is advanced, the difference between cover crops are also more pronounced. Among the cover crops, C_2 is significantly superior than C_1. From March 92 onwards, fertilizer treatments were also showing definite advantage. Higher dose of fertilizer applied treatments recorded maximum moisture content followed by F_2 which is significantly superior to F_0. During April 92 also the same trend is observed and F_2 is significantly superior to F_0 and F_1.

During the first year for the bottom soil (30-60 cm depth), the soil moisture in the cover cropped plots were more than the absolute control. Among the cover crops Puereria is superior than Mucuna. Fertilizer levels also improved the soil moisture at latter months. F_2 level is found sufficient as the levels F_2 and F_4 are on par with each other.

During the second year of observation the soil moisture content in the top soil did not show any significant difference between the cover crops.

The fertilizer levels exhibited same trend as the first year of observation where in the effect was noticed from March to April (Peak summer months). During March and April, F_2 is superior than F_3, F_1 and F_0.

During the second year of observation, in the lower depth of soil, the cover cropped plots recorded more moisture than the absolute control. Among the cover crops, Pueraria is superior than Mucuna. The fertilizer levels responded as in the case of I year. (Fig. 14).

The cover cropped treatments registered highest soil moisture per cent than the absolute control. The cover crop covered over the soil surface like a thick mat and might have intercepted the precipitation to the maximum extent, reduced runoff losses, avoided the loss through evaporation and there by improved the water retention capacity of the soil (Tables 21-24). This might be the reason for the highest soil moisture content in the cover cropped plots. In contrast, the absolute control plots were infested with weeds completing there life cycle in short span and the process was continuous and this resulted least soil

Table 19. Soil moisture % at 0-30 (Jan.1993)

F	0	1	2	3	4	Mean C
C1	16.25	16.20	16.82	16.15	16.92	16.47
C2	17.53	17.73	18.10	17.42	18.95	17.95
Mean F	16.892	16.967	17.46	16.783	17.93	

Mean of control 7.500

CD tr (vs) ct 2.489

Table 19a. Soil moisture % at 0-30 (Fed.1993)

F	0	1	2	3	4	Mean C
C1	15.98	15.38	16.72	15.47	16.50	16.010
C2	16.27	16.62	17.95	16.75	18.68	17.253
Mean F	16.125	16.000	17.333	16.108	17.592	

Mean of control 8.067

CD tr (vs) ct 2.687

Table 19b. Soil moisture % at 0-30 (March 1993)

F	0	1	2	3	4	Mean C
C1	13.23	14.227	15.38	14.45	15.93	14.643
C2	14.17	14.47	16.78	15.43	17.72	15.713
Mean F	13.700	14.342	16.083	14.942	16.825	

Mean of control 6.383

CD tr (vs) ct 2.162

CDf 2.061

Table 19c. Soil moisture % at 0-30 (April 1993)

F	0	1	2	3	4	Mean C
C1	12.30	13.117	15.35	12.97	16.03	13.953
C2	13.13	13.817	16.57	14.28	17.25	15.010
Mean F	12.717	13.470	15.958	13.625	16.64	

Mean of control 5.45

CD tr (vs) ct 1.857

CD tr 2.505

CDf 1.771

Table 20. Soil moisture % at 30-60 (Jan.1993)

F	0	1	2	3	4	Mean C
C1	17.89	18.48	18.59	18.79	19.75	18.70
C2	17.50	17.40	17.50	17.10	18.25	17.55
Mean F	17.695	17.940	18.045	17.945	19.000	

Mean of control 8.725

CD tr (vs) ctrl 2.945

CDc 1.657

Table 20a. Soil moisture % at 30-60 (Feb.1993)

F	0	1	2	3	4	Mean C
C1	17.23	15.60	18.73	17.45	19.77	17.757
C2	15.48	15.42	15.93	15.40	16.68	15.783
Mean F	16.358	15.508	17.333	16.425	18.225	

Mean of control 8.216

CD tr (vs) ct 2.972

CDc 1.792

Fig. 14. Effect of cover crops and their nutrition on soil moisture percentage during 1993 summer at 0-30 cm

Table 20b. Soil moisture % at 30-60 (March 1993)

F	0	1	2	3	4	Mean C
C1	14.67	14.80	17.42	15.60	18.03	16.103
C2	13.63	14.65	15.70	14.85	15.65	14.897
Mean F	14.150	14.725	16.558	15.225	16.842	

Mean of control 6.783

CD tr (vs) ct 2.027

CDc 1.905

CDf 1.933

Table 20c. Soil moisture % at 30-60 (April 1993)

F	0	1	2	3	4	Mean C
C1	13.82	14.08	16.43	14.50	16.88	15.143
C2	12.72	13.77	14.72	13.63	15.88	14.143
Mean F	13.267	13.925	15.575	14.067	16.383	

Mean of control 6.133

CD tr (vs) ct 2.216

CDc 1.945

CDf 2.112

Fig. 15. Effect of cover crops and their nutrition on soil moisture percentage during 1993 summer at 30-60 cm

moisture. These findings are in line with the work of Soong et al. (1976).

During the first and second year of observation the top soil moisture in the Mucuna cover cropped plots were higher because, the thick mat of mulching by the cover alone is there in this zone. Active rhizophere of Mucuna is below 45 cm depth where as the Pueraria roots are active at top 45 cm layer hence there was least moisture content. (Fig. 15).

In contrast the lower depth soil moisture content of Pueraria is higher than Mucuna . (Fig. 14). It is because of the active rhizophere of Pueraria at 45 cm of top soil layer. Hence the soil moisture below 45 cm is higher in Pueraria where as in the case of Mucuna, its active rhizophere is below 45 cm depth and recorded least soil moisture at deeper depth. These findings are in confirmative with the work of Kothandaraman et al. (1990).

4.1.6. Soil physical characters

The effect of cover crops and their nutrition on moisture retention, total porosity, bulk density and aggregation percentage at two depths viz., 0-30 and 30-60 cm are presented and discussed below.

4.1.6.1. Soil moisture retention capacity

The moisture retentive capacity was worked out at the begining and end of the experiment at -0.033 MPa and at -1.5 Mpa pressure at two depths viz., 0-30 and 30-60 cm and are presented in Tables 21-24. At -0.033 Mpa, growing of cover crops have significantly increased the moisture retentive capacity over the absolute control at both the depths. Among the cover crops, Mucuna grown plots have significantly superior moisture retentive capacity than Pueraria grown plots in the 0-30 cm Soil depth. Whereas when the depth was increased, there was no significant difference in soil moisture retention. The levels of fertilizers applied to cover crops had significant effect on the moisture retention at both depths. Among the levels F_4 has recorded the highest moisture retention followed by F_2, F_3, F_1 and F_0.

In the cover cropped treatments the dead litter materials deposited on the surface of soil and form a thick mat like structure and reduced the evaporation losses and

Table 21. Effect of covercrops and their nutrition on the moisture retention at (0-30 cm) -0.033 MPa

F	0	1	2	3	4	Mean C
C1	24.83	25.10	26.25	25.75	26.43	25.673
C2	25.05	25.15	26.88	25.55	26.86	25.899
Mean F	24.942	25.125	26.567	25.650	26.447	

Mean of control 24.833

CD t 0.1314

CD cf 0.131

CD c 0.059

CD f 0.093

CD tr vs ct 0.098

Table 22. Moisture retention at (30-60 cm) -0.033 MPa

F	0	1	2	3	4	Mean C
C1	28.90	29.13	30.07	29.67	30.15	29.583
C2	28.23	29.08	30.60	29.07	30.81	29.553
Mean F	28.567	29.107	30.333	29.367	30.482	

Mean of control 28.70

CD t 0.374

CD c 0.167

CD f 0.265

CD cf 0.374

Table 23. Moisture retention at (0-30 cm) -1.5 MPa

F	0	1	2	3	4	Mean C
C1	17.93	17.85	19.45	18.13	19.40	18.553
C2	18.48	18.97	19.67	19.00	19.95	19.213
Mean F	18.208	18.408	19.558	18.567	19.675	

Mean of control 17.75

CD t 0.382

CD c 0.171

CD f 0.271

CD cf 0.3827

CD tr (vs) ct 0.284

Table 24. Moisture retention at (30-60 cm) -1.5 MPa

F	0	1	2	3	4	Mean C
C1	22.05	22.75	23.35	22.88	23.65	22.937
C2	22.48	22.80	23.75	22.95	23.87	23.170
Mean F	22.267	22.775	23.550	22.917	23.758	

Mean of control 22.017

CD t 0.206

CD c 0.0922

CD f 0.146

CD cf 0.20

CD tr (vs) ct 0.153

improved the infiltration of rain water into the soil. Organic matter addition in the cover cropped plots were very high were compared to control plots. This organic matter added got decomposed and increased the total porocity (Table 25). Increased biomass of cover crops as evidenced from Table 31, and increased soil microbial population (Table 35) were also contributed for the higher moisture retention. These might be the reasons for the highest soil moisture retention at both depths under both pressures in Mucuna grown plots. These findings are in line with the work of Soong (1971), Soong et al (1976) and Krishnakumar et al (1990).

Regarding the levels of fertilizers, the higher dose has produced increased quantum of organic carbon by increased quantity of biomass. Hence higher moisture retention at higher fertilizer level.

4.1.6.2. Total porosity

The soil was analysed for its total porosity at the beginning and end of the experiment at two depths viz., 0-30 and 30-60 cm and are presented in Tables 25 and 26. The total porosity of the soil at 0-30 cm depth was significantly

Table 25. Effect of covercrops and their nutrition on the total porosity % (0-30 cm)

F	0	1	2	3	Mean C
C1	45.08	46.83	48.50	47.93	49.00
C2	16.13	47.18	48.78	47.95	49.10
Mean F	45.608	47.008	48.642	47.942	

Mean of control 44.83

CD tr (vs) ct 0.162

Table 26. Total porosity % (30-60 cm)

F	0	1	2	3	4	Mean C
C1	47.70	49.10	47.12	49.80	50.80	48.904
C2	48.15	49.12	50.88	39.80	51.23	47.837
Mean F	47.925	49.108	49.002	44.800	51.017	

Mean of control 47.85

CD t NS

CD c NS

CD f NS

CD cf NS

CD tr (vs) ct NS

higher in the cover cropped treatment plots than the absolute control plots. There was no significant difference found between the cover crops as well as between the levels of fertilizers. Also there is no significant difference observed at lower depth of soil.

In the cover cropped treatment plots the dead litter materials of cover crop deposited on the surface of soil and got decomposed. This decomposed organic matter might have improved the organic carbon content and there by the pore spaces were improved. The studies made elsewhere relate such differential effects to the amount of the organic matter returned to the soil and also the vigour of the root system. The ramifications made by the cover crop roots and the organic matter added in the top soil might have contributed to the increased total pore space. These findings are in corroborative with the works of Harris et al. (1966), Soong et al (1976) and Krishnakumar (1989).

4.1.6.3. Bulk density

The bulk density of the soil from the experimental area was analysed and is presented in the Tables 27 and 28. The bulk density of the soil did not show either any

Table 27. Effect of covercrops and their nutrition on the Bulk density (0-30 cm)

F	0	1	2	3	4	5	Mean C
C1	1.25	1.26	1.23	1.23	1.23	1.23	1.242
C2	1.24	1.23	1.25	1.24	1.24	1.29	1.253
Mean F	1.247	1.247	1.243	1.237	1.237	1.263	

Mean of control 1.236

CD tr (vs) ct 0.007

Table 28. Bulk Density (30-60 cm)

F	0	1	2	3	4	Mean C
C1	1.37	1.197	1.18	1.20	1.19	1.227
C2	1.22	1.22	1.20	1.19	1.18	1.202
Mean F	1.292	1.208	1.19	1.95	1.187	

Mean of control 1.217

CDt NS

CDc NS

CDf NS

CDcf NS

Cd Ct NS

CD tr (vs) ct NS

significant difference among the cover crops or any among the levels of fertilizers applied to the cover crops.

In normal case the effect of cover crops on the bulk density of the soil could be occurred at a long span of time. This finding is in relation with the work of Soong et al. (1976).

4.1.6.4. Aggregation percentage

The results of aggregation analysis done at the beginning ard end of the experiment is presented in the Tables 29 and 30. The aggregation percentage was found to be higher in the topsoil (0-30 cm depth) than the bottom soil (30-60 cm depth). The cover cropped treatment plots recorded significantly higher aggregation percentage over the control plots at both depths. Among the cover crops there is no significant difference observed. Regarding the levels of fertilizers applied to cover crops F_4 and F_2 were on par and these levels were significantly superior than the other levels.

In the cover cropped plots the dead litter materials added have improved the organic carbon content, and

Table 29. Effect of covercrops and their nutrition on the Aggregation % (0-30cm)

F	0	1	2	3	4	Mean C
C1	87.23	86.77	89.50	88.50	88.60	88.120
C2	87.37	87.40	89.37	88.47	89.63	88.447
Mean F	87.300	87.083	89.43	88.483	89.117	
				Mean of control		87.133

CD cf 0.555

CDc 0.348

CDf 0.393

CD tr (vs) ct 0.412

Table 30. Aggregation % (30-60cm)

F	0	1	2	3	4	Mean C
C1	80.73	80.53	82.60	81.56	82.63	81.613
C2	80.87	80.77	81.06	81.60	80.70	81.000
Mean F	80.800	80.650	81.833	81.583	81.667	
				Mean of control		80.067

CD cf 0.444

CDc 0.799

CDf 0.314

CD tr (vs) ct 0.329

total pore space and there by improved the aggregation percentage. The vigorous root growth and its ramification process also might have contributed to better pore space and aggregation percentage. Same line of observations were reported by Harris et al. (1966), Soong (1971), Soong et al (1976).

4.1.7. Covercrop Biomass production kg ha^{-1}

Biomass of cover crops produced from October 91 to October 93 were recorded at six monthly interval analysed and discussed below.

During the early stage, October 1991 Pueraria recorded significantly highest biomass. From April 1992 onwards Mucura is overtaking Pueraria. Mucuna produced almost double the quantity of biomass at latter stage. Among the levels of fertilizers F2 is found superior in earlier stage as the growth is limited, addition of 10 kgN has increased the nodules count with that the biomass. At this stage F2 is sufficient and cover crops has no capacity to utilize 60 kg P and K. As the time passes, more uptake of P and K is noticed and from first year onwards F4 is superior and is followed by F2.

Table 31. Effect of nutrition on the cover Biomass kg ha^{-1}

October 1991

	F0	F1	F2	F3	F4	Mean C
C_1	352.67	378.33	478.33	435.00	483.33	425.53
C_2	325.00	380.00	451.67	381.67	423.33	392.33
Mean F	338.833	379.167	465.000	408.330	453.33	

CD t 44.273
CD c 19.799
CD f 31.306

Table 31a. April 1992

	F0	F1	F2	F3	F4	Mean C
C_1	423.33	465.00	581.67	500.00	646.67	523.33
C_2	818.33	841.67	1090.00	928.99	1143.33	964.33
Mean F	620.833	653.333	835.833	714.167	895.00	

CD c 34.492
CD f 54.537
CD t 77.127

Table 31b. October 92

	F0	F1	F2	F3	F4	Mean C
C_1	962.667	988.33	1088.33	1080.00	1155.00	1054.867
C_2	1543.33	1651.67	2183.33	1680.00	2336.66	1879.00
Mean F	1253.00	1370.007	1635.83	1380.00	1745.83	

CD c 39.977 CD cf 89.39
CD f 63.209 CD t 89.39

Covercrop biomass Kg ha^{-1}

Table 31c. April 1993

	F0	F1	F2	F3	F4	Mean C
C_1	1365.00	1421.67	1601.57	1498.33	1610.00	1499.33
C_2	2090.00	2175.00	2628.33	2275.00	2861.67	2406.00
Mean F	1727.5	1798.33	2115.00	1886.87	2235.83	

CD c 57.375 CD f 81.231 CD cf 114.877
CD t 114.877

Table 31d. October 1993

	F0	F1	F2	F3	F4	Mean C
C_1	2625.0	2663.33	3068.33	2670.00	3245.00	2854.333
C_2	3065.0	3265.00	3868.33	3768.33	4676.67	3728.667
Mean F	2845.0	2964.17	3468.33	3219.167	3960.83	

CD c 65.141 CDf 98.751 CDcf 127.41 CD t 127.41

During the early stage *Pueraria* grown faster and *Mucuna* is a slow grower. As time passed *Mucuna* picked up the growth and overtook the other.

This finding is in line with the work of Kothandaraman *et al*. (1990). Regarding the levels of N, P and K at the early stage, F2 level is sufficient and same type of reporting was done by Pushparajah (1977). During the latter stages of growth the level F4 is required because of increased biomass addition and its increased P and K requirement is met by the F4 level.

4.1.7.1. Effect of nutrition on the uptake of nutrients by cover crops Kg ha^{-1}

The uptake of N, P, K, Ca and Mg in the different years of observations are presented in Table 31e-31i. In the first year of observation there was no significant differences observed between the covercrops and among the levels, F_2 and F_4 were on par with each other. During the second and third year of observations Mucuna recorded significantly higher uptake of N. Among the levels, F_2 and F_4 were on par. This showed the sufficiency of the level 10:30:30 for both covercrops.

Table 31e. Effect of nutrition on the nutrient uptake of N kg ha^{-1} by cover crops

October 1991

	F0	F1	F2	F3	F4	Mean C
C_1	8.22	9.22	11.89	10.56	12.03	10.35
C_2	7.75	9.52	11.55	9.49	10.87	9.81
Mean F	7.985	9.37	11.72	10.03	11.45	

CD f 2.565

October 1992

	F0	F1	F2	F3	F4	Mean C
C_1	23.23	24.70	27.20	27.08	29.79	26.40
C_2	38.68	43.05	58.07	43.34	62.61	49.35
Mean F	30.955	38.875	42.635	35.210	46.200	

CD c 7.425
CD f 10.265

October 1993

	F0	F1	F2	F3	F4	Mean C
C_1	64.49	68.44	80.90	68.97	83.57	73.674
C_2	78.37	86.75	103.28	99.59	125.79	99.156
Mean F	71.43	73.595	92.09	84.28	104.68	

CD c 8.40
CD f 12.125

Table 31f. Effect of nutrition on the nutrient uptake of P $kg\ ha^{-1}$ by cover crops

October 1991

	F0	F1	F2	F3	F4	Mean C
C_1	0.53	0.41	0.84	0.66	0.80	0.688
C_2	0.54	0.63	0.87	0.67	0.84	0.702
Mean F	0.535	0.620	0.855	0.665	0.815	

CD c 0.065
CD f 0.210

October 1992

	F0	F1	F2	F3	F4	Mean C
C_1	3.25	3.90	4.98	4.01	6.02	4.432
C_2	3.42	4.05	5.49	4.55	7.01	4.104
Mean F	3.335	3.975	5.235	4.28	6.515	

CD c 0.400
CD f 1.502

October 1993

	F0	F1	F2	F3	F4	Mean C
C_1	5.15	5.98	8.65	7.01	9.10	7.178
C_2	5.45	6.40	9.31	7.45	10.55	7.802
Mean F	5.30	6.19	8.98	7.23	9.825	

CD c 0.605
CD f 1.720

Table 31g. Effect of nutrition on the nutrient uptake of K kg ha^{-1} by cover crops

October 1991

	F0	F1	F2	F3	F4	Mean C
C_1	6.92	8.05	9.75	9.05	9.65	8.684
C_2	7.19	8.15	10.80	9.50	10.65	9.258
Mean F	5.634	8.10	10.275	9.275	10.15	

CD c NS
CD f 3.450

October 1992

	F0	F1	F2	F3	F4	Mean C
C_1	30.92	36.51	46.59	38.45	54.65	41.30
C_2	34.45	38.05	52.45	42.45	60.65	45.63
Mean F	32.435	37.33	49.475	40.45	51.65	

CD c 2.751
CD f 6.450

October 1993

	F0	F1	F2	F3	F4	Mean C
C_1	39.15	42.5	59.45	46.55	70.3	51.58
C_2	52.45	46.5	85.40	65.90	95.4	69.13
Mean F	45.80	44.5	72.125	56.2	82.85	

CD c 5.251
CD f 9.250

Table 31h. Effect of nutrition on the nutrient uptake of Ca kg ha^{-1} by cover crops

October 1991

	F0	F1	F2	F3	F4	Mean C
C_1	2.05	2.15	3.05	2.60	3.15	2.60
C_2	2.25	2.35	3.23	2.71	3.25	2.66
Mean F	2.15	2.25	3.14	2.41	3.20	

CD c NS
CD f NS

October 1992

	F0	F1	F2	F3	F4	Mean C
C_1	7.45	9.45	13.25	11.25	19.45	12.17
C_2	11.85	12.55	19.45	16.25	23.40	16.69
Mean F	9.65	10.98	16.35	13.75	21.43	

CD c 1.245
CD f 3.430

October 1993

	F0	F1	F2	F3	F4	Mean C
C_1	14.30	15.40	24.15	20.42	26.5	20.154
C_2	17.20	19.15	30.45	24.5	33.40	24.94
Mean F	15.75	17.28	27.3	22.46	29.95	

CD c 2.055
CD f 6.250

Table 31i. Effect of nutrition on the nutrient uptake of Mg kg ha^{-1} by cover crops

October 1991

	F0	F1	F2	F3	F4	Mean C
C_1	0.48	0.65	0.90	0.65	1.05	0.75
C_2	0.62	0.85	1.05	0.90	1.25	0.95
Mean F	0.55	0.75	0.98	0.81	1.15	

CD c NS
CD f NS

October 1992

	F0	F1	F2	F3	F4	Mean C
C_1	3.05	3.45	5.15	4.75	6.45	4.57
C_2	3.50	4.32	6.45	5.25	8.01	5.51
Mean F	3.28	3.89	5.80	5.00	7.23	

CD c 0.451
CD f 1.245

October 1993

	F0	F1	F2	F3	F4	Mean C
C_1	4.15	5.20	7.45	7.05	9.42	6.65
C_2	5.25	6.35	7.75	8.15	12.25	8.35
Mean F	4.70	5.78	8.60	7.60	10.84	

CD c 1.055
CD f 3.265

Reasons for the increased uptake of nutrients by covercrops as the growth progressed were mainly due to the increased biomass production (Table 31-31d). When 10 kg extra dose of N was not given to covercrops, it might have improved the early establishment and better vegetative growth. For supporting these growth, increased P, K, Ca and Mg uptake were observed. This findings in confirmation with the work of Pushparajah (1977).

4.1.8. Root studies of cover crops

The cover crop root analysis for the measurements like vertical root penetration, shoot weight and root weight, were worked out, presented and discussed in this chapter.

The vertical root penetration measurements taken from 3rd month to 30th Month after sowing were presented in Tables 32-32e. During the 3rd month observation the cover crop C1 found significantly superior over the cover crop C_2. Among the levels of fertilizers, level F4 and F2 were on par and superior than F_3, F_1 and F_0. In the 6th month of observation the cover crop C_2 was found significantly superior over C_1. Among the levels there is no difference

Table 32. Effect of nutrition on the vertical penetration of root (cm) 3rd month

	F0	F1	F2	F3	F4	Mean C
C_1	35.13	36.53	42.55	38.09	43.19	39.094
C_2	26.20	27.69	32.89	28.86	33.46	29.819
Mean F	30.663	32.108	37.72	33.48	38.31	

CDt 1.100
CDc 0.492
CDf 0.778

Table 32a. Vertical penetration of root (cm) 6th month

	F0	F1	F2	F3	F4	Mean C
C_1	68.50	67.78	74.23	68.73	75.80	69.009
C_2	71.70	72.68	75.14	73.23	79.07	73.967
Mean F	70.10	70.23	74.69	70.99	76.43	

CDt 2.200
CDc 0.984
CDf 1.886

Table 32b. Vertical penetration of roots (cm) 12th month

	F0	F1	F2	F3	F4	Mean C
C_1	74.63	76.60	84.217	82.42	85.82	80.74
C_2	103.32	106.21	114.22	103.14	121.01	109.58
Mean F	88.975	91.405	99.217	92.78	103.42	

CDt 2.469
CDc 1.104
CDf 1.746
CDcf 2.469

Table 32c. Vertical penetration of roots (cm) 18th month

	F0	F1	F2	F3	F4	Mean C
C_1	81.92	84.25	91.52	90.83	92.77	88.75
C_2	137.40	142.60	165.50	146.97	169.50	152.393
Mean F	109.66	113.43	128.51	118.89	131.13	

CDt 1.487
CDc 0.665
CDf 1.051
CDcf 0.501

Table 32d. Vertical penetration of roots (cm) 24th month

	F0	F1	F2	F3	F4	Mean C
C_1	85.27	88.60	103.22	98.47	105.38	96.19
C_2	176.50	187.77	203.30	194.17	212.47	194.84
Mean F	130.88	130.18	153.26	146.317	158.93	

CDt 3.051
CDc 3.365
CDf 2.157
CDcf 3.051

Table 32e. Vertical penetration of roots (cm) 30th month

	F0	F1	F2	F3	F4	Mean C
C_1	88.70	95.19	109.42	100.07	114.23	101.52
C_2	187.30	200.07	247.43	198.63	256.00	217.89
Mean F	138.00	147.63	178.43	149.35	185.12	

CDt 4.277
CDc 1.913
CDf 3.094
CDcf 4.279

noted. During 12th, 18th, 24th and 30th month of observation it is noted that cover crop C_2 is significantly superior over C_1, and among the levels F_4 was found superior over all the other levels followed by F_2, F_3, F_1 and F_0.

At 3rd month the cover crop C_1 has recorded higher root length than C_2. The cover crop C_1 has the tendency to produce root system deeper at the very beginning stage. This cover crop C_1, is a fast growing one in the initial months than C_2. This finding is in line with the work of Chandapillai (1968). From 6th month onwards th cover crop C_2 is overtaking C_1 on root length. Penetration of C_2 is double at latter stages of observation. Since the root length of Mucuna is deeper than rubber roots there is no competetion observed between Mucuna and Rubber.

Regarding the levels of fertilizers for better root penetration, level F_2 is better upto 6th month. F4 is required from 12th month onwards. F_4 is significantly superior because C_2 required high P, K, for proportionately higher biomass (Table 31-31d) production ie. why interaction is significant from 12th month onwards.

4.1.8.1. Shoot and Root weight

The weight of shoot and root were worked out from 3rd month to 30th month of the study and found that during all the stages of cover crop growth, *Mucuna* recorded significantly higher quantity of shoot and root weight. Regarding the levels of N, P and K applied to cover, F_4 level has recorded maximum weight of shoot and root followed by F_2. Among the levels the F_0 level has recorded the least quantity of shoot and not weight.

The reason for the luxurious growth of *Mucuna sp.* is genetical. Regarding the levels, F_4 and F_2 were given with 10 kg extra dose of nitrogen which would have helped in better uptake by cover crops (Table 31e-31i) and better quantity biomass of cover crops (Table 31-31d). This finding is in line with the report of Kothandaraman *et al*. 1987 and 1990.

4.1.8.2. Cover crop root nodules count and fresh weight

The root nodule count were taken on 40 days after sowing of cover crops. The nodule weight per plant were also

Table 33. Effect of nutrition to cover on the weight of shoot (g) 3rd month

	F0	F1	F2	F3	F4	Mean C
C_1	5.807	11.200	12.710	13.390	15.133	11.448
C_2	7.040	12.760	14.500	14.387	15.530	12.843
Mean F	6.423	11.980	13.605	13.888	14.832	

CDt 1.074
CDc 0.480
CDf 0.759
CDcf NS

Table 33a. Weight of shoot (g) 6th month

	F0	F1	F2	F3	F4	Mean C
C_1	93.617	96.180	110.88	89.25	113.40	100.665
C_2	102.350	113.850	126.77	115.69	128.11	117.254
Mean F	97.983	105.015	118.575	102.47	120.755	

CDt 8.859
CDc 3.962
CDf 6.264
CDcf NS

Table 32b. Weight of shoot (g) 12th month

	F0	F1	F2	F3	F4	Mean C
C_1	369.88	403.580	457.24	400.43	473.57	420.941
C_2	488.40	498.96	545.28	507.36	575.52	523.105
Mean F	429.192	451.275	501.26	453.89	524.55	

CDt 25.332
CDc 11.329
CDf 17.912
CDcf NS

Table 32c. Weight of shoot (g) 24th month

	F0	F1	F2	F3	F4	Mean C
C_1	624.967	624.170	745.64	651.78	750.12	679.322
C_2	852.28	855.77	938.38	870.09	1023.03	907.911
Mean F	738.62	739.94	842.01	760.94	886.57	

CDt 14.746
CDc 6.595
CDf 10.427
CDcf 14.745

Table 32d. Weight of shoot (g) 18th month

	F0	F1	F2	F3	F4	Mean C
C_1	539.46	548.34	640.35	541.93	546.51	563.317
C_2	651.27	672.25	751.75	655.93	771.04	700.447
Mean F	595.36	610.29	696.05	598.93	658.78	

CDt 95.697
CDc 42.797
CDf 67.668
CDcf NS

Table 32e. Weight of shoot (g) 30th month

	F0	F1	F2	F3	F4	Mean C
C_1	657.04	667.63	779.45	703.62	796.93	720.935
C_2	942.50	960.30	1252.36	1006.48	1333.90	1099.120
Mean F	799.770	813.97	1015.90	855.05	1065.42	

CDt 19.684
CDc 8.803
CDf 13.918
CDcf 19.684

Table 33. Weight of root (g) 3rd month

	F0	F1	F2	F3	F4	Mean C
C_1	0.937	1.807	2.050	2.160	2.28	1.847
C_2	1.067	1.933	2.197	2.100	2.35	1.946
Mean F	1.002	1.870	2.123	2.170	2.317	

CDt 0.168
CDc 0.075
CDf 0.119
CDcf NS

Table 33a. Weight of root (g) 6th month

	F0	F1	F2	F3	F4	Mean C
C_1	14.93	15.27	17.60	14.17	18.00	15.993
C_2	14.93	16.50	18.30	16.77	18.57	17.013
Mean F	14.93	15.88	17.50	15.47	18.28	

CDt 1.424
CDc 0.637
CDf 1.007
CDcf NS

Table 33b. Weight of roots 12th month

	F0	F1	F2	F3	F4	Mean C
C_1	53.83	58.50	66.27	58.03	68.63	61.053
C_2	67.83	69.30	78.03	70.47	79.93	73.113
Mean F	60.833	63.900	72.15	64.250	74.283	

CDt 2.799
CDc 1.252
CDf 1.979
CDcf NS

Table 33c. Weight of roots (g) 18th month

	F0	F1	F2	F3	F4	Mean C
C_1	73.50	74.10	84.53	73.23	87.37	78.547
C_2	73.17	75.53	84.47	73.70	86.63	78.700
Mean F	73.333	74.82	84.50	73.47	87.00	

CDt 2.631
CDc NS
CDf 1.860
CDcf NS

Table 33d. Weight of root (g) 24th month

	F0	F1	F2	F3	F4	Mean C
C_1	74.40	75.43	88.77	78.23	89.30	81.227
C_2	86.83	88.53	96.90	89.70	105.47	93.487
Mean F	80.617	81.983	92.833	83.967	97.383	

CDt 1.478
CDc 0.661
CDf 1.045
CDcf 1.478

Table 33e. Weight of root (g) 30th month

	F0	F1	F2	F3	F4	Mean C
C_1	76.40	77.63	90.63	81.70	92.67	83.807
C_2	75.30	97.00	126.50	101.63	132.63	110.613
Mean F	85.85	87.32	108.57	91.67	112.65	

CDt 0.767
CDc 0.343
CDf 0.542
CDcf 0.767

Table 34. Nodule count/plant (40th DAS)

	F0	F1	F2	F3	F4	Mean C
C_1	6.40	6.60	6.90	6.87	7.23	6.800
C_2	3.37	3.60	3.87	3.33	4.07	3.647
Mean F	4.883	5.10	5.38	5.10	5.65	

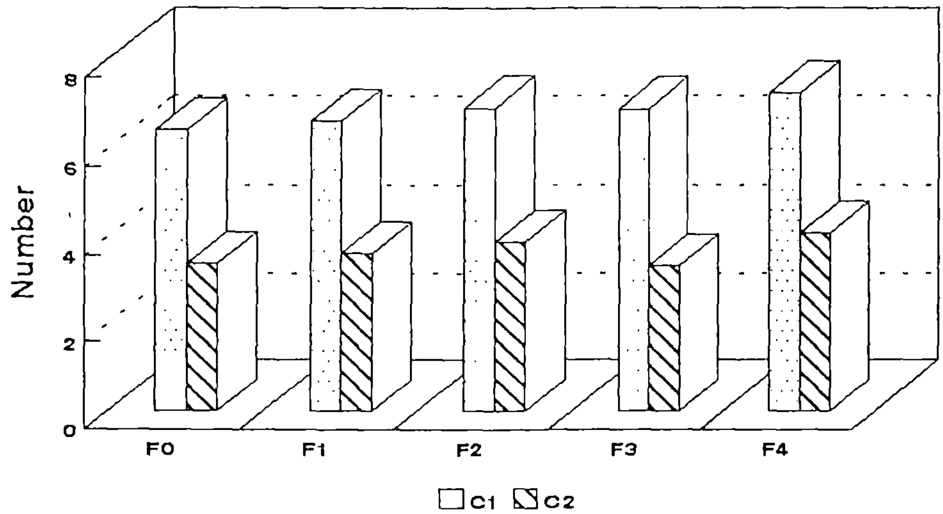
CDt 0.341
CDc 0.153
CDf 0.241
CDcf NS

Table 34a. Nodule fresh weight/plant

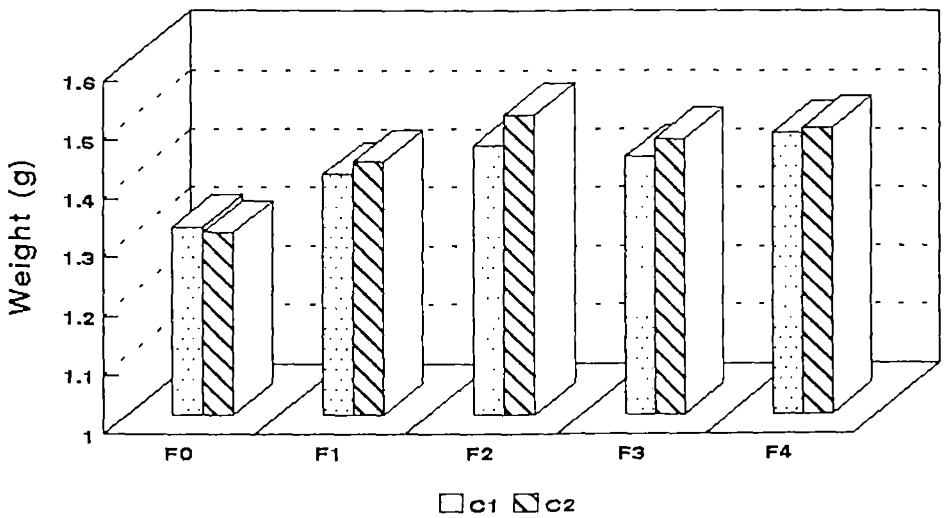
	F0	F1	F2	F3	F4	Mean C
C_1	1.32	1.41	1.46	1.44	1.48	1.422
C_2	1.31	1.43	1.51	1.47	1.49	1.442
Mean F	1.315	1.420	1.485	1.455	1.485	

CDt 0.109
CDc NS
CDf 0.130
CDcf NS

Fig. 16. Effect of nutrition to cover crops on nodule count and nodule weight (40 DAS)



Nodule count plant $^{-1}$ (40 DAS)



Nodule weight plant $^{-1}$ (40 DAS)

Levels of nutrients

nodules count for the Pueraria sp. was found to be significantly higher than Mucuna sp. Regarding the weight of nodule per plant is concerned there was no significant difference found. Among the levels of NPK, F_4 and F_2 were significantly superior and on par with each other for the nodule count, these levels were on par with all the other levels except F_0. (Fig. 16).

The reasons for the increased nodule number in Pueraria sp. is purely genetical and regarding the levels F_4, F_2 were given with extra dose of 10 kg N, which would be highly beneficial for the leguminous cover crop for its early vigourous establishment. As far as the nodule weight per plant is concerned, the NPK fertilizer application is essential for the better nodular weight. These findings were in corroborative with Pushparajah (1977) and Kothandaraman et al. (1990).

4.1.9. Microbial population in soil

The microbial population of the soil were analysed for the generalised count of Bacteria, fungi and phosphate solubilisers at the end of the experiment. The data were analysed and presented as 10^4 g^{-1} of dry soil Table 35. All the microbial species count were increased over the initial count. The microbes namely bacteria, fungi and phosphate solubilisers were increased in their population under the cover cropped plots over the absolute control tremendously. Among the levels of fertilizers, F_4, F_2, and F_3 were found to be good for bacterial population and phosphate solubilisers. F_1, F_2, F_4 and F_3 were found to be better for fungi. Among the cover crop, Mucuna sp recorded significantly higher percentage of increase.

The reasons for the increase in the population of microbes are due to the increased biomass production and increased quantity of soil moisture in summer, urder Mucuna sp and the level F_2 has improved much on the organic carbon content and cover crop biomass. This must have cumilatively attributed to increased microbial population. These findings are in line with the report of Kothandaraman et al. (1990).

Table 35. Effect of covercrops and their nutrition on the microbial population of soil Bacteria x 10^4 g^{-1} of dry soil

	F0	F1	F2	F3	F4	Mean C
C_1	29.067	30.800	33.80	34.77	36.40	32.967
C_2	35.633	36.433	42.47	41.47	45.97	40.393
Mean F	32.350	33.617	38.133	38.117	41.183	
				Mean of control		28.933

CDt 1.380
CDc 0.617
CDf 0.976
CDcf 1.022

Table 35a. Fungi x 10^4 g^{-1} of dry soil

	F0	F1	F2	F3	F4	Mean C
C_1	9.67	10.30	10.23	9.60	9.67	9.893
C_2	9.90	10.10	9.70	10.20	10.27	10.033
Mean F	9.783	10.200	9.867	9.900	9.967	9.963
				Mean of control		8.130

CDt 0.215
CDc 0.096
CDf 0.152
CD tr vs ct 0.215

Table 35b. Phosphate solubilizers x 10^4 g^{-1} of dry soil

	F0	F1	F2	F3	F4	Mean C
C_1	4.68	4.82	5.21	5.20	5.133	5.045
C_2	6.49	6.13	7.43	7.15	7.700	6.981
Mean F	5.585	5.475	6.322	6.175	6.507	

Mean of control 4.440

CDt 0.613
CDc 0.274
CDf 0.433
CDcf 0.454

4.2. Experiment II

Effect of cover crop and its nutrition on mature rubber

4.2.1. Growth characters

4.2.1.1. Girth increment

The girth increment for the two years period 1991-1993 for the mature rubber is presented in Table 36. It is observed that all the treatments with cover crops were significantly superior to the absolute control where there was no cover crop. Among the levels of fertilizers to cover crop, F_4 and F_2 were on par and significantly superior to F_3, F_1 and F_0. The level F_0 is significantly inferior to all other levels. (Fig. 17).

Growing of cover crop even without any fertilizer has given more girth increment than plots without any cover crop, thereby showing the distinct advantage of cover crop alone.

Application of fertilizer to cover crops has further increased the girth increment over F_0 as evidenced from the treatments. The highest level of fertilizers have recorded the maximum girth, however this is on par with

Table 36. Effect of covercrop and its nutrition on girth increment 1991-1993 (cm)

Treatments	Girth increment in (cm)
F_0	3.90
F_1	5.01
F_2	5.29
F_3	5.10
F_4	5.32
C	2.63
SE	0.054
CD	0.161
	S**

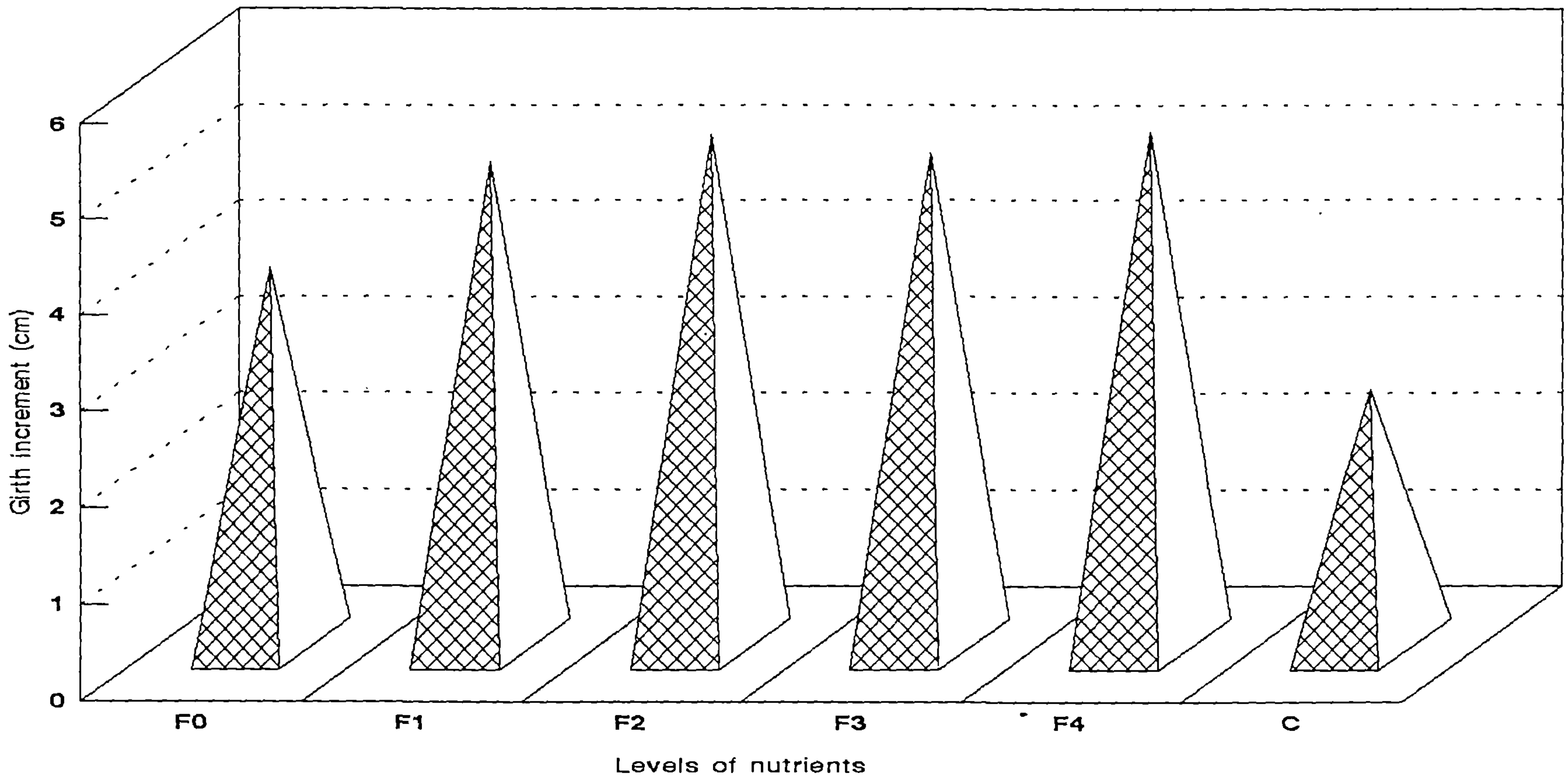
S** Significant at P = 0.01 level.

Table 37. Effect of covercrop and its nutrition on the virgin bark thickness 1993 (mm) of Hevea

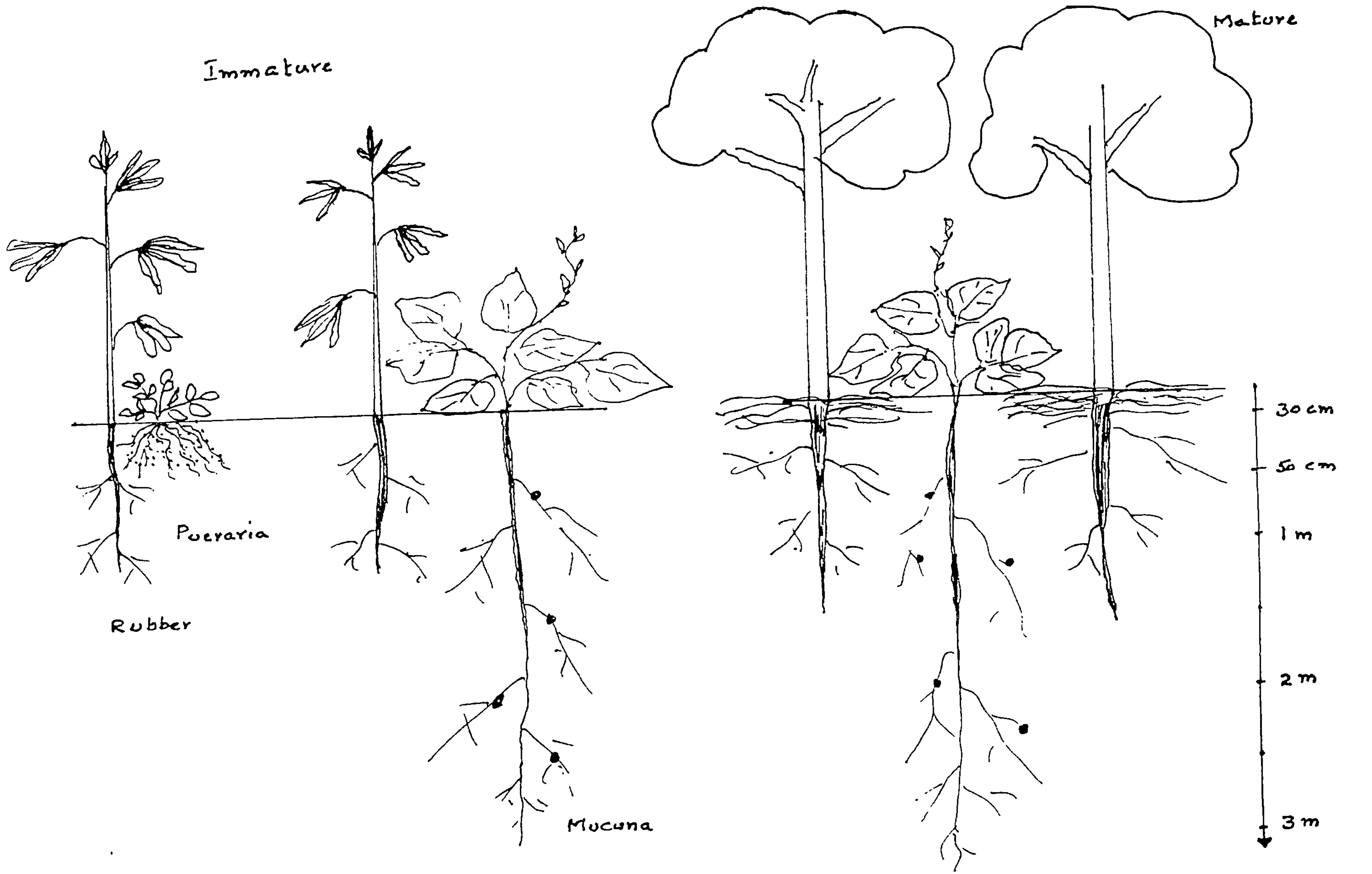
Treatments	VBT (mm)
F_0	7.87
F_1	8.02
F_2	8.82
F_3	8.06
F_4	8.29
C	6.94
SE	0.243
CD	0.372
	S**

S** Significant at P = 0.01 level.

Fig. 17. Effect of cover crop and its nutrition on the girth increment (cm) 1991-1993



Diagramatic representation of rooting pattern of rubber and cover crops.



fertilizer level F_2, there by indicating the sufficiency of the later level. This shows that fertilizer application beyond 10:30:30 has not any specific advantage.

The reasons for the girth increment through cover crop and nutrition have been already discussed in the Experiment I.

The other reason for the girth increment are by the absorption of nutrients form the lower levels and bringing the same to the surface and insitu incorporation in the surface would have definitely benefited the main crop.

Maximum absorbing roots are present in the interow area and fertilizers applied in the rubber trees are benefited by the direct application on the surface as well as through the indirect application through the deposition of drymatter of cover crop. Diagram presented also shows that there is no competetion between rubber and Mucuna because the feading zones are entirely different.

4.2.1.2. Effect of cover crop and its nutrition on virgin bark thickness

Growing of cover crop significantly increased the virgin bark thickness (Table 37) over the absolute control plot. Among the levels of fertilizers to cover crop F_4 has recorded the maximum bark thickness and also on par with F_2. All the other levels except F_0 were on par with each other.

It is seen that growing of cover crop significantly improved the virgin bark thickness over the absolute control. This improvement of bark thickness is due to the addition of nutrients through the litter added from the cover crop and the moisture conserved in the soil (Tables 52 and 53). The positive response obtained here in the virgin bark thickness was in agreement with the findings of Watson (1961). The favourable effects of different levels of nutrition to cover crop on the bark thickness is also in agreement with the findings of Dijkman (1951) and Samsidar BTE Hamzah and Mahmood (1975).

It may also be noted that the positive effect of cover crop and applied nutrition on bark thickness were also reflected on the girth increment already discussed. The girth of the tree is a measurement which also included the thickness of the bark and a greater bark thickness to a certain extent can lead to a higher girth of the trunk (Owen *et al*. 1957).

4.2.2. Effect of cover crop and its nutrition of the leaf litter production of *Hevea*

The leaf litter production of *Hevea* was influenced by the growth of cover crop and its nutrition during 1992 and 1993 and are presented in Table 38. It is seen that growth of cover crop in the plots had influenced the leaf litter products significantly (Fig. 18). All the treatments with cover crop have produced significantly higher quantity of leaf litter over absolute control during both years. Among the levels of nutrition to cover crop, F_4 was significantly higher than all other levels, followed by F_2, F_3, F_1 and F_0. From the visual observation during the last year, the wintering was delayed 26 days in the cover cropped plots (Plates 5 and 6) there by giving 10 extra tapping days. N, P and K are the elements related to growth and their application to cover crop has resulted in the enhancement of foliage of cover and *Hevea* (Brady, 1988). This increased folliage by cover crop and its addition through insitu incorporation and decomposition might have improved the nutrient status of soil and inturn more uptake of nutrients by the cover crop (Table 52a-52e), thus resulting in significantly higher quantity of leaf litter produced.

Table 38. Effect of covercrop and its nutrition on the leaf litter production of Hevea (t ha^{-1})

Treatments	1991	1992	1993
F_0	2.730	3.060	3.473
F_1	2.675	3.202	3.665
F_2	2.875	3.447	3.938
F_3	2.740	3.230	3.745
F_4	2.800	3.490	4.118
C	2.715	2.940	3.323
SE	0.068	0.035	0.036
CD		0.104	0.109
	NS	S**	S**

S** Significant at P = 0.01 level NS Not significant

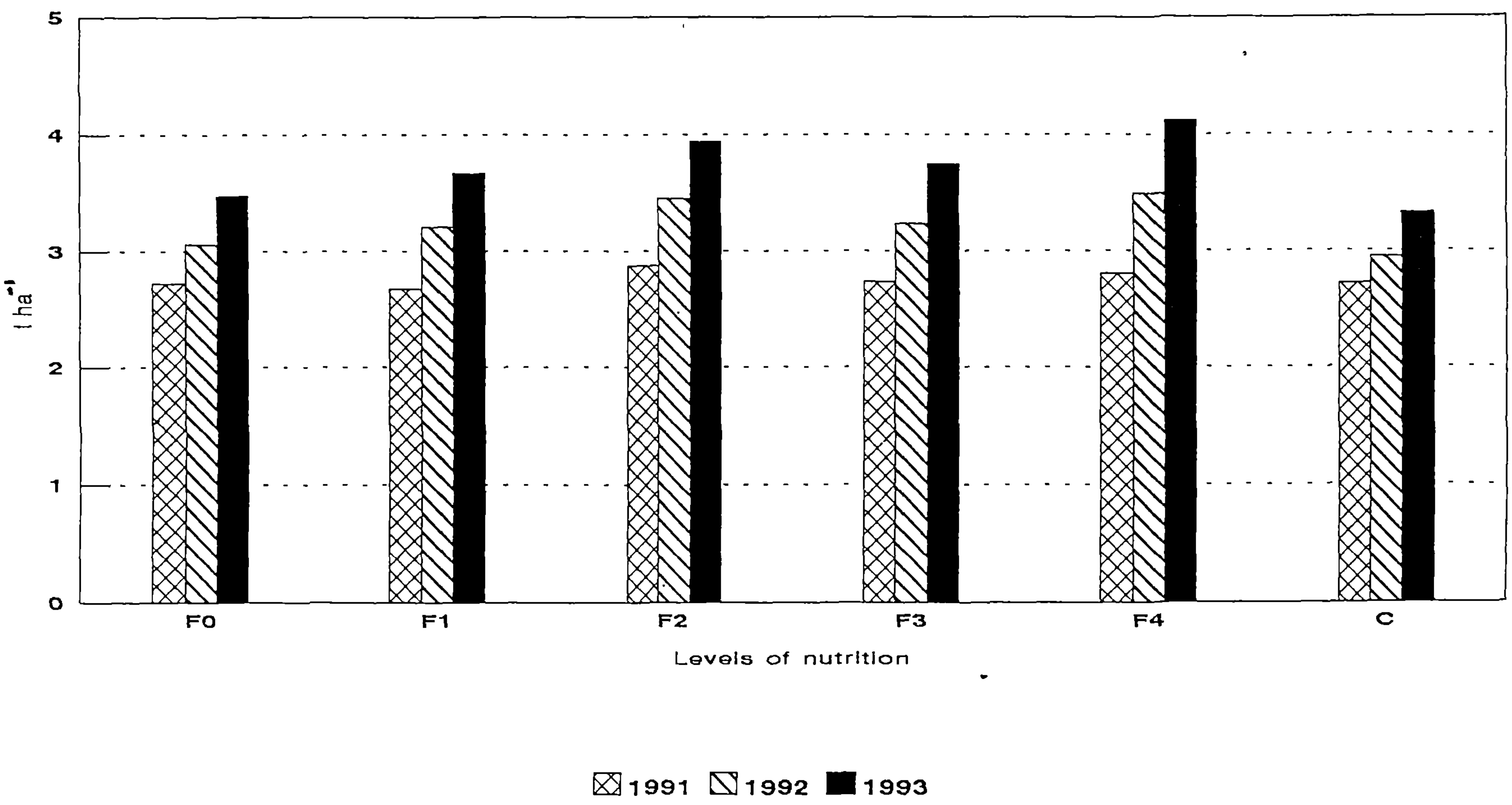
Table 39. Effect of covercrop and its nutrition on the latex flow characteristics

Treatment	Initial flow rate (ml min^{-1})	Total Vol. (ml)	Plugging index	Dry rubber content (per cent)
F_0	3.473	133.32	2.708	37.19
F_1	3.665	144.45	2.783	37.98
F_2	3.938	146.96	2.730	38.37
F_3	3.745	145.09	2.768	38.08
F_4	4.118	150.06	2.745	38.53
C	3.223	127.59	2.853	36.19
SE	0.036	5.239	0.004	0.132
CD	0.109	15.787	0.012	0.398
	S**	S*	S**	S**

S* Significant at P = 0.05 level

S** Significant at P = 0.01 level

Fig. 18. Effect of cover crop and its nutrition on the leaf litter production of Hevea (t ha^{-1})



Among the levels of nutrition to cover crop 10 kg nitrogen and 60 kg each of P,K has produced significantly higher quantity of leaf litter. Nitrogen is the chief nutrient related to growth and its application to cover crop has resulted in the enhancement of foliage (Brady, 1988). Though the N content of the soil in the site was not low it would not have been sufficient to support optimum growth. Application of P has increased the production of leaf litter, phosphorous is also important for growth and its application has lead to production of more foliage. Application of K also has helped in increasing the leaf litter production. The role of K in dry matter production and growth is very important (Brady, 1988).

4.2.3. Effect of cover crop and its nutrition on latex flow characteristics

The latex flow characteristics viz; the initial flow rate, total volume, plugging index and dry rubber content of latex were recorded in october 1993. During the period under reporting the yield is higher and leaves are fully grown and have more or less steady status of nutrients.

4.2.3.1. Initial flow rate

Growing of cover crop has improved the initial flow rate of Hevea, over a period of time (Table 39) over the absolute control plot. Regarding the levels of nutrition to cover crop F_4 has recorded significantly highest initial flow rate followed by F_2, which was also higher than F_3, F_1 and F_0. The control plot recorded the least initial flow rate.

Growing of cover crop has improved the soil nutrient status (Tables 41-46), soil moisture content during summer months, (Tables 52 and 53) and thus improved the initial flow rate. The level of nutrition F_4 and F_2 recorded the highest initial flow rate of latex. The initial flow rate has of course a small contribution to the total yield since it is the average of the initial five minutes flow. The positive effect of applied nutrients on this parameter was reflected in the yield of rubber also to certain extent. These findings are in line with the work of Pushparajah (1977) and Punnoose (1993).

4.2.3.2. Total volume

Cultivation of cover crop in the mature plantation has significantly increased the total volume of latex over the absolute control. Among the levels of N,P,K, F_4 registered highest content of total volume and was on par with F_2, F_3 and F_1. The absolute control plot has recorded the least.

The reasons for the increased production of total volume in cover cropped plots are similar to that explained in the initial flow rate.

It is seen that application of all the nutrients to cover crop had a favourable effect on the total volume of latex. The total volume of latex is the component which has the closest positive relationship with the yield of rubber. These nutrients through their role in improving photosynthesis and metabolic activity of the tree might have helped the synthesis of more latex as reported by Punnouse (1993).

4.2.3.3. Plugging index

In the mature plantation, growing of cover crop has significantly reduced the plugging index over the control plot. As for the levels of fertilizers are concerned, F_2 and

F_4 has recorded the least plugging index and are on par with each other. F_0 has recorded the highest plugging index next to absolute control plot. Plugging index has generally a negative response or relation with yield.

Reduction in the plugging index in cover cropped plots might be due to the reasons already explained under initial flow rate. Application of N and K to cover has reduced the plugging index. The increasing in yield with application of N and K in the experiment could be to some extent related to the effect of these nutrients in lowering plugging index. That is the reason why the levels F_4 and F_2 registered a low plugging index. This observation is corroborative with the thoughts of Pushparajah (1981), Yeang and Paranjothy (1982) and Punnoose (1993).

4.2.3.4. Dry rubber content

The dry rubber content of the latex from the cover cropped plots were significantly higher than that of control plot. The plot without cover crop recorded the least dry rubber content. Among the levels of fertilizers to cover crop F_4 and F_2 were on par and significantly superior over F_0, F_2 is on par with F_3 and F_1.

It is noted that growing of cover crop under mature plantation has improved the dry rubber content. The reasons for the improvement are already explained in the initial flow rate. *It is also noted that the dry rubber content of latex* has been increased by application of the various nutrients. This could be the result of the favourable effect of these nutrients in improving the conditions of the rubber tree to produce latex. The volume of latex remaining constant the yield is directly dependent on the dry rubber content of latex. The favourable effect of the various applied nutrients in increasing the dry rubber content of latex has been reflected in the yield of rubber also. This finding is in line with the work of Punnoose (1993).

4.2.4. Effect of cover crop and its nutrition on the yield

The mean yield expressed as g tree^{-1} tapping^{-1} for 1991-1993 period is presented in Table 40.

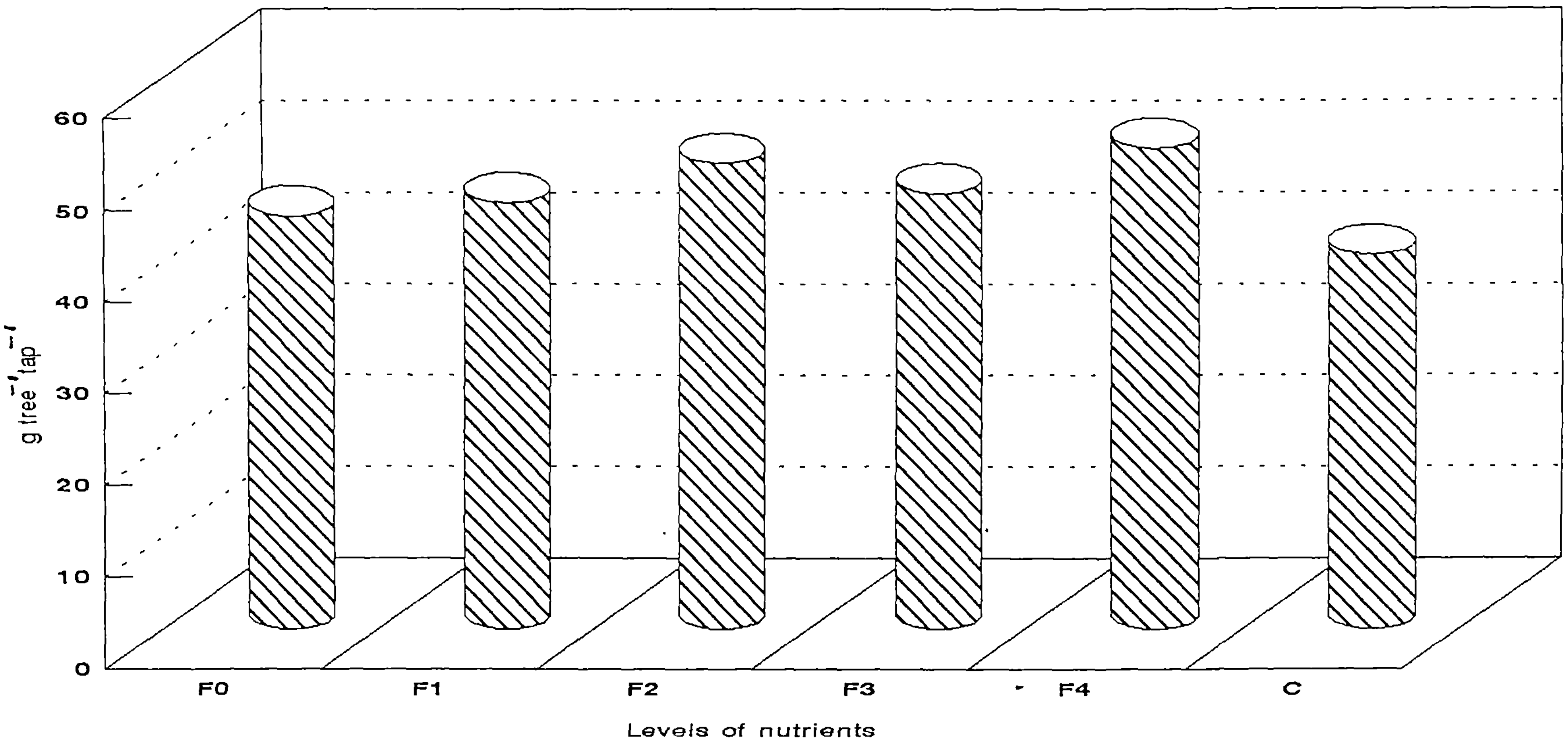
In the mature plantation, growing of cover crop has improved the yield of rubber significantly over the absolute control where there was no cover crop. The level F_4 and F_2 were recorded significantly higher yield than F_3, F_1 and F_0

Table 40. Effect of covercrops and its nutrition on the yield of rubber (g $tree^{-1}$ tap^{-1})

Treatments	Yield
F_0	45.10
F_1	46.51
F_2	50.77
F_3	47.49
F_4	52.42
C	40.79
SE	0.897
CD	2.703
	S**

S** Significant at P = 0.01 level.

Fig. 19. Effect of cover crop and its nutrition on the latex yield (g $tree^{-1}$ tap^{-1})



and are on par with each other. Ferrusal of yield attributing characters like girth increment, bark thickness and latex flow characters have clearly broughtout the superiority of F_4 and F_2 in influencing the performance of above attributes. It is to be particularly mentioned that all other levels like F_3, F_1 and F_0 are inferior to F_4 and F_2. Addition of 10 kg N to the cover crop over the recommended dose of 30 kg each P and K had definitely produced a substantial yield increase of rubber. Increasing the level of P and K to 60 kg each in the absense of nitrogen has resulted in drastic reduction of yield. (Fig. 19).

The addition of 10 kg N supplemented with 60 kg each of P and K didn't produce any increase in yield over 10:30:30. Application of N has significantly increase the yield. The role of N in increasing the rate of photosynthesis and metabolism is an established phenomenon (Sutcliff and Baker, 1974 and Bidwell, 1979). This might have resulted in direct increase in yield with application of N. This is further supported by the significant increase in leaf litter production (Table 38) with application of N. The tables on soil organic carbon and <u>Hevea</u> leaf N clearly showed that these parameters were significantly higher in N applied plots (F_2 and F_4). It is also seen from Table 39 that the total volume and dry rubber content were significantly higher at F_2 and F_4 levels. Positive responses to applied N were reported by Owen et al. (1957), Guha (1975), Potty et al. (1976) and Punnoose (1993).

Phosphorous is important as a structural part of many compounds in the plant notably nucleic acids and phospholipids and has important role in photosynthesis and energy metabolism (Bidwel, 1979). Application of P to cover crop might have improved the rate of photosynthesis of the tree and thereby increased the yield indirectly. The significant increase in soil available P and leaf P content (Tables 43 and 48) in the P applied plots for further supports the response to P application(Yogaratram and Weerasuriya (1984), Mathew et al. (1989) and Punnoose (1993)).

Potassium is an activator in enzyme systems and has a definite role in the transport of ATD-ase (Sutcliff and Baker, 1974). It is important for the development of chlorophyll and for photosynthesis. Table 38 indicates that leaf litter production was significantly increased by the addition of K at 60 kg. The available K as well as the leaf

K contents were significantly improved by the addition of 60 kg K to cover crop. Direct response in yield obtained to application of K also be reported by Angkapradipta *et al*. (1986) and Punnoose *et al*. (1993).

4.2.5. Soil nutrient status

The effect of cover crop and its nutrition on soil organic carbon and available N,P,K,Ca and Mg are presented and discussed.

4.2.5.1. Organic carbon

The results obtained from the three years are presented in Table 41. As time progresses the growing of cover crop has significantly increased the organic carbon content over the absolute control plots. Among the levels of fertilizers applied to cover crop, F_4 and F_2 were significantly superior to other levels and these two levels were on par with each other during 1992. During the end of the experiment, F_4 and F_2 were significantly higher to other levels and are significantly different from one another. During the entire period of the experiment the absolute .lh8 control plots recorded significantly lesser organic carbon content.

Table 41. Effect of covercrop and its nutrition on the soil organic carbon (per cent)

Treatments	1991	1992	1993
F_0	1.028	1.083	1.143
F_1	1.050	1.108	1.165
F_2	1.030	1.183	1.288
F_3	1.055	1.118	1.183
F_4	1.048	1.210	1.308
C	1.055	1.048	1.083
SE	0.009	0.006	0.005
CD		0.019	0.017
	NS	S**	S**

S** Significant at P = 0.01 level

NS Not significant

In the cover cropped treatment plots the dead litter materials deposited on the surface of soil and insitu incorporation resulted in the progressive increase in the organic carbon content when compared to plots without cover crop. These findings are in line with the observation of Watson (1961) and Watson et al. (1964b).

It is also noted that by addition of all the nutrients are in adequate supply in soil there will be better conservation of organic content of soil (Stevenson, 1964 and Brady, 1988). The gradual buildup of organic carbon in the soil could be the result of continuous addition of leaf litter from the trees and cover crop. The effect of N on the organic carbon status is well known. In rubber grown soil it is all the more enhanced. Hence it is not discussed in detail. Reports of Rubber Research Institute of Malaysia (1976) indicated that application of fertilizers especially N increased the level of organic carbon in the soil.

4.2.5.2. Available N

The available N content in the different years of observations are presented in Table 42. The cover crop plots recorded significantly higher available N content than the

Table 42. Effect of covercrop and its nutriton on soil available nitrogen (kg ha^{-1})

Treatments	1991	1992	1993
F_0	182.45	209.45	230.88
F_1	186.45	230.42	259.52
F_2	189.70	285.65	315.35
F_3	190.45	245.25	265.20
F_4	185.32	292.30	326.45
C	186.45	202.85	215.65
CD	30.350	33.450	36.420
	NS	S**	S**

S** Significant at P = 0.01 level

NS Not significant

control plots during the second and third year of observations. Available N content in the F_4 and F_2 levels were on par and significantly higher than all other levels.

The reasons for the increased available N content in soil were already explained in Experiment 1.

4.2.5.3. Available P

The available P content in the different years of observations are presented in Table 43. The cover cropped plots recorded significantly higher available P content than the control plots during the second and third year of observation. Available P content in the F_4, F_2 level applied plots were significantly higher than all other levels.

4.2.5.4. Available K

The available K content of soil in different years of observations are presented in Table 44. As in the Experiment I, it is noted that in Experiment II also cover cropped plots recorded significantly higher available K content in the soil over the control plots. Among the levels, F_3 recorded significantly higher soil available K.

Table 43. Effect of covercrop and its nutrition on soil available P (kg ha^{-1})

Treatments	1991	1992	1993
F_0	20.170	22.565	30.508
F_1	20.288	25.685	31.883
F_2	20.233	27.715	37.740
F_3	20.205	26.448	32.413
F_4	20.313	28.768	38.010
C	20.248	21.470	25.413
SE	0.220	0.091	0.245
CD		0.275	0.738
	NS	S**	S**

S** Significant at P = 0.01 level

NS Not significant

Table 44. Effect of covercrop and its nutritor on soil available K (kg ha^{-1})

Treatments	1991	1992	1993
F_0	128.098	159.098	194.668
F_1	131.048	155.340	191.843
F_2	129.293	148.840	169.368
F_3	130.660	147.493	187.768
F_4	129.183	146.638	160.120
C	129.115	150.755	190.053
SE	2.239	2.404	3.113
CD	6.623	6.819	9.383
	NS	S**	S**

S** Significant at P = 0.01 level

NS Not significant

The reasons for this increase were also already narrated in Experiment I.

It was observed that application of K significantly increased the available K content of soil as also opined by Pushpadas et al. (1978), Lau (1979) and Dissanayake and Mithrasena (1986).

4.2.5.5. Available Ca

The available Ca content of the soil are presented in Table 45. Covercrop grown plots were significantly superior than the absolute control on the available Ca content. The levels of fertilizers F_3, F_4 are found superior than other levels and were on par with each other. Control plots recorded the least value.

The reasons for the increased quantity of available Ca content in the cover cropped plots and in the F_3 and F_4 levels were already explained in Experiment I.

4.2.5.6. Available Mg

The available Mg content in the soil are presented in the Table 46. The available Mg content of cover cropped

Table 45. Effect of covercrop and its nutriton on soil available Ca (kg ha^{-1})

Treatments	1991	1992	1993
F_0	212.045	280.21	319.33
F_1	213.97	305.71	355.35
F_2	221.035	302.38	362.09
F_3	213.698	365.58	426.57
F_4	212.22	363.12	424.85
C	214.948	263.01	288.39
SE	0.345	0.418	0.536
CD	1.039	1.260	1.616
	S*	S**	S**

S* Significant at P = 0.05 level

S** Significant at P = 0.01 level

NS Not significant

Table 46. Effect of covercrop and its nutriton on soil available Mg (kg ha^{-1})

Treatments	1991	1992	1993
F_0	118.57	138.09	157.97
F_1	120.51	156.64	179.14
F_2	118.11	164.63	174.82
F_3	112.63	158.72	171.08
F_4	114.77	154.02	169.06
C	116.61	136.91	155.08
SE	0.315	0.349	0.356
CD	0.948	1.052	1.074
	S**	S**	S**

S** Significant at P = 0.01 level

plots were significantly higher over the absolute control, among the levels F_1 has recorded the highest value followed by F_2, F_3, F_4 and F_0. These levels were significantly differing from one another.

4.2.6. Effect of cover crop and its nutrition on the Hevea leaf nutrients contents

4.2.6.1. Hevea leaf Nitrogen contents

The reults obtained from 1991 to 1993 are presented in Table 47. It is observed that there was significant difference between the levels of treatments and absolute control. The cover cropped plots registered significantly higher leaf N content. It may be also seen from the Table on organic carbon that in all the three years the organic carbon content was more in the cover crop grown plots than that of control plot. Among the levels of fertilizers applied to cover crop, F_4 and F_2 recorded significantly higher Hevea leaf N.

The reasons for the higher leaf N content of Hevea under cover cropped area were already discussed in Experiment I.

Table 47. Effect of covercrop and its nutrition on Hevea Leaf N (per cent)

Treatments	1991	1992	1993
F_0	3.216	3.320	3.427
F_1	3.285	3.434	3.569
F_2	3.419	3.626	3.711
F_3	3.305	3.529	3.663
F_4	3.424	3.655	3.906
C	3.043	3.074	3.102
SE	0.002	0.066	0.002
CD	0.005	0.199	0.006
	S**	S**	S**

S** Significant at P = 0.01 level

Regarding the levels of NPK the increase in the *Hevea* leaf N content in F_4, F_2 are due to the application of 10 kg extra nitrogen. This application of N has increased the soil organic carbon (Table 41) which might have lead to greater absorption of N and increased N content of leaf. Similar increase in the leaf N content of *Hevea* from application of N fertilizers were reported by Shorrocks (1962) and (1964), Kalam *et al*. (1980), Sivanadyan (1983) and Punnoose (1993).

4.2.6.2. *Hevea* leaf P content

The results of *Hevea* leaf P obtained for the period from 1991 to 1993 are presented in Table 48. The treatments with cover crop recorded significantly higher leaf P content than the control plots.

The reasons for the increased *Hevea* leaf P content in the cover cropped plots were already discussed in detail in the Experiment I.

Among the levels of NPK, F_4 recorded significantly higher quantity of leaf P content followed by F_2, F_3, F_1 and F_0 and they were on par with each other.

Table 48. Effect of covercrop and its nutrition on Hevea Leaf P (per cent)

Treatments	1991	1992	1993
F_0	0.227	0.234	0.237
F_1	0.236	0.244	0.264
F_2	0.244	0.255	0.274
F_3	0.238	0.249	0.260
F_4	0.251	0.264	0.314
C	0.223	0.225	0.228
SE	0.001	0.002	0.011
CD	0.005	0.005	0.032
	S**	S**	S**

S** Significant at P = 0.01 level

Application of P has significantly increased the P content of leaf. It was already seen that there was significant increase in the soil P level from application of P fertilizers. The high P status of soil might have helped in better absorption of P resulting in high P content of leaf. Shorrocks (1962), Pushpadas et al. (1978) and Yogaratnam et al. (1984) also reported that application of P improved the leaf P content of Hevea.

4.2.6.3. Hevea leaf K content

The results of Hevea leaf K content for the period from 1991 to 1993 are presented in Table 49. It is observed that all the treatments with cover crop registered significantly higher leaf K content than the control plots. The reasons are already explained in Experiment I.

Among the levels F_4 has recorded significantly higher value followed by F_3, F_2, F_1 and F_0 and these values were significantly differing from one another. It was already seen that there was significant increase in the soil K level from application of K fertilizers. The high K status of soil might have helped in better absorption of K resulting

Table 49. Effect of covercrop and its nutrition on Hevea Leaf K (per cent)

Treatments	1991	1992	1993
F_0	1.269	1.306	1.349
F_1	1.304	1.350	1.429
F_2	1.319	1.331	1.475
F_3	1.347	1.496	1.606
F_4	1.459	1.531	1.695
C	1.209	1.235	1.279
SE	0.002	0.033	0.002
CD	0.006	0.009	0.006
	S**	S**	S**

S** Significant at P = 0.01 level

in high K content of leaf (Shorrocks (1961a), Yogaratnam et al. (1984), Yogaratnam and Mel (1985) and Punnoose (1993)).

4.2.6.4. Hevea leaf Ca content

The results of Hevea leaf Ca content for the period from 1991 to 1993 are presented in Table 50. It is observed that all the treatments with cover crop recorded significantly higher value over the absolute control and the reasons are already explained in Experiment I.

The level F_4 has recorded significantly higher value followed by F_3, F_2, F_1 and F_0 and these values were significantly differing from one another. The significant increase in the leaf Ca content with application of P could be the result of addition of rock phosphate which also contains Ca. This is in agreement with the reports of Shorrocks (1961a) , Pushparajah (1969) and Punnoose (1993).

4.2.6.5. Hevea leaf Mg content

The results of Hevea leaf Mg content for the period from 1991 to 1993 are presented in Table 51. It is noted that

Table 50. Effect of covercrop and its nutrition on Hevea Leaf Ca (per cent)

Treatments	1991	1992	1993
F_0	0.823	0.829	0.852
F_1	0.865	0.894	0.923
F_2	0.874	0.892	0.933
F_3	0.874	0.922	0.969
F_4	0.877	0.946	0.981
C	0.816	0.821	0.833
SE	0.002	0.002	0.002
CD	0.006	0.005	0.005
	S**	S**	S**

S** Significant at P = 0.01 level

Table 51. Effect of covercrop and its nutrition on Hevea Leaf Mg (per cent)

Treatments	1991	1992	1993
F_0	0.348	0.374	0.395
F_1	0.348	0.375	0.399
F_2	0.350	0.383	0.407
F_3	0.344	0.381	0.398
F_4	0.351	0.383	0.406
C	0.342	0.365	0.381
SE	0.002	0.002	0.002
CD	0.006	0.006	0.006
	S**	S**	S**

S** Significant at P = 0.01 level

cover cropped treatments registered significantly higher *Hevea* leaf Mg content.

The levels F_2, F_4 were significantly higher on *Hevea* leaf Mg and on par with each other and followed by F_3, F_1 and F_0.

4.2.7. Effect of cover crop and its nutrition on soil moisture

The soil moisture content in summer months viz January, February, March and April 1992 and 1993 were estimated, analysed and discussed below.

From the table it is seen that during the first year for the shallow depth, the soil moisture in the cover cropped plots were higher than absolute control. Nutrition to cover crop also increased the moisture content combined effect of both is more pronounced and is significant. The level F_4 recorded higher soil moisture content followed by F_2 during the all the summer months. These two levels were on par with each other. These two levels were followed by F_3, F_0 and F_1.

Table 52. Effect of covercrop and its nutrition on the soil moisture (per cent) at 0-30 cm and 30-60 cm depth (1992)

Treatment	Jan		Feb		March		April	
	0-30	30-60	0-30	30-60	0-30	30-60	0-30	30-60
F_0	17.23	16.39	14.96	15.44	15.29	14.74	15.24	14.28
F_1	17.10	16.18	16.68	15.61	15.68	14.95	15.58	14.68
F_2	17.99	17.00	17.30	16.35	16.10	15.50	16.04	15.10
F_3	17.16	16.25	17.20	15.64	15.74	15.09	15.78	14.73
F_4	18.01	16.78	17.48	16.46	16.20	15.74	16.25	15.34
C	11.86	12.21	11.15	11.51	9.22	11.61	9.14	10.35
SE	0.111	0.146	0.070	0.099	0.066	0.108	0.122	0.094
CD	0.335	0.439	1.838	0.216	0.020	0.326	0.367	0.283
	S**	S**	S**	S**	S**	S**	S**	S**

S** Significant at P = 0.01 level

Table 53. Effect of covercrops and its nutrition on the soil moisture (per cent) at 0-30 cm and 30-60 cm depth (1993)

Treatment	Jan		Feb		March		April	
	0-30	30-60	0-30	30-60	0-30	30-60	0-30	30-60
F_0	17.23	16.05	16.55	15.68	16.25	15.16	16.18	14.88
F_1	17.35	16.27	16.69	15.83	16.39	15.19	16.50	14.95
F_2	18.21	17.15	17.69	16.55	17.10	16.16	17.04	15.78
F_3	17.83	16.36	16.60	16.08	16.70	15.34	16.55	15.04
F_4	18.04	17.19	17.74	16.65	17.26	16.33	17.19	16.10
C	12.63	12.58	12.06	12.08	10.15	11.35	10.01	11.05
SE	0.099	0.072	0.052	0.072	0.094	0.044	0.056	0.057
CD	0.298	0.217	0.157	0.222	0.283	0.133	0.169	0.172
	S**	S**	S**	S**	S**	S**	S**	S**

S** Significant at P = 0.01 level

During first year for the bottom depth the cover cropped plots recorded significantly higher soil moisture over absolute control. Nutrition to cover crop also increased the soil moisture content at later months. F_2 level was found sufficient on these two levels were on par with each other.

During the second year of observation the soil moisture content in the top soil and bottom soil exhibited the same trend as that of the first year. The cover cropped plots recorded significantly higher soil moisture content over the absolute control. The levels F_4 and F_2 have registered a higher value than other levels. These levels were on par with each other and followed by F_3, F_4 and F_0.

The reasons for the increase in the soil moisture content in the cover cropped treatments as well as the nutritional effects were already explained in Experiment I.

4.2.8. Effect of nutrition on the uptake of nutrients by cover crop $Kg\text{-}ha^{-1}$

The nutrients uptake by cover crops were presented in Table 53a-53e.

Table 53a. Effect of nutrition on the uptake of N Kg ha^{-1} by covercrop

Treatment	Oct 1991	Oct 1992	Oct 1993
F_0	7.90	36.52	55.980
F_1	8.69	40.92	64.200
F_2	11.74	57.41	91.94
F_3	10.25	45.40	69.83
F_4	11.68	67.83	100.88
SE	0.810	0.810	0.9
CD	2.470	2.470	2.774
	S**	S**	S**

Table 53b. Effect of nutrition on the uptake of P Kg ha^{-1} by covercrop

Treatment	Oct 1991	Oct 1992	Oct 1993
F_0	0.54	3.39	5.420
F_1	0.63	4.14	6.380
F_2	0.86	5.68	9.210
F_3	0.68	4.58	7.290
F_4	0.83	6.94	10.470
SE	0.20	0.50	0.80
CD	1.541	1.541	2.470
	S**	S**	S**

Table 53c. Effect of nutrition on the uptake of K Kg ha^{-1} b: covercrop

Treatment	Oct 1991	Oct 1992	Oct 1993
F_0	7.18	33.45	52.22
F_1	8.11	38.06	45.83
F_2	10.75	51.41	83.35
F_3	9.44	41.49	64.78
F_4	10.59	60.64	91.28
SE	1.700	1.30	1.4
CD	NS	4.006	4.314
		S**	S**

Table 53d. Effect of nutrition on the uptake of Ca Kg ha^{-1} by covercrop

Treatment	Oct 1991	Oct 1992	Oct 1993
F_0	2.15	11.71	17.19
F_1	2.25	13.61	19.04
F_2	3.23	18.54	29.30
F_3	2.68	15.09	22.72
F_4	3.18	22.34	32.51
SE	0.80	1.20	1.1
CD	N.S.	3.698 S**	3.389 S**

Table 53e. Effect of nutrition on the uptake of Mg Kg ha^{-1} by covercrop

Treatment	Oct 1991	Oct 1992	Oct 1993
F_0	0.61	3.54	5.12
F_1	0.80	4.25	6.38
F_2	1.09	6.28	9.56
F_3	0.95	4.93	7.07
F_4	1.30	7.81	11.42
SE	0.50	0.80	0.5
CD	N.S.	N.S	N.S

During the first year all the nutrients except N, there was no significant differences noted between the treatments. From the second year onwards among the levels F_2 and F_4 were on par for the P uptake. For all the other nutrients the level F_4 was found significantly superior over F_2, F_3, F_1 and F_0.

Reasons were already explained in Experiment I.

4.2.9. Effect of cover crop and its nutrition on the growth of *Hevea* roots and cover crop roots

The effect of cover crop and application of nutrition to cover crop on the growth and development of *Hevea* root and cover crop root were analysed and presented in Table 54-57. The weight of roots were expressed as gm^{-2}.

4.2.9.1. *Hevea* roots at 0-7.5cm soil layer

Covercrop grown treatments recorded significantly higher weight of *Hevea* roots than under no cover. Among the levels F_4 has recorded significantly higher root weight than F_2 and followed by F_3, F_1 and F_0.

Table 54. Effect of growing covercrops on the growth of rubber roots(gm^{-2}) 0-7.5cm soil layer

Treatment	1991	1993
F_0	312.308	411.013
F_1	331.963	432.770
F_2	326.380	487.875
F_3	331.045	471.238
F_4	338.93	514.63
C	245.013	246.388
SE	8.012	5.438
CD	24.145	16.389
	S**	S**

S** Significant at P = 0.01 level

Table 55. Rubber roots$(gm)^{-2}$ above ground level

Treatment	1991	1993
F_0	123.450	159.8
F_1	135.588	177.013
F_2	142.978	209.5
F_3	144.233	202.463
F_4	154.638	220.163
C	74.813	112.595
SE	2.885	6.168
CD	8.694	18.587
	S**	S**

S** Significant at P = 0.01 level

4.2.9.2. *Hevea* roots above ground level

The situation is similar to that at 0-7.5cm soil layer. The reasons for the vigorous development of surface roots at both 0-7.5cm and above ground level under legume cover are due to the heavy mulch of dead leaves that built up under cover crop (Table 54). This would have increased the soil moisture content (Tables 52 and 53). Under the absolute control treatment, there was no cover crop and fully infested with weeds, predominately by grasses. These grasses rooted vigorously on surface and hence least *Hevea* root development occured in the control treatment. Similar finding was observed by Watson *et al*. (1964).

4.2.9.3. Covercrop roots at 0-7.5cm soil layer, and above ground level

Among the levels, F_4 and F_2 had recorded significantly higher weight of cover crop roots than all the other levels. F_4 and F_2 were on par with each other. This might be due to the direct effect. At F_4, F_2 levels the biomass of cover crop (Table 59) were also highest and hence better rooting under these levels.

Table 56. Effect of nutrition to covercrops on the growth of covercrop roots 0-7.5 cm layer of soil (gm^{-2})

Treatments	1991	1993
F_0	15.275	67.868
F_1	17.175	66.968
F_2	18.563	73.993
F_3	18.075	69.868
F_4	19.198	81.900
SE	1.801	2.810
CD	5.427	8.469
	S*	S**

S* Significant at P = 0.05 level

S** Significant at P = 0.01 level

Table 57. Effect of nutrition to covercrop on the growth of covercrop roots above ground level ($g\ m^{-2}$)

Treatments	1991	1993
F_0	6.943	37.270
F_1	9.565	42.370
F_2	10.615	46.278
F_3	9.100	41.243
F_4	10.825	81.593
SE	0.278	1.549
CD	0.838	4.667
	S*	S**

S* Significant at P = 0.05 level

S** Significant at P = 0.01 level

Table 58. C/N ratio (1993)

Treatment	C:N ratio
F_0	14.35
F_1	13.38
F_2	11.40
F_3	13.30
F_4	11.18
C	26.68
SE	1.056
CD	3.181
	S**

S** Significant at P = 0.01 level

4.2.10. Effect of cover crop and its nutrition on the C/N ratio

The impact of cover crops and its nutrition on the C/N ratio are presented in Table 58.

Among the treatments the cover crop grown plots recorded significantly lower C/N ratio, where as the control plot recorded the highest C/N ratio. Among the levels F_4 and F_2 recorded least value and are on par with all other levels grown with cover crop.

Leguminous creaper has been shown to mobilise greater quantities of nitrogen, phosphorus and calcium than the control plots. Since the litter from the cover crop has a low C/N ratio it would be expected to mineralise rapidly with its nutrient content becoming quickly available again for uptake by Hevea or cover crop itself. These results are in conformative with the work of Watson (1961).

4.2.11. Effect of cover crop and its nutrition on the biomass production of cover crop(Kg ha^{-1})

Biomass of cover crop produced from October 1991 to October 1993 were recorded at six monthly interval, analysed and discussed below.

Table 59. Effect of nutrition to covercrop on its biomass (Kg ha^{-1})

Treatment	1991 Oct 1991	1992 April 92	 Oct 92	1993 April 93	 Oct 93
F_0	324.50	791.50	1457.75	1773.50	2277.25
F_1	359.00	841.25	1635.00	2043.50	2573.50
F_2	460.50	1100.00	2143.75	3170.75	3476.00
F_3	413.00	992.50	1774.75	2265.25	2770.75
F_4	451.00	1176.75	2495.50	3492.50	3767.25
SE	14.547	10.739	20.708	15.231	15.341
CD	44.827	33.094	63.814	46.937	47.273
	S**	S**	S**	S**	S**

S** Significant at P = 0.01 level.

During the early stage Oct 91 F_2 was found to be superior as the growth in limitted, addition of 10 Kg Nitrogen has increased the nodule count with that higher biomass. At this stage F_2 is sufficient, and cover crop has no capacity to utilize 60 Kg P and K. As the time passed, more uptake of P and K is noticed and from first year onwards F_4 is superior and is followed by F_2.

The reasons were already explained th Experiment I.

4.2.12. Effect of cover crop and its nutrition on weed drymatter production

The quantity of weed drymatter produced in Kg ha^{-1} in the experiment in analysed and the same is presented and discussed. The recording of weed drymatter production were undertaken at six monthly interval.

It is noticed from the table that during all the three years form October 1991 to Oct 1993 there was significant difference found between the treatments and absolute control on the weed DMP. There was a drastic reduction in weed DMP when the level of fertilizers to

Table 60. Effect of covercrop and its nutrition on the weed DMP (Kg ha^{-1})

Treatment	1991 Oct 1991	1992 April 92	Oct 92	1993 April 93	Oct 93
F_0	501.75	766.50	1095.00	903.25	873.00
F_1	405.00	659.00	960.25	781.50	769.50
F_2	605.00	504.75	789.75	568.00	494.25
F_3	525.75	638.25	888.50	758.50	742.75
F_4	287.25	458.25	765.00	620.75	499.00
C	1010.25	1489.25	1830.75	1713.50	1921.75
SE	25.123	37.556	31.036	42.539	19.367
CD	75.713	113.185	93.533	128.198	58.365
	S**	S**	S**	S**	S**

S** Significant at P = 0.01 level.

cover crop were increased. The level F_2 was found to be optimum in 1993, where as F_2 and F_4 were found on par in 1991 and 1992.

The reasons were already explained in Experiment I

4.2.13. Soil physical characters

The effect of cover crop and its nutrition on soil moisture retention, total porosity, bulk density and aggregation percentage at two depths viz., 0-30 and 30-60 cm are presented and discussed below.

4.2.13.1. Soil moisture retention capacity

The moisture retentive capacity of the soil was worked out at the beginning and end of the experiment at -0.033 Mpa and at -1.5 Mpa pressures at two depths viz., 0-30 and 30-60 cm and are presented in Tables 61 and 62. Soil moisture retention was higher in the cover cropped plots than absolute control. At -0.033 Mpa and at -1.5 Mpa pressure the final analysis of soil moisture retention of shallow depth were significantly differing each other. Among the levels at

Table 61. Effect of covercrops and its nutrition on the soil moisture retention capacity at -0.033 Mpa

Treatment	0 - 30 cm depth 1991 initial	1993 final	30 - 60 cm depth 1991 initial	1993 final
F_0	28.853	27.075	29.050	30.475
F_1	26.600	27.375	28.863	31.195
F_2	25.688	28.875	28.575	32.100
F_3	26.575	27.938	29.200	31.138
F_4	26.438	28.913	29.350	32.500
C	26.188	26.350	29.438	29.813
SE	1.103	0.252	0.377	0.388
CD	NS	0.758 S*	NS	NS

S* Significant at P = 0.05 level

NS Not significant

Table 62. Effect of covercrops and its nutrition on the soil moisture retention capacity at -1.5 MPa

Treatment	0 - 30 cm depth 1991 initial	0 - 30 cm depth 1993 final	30 - 60 cm depth 1991 initial	30 - 60 cm depth 1993 final
F_0	19.463	20.650	22.050	23.763
F_1	18.938	20.800	23.238	24.800
F_2	19.125	21.825	23.880	25.588
F_3	19.138	21.338	23.500	24.700
F_4	19.113	22.013	23.438	25.800
C	19.013	19.263	22.475	22.850
SE	0.253	0.192	0.254	0.259
CD	NS	0.358 S**	NS	NS

S** Significant at P = 0.01 level

NS Not significant

shallow depth, F_4 was found on par with F_2 at both pressures. At deeper depth there was no significant change observed.

The reasons were already explained in Experiment I

4.2.13.2. Total porosity, bulk density and aggregation percentage

The soil was analysed for its total porosity, bulk density and aggregation percentage at the end and begining of the experiment at two depths viz., 0-30 and 30-60 cm and were presented in Table 63. All three characters of soil at 0-30 cm depth were significantly higher in the cover cropped treatments than the absolute control. At shallow depth of soil these physical properties were improved by cover cropping. Among the levels F_4 and F_2 were on par with each other.

The reasons for the above results were already explained in Experiment I.

4.2.14. Effect of cover crop and its nutrition on the microbial population in soil

The microbial population of the soil were analysed for the generalized count of bacteria, fungi and phosphate

Table 63. Effect of growing covercrops and its nutrition on the physical properties of soil

Treatment	Total porosity %				Bulk density $g cc^{-1}$				Aggregation %			
	0-30		30-60		0-30		30-60		0-30		30-60	
	1991	1993	1991	1993	1991	1993	1991	1993	1991	1993	1991	1993
F_0	46.51	47.9	48.71	49.16	1.21	1.20	1.26	1.25	85.63	88.50	79.48	80.93
F_1	46.89	48.93	48.71	50.66	1.21	1.20	1.25	1.24	85.18	89.55	79.18	80.23
F_2	47.65	49.51	48.79	52.66	1.22	1.19	1.26	1.24	56.25	92.35	78.88	80.05
F_3	48.23	49.65	48.75	61.43	1.21	1.20	1.25	1.24	85.93	90.83	79.78	80.93
F_4	47.64	49.79	47.89	52.70	1.21	1.19	1.25	1.24	79.08	91.95	79.43	80.48
C	46.58	47.38	48.30	49.53	1.21	1.21	1.26	1.25	85.80	87.35	79.8	80.50
SE	0.360	0.267	0.299	4.04	0.010	0.005	0.008	0.005	0.709	0.326	0.849	0.304
CD	NS	0.805	NS	NS	NS	0.014	NS	NS	NS	0.982	NS	NS
		S**				S**				S**		

S** Significant at P = 0.01 level

NS Not significant

Table 64. Effect of growing covercrop and its nutrition on the microbial population of the soil x 10^4 g^{-1} of soil

Treatment	Bacteria		Fungi		Phosphates solublizers	
	Initial	Final	Initial	Final	Initial	Final
F_0	27.025	37.600	9.750	11.503	4.638	6.538
F_1	28.650	38.625	10.075	12.600	4.620	7.500
F_2	28.675	49.375	9.750	13.563	4.543	7.333
F_3	28.175	46.825	10.125	13.280	4.700	7.675
F_4	27.650	49.050	10.025	13.918	4.543	7.813
C	27.450	29.85	9.875	10.888	4.355	4.488
SE	0.463	0.938	0.675	0.082	0.103	0.061
CD	NS	2.856	NS	0.246	NS	0.185
		S**		S**		S**

S** Significant at P = 0.01 level

NS Not significant

solublizers at the begining and end of the experiment. The data were analysed and presented as X 10^4 g^{-1} of soil Table 64. All the microbial population were increased over the initial count in the cover cropped plots which was found significantly higher than the absolute control.

Among the levels, F_4 and F_2 were found to be on par with each other and significantly higher in the bacteria and fungi count. Phosphate solublizers were higher in F_4 level followed by F_3, F_1, F_2 and F_0.

The reasons were already explained in Experiment I.

4.3. Experiment III

Inorder to study the comparative effect of cover crops alone and that of cover crops with rubber, a series of microplots were put under Pueraria and Mucuna. The cover crops were retained for 3 years and various biometric observations, moisture content at different depths, nutrient uptake, soil status of available nutrients and microbial activities were studied. The data obtained from these microplots were compared with cover crop grown with immature rubber as well as that of mature. In mature plot only Mucuna was grown as cover crop. These data were complied from three different experiments and hence statistical interpretation is not attempted.

4.3.1. Soil moisture percentage

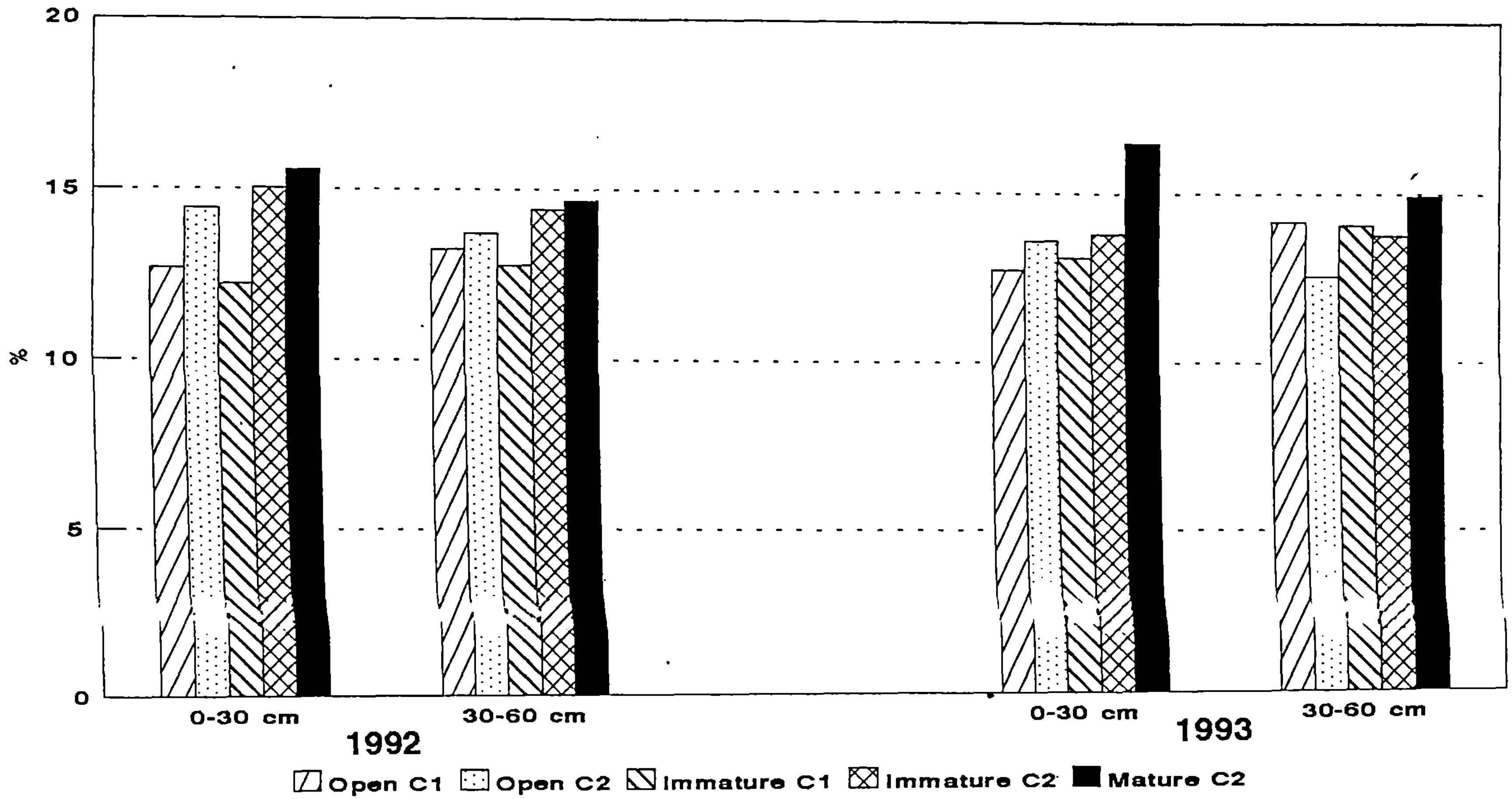
The data of soil moisture in percentage is presented in Table 65.

In the second year of observation (1992) at shallow depth Mucuna (C_2) has recorded more moisture than Pueraria (C_1) in both pure cover cropped area as well as cover crop grown with immature rubber. More or less same trend is noted at deeper layer also. In 1993 April at 0-30cm depth also the trend is somewhat similar. Where as at 30-60cm depth C_2 has recorded lesser moisture content than C_1 under both pure and immature rubber situation. In the initial stages of cover crop C_2 has more moisture percentage because of more soil cover. However in the deeper layer C_2 has recorded lesser moisture content in both situations probably because of its deep roots and would have obsorbed more moisture from the deeper layers. The performance of C_2 in mature rubber

Table 65. Comparison among open, immature and mature situation on soil moisture percentage (Apirl 1992 & 1993)

	1992 April		1993 April	
	0-30 cm	30-60 cm	0-30 cm	30-60 cm
Open				
C_1	12.66	13.25	12.75	14.19
C_2	14.45	13.70	13.62	12.59
Immture				
C_1	12.20	12.78	13.12	14.08
C_2	15.05	14.42	13.82	13.77
Mature				
C_2	15.58	14.68	16.50	14.95

Fig. 20. Effect of cover crops on the soil moisture percentage (April 1992 & 1993)



showed that at 30-60 cm depth, there was reduction of soil moisture content than shallow depth. This decreased soil moisture percentage at lower depth by C_2 has no way affected the girth of rubber and is seen from girth increment, height increment, latex yield (Tables 36, 37 and 40) . This shows that there was no competetion for moisture at deeper depth by growing Mucuna (C_2).

4.3.2. Soil nutrient status

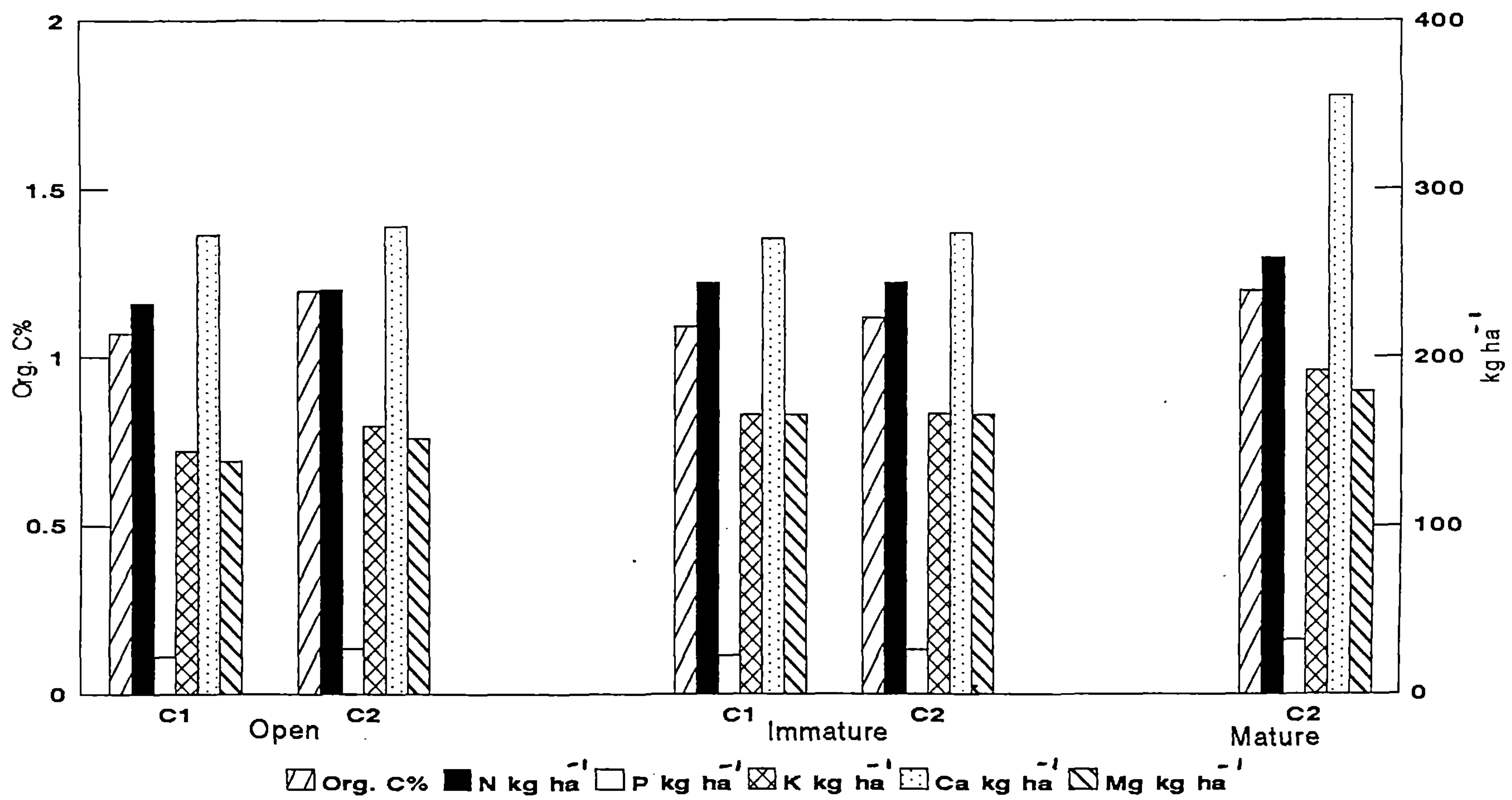
The data of soil available nutrients viz. organic carbon (%), nitrogen, phosphorus, potash, calcium and magnesium (kg ha^{-1}) are presented in Table 66.

Organic carbon, nitrogen, phosphorus, potash, calcium and magnesium are at a higher level in the mature area, than the other two situations (Fig. 21). Among the cover crops C_2 has registered higher values of all the available nutreints than C_1, under both pure as well as in the immature stage. The table on the leaf litter production under mature condition showed that a huge quantity of Hevea leaf litter is added at every year which contains lot of nutrients. This phenomenon is lacking under the pure as well as in the immature stage. Among th ecover crop C_2 has

Table 66. Comparison among open, immature and mature situation on soil nutrient status

	Organic carbon %	N kg ha^{-1}	P kg ha^{-1}	K kg ha^{-1}	Ca kg ha^{-1}	Mg kg ha-$^{-1}$
Open						
C_1	1.072	232.740	21.805	194.230	273.220	137.695
C_2	1.201	240.610	26.800	158.470	277.885	151.635
Immature						
C_1	1.093	244.570	22.980	165.220	270.43	165.170
C_2	1.120	244.830	26.020	165.850	273.87	165.220
Mature						
C_2	1.200	259.520	31.883	191.843	355.350	179.82

Fig. 21. Effect of cover crops on the soil nutrient status (1993)



produced more of dead leaf litter which is added insitu and incorporated. This might have contributed to the increased available nutrients over C_1 under pure and immature situations.

4.3.3. Uptake of nutrients by cover crops

The uptake of nutrients by cover crop is presented in Table 67.

Uptake of nutrients under open and immature situations are higher than that under mature situation. (Fig. 22). Among the cover crops C_2 has taken highest quantities of nutrients than C_1 and thus produced higher biomass and lesser weed DMP. Uptake of nutrients by cover crops under open and immature situations are more or less similar. Higher biomass production of cover crops under open and immature situations might have contributed to the increased uptake of nutrients.

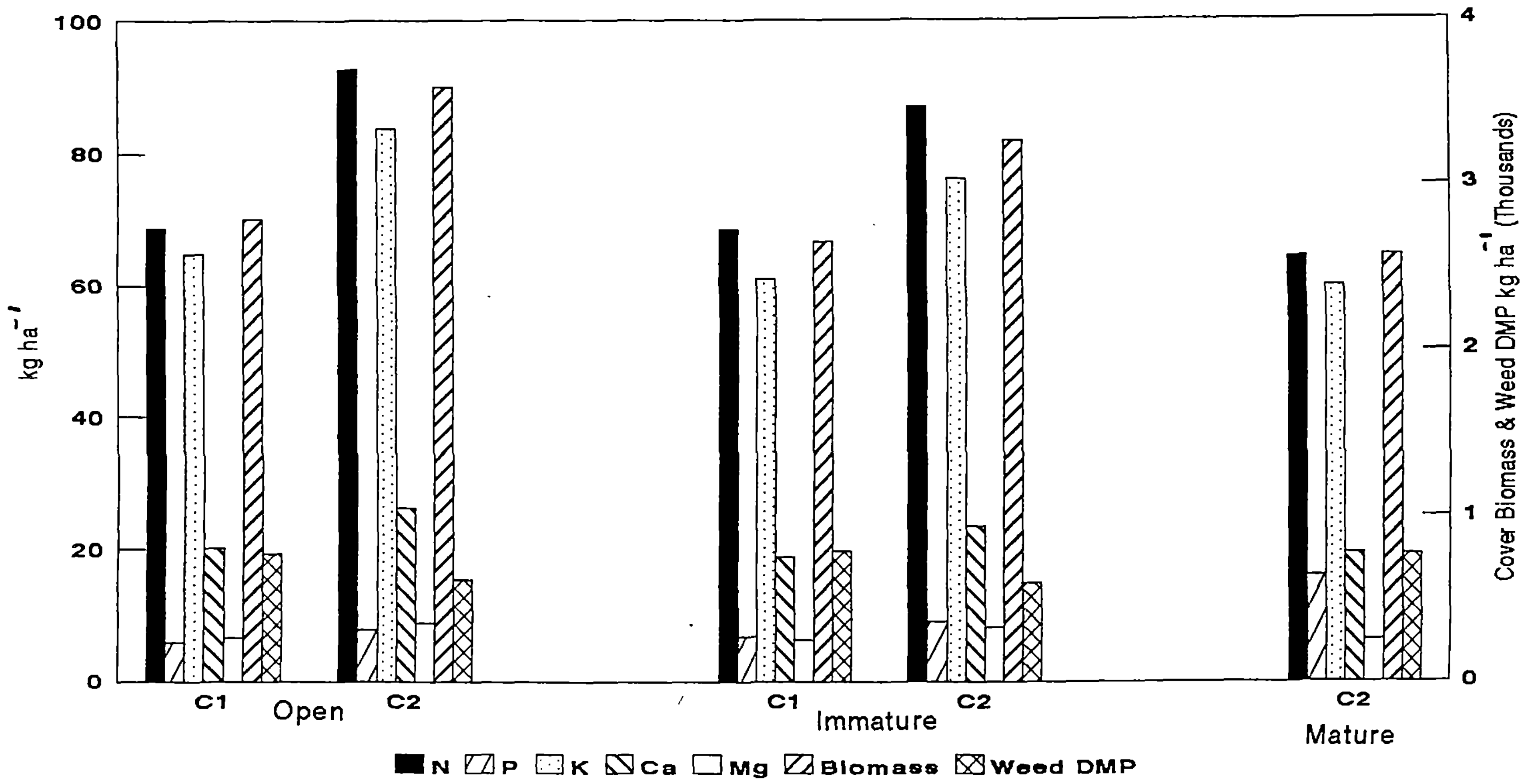
4.3.4. Biomass of cover crops kg ha^{-1}

The biomass produced by cover crop is presented in Table 67.

Table 67. Uptake of nutrients by cover crops, Biomass of cover crop and Weed Dry Matter Production (Kg ha^{-1})

	Nitrogen	Phos-phorus	Potash	Cal-cium	Magne-sium	Bio-mass	Weed DMP
Open							
C_1	68.75	5.95	64.80	20.19	3.76	2805.00	776.1
C_2	92.75	7.92	83.65	26.26	8.89	3598.00	617.9
Immature							
C_1	68.44	5.98	42.50	15.40	5.20	2663.33	790.0
C_2	86.84	6.40	46.50	19.15	6.35	3265.00	598.0
Mature							
C_2	64.20	6.38	45.83	19.04	6.38	2573.5	769.5

Fig. 22. Effect of covercrops on nutrient uptake, Biomass of cover and weed DMP (kg ha^{-1})



Biomass of cover crops produced under pure stand is higher than that under immature situation (Fig. 22). The cover crop C_2 has produced more quantities of biomass which is comparable with C_1 under immature and pure situation. The C_2 under mature situation is comparitively lesser over the other two situations.

Under pure stand there was no shade effect and hence better quantum of biomass, which was absent under immature situation. Under immature situation partial shade from young rubber plants might have reduced the biomass of cover crop. The cover crop C_2 is genitically vigours in growth and has produced more biomass. C_2 can be recommended as a good cover crop under mature plantation. Under mature situation, canopy of Hevea is fully closed and light penetration is limitted, hence biomass of C_2 is comparitively lesser than the other two situations.

4.3.5. Weed drymatter production

The weed drymatter production is presented in Table 67.

Weed drymatter produced under all the three situations are similar (Fig. 22). Among the cover crops C_2 has registered lowest quantity of weed dry matter under pure as well as immature situation proving its efficiency in smothering weeds.

4.3.6. Soil microbial population

The data of soil microbial population is presented in Table 68. The general count of bacteria, fungi and phosphate solubilizers were under taken and discussed with respect of the situation. (Fig. 23).

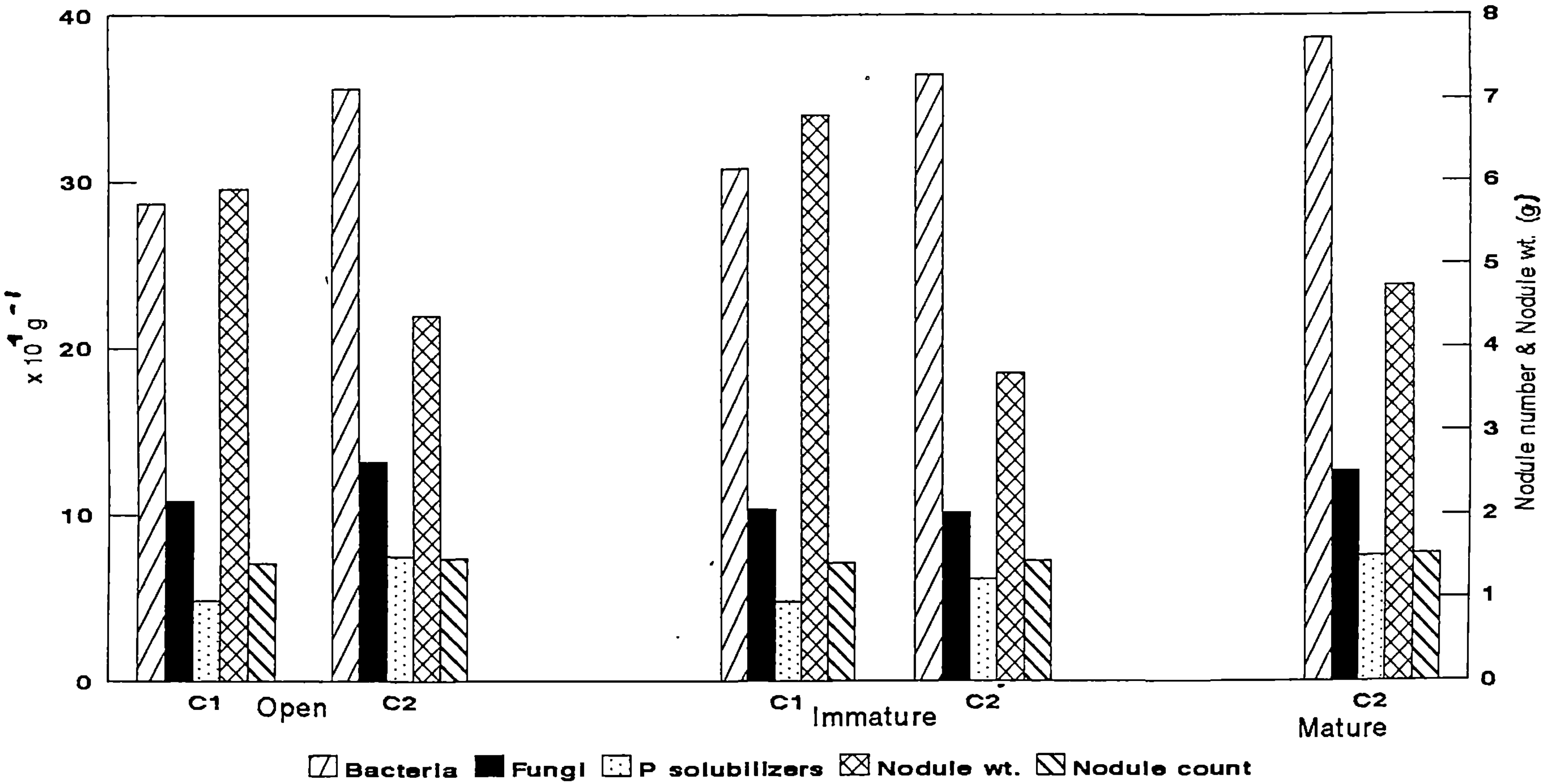
The microbial count of the soil showed that the count under mature situation is higher than the other two situations. Among the pure and immature stand there was not much difference. The cover crop C_2 has recorded higher count of microbes over C_1 under all the situations.

The soil moisture content and the organic carbon content (Tables 65 and 66) were higher under mature situation. This might be the reason for the increased microbial population. Among the cover crops, under C_2 the

Table 68. **Comparison among open, immature and mature situations on soil microbial population x 10^4 g^{-1} of soil, nodule count and weight (g^{-2})**

	Bacteria	Fungi	Phosphate solubilizers	Nodule	
				Count No.	Wt. g^{-2}
Open C_1	28.71	10.787	4.860	5.920	1.410
C_2	35.57	13.175	7.505	4.400	1.475
Immture C_1	30.800	10.30	4.82	6.800	1.422
C_2	36.433	10.10	6.13	3.700	1.442
Mature C_2	38.625	12.600	7.500	4.750	1.525

Fig. 23. Effect of covercrops on the soil microbial population x 10^4 g^{-1} of soil (1993), Nodule count and weight $plant^{-1}$ (40DAS)



biomass addition of cover litter, higher soil moisture content and organic carbon content might have increased the soil microbial activities.

4.3.7. Nodule count and weight plant^{-1}

Nodule count and weight are presented in the Table 68. The nodule count of C_1 is higher than C_2. The weight of nodules under C_1 are comparable with C_2. The reason is that the nodule size of C_2 is bigger than C_1. (Fig. 23).

4.4. Correlation studies

In order to explain the relationship between some of the important characteristics with girth and height increment of cover crop under immature and girth and yield under mature situations, correlation studies were attempted. The correlation coefficients have been worked at on all possible relationships, however only the important and relevant correlations are presented and discussed in the text.

4.4.1. Correlation of girth with other characteristics of C_1 and C_2 under immature situation

Table 69 indicated that girth was significantly and positively correlated with cover crop biomass, nutrient uptake, soil available nutrients, soil moisture contents, Hevea leaf nutrients and significantly and negatively correlated with weed dry matter production under both C_1 and C_2 grown conditions.

It is noted that N content of soil and leaf were positively correlated with girth increment and the correlation was significant. It has already been noticed that application of N increased the girth increment (Tables 63 and 67) as well as the N contents in leaf Table 47. Application of N has enhanced the girth increment because of the effect of this nutrient on vegetative growth characters. This is evidenced by the correlation obtained between girth increment and N contents of leaf and soil. The increased N content in the Hevea plant might have helped in enhancing the girth.

The girth increment was also correlated with the P and K content of soil and leaf. This could be due to the

Table 69. Correlation coefficient (r) of girth & height increment as related to important characteristics (Immature Hevea)

Characteristics		Girth increment (r) 1991-1993		Height increment (r) 1991-1993	
Cover crop biomass		0.6611**	0.7920**	0.7959**	0.7764**
Cover crop nutrient uptake					
	N	0.9592**	0.8130**	0.7516**	0.6718**
	P	0.8483**	0.8018**	0.6016**	0.6048**
	K	0.4574**	0.7743**	0.4675**	0.6677**
	Ca	0.6512**	0.6215**	0.6212**	0.6055**
	Mg	0.8010**	0.7916**	0.7560**	0.7422**
Soil available organic					
	C	0.6003**	0.6470**	0.7962**	0.5723**
	N	0.9497**	0.9480**	0.7835**	0.7370**
	P	0.8065**	0.7734**	0.7570**	0.6197**
	K	0.8250**	0.8402**	0.8561**	0.7256**
	Ca	0.7544**	0.7956**	0.4808**	0.5680**
	Mg	0.9019**	0.5418**	0.5785**	0.3078**
Soil Moisture	J	0.8601**	0.8876**	0.7342**	0.6192**
0-30 cm	F	0.7394**	0.8591**	0.6253**	0.5977**
	M	0.8609**	0.7185**	0.7539**	0.7172**
	A	0.8035**	0.8578**	0.7288**	0.6888**
30-60	J	0.6991**	0.8293**	0.7289**	0.7428**
	F	0.6008**	0.5206**	0.6894**	0.6709**
	M	0.3854**	0.7611**	0.5110**	0.7119**
	A	0.8894**	0.7907**	0.8093**	0.7754**
Hevea leaf nutrients					
	N	0.8035**	0.8102**	0.8127**	0.7117**
	P	0.6376**	0.6244**	0.8391**	0.5986**
	K	0.4738**	0.4823**	0.7003**	0.3508
	Ca	0.9598**	0.7704**	0.8294**	0.6922**
	Mg	0.8088**	0.6508**	0.9031**	0.7465**
Weed dry matter production					
		-0.6215**	-0.7321**	-0.7145**	-0.7040**

** Significant at P = 0.01 level

favourable effect of applied P and K on these characters. There was positive correlation between girth increment and Ca contents of leaf and soil. Calcium is very important for growth as it is constituent of the cell wall (Sutcliff and Baker, 1974). Similar correlation between girth increment and soil N and P were reported by Puspharajah _et al_. (1984) and correlation between girth increment and leaf N by Sivanadyan (1983) and Weerasuriya and Yogaratnam (1988).

The girth increment and height were also correlated with soil moisture content during summer months. Soil moisture content during summer months were significantly and positively correlated with girth and height increments. The reasons may be correlation of girth and yield with other important characteristics under mature situation.

4.4.2. Correlation of girth and yield with other characteristics of C_1 and C_2 under mature situation

Table 70 indicates that girth and yield were significantly and positively correlated with soil, leaf and uptake of nutrients by cover crop. It may be noted that the application of N, P and K to cover crop might have improved

Table 70. Correlation coefficient (r) of girth and yield as related to important characteristics (Mature Hevea

Characteristics		Girth (r)	Yield (r)
Hevea leaf litter		0.8312**	0.8154**
Soil available	N	0.7108**	0.8710**
	P	0.7288**	0.8550**
	K	0.6841**	0.5602**
	Ca	0.7215**	0.5382**
	Mg	-0.7799**	-0.7539**
Hevea leaf nutrients			
	N	0.8351**	0.8486**
	P	0.6225**	0.6884**
	K	0.7196**	0.6586**
	Ca	0.8986**	0.6480**
	Mg	-0.6093**	-0.6242**
Soil Moisture	J	0.2589	0.3577**
0-30	Feb	0.3764**	0.4925**
	Mar	0.7264**	0.9167**
	Apr	0.8143**	0.8830**
30-60	Jan	0.4731**	0.7756**
	Feb	0.5162**	0.5724**
	Mar	0.6149**	0.8449**
	Apr	0.6152**	0.8837**
Weed dry matter		-0.7731**	-0.8307**
Cover crop biomass		0.7776**	0.8891**
Uptake of	nutrients		
by cover crops	N	0.7409**	0.8729**
	P	0.6333**	0.6548**
	K	0.7032**	0.8409**
	Ca	0.5814**	0.6894**
	Mg	0.7582**	0.8206**

** Significant at P = 0.01 level

the soil leaf nutrients, resulting in a significant an positive correlation. Similar relation were also obtained between soil moisture and the above characteristics girth and yield, moisture content during summer months.

Weed dry matter production was significantly and negatively correlated with the girth and yield of Hevea.

The reports of Shorrocks (1962) Pushparajah (1969) and Pushparajah (1977) also indicated positive correlation between girth and yield with nutrient contents of soil and leaf. Negative relations of Mg were also reported by Yip (1990).

SUMMARY

5. SUMMARY

Field experiments were conducted to study the effect of cover crops on the nutrient dynamics in rubber plantations. There were three field experiments and were conducted at Bethany Estate, Mukkampala, Kanyakumari District from February 1991 to October 1993, they were :

1. The effect of cover crops on the nutrient dynamics in the immature rubber plantation
2. The effect of cover crop on the nutrient dynamics in the mature plantations and
3. Microplot study of cover crops alone.

In Experiment I there were two cover crops viz. *Pueraria phaseoloides* and *Mucuna bracteata* and five levels of NPK viz. 0:0:0, 0:30:30, 10:30:30, 0:60:60 and 10:60:60 with one year old RRII-105, replicated thrice and statistically laid in RBD. In Experiment II there was one cover crop *Mucuna sp* alone with five levels of NPK as above with 8 years old RRII-105 replicated 4 times and statistically laid in RBD. In Expt. III there were 10 microplots, with both cover crops. The results of the investigations are summarised below.

Salient findings

(1) N, P, K, Ca, Mg content of both Hevea and cover crops were increasing as the crops growth progressed. Fertilizer application to cover crops improved the Hevea leaf nutrient content than the absolute control. Among the levels 10:30:30 was found optimum. Mucuna was found better than Pueraria in increasing the Hevea leaf nutrient content.

(2) Girth increment was better with 10:30:30. This was found to be optimum under both experiments. More height increment was observed in this level, as well as in cover cropped treatments when compared to absolute control.

(3) Biomass production of cover crops were maximum at 10:60:60 followed by 10:30:30 under both experiments

(4) Root weight and length were higher in Mucuna and it was found increasing as the crop growth progressed.

(5) Nodule count was higher in Pueraria and the fresh weight of nodule per plant was higher in Mucuna as the size of its nodule was found bigger.

(6) Soil moisture retention capacity was found higher under cover cropped plots at both shallow (0-30cm) and deeper (30-60cm) soil depths at -0.033 and -1.5 MPa pressures than control. Pore space and aggregation percentage were improved where as bulk density decreased. Among the levels of NPK, 10:30:30 was found optimum in improving the soil physical properties. The percentage of improvement was found greater at shallow depth of soil than deeper. Soil moisture content during summer months were improved in the cover cropped area. The soil moisture in the top soil (0-30cm) was lesser than the bottom soil (30-60cm) in Pueraria grown plots. This trend was reverse in the case of Mucuna. Reason for this trend is attributed to the deep rooted nature of Mucuna.

(7) Growing of cover crops improved the microbial population of bacteria, fungi and phosphate solubilising organisms. The level 10:30:30 was found optimum for the better microbial activity.

(8) 10:30:30 was found optimum for better yield and Latex Flow Characteristics. Covercropping has increased the latex yield by 15-20%.

(9) 10:30:30 was optimum for better leaf litter production of _Hevea_. In cover cropped plots the leaf litter production was higher and wintering was delayed by 26-30 days over the control. This has enhanced 10 additional tapping days.

(10) Girth is positively correlated with cover crop biomass, nutrient uptake, soil available nutrients, soil moisture contents and _Hevea_ leaf nutrient contents. Strongest correlation for girth was found with _Hevea_ leaf N content, and uptake of N by cover crops, suggesting the importance of foliar diagnosis. Yield was negatively correlated with Mg content of soil.

Conclusion

1. Growing of cover crop is beneficial and absolutely essential in rubber plantations

2. Best cover crop for rubber is _Mucuna_, self generating, fast growing, shade tolerant and not eaten by cattle performs well under immature and mature phase of _Hevea_.

3. Optimum level of nutrition for cover crop is 10:30:30, from the point of its contribution to the rubber plants are concerned.

4. Soil physical, chemical and biological properties were improved by growing cover crops.

5. There was absolutely no competition for moisture between cover crops and main crop.

6. Weed growth was suppressed to a greater extent.

7. Yield and Latex Flow Characteristics were greatly enhanced by the cover crops.

8. Wintering was delayed to an extent of 30 days thereby giving 10 extra tapping days.

9. Growing of cover crops are absolutely essential for maintaining higher productivity of the rubber soil especially in a tropical situation like ours where rainfall is very high.

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APPENDIX

APPENDIX I

Weather data during the period of the Experiment and means of previous 25 years (1966-1990) at the Experiment site (Kulasekaram)

Months	Total Rianfall (mm) 1964-90	1991	1992	1993	No. of rainy days 1964-90	1991	1992	1993
January	31	32	21	27	5	4	5	6
February	38	54	47	48	4	3	4	3
March	85	47	85	56	6	4	3	4
April	178	176	105	182	9	9	11	9
May	230	111	148	140	12	14	16	11
June	322	780	665	715	22	28	26	23
July	196	150	195	175	14	12	16	14
August	90	54	38	115	7	3	4	13
Septmber	183	138	265	170	8	9	4	7
October	318	248	195	242	18	19	21	16
November	274	264	322	248	14	14	11	10
December	86	30	42	36	3	2	3	3
Total	2031	2084	2128	2154	122	121	124	119

	Maximum Temperature Monthly mean (°C)				Minimum Temperature Monthly mean (°C)				Relative Humidity Monthly mean (%)			
Months	1966-90	1991	1992	1993	1966-90	1991	1992	1993	1966-90	1991	1992	1993
January	31.7	31.8	31.6	31.9	18.4	18.2	17.9	18.5	68.5	68.5	67.0	69.0
February	33.8	33.8	33.4	34.0	19.9	19.2	19.1	18.2	69.0	70.0	69.5	70.5
March	34.5	34.2	34.2	34.5	22.6	22.0	20.5	21.7	73.5	73.5	74.0	72.5
April	35.1	33.8	34.5	34.2	23.4	23.6	17.9	18.5	68.5	68.5	67.0	69.0
May	31.2	31.6	31.5	31.0	23.5	22.9	21.6	23.5	80.0	79.5	81.0	80.5
June	30.2	30.8	31.0	30.6	24.0	23.4	24.0	22.7	86.5	87.0	85.5	86.0
July	30.1	29.8	30.5	30.2	22.8	22.5	22.6	23.7	86.0	85.0	86.5	86.0
August	30.5	30.5	33.1	30.3	23.5	23.4	23.8	21.9	83.5	83.5	84.0	85.0
September	32.1	32.3	32.5	32.4	22.2	22.3	23.0	21.8	81.0	82.0	81.5	82.0
October	32.0	32.1	32.6	32.0	22.0	22.2	21.8	22.0	83.5	85.0	84.0	85.0
November	31.0	30.6	31.2	31.6	23.0	22.5	21.9	21.2	82.0	83.0	82.5	81.0
December	32.0	31.1	31.8	31.8	21.5	20.9	20.2	20.2	72.5	75.5	73.5	74.0

Plate 1. View of the site of Experiment I

Plate 2. View of the site of Experiment II


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AGRONOMY
Project
Dynamics
Investigator. PRATHAPAN K
Major Advisor
Clone
Covercrop

Plate 3. Comparision of covercropped plot with absolute control (immature)

Plate 4. Comparison of covercropped plot with absolute control (mature)


CONTROL

Plate 5. Comparison of wintering in covercropped and absoulte control plot

Plate 6. Level 10:30:30 applied *Pueraria phaseoloides* plot

Plate 7. Level 10:30:30 applied *Mucuna bracteata* plot


Pueraria phaseoloide
:30:30


Mucuna bracteata
10:30:30

EFFECT OF COVER CROPS ON NUTRIENT DYNAMICS IN THE RUBBER PLANTATIONS

BY

K. PRATHAPAN

ABSTRACT OF THE THESIS
SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENT FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY
FACULTY OF AGRICULTURE
KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF AGRONOMY
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM

1995

ABSTRACT

Three field experiments were conducted at Bethany Estate, Mukkampala, Kanyakumari District from February 1991 to October 1993 to study the effect of cover crops on the nutrient dynamics in immature, mature rubber plantation and in an open area.

In Experiment I there were two cover crops viz. Pueraria phaseoloides and Mucuna bracteata and five levels of NPK viz. 0:0:0, 0:30:30, 10:30:30, 0:60:60 and 10:60:60 with one year old RRII-105, replicated thrice and statistically laid in RBD. In Experiment II there was one cover crop Mucuna sp alone with five levels of NPK as above with 8 years old RRII-105 replicated 4 times and statistically laid in RBD. In Expt. III there were 10 microplots, with both cover crops.

N, P, K, Ca, Mg content of both Hevea and cover crops were increasing as the crops growth progressed. Fertilizer application to cover crops improved the Hevea leaf nutrient content than the absolute control. Among the levels 10:30:30 was found optimum. Mucuna was found better than Pueraria in increasing the Hevea leaf nutrient content.

Girth increment was better with 10:30:30. This was found to be optimum under both experiments. More height increment was observed in this level, as well as in cover cropped treatments when compared to absolute control.

Biomass production of cover crops were maximum at 10:60:60 followed by 10:30:30 under both experiments. Biomass production, root weight and length were higher in Mucuna and it was found increasing as the crop growth progressed. Nodule count was higher in Pueraria and the fresh weight of nodule per plant was higher in Mucuna as the size of its nodule was found bigger.

Soil moisture retention capacity was found higher under cover cropped plots at both shallow (0-30cm) and deeper (30-60cm) soil depths at -0.033 and -1.5 MPa pressures than control. Pore space and aggregation percentage were improved where as bulk density decreased. Among the levels of NPK 10:30:30 was found optimum in improving the soil physical properties. The percentage of improvement was found greater at shallow depth of soil than deeper. Soil moisture content during summer months were improved in the cover cropped area. The soil moisture in than the top soil (0-30cm) was lesser than the bottom soil (30-60cm) in Pueraria grown plots. This trend was reverse in the case of Mucuna.

Growing of cover crops improved the microbial population of bacteria, fungi and phosphate solubilising organisms. The level 10:30:30 was found optimum for the better microbial activity.

10:30:30 was found optimum for better yield and Latex Flow Characteristics. Covercropping has increased the latex yield by 15-20%. .1h10

10:30:30 was optimum for better leaf litter production of Hevea. In cover cropped plots the leaf litter production was higher and wintering was delayed by 26-30 days over the control. This has enhanced 10 additional tapping days.

Girth is positively correlated with cover crop biomass, nutrient uptake, soil available nutrients, soil moisture contents and Hevea leaf nutrient contents. Strongest correlation for girth was found with Hevea leaf N content, and uptake of N by cover crops, suggesting the importance of foliar diagnosis. Yield was negatively correlated with Mg content of soil.