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RUBBER RESEARCH INSTITUTE OF SRI LANKA

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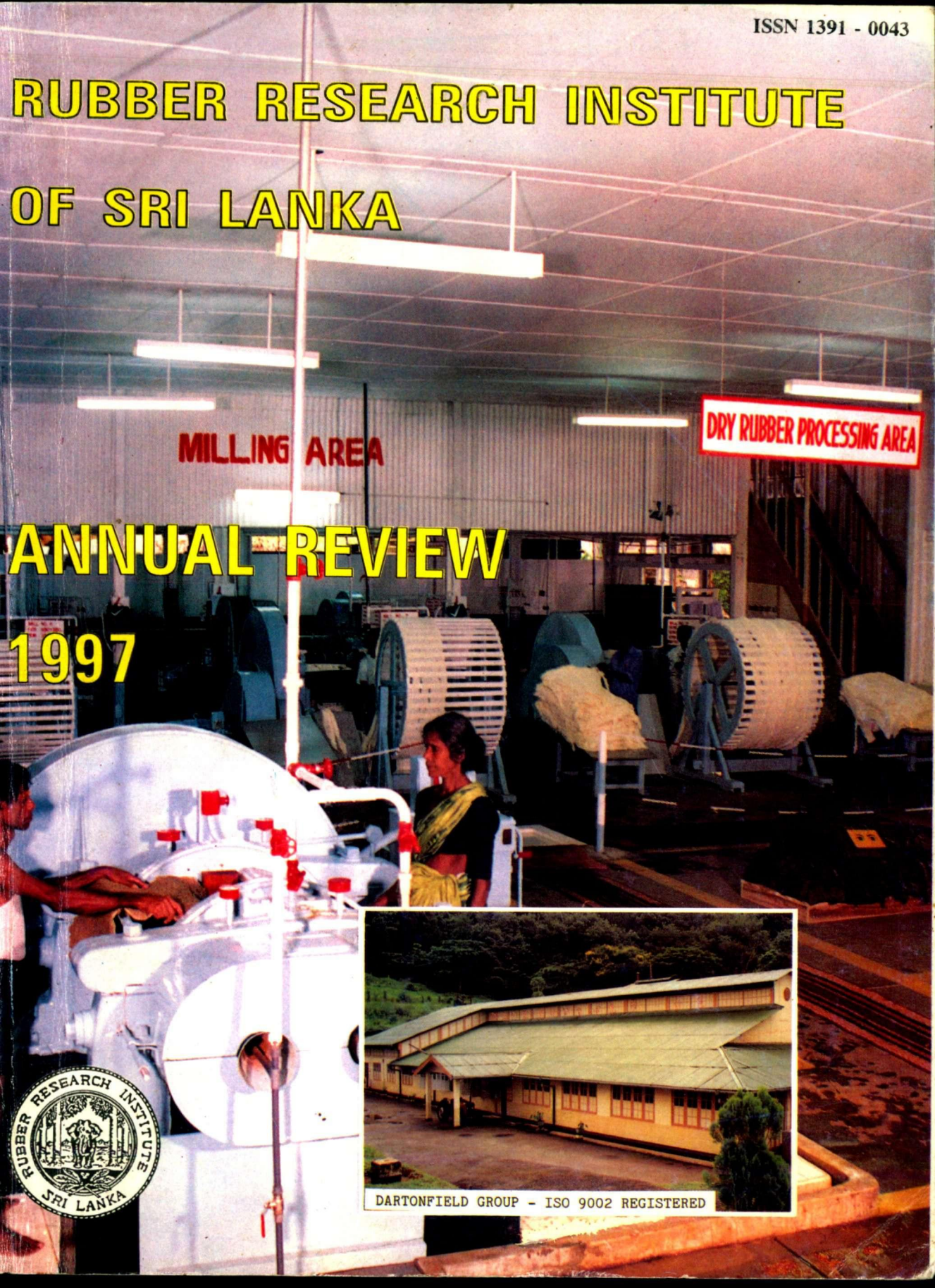

Cover : ISO 9002 Registered Dartonfield Crepe Rubber Factory.
Photographs by : Wimal Amaratunge.

Rubber Research Institute of Sri Lanka

Annual Review - 1997

1st January 1997 to 31st December 1997

Editors
L M K Tillekeratne, PhD (Aston)
N Yogaratnam, PhD (Lond.)

Headquarters & Laboratories
Dartonfield
Agalawatta

Board Office & Laboratories
Telawala Road
Ratmalana

CONTENTS

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Mr C W Abeysuriya, Rubber Development Department, P.O. Box No.184, Colombo

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Mr Harin Weerasinghe, Forbes Plantations Ltd., 46/38, Nawam Mawatha, Colombo 2

Mr N L D Ariyaratne, Kahawatta Plantations Ltd., Seva Mandiraya, 46/38, Nawam Mawatha, Colombo 2

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Mr D Madawela, General Manager, Balangoda Plantations Ltd., P.O. Box No.6, Ratnapura

Provident Fund Committee

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Dr L M K Tillekeratne, Director, RRISL
Mr B M S Bandaranayake, Secretary
Mrs L J C Perera, Secretary, RRB
Mr S S Warnapura, Elected Committee Member
Mr W Kularatne, Elected Committee Member
Mr G H I Silva, Building Maintenance Officer, Rubber Development Department

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Confidential Clerk/Stenographer	Mrs P Balasooriya
Clerk/Typist	Mrs S N Munasinghe

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Attorney General's Department
(Government Institutions)
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Chartered Accountants
107/1, Elvitigala Mawatha
Colombo 8

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Corporate Branch
75, Janadhipathi Mawatha
Colombo 1

Bank of Ceylon
Agalawatta

Headquarters and Laboratories

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Rubber Research Institute - Substation
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Telephone: 034 - 47368

Rubber Research Institute - Substation
Kuruwita, Ratnapura

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Raw Rubber and Chemical Analysis Department
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	01 - 635852
Fax :	01 - 605171

RUBBER RESEARCH INSTITUTE OF SRI LANKA

STAFF

DIRECTORATE

Director	L M K Tillekeratne, BSc (Cey.), MSc (Aston), PhD (Aston), FI Chem C, FPRI, FNASSL
Deputy Director - Research (Biology)	N Yogaratnam, BSc Agric (Alld), PhD (Lond.)
Deputy Director - Research (Technology)	Mrs K G K de Silva, BSc (SL), MSc (SL), PhD (Aston) (w.e.f. 13.01.1997)

RESEARCH DEPARTMENTS

Genetics and Plant Breeding

Acting Head of Department	D P S T G Attanayake, BSc Agric (SL), PhD (Birm.)
Assistant Geneticist and Plant Breeder	Mrs S Herath, BSc Agric (SL)
Experimental Officer	K W Rupatunga
Senior Experimental Assistant	B M S G Peiris
Technical Officers	I D M J Sarath Kumara
	T M S K Gunasekera
	Miss A K Gamage
Clerk/Typist	Mrs S D P K L Peiris

Plant Science

Head of Department	R C W M R A Nugawela, BSc (SL), MSc (Lond.), PhD (Essex)

Botanists	Mrs G P W P P Seneviratne, BSc (SL), PhD (Bath)
	L S S Pathiratne, M I Biol, MSc (Reading), MPhil (SL)
Research Officer (Intercropping)	V H L Rodrigo, BSc Agric (SL), MSc (Essex), PhD (Wales)
Assistant Botanists	A M W K Senevirathna, BSc (SL), MSc (SL)
	K M G S N Kaluwewe, BSc (SL)
Experimental Officers	R B Gunaratne
	L S Kariyawasam
Senior Technical Officers	K A G B Amaratunga
	R P Karunasena
	Mrs G A S Wijesekera
Senior Experimental Assistant	S Wilbert
Technical Officers	Mrs C W Ranasinghe, BA (SL)
	Mrs R K Samarasekera
	U S Weerakoon
	T U K Silva
	M K P Perera
	W D M N de Alwis
	H P Peiris
	D L N de Zoysa
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Plant Pathology and Microbiology

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Plant Pathologists	A H R Jayaratne, BSc (SL), MSc (SL), PhD (Sheffield)
	K E Jayasuriya, MSc Agronomy (USSR), MPhil (Edinburgh)
	Miss W P K Silva, BSc (SL), MSc (SL)
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Senior Technical Officer	Mrs P C Wettasinghe
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	Miss T H P S Fernando, BSc (SL)
	Miss E A D D Siriwardene
	Miss U M S Priyanka
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Audio Visual Aids Production Officer	L W Amaratunge

Soils and Plant Nutrition

Head of Department	Mrs M L A Samarappuli, BSc Agric (SL), MSc (California), PhD (SL)
Soils Chemist	D M A P Dissanayake, BSc Agric (SL), PhD (Aberdeen)
Assistant Soils Chemist	R S Dharmakeerthi, BSc Agric (SL), MSc (SL)
Experimental Officers	A M A Perera
	H D S P Perera, BSc (SL)
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	A N Yakandawala
	T B Dissanayake
	M D C Seneviratne (up to 28.10.1997)
	Mrs H D D Senaratne
	Miss V U Edirimanne
	Miss A P Thewarapperuma
	P A C R Puhambugoda, Dip. Agric.
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Technical Officer	D Ramawickrema
Specification Assistant	P D J Rodrigo

Polymer Chemistry

Head of Department	Mrs K G K de Silva, BSc (SL), MSc (SL), PhD (Aston)
Rubber Chemist	Mrs S A P P Gunatilleke, BSc (SL), PhD (Sussex) (up to 21.07.1997)

Experimental Officers	H N K K Chandralal, BSc (SL), MSc (SL)
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Senior Technical Officers	Mrs W C M Kuruppu
	S S Warnapura
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	Miss D M S Wijesekera
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Raw Rubber and Chemical Analysis

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Assistant Rubber Chemist	*Mrs J A G S G Gunawardena, BSc (SL), MSc (SL)
Senior Technical Officer	Mrs L Wanigatunga
Technical Officers	Mrs K N A Baduge, BA (SL)
	Mrs H V K Gamage
	Mrs C S Lokuge
	R S Wijesundera
	G Wanigatunga
	P L Perera
	L P P Vitharana
	Miss R P G R Rajapakse, BSc (SL)
	C M Gamage
Specification Assistants	B Gunasiri
	K R N Karunatilleke

Specification Assistants	W D Wimaladasa
	J A Sarath Chandrasiri
Clerk/Typist	Mrs I Wijesinghe

Electronic Instruments Repair Unit

Instrument Technician	**L G P Lelwela

Rubber Technology and Development

Head of Department	Mrs N M V K Liyanage, BSc (SL), PhD (Lond.)
Assistant Rubber Chemists	Mrs H M M de S Jayasuriya, BSc (SL), MSc (SL)
	*Mrs D G Edirisinghe, BSc (SL), MSc (SL)
Experimental Officer	Mrs H S Weeraman
Senior Technical Officer	Mrs M K Mahanama
Technical Officers	Mrs S I Yapa
	K M U Mitranande

Raw Rubber Process Development and Chemical Engineering

Head of Department	W M G Senevirante, BSc (SL), PhD (Sussex)
Assistant Rubber Chemist	S Siriwardena, BSc (SL), MSc (Australia)
Research Assistant	R M U N Ratnayake, BSc (SL)
Experimental Officer	P H Sarath Kumara, DPRI
Technical Officers	Mrs W K C Nalinie
	T A S Siriwardene
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Biometry Section

Assistant Biometrician	Mrs B W Wijesuriya, BSc Agric (SL), MPhil (SL)
Senior Technical Officer	Mrs N Wanigatunga
Technical Officers	Mrs H K D C S Munasinghe
	Miss K V V S Kudaligama, BSc (SL)
	O V Abayawardana

Adaptive Research Unit

Research Assistant/Agronomy	S M M Iqbal, BSc Agric (SL), MPhil (SL)
Development Officers	P P Jayasinghe, LPRI
	K B A Karunasekera
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	R M A K B Naranpanawa, BSc Agric (SL)

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Librarian and Publications Officer	Mrs Kamani Perera (ASLLA) (up to 30.11.1997)

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	P R N Pandikorala, BSc Agric (Cey.) (Colombo Office) (up to 01.10.1997)
Assistant Medical Practitioner	K V de Silva, A.M.P., Ayur. M.P., M.Ac.F., M.M.A., F.Ac.F., M.F.Hom. (SL), R.M.C.I.Ac. & N.M. (UK)
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Pharmacist	S Lankeshwara

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	Mrs K Jagoda, BA (SL)
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	G A Kannangara
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	Mrs Irene Perera
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	Mrs K Kapuge

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	Mrs R Handungoda
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Assistant Purchasing Officer	K D Sumanasena

DARTONFIELD GROUP

Acting Estate Superintendent	R C W M R A Nugawela, BSc (SL), MSc (Lond), PhD (Essex) (up to 17.04.1997)
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Chief Clerk	P Kannangara
Senior Clerk	K K P Gunawardena
Junior Clerks	Mrs C Dissanayake
	Mrs S I K Pathirage
	A K D A Wickremasinghe
Factory Officer	D S K Ranaweera
Assistant Factory Officer	W D D Senanayake
Field Officers	S K S de Silva (attending to Estate Office Work)
	J A Wimalasena
	T Somaratne
Assistant Field Officers	H M J Premalal
	N L D Reggie
	S R Vadivel

Junior Assistant Field Officers	K A Sarath Kumara
	B M Siriwardena
	J K Nakandala
	N L D Nihal

Kuruwita Sub-Station

Visiting Superintendent	N M Cooray
Assistant Estate Superintendent	S A R Samarasekera
Assistant Field Officer	A K D I Rukmal

* On study leave overseas

** On no pay leave overse

PRESIDENTIAL AWARD FOR INVENTORS - 1997
Consolation prize

Mr P L Perera, a Technical Officer attached to the Institute was awarded a consolation prize of the Presidential award for inventors 1997 for his development of an automatic filling and zero setting burette used in non aqueous titration. Mr Perera was awarded a cash prize and a certificate for this invention by Her Excellency the President on the 11th March 1998.

RUBBER RESEARCH INSTITUTE OF SRI LANKA

DIRECTOR'S REVIEW

L M K Tillekeratne

The rubber production in the country in the first half of 1997 was progressing well aiming at a total production at least equal to the production figures of 1996. However, with the currency turmoil in Asia, situation was on a severe off balance from the beginning of July. This currency turmoil in Asia began with the devaluation of the Thai - Bhat on the 2nd July 1997 and then this turbulence spread to Indonesia, Malaysia, Philippines, South Korea and to a lesser extent to Singapore, Taiwan and Japan. Their economy was badly affected as a result of the currency depreciation.

With the vast devaluation of the currencies in East Asian Countries (by about 20 to 210%) the price of Natural Rubber (NR) in terms of their respective local currencies went up especially in the major NR producing countries; Indonesia and Thailand. Due to this high price gained by the rubber producers, the production increased at a rate in East Asian Countries resulting in an over supply situation in the world market. Hence, the New York and London price of NR in term of hard currency, indicated a steady decline while the Kuala-Lumpur price of rubber showed an upward trend reflecting the effect of currency devaluation. Similarly with the currency devaluation, the export price (in pound or dollar terms) declined accordingly. Hence NR was sold at cheaper price to consuming countries. At the same time inputs became expensive. The long-term impact of this currency turmoil is still not clear. However, the most likely scenario is that (a) Increase in cost of production due to the high cost of imported machinery, chemicals and equipment (b) Reduction in the producers profit margin (c) High rate of inflation and (d) Reduced investment.

The world NR consumption in 1997 (up to Nov-97) was reported as 6.39 million tons, 96,000 tons above the world total production during that period. However, due to the recent economic crisis, demand for NR in the far east, including Korea and Japan, will be reduced. This would further reduce rubber prices. Moreover with the record reduction in the new car registration in Japan and with the world NR stock reaching a record high level of two million tones, the price of NR is not expected to improve in the foreseeable future. However, the World Bank and the EIU have predicted NR price to rise sharply in 1998. But operators believe that it will remain low for a certain period of time. Nevertheless, the NR price could increase in the international market if a social unrest develops in producing countries

due to the deepening of the recession and thereby creating a cut down (shortage) in NR production.

However, most economists have predicted that a shortage of NR in the world market will occur by the turn of the century. Yet, such perception may not materialize due to the unknown implications of the recent currency turmoil.

Depreciation of Asian currencies against the US $ from 1st July 1997 to 14th January 1998

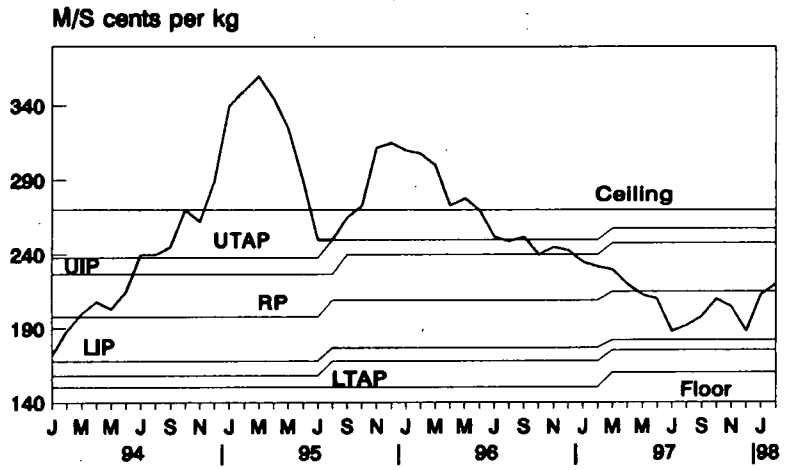
		Exchange rate (per US $)		
Country	Currency	On 01.07.97	On 14.01.98	% Depreciation
Malaysia	RM	2.52	4.35	73
Singapore	S$	1.43	1.75	23
Thailand	Bhat	24.10	50.80	111
Indonesia	Rupee	2431	7475	207

Change in rubber price in Malaysia compared to Sri Lanka

		Price of RSS per kg (FOB)		
Country	Currency	On 01.07.97	On 14.01.98	% Change
Malaysia	RM	250.50	292.00	+ 17%
Sri Lanka	Rupee	50.28	40.28	- 32%
	US $	0.838	0.649	- 30%

International Natural Rubber Organization (INRO) could not intervene to help the rubber growers in the world because, since Oct. 1997, DMIP of rubber in the market was only slightly bellow the reference price of M/S 214.95 cts/Kg. Which is still M/S 23 cents above the may buy level. INRO member countries are now planing to express DMIP in S$ cents or in US$ cents to overcome this situation in the future. As a result of the currency crisis the local FOB price of all major grades of NR declined in the world market. RSS and TSR, were the grades mostly effected from this currency crisis. However crepe rubber which has already reached Niche states was not affected at all. Latex crepe 1X grade fetched a price not less than Rs.79 per Kg while sole crepe was fetching over Rs.130 per Kg.

INRO DMIP, Jan'94 - Feb'98



Source : INRO

UTAP - Upper Trigger Action Price
RP - Reference Price
LTAP - Lower Trigger Action Price
UIP - Upper Intervention Price
LIP - Lower Intervention Price

Price of centrifuged latex in the world market declined rapidly and at one stage the price of one dry Kg of centrifuged latex was more than Rs 25 below the price of a dry Kg of centrifuged latex sold in Sri Lanka. Hence, the local rubber product manufacturers, particularly the gloves manufacturers were badly affected as their competitors in South East Asian (SEA) countries offered examination gloves at a very much lower price than the price quoted by the Sri Lanka manufacturers. In order to rectify this situation the rubber product manufacturers operate under the BOI sought permission to import cheap latex from Thailand and Malaysia. But, the prompt action taken by the authorities prevented them from placing orders for large scale imports of latex from SEA. The total amount of latex imported under this conditions so far is less than 2.5% of the total rubber requirement in the country. Hence, it is unfair to blame that importation of foreign latex effected the domestic market price of the rubber. However, purchase of latex from SHH of the country by the latex concentrate manufactures have reduced tremendously during the last few months. This low consumption of SHH latex by the BOI approved projects is due to many other reasons.

However, during this exercise it was observed that Sri Lanka has imported approximately 1,000 MT of reclaimed rubber annually, mainly from India, for the rubber product industries.. Reclaimed rubber, being a very low quality material containing less than 60% NR, is recommended to be used blended with good quality rubber for non dynamic products like carpets and for mixing with bitumen in road surfacing. But, when such material is used by the tyre retreaders in large proportion in their formulations, naturally the quality of retrads go bellow the standard and the poor consumers have to bear that loss too. Further, users of reclaimed rubber does not have to pay the defense levy and the excise duty too. Hence, this was reported to the authorities concerned to take immediate appropriate action to restrict the importation of reclaimed rubber. It should also emphasize here that Sri Lanka has been importing about 1,000 MT of reclaimed rubber while exporting nearly 3,000 MT of reclaimed rubber annually. It is clear that the importation of reclaimed rubber has effected the domestic price of low grade sheet and scrap crepe rubber in a big way.

Indian NR prices are at a four year low as world demand has fallen and stocks held by the government have climbed to more than 170,000 MT ; which is sufficient for the Indian rubber Industry for 3-4 months. According to Indian Rubber Board, Indian NR production in 1997 - 1998 will rise by 41,000 MT; but the consumption will grow only by 17,000 MT as the automobile industry which is the single biggest consumer of NR is hit by recession. This will effect the marketing of Sri Lankan rubber to some extent as India imports a fair amount of NR, specially low grades of RSS, from Sri Lanka annually.

Hence, it is necessary for the authorities in Sri Lanka to upgrade the quality of RSS produced by the smallholders in the future, otherwise finding markets for such low grade will become a problem. At present, due to the bulk purchasing system operating at the village level, the production of RSS 1 has dropped to as low as 14% and production of low grades are on the increase.

Although Sri Lanka has been able to achieve Niche states for the latex crepe rubber enjoying premium of nearly 100% over RSS; this situation will prevail only until the producers maintain the quality of this top grade which is used for the manufacture of food and pharmaceutical rubber appliances and infant toys. If the quality deteriorates the situation can change overnight. Hence, obtaining ISO 9000 registration for all the latex crepe factories in the country is of paramount importance to maintain this status in the future.

The predicted El-Nino effect may have an impact on Asian countries in the 1st half of 1998. Nevertheless, it will have rather low impact on rubber plantation unlike in tea. However, instructions were given to estates and SHH to be vigilant about timing their replanting periods and also to use mulching materials in young plantations to minimize the mortality rates. However, there is no reason for rubber

farmers to be extra vigilant about this prediction as this prediction can go wrong easily with a slight variation in the atmosphere.

It was reported last year that in order to bring the RRIC 102 population in the country to the acceptable level of 33%, issuing RRIC 100 plants from the nurseries was restricted and RRIC 102 plants were given instead. Later it has been observed that the clone population in immature areas of the estates sector too needs correction. Though RRI has recommended to plant RRIC 100, 102 121, PB 28/59, and PB 217 in equal proportions, according to statistics of clone population in their immature areas as reported by Plantation Companies are, RRIC 100- 55% , RRIC 121- 21% and RRIC 102 - 2%. But, the planted area of other two recommended clones PB 217 is almost negligible while the PB 28/59 extent is zero.

PB 28/59 and PB 217 are recommended for areas getting rainfall bellow 3750 mm per annum; as they are susceptible to leaf diseases at high humidity levels. But, there is an added advantage in both these clones. Since they are tapped once in every three days, the tappers requirement in these blocks is reduced by 33%. From the available data from estates, PB 28/59 has given an yield of over 1800 Kg/ha/year in almost all the places. Hence, it is essential that all plantations should follow these instructions carefully and replant new fields strictly according to the RRI recommendations. This would eliminate the possibility of a particular pathogen effecting the entire rubber plantation in the country which could happen when a suceptible mono clone is planted all over.

RRI is well aware of the fact that there should be several clones in the basket recommended by the RRI for estates to plant. But we are not prepared to face for problems of the nature of *Corynespora* effected RRIC 103 recommended for smallholders to plant in the wet-zone without fully studying it in Sri Lanka for 15 years. Further, any particular clone performing well in an other country cannot be blindly recommend for planting in Sri Lanka without studying it for the complete period of 15 years.

Research

Institute's planting recommendations were revised to upgrade three clones *viz.* RRIC 117, RRIC 130 and PB 235 into the group II where planting of each of these clones up to 25 ha is recommended. Two new clones RRISL 200 and RRISL 203 were also added to the group IV of the recommended clones.

In trees opened at higher girth, the g/t/t is higher. Low Frequency Tapping (LFT) continues to give a higher g/t/t and similar YPH to ½S d/2 tapping. Incidence of TPD is similar with ½S d/2 and ½S d/3 +E tapping systems. LFT on clone PB 86 in the smallholder sector also gives similar results. The response to stimulation is poor in clones recommended for d/3 tapping, *eg.* RRIC 101. Commencing to tap

B1-1 and B1-2 panels at the initial height of opening, gives relatively higher yields than opening above initial height of opening. Exploiting higher panels upward gives better yields than exploiting downwards.

Planting double rows, with a wider space between two double rows, appears to be more appropriate for intercropping rubber with perennial crops.

Flemingia congesta and *Crotolaria anagyroides* were identified as tree legume species that can be grown successfully between the rows of rubber plants and which would provide sufficient biomass for mulching; *Flemingia* from the beginning of year 2 until the end of immature period of rubber and possibly even during the mature phase, whereas *Crotolaria* from 3 months after planting until the end of year 2.

Combination of Paraquet with other herbicides are more effective than Paraquet alone for weed control under rubber. On the other hand, application of Glyphosate alone is more effective than Glyphosate based herbicide mixtures.

Foliar feeding of NPK and Mg alone without soil application is not an efficient method of fertilizer application for rubber plants raised by young budding technique. It also appears that currently recommended soil application of soluble fertilizer formulation is more effective compared to soil application with foliar feeds in relation to plant growth.

Secondary leaf fall was mild in all rubber growing districts during the refoliation period. Though the abnormal leaf fall was extremely mild during the early months of the South West monsoon season, a considerable leaf fall was seen on susceptible clones, PB 86 and RRIC 121 towards the latter part of the year. Anvil (hexaconazole) was recommended as an effective fungicide in controlling *Rigidoporus lignosus*, the causative agent of white root disease of *Hevea* rubber.

Adaptive research programmes on clone evaluation, soil and moisture conservation practices, organic manure and nursery techniques techniques were in progress.

The compatibility, morphology and mechanical properties of a range of blends of Polypropylene and treated tyre crumbs were characterized. Biodegradable shopping bags were developed using natural rubber latex as the coating material for cotton based woven bags. Improvements were also made in conductive rubber pads used in muscle tonning machines. Rubber wood fibers and trimmings were used in Medium Density Fiber (MDF) board manufacture.

Maturation period of centrifuged NR latex prior to irradiation was found to influence the technological properties and N_2 content of leached and aged RVNRL films. Some NR/bitumen based vulcanisable hard backings for coir based carpets were developed.

Effluent treatment by anaerobic coupled with aerobic mechanism which were developed and introduced in five rubber factories are in full operation. Distillery and

meat processing waste water which contains high level of organic matter were also found to be readily digested under properly acclimatized anaerobic conditions. It was observed that a system efficiency of 17% could be achieved with the green house type dryer developed for drying of sheet rubber.

OVERSEAS VISITORS

Mr Pierre Narboux. Paris. France
Mr. M Brahman. Regional Research Laboratory. India
Prof. A Chisholm. Australia
Mrs A Chilsholm. Australia

GENETICS AND PLANT BREEDING

D P S T G Attanayaka

SUMMARY

RRISL planting recommendations were revised to upgrade three clones *viz.* RRIC 117, RRIC 130 and PB 235 into the group II where planting of each of these clones up to 25 ha is recommended. Two new clones RRISL 200 and RRISL 203 were also added to the group IV of the recommended clones. It was agreed at the Scientific Committee meeting to adopt ½S d/3 system throughout in tapping the high yielding clone RRIC 130.

The construction work of the new gene-technology laboratory was completed.

DETAILED REVIEW

Staff

Dr D P S T G Attanayake, Geneticist and Plant Breeder, was appointed as the Acting Head of Genetics & Plant Breeding Department with effect from 2nd October 1997. Mrs S P Herath, Assistant Geneticist and Plant Breeder, Mr K B Karunasekera, Development Officer, Mr K W Rupatunga, Experimental Officer, Mr B M S G Peries, Senior Experimental Assistant, Mr I D M J Sarath Kumara Technical Officer were on duty throughout the year. Miss A K Gamage and Mr T M S K Gunasekera assumed duties as Technical Officers with effect from 3rd June 1997. Mrs S D P K L Pieris assumed duties as clerk/Typist with effect from 3rd July 1997. Mr R A S K Ranatunge Technical Officer resigned from the Institute with effect from 8th May 1997.

Meetings and Workshops

Dr D P S T G Attanayaka attended the scientific committee meetings and spoke on Revised clone recommendation at the meeting held on 29 August 1997.

Third meeting of the Plant Biotechnology Working Group was organised by the Genetics and Plant Breeding Department in collaboration with Dr Priyani Seneviratne and Miss W P K Silva under the guidance of Dr N Yogaratnam, Deputy Director Research of the Institute. Forty three participants were present on this occasion.

Mrs S P Herath spoke on DNA technology in the improvement of the rubber tree at the third meeting of the Plant Biotechnology Working Group.

Research students/training

Mrs K Vivekananthan, completed her thesis on "Preliminary studies towards developing molecular markers for the improvement of *Hevea brasiliensis*" under the joint supervision of Dr D P S T G Attanayaka and Prof. Eric H Karunanayake of the Colombo Medical faculty which was submitted to the University of Colombo in partial fulfillment of the requirement for the MSc degree.

Four students who were following the National Diploma in Technology Apprentices Programme obtained training in this department during their in-plant training at RRI.

Miss T R Ukwattage a student of the Aquinas College of Higher studies obtained her training in this Department and completed a report in Sinhala medium on the Development of Clones and their usefulness to the rubber industry.

LABORATORY INVESTIGATIONS

Molecular biology of *Hevea* GPB/MM/97

RFLP studies were continued with six DNA probes identified from the preliminary experiments. These six probes were divided into two pools. Each pool of probes were labeled with p32 and used in the Southern analysis of genomic DNA isolated from clones RRIC 121, GPS I, RRIC 102, GPS II digested with restriction enzymes EcoR I, EcoR V, Dra I and Sac I.

Both sets of pools identified the genetic differences of the rubber clones, more significantly the differences of the genotypes RRIC 102 and GPS I. Further it was revealed that the clones RRIC 121 and RRIC 102 could be differentiated on Eco R V and Sac I blots by probe number 42.

The technique of RAPD was also used to identify the genetic differences among the rubber clones. RAPD analysis using twelve 10-mer primers showed extremely good results. Six random primers produced genetic polymorphisms out of which the primer OPB 4 was found to be the best in detecting the genetic variation among the *Hevea* clones (D P S T G Attanayaka, S Herath and E H Karunanayaka, Colombo Medical Faculty).

FIELD EXPERIMENTS

Hand pollination programme for 1997(GPB/BST/HP/97)

Mother trees of RRIC 121 and RRIC 100 from the Dartonfield group and PB 260 from the Malaboda division were selected for the cross pollination programme. The number of pollinations done in each cross, number of pods harvested and seedlings obtained are given in Table 1 (D P S T G Attanayaka, K B Karunasekera and I D M J Sarath Kumara).

Table 1. *Details of 1997 hand pollination programme*

Cross	No. of pollinations	No. of pods harvested	No. of seedlings
RRIC 121 x RRIC 121	251	-	
RRIC 121 x PB 260	42	-	
RRIC 100 x 36-25	30	02	03
RRIC 100 x PB 260	66	03	06
RRIC 100 x GPS I	82	03	08
PB 260 x RRIC 100	297	20	58
PB 260 x RRIC 130	45	05	08
GPS I x GPS I	98	-	
GPS I x RRIC 121	585	06	
Total	1496	39	83

Evaluation of selections from 1974 hand pollinated (H.P.) Seedlings at Kuruwita Sub-station (GPB/BST/HPS/74/3)

Only promising genotypes (07) along with control clone. RRIC 121 were test tapped. Table 2 shows the Mean yield and Mean girth of these selections.

The control clone. RRIC 121 has given the highest yield and the highest girth. RRISL 201 continued to register the highest girth among promising genotypes (D P S T G Attanayaka. B M S G Peries and K B Karunasekera).

Table 2. *Mean yield in grams per tree per tapping (g/t/t) and mean girth of promising clones and the control (GPB/BST/HPS/74/3)*

Clone	Mean yield (g/t/t)	Mean girth (cm)
RRISL 200	83.06	85.5
RRISL 201	84.28	87.64
RRISL 202	76.97	80.89
RRISL 203	46.09	67.42
74-139	43.53	61.68
74-180	46.22	68.65
74-205	67.85	75.35
RRIC 121 (control)	98.18	91.25

Evaluation of 1975 H.P. Selections - Clyde Estate (GPB/BST/HPS/75/2)

Only two test tappings were carried out. Average yield of two RRISL clones, 205 and 204 recorded 48.09 and 26.76 (g/t/t) respectively. With respect to girth RRISL 205 had a mean girth of 100.5 cm while RRISL 204 recorded a mean girth of 77.89 cm. The control clones RRIC 121. RRIC 100 and RRIC 130 yielded 28.56, 14.92. 16.89 (g/t/t) respectively. The mean girth of the control clones in the same order was 84.4cm. 66.3 cm. and 57.94cm (D P S T G Attanayaka and I D M J Sarath Kumara).

Evaluation of 1976 H.P. Selections. Tempo Division, of Hillstream Estate. (GPB/BST/HPS/76/1)

From 1996 only 10 clones including two control clones (RRIC 100, and RRIC 121) have been selected for further testing. Table 3 summarises the mean yield and the girth obtained from these clones.

Table 3. *Mean yield tn grams per tree per tapping (g/t/t) and mean girth of promising clones and the control (GPB/BST/HPS/76/1)*

Clone	Mean yield (g/t/t)	Mean girth (cm)
76-121	32.78	71.19
76-158	49.55	74.19
76-182	79.81	80.58
76-198	51.53	78.01
76-52	75.81	83.00
76-8	57.80	89.79
76-82	53.44	82.81
76-9	39.19	68.29
RRIC 100	46.78	70.62
RRIC 121	70.81	87.20

The clones 76-182 and 76-52 has given the mean yields higher than the control clone, RRIC 121. The highest mean girth was recorded by the clone 76-9 (D P S T G Attanayaka and K W Rupatunge).

1979 H.P. Seedlings - Eladuwa Estate (GPB/BST/HPS/79/1)

Average yield and the mean girth (1997) of this seedling population are given in Table 4.

Table 4. *Average yield and girth of 1979 HP seedlings (GPB/BST/HPS/79/1)*

Clone	Average yield (g/t/t)	Mean girth (cm)
79-347 (RRISL 207)	66.60	88.50
79-457	27.00	73.50
79-42	74.50	80.00
79-337	49.16	73.00
79-292	44.30	74.50
79-458	31.16	82.00
79-145	55.00	73.55
79-466 (RRISL 209)	65.30	80.50
79-255	32.50	73.50
79-341	27.80	87.50

(D P S T G Attanayaka and I D M J Sarath Kumara).

Evaluation of 1980 H.P. Seedlings - Eladuwa Estate (GPB/BST/HPS/80/2)

Mean yield and mean girth (1997) of this seedling population are given in Table 5.

The mother tree of RRISL 214 was unscored due to the occurrence of TPD.

Table 5. *Mean yield and mean girth of promising H.P. seedlings*

Clone	Average yield for 1997 (g/t/t)	Mean girth 1997 (cm)
RRISL 212	47.16	83.00
RRISL 213	27.60	85.50
RRISL 215	124.16	108.0
RRISL 216	32.0	84.5

(D P S T G Attanayaka and I D M J Sarath Kumara).

Evaluation of 1981 H.P. seedlings - Eladuwa estate (GPB/BST/HPS/81/2)

Yield and girth data of the clones RRISL 217, RRISL 221, RRISL 224, RRISL 226, RRISL 227 and 81-197 have not been recorded due to the loss of trees by wind damage and tapping panel dryness.

Mean girth and mean yield of the other RRISL 200 series clones are given in Table 6.

Table 6. *Mean yield and mean girth of promising H.P. seedlings*

Clone	Mean yield 1996 (g/t/t)	Mean girth (cm)
81-30 (RRISL 218)	44.28	96.50
81-50 (RRISL 219)	57.60	78.00
81-111 (RRISL 220)	57.64	93.00
81-192 (RRISL 222)	49.66	82.50
81-69	87.00	93.50

(D P S T G Attanayaka, I D M J Sarath Kumara and K B Karunasekera).

Evaluation of 1982 H.P. selections - Clyde estate (GPB/BST/HPS/82/2)

In this trial 61 new clones are being tested along with five control clones. Five test tappings were possible during this year which was the second year of tapping in this planting. Table 7 shows the mean yield and the girth of three new promising selections along with the performances of the control clones.

Table 7. *Mean yield and mean girth of promising H.P. seedlings Clyde estate (GPB/BST/HPS/82/2)*

Clone	Mean yield (g/t/t)	Mean girth cm
82 - 15	63.19	71.38
82-140	50.61	71.00
82-110	39.43	73.05
RRIC 100	29.52	62.54
RRIC 102	40.33	68.97
RRIC 121	41.02	67.67
RRIM 600	28.25	57.78

(D P S T G Attanayaka, K W Rupatunga and K B Karunasekera).

Evaluation of 1985 H.P. Selections - Tempo Division, Hillstream Estate. (GPB/BST/HPS/85/2)

The mean g/t/t yield of the first year of tapping and the mean girth of the best four HP clones along with the performances of the control clones are given in Table 8.

Table 8. *Mean yield and mean girth of promising H.P. clones-Tempo Divisio (GPB/BST/HPS/85/2)*

Clone	Mean yield (g/t/t)	Mean girth cm.
85-28	29.06	62.91
RRIC 102	28.19	64.16
85-31	26.00	61.00
85-18	25.25	65.36
RRIC 121	23.58	63.73
85-3	23.56	55.00
RRIC 100	23.38	59.13
BPM 24	19.82	48.34

(D P S T G Attanayaka, K W Rupatunga and K B Karunasekera).

Testing of proven foreign clones received under SRRP (GPB/FC/SRRP/91/2)

A girth measurement was taken from all the experimental sites. Mean girth of clones planted in large trials (Eladuwa and Salawa Estate) are given in Table 9. On Eladuwa, one plot of each clone is planted and plot size is approximately 300 trees. On Salawa 2 such plots (P1 and P2) per clone have been planted.

Table 9. *Mean girth (cm) clones planted at Eladuwa and Salawa*

Clone	Eladuwa	Salawa	
		P1	P2
PB 217	48.06	44.81	46.75
RRIC 110	50.42	48.69	48.10
PB 260	51.48	44.62	47.48
PR 255	43.13	43.18	44.51
PR 261	43.13	47.12	41.43
PB 235	56.52	51.24	50.47
RRIC 121	52.07	47.55	46.32
BPM 24	49.57	43.52	44.62
RRIC 100	52.61	50.41	47.88
RRIM 712	46.01	37.79	40.59

Mean girth of clones in four small experiments (Three 25 tree plots per clone per site) are given in Table 10.

Table 10. *Mean girth (cm) of clones in four experimental sites*

Clone	Yatawatta	Bentota	Kuruwita	Atale
RRIC 121	39.91	49.91	47.90	57.78
PB 260	39.46	54.53	46.63	54.31
PB 235	37.21	58.42	51.74	55.79
RRIM 712	36.12	36.62	37.18	52.90
PR 255	35.01	40.30	37.09	52.55
BPM 24	33.68	43.68	38.43	49.62
PR 261	25.24	32.90	36.30	51.67

(D P S T G Attanayaka, K W Rupatunga, I D M J Sarath Kumara, B M S G Peiris, R A S K Ranatunga and K B Karunasekara).

Conservation and evaluation of the IRRDB germplasm (GPB/GP/85/2)

The *Hevea* germplasm collection was maintained by adopting routine agronomic practices. Clone 36-25 was used as a pollen parent in this year HP programme (D P S T G Attanayaka and K B Karunasekera).

Studies on clonal response to different combinations of N P K and Mg (GPB/SPN/NUT/94/2)

A girth measurement was recorded in this experiment. The experimental plot of the clone RRIC 110 at Tempo division which was found to be affected with *Corynespora* leaf disease was sprayed twice in the year with fungicides (D P S T G Attanayaka, S Dharamakeerthi, K B Karunasekera, K W Rupatunge and I D M J Sarath Kumara).

New Planting

Following observation plots of new clones were established in 1997. Details of the observation plots established are given in Table 11.

Table 11. *Details of observation plots established in 1997*

Clone	Estate/site	Planting season	No. of tapping tasks
RRISL 204	Vogan	S.W.	01
RRISL 205	do	do	01
RRISL 217	do	do	01
GPS I	do	do	01
RRISL 204	Neuchatle	S.W.	02
RRISL 205	do	do	02
RRISL 206	do	do	02
PB 255	Bibile	N.E.	01
GPSI	do	do	01
RRII 105	do	do	01

PLANT SCIENCE

A Nugawela

SUMMARY

RRIC 102 plants were distributed to Private Commercial Nursery owners to make this clone more available to the smallholder sector. Crown budding was undertaken to replace canopies susceptible for diseases. Young budding reduces immature period through improved and uniformity of girthing.

g/t/t is high when trees are opened at higher girth. Girth increment after tapping is similar in all girth classes tested. A clonal difference is apparent with regard for girthing after commencement of tapping.

Low Frequency Tapping (LFT) continues to give a higher g/t/t and similar YPH to ½S d/2 tapping. Incidence of TPD is similar with ½S d/2 and ½S d/3 +E tapping systems. LFT on clone PB 86 in the smallholder sector also gives similar results. The response to stimulation is poor in clones recommended for d/3 tapping, eg. RRIC 101. Commencing to tap B1-1 and B1-2 panels at the initial height of opening gives relatively higher yields than opening above initial height of opening. Exploiting higher panels upward gives better yields than exploiting downwards.

"Ethrel Super" and "Ethilin" novel yield stimulants were tested and their performance is similar to Ethrel. Planting 700 points/ha has not resulted in a significant competition even after 5 years from establishment.

Planting double rows, with a wider space between two double rows, appears to be more appropriate for intercropping rubber with other perennial crops. Alstornia appears to be a suitable timber species to interplant with rubber. Banana triple row intercrop system increases biomass productivity and economic yields. Increase in productivity is due to that of resource capture and on average radiation and water use are increased by 73 and 140% respectively. Though economic yields could be harvested initially, grasses get completely smothered after 4-5 years and also result in a negative influence on the growth of rubber plants.

DETAILED REVIEW

Staff

The Head of Department, Dr A Nugawela, Mr L S S Pathiratna, Botanist, Mr A M W K Seneviratna and Mr K M G S N Kaluwewa, Assistant Botanists, Mr R B Gunaratne and Mr L S Kariyawasam, Experimental Officers, Mr R P

Karunasena and Mr K A G B Amaratunge, and Mrs G A S Wijesekera, Senior Technical Officers, Mr S Wilbert, Senior Experimental Assistant, Mrs C W Ranasinghe, Mr U S Weerakoon, Mrs R K Samarasekera, Mr M K P Perera, Mr M N de Alwis and Mr H P Peries, Technical Officers and Mrs D E Jayawardena, Clerk/Typist were on duty throughout the year.

Dr (Mrs) P Seneviratna, Botanist went on maternity leave from 23.12.1997.

Dr V H L Rodrigo, Botanist, reported for work on 03.06.1997 after successfully completing his post-graduate studies in UK leading to a PhD.

Mr T U K Silva, Technical Officer was on study leave from 11.04.1997 to 11.08.1997.

Mr L P Vitharana, Technical Officer was transferred to Polymer Chemistry Department with effect from 03.06.1997. Mr Laknath Soyza, Technical Officer, assumed duties on 03.06.1997

Research students

Mr T U K Silva, an under graduate student from the University of Ruhuna completed his final year project on "Recovery tapping to minimize crop loss due to interference of rain on exploitation of *Hevea brasiliensis* Muell. Arg. plants" under supervision of Dr A Nugawela.

Miss K C Wasalathanthiri, an under graduate student from the University of Ruhuna completed her final year project on "The effect of spacing on growth and budgrafting success of seedling plants of *Hevea brasiliensis*" under supervision of Dr (Mrs) P Seneviratna.

Miss Ratnamali Walpita of Aquinas College completed her project for the Diploma Course on "The importance of vegetative propagation methods of rubber" under the supervision of Dr (Mrs) P Seneviratna.

Mr M Bandula, A MSc Student of University of Colombo completed his research project on "Clonal differences of *Hevea in vitro*" under the supervision of Dr (Mrs) P Seneviratna.

Meetings and Conferences

The Head of Department addressed at the following meetings and conferences:

* Scientific Committee Meetings. Dr (Mrs) P Seneviratne, Dr V H L Rodrigo and Mr L S S Pathiratna also participated.
* Estate Committee Meetings (up to April).

* Seminar for Planting Executives of Namunukula Plantations on increasing productivity.
* Field day at Atale Estate on Tapping for RPK Plantations.
* Field day at Rucastle Estate on Tapping for Bogawantalawa Plantations.
* Field day at Nakiadeniya Estate.
* Addressed on "Inadequacies in new clearings" for Planting Executives of Bogawantalawa Plantations.
* Seminar on Nursery Practices for Planting Executives and Field Staff of RPK Plantation Ltd..
* Field day at Yatadola Estate on "Tapping and Rainguards".
* Dr (Mrs) P Seneviratna addressed the Planting Executives of Kotagala Plantations on Exploitation and Planting Techniques.

The Department Staff also conducted the following programmes.

* Refresher course for Rubber Development Officers.
* Training programmes on Budgrafting. Young budding. Tapping and Rainguards.
* Seminars for mini-estate owners.

LABORATORY INVESTIGATIONS

Tissue culture

Successive grafting to induce juvenility is continued. Explants harvested from rejuvenated material were tested for the degree of juvenility *in vivo*. *In vitro* micro-grafting to rejuvenate clonal material is also being tested. The ability of axillary buds to proliferate was tested for different clones in different culture media (P Seneviratne, W Seneviratna and G A S Wijesekera).

FIELD EXPERIMENTS

Seed production

The study was restricted to Dartonfield Estate. As reported in the previous year, seed production and the germination rates were poor (P Seneviratna and L P Peries).

Rootstock nurseries

Studies on different spacing and thinning out systems are being continued (P Seneviratna and K A G B Amaratunga).

Budwood nurseries

The progress of RRIC 102 nurseries established in selected private commercial nurseries in all rubber growing regions were monitored.

A budwood nursery having 25 points from each of the 26 clones recommended for planting was established at Dartonfield Estate. Budded stumps raised will be issued to both Plantation and Smallholder sectors to establish multiplication nurseries (P Seneviratna, A Nugawela, U S Weerakoon and M N Alwis).

The effect of the quality of budwood on grafting success and scion growth was tested (P Seneviratna and G A S Wijesekera).

Young budding

Nurseries were established in selected Private Commercial Nurseries to popularise this technique. It is evident that more development work is needed to promote the technology of young budding in this sector (P Seneviratne, W Seneviratna and M N Alwis).

Polybag plants

Alternate methods for polybag plants are being tested (P Seneviratne and G A S Wijesekera).

Crown budding

Test tapping of RRIC 130 plants crown budded with *H. spruciana* yielded significantly than *Hevea spruciana*

The growth of RRIC 110 plants crown budded with clones RRIC 100, 102, 117, 130 and also with *Hevea spruciana* is being monitored (P Seneviratne, R B Gunaratna and M N Alwis).

Mist propagation and rooted cuttings

The growth of rooted cuttings established using clonal, juvenile and juvenility induced, *i.e.* by successive grafting, materials is being monitored. Cloning of high yielding genotypes through mist propagation had low success (P Seneviratne and G A S Wijesekera).

Mixed planting

The growth of the plants was badly affected by incidence of Phytophthora leaf disease (P Seneviratna, A Nugawela and H P Peiris).

Planting techniques

The objective of these experiments is to compare the performance, *i.e.* establishment rate and early growth of different types of planting material, in different agroclimatic conditions where rubber is grown in Sri Lanka.

Padukka (PT/91/1)

This trial was terminated during the year. Young buddings reached tappability relatively earlier than the other types of planting material tested (A Nugawela and K A G B Amaratunga).

Pallegama (PT/93/1)

The trial was established during South West 1993. The establishment success (%) of different types of planting material and the girth after 4 years of growth are given in Table 1.

Table 1. *The different types of planting material tested and their establishment success and growth after 4 years*

Planting material	Establishment Success (%)	Girth (cm)
Bare root green budding	91.0	36.98
Bare root brown budding	82.3	35.53
Green budding polybags	99.2	35.43
Young buddings	100.0	36.47
Brown budding polybags	98.8	34.38

When both establishment success and growth are considered young buddings are superior than other types of planting material tested (A Nugawela and K A G B Amaratunga).

Girth at opening

RRIC 130, 1990 Replanting - Dartonfield (TG/95/1)
RRIC 121, 1990 Replanting - Dartonfield (TG/95/2)
RRIC 100, 1990 Replanting - Dartonfield (TG/95/3)

From each clone above, trees from girth classes 42-44cm (GC1), 44-46cm (GC2) and 49-51cm (GC3) were selected. The following treatments were introduced randomly (single tree plots) for each clone. Twenty trees were assigned for each treatment. The trial commenced in 1995, and the data are reported in the Annual Review of same year.

Treatments

T_1 Commencing tapping at GC1
T_2 GC1 untapped trees
T_3 Commencing tapping at GC2
T_4 GC2 untapped trees
T_5 Commencing tapping at GC3
T_6 GC3 untapped trees
T_7 GC1 trees to be tapped when reach GC 2
T_8 GC 2 trees to be tapped when reach GC 3.

The mean yield, *i.e.* g/t/t for different clones and girth classes are given in Table 2.

Table 2. *The mean yield, i.e. g/t/t in 1997 when tapping commenced at different girths in different clones*

	Clones and Mean g/t/t			
Treatment	RRIC 130	RRIC 121	RRIC 100	Mean
T1	45.24	19.94	22.44	29.2
T2	44.75	25.16	27.01	32.3
T3	47.67	20.95	27.04	31.9
T4	51.11	25.95	31.09	36.1
T5	56.82	24.75	32.56	38.0

Generally, in all clones the g/t/t increases with increase in girth class.

The girth increment during the second year of tapping is less than that during the first year. Further, girthing after commencement of tapping continues to be less in clone RRIC 100 (Table 3).

Table 3. *Influence of girth at opening on the subsequent growth in clones RRIC 100, 121 and 130*

Clone	Treatment	Initial Girth (cm)	Girth Increment(cm) 1st year	2nd year
RRIC 100	T_1	41.9	4.5	3.5
	T_2	41.7	8.2	6.5
	T_3	44.6	4.8	3.5
	T_4	45.1	8.8	7.0
	T_5	50.2	3.7	4.5
	T_6	49.3	9.3	6.6
	T_7	42.0	8.3	3.9
	T_8	45.0	8.9	3.8
RRIC 121	T_1	42.2	5.1	4.3
	T_2	42.6	6.3	5.5
	T_3	44.9	5.2	4.2
	T_4	44.6	6.6	5.2
	T_5	49.6	6.2	4.5
	T_6	49.6	7.6	5.8
	T_7	42.6	7.1	4.1
	T_8	44.7	6.1	4.3
RRIC 130	T_1	42.9	4.9	4.2
	T_2	42.4	8.1	6.2
	T_3	44.6	5.7	5.5
	T_4	45.1	8.8	6.8
	T_5	49.5	5.7	5.0
	T_6	49.8	9.6	7.6
	T_7	42.6	8.2	3.9
	T_8	44.7	8.5	4.2

(A Nugawela, S Wilbert and R K Samarasekera).

RRIC 100, 192 Replanting - Yatadola

A girth at opening trial, similar to the one described above was initiated at Yatadola Estate in an RRIC 100 clearing.

Table 4. *The yield and girth increment at different girths of opening in genotype RRIC 100*

Treatment	Yield (g/t/t)	Girth Increment(cm)
T_1	18.73	5.9
T_2	-	7.8
T_3	21.17	5.3
T_4	-	7.9
T_5	26.89	5.7
T_6	-	8.7
T_7	-	8.1
T_8	-	8.3

Low frequency tapping

The objective of these trials is to find out whether it is more economical to exploit newly introduced clones with low frequency tapping with stimulation than though the presently recommended ½S d/2 system. Low frequency tapping systems can have the advantage of low tapping costs, low tapper requirement and longer tapping cycles.

RRIC 121, 1985 Replanting - Kiriwanaketiya (LFT/91/1)

Though the yield per tree per tapping (g/t/t) is highest in the ½S d/3 + E* system, the annual total yield is highest in the conventional ½S d/2 systems (Table 5).

Girth increment during the year is marginally high with conventional tapping. Incidence of tapping panel dryness is slightly lower in the low frequency tapping systems (Table 5).

Table 5. *Effect of low frequency tapping with stimulation on yield, growth and tapping panel dryness in clone RRIC 121*

Tapping system	Yield		Growth		TPD
	g/t/t	kg/t/year	Girth (cm)	increment (cm)	(%)
½S d/2	31.7	5.71	85.3	3.7	9
½S d/4+ E*(6/y)	43.1	3.88	80.3	3.0	7.4
½S d/3+E*(6/y)	39.4	4.73	80.7	2.6	7.1
½S d/3+ E*(4/y)	36.3	4.36	78.7	2.2	6.3

E* 2.5% ET, Ba 1.6(2.5)
(A Nugawela and S Wilbert)

RRIC 102, 1981 Replanting - Neuchatle (LFT/88/2)

The annual mean dry rubber yield per tree per tapping (g/t/t) is highest in the two ½S d/3 systems tested with 4 and 6 rounds of stimulations per annum. Further the total annual dry rubber yield per tree is also highest in these two systems (Table 6).

Table 6. *Effect of low frequency tapping with stimulation on yield, growth and tapping panel dryness in clone RRIC 121*

Tapping system	Yield		Girth (cm)	BRC (cm)
	g/t/t	kg/t/year		
½S d/2	27.2	3.73	71.6	20.4
½S d/3	47.0	4.42	73.2	16.6
½S d/3+E*(4/y)	64.9	6.10	73.2	17.3
½S d/4+E*(6/y)	52.7	3.27	73.7	15.5
½S d/3+ E*(6/y)	63.5	5.97	73.5	16.9

E* 2.5% ET, Ba 1.6(2.5)

The annual bark consumption rates are significantly less in low frequency tapping systems tested (A Nugawela and K A G B Amaratunga).

RRIC 100, 1981 Replanting - Gallewatta (LFT/88/1)

The yield per tree per tapping (g/t/t) and the total annual yield per tree are both highest in ½s d/3 +E* tapping system. Girth is not negatively affected by tapping with stimulation. Incidence of TPD is marginally high in the ½S d/3 + E* tapping system (Table 7).

Table 7. *Effect of low frequency tapping with stimulation on yield, growth and tapping panel dryness in clone RRIC 100*

Tapping system	Yield		Growth		TPD
	g/t/t	kg/t/year	Girth(cm)	Increment(cm)	(%)
½S d/2	34.2	6.16	80.14	1.3	7.6
½S d/2 + E*(6/y)	27.6	4.97	90.8	4.7	4.1
½S d/3 + E*(6/y)	55.3	6.64	85.9	3.6	10.2
½S d/4 + E*(6/y)	60.7	5.46	84.3	2.3	4.2

*E 2.5% ET, Ba 1.6(2.5).
(A Nugawela, S Wilbert and R K Samarasekera)

RRIC 100, 1991 Replanting - Ambetanna (LFT/97/1)

½S d/3 tapping with different frequencies of stimulation was tested with ½S d/2 system of tapping.

Treatments are as follows:

1. ½S d/3 2.5 ET, Ba 1.6(2.5)4/y
2. ½S d/3 2.5 ET, Ba 1.6(2.5)5/y
3. ½S d/3 2.5 ET, Ba 1.6(2.5)6/y
4. ½S d/2

Three tapping blocks were selected for each d/3 system whilst two blocks were selected for the d/2 system. One tapper was assigned for each treatment. The task size was 250 trees.

Though the tapper productivity, *i.e.* kg/annum/tapper, g/t/t and IPT is highest in d/3 systems with stimulation the productivity, *i.e.* crop per unit land area (kg/annum/block) is highest in the conventional d/2 system (Table 8). Among the different frequencies of stimulation tested 6 stimulations per annum gives highest yield (A Nugawela, S Wilbert and R K Samarasekera).

Table 8. *The total crop per tapper and per tapping block, mean intake per tapper (IPT) and yield per tree per tapping (g/t/t) for different treatments*

	Total crop (kg) per annum			
Tapping system	Tapper	Block	IPT	g/t/t
1. ½S d/3+E*(4/y)	515.2	171.7	4.7	18.7
2. ½S d/3+E*(5/y)	588.6	196.2	5.1	20.3
3. ½S d/3+E*(6/y)	611.4	203.8	5.6	23.4
4. ½S d/2	524.5	262.3	4.4	17.8

Low frequency tapping of clone PB 86 in the smallholder sector

Trials were commenced in 1996 in Kalutara, Ratnapura and Kegalle Districts. For each trial, holdings with atleast 5 tapping tasks were selected to test the following treatments.

T_1 ½S d/2 (2 tasks).
T_2 ½S d/3 + 2.5%ET, Ba 1.6(2.5) 4/y (1 task)
T_3 ½S d/3 + 2.5%ET, Ba 1.6(2.5) 6/y (1 task)
T_4 ½S d/3 + 1.0%ET, Ba 1.6(2.5) 6/y (1 task)

Above treatments were introduced randomly to the 5 tapping tasks. Two tappers, *i.e.* one for the two d/2 blocks and the other for the three d/3 blocks, were employed.

In all districts the tapper productivity is highest in d/3 systems with 2.5% Ethrel stimulation. Anyhow, the productivity per unit land area is marginally less than in conventional ½S d/2 system (Table 8). There is no evidence for a higher incidence of TPD in stimulated trees. Bark consumption is less with d/3 tapping (Table 8).

There is no evidence for a higher percentage of dry trees in stimulated trees (A Nugawela, K A G B Amaratunga, R P Karunasena and S Wilbert).

Table 9. *Intake per tapper (IPT,kg), annual crop per task (Crop/Task,kg), % incidence of dryness (% TPD) and annual bark consumption (BCR,cm) in different tapping treatments*

District	Treatment	IPT (kg)	Crop/Task (kg)	% TPD	BCR (cm)
Ratnapura	T1	5.38	533	8	22.5
	T2	7.27	501	4.5	19.3
	T3	7.51	503	4	18.2
	T4	504	333	5	17.3
Kegalle	T1	5.27	527	1.4	22.7
	T2	6.1	456	2	15.6
	T3	5.7	438	3.2	17.4
	T4	5.92	438	6.0	15.3

Low frequency tapping systems and clones - Eladuwa (F/76/5)

The conventional ½S d/2 system was compared with ½S d/3 system with 4 and 6 rounds of stimulation per annum using clones RRIC 100. RRIC 101 and PB 86.

The mean yield per tree per tapping (g/t/t) is highest in ½S d/3 system of tapping with 6 rounds of stimulation per annum (Table 10).

There is no evidence for treatment differences with regard to TPD (Table 10).

Table 10. *Effect of different tapping systems on the yield per tree per tapping (g/t/t), annual yield per tree (kg/t/annum) and incidence of TPD (%) in clones*

Tapping System	Clones and Yield								
	RRIC 100			PB 86			RRIC 101		
	g/t/t	kg/t/y	%TPD	g/t/t	kg/t/y	%IPT	g/t/t	Kg/t/y	%TPD
½S d/2	30.2	5.4	3.2	21.2	3.8	1.8	36.8	6.62	2.7
½S d/3 + E*	40.8	4.9	1.2	31.4	3.8	0.8	32.0	3.84	2.3
½S d/3 + E**	43.4	5.2	2.7	36.6	4.4	1.2	38.2	4.58	1.2

E* 2.5% ET,Ba 1.6(2.5) 4/y E** 2.5% ET.Ba 1.6(2.5)6/y

(A Nugawela and C W Ranasinghe).

Low frequency tapping systems and frequency of stimulation (LFT/95/1)

½S d/3 tapping system with different frequencies of stimulation, i.e. 12/y with 1% ethrel, 6/y with 2.5% ethrel, and 4/y with 2.5% ethrel is tested on clones RRIC 100,102,121 and 130.

The mean g/t/t recorded during 1997 for the 4 clones tested are given in Table 11.

Table 11. *Annual mean g/t/t for different frequencies of stimulation in clones RRIC 100, RRIC 102, RRIC 121 and RRIC 130*

	Clone and Yield (g/t/t)			
Treatment	RRIC 100	RRIC 102	RRIC 121	RRIC 130
1% ET.Ba 1.6(2.5)12/y	29.6	36.2	38.4	29.8
2.5%ET.Ba 1.6(2.5)6/y	38.6	33.0	42.5	39.0
2.5%ET.Ba 1.6(2.5)4/y	37.4	30.3	36.8	35.2

Generally, 2.5%ET. Ba 1.6(2.5)6/y gives a better yield per tree.

Incidence of dryness is relatively high in clone RRIC 102 than in the other clones tested. Girthing is similar in all stimulation systems tested (Table 12).

Table 12. *Percentage incidence of dryness (% TPD) and girth increment (GI, cm) with different stimulation systems tested*

		Clones			
Treatment	Parameter	RRIC 100	RRIC 102	RRIC 121	RRIC 130
1% ET.Ba 1.6(2.5)12/y	TPD (%)	0	0	0	0
	GI (cm)	2.5	4.4	2.6	2.3
2.5%ET.Ba 1.6(2.5)6/y	TPD (%)	0	10	0	0
	GI(cm)	2.0	4.7	4.2	3.0
2.5%ET.Ba 1.6(2.5)4/y	TPD (%)	0	20	10	0
	GI (cm)	1.5	3.6	3.7	3.0

High intensity tapping of virgin panels

Trials on the above were initiated during 1993 with the objective of finding out whether total yields obtained during the presently recommended 24 year tapping cycle could be realized during a shorter tapping cycle and if so, whether such tapping systems are more economical.

RRIC 100, 102, 121 and 130, 1988 Replanting - Dartonfield (HIT/93/1)

The experimental details are given in Annual Review 1993. Except in clone RRIC 130,in all other clones the g/t/t is generally low with ½S d/1 tapping. ½S d/2 + E* does not give a significant yield increase over ½S d/2 (Table 12). Among the different tapping systems tested ½S d/1 gives the highest annual yield per tree (kg/t/year).

Table 13. *Effect of tapping systems at different fertilizer levels on dry rubber yields of different clones. Annual girth increment is given within brackets.*

Tapping system	Fertilizer level	Yield (g/t/t)			
		RRIC 100	RRIC 102	RRIC 121	RRIC 130
½S d/1	Level -1	38.2 (2.5)	27.4 (1.2)	27.8 (4.2)	38.1 (2.8)
	Level -2	35.6 (2.1)	24.4 (2.9)	26.5 (4.9)	30.4 (2.8)
½S d/2	Level -1	42.0 (2.6)	40.3 (2.3)	35.1 (3.8)	35.5 (2.2)
	Level -2	44.6 (1.7)	31.6 (2.4)	43.7 (5.4)	24.0 (2.7)
½S d/2 +E*	Level -1	35.7 (2.0)	33.2 (2.1)	31.3 (4.7)	37.1 (3.8)
	Level -2	44.8 (1.9)	26.9 (2.7)	42.2 (4.1)	31.2 (2.5)
½S d/3+E*	Level -1	38.6 (2.5)	36.9 (2.1)	39.6 (3.9)	42.0 (3.1)
	Level -2	52.9 (2.1)	27.7 (2.4)	50.6 (4.7)	47.9 (3.6)

E* 2.5% ET, Ba 1.6(2.5) 4/y.

Clones RRIC 130 and RRIC 102 appear to be susceptible to TPD among the four clones tested (Table 14). Further. among the different tapping systems tested incidence of TPD is relatively low in the low frequency tapping system tested. *i.e.* ½S d/3 + E*.

Table 14. *Effect of tapping systems at different fertilizer levels on the incidence of tapping panel dryness (TPD) in different clones*

Tapping system	Fertilizer level	TPD (%)				Mean
		RRIC 100	RRIC 102	RRIC 121	RRIC 130	
½S d/1	Level -1	0	0	0	14.3	3.6
	Level -2	0	25	0	12.5	9.4
½S d/2	Level -1	0	0	0	14.3	3.6
	Level -2	12.5	12.5	25	37.5	21.9
½S d/2 +E*	Level -1	0	12.5	0	12.5	6.3
	Level -2	0	14.3	0	14.3	7.2
½S d/3+E*	Level -1	0	12.5	0	12.5	6.3
	Level -2	0	0	0	0	0
	Mean	1.3	9.6	3.1	14.7	

Additional fertilizer has not improved the yields or the growth in all treatments tested. Further, it has no clear influence on the incidence of TPD (A Nugawela and R P Karunasena in collaboration with the Soils and Plant Nutrition Department).

Exploitation of renewed bark

The objective of this trial is to identify suitable bark for tapping once the virgin panels, *i.e.* BO-1 and BO-2 are tapped.

PB 86, 1971 Replanting - Payagala Estate (ERB/93/1)
PB 86, 1971 Replanting - Perth Estate (ERB/93/2)

The tapping panels were changed from BI-1 to B1-2 in treatments T_1 and T_2 during January and June respectively. Puncture tapping of upper virgin bark was completed in T_5 and in these trees treatments similar to T_3 and T_4 were introduced.

The annual mean yield per tree per tapping, *i.e.* g/t/t for different tapping treatments are given in Table 15.

Table 15. *The dry rubber yield (g/t/t) of the different treatments in trials ERB/93/1 and ERB/93/2*

	Annual Mean Yield (g/t/t)	
Treatment	ERB 93/1	ERB 93/2
T_1 Panel BI-1	39.8	30.6
T_2 6" above BI-1	32.9	29.3
T_3 Upper Virgin Bark (↑)	37.0	39.6
T_4 Upper Virgin Bark (↓)	33.0	32.8
T_5 Puncture Tapped Bark as T_3	38.0	45.2
T_6 Puncture Tapped Bark as T_4	24.7	37.6

Data collected from panel B1-2 also suggest that exploiting 6" above panel B1-2 would result in a poor crop than exploiting at initial height of opening. Also, exploiting upper virgin panels upward results in more crop than exploiting upper virgin panels from down-ward cuts. Previously puncture tapped upper panels give yields comparable to that of non puncture tapped panels (Table 15) (A Nugawela and R P Karunasena).

Tapping panel dryness

The objective of this study is to identify factors that may be associated with the incidence of tapping panel dryness.

RRIC 100, 1986 Replanting - Eladuwa estate (TPD/93/1)
RRIC 110, 1986 Replanting - Eladuwa estate (TPD/93/2)

The experimental details are given in the Annual Review 1994. The % incidence of tapping panel dryness for different treatments and clones are given in Table 16.

Table 16. *Effect of different agronomic practices on yield (g/t/t), girth increment (GI,cm) and incidence of tapping panel dryness (% TPD) in clones RRIC 100 and RRIC 110*

Treatment	Fert. Level	% incidence of TPD	
		RRIC 100	RRIC 110
Rainguarding	1	13.3	0
	2	6.7	6.7
Rainguarding and Stimulation	1	0	26.6
	2	26.6	33.3
Stimulation	1	6.7	13.3
	2	13.3	20.0
Control	1	0	26.6
	2	26.6	6.7

When individual clones are considered significant correlation between any of the agronomic practices and incidence of dryness is not apparent.

The % incidence of tapping panel dryness recorded for different treatments at the end of each year since 1994 is given in Table 17.

Table 17. *Agronomic practices and the (%) incidence of dryness*

Practice	Treatment	TPD (%)			
		1994	1995	1996	1997
Rainguarding	With	10.0	6.7	17.5	14.2
	Without	13.3	6.7	11.7	14.2
Stimulation	With	16.7	9.2	16.7	17.5
	Without	6.7	4.2	12.5	10.8
Clone	RRIC 100	16.7	5.0	11.7	10.8
	RRIC 110	6.7	8.3	17.5	16.7

Incidence of dryness is consistently high in stimulated trees. In clone RRIC 110, it is relatively higher than in clone RRIC 100 during past 2-3 years and this may be due to *Corynespora* leaf fall (A Nugawela and C W Ranasingha).

Survey on tapping panel dryness (TPD)

This study was designed to find out the propensity of present extensively grown clones to the incidence of Tapping Panel Dryness and also to investigate the possible factors responsible for this disorder.

For each clone, five clearings were selected from each panel, *i.e.* B0-1, B0-2 and B1-1 and from each clearing two tapping blocks, tapped by different tappers were selected for the survey.

The study is being done at Kalutara District initially (A Nugawela, W Seneviratna, V H L Rodrigo and S Wilbert).

Exploitation of dry trees

RRIC 100 1982 Replanting Neuchatle (TPD/97/1)
RRIC 102 1982 Replanting Neuchatle (TPD/97/2)

The trial was commenced during May 1997 at Neuchatle Estate with the objective of finding ways of exploiting trees affected with Tapping Panel Dryness. Thirty two trees affected with Tapping Panel Dryness were selected from each tapping block with tapping frequencies of d_2, d_3 and d_4 and following different tapping systems were used as treatments. Eight trees were assigned for each treatment.

Treatment 1 - Resting dry trees for six month period.
Treatment 2 - Continuous tapping of already dry panel.
Treatment 3 - ½S (↓) cut on opposite base panel.
Treatment 4 - ¼S(↑) cut on opposite higher panel.

According to results obtain so far,only a negligible amount of yield was recorded with the continuous tapping of already dry panel. Comparatively high yield was observed with ½S (↓) cut on opposite base panel (Tr.3) and from ¼S (↑) cut on opposite higher panel(Tr. 4). However yield difference was not significant among Tr.3 and Tr.4 ($p < 0.005$) (Table 18). The percentage number of trees with latex was low in Tr.2 while in Tr3 and Tr4 it was high (Table 18).

Table 18. *The mean yield i.e. g/t/t of already dry trees and percentage number of trees with latex with different tapping systems (clone RRIC 102)*

Treatment	Tapping Frequency		
	D/2*	D/3**	D/4***
Tr.1(Resting)	-	-	-
Tr.2(Continues Tapping)	9.58b*(55%)	5.54b**(62%)	1.61b***(39%)
Tr.3 (½S(↓) Opp. Panel)	30.45a*(87%)	15.48c**(85%)	40.58a***(89%)
Tr.4(1/4S(↑) Opp Higher Panel)	23.38a*(90%)	20.47a**(93%)	22.98a***(79%)

abc- Duncan Multiple Range Test
($p < 0.005$)

(A Nugawela, N Kaluwewa, S Wilbert and K A G B Amaratunga).

Yield stimulants (YS)

RRIC 100, 102 and 121. 1992 Replanting
Gallewatte Division (YS/97/1)

The objective of the trial is to compare the performance of Ethrel with new stimulants "Ethrel Supper" and "Ethlin" under two fertilizer levels. However Ethepon is the basic compound of all three stimulant types tested.

From each clone, trees of even growth stage and being are tapped on BO I panel were selected. Twenty trees were assigned for each treatment from each clone. The trial was commenced during May 1997 with the following treatments.

Fertilizer level I - Normal fertilizer applications

Treatment 1 - "Ethrel" 2.5% with normal fertilizer application.
Treatment 2 - "Ethrel Supper 946" with normal fertilizer application.
Treatment 3 - "Ethin" with normal fertilizer application.

Fertilizer level II - 25% more fertilizer

Treatment 4 - "Ethrel" 2.5% with 25% more fertilizer .
Treatment 5 - "Ethrel Supper 946" with 25% more fertilizer.
Treatment 6 - "Ethin" with 25% more fertilizer.

According to results obtained so far the Treatment x Fertilizer Level interaction was not significant for any clone tested. Significant increase of yield ($p < 0.005$) was apparent with all three stimulants against the control i.e. without any stimulant. However the yield increase with new stimulants is comparable to "Ethrel". Furthermore yield increase with "Ethrel Supper" and "Ethlin" is also comparable (Table 19).

Table 19. *The mean yield i.e. g/t/t with three stimulant types*

		Yield Stimulant		
Clone	Control	Ethrel	Ethrel Supper	Ethlin
RRIC 101[1]	31.57[a1]	33.06[a1]	32.70[a1]	34.93[a1]
RRIC 102[2]	24.70[b2]	35.61[a2]	39.84[a2]	34.51[a2]
RRIC 121[3]	24.85[b3]	47.30[a3]	48.68[a3]	49.41[a3]
Mean[4]	27.04[b4]	38.65[a4]	42.07[a4]	39.61[a4]

a. b. c Duncan's Multiple Range test.
($p < 0.005$)

(A Nugawela, N Kaluwewa, S Wilbert and R K Samarasekara in collaboration with Soils and Plant Nutrition Dept.)

Recovery tapping

RRIC 100 1981 Replanting - Gallewatte Division (RT/97/1)
RRIC 121 1981 Replanting - Gallewatte Division (RT/97/2)

The trial was commenced during May 1997 and following treatments are tested with the objective of studying the annual yield gain and other related parameters when recovery tapping is undertaken.

Treatment 1 - Tapping with recommended level of recovery tapping.
Treatment 2 - Tapping without recovery tapping.

From each clone two tapping blocks were selected for each treatment. Yield data were collected from estate records. The monthly crop harvested with and without recovery tapping is not significantly different (Table 20).

Table 20 *Monthly crop per tapper per block with and without recovery tapping (clone RRIC 100 and RRIC 121)*

Month	RRIC 100			RRIC 121		
	Tr.1	Tr.2	Significance	Tr.1	Tr.2	Significance
June	93.0 (12*)	82.0 (11*)	NS	94.0 (11*)	78.0 (10*)	S
July	40.0 (8*)	45.5 (8*)	NS	44.0 (7*)	39.0 (7*)	NS
August	139.0 (16*)	88.0 (12*)	NS	144.0 (16*)	116.0 (12*)	NS
September	62.0 (7*)	59.0 (7*)	NS	51.5 (7*)	36.5 (5*)	NS
October	86.0 (9*)	82.0 (9*)	NS	65.5 (9*)	68.0 (9*)	NS
November	89.5 (11*)	90.0 (9*)	NS	125.0 (14*)	106.0 (12*)	NS
December	144.0 (14*)	116.5 (13*)	NS	117.0 (15*)	112.0 (13*)	NS

(*) - Number of tapping days
S - Significantly different at 0.05% level
NS - Not Significantly different at 0.05% level

Six recovery tapping days per month (recommended level) was not achieved during any of above months mainly due to rain interference (A Nugawela, N Kaluwewa and K A G B Amaratunga).

Planting density

The objective of these trials is to examine the possibility of increasing the planting density of rubber to increase productivity and profitability per unit area of land.

High density

Kuruwita 1992 Replanting - PD/92/1

Details of the experiment appeared in the Annual Review 1992. Highest density, *i.e.* 800 trees per hectare showed the lowest girth values in clone RRIC 110 & 121. In general, plants in densities up to 700 trees per hectare were statistically similar in girth. Growth of clone RRIC 121 was superior to that of both RRIC 100 & 110 in the density of 500 tree per hectare and the clone RRIC 110 was less in growth at all densities tested (Table 21).

Table 21. *Mean girth of plants at 90 cm height from the bud grafted union*

Trees/Hectare	RRIC 100	RRIC 110	RRIC 121
500	42.5	42.7	44.6
600	46.0	42.4	44.3
700	45.0	41.1	44.8
800	43.9	40.7	43.2

(V H L Rodrigo, A Nugawela and L S Kariyawasam in collaboration with the Genetics and Plant Breeding Department)

Low density

The objective of the study is to find out whether planting at low densities will enhance the economic return through the income generated from both latex and timber.

Gallewatta (Dartonfield Group) 1996 Replanting - PD/96/1
Nivitigalakele (Dartonfield Group), 1996 Replanting - PD/96/2

The experimental details are described in Annual Review of 1996. Infilling was done to maintain the densities being tested. For the trial at Gallewatta infilling had to be done using clone RRIC 100 as suitable material from other clones were not available (A Nugawela, L S Kariyawasam and U S Weerakoon).

Intercropping

Spatial arrangements

Different spacings for planting rubber are tested to identify systems which provide more light for a longer period to facilitate intercropping.

Usk Valley, 1992 Replanting - IC/S/92/1

Details of the experiment are given in the Annual Review 1992. According to the girth measurements at 90 cm height, performance of the system 4 continued to be superior, whilst of system 3 was inferior than the other systems tested (Table 22). Although growth of Rubber in the double row system, *i.e.* system 2, was not the best, this system appeared to be more suitable to undertake intercropping. Nevertheless, for better growth of rubber more space will have to be given within the two rows.

Table 22. *Mean girth of rubber at 90 cm in different spatial systems in 1997.*

System	Girth (cm)
1	39.98
2	38.79
3	37.46
4	43.83
5	41.20

(V H L Rodrigo and L S Kariyawasam)

Perth 1992 Replanting - IC/S/92/2

This experiment was established in 1992 and the objective and experimental details are described in annual review of the same year.

The growth of the rubber trees was not affected significantly by the spatial arrangements, *i.e.* row or contour plantings. But the growth of rubber in grass plots, irrespective of the spacial arrangement, was lower than those with the other two intercrops (Table 23). The growth of Coffee, the yield of grass and Cinnamon (g/bush) ware unaffected by the spacial arrangements at this stage (Table 24). Out of the four coffee rows in the rubber inter row, the two centre rows yielded

significantly higher yield the two rows closer to the rubber trees irrespective of the rubber planting system (Table 25).

Table 23. *Effect of intercrop on the growth of rubber*

Treatments	Girth of rubber (cm)
Rubber + grass	36.6 B
Rubber + Cinnamon	42.5 A
Rubber + Coffee	41.6 A
Rubber only	40.6 A
(Values with the same letter are not significantly different)	

Table 24. *Effect of rubber spatial arrangement on the growth of Coffee cumulative bark yield of Cinnamon and the yield of grass*

Treatments	Stem diameter of Coffee (cm)	Cumulative bark yield (g/bush)	Yield of grass kg/ha
Row planting - Rubber + Grass	-	-	1475.5
Row planting - Rubber + Coffee	3.4	113.9	-
Contour planting - Rubber + Grass	-	-	1653.8
Contour planting - Rubber + Coffee	3.1	114.0	-

Table 25. *The effect of closeness to the rubber row on the yield of coffee.*

Coffee row	Yield g/bush
1. row next to the rubber row	642.8 B
2. middle row	1088.3 A
3. - do -	1179.6 A
4. row next to the rubber row	442.6 B
Values with the same letter are not significantly different	

(L S S Pathiratna and M K P Perera)

Intercropping systems

Rubber and timber

Usk Valley, 1992 Replanting - IC/RT/92/1
Ambatenna, 1992 Replanting - IC/RT/92/2

Experimental details are in Annual Review 1992. Establishment and growth of all timber species planted, except Alstonia, appeared to be poor. The Forest Department was consulted in this regard and their view was to continue with Alastonia and replant Mahogani under the shade of rubber in order to protect the plants from borer attack. Among rubber/ timber systems, though girth of rubber intercropped with Alstonia was the least, differences were not significant (Table 26). No significant difference was evident between two planting systems adopted to intercrop rubber. Also, high density planting systems of rubber showed no decline in growth.

Table 26. *Girth of rubber at 90 cm from the bud grafted union*

Spacing of rubber	Intercrop	Usk Valley IC/RT/92/1	Ambatenna IC/RT/92/2
1. 8' x 27'	No timber	41.6	40.9
	Halmilla	40.3	40.1
	Alastonia	41.2	38.9
	Teak	42.4	38.0
	Mahogani	43.2	40.2
2. (8' x 8') x 54'	No timber	40.3	36.7
	Halmilla	42.8	38.4
	Alastonia	40.7	36.1
	Teak	41.4	35.9
	Mahogani	43.6	38.2
3. 8' x 17'		43.4	41.9
4. 8' x 15'		42.9	40.7

(V H L Rodrigo and L S Kariyawasam)

Rubber and cardamom - Dartonfield (IC/RC/96/1)

Experimental details appear in the annual review of 1996. Growth of cardamom was satisfactory with average number of 6-7 pseudostems per clump. Mean girths of pseudostems in both single and double row planting systems were comparable with values of 5.37 cm and 5.52 cm, respectively. Light use of cardamom was studied with instantaneous measurements by a Ceptometer (Delta-T Devices, UK). Results showed that light penetration through the rubber canopy was ca. 45% and cardamom was capable of capturing most of this light giving values of. 41-42% for fractional interception of total incoming light (V H L Rodrigo and L S S Pathiratne in collaboration with the Department of Export Agriculture. This project is funded by CARP Research Grant 12/316/240).

Rubber x Banana intercrop

The versatility of banana, being both a food and cash crop, makes it an important component of intercropping systems. The present recommendations in Sri Lanka for planting density of banana in rubber/banana intercrops is only 30% of that of the sole crop and therefore is likely to be well below the optimum density that can be supported without any deleterious effect on either component crop. The overall aim of this study was to determine the extent to which banana density could be increased in rubber/banana intercrops in order to maximise light and water use and ultimately economic yield of banana.

A large-scale experiment was established on a 5 ha area at the Kuruwita sub-station of the Rubber Research Institute of Sri Lanka and a smaller-scale replicate experiment was set up at Pallagoda in the Kalutara district. The experiment comprised five treatments, sole crop rubber (R), sole crop banana (B) and three intercropping treatments consisting of an additive series of one (BR), two (BBR) and three (BBBR) rows of banana to one row of rubber. In addition to the analysis of growth and resource use, a socio-economic study of intercropping on smallholder immature rubber lands was undertaken.

Biomass productivity and banana yield were continuing to increase from the single to triple row intercrop system. Despite an increase in shading with planting density, there was no evidence that growth was limited by either light or water during first two years of growth. Instead, growth of both crops benefited from mutual shading. Since bunch yield per plant and percentage of plants yielding were unaffected by density, economic yield of banana was greatest in the high density BBBR intercrop up to the second year. However, percentage of plants yielding was extremely poor in all treatments in third and fourth years due to drought effects.

Increased productivity in the high density intercrops was driven by an increase in resource capture and on average, radiation and water use in the BBBR crop increased by 73 and 140%, respectively over the presently recommended BR system. Increased shading in the high density intercrops had no major impact on photosynthesis and respiration at the leaf level. Consequently, the increase in light-use efficiency and whole plant photosynthesis (due to the larger canopy area under shade) were identified as the major factors responsible for the improved biomass productivity per plant in the high density intercrops. Intercropping had beneficial effects on growth of rubber, resulting in an increase in both girth and plant height. Since girth is associated with the potential latex yield and also used as a criterion for determining the onset of tapping, the increase in girth of rubber suggests that intercropping may either increase latex productivity at maturity or reduce the length of the period between establishment and onset of tapping for latex. Similarly, the improved girth and height of rubber when intercropped suggests possible benefits to future timber yields. There was clear and consistent evidence from both experiment sites that intercropping markedly reduced the incidence of Fusarium wilt disease in banana.

Increased cost, particularly in terms of fertilizer for banana, was identified as a possible drawback to the adoption of the high density intercrops at the smallholder level and further studies are required to establish whether fertiliser applications can be reduced in the high density BBBR intercrops. Furthermore, on-farm trials are required in order to test the high density banana system under a variety of smallholder conditions, with the added benefit of acting as an extension tool to improve the transfer of research results to the end user - the farmer (V H L Rodrigo, R K Samarasekera and L S Kariyawasam with the collaboration of Agricultural Economic Unit, Rubber Development Department and National Engineering Research Development Centre, Sri Lanka and the Institute of Terrestrial Ecology, UK. The project was funded jointly by the CARP Research Grant 12/156/125, ODA Plant Science Programme and SRRP II.)

Rubber and Grass/Legume - Neuchetal IC/GL/91/1

The trial was started in 1991 and the experimental details are reported in the Annual Review of the same year.

The grasses were completely smothered by the shade of rubber trees. The growth of tree legumes was also poor and they were removed.

The effect of different treatments on the growth of rubber was not significant at this stage (Table 27). The rubber trees in this experimental area are now in tapping.

Table 27. *Effect of cropping system on the growth of rubber.*

Treatment	Growth of rubber (cm)
1. Rubber (Control)	51.9
2. Rubber + *Panicum maximum* (PM)	54.3
3. Rubber + *Brachiaria brizantha* (BB)	47.9
4. Rubber + Gliricidia	48.9
5. Rubber + Ipil Ipil	51.6
6. Rubber + PM + Gliricidia	52.1
7. Rubber + PM + Ipil Ipil	51.1.
8. Rubber + BB + Gliricidia	52.1
9. Rubber + BB + Ipil Ipil	46.8

Rubber and Cocoa/Cinnamon

Dartonfield - IC/CC/91/2

This trial was established in 1991 (Annual Review 1991) to investigate the possibility of intercropping Cinnamon and Cocoa with rubber. Experimental details are reported in the Annual Review of 1991.

The growth of rubber was not affected by the intercrops at this stage (Table 28). Per bush bark yield of Cinnamon is similar in different spacing systems tested (Table 28).

Table 28. *Effect of intercrops on the growth of rubber (cm) and yield of Cinnamon under different spacing treatments*

Treatments	Girth of rubber (cm)	Bark yield of Cinnamon g/bush
1. Rubber only	44.5	-
2. Rubber + Cinnamon (spacing 1)	49.1	77.9
3. Rubber + Cinnamon (Spacing 2)	46.9	102.8
4. Rubber + Cinnamon (Spacing 3)	48.5	80.4
5. Rubber + Cocoa (Spacing 1)	41.5	-
6. Rubber + Cocoa (Spacing 2)	40.8	-
7. Rubber + Cocoa (Spacing 3)	43.0	-

Cocoa trials - Perth, Neuchetal, Tempo and Miriswatta

The pods were harvested twice during the year and the bean dry weight was estimated. The growth of rubber is not affected by Cocoa in these trials (Table 29). The bean yield of cocoa was considerably low due to thieving of pods.

Table 29. *The effect of intercrop on the girth of rubber(cm) and the yield of cocoa beans (Kg) in different sites*

Treatment	Parameter	Perth	Neuchatal	Tempo	Miriswatta
Rubber and Cocoa double row	Girth(cm)	71.4	66.2	70.5	75.5
	Bean yield(kg)	2.5	1.6	1.8	2.0
	No.of Cocoa plants	267	146	252	305
Rubber and Cocoa single row	Girth(cm)	71.3	66.3	71.6	75.1
	Bean yield (kg)	1.2	1.0	1.0	1.4
	No. of cocoa plants	179	97	134	162
Rubber only	Girth(cm)	66.8	67.5	70.2	68.5

Rubber-Rattan/intercropping trial - Kuruwita Sub station

The trial was established in October 1996 with three indigenous species of rattan *viz. Calamus zeylanicus, C. ovoideus and C. pseudotenuis* in a 1984 rubber clearing at the RRI Sub-station, Kuruwita. The experimental details and the objectives are given in Annual Review 1996. The initial growth of rattan plants were slow. No measurements were taken during this period.

Expansion of rubber into areas marginal with regard to elevation, *viz.*, mid country wet zone

The objective of the study is to test and recommend area specific technology for growing rubber beyond the traditional areas.

In this trial clones RRIC 100, RRIC 102, RRIC 130 and PB 260 were planted, replicated 4 times to accommodate the different micro-environment conditions. From each replicates 50 plants were selected randomly for annual growth measurements.

The growth of all clones is satisfactory and clonal differences are not apparent (Table 30).

Table 30. *The mean stem diameter at 6" above union of different clones tested*

	Clone and diameter (cm)			
Replicate	RRIC 100	PB 260	RRIC 130	RRIC 100
1	2.97	2.68	2.53	2.62
2	2.96	2.68	2.92	2.59
3	1.96	1.98	1.73	2.25
4	2.13	2.29	2.11	2.10
Mean	2.51	2.40	2.33	2.3

(A Nugawela, K A G B Amaratunga and S wilbert in collaboration with all Biology Department and Free Lanka Management Company. The project is partly funded by CARP Research Grant 12/296/260).

Nursery Inspection Unit

Inspections

A total of one hundred and fifty nine private commercial nurseries were inspected and reports were submitted to the Rubber Development Department for the issue of permits (Table 31).

Table 31. *The number of private commercial nurseries inspected from different regions*

Region	No. Nurseries inspected
Kalutara	53
Ratnapura	17
Kegalle	21
Galle	34
Homagama	23
Gampaha	02

The Rubber Development Department nurseries, *i.e.* Egaloya, Gurugoda, Weilikadamulla, Meerigama and Karapincha were visited monthly to attend to the meetings of the Nursery Monitoring Committee appointed under the SRRP 11 project.

Issue of budded stumps for establishment of budwood nurseries

Budded stumps were issued to the Plantation Sector for establishment of multiplication nurseries. Details are given in Table 32.

Table 32. *The clones and number of plants issued from each clone to both estates and smallholder sector*

Clone	Number of budded stumps issued
RRIC 102	25
RRIC 130	252
RRIC 131	25
RRIC 133	98
RRIC 117	94
RRII 105	61
PB 235	97
PB 260	75
BPM 24	25
Total	777

(A Nugawela, P Seneviratna, R B Gunaratna, U S Weerakoon and M N de Alwis)

PLANT PATHOLOGY AND MICROBIOLOGY

C K Jayasinghe

SUMMARY

Secondary leaf fall was mild in all rubber growing districts during the refoliation period. Though the abnormal leaf fall was extremely mild during the early months of the South West monsoon season, a considerable leaf fall was seen on susceptible clones, PB 86 and RRIC 121 towards the latter part of the year. However, bark rot incidence remained insignificant.

The attention of the Directors and Estate Managers was drawn to new nursery diseases of rubber identified during the recent past and management strategies were discussed with seven plantation companies. Planting community was addressed several instances on *Corynespora* leaf fall disease and it was shown that most outstanding rubber clones in Asian and African continents which were reported to be resistant previously have now succumbed to the disease.

Anvil (hexaconazole) was recommended as an effective fungicide in controlling *Rigidoporus lignosus*, the causative agent of white root disease of *Hevea* rubber. Fungicides; benomyl, trimiltox, mancozeb, sandofan, tilt and antracol reached $LD_{(100)}$ within the tested range in both poisoned food technique and conidial germination inhibition test when twenty one fungicides were screened against the fungus *Corynespora cassiicola*. Culture characteristics and reproductive morphology of the *Hevea* isolates of *Colletotrichum acutatum* and *Geotrichum* sp. were established. Multivariate analysis technique was developed to distinguish *C. acutatum* from *C. gloeosporioides* and an appeal was made to reinvestigate the pathogen responsible for *Colletotrichum* leaf disease in other rubber growing countries in Africa and Asia. A long-term study on biology, epidemiology, pathogenicity and management of *Cylindrocladium quinqueseptatum*, a potential pathogen of *Hevea* in Sri Lanka was completed. Sixteen potential clones were established at eight localities for screening purposes.

DETAILED REVIEW

The Head of the Department, Dr C K Jayasinghe and Plant Pathologists, Dr R Jayaratne, Mr K E Jayasuriya and Miss W P K Silva were on duty throughout the year. Mr W Amaratunge, Audio Visual Production Officer continued to work in the Department. Miss W P K Silva and Mr K E Jayasuriya commenced their PhD projects on 1.2.97 and 7.4.97 respectively with the collaboration of the University of Colombo.

Experimental Officers Messers D S Wettasinghe and E B Fernando; Senior Technical Officer Mrs J L P C Wettasinghe were on duty throughout the year. Technical Officers Mrs B I Thennakoon, Misses T H P S Fernando, D Siriwardene, U M S Priyanka and Clerk/Typist Mrs P Amarasekera were continued to work in the Department. Miss K D S Samararatne assumed duties as a temporary Technical Officer on 16th July 1997 under the CARP Project 12/364/263.

Visits

The Department staff made 43 Advisory visits, 235 for experimental and 135 for other purposes.

Training/Lectures/Seminars

Dr C K Jayasinghe, Dr R Jayaratne, Mr K E Jayasuriya and Miss W P K Silva were involved in training Superintendents, Assistant Superintendents, Rubber Development Officers, Undergraduates, Post-graduate students and NDT Trainees. Mr S Wettasinghe and Mr E B Fernando also participated in the training programmes conducted to educate Asst. Superintendents, Field Officers and Rubber Smallholders.

Dr C K Jayasinghe delivered a lecture entitled "Impact of management strategies of *Hevea* diseases on environment" at the seminar on "Rubber as an environment friendly raw material and renewable resource" held in Colombo on 14th March 1997.

Dr C K Jayasinghe attended the workshop on popular science writing on 7th and 8th March, 1997 organized by NARESA.

Mr K E Jayasuriya, Plant Pathologist attended a workshop on "Molecular Biology, Genetic Engineering and Analytical Biochemistry" held in Ruhuna University from 7th to 20th May 1997 with the collaboration of Institute of Molecular Biology, Free University of Brussels.

The objective of the refresher course for Rubber Development Officers for the year 1997 was to educate them to carry out various operations at village level. Hence, they were trained on "Management of white root disease" and "Judicious application of panel dressings" to suite the new objective.

Committees

The Head of the Department served in the Pesticides Technical and Advisory Committee and Steering Committee of National Plant Quarantine. Dr C K Jayasinghe, Dr R Jayaratne, Mr K E Jayasuriya and Miss W P K Silva attended the Scientific Committee meetings of the Rubber Research Board.

GENERAL

Dry weather that prevailed at the beginning of the year resulted in early and fairly even wintering. Consequently, most clones escaped from secondary leaf fall caused by *Oidium heveae*, *Colletotrichum acutatum* and *Colletotrichum gloeosporioides*. Phytophthora leaf fall and bark rot were extremely mild during the early months of the second quarter due to the unexpected dry weather prevailed during April and May in all rubber growing regions. However, a considerable leaf fall was evident on susceptible clones towards the end of June as weather conditions became ideal for the propagation of the pathogen during that time. South West monsoon was protracted over several months in 1997 and as a result, abnormal leaf fall was evident for the second time also in rubber plantations in Avissawella, Ratnapura, Kalutara and Kegalle regions. This situation was predicted early and an interim circular was sent on 1st September to the Director general of the Rubber Development Department and all estate managing companies requesting them to be vigilant and to apply relevant fungicides during October and November which is against our general recommendations.

A programme was launched to educate the Directors, Estate managers and Asst. Superintendents on new diseases of rubber discovered during the recent past from nurseries. Their attention was drawn to the potential danger of the spread of these new diseases and at the same time it was clearly pointed out that most of these disease could be easily prevented merely by adhering to the correct cultural practices recommended by the Rubber Research Institute of Sri Lanka. The clusters of the Watawala Plantations Ltd., Kelani Valley Plantations Ltd., Horana Plantations Ltd., BC Plantations Ltd., Pussellawa Plantations Ltd. and Bogawantalawa Plantations Ltd were covered during 1997.

An unrest was created among the planters with the appearance of an article entitled "The Rubber Industry's Biological Nightmare" in FORTUNE, August issue. As a response to their various requests a document was prepared giving all the strategies taken to prevent South American Leaf Blight (SALB) entering into the territory of our island. A discussion with the executive officers of the Planters Association was also held in November 1997 and a presentation was made at the 12th Scientific Committee meeting to explain the present situation of SALB and management strategies to planting community.

A training programme was conducted on 11th March 1997 to increase the awareness on the danger of SALB of rubber. Plant Quarantine Officers, Custom Officers and Officers from Rubber Development Department participated in this seminar. Country Committee Meeting on South American Leaf Blight was held on 9th December 1997 with the participation of Senior Secretary, Senior Assistant Secretary and Asst. Secretary of Plantation Industries Division of the Ministry of Public Administration, Home Affairs and Plantation Industries. A mock exercise on defoliation was carried out on 10th December 1997. The main purpose of this operation was to test the efficiency of chemicals and machinery imported into the country during the recent past.

The final report on the studies on *Ganoderma* root disease of coconut was submitted to the Director, Coconut Research Institute, Lunuwila after completing all initial studies. The Scientists involved in the project from CRI were Mrs C N K Rajapakse, Head Crop Protection Div., Dr (Mrs) P Fernando, Entomologist and Mr H T R Wijesekara, Research Officer of Crop Protection Division.

After nearly a decade of the first epidemic of *Corynespora* Leaf Fall (CLF) disease, most outstanding clones in Africa and Asia which were considered as resistant clones previously have now succumbed to the disease and CLF has become a threat to the world natural rubber industry. It was concluded in an international workshop held in Medan, Indonesia that *C. cassiicola* tends to adopt easily to different environmental conditions by forming new virulent strains. In that assembly it was further shown that molecular genetic variability of the fungus is responsible for attacking clones which were shown to be resistant previously.

An appeal was made through the IRRDB newsletter (Part 4, 1997) requesting other rubber growing countries in the Asian and African continents to reinvestigate the pathogen responsible for the *Gloeosporium* leaf disease (GLF) of *Hevea* rubber after the discovery of *C. acutatum* as the main cause of GLF in Sri Lanka. It was further pointed out that cluster analysis method developed at RRISL could be used as a reliable guide for this purpose.

LABORATORY AND FIELD INVESTIGATIONS

Chemical control of *Hevea* diseases (CC/89/1)

A. Screening of fungicides against Rigidoporus lignosus (Rigidoporus microporus *(Fr.) Overeem)*

A_1. Field Experiments carried out to determine the effectiveness of fungicide Anvil 5sc (Hexaconazole) was completed. Based on these results Anvil was recommended

as an effective fungicide to be used against *Rigidoporus lignosus*. Twenty milliliters of the fungicide to be mixed with one litre of water and to be used as a drench application. A second application to be carried out after 6 months (R Jayaratne, C K Jayasinghe and P C Wettasinghe).

A_2. The field experiments initiated at Peenkanda and Madeniya estates to monitor the effectiveness of fungicide "Tilt" (Propiconazole) had to be abandoned due to loss of trees. This indicates that "Tilt" may not be very effective in controlling the white root disease effectively under field conditions (R Jayaratne, C K Jayasinghe and P C Wettasinghe).

A_3. A new field experiment was initiated at Dartonfield estate and Gallewatta Div. and Malaboda Estate, Matugama to determine the effectiveness of fungicide "Folicur" (Tebuconazole) as a drench application. The first assessment was taken after 5 months by inspecting the collar region of the treated trees.

From these preliminary results it appears that the fungicide "Folicur" can be used as an effective chemical in controlling the white root disease (Table 1). This experiment is in progress. Further experiment will be carried out with "Folicur" in an artificially inoculated nursery site at Dartonfield (R Jayaratne, C K Jayasinghe and P C Wettasinghe).

Table 1. *Effectiveness of "Folicur" in controlling white root disease*

Estate	Pretreatment assessment					1st assessment after 5 months				
	No. of trees treated with disease score					No. of trees with disease score				
Malaboda	0	1	2	3	4	0*	1	2	3	4
	-	11	5	2	-	17	1	-	-	-
Dartonfield	-	4	3	3	-	5	3	1	1	-

* Disease scores

0 - Collar tree of infection
1 - Collar slightly affected with no foliar symptoms.
2 - Collar half circumference rotted with light foliar symptoms.
3 - Collar badly rotted with severe foliar symptoms.
4 - Collar completely rotted with fully wilted leaves.

A_4. *In vitro* experiments another locally available triazole fungicide "Baycor" was found to be effectively controlling the growth of *Rigidoporus* fungus at concentrations of 0.16% ai and above. The effectiveness will be tested under field conditions (R Jayaratne, C K Jayasinghe and P C Wettasinghe).

A_5. *In vitro* experiments it was found that CaOCl to be fungi toxic at concentration of 2-4% (w/w) when mixed with soil. Therefore a field testing was carried out by treating few infected plants at Dartonfield by mixing the CaOCl around the plants to soil. The results obtained from this experiment was not very promising as the infection on the root systems did not disappear and few trees died after sometime due to infection. However further work is in progress with different formulation of CaOCl to be applied to infected root systems to enhance the effectiveness under field conditions (R Jayaratne C K Jayasinghe and P C Wettasinghe).

A_6. Observations of the *in vitro* tests performed to screen clove oil as a chemical to manage white root disease indicated that total inhibition of the mycelial growth could be obtained when 20% of crude oil is incorporated into grease base. Field experiments are now in progress to evaluate the efficacy of this chemical *in vivo* (C K Jayasinghe, R Jayaratne, E B Fernando).

B. Screening of fungicides against Corynespora cassiicola

B_1. Spraying of fungicides, mancozeb, and benomyl in immature clearings of RRIC 110 at Kuruwita, Hillstream, Malaboda and Salawa estates were continued at the experimental sites of the Plant Breeding Dept. (International clone exchange trial). In Malaboda and Salawa estates, three rounds of fungicides were applied at monthly intervals. First two rounds were sprayed with benlate (0.6%) followed by another round of dithane/thiovit (1.7% and 0.6%). Plant Breeding Department was requested to undertake the future spraying programme. However, at Kuruwita and Hillstream estates, four rounds were applied and there is a marked improvement in the canopies. Spraying programmes at these two sites will be continued by the Plant Pathology Department Staff (C K Jayasinghe, R Jayaratne, B Fernando and S Wettasinghe).

B_2. Oil dispersible formulation of mancozeb sample received from India were compared in water and in diesolene oil by spraying onto a budwood nursery and estimating the spore germination of fungus *Corynespora* on the leaf surfaces with

time intervals (Table 2). This was a repeat experiment to confirm the results obtained from the earlier experiment (Annual Review 1996) (R Jayaratne, C K Jayasinghe, D S Wettasinghe and D Siriwardena).

B_3. Twenty one fungicides available in Sri Lanka were tested *in vitro* against *C. cassiicola*. Six fungicides namely benomyl, trimiltox, mancozeb, sandofan, tilt and antracol reached $LD_{(100)}$ within the tested range in both Poisoned Food Technique and Conidial Germination Inhibition tests. Experiments are in progress to screen all effective fungicides for polybag plants under field condition (C K Jayasinghe, T H P S Fernando and U P S Priyanka).

Table 2. *Mean percentage spore germination of* Corynespora

	5 hrs after inoculation		8 hrs after inoculation	
	Lower side	Upper side	Lower side	Upper side
Mancozeb in water	0%	1.9%	0%	8%
Mancozeb in Diesel	25.4%	0%	38.3%	0%
Control	88.1%	96.9%	98.%	97.2%
Mancozeb in water	0%	0%	16.4%	4.2%
Mancozeb in Diesel	36.2%	7.4%	35.3%	39.5%
Control	77.7%	97.5%	85.1%	90%
Mancozeb in water	9.5%	35.9%	19.76%	26.6%
Mancozeb in Diesel	40.2%	27.8%	45.6%	54.1%
Control	84.4%	84.7%	80.6%	83.2%

(C K Jayasinghe, R Jayaratne, S Wettasinghe and D Siriwardene).

Micro-organisms and pests associated with the rubber plantations (MP/89/1)

A. Colletotrichum acutatum: *the main cause of* Colletotrichum *leaf disease in Sri Lanka.*

During the year 1996 it was shown that *Colletotrichum acutatum* is the main cause of *Colletotrichum* leaf disease (CLD) of *Hevea* rubber in Sri Lanka contrary to the general belief that *C. gloeosporioides* is the only cause of CLD since early 1900's. Though the pathogen *C. gloeosporioides* has been studied extensively in Sri Lanka and other parts of the world, no literature is available on *Hevea* isolate of *C. acutatum*. Under the light of this situation an extensive research programme was launched in 1997 to investigate the biology, pathology, epidemiology and management of this pathogen. A CARP grant (12/364/263) was also awarded for the project to fulfil the man power requirements, laboratory and travelling expenditure. Part of this work will be submitted to the University of Colombo as a requirement for the fulfilment of a MSc degree. Following aspects are being under investigation.

A1. Culture characteristics and reproductive morphology of C. acutatum

This study was completed and a descriptive paper together with photomicrographs was sent for publication (C K Jayasinghe and T H P S Fernando).

A2. Multivariate analysis of vegetative and reproductive characters to authenticate Hevea *isolate of* C. acutatum.

Generally, *Colletotrichum acutatum* produces white to slight shade of grey colonies which are orange or rose with a cream reverse. The fungus forms characteristic fusiform (tapered to a point on both ends) conidia. The growth rate was significantly less than that of the *C. gloeosporioides* isolates and a perfect stage is never produced. In this study, four characters: colony growth, conidial shape, colony colour of the reverse and intensity of colour have been incorporated into the analysis. The analysis was performed using PROC CLUSTER available in the statistical package SAS. Two variables, colony diameter and conidial shape, were standardized by dividing each observation with the standard deviation. The clustering method employed was average linkage. The dendrogram derived from the cluster analysis showed two distinct clusters. These two clusters fused together only when the normalized root mean square (RMS) distance approaches 1.414. Initially two isolates suspected as being *C. acutatum*, and later four isolates (randomly selected

from the *C. acutatum* cluster) were sent to the Commonwealth Institute of Mycology for authentication. The authenticity of all these cultures were confirmed as *C. acutatum* [IMI 370090 (KT2); IMI 370092 (AV 1); IMI 375216 (RT 2); IMI 375786 (KT 5); IMI 375787 (KT 11); IMI 375788 (AV 2)]. Hence, it seems that this multivariate technique is an appropriate method for distinguishing the rubber isolate of *C. acutatum* from *C. gloeosporioides* (C K Jayasinghe, B W Wijesuriya and T H P S Fernando).

A3. Factors affecting the growth and spore production of C. acutatum

Colonies grew in all tested media namely potato dextrose agar, lima bean agar, czepek dox agar, malt agar, corn meal agar and water agar. However, density of the mycelium on water agar was extremely low. The best temperature range for the growth of all tested isolates was between 25-30° C. Potato dextrose agar was found to be the best medium for the sporulation of all the isolates. The isolate KT5 was identified as a very poor sporulator and it was shown that a significant increase in spore production of this isolate could be obtained from spore imprint method (T H P S Fernando, C K Jayasinghe, R L C Wijesundera and K D S Samararatne) (a collaborative project with the University of Colombo leading to MSc degree).

A4. Role of cell wall degrading enzymes in pathogenicity of C. acutatum.

Studies on secretion of pectic lyases and cellulases *in vitro* and *in vivo* by *C. acutatum* isolates are in progress (T H P S Fernando, C K Jayasinghe, R L C Wijesundera and K D S Samararatne) (A collaborative project with the University of Colombo leading to a MSc degree).

A5. Two more characteristics to distinguish C. acutatum *from C. gloeosporioides.*

It was shown that benomyl sensitivity could be used to distinguish *C. acutatum* from *C. gloeosporioides* as latter species is highly sensitive to the fungicide benomyl. Further, it was found that growth at a temperature range of 10-35° C was significantly low in *C. acutatum* and hence this character also could be utilized in separating the both species (C K Jayasinghe and T H P S Fernando).

B. *Biology, epidemiology and management of* Cylindrocladium quinqueseptatum, *a potential pathogen of* Hevea brasiliensis

The leaf diseases caused by the fungi *Guignardia, Fusicoccum* and *Cylindrocladium* were also shown to be the potentially threatening leaf diseases of

Hevea in addition to *Corynespora* leaf fall, in a workshop held in 1988 at the RRIM Experimental Station, Sungei Buloh, Malaysia. In Sri Lanka, the fungus *Cylindrocladium quinqueseptatum* was first recorded in 1982 as a pathogen of *Eugenia carryopphyllata*. During early 1990's our attention was drawn to this pathogen again as we received a report from Malaysia stating that one of two clones severely affected in Malaysian budwood nurseries is RRIC 36, a clone bred and released by the Sri Lankan Scientists. Under the light of this situation a series of experiments was launched in 1993 with the collaboration of University of Colombo to study various aspects of the clove isolate of *C. quinqueseptatum* after proving the pathogenicity of this isolate on *Hevea* rubber. This project was partially funded by CARP grant 12/234/184 and investigations were successfully completed in the year 1997 leading to following conclusions.

1. Significant variations in morphology and virulence exist among the isolates of *Cylindrocladium quinqueseptatum* investigated.
2. Susceptibility to *C. quinqueseptatum* among *Hevea brasiliensis* clones varied.
3. A toxin produced by *C. quinqueseptatum* appears to play a major role in disease development.
4. Free water and high relative humidities are essential for disease establishment and development.
5. Epidemics of *C. quinqueseptatum* on rubber plantations in Sri Lanka can be predicted because,
    - susceptible clones are grown,
    - Optimum weather conditions occur in major rubber growing regions,
    - Clove and rubber are planted in the same locality.
6. Fungicides such as benomyl, mancozeb, metalaxyl 8% + mancozeb 64%, oxadixyl 10% + mancozeb 56% may be used to manage *Cylindrocladium quinqueseptatum* epidemics. However, long term solution will be the development of resistant clones using IAN 873, AV 1373, RRIC 102 and IAN 717 as parental material.

Details of the findings have been published in referred journals.

(Principal investigator: C K Jayasinghe, Collaborative Scientist: Prof. R L C Wijesundera, Technical Assistants: T H P S Fernando, U M S Priyanka and C Ariyaratne).

C. *Culture characteristic and reproductive morphology of* Geotrichum

This project was completed and a manuscript was prepared using photomicrographs. In this presentation the characteristics which could be utilized in distinguishing *Geotrichum* from *Rigidoporus lignosus* were highlighted as this has become a controversial issue in early 1990's among the nursery owners in Sri Lanka (C K Jayasinghe and J L P C Wettasinghe).

D. Cylindrocladium candelabrum

Cylindrocladium candelabrum was consistantly yielded when isolations were made from diseased *Hevea* leaves brought from Hillstream Estate, Neboda (C K Jayasinghe and E B Fernando).

E. Periconia sp.

The fungus *Periconia* sp. was isolated from diseased leaves collected from several rubber estates in Kalutara region. However, it was unable to prove Koch's postulates todate (C K Jayasinghe, R Jayaratne, T H P S Fernando and U M S Priyanka).

F. *Studies on the phylloplane microflora of* Hevea brasiliensis

Investigation conducted for two consecutive years revealed that predominant phylloplane microflora of rubber consists of *Altlernaria* spp., *Aspergillus* spp. *Beltrania* spp., *Botryodiploidea* spp., *Colletotrichum acutatum*, *Colletotrichum gloeosporioides*, *Cladosporium* spp., *Curvularia* spp., *Fusarium* spp., *Mucor* spp., *Penicillium* spp., *Phomopsis* spp., *Periconia* spp., *Pestalotiopsis* spp. and *Trichoderma* spp. (C K Jayasinghe, T H P S Fernando and S Samararatne).

G. Fusarium sp. *from Bentota estate*

It was brought to our notice that the clone RRIM 712 of the multilateral clone exchange trial at Bentota Estate was infected again with a fungal pathogen. The genera *Phytophthora* sp. and *Fusarium* sp. were consistently yielded when isolations were made from the diseased lesions (C K Jayasinghe and D S Wettasinghe).

Biological control of *Hevea* diseases (BC/89/1)

A. Biological control of white root disease

Viable inocula in dried pelleted form was prepared in large quantities from *Trichoderma harzianum* (strain TV12,b) for field application. Fungal biomass (1.2g of dry weight equivalent contained 18 x 10^7 spores) grown for 7 days on 200ml of sterilized 3% aqueous molasses, homogenized and mixed with vermiculite - 830g/bran - 33g/sodium alginate (commercial grade) - 45g/400ml of fresh sterilized molasses /25 ml of 50% sulfur dispersion /1400ml of sterilized distilled water (Formula 1). Pellets were formed in 0.25M $CaCl_2$ solution by dropping the whole mixture into the solution and oven dried at 35 °C for 3 days. Formula 2 was composed with 50 ml of sulfur dispersion where all other ingredients were same, as in formula 1.

Viable inocula of *T. harzianum* (strain P41.12) prepared as described above were tested up to 5 months for viability and found that the inocula produced as dried pellets retain it's viability for 2-3.5 months. However, inocula made by powdered plant leaves (air dried rubber, *Pueraria* or *Desmodium* leaves) and mixed with vermiculite, retained viability for 4-5 months.

Application of viable inocula to the white root disease affected rubber plants was carried out in the experimental block at the Nivithigalakele division. Plants were pre-inoculated with laboratory made *Rigidoporus lignosus* inocula incorporated with naturally infected root pieces. After 4-6 months period, out of 38 affected plants, 14 were randomly selected and applied with 100g of the inocula around the collar region. Thereafter, the level of the infection of treated plants were recorded up to 4 months period. The data are summarized in the Table 3.

Interpretation of the results in the table was slightly difficult due to the fact that the control plants did not retain the infection throughout the experiment. This incident was prominent in most of the experiments of this nature which caused the long delay on making firm conclusions. Therefore, it would be necessary to repeat the experiment (K E Jayasuriya and B I Tennakoon).

Table 3. *Infection levels of* R. lignosus [R. microporus *(Fr.) overeem] before and after treatment with* T. harzianum *formulas*

Plant No.	Formula treated	Infection level before treatment		Infection level after 4 months	
		Foliage*	Collar**	Foliage*	Collar**
93	Th-formula 1	0	+	0	-
95	Th-formula 1	0	+	0	-
138	Th-formula 1	0	++	0	+
155	Th-formula 1	0	++	0	--
179	Th-formula 1	0	++	0	--
186	Th-formula 1	0	+	0	-
187	Th-formula 1	0	+	0	-
103	Th-formula 2	+++	+++	++-	---
109	Th-formula 2	++	++	++	--
122	Th-formula 2	+	+++	-	---
124	Th-formula 2	0	+	0	-
136	Th-formula 2	0	+	0	_
180	Th-formula 2	0	+	0	++
181	Th-formula 2	0	+	0	-
113	Control	0	+	0	-
117	Control	0	++	0	--
121	Control	0	++	0	--
127	Control	0	+	0	-
152	Control	+	++	-	--
165	Control	0	+	0	-
184	Control	0	+	0	-

*0 = no symptoms, + = slight yellowing of top whorl, ++ = yellowing and slight buckling of top whorls, +++ = yellowing & downward buckling of leaves with wilting signs, - = this sign refers to curing of the + mark.

** 0 = no infection on collar, + = 25% of the collar surface is infected, ++ = 50% of the collar is infected having partially dead bark, +++ = collar fully infected having 75% dead bark.

B. Biological control studies on rubber nursery pathogens

The interactions between *Trichoderma* spp. against *C. gloeosporoides*, and *C. cassiicola* were studied on sterilized glass slides. Effect of germinated *Trichoderma* on *Colletotrichum* spore germination and the development of the mycelium was studied. Experiments are temporary withhold due to insufficiency of research time (K E Jayasuriya and B I Tennakoon).

Screening of clones for leaf and panel diseases (SC/89/1)

A. Establishment of RRISL 200 series clones and other recommended and potential clones in nursery sites.

Twenty two clones namely RRISL 202, RRISL 201, RRISL 217, RRISL 218, RRISL 219, GPS 1, RRIC 130, PB 217, PB 235, RRIC 121, RRIC 102, RRIC 100, PB 255, PB 260, PR 255, PB 28/59, RRIC 117, RRIM 717, PB 86, PR 261, PR 305, BPM 24 and RRIM 600 were established in eight nursery sites *viz*. Atale, Polatagama, Padukka, Petiyakanda, Nakiyadeniya, Bibile, Happugastenna and Dartonfield estates (W P K Silva, C K Jayasinghe and D S Wettasinghe).

B. Field surveys on Corynespora *leaf fall disease*

Observations of the field surveys carried out island-wide indicated that certain clones which were resistant to CLF previously have now succumbed to the disease. For instance, few spots of the disease were detected on the leaves of RRIC 121, RRIC 130, PB 235, RRIC 131, RRIC 133 in certain localities. However, no defoliation was noticed at all sites (C K Jayasinghe and D S Wettasinghe).

Biology of common pathogens of *Hevea* (BCP/90/1)

A. Phytophthora *spp. (Studies on the genetical variations of* Phytophthora *species on rubber in Sri Lanka and defense responses of some clones against them.)*

A_1. Around 40 isolates of *Phytophthora* spp. were collected from infected rubber plantations and nurseries in Kalutara, Ratnapura, Kegalle, Galle, and Colombo districts and some cocoa plantations in Matale. Preliminary studies on the growth and some morphological characters of the single-spore cultures were carried out during the year.

The Scanning Electron Microscope (SEM) was used to study the nature of surface ultra-structures of tissues of different clones - leaf central vein, petiole, immature bark, immature pod. The scanning work was continued.

Preliminary arrangements were made to extract crude DNA from fungal specimens for amplification using Ploymerase Chain Reaction (PCR) techniques with the collaboration of the Plant Breeding and Genetics Department. This is a collaborative project with the University of Colombo leading to a PhD degree (K E Jayasuriya, R L C Wijesundera, D P S T G Attanayake, C K Jayasinghe and B I Thennakoon).

A_2. *Preliminary studies were initiated to study the anatomical and biochemical reactions involved in* Hevea *plants against* Phytophthora *infection.*

Leaf and petiole tissue extracts of clone RRIC 100 (resistant), PB 86 (moderately resistant), and RRIM 600 (highly susceptible) were obtained using C_2H_5OH and $CHCl_3$. The compounds in the extracts were separated using thin layer chromatography and cladoporium bioassays were carried out to detect the antifungal compounds. Few inhibition zones were detected in all three clones. The separation of these inhibitory compounds are in progress with an view of identification using NMR in collaboration with Colombo University, Botany Department (R Jayaratne and P C Wettasinghe).

Effect of leaf exudates on the zoospore germination of Phytophthora of the above 3 clones were compared. Spore germination percentages were much less in RRIC 100 exudated collected upto 48 hours compared to RRIM 600 (R Jayaratne and P C Wettasinghe).

Scanning Electron Micrographs (SEM) were taken with the collaboration of Colombo University, Botany Dept. to compare the surface anatomical features of petiole tissues in these 3 clones with and without inoculation with Phytophthora zoospores (R Jayaratne and P C Wettasinghe).

B. Corynespora cassiicola

B_1. *Studies on* C. cassiicola *collected from hosts associated with rubber plantations*

Corynespora cassiicola was isolated from manihot, papaw, cocoa, tomato, sweet potatoes, bitter guard and dambala. RAPD - PCR studies with above isolates indicated that isolates collected from different host plants have variations in their genetic make up (W P K Silva, C K Jayasinghe and U M S Priyanka).

B_2. Corynespora cassiicola *isolates collected from* Hevea

DNA was extracted from 40 isolates of *Corynespora cassiicola* collected from different clones of rubber. RAPD - PCR studies with 10 primers indicated their genetic variations (W P K Silva, and U M S Priyanka with the collaboration of Prof. E H Karunanayake, Faculty of Medicine, University of Colombo). The results of this project will be submitted for the fulfillment of a PhD degree.

C. Production of cell wall degrading enzymes by Hevea *pathogens*

Studies were commenced on four pathogens in 1995 and investigations on the role of cell wall degrading enzymes in pathogenicity was completed with two common pathogens namely *C. cassiicola* and *P. meadii* and the potential pathogen *C. quinqueseptatum*. The characterization of the cell wall degrading enzymes produced by *Corynespora* sp., *Phytophthora* sp., *Cylindrocladium* sp. and *Dreshslera* sp is in progress (C K Jayasinghe, T H P S Fernando).

Improvement of cultural practices in management of *Hevea* diseases (CP/89/1)

A. Effect of an additional dose of fertilizer on yield of Hevea *plants defoliated due to* Phytophthora *epidemics*

The above experiment initiated in 1993 continued at Halwatura, Sirikandura, Eladuwa and Padukka estates. Application of an additional fertilizer doze and the collection of yield data carried out (R Jayaratne, D Siriwardene and U Mitrasena. A collaborative project with Soils and Plant Nutrition Department).

Studies on VA Mycorrhiza (M/86/1)

A. The field experiment initiated to ascertain the effect inoculation of arbusculaar mycorrhizal association in competition with natural populations was continued. The successfully bud-grafted plants were planted in the field at Dartonfield estate, Gallewatta Division. The experimental design was a randomized block design. The plants were established well during the South-west monsoon period. The first assessment on girth was taken after 3 months of planting (Table 4) (R Jayaratne and D Siriwardene).

Table 4. *Mean diameter of the field established plants after 3 months. (cm). (Mean of 5 replicates consisting 10 plants for each replicate)*

Mycorrhizal type	+ P (added P)	- P (no addition of P)
1. *Gigaspora margarita*	3.23	2.78
2. *Acaulospora* sp.	3.03	2.58
3. Natural population	2.55	2.35
4. Non-mycorrhizal (initially)	2.42	2.27

LSD (P = 0.05) = 0.19 (Between P treatments)

B. The experiment laid down with the collaboration with soils and Plant Nutrition Dept. to ascertain the effect of VA mycorrhiza on uptake of phosphorus from different sources in polybags was completed. The fresh and dry weights of leaves, shoots and roots were taken separately (Table 5). Fresh root sample were fixed in FAA to determine the percentage of mycorrhizal infection in roots. Root, shoot nutrient levels too will be analyzed.

Table 5. *Dry and fresh weights of leaves, petioles, shoots and roots of* Hevea *seedlings (g/plant) (Mean 6 replicates)*

Treatment		Fresh leaves	Dry leaves	Petioles fresh	Petioles dry	Shoots fresh	Shoots dry	Root fresh
T1	NM	2.86	0.72	0.862	0.202	35.79	14.38	43.31
No P	M	7.08	2.08	1.97	0.470	52.98	22.97	63.51
Mean		4.97b	1.40b	1.466b	0.348b	45.17b	18.99b	54.33b
T2	NM	21.67	5.98	4.64	1.16	67.07	28.58	80.51
ERP	M	46.12	15.98	9.73	2.70	103.90	42.80	108.39
Mean		35.00a	11.435a	7.418a	2.00ab	87.16a	36.34a	95.73 a
T3	NM	27.48	9.25	6.88	1.97	85.99	36.40	86.04
IRP	M	37.75	12.21	9.15	4.25	82.7	33.81	114.06
Mean		33.08a	10.87a	8.124a	8.213a	84.20a	34.989a	101.33a
T4	NM	18.99	7.29	7.01	1.67	90.30	34.13	90.52
ERP + IRP	M	14.12	4.10	4.64	1.05	69.04	27.21	65.98
Mean		20.15ab	5.70ab	5.825ab	1.367ab	79.71a	30.675ab	78.26ab

Means with same letters are not significantly different at 0.05% level by DMRT along the columns.

NoP	- Without Phosphate
ERP	- Eppawela Rock Phosphate
IRP	- Imported Rock Phosphate
ERP + IRP	- Eppawela Rock Phosphate + Imported rock Phosphate
NM	- Nonmycorrhizal plants
M	- Mycorrhizal plants

C. Arbuscular mycorrhizal inoculum that can be used in commercial scale application was produced using commonly occurring two waste organic products. Arrangements have been made to Patent this product in Sri Lanka. This will be very cheap "bio fertilizer" for many bio plants products (R Jayaratne and D Siriwardene).

SOILS AND PLANT NUTRITION

Lalani Samarappuli

SUMMARY

Research on improvement in soil fertility, increasing efficiency of nutrient uptake, economizing on fertilizer use, improved methods of soil, water and nutrient conservation and weed control have been the main objectives of this Department.

It is evident that the residual effect of mulching during the immature period of rubber would persist for about 10 years. Girth of rubber plants continued to be significant even in the renewed panel, although the girth increment was not significantly different. *Flemingia congesta* and *Crotolaria anagyroides* were identified as tree legume species that can be grown successfully between the rows of rubber plants and which would provide sufficient biomass for mulching; *Flemingia* from the beginning of year 2 until the end of immature period of rubber and possibly even during the mature phase whereas *Crotolaria* from 3 months after planting until the end of year 2. Although the creeping type of legume, *Mucuna bracteata*, appears to take longer period to establish fully, it provided higher biomass and litter during the latter part of the 1st year and during the 2nd year. It also tolerated drought condition and suppressed weeds very effectively.

Studies on weed control suggested that combinations of Paraquat with other weedicides are more effective than application of Paraquat only. It appeared that Paraquat + Diuron mixture was the most effective when compared with other weedicide treatments. It also seems to suggest that application of Glyphosate alone is more effective than application of Glyphosate mixtures. If sufficient material for mulching such as lopping of tree legumes, straw etc. are available, mulching the inter-row area could be a satisfactory method of weed control. The data suggested that mulching after clean weeding was more effective than mulching without clean weeding.

The foliar nutrition study suggested that foliar feed of NPK and Mg alone without soil application is not an efficient fertilizer formulation for rubber plants raised by young budding technique. It also appeared that currently recommended soil application of soluble fertilizer formulation is more effective compared to soil application with foliar feeds in relation to plant growth.

The experimental results seem to suggest that it may be possible to apply young budding mixtures at monthly intervals as efficiently as biweekly intervals.

The soil and foliar survey programme provided data for fertilizer recommendations for 5000 hectares in the estate sector.

DETAILED REVIEW

Staff

The Head of the Department, Dr (Mrs) Lalani Samarappuli and Assistant Soils Chemist, Mr S Dharmakeerthi were on duty throughout the year. Soils Chemist, Dr D M A P Dissanayake proceeded to Malaysia in October for a period of 6 months to participate in a training programme organized by the IAEA.

The Experimental Officers, Messrs A M A Perera, H D S P Perera, G de Mel and R Hettiarachchi were on duty throughout the year.

Senior Technical Officer, Mr S N Silva, Technical Officers Messrs P Karunadasa, U Mitrasena, A N Yakandawela, V Edirimanne, D Senaratne and A Thevarapperuma, Senior Testing Officer Mr T M Ahamadeen and the English stenographer Mrs L Rupasinghe were on duty throughout the year. Senior Technical Officer Mrs C Maheepala and Technical Officer Mr T B Dissanayake were on overseas training at RRI of India and University of Malaysia during the periods, 6th August to 22nd December and 6th October to 5th December, respectively.

Mr P R Puhambugoda joined the institute as a Technical Officer in June.

Research students

Mr P A N D Perera, an undergraduate student from the University of Peradeniya, completed his final year project on "Performance of different weed control methods under immature rubber" under the supervision of Dr (Mrs) Lalani Samarappuli.

Miss N S P N Vithana, an undergraduate student from the University of Peradeniya, completed her final year project on "Effect of N, P, K and Mg as foliar spray on the performance of rubber plants raised by young budding technique" under the supervision of Dr (Mrs) Lalani Samarappuli.

Miss L P C Fernando, an undergraduate student from the University of Ruhuna, completed her final year project on "Effect of Mn, Mo and Zn as foliar spray on the performance of rubber plants raised by young budding technique" under the supervision of Dr (Mrs) Lalani Samarappuli.

Visits

Dr D M A P Dissanayake was awarded a fellowship to participate in a training programme organized by the IAEA from 10th October, in the Dept. of Soil

Science, University of Malaysia. He also attended the IRRDB Conference held in Vietnam in October and presented a paper.

Mrs C Maheepala participated in a training programme on analytical techniques in the Dept. of Agronomy, RRI of India. Mr T Dissanayake participated in a training programme organized by the IAEA, in the Dept. of Soil Science, University of Malaysia.

The Departmental staff paid advisory visits to plantations and smallholdings and routine visits to experimental areas where necessary.

Seminars, Meetings, Workshops and Training

Dr (Mrs) Lalani Samarappuli addressed the following:

* Seminar on "Rubber as an environment friendly raw material and renewable resource" organized by the Rubber Development Department, on "Soil management practices and their effects on the environment".

* Seminar on "Nuclear techniques for better agricultural productivity" organized by the AEA, University of Ruhuna and SLAAS Section B, on "Application of nuclear techniques in soil moisture studies under rubber".

* Seminar on "The use of nuclear techniques in studies of soil/plant relationships with emphasis on soil water management" organized by the AEA.

* Ninth National Workshop on "Multipurpose trees for environmental conservation" organized by the National Research Network on Multipurpose trees and sponsored by The Royal Netherlands Embassy on "Management of tree Legumes towards higher productivity in rubber plantations".

Dr D M A P Dissanayake addressed the following seminars:

* Seminar on "Nuclear techniques for better agricultural productivity" organized by the AEA, University of Ruhuna and SLAAS Section B, on "Use of P^{32} in the bioassay for assessing phosphate availability and requirement of different crop species".

* IRRDB Seminar on "Potential of Rock Phosphate use in rubber cultivation".

Dr (Mrs) Lalani Samarappuli[1] and Dr D M A P Dissanayake[2] attended the following seminars, meetings and workshops:

* Fertilizer Advisory Committee[1].
* The Working Group on Fertilizer Mixtures of the Sri Lanka Standards Institution[1].
* Central Scientific Committee[1,2].

Training programmes

Lalani Samarappuli, D M A P Dissanayake and S Dharmakeerthi were involved in the following training programmes as resource personnel:

* Rubber Development officers of the Rubber Development Department
* Owners and Managers of middle level estates
* Superintendents, Assistant superintendents and Field officers of Plantation Management Companies
* Superintendents/Assistant Superintendents for the Diploma Course in Plantation Management
* University Students/NDT Trainees

LABORATORY AND FIELD INVESTIGATIONS

1. Soil fertility and moisture conservation

1.1 *Agronomic practices in relation to moisture conservation*

1.1.1 *Use of live and dead mulch*

1.1.1.1 Comparison of different management practices

Investigation on the residual effect of mulching during the immature period, on latex production and girthing of trees was continued in experiment SMC-Ag/M/82/5. The residual effect of treatments on yield and girth in the renewed panel

are given in Table 1 and 2, respectively. No significant difference was observed among the different treatments for latex yield. It is evident that the residual effect of mulching during the immature period of rubber would persist for about 10 years. Girth of rubber plants continued to be significant even in the renewed panel, although the girth increment was not significantly different.

In experiment SMC-Ag/M/88/1, application of mulching was continued during mature phase. The effect of this treatment in comparison with the residual effect of mulching on yield and girth of rubber plants is given in Table 3. No significant difference was observed among the two treatments for girth. Yield of rubber plants was significantly different among the two treatments (L Samarappuli, P Karunadasa and U Mitrasena).

Table 1. *Residual effect of different soil management practices on yield*

Treatment	Yield	
	(g/t/t)	(kg/ha/yr)
Legumes	16.86[a]	1062[a]
Naturals	16.88[a]	1063[a]
Dead mulch	17.42[a]	1098[a]

1.1.1.2 Optimum N P K levels for rubber mulched with rice straw

In this experiment (SMC-Ag/M/83/1), the N,P,K requirements for rubber, mulched with rice straw, was studied in a 3x3x3 factorial design in which three levels of N,P and K were applied with and without mulching in the sub-plots. The effect of application of paddy straw on girth and girth increment are given in Table 4 (L Samarappuli, P Karunadasa and U Mitrasena).

Table 2. *Residual effect of different soil management practices on girthing of* Hevea

Treatment	Girth (cm)	Girth Increment (cm)
Legumes	66.75[ab]	3.02
Naturals	64.13[b]	2.43
Dead mulch	70.33[a]	1.91

Table 3. *Effect of mulching during mature phase on girth and yield of* Hevea

Treatment	Girth (cm)	Yield (g/t/t)	Yield (kg/ha/yr)
Without mulching	57.1[a]	22.5[a]	1418[a]
With mulching	57.5[a]	24.8[a]	1562[a]

Table 4. *Effect of mulching on girth and girth increment of rubber*

Treatment	Girth (cm)	Girth Increment (cm)
Without mulch	56.8[a]	2.2
With mulch	60.5[b]	2.0

1.1.1.3 Different mulching materials

A field experiment (SMC-Ag/M/97/1) is in progress at Sapumalkanda estate, Deraniyagala to study the effect of different quantities of refused tea and wood ash on growth of *Hevea* plants. Treatments consisted of three quantities of refused tea and wood ash; no refused tea (T0), ½kg refused tea/plant (T1), 1kg refused tea/plant (T2), no wood ash (W0), ½kg wood ash/plant (W1) and 1kg wood ash/plant (W2). Plant diameter at 6 months after planting is given in Table 5 (L Samarappuli, P Karunadasa and U Mitrasena).

1.1.2 *Fertilizer practices for overcoming moisture stress*

A field experiment (SMC-Ag/F/88/3) is in progress at Nalanda Estate, Ulpotha to study the effect of different levels of potassium on growth of *Hevea* plants in a comparatively drier area. Eventhough the tapping was commenced in the experimental area in May 1997, test tapping was not done during the year 1997.

In experiment SMC-Ag/M/88/1, with and without K, girth and yield data indicated higher girthing and higher yield (Table 6) with potassium at K1 level.

In field experiment (SMC-Ag/F/95/1), the effect of both potassium and mulching on moisture stress and growth of *Hevea* was studied. Treatments consisted of three mulching techniques; no mulch (M0), surface mulching (M1) and sub surface mulching (incorporation) (M2) and four potassium levels; half the recommended level

(K1), recommended level (K2), one and half the recommended level (K3) and double the recommended level (K4). Girth measurements at two and a half years after planting are given in Table 7 (L Samarappuli, P Karunadasa and U Mitrasena).

Table 5. *Effect of refused tea and wood ash on diameter of rubber plants*

Treatment	Diameter (cm)
T_0W_0	16.6
T_0W_1	17.6
T_0W_2	14.9
T_1W_0	16.4
T_1W_1	15.2
T_1W_2	17.6
T_2W_0	15.5
T_2W_1	18.8
T_2W_2	15.4

Table 6. *Effect of potassium on girth and yield of rubber plants*

K levels	Girth (cm)	Yield	
		(g/t/t)	(kg/ha/yr)
K_0	52.4	13.3	838
K_1	56.1	19.2*	1210*
LSD	1.2	2.2	139

Table 7. *Effect of potassium and mulching on girth of rubber plants*

Treatment	Girth (cm)	Girth Increment (cm)
K_3M_2	22.62[a]	9.67
K_4M_1	22.48[a]	9.38
K_3M_1	22.20[a]	8.90
K_4M_2	22.00[a]	8.85
K_4M_0	21.32[a]	8.74
K_1M_1	21.58[a]	8.73
K_2M_2	21.58[a]	8.65
K_3M_0	21.90[a]	8.62
K_2M_0	22.00[a]	8.55
K_2M_1	22.12[a]	8.54
K_1M_2	21.50[a]	8.50
K_1M_0	21.32[a]	8.12

1.1.3 *Rubber based cropping systems to increase water use efficiency of rubber plants*

Access tubes were installed at 4 points in each plot in the experimental area on multicropping of rubber with tea at the RRI Sub Station in Kuruwita (SMC-Ag/I/93/1) and monitoring of soil moisture content using Neutron Probe was done. The soil moisture contents under rubber and tea multi cropping system are given in Table 8.

Access tubes were also installed in each plot in the experimental area on multicropping of rubber with tea at Perth estate, Ingiriya (SMC-Ag/I/96/1) and monitoring of soil moisture content was done. The difference in soil moisture content between the different spacings of rubber and tea and between positions of rubber and tea plants are given in Table 9 and 10. Leaf water potential also showed a marked difference between planting practices and positions of tea and rubber plants (Table 11) (L Samarappuli, N Yogaratnam, S M Iqbal, P Karunadasa and U Mitrasena).

Table 8. *Effect of different planting practices of tea and rubber on soil moisture content*

Treatment	Moisture content (kg/M^3)			
	(1)*	(2)*	(3)*	(4)*
Tea only (rehabilitated)	-	-	-	473.3
Rubber only	497.8	-	-	-
Tea and rubber (rehab.)(8'x27')	449.0	477.8	477.5	497.3
Tea and rubber (unrehab.)(8'x27')	454.2	458.7	454.0	460.7
Tea and rubber (rehab.)(8'x40')	444.5	419.8	429.2	457.0
Tea and rubber (unrehab.)(8'x40')	432.5	432.8	431.7	459.3

(1)* - Rubber planting row
(2)* - Between rubber and tea plants
(3)* - 1st row of tea plants
(4)* - Middle row of tea plants

Table 9. *Effect of different spacings of rubber and tea on soil moisture content*

Treatment	Moisture content (kg/M^3)			
	17/02/97	03/03/97	13/03/97	24/04/97
Rubber only	465.0	411.5	451.5	510.5
Tea & rubber (8'x8'x46')	406.7	363.0	395.3	441.2
Tea & rubber (8'x8'x60')	485.0	430.2	476.7	526.5
Tea & rubber (8'x8'x70')	431.0	391.3	427.0	476.0
Tea & rubber (8'x60')	438.0	392.8	438.3	474.5
Tea only	437.0	394.0	427.5	493.5

Table 10. *Effect of different positions of tea and rubber plants on soil moisture content under tea and rubber multicropping system*

Position	Moisture content (kg/M^3)			
	T&R (8'x8'x46')	T&R (8'x8'x60')	T&R (8'x8'x70')	T&R (8'x60')
Rubber planting row	406.2	478.8	462.6	427.0
Between rubber & tea plants	410.5	473.6	438.5	439.6
1st row of tea plants	378.9	479.6	392.9	441.1

Table 11. *Effect of different spacings of rubber & tea on leaf water potential (LWP)*

Treatment	Leaf water potential (bars)		
	Rubber	Tea (1)"	Tea (2)"
Rubber only	11.7	-	-
Tea & rubber (8'x8'x46')	10.2	7.8	7.1
Tea & rubber (8'x8'x60')	9.9	7.4	6.6
Tea & rubber (8'x8'x70')	10.3	7.2	6.5
Tea & rubber (8'x60')	10.2	7.1	6.8
Tea only	-	-	6.7

(1)" - 1st row of tea adjoining rubber row
(2)" - center of tea rows

1.1.4 *Fertilizer and soil moisture requirement of rubber under different densities*

An experiment (SMC-Ag/D/96/1) was started at Mucalana Division, Sirikandura Estate to study the fertilizer and soil moisture requirement of rubber under different densities. Treatments consisted of (a) Four different densities; (i) 500 trees/ha [4.5m x 4.5m], (ii) 600 trees/ha [4.2m x 4.2m], (iii) 700 trees/ha [3.8m x 3.8m] and (iv) 800 trees/ha [3.5m x 3.5m] (b) Three fertilizer treatments; (i) recommended level, (ii) reduced level and (iii) 1st three years recommended level and

thereafter reduced level. Effect of different densities on girth of rubber plants at the end of 18 months from planting is presented in Table 12 (L Samarappuli, P Karunadasa and U Mitrasena in collaboration with the Plant Science Department).

Table 12. *Effect of different plant densities and fertilizer treatments on girth of rubber plants*

Treatment	Girth (cm)
500 trees/ha [4.5m x 4.5m]	9.7[a]
600 trees/ha [4.2m x 4.2m]	9.9[a]
700 trees/ha [3.8m x 3.8m]	9.4[a]
800 trees/ha [3.5m x 3.5m]	10.2[a]
Recommended fertilizer level	10.0[a]
Reduced fertilizer level (1)	9.6[a]
Reduced fertilizer level (2)	9.8[a]

1.2 *Feasibility of growing rubber in drier areas*

A field experiment (SMC-Ag/F/88/3) is in progress at Nalanda Estate, Ulpotha to study the feasibility of growing rubber in a comparatively drier area. A site was selected in Kumarawatta estate, Monaragala to study the same with different soil management and fertilizer practices (L Samarappuli, P Karunadasa and U Mitrasena).

1.3 *Ground cover management and nutrient recycling*

1.3.1 *Ground cover management*

1.3.1.1 Comparison of different cover types

Experiment, SMC-Ag/M/88/1, was started to study the influence of creeping, bush and tree legumes on some soil characteristics and their effects on the performance of rubber in *Boralu* series soils. Effect of different types of legumes on girth and yield rubber is given in Table 13 (L Samarappuli, P Karunadasa and U Mitrasena).

Table 13. *Effect of different types of legumes on girth and yield of* Hevea

Treatment	Girth (cm)	Yield (g/t/t)	Yield (kg/ha/yr)
Pueraria (Creeping type)	55.3[a]	20.6[a]	1298[a]
Desmodium (bush type)	52.8[b]	19.6[a]	1235[a]
Stylosanthus (bush type)	53.7[b]	17.5[a]	1102[a]
Tephrosia (tree type)	50.6[b]	20.3[a]	1279[a]

Another field experiment is in progress at Perth Estate, Horana to compare the effectiveness of tree legumes with the conventional creeping type *Pueraria phasioloides*. Effect of these legumes on girth of rubber plants at the end of 18 months from planting is presented in Table 14 (L Samarappuli, P Karunadasa and U Mitrasena).

Table 14. *Effect of different tree legume species on girth of rubber plants*

Treatment	Girth (cm)
Pueraria phasioloides	10.22[a]
Crotolaria anagyroides	12.34[b]
Flemingia congesta	10.94[c]
Tephrosia vogellie	10.68[ac]

1.3.1.2 Comparison of different tree legumes

A field experiment (SMC-GC/TL/96/1), was started to study the comparative efficiency of *Tephrosia vogellie, Crotolaria anagyroides and Flemingia congesta* as successful tree legume species that can be grown between the rows of rubber plants which could provide enough material for mulching in Kalutara District. Although the growth rate of *Flemingia congesta* during the early stages appeared to be slow, it was observed that the growth rate and recovery after lopping of *Flemingia congesta* is much higher than the other two species. Effect of different types of tree legumes on

girth of rubber plants at the end of 18 months from planting is presented in Table 15. Soil moisture content and leaf water potential of rubber plants under different tree legume species are presented in Table 16 (L Samarappuli, P Karunadasa and U Mitrasena).

Table 15. *Effect of different tree legume species on girth of rubber plants*

Treatment	Girth (cm)
Crotolaria anagyroides	12.34[a]
Flemingia congesta	10.94[b]
Tephrosia vogellie	10.68[b]

Table 16. *Effect of different tree legume species on soil moisture content and leaf water potential (LWP)*

Treatments	Soil moisture content (kg/M^3)	LWP (bars)
Crotolaria anagyroides	491[a]	10.5[a]
Flemingia congesta	528[a]	11.6[a]
Tephrosia vogellie	519[a]	10.3[a]

Another field experiment (SMC-GC/TL/97/1), was started to study the effectiveness of tree legumes under rubber in Parambe estate, Kegalle District. Treatments consisted of four types of tree legumes: *Tephrosia vogellie, Gliricidia sepium, Crotolaria anagyroides, Flemingia congesta* and conventional creeping type *Pueraria phaseoloides*. Effect of different species on girth of rubber plants at the end of 6 months after planting is presented in Table 17 (L Samarappuli, N Yogaratnam, P Karunadasa, U Mitrasena and E A T Senadeera).

Table 17. *Effect of different tree legume species on diameter of rubber plants.*

Treatment	Diameter (mm)
Pueraria phaseoloides	24.7[a]
Tephrosia vogellie	25.1[a]
Crotolaria anagyroides	26.1[a]
Flemingia congesta	24.5[a]
Gliricidia sepium	23.5[a]

1.3.1.3 Phosphate fertilizers for cover crops

A field experiment, (SMC-GC/P/97/1) was started in Weniwella estate, Kegalle to study the effectiveness of Eppawela rock phosphate as a source of P for leguminous ground covers, both creeping and bush/tree types. Treatments consisted of three P sources: no P, ERP and IRP and two cover types: *Mucuna bracteata and Flemingia congesta* (L Samarappuli, A Dissanayake, N Yogaratnam, P Karunadasa, U Mitrasena and E A T Senadeera).

1.3.1.4 New cover crop species

At Perth Estate, Horana an experiment (SMC-GC/C/96/1)) was started to study the efficiency of *Mucuna bracteata*, on growth, nutrient enrichment and other desirable characteristics in comparison with *Pueraria*. *Mucuna bracteata* appears to fully establish 6 months after planting in Kalutara District. Effect of two different types of legumes on girth of rubber plants at the end of 18 months from planting is presented in Table 18 (L Samarappuli, P Karunadasa and U Mitrasena).

At Sapumalkanda estate, Deraniyagala an experiment (SMC-GC/C/97/1)) was started to study the efficiency of *Wedelia biflora* (Arunadevi), on growth, nutrient enrichment and other desirable characteristics in comparison with *Pueraria*. Effect of this cover crop on diameter of rubber plants at the end of 6 months from planting is presented in Table 19 (L Samarappuli, P Karunadasa and U Mitrasena).

Another field experiment (SMC-GC/C/98/1), was planned to study and identify leguminous cover crop species with multiple advantages and which would satisfy a dual function of being a cover crop and a cash crop at the same time. A site was selected at Dartonfield estate for this experiment (L Samarappuli, P Karunadasa and U Mitrasena).

Table 18. *Effect of two different legume species on girth of rubber plants*

Treatment	Girth (cm)
Mucuna bracteata	11.0[a]
Pueraria phaseoloides	10.2[b]

Table 19. *Effect of Wedelia biflora (Arunadevi) on diameter of rubber plants*

Treatment	Diameter (mm)
Pueraria phaseoloides + P	11.0
Wedelia biflora + P	9.9
Wedelia biflora + NPKMg (level 1)	10.1
Wedelia biflora + NPKMg (level 2)	10.7

1.3.2 *Nutrient recycling*

1.3.2.1 Sludge as a potential fertilizer for *Hevea*

An experiment was started at Payagala estate to evaluate sludge as a fertilizer for immature rubber (SMC-GC/RC/93/2 and SMC-GC/RC/93/3), and for legume covers (SMC-GC/RC/93/1). Different levels of fertilizers and sludge were applied according to the design. Effects of treatments on girth of rubber plants are given in Tables 20 and 21 (L Samarappuli and A M A Perera).

Table 20. *Effect of application of sludge on girth of rubber plants*

Treatment	Girth (cm)
Without sludge	29.2[a]
With sludge	32.1[a]

Table 21. *Effect of application of sludge to covers on girth of rubber plants*

Treatment	Girth (cm)
No P fertilizer	28.5[a]
IRP (recommended level)	30.3[a]
Sludge (normal level)	29.6[a]
Sludge (double level)	30.4[a]

1.4 *Soil conservation and development of degraded lands*

In a field experiment SMC-Ag/M/82/5, with two slopes *viz* 6% and 12%, the soil degradation and development aspects were studied. In 6% slope, girth and yield were higher compared to 12% slope (Table 22). (L Samarappuli, N Yogaratnam, P Karunadasa and U Mitrasena).

Table 22. *Effect of different slopes on girth and yield of rubber plants*

Slope	Girth (cm)	Yield	
		(g/t/t)	(kg/ha/yr)
6%	68.8[a]	19.1[a]	1203[a]
12%	64.1[b]	15.8[b]	995[b]

1.5 *Weeds and weed control*

1.5.1 *Weed control under smallholder condition*

A field experiment was started to compare manual and chemical weeding during immature phase of rubber under small holder conditions. Treatments consisted of (1) manual weeding, (2) chemical weeding (level 1), (3) chemical weeding (level 2), (4) chemical weeding (level 3) and (5) chemical weeding (level 1) and legume covers. Herbicides were sprayed according to the experimental design (L Samarappuli, P Karunadasa and U Mitrasena).

1.5.2 *Chemical control of weeds*

Another field experiment was started to study the effects of different weedicides under immature rubber. Seven weed control practices that were studied in a randomized block design with four replicates are; (1) No weeding, (2) Manual weeding with cover establishment, (3) Glyphosate (20ml/8 litres water), (4) Glyphosate + 2.4.D Amine salt, (5) Paraquat (25ml/4 litres water), (6) Paraquat + Diuron and (7) Diuron. Effect of different weed control methods on weed growth after 3rd, 5th and 7th week is given in Table 23 (L Samarappuli and N Perera).

Table 23. *Effect of different chemical control methods on weed growth*

Treatment	Weed percentage (%)		
	3rd week	5th week	7th week
No weeding	100[a]	100[a]	100[a]
Paraquat I	16[b]	47[b]	83[ab]
Manual weeding	10[bc]	36[bc]	57[cd]
Glyphosate II	7[cd]	24[c]	49[cd]
Glyphosate + 2.4.D Amine	6[cd]	20[cd]	45[d]
Diuron	1[d]	5[d]	17[e]
Paraquat + Diuron	1[d]	6[d]	8[e]

1.5.3 *Weed control by mulching*

This experiment was started to study the performance of agronomic practices on weed control. Treatments consisted of ten different agronomic practices:

T1 - No weeding
T2 - Manual weeding with cover establishment
T3 - Mulching with straw after clean weeding
T4 - Mulching with straw without clean weeding
T5 - Mulching with *Flemingia* after clean weeding
T6 - Mulching with *Flemingia* without clean weeding
T7 - Mulching with *Crotolaria* after clean weeding
T8 - Mulching with *Crotolaria* without clean weeding
T9 - Mulching with weeding materials after clean weeding
T10 - Mulching with weeding materials without clean weeding

Effect of different weed control methods on weed growth after 3rd, 5th and 7th week is given in Table 24 (L Samarappuli and N Perera).

Table 24. *Effect of different chemical control methods on weed growth*

Treatment	No of weeds/0.25 m^2
T8	138[a]
T2	120[a]
T10	69[bc]
T6	66[bc]
T7	63[bc]
T4	63[bc]
T1	63[bc]
T9	57[bc]
T3	42[cd]
T5	10[d]

2. Fertilizer use and plant nutrition

2.1 *NPKMg requirement of rubber*

2.1.1 *Fertilizers to nursery plants*

2.1.1.1 Application frequency

An experiment was carried out to evaluate the efficiency of a more soluble fertilizer mixture for young budding at the Eladuwa Estate. Following treatments were allocated in a randomized complete block design with 25 poly bags per treatment and 4 replicates.

Treatment 1 - no fertilizer control

Treatment 2 - 50g RP + biweekly application of currently recommended liquid formulation

Treatment 3 - 50g RP + monthly application of currently recommended liquid formulation

Treatment 4 - 75g RP + biweekly application of SA/SOP/CES liquid formulation

Treatment 5 - 75g RP + Monthly application of SA/SOP/CES liquidformulation

No significant difference was observed between the currently recommended formulation and the new formulation (Table 25). However, as the new formulation is more easily soluble, this could be used more efficiently in young budding. Further, it appears possible to apply both mixtures at monthly intervals as efficiently as biweekly intervals (R S Dharmakeerthi, L Samarappuli and S N Silva).

Table 25. *Effect of different fertilizers on young budding*

Treatment	Diameter (mm)	Buddability (%)	Budding success (%)	Die back (%)	Recovery at planting (%)
1	6.01[b]	52.1[b]	92.0[a]	2.5[a]	49.0[b]
2	7.01[a]	72.1[a]	97.0[a]	1.5[a]	69.1[a]
3	6.60[a]	85.3[a]	100.0[a]	4.1[a]	80.6[a]
4	6.60[a]	75.3[a]	98.2[a]	4.2[a]	75.3[a]
5	6.70[a]	74.8[a]	98.1[a]	1.2[a]	65.3[a]

2.1.1.2 Requirement of a basal application when young budding are planted in the field

Statistical analysis of the data has indicated that the application of 100g RP + 50g NPK + 25g kieserite to the planting hole has significantly increased the plant height and girth of young budding plants when measured at 6 months after planting (Table 26). Further the significantly higher girth of these plants could be observed at one year after planting as well (R S Dharmakeerthi, L Samarappuli, S N Silva and A Yakandawela).

Table 26. *Effect of planting hole application on the growth of young budding plants at the field*

Treatment No.*	Plant Height (cm)	No. of leaves	Girth (cm)	Girth (cm)
	6 months after planting			1 year after planting
1	199^{b}	166^{a}	6.2^{b}	9.7^{bc}
2	197^{b}	165^{a}	6.3^{b}	9.4^{b}
3	218^{a}	186^{a}	6.5^{a}	10.2^{a}
4	196^{b}	164^{a}	6.1^{b}	10.0^{ac}

* - For treatments please see the Annual Review - 1996

2.1.2 *Fertilizer requirement of new clones*

The significant clone and fertilizer level interaction which was observed at the 4th year, could be observed ($P < 0.05$) after the 5th year also (Table 27).

Table 27. *Girth (cm) after 5 years of planting*

Treatment	Clone				Mean
	RRIC 121	RRIC 110	PB 260	RRISL 203	RRIM 712
Control	$^{c}37.5_{AB}$	$^{c}41.3_{A}$	$^{c}40.6_{A}$	$^{b}29.7_{B}$	$^{b}33.9_{AB}$
2 currently Rec. Level	$^{b}43.4_{A}$	$^{b}47.0_{A}$	$^{bc}44.1_{A}$	$^{a}44.3_{A}$	$^{a}41.6_{A}$
Currently Rec. level	$^{bc}41.3_{C}$	$^{ab}51.1_{A}$	$^{ab}47.0_{B}$	$^{a}47.5_{AB}$	$^{a}43.9_{BC}$
½ Currently Rec. level	$^{a}47.6_{B}$	$^{a}53.0_{A}$	$^{a}49.6_{B}$	$^{a}49.2_{B}$	$^{a}44.1_{C}$

* Values with the same superscript in a column and same subscript in a raw are not significantly different.

Increasing the fertilizer level has significantly increased ($P<0.01$) the tappability and when fertilizer were applied at 1½ times the currently recommended level, 60.1% of plants have come to tappability after 5 years irrespective of the clone (Table 28). Further, 61.7% of plant in clone RRIC 110 have reached the tappable girth of 50 cm at this age and this is significantly higher ($P<0.001$) than that of the other clones tested (R S Dharmakeerthi, L Samarappuli, S N Silva and A N Yakandawela)

Table 28. *The effect of fertilizer levels on the % tappability at 5 years after planting*

Treatment	Clone					Mean
	RRIC 121	RRIC 110	PB 260	RRISL 203	RRIM 712	
No Fertilizer Control	1.2	26.8	10.0	0.0	0.0	7.6^{d}
½ currently rec. level	22.7	46.5	19.8	37.2	16.4	28.9^{c}
Currently rec. level	26.7	84.9	40.9	49.4	27.0	45.8^{b}
1½ currently rec. level	41.8	88.6	72.5	70.3	27.3	60.1^{a}
Mean	23.1_{C}	61.7_{A}	35.8_{B}	39.7_{B}	17.7_{C}	

* Values with the same superscript in the column and same subscript in the row are not significantly different.

2.2 *Phosphate nutrition*

2.2.1 *ERP as a source of P for nursery, immature and mature plants*

2.2.1.1 Nursery plants

2.2.1.1.1 Seedling nurseries

The experiment started at Nivitigalakele Sub Station to study the suitability of different P fertilizers from Eppawela viz. CERP,HERP,SERP and PAERP in comparison with that of IRP and Ridigama rock phosphate (RRP) for nursery plants was terminated. Interpretation of data was continued (A Dissanayake, T Dissanayake and Peter Perera).

2.2.1.1.2 Poly bag nurseries

A new experiment was started at Dartonfield to study the suitability of Eppawala rock phosphate and IRP in comparison with Fused Magnesium Phosphate, "YOORIN", a Japanese product for polybagged plants. Several treatment combinations were allocated in this experiment with 8 replicates and plants were arranged in a randomized block design. This experiment was continued (A Dissanayake, C K Maheepala and Peter Perera).

2.2.1.2 Immature rubber

2.2.1.2.1 Effect of different sources and levels of P

This experiment (P/IM/87) was continued (A Dissanayake, T Dissanayake and Peter Perera).

2.2.1.3 Mature rubber

2.2.1.3.1 Residual effect of added rock phosphates

This experiment (P/M/76) was continued for a further period of one year (A Dissanayake, T Dissanayake and Peter Perera and C Maheepala).

2.2.2 *Evaluation of clonal differences in phosphate utilization*

Experiment P/IM/93-01

This experiment started at Devalakanda Estate was continued.

Experiment P/IM/94

This experiment started at Lagos Division, Payagala Estate to study the ability of different RRIC clones (RRIC 110 and 121) in utilization of ERP was continued for the 4th year (A Dissanayake, T Dissanayake, Peter Perera and C Maheepala).

Experiment P/IM/96 - 01

This experiment was started at Ambadeniya Division, Aranayake of

Ambadeniya estate to study the possibility of using Eppawala and IRP in Parambe soils. Three different clones namely RRIC 100, 102 and 121 planted according to the experimental design and fertilizer treatments were applied (A Dissanayake, T Dissanayake, Peter Perera and C Maheepala).

Experiment P/IM - 93 - 02

The experiment started at Vogan Estate to study the possibility of using both Eppawala and imported rock phosphates was continued (A Dissanayake, T Dissanayake and Peter Perera).

2.2.3 *Techniques to increase availability of P from ERP*

2.2.3.1 Mulching and liming

The experiment (P/Ag/93) started at Culloden Estate to study the effect of different agronomic practices on availability of P from ERP was continued (A Dissanayake, L Samarappuli, T Dissanayake and Peter Perera).

2.2.3.2 Suitability of ERP to cover crops (Mycorrhizal aspect)

The experiment started to study the effect of mycorrizae on the efficiency of P uptake from Eppawela rock phosphate by rubber plants grown in poly bags was continued ((A Dissanayake, R Jayaratne, T Dissanayake and C Maheepala).

2.2.4 *Phosphate status and availability from soils*

2.2.4.1 P fixation in rubber soils

Soils collected to represent all the rubber growing areas were analyzed for some of physical and chemical parameters. Interpretation of data was continued (A Dissanayake, T Dissanayake and C Maheepala).

2.3 *Sulphur nutrition*

An experiment was started in a replanting of Pallegoda Estate to study the effect of sulphur on the performance of clone RRIC 100 and 121. Three different sources of sulphur containing fertilizers (Ammonium sulphate, kieserite and Elemental S) are being tested in a randomized block design with 4 replicates (A Dissanayake, T Dissanayake and Peter Perera).

2.4 *Micro nutrients*

Effect of Mn, Mo and Zn as a foliar spray on the performance of rubber plants raised by young budding technique was studied in this experiment with a randomized complete block design in factorial lay out with five replicates. According to the response surface analysis of the data indicated that the diameter of plants at two and a half months has responded only to Mn and Zn. The function reached the maximum diameter of 6.75cm at the of 0.64 and 1.00 for Mn and Zn. This concentrations approximate 0.6% solution of Mn and 1.0% solution of Zn. Plant height has not responded to Mo and Zn. The maximum height of 51.3cm could be obtained with Mn 1.23 level (1.2% solution). In this experiment more emphasis was given to diameter as girth increase is more relevant to bud grafting compared to height. For further studies these concentrations could be used as a guide to decide Mn and Zn levels for nursery rubber plants (L Samarappuli and C Fernando).

2.5 *Foliar nutrients*

Effect of N, P, K and Mg as a foliar spray on the performance of rubber plants raised by young budding technique was studied in this experiment with a randomized complete block design with five replicates. The initial data suggested that foliar feed of N, P, K and Mg alone without soil application is not an efficient fertilizer formulation for rubber plants raised by young budding technique. It also appeared that currently recommended soil application of soluble fertilizer formulation is more effective compared to foliar feeds in relation to plant diameter and height (Table 29). (L Samarappuli and S Vithana).

Table 29. *Effect of NPK and Mg as a foliar spray on diameter and height of rubber plants*

Treatment					Diameter (mm)	Height (cm)
Soil fertilizer only					6.66^{a}	58.35^{a}
	N	P	K	Mg		
Soil fertilizer	+ 0	0	1	0	6.60^{ab}	56.75^{ab}
Soil fertilizer	+ 0	0	0	1	6.41^{abc}	53.95^{abc}
Soil fertilizer	+ 0	1	0	0	6.39^{abc}	53.25^{abc}
Soil fertilizer	+ 1	0	0	0	6.39^{abc}	50.40^{bc}
No soil fertilizer	+ 1	1	1	1	6.09^{c}	47.80^{c}
No soil fertilizer	+ 0	0	0	0	5.44^{d}	39.04^{d}

2.6 *Use of rubber factory effluent*

A field experiment was started at Eladuwa Estate to study the effect of rubber factory effluent on the performance of young rubber plants. The efficiency of ERP and IRP in the presence of rubber factory effluent will also be evaluated in this experiment. Treatments were allocated in a randomized block design with 5 replicate. Approximately a litre of rubber factory effluent was applied weekly per plant in addition to normal fertilization (A Dissanayake, T Dissanayake and C K Maheepala).

2.7. *Organic fertilizers*

2.7.1. *Use of organic materials in poly bagged nursery plants*

An experiment (FPN-Org/95/1), was done to study the possibility of using organic materials as a substitute for top soil in poly bagged nursery plants. Treatments consisted of (a) top soil (control), (b) top soil and sub soil (1:1), (c) sub soil and coir dust (1:1), (d) sub soil and paddy husk (1:1), (e) sub soil and poultry litter (2:1), (f) sub soil and saw dust (1:1), (g) sub soil, saw dust and poultry litter (1:1:1), (h) sub soil, paddy husk and poultry litter (1:1:1), (i) sub soil, coir dust and poultry litter (1:1:1) and sub soil and refuse tea (1:1). The data collected are being analyzed (L Samarappuli and R Hettiarachchi).

2.7.2 *Use of animal wastes in rubber cultivations*

A field experiment (FPN-Org/An/95/3), is in progress at Dorset Division, Clyde Estate to study the effect of poultry litter as an organic manure for rubber. Treatments consisted of (a) Inorganic fertilizer (recommended level), (b) Inorganic fertilizer (½ recommended level) + poultry litter, (c) Inorganic fertilizer (¼ recommended level) + poultry litter, (d) Poultry litter only, (e) Poultry litter + IRP + MOP, (f) Poultry litter + IRP + paddy straw and (g) Poultry litter only with natural cover. Effects of treatments on girth and girth increment of rubber plants at the end of two and a half years are given in Tables 30 (L Samarappuli, P Karunadasa and U Mitrasena).

Table 30. *Effect of different treatments on girth of rubber plants*

Treatment	Girth (cm)	Girth Increment (cm)
Inorganic fertilizer (¼ recommended level) + poultry litter	21.03[a]	8.9
Poultry litter only	20.32[ab]	8.0
Poultry litter only with natural cover	20.31[ab]	8.2
Inorganic fertilizer (½ recommended level) + poultry litter	20.29[ab]	8.4
Poultry litter + IRP + MOP	19.79[b]	8.9
Poultry litter + IRP + paddy straw	19.50[b]	8.5
Inorganic fertilizer (recommended level)	19.45[b]	7.1
No fertilizer (control)	15.40[c]	5.1

2.7.3 *Use of green manure in rubber cultivation*

Two field experiments (FPN-Org/Gm/97/1) and (FPN-Org/Gm/97/2) are in progress at Dartonfield estate (*Agalawatta* series) and Dorset Division, Clyde estate (*Boralu* series) to study the effect of plant materials as an organic manure for rubber. Ten different treatments were applied in a randomized block design with four replicates. Effects of treatments on plant diameter at the end of 6 months are given in Table 31 (L Samarappuli, P Karunadasa and U Mitrasena).

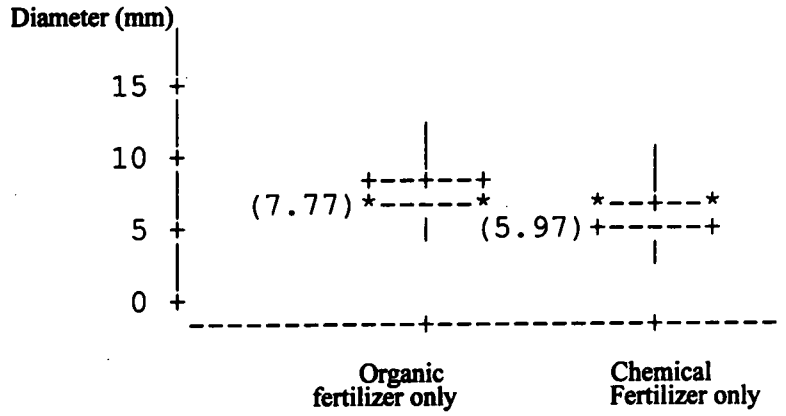
Table 31. *Effect of different treatments on diameter of rubber plants*

Treatment	Diameter (mm)	
	Agalawatia soil	*Boralu* soil
N (full inorganic) + K (full inorganic)	16.0[a]	16.9[a]
N (full inorganic) + K (½ inorganic + ½ straw)	15.2[a]	18.1[a]
N (full inorganic) + K (full straw)	15.4[a]	16.4[a]
N (½ inorganic + ½ green manure) + K (full inorganic)	15.8[a]	15.8[a]
N (½ inorganic + ½ green manure) + K (½ inorganic + ½ straw)	14.9[a]	16.8[a]
N (½ inorganic + ½ green manure) + K (full straw)	16.9[a]	16.4[a]
N (full green manure) + K (full inorganic)	14.4[a]	14.1[a]
N (full green manure) + K (½ inorganic + ½ straw)	15.7[a]	16.3[a]
N (full green manure) + K (full straw)	15.2[a]	15.0[a]
No fertilizer (control)	14.8[a]	15.8[a]

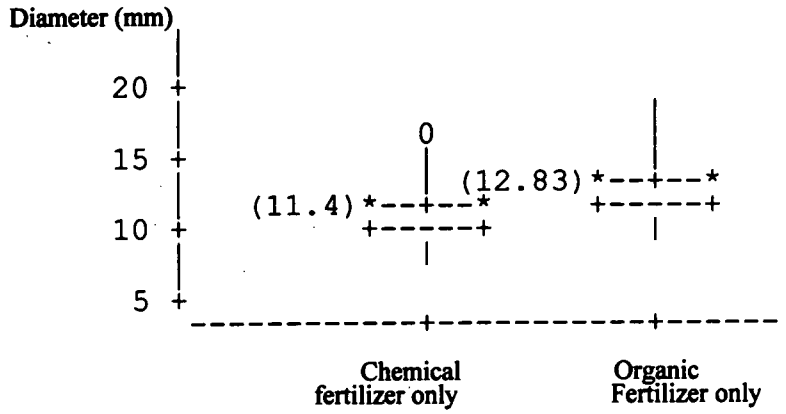
2.7.4 *Organic rubber*

An experiment is in progress to develop a sustainable system which is commercially suitable for plantation as well as for small holders to produce an environmental friendly new grade rubber (organic rubber) to meet the increasing demand for "bio-market". No adverse effects were observed in growth of rubber plants in the nursery or in the field by using only organic and natural (mined) fertilizers (Fig. 1) (L Samarappuli. N Yogaratnam. L M K Tillekeratne. P Karunadasa and U Mitrasena).

(a) Nursery (4 months after planting of seed in the poly bags)



(b) Field (6 months after planting in the field)



* Figures in paranthesis are mean values

Fig. 1. Effect of organic and chemical fertilizers on diameter of rubber plants

2.8 *Efficiency of fertilizer utilization*

2.8.1 *Reduced frequency of fertilizer applications*

A field experiment (F/Ap/95/1), is in progress to the study the effect of reduced frequency of fertilizer applications during the immature period on the growth of rubber plants. Treatments consisted of (a) 25 applications/immature six year period (urea based), (b) 20 applications/immature six year period (SA based), (c) 19 applications/immature six year period (urea based), (d) 14 applications/immature six year period (SA based) and (e) 14 applications/immature six year period (urea based). Effects of treatments on girth of rubber plants at the end of two and a half years are given in Tables 31 (L Samarappuli, P Karunadasa and U Mitrasena).

Table 31. *Effect of different treatments on girth of rubber plants*

Treatment	Girth (cm)	Girth increment (cm)
25 applications/immature six year period (urea based)	19.75[a]	7.4
20 applications/immature six year period (SA based)	19.72[a]	7.3
1a applications/immature six year period (urea based)	18.48[a]	6.8
14 applications/immature six year period (SA based)	18.65[a]	7.0
14 applications/immature six year period (urea based)	18.18[a]	6.8
No fertilizer	13.66[b]	4.4

2.8.2 *Economics of fertilizer use in mature rubber*

Economics of fertilizer utilization by mature rubber is being investigated in an experiment (F/EC/92/1), at Clyde estate, Dorset Division. Following treatments were allocated to each plot in a randomized complete block design with five replicates. As results obtained were not conclusive, a new site was selected at same estate to repeat the experiment again next year (L Samarappuli, N Yogaratnam, P Karunadasa and U Mitrasena).

T_1 No fertilizer from the first year of panel C
T_2 No fertilizer from the second year of panel C
T_3 No fertilizer from the third year of panel C
T_4 No fertilizer from the fourth year of panel C
T_5 Fertilizing throughout the panel C

2.8.3 *Dolomite as a source of Mg for mature rubber*

An experiment (F/Mg/94/1), is in progress in Dorset Division, Clyde Estate to study the feasibility of using Dolomite even during the mature stage. Treatments consisted of kieserite throughout the immature and mature period, kieserite in immature period and dolomite in mature period, dolomite throughout the immature and mature period, dolomite in immature period and kieserite in mature period. Data on plugging index, initial flow rate, total volume, dry rubber yield and DRC % monitored during the year are being analyzed (L Samarappuli, S M M Iqbal, P Karunadasa and U Mitrasena).

2.8.4 *SUL-PO-MAG based fertilizer mixtures*

An experiment (F/SPMg/94/1), was started in Culloden Estate, Neboda to study the effectiveness of SUL-PO-MAG based mixtures in comparison with the conventional mixtures 12:14:14 and 7:9:9:3 in immature rubber. SUL-PO-MAG based treatment was formulated by adding urea, rock phosphate and muriate of potash to SUL-PO-MAG to meet the nutrient ratios of N,P,K and Mg recommended for rubber in conventional mixtures. Growth was significantly higher in plants that received fertilizers compared to no fertilizer treatment. However, there was no significant difference in girth between the three fertilizer treatments (Table 32) (L Samarappuli, N Yogaratnam and J G de Mel).

Table 32. *Effect of different fertilizer mixtures on girth of rubber plants*

Treatment	Girth (cm)
Control (no fertilizer)	25.4[a]
Urea based	32.5[b]
SA based	31.7[b]
Sulpomag based	32.3[b]

2.8.5 *Slow release fertilizers*

A joint project (F/SR/95/1) with Polymer Chemistry Department was commenced to study the possibility of using encapsulated coir blocks for poly bagged nursery plants. Effect of different quantities of encapsulated fertilizers on the growth of poly bagged plants is studied in this experiment (L Samarappuli, K G K de Silva, R Hettiarachchi and M Wijesekera).

2.9 *Soil and foliar survey programme*

2.9.1 *Improvements to soil and foliar survey programme*

An experiment (F/SF/95/2). is in progress to further substantiate the early findings of sampling intensity for formulation of appropriate practices in sampling technique for soil and foliar survey programme. Fourteen different sampling intensities are being evaluated and this experiment further examines the sub sampling procedures and leaf nutrient variation pattern of different clones of rubber with the time. The results are being analyzed (L Samarappuli, N Yogaratnam, W Wijesuriya, V Edirimanne, P Karunadasa and U Mitrasena).

2.9.2 *Soil and foliar survey programme - Fertilizer recommendation*

Estate sector

The soil and foliar survey programme for 1997 commenced in July and approximately 5000 ha were surveyed this year. Fertilizer recommendations based on this survey were sent to all the estates before December (L Samarappuli and V Edirimanne in collaboration with the TPL Laboratory, Walahanduwa).

Smallholder sector

The soil and foliar survey programme for the small holder sector was extended to Colombo and Gampaha districts. Due to some problems in coordinating the field work with the Rubber Development Department this programme had to be terminated half way (L Samarappuli, A M A Perera, V Edirimanne, A Thevarapperuma, G de Mel and T Ahamadeen).

3. Land use planning

3.1 *Soil survey and classification*

This experiment was continued (A Dissanayake and C K Maheepala).

4. Analytical services and techniques

Routine chemical analysis of soil, leaf, latex and fertilizer samples collected for experimental and advisory purposes were carried out. Samples from other Departments and Organizations were also analyzed (L Samarappuli, A M A Perera, V Edirimanne and A Thevarapperuma).

5. Adaptive research programme

5.1 *Effectiveness of bush/tree legumes*

Experiments were started to compare the effectiveness of growing bush/tree legumes with the current practice of growing creeping legumes on soil and moisture conservation in smallholdings in Kalutara and Kegalle Districts (L Samarappuli, N Yogaratnam, S M M Iqbal and E A T Senadeera).

5.2 *Use of poultry manure*

Use of poultry manure as a substitute for inorganic fertilizer in immature and mature rubber smallholdings is also being studied under Adaptive Research Programme (L Samarappuli, N Yogaratnam, S M M Iqbal and E A T Senadeera).

5.3 *Mulching with rice straw*

A new set of experiments was started to evaluate the effectiveness of mulching with rice straw in smallholdings (L Samarappuli, N Yogaratnam, S M M Iqbal and E A T Senadeera).

5.4 *Use of* Vetiver *grass*

A site was selected to grow *Vetiver* grass as hedges in inter row area as a substitution for drains and stone terraces (L Samarappuli, N Yogaratnam, S M M Iqbal and E A T Senadeera).

5.5 *Evaluation of ERP*

A new set of experiments was started in smallholdings to evaluate the effectiveness of ERP and IRP mixture (50:50) on the performance of immature rubber (A Dissanayake, N Yogaratnam and S M M Iqbal).

Experimental details and results of the above experiments are discussed in the Review of the Adaptive Research Unit.

BIOCHEMISTRY AND PHYSIOLOGY

M T Warnakula

SUMMARY

The main focus was on, appropriate technology for environmental friendly management of rubber factory waste.

Staff

Assistant Biochemist, Mr M T Warnakula and Technichnical Officers, Miss K V V S Kudaligama, Mr D Ramawickrama and Specification Assistant, Mr P D J Rodrigo were on duty throughout the year. Mr M D C Seneviratne retired from 1997.10.29.

LABORATORY AND FIELD EXPERIMENTS

Development of appropriate technology for Environmentally friendly management of rubber factory waste

Research and development

Relevant experiments on this were continued during the year.

Development of cost effective suitable media for biological waste water treatment

Continued work on development of media using coconut fiber as the base material was successful. Several successful packing configurations other than the Bio-Brush medium were tested.

Research work on improvement of the quality of Bio-Brush were also continued. Several natural and synthetic materials which are locally available were also tested for their feasibility, to be used as the medium (M T Warnakula, K V V S Kudaligama, D Ramawickrama and P D J Rodrigo).

Odour filters

Research on developing odour filters for controlling possible odour emissions

from waste treatment systems was continued (M T Warnakula, K V V S Kudaligama, D Ramawickrama and P D J Rodrigo).

Low cost treatment system configurations

Several appropriate treatment system configurations other than the "Covered Activated Ditch (CAD)" were tested considering, the cost, different topographical conditions, different soil conditions and different types of rubber products (M T Warnakula, K V V S Kudaligama, D Ramawickrama and P D J Rodrigo).

Minimization of waste at production

Research on reducing the amount of waste generated during the production without affecting the quality of the rubber was continued (M T Warnakula, K V V S Kudaligama, D Ramawickrama and P D J Rodrigo).

Waste water recycling

Work on the development of technology for treating; milling and cooling water for recycling was continued. Many Crepe rubber factory managers who suffer from the scarcity of water in dry spells had requested us to design water recycling systems for their factories. A pilot testing has been planned before making any official recommendation (M T Warnakula, K V V S Kudaligama, D Ramawickrama and P D J Rodrigo).

Trouble free coagulation of skim latex with organic acids

Experiments were continued for developing techniques for trouble free coagulation of skim latex using organic acids.

Developing appropriate techniques for removing ammonia from skim latex, before the coagulation was of great interest. Experiments for developing continuous coagulation technique for skim latex was also continued (M T Warnakula, K V V S Kudaligama, D Ramawickrama and P D J Rodrigo).

Use of roots of marshy plants as oxygenation devices for waste water treatment

Research were carried out to investigate the possibility of using the roots of some marshy plants for supplying oxygen for biological waste water treatment. Preliminary results are encouraging (M T Warnakula, C K Jayasinghe and K V V S Kudaligama).

Implementation of new developments

All the systems were designed and constructed using the "Bio-Brush" medium as the biomass retainer.

Rayigam Estate Crepe Rubber Factory

A CAD system was installed for the above factory. This constructed system was commissioned in June. After a three month start up period, the system matured enough to operate at its full designed capacity, with COD and BOD values always meeting the CEA standards (M T Warnakula, K V V S Kudaligama, D Ramawickrama and P D J Rodrigo).

Thotamune Rubber Mills

Another CAD system was installed for the above factory. Construction of the system was completed by the end of the year (M T Warnakula, K V V S Kudaligama, D Ramawickrama and P D J Rodrigo).

Mayadunne Rubber Industries

A CAD system was designed for the above factory with facilities for recycling the treated water for milling of scrap rubber. Construction of the system was started (M T Warnakula, K V V S Kudaligama, D Ramawickrama and P D J Rodrigo).

Pallegama Estate Sole Crepe Rubber Factory

The available land area of this factory for a treatment system is very limited. A cost effective compact treatment system was designed to suit the available land area. The detailed engineering design and the BOQ was forwarded to the Plantation Management Company (M T Warnakula, K V V S Kudaligama, D Ramawickrama and P D J Rodrigo).

Parambe Estate Crepe Rubber Factory

The available site for a treatment system of this factory allows for constructing a high rate maturation pond type treatment system. The detailed

engineering design and the BOQ was forwarded to the Plantation Management Company (M T Warnakula, K V V S Kudaligama, D Ramawickrama and P D J Rodrigo).

Atale Estate Crepe Rubber Factory

The available land area of this factory for a treatment system is also very limited. A compact treatment system was designed to suit the available land area (M T Warnakula, K V V S Kudaligama, D Ramawickrama and P D J Rodrigo).

Arappolakanda Estate Crepe Rubber Factory

A CAD system was designed for the above factory, but the detailed engineering design and the BOQ was not forwarded to the Plantation Management Company, awaiting the analytical results of the treated water of previously installed CAD systems in other factories (M T Warnakula, K V V S Kudaligama, D Ramawickrama, and P D J Rodrigo).

Payagala Estate Crepe Rubber Factory

A CAD system was designed for the above factory, but the detailed engineering design and the BOQ was not forwarded to the plantation management, awaiting the analytical results of the treated water quality of previously installed CAD systems in other factories (M T Warnakula, K V V S Kudaligama, D Ramawickrama and P D J Rodrigo).

AL-KAMAR Paper (Private) Ltd.

A waste minimization system was designed and implemented for the above factory.

Operation of this paper factory resulted with serious environmental pollution problems and hence an organized public protest against the operation of the factory was developed. At the request of the management, for minimizing the pollution caused by the factory discharge, a water recycling system was introduced.

As the first step directly recyclable waste streams were separated from the main waste stream at the production. After implementing this waste separation system alone, the combined effluent discharged was meeting the CEA standards for suspended solids and saved a significant amount of paper pulp which was previously wasted.

As the second step the combined effluent discharged was subjected to a basic physical treatment, enabling the treated water and separated pulp to be recycled completely. By implementing this step the paper factory became an industry with no waste discharge (M T Warnakula, K V V S Kudaligama, D Ramawickrama and P D J Rodrigo).

Other methods of waste utilization and disposal

A new medium for growing antagonistic fungi

Collaborative research work with the Plant Pathology and Microbiology was continued, for producing a new biological medium based on skim latex and coir-dust for culturing different antagonistic fungi used in biological control of white root disease in rubber (M T Warnakula, K E Jayasuriya, K V V S Kudaligama, D Ramawickrama and P D J Rodrigo).

Coir-coirdust mat bound with skim rubber

Experiments were continued for further development of quality of coirdust mat bound with skim rubber for using as a growing support media for grass turf or other horticultural material. The objective of this is to utilize the rubber in the skim latex for a valuable product where the serum is not separated as a waste of the production (M T Warnakula, K V V S Kudaligama, D Ramawickrama and P D J Rodrigo).

Biological and biochemical treatment of rubber wood

Preliminary studies on biological and biochemical treatment of rubber wood was carried out (M T Warnakula, C K Jayasinghe, K G K de Silva, I N Samarappuli, K V V S Kudaligama, D Ramawickrama and P D J Rodrigo).

Biochemical carving of rubber wood

Preliminary studies on biochemical carving of rubber wood was carried out (M T Warnakula, A M W K Seneviratna, K V V S Kudaligama, D Ramawickrama and P D J Rodrigo).

RUBBER TECHNOLOGY AND DEVELOPMENT

N M V Kalyani Liyanage

SUMMARY

Performance characteristics of a sand sealing carried out using a modified positex/bitumen blend was found to be very good.

Maturation period of centrifuged NR latex prior to irradiation was found to influence the technological properties and N_2 content of leached and aged RVNRL films.

A large scale trial on the production of RVNRL carried out at the Ansells Lanka Ltd, produced RVNRL of much improved tensile properties.

Applicability of DPG as a secondary gelling agent in SSF based foam manufacture was evaluated.

Some NR/bitumen based vulcanisable hard backings for coir based carpets were developed.

DETAILED REVIEW

Staff

Dr (Mrs) N M V Kalyani Liyanage, Head, Rubber Technology and Development was on duty throughout the year. Mrs D G Edirisinghe, Assistant Rubber Chemist continued her postgraduate studies at the University of Loughborough, UK.

Mrs M M Jayasooriya resumed duties on 17th September after completing a training program on Radiation Prevulcanisation of Natural Rubber Latex at Takasaki Radiation Chemistry and Research Establishment, Japan.

Mrs Manal Mahanama, Senior Technical Officer, Mr K M U Mithrananda and Mrs Sriyani Yapa, Technical Officers were on duty throughout the year.

Research students

Mr H S Nissanka and Mr Densil Tennakoon, NDT students, were trained on various aspects of RVNRL technology and reinforcement of dry Rubber compounds respectively.

Meetings, Seminars and Lectures

Dr (Mrs) N M V Kalyani[1] and Mrs Madupani Jayasuriya[2] participated in the following;

* Committee meetings of the Sri Lankan research group on "Radiation Prevulcanisation of Natural Rubber Latex" held at the Atomic Energy Authority[1,2].

* A workshop on "Quality Control of PVNRL" held at Batan, Jakarta, Indonesia from 21-25 July 1997[1].

* The Diploma course for factory superintends organized by the NIPM, as a Lecturer[1].

* A Diploma course on "Rubber Technology" organized by the Plastics and Rubber Institute as a lecturer[1].

* Inauguration meeting of the 21st Assembly of ANRPC held at Hotel Ceylon Intercontinental, Colombo on 09th November 1997[1].

* Central Scientific Committee Meetings of RRI[1].

* Research Discussions among the scientific staff officers held at Dartonfield[1,2].

* A course on "Rubber Products Manufacture" held at Hanwella[1].

* A workshop on "Scientific writing" held at NARESA[1].

* A workshop on "Rubber Products Industry" held at Hotel Taj Samudra organized by the Export Development Board[1].

* An MSc course on "Rubber Technology conducted by the University of Sri Jayawardanapura" as a Lecturer[1].

* A post graduate Diploma course on "Chemical Analysis" conducted by the University of Colombo as a Lecturer[1].

LABORATORY INVESTIGATIONS

1. Latex technology

1.1 Latex bitumen emulsions in road construction

Performance characteristics of a sand sealing carried out, using an emulsion distributor with latex/bitumen blend was found to be very satisfactory. Some lab scale trials on the effects of rubber content in latex/bitumen blend on its stability characteristics revealed that with increasing the rubber content the stability of the latex/bitumen blend decreases.

A new set of lab-scale trials were carried out using a bitumen emulsion prepared with a new cationic emulsifier. The stability of the resultant blend was found to be poor. However, with the incorporation of density modifiers to the latex, the stability of latex bitumen blends was improved (N M V Kalyani Liyanage, M M Jayasooriya, Manel Mahanama, Sriyani Yapa and H S Nishantha (NDT Student).

1.2 Radiation prevulcanisation of Natural Rubber Latex.

1.2.1 Effects of latex maturation period

Physical properties and the nitrogen content of a series of irradiated latex samples which were matured for different periods of time duration before irradiation were investigated. It was anticipated that the protein content of the latex samples would vary with the maturation of latex and hence the protein content and the physical properties would vary accordingly. However there was no significant variation in the physical properties with maturation before ageing. It was observed that the N_2 contents of the irradiated and leached samples were lower than those of unirradiated and leached samples. Further, the difference in N_2 contents of the above two sets of samples were found to be increasing with increasing the maturation period. Ageing characteristics of the irradiated films were found to be inferior to those of sulphur vulcanised films and with the maturation period, the technological properties of the aged films were further reduced (N M V Kalyani Liyanage, M M Jayasooriya, H N K K Chandralal, M M Mahanama and S S Kulathunga (Atomic Energy Authority).

1.2.2 A trial on large scale irradiation

A batch of 10 litres of latex was irradiated using the ^{60}Co irradiation facility at the Ansells Lanka (Pvt) ltd., and the resultant latex was used in the production of some hand dipped gloves using the coagulant dipping technique. The physical properties of the rubber gloves were determined at Ansells, IDB and RRISL. All three institutions reported more or less the same results and average Tensile Strength of unaged gloves was found to be above 25MPa which is far above the ASTM Standard, 14MPa. Arrangements are being made to asses the tear resistance properties of RVNRL films and some preliminary trials have also been done on the effects of fillers on the tear properties of RVNRL films (N M V Kalyani Liyanage, M M Jayasooriya, H N K K Chandralal and S S Kulathunga (Atomic Energy Authority).

1.2.3 New sensitizer for radiation vulcanization of NR latex.

A study had been carried out to investigate a monomer which can be used in radiation vulcanization of latex, in order to replace n-Butyl acrylate, sensitizer, which is used in RVNRL production at present. Natural rubber latex was irradiated with various sensitizers by means of γrays by using a ^{60}Co source and physical properties of RVNRL films were evaluated. It is found that phenoxy ethyl acrylate is the most effective sensitizer and it can be used successfully for radiation vulcanization of latex. Further more, effects of monomer concentration, radiation dose, dose rate, dry rubber content of latex on physical and mechanical properties of RVNRL films were investigated. In addition attempts were made to do vulcanization by means of UV radiation and it was successful to a certain extent. However further studies are needed on this subject (M M Jayasuriya, F Yoshi and K Makuuchi).

1.3 Latex foam

A request came from an industrialist for a suitable latex compound for the manufacture of spread foam containing a large percentage of clay to be used in underlays of coir based carpets. A latex compound containing EFA as a secondary gelling agent was developed and the resultant foam was found to have excellent foam stability.

Applicability of DPG as the secondary gelling agent in SSF based foam was also tested. Compounds containing no fillers produced satisfactory results. However, with the incorporation of fillers foam stability was found to be reduced and addition of a secondary stabilizer such as Wettam was necessary.

Some trials on the use of ZnO/NH_4AC heat sensitive system to prepare foam for carpet underlays were also performed. Formulations containing fillers up to 60% were developed with reasonably good foam stability (N M V Kalyani Liyanage and Sriyani Yapa).

1.4 NR latex based coatings for water level indicators

A request came from an individual for a suitable rubber coating for a water level indicator made out of plastics. A few formulae based on dry rubber as well as latex were tried out and a latex based room temperature curing formula was found to serve the purpose best (N M V Kalyani Liyanage, S I Yapa, K M U Mithrananda and H S Nisshanka (NDT Student).

2. Dry rubber technology

2.1 Artificial limbs for disabled soldiers

Some trials were carried out with compounds based on EPDM and EPDM/NR blends to develop a compound suitable for the production of a foot of less weight as well as a better finish. However, the performance of NR based compound was found to be superior to all the other compounds tested (N M V Kalyani Liyanage and K M U Mithrananda).

2.2 Bituminous backings for carpets

Waycoir (Pvt) Ltd. made a request for a NR based hard backing for coir based carpets. A series of componds were developed by using blends of NR/Bitumen Polythene/Bitumen and NR/Polythene/Bitumen. The NR/Bitumen vulcanisable backing was found to be the best for this purpose (N M V Kalyani Liyanage, L Karunanayake and K R N Karunathilake).

2.3 EPDM based gaskets

A request came from Associated Polymers and Allied Products for assistance in optimisation of curing conditions of some silicone based rubber compounds to be used in Thermos flask gaskets. The optimum curing conditions suitable for this purpose were recommended after conducting a few trials (N M V Kalyani Liyanage and K M U Mithrananda).

2.4 Application of various fillers/filler combinations in retread compounds

An in-depth study was initiated to get a better understanding of the behavior of various kinds of fillers in retread compounds. Initial trials were carried out by using the most commonly used filler in the local retreading industry, *i.e.* N 330. Physical properties of the resultant compounds were compared with those of compounds made by using N 330/silica filler combinations. Applicability of locally available materials such as Rice Husk Ash (RHA) as fillers in retread compounds is also being studied (N M V Kalyani and K M U Mithrananda).

Industrial extension

The following industrialists have requested the services of the Department in product development and testing

Midland Retreads (Pvt) Ltd.	Testing of precured tread compounds
Plymouth Industries	Testing of chemicals
Sri Lanka Standards Institution	Testing of bicycle tyre tubes
Automic Energy Authority	Testing of latex gloves
Lanka Tyre Retreaders	Testing of tread compounds
Waycoir (Pvt) Ltd.	Development of foam compounds for carpet backings
Ceyesta Ltd.	Testing of latex compounds
Associated Motorways Ltd.	Testing of rubber compounds for toxicity
Associated polymers and Allied products	Development of EPDM gaskets
Associated Speciality Rubbers	Testing of processability of rubber compounds
Road Grip	Testing of retread compounds
State Engineering Corporation	Compounding of Nitrile rubbers
Asia Industrial Enterprise (Pvt) Ltd.	Development and testing of shoe soles

POLYMER CHEMISTRY

K G Karnika de Silva

SUMMARY

One of the priority projects handled by the Polymer Chemistry Department during the past year was "Utilization of waste tyres as vulcanized rubber crumbs in useful applications" which involved a detailed study on tyre crumbs and plastic blends. This project was initiated at the RRISL and continued at University Sains Malyasia (USM) in Penang, Malaysia from June - December '97. This project was funded by the USM and the Ministry of Science and Technology of Malaysia and the Research Fellowship was granted to Head of the Polymer Chemistry Department to work on her sabbatical leave.

The main aim of this research was to see the possibilities of using a waste tyres which has become a cumulative and growing environmental problem. Having characterized the compatibility, morphology and mechanical properties of a range of blends of polypropylene and treated tyre crumbs, it was possible to identify the improved processing techniques that allows vulcanized tyre crumbs to disperse rapidly in the polypropylene phase. This process offers cost advantages and property performance acceptable to most applications specially in the automobile industry.
The other important projects handled by the Polymer Chemistry Department involved the development of biodegradable shopping bags using natural rubber latex as the coating material for cotton fibers, improvements in conductive rubber pads used in muscle tonning machines and the use of rubber wood fibers and trimmings in Medium Density Fiber (MDF) board manufacture. All three projects have been either semi commercialized or accepted for implementation by the small and large scale industrialists. All these projects offer technical importance and environmental benefit to the country. Work on sticker type rain guards, water proofing membranes based on bitumen and latex/ dry rubber, polymeric membranes for slow release fertilizers, briquettes from saw dust and non toxic bonding agents were continued. Different mixtures of cinnamon oil in different media were prepared on a request made by the Plant Pathology Department. These were tested for easy applications on roots to prevent white root decease in rubber plantations.

Four projects, namely epoxidized rubber, cyclized rubber, CV rubber and SP rubber received little attention due to lack of research and assistant staff in the department.

Experiments on adhesives, sealants, NR/NBR blends with compatibilizers, MG rubber, and positex were conducted on requests by the industrialists. Test reports

were also issued on elastomer analysis, toxicity tests, gel content upon storage, blooming and latex protein analysis on requests.

Three samples of flooring used in artificial sports tracks from Germany, USA and Eastern Block were tested to find the elastomer used before finalizing the tender procedures in laying artificial sports track at the Sugathadasa Stadium. Each sample was carefully analyzed for the performance and the comments were put forward to the requested party. Several samples of butyl rubber based bicycle tubes were tested on requests made by the SLSI to confirm the elastomer used. Different formulations with NR and butyl rubber were tested for physical properties to study the performance of the blends, on requests made by DSI Galle.

DETAILED REVIEW

Staff

Dr K G Karnika De Silva was promoted as the Deputy Director Research (Technology) with effect from 13th January 1997. She left for Malaysia on the 20th June 1997 on a one year fellowship grant offered to her by the University of Malaysia and the Ministry of Science and Technology of Malaysia to carryout a project on her sabbatical leave. She was called back after six months by the Rubber Research Board to resume duties due to the resignation of a Senior Research Officer who was assigned to carry out duties of the Polymer Chemistry Department. To honour this request. Dr Karnika De Silva returned and reported back on the 21st December 1997.

Dr S A P Pushpa Goonethilake resigned from the post of Senior Research Officer with effect from 9 July 1997.

Mr H N K K Chandralal, Experimental Officer, returned to the country from Saudi Arabia after completing his two years of no-pay leave.

Mrs Indra Denawaka, Experimental Officer, Mr S S Warnapura and Mrs Chitra Kuruppu, Senior Technical Officers, and Miss Medavi Wijesekara and Mr A Samarakoon, Technical Officers were on duty through out the year.

Mr S L G Ranjith, Technical Officer was on no pay leave in Saudi Arabia and returned to the country to assume duties from 25 July 1997.

Mrs Renuka Wijeratne, Clerk/Typist was on duty through out the year. Messrs Sunil Weerasiri and P R Sigera, Laboratory Attendants and Messrs L L Piyasena, W D S Dharmasena Laboratory Labourers were on duty through out the year.

Visits

Dr K G Karnika de Silva left for Malaysia on 20th June 97 on sabbatical leave to work on a Malaysian Government funded project on recycling of tyre wastes.

Meetings, seminars, programmes and workshops

* Dr K G Karnika de Silva participated and presented papers at IRC'97 and PRI - AGM held in Kuala Lumpur, Malaysia.

* Dr K G Karnika de Silva paricipated as an observer at the IRRDB meeting held in KL, Malaysia.

* Dr K G Karnika de Silva served as a committee member in formulating a syllabus for a university degree course for the officers in the plantation sector organized by NIPM.

* Dr K G Karnika de Silva and Dr S A P P Goonetilleke participated at four Scientific Committee Meetings, a seminar on Environmental Friendly Natural Rubber held at Dartonfield.

* Dr K G Karnika de Silva delivered a lecture on rubber wood treatment at the work shop on Plantation management practices for the staff of Watawala Plantaions held at Nakiyadeniya Rubber factory.

* Dr K G Karnika de Silva and Dr S A P P Goonetilleke delivered lectures for NIPM Diploma Course.

* Dr K G Karnika de Silva participated at a launching ceremony of disposal Shopping bags based on natural rubber formulation developed at RRISL.

* Staff of the Chemistry Department helped two rubber products manufacturers in designing posters on rubber plantations and rubber based products manufacture for trade exhibition held in England and Turkey.

LABORATORY INVESTIGATIONS

Natural rubber composites

The project on Utilization of Vulcanized Natural Rubber Waste Materials

from Scrap Tyres and Industrial Wastes in Value Added Applications received high priority during the past year. Continuation of research on this project was carried out at the University Sains Malaysia in Penang, Malaysia. The expenses on this project during June - December was borne by the Post Doctoral Fellowship Scheme and the Ministry of Science and Technology in Malaysia.

Natural rubber vulcanizates from natural rubber tyre and industrial wastes were treated with delinking agent before incorporating polypropylene using melt mixing technique. A wide range of compounds using different processing techniques was carried out and the mechanical properties, morphology and the processing properties were evaluated. Better incorporation of tyre crumbs into the polypropylene matrix was achieved by improved mixing techniques. The Scanning Electron Micrographs showed that the compatibilizing agents and cross-linking agents could improve the morphology of the compounds. A comprehensive report on this research has been submitted to the relevant authorities and a research paper is being prepared for publication.

Further work on the project is in progress (K G Karnika de Silva, Baharin Azahari and M Nasir of USM - Malaysia).

Biodegradable Natural rubber Latex based materials

Suitable modifications were done to improve the spreadability and adhesion properties of the natural rubber latex based formulations developed to coat cotton fabrics used to manufacture export quality biodegradable shopping bags. A ceremony to mark the occasion of commercialization of these bags to the local and export market was held at Savsiripaya. These bags will be manufactured by Decent Lanka Ltd. and marketed by Kale Marketing Services Ltd (K G Karnika De Silva, Chithra Kuruppu).

Rubber wood saw dust and trimming in MDF board and briquette manufacture

Several trials were conducted on a request made by the industry to get good bonding properties of rubber wood saw dust and trimmings using phenol formaldehyde resin and urea formaldehyde resins. The trials were also conducted with ammonium chloride to see the bonding properties. Different conditions and concentrations were used to find the optimum conditions for excellent bonding. Initial trials were also conducted successfully on bleaching the rubber wood to get more whiter boards which can subsequently dyed to give different colours required by the consumers (K G Karnika de Silva and H N K K Chandralal).

Several trials were conducted with rubber wood saw dust and non toxic binders to turn out briquettes out of rubber wood to be used in tea drying. Very firm briquette could be produced by using a hand press at the room temperature. Further work in the project is in progress and possible technology transfer will be explored in the future.

Papers on rubber wood industry and rubber wood treatment were submitted to Rubber Puwath and RRISL Bulletin for publication (K G Karnika de Silva and S S Warnapura).

Constant viscosity rubber

CV rubber samples were prepared incorporating different concentrations of bleaching agent. Drying was carried out at 140°C in the laboratory by using assembly which was fabricated to insert into the hot air oven. Samples were taken at different time intervals and the Accelerated Storage Hardening test and mooney viscosity were determined. The concentration of bleaching agent appropriate for CV 60 was chosen and it was planned to repeat these experiments. Samples of CV rubber were presented by air-drying at room temperature instead of drying them at 140°C in an oven. This was carried out to see the difference in properties between the products obtained by oven drying and air drying. It was observed that in all samples containing different concentrations of water soluble bleaching agent, the Mooney viscosity is higher than in the oven dried method. This is probably due to the faster action of the peptizers on natural rubber molecules at high temperature.

Constant viscosity rubbers were prepared using different concentrations of bleaching agent under various drying conditions (Pushpa Goonetilleke and Chithra Kuruppu).

Sticker type rain guard sealant

Attempts were made to turn out sticker type rain guards using latex based tar emulsions. Several trials were performed using different types of bitumen emulsions. Preliminary trials showed promising results but the project was temporarily suspended until the next year (K G Karnika de Silva and Chitra Kuruppu).

Creaming of latex using tamarind seeds

The out come of this project will benefit the smallholders who are interested in starting up latex based industries in small scale using their own latex. Initial trials with tamarind seed powder showed very efficient creaming of field latex within a few hours unlike the control with commercially available alginates which took over 24hrs.

to start the creaming process. The testing of physical properties of the films is in progress (K G Karnika de Silva and Chitra Kuruppu).

Epoxidised Natural Rubber

Work on this project was continued during this quarter ENR 25 was prepared and evaluation of physical properties was performed. Experiments were also carried out to monitor the effect of reaction time on extent of epoxidation. The epoxy contents were analyzed by NMR spectroscopy at University of Colombo. It was found that lauric acid added to stabilize the ammoniated latex has an effect on epoxidation reaction (Pushpa Goonetilleke, Ananda Samarakoon and Wijegoonewardene (University student).

Rice husk ash (RHA) as a filler for ENR

A study was commenced to use rice husk ash as filler for NR on a request made by Ceramics Research and Development Corporation, CR and DC. Experiments were carried out with ENR using RHA silica and carbon black as fillers. Results obtained so far has shown that the reinforcing action of RHA is very much lower than that of carbon black and silica. The reason for this is the particle size of RHA. CR and DC has agreed to do trials to prepare RAH with smaller particle size.

Work on this project was also concluded and the research student from the university returned to the university after submitting a report (Pushpa Goonetilleke, A Samarakoon and Wijegoonewardene (University student).

Latex properties during storage

LATZ latex with and without hydroxyl amine neutral sulfate was stored for four months during which the gel content and prevulcanisation characteristics were determined. Preliminary experiments reveal that HNS is capable of keeping the gel content of latex at a constant value. The sample without HNS shows a marked increase in gel content. Therefore there is a possibility of preparing constant viscosity latex for product industry as the property variations associated with the gel content of latex increasing during storage is a current problem. (Pushpa Goonetilleke and Indra Denawake).

Slow release fertilizers

Efforts were made to encapsulate Urea fertilizer which is the most volatile nutrient in a normal rubber fertilizer, in a coir dust membrane. Pellets produced in this manner were handed over to the Soils and Plant Nutrition Department to study the rate at which Urea is released from these pellets when burried in the soil.

Role of the saw dust in enriching the soil will also be studied this project. The same experiment was tried out using foam rubber as the encapsulating agent for volatile Urea Crystals. Experiments were conducted with foam rubber urea pellets to see their suitability as slow release membranes. Attempts were made to determine the rate at which urea was released from rubber pellets at different time intervals. Preliminary investigations indicated that this technique, helps to release urea from rubber pellets, at a controllable way depending on a number of variables. Further research work on the project is in progress (K G Karnika de Silva, Lalani Samarappuli, Medhavi Wijesekera and R Hettiarchchi).

MG 30 and MG 49 rubber

In order to solve a problem encountered by C W Mackie & Co some trials were carried out to prepare MG 30 and MG 49 Rubber in pilot plant scale using the model reactor at Agalawatte. Samples of MG 49 rubber was sold to a private party through IDB to turn out large rollers. The performance of the rollers used in the printing industry seems to be very satisfactory and request for another 300kg of MG rubber has been made by the same party (K G Karnika de Silva and S S Warnapura).

SP 20 rubber

A large scale batch of SP 20 rubber was made by using the pilot plant by conventional sulfur vulcanization. Tests were performed on physical properties. Raw rubber and technological properties of SP 20 rubber compounds were found to be superior to the control sample (K G Karnika de Silva, Chitra Kurruppu and S S Warnapura).

Utilization of buffing dust

This study was initiated with the aim of investigating the effect of buffing dust as a raw material and as a filler on the technological properties of rubber compounds. (Madhupani Jayasooriya and S Nissanka University of Moratuwa).

Traffic cone bases

A request to turn traffic cones out of rubber based material was forwarded to the dept. These bases are required for an export order to Japan and the cost of a base of 2 kg of weight was requested to keep at very low. This was an impossible task with NR as a base material but several trials were conducted using a high percentage of bitumen as a cheap filler in the formulation. The samples turned out were acceptable to the requested party. These samples seem to be very useful in certain other applications and further trials will be conducted to find the physical properties of these samples for other uses (K G Karnika de Silva, Laleen Karunanayake and Nimal Karunanayake).

Industrial Extension

Mal Lanka	CS_2 analysis
IDB	PVC/NBR blends
Richard Peries	Foam rubber, toxicity tests, elastomer analysis
Slim Quest	Conductive rubber
Malindu Timber	MDF Boards out of rubber wood
Sugathadasa Stadium	Artificial sports tracks
Private Company	Traffic cones
Formosa Industries	PP sacks
Decent Lanka	Disposable shopping bags
DSI	Rubber formulations
AMW	Toxicity studies
Textrip	Latex protein in dental dams
Dipped products	Latex proteins
Hanwella Rubber Products	Latex proteins, Latex stability

RAW RUBBER AND CHEMICAL ANALYSIS

L Karunanayake

SUMMARY

This Department was engaged in the following activities during the year:

a. Analysis, grading and issuing shipping certificates for all TSR produced in the country.
b. Analysis and issuing quality certificates for sheet and crepe rubber.
c. Analysis and certification of concentrated latex manufactured in the country for local industries and for exports.
d. Analysis of chemicals and water used in the NR industry.
e. Testing of finished products. (e.g. Presence of SPP in rubber gloves, rubber content in vulcanized products).
f. Analysis and certification of master batch and reclaimed rubber for export.
g. Participation in Round Robin cross check on dry rubber testing for regional laboratories conducted by Rubber Research Institute of Malaysia.
h. Organizing demonstrations on preparation of rainguard sealant for smallholders.
I. Assistance was rendered to other departments in their research and extension work by analyzing dry rubber, latex, chemicals and water samples .
J. Training programmes were undertaken and carried out on latex and dry rubber testing for Technical Officers/Assistants of private sectors rubber factories.
k. Organization of training programme on the use of computers for technical staff and clerical staff of Colombo Office.
l. The following research projects were in progress:

1. Manufacturing of briquetts out of rubber wood saw dust.
2. Use of bitumen in dry rubber product applications.
3. Use of dry rubber backings in coir products.
4. Manufacture of rubber wood charcoal.

DETAILED REVIEW

Staff

Mr L Karunanayake, Assistant Specifications Officer, submitted his PhD thesis to the University of North London in December 1997.

Mrs Anoma Gunawardena, Assistant Rubber Chemist was on study leave throughout the year.

Mrs Sriyanthi Weeraman, Experimental Officer and Mrs Leela Wanigatunga, Senior Technical Officer were on duty throughout the year.

Technical Officers, Mrs Nanda Baduge, Mrs Vasantha Gamage, Mr R S Wijesundara, Mrs Geethani Rajapakse, Mrs Champa Lokuge, Mr Gamini Wanigatunga, Mr P L Perera were on duty throughout the year.

Mr Mahes Gamage was transferred to Raw Rubber Process Development and Chemical Engineering Department with effect from 04.06.97 and Mr L P Vitharana was transferred from Plant Science to this department with effect from 04.06.97.

Mr P Lelwala, Instrument Technician went for an overseas assignment on No-pay leave.

Specifications Assistants, Messrs B Gunasiri, K R N Karunatilake, Wimaladasa Vithanage and Sarath Chandrasiri were on duty throughout the year.

Mrs Indrani Wijesinghe, Clerk/Typist was on duty throughout the year.

Mr Sirisena Gallege, the Laboratory Attendant was on duty throughout the year.

Laboratory labourers, Messrs G H Somasiri and Piyatissa Vithanage were on duty throughout the year.

Meetings, Seminars and Lectures

Mr L Karunanayake participated in the following:

* A workshop on quality control of RVNRL held in Jakarta, Indonesia for a period of one week.
* A workshop on NMR techniques at University of Colombo.
* A workshop on latex weighing organized by Rubber Development Department.
* Committee meetings on Standardization of Metrolac ready reckoner chart organized by SLSI.

* Delivered a lecture on manufacturing of TSR for Factory Officer training programme organized by NIPM.
* Delivered lectures on manufacturing of TSR and latex weighing for Diploma in Plantation Management course organized by NIPM.

Mr R S Wijesundara carried out a training programme on the use of computer for the benefit of the Technical and Clerical staff of Ratmalana Laboratory complex fundamentals of computers and use of software packages based on Windows '95 were illustrated in detail.

Mr Mahes Gamage, attended a Seminar organized by PRI on Rubber Technology and Machinery.

LABORATORY INVESTIGATIONS

Sealant for rainguard

Educational and demonstrational programmes were continued to educate the small holders on the method of manufacturing rainguard sealant (L M K Tillekeratne, Nimal Karunatilake and W Vithanage).

Manufacturing of briquetts out of rubber wood saw dust

Briquetts of different shapes were prepared by incorporating small amounts of wet starch to saw dust and wood shavings and by compression moulding. Special mould was designed to apply the required pressure using galvanized pipes. These briquetts were dried at 100°C without removing from the mould. They were removed from the mould after cooling to ambient temperature.

It was observed that the briquetts prepared can be kept for a long time without any mould contamination when stored in a dry place. There is no toxic fume emission due to use of non toxic chemicals.

Hence, this material can be utilized in drying processes such as in tea drying and as an alternate fuel to fire wood (L M K Tillekeratne, P L Perera, N Karunatilake and G Wanigatunga).

Use of bitumen in dry rubber product applications

It was found that bitumen can be used as a low cost raw material in dry rubber products. Different properties can be achieved by changing the rubber/bitumen/filler ratio. Very good surface finish can be obtained by incorporating

bitumen in dry rubber products. Further trials are in progress (L Karunanayake and N Karunatilake).

Use of dry rubber backings in coir products

On a request made by an industrialist, rubber/bitumen based backing material was developed for coir mats and carpets. It was found that both melt blending and physical blending methods can be used in this application depending on properties and quality requirements (L Karunanayake and N Karunatilake).

Manufacturing of base component for traffic cone

Based on a request made by a BOI company an attempt was made to formulate a high density low cost material to be used in the base component of traffic cones. This requirement was achieved by incorporating bitumen and China clay in the compound with very small amounts of rubber (K G Karnika de Silva, L Karunanayake and N Karunatilake).

Manufacture of rubber wood charcoal

A large scale trial was carried out to investigate the possibility of manufacturing wood charcoal out of rubber wood. In this trial, roots of uprooted rubber trees were used as the main source of raw material for charcoal production. It was possible to obtain good quality wood charcoal by this process (L M K Tillekeratne and P L Perera).

Patents

P L Perera, Patent No.11114, Electrically Controlled Filling and Autozero Adjustable Attachment for Burettes used in Non Aqueous Titrations.

Training

Miss Abirami Rajagopal, Chemical Engineering student of University of Moratuwa, under went a training in this department.

Inspection visits

Inspection visits were made to C.W. Mackie's Block Rubber Factory and Statcon Block Rubber Factory.

Analytical service

The Number of samples tested from each TSR factory during this year are given in Table 1.

Table 1. *TSR samples*

Producer	No. of Samples
Statcon Block Rubber Factory, Getahetta	1330
Sherman Block Rubber Factory, Ingiriya	661
Ceymac Block Rubber Factory, Horana	1952
Total	3943

Other samples tested during this year are given bellow:

Rubber samples	485
Latex samples	292
Chemical samples	235
Master batch samples	14
Gloves samples	74
Water samples	06
Polythene samples	16
Reclaimed rubber	342
Total	1464

RAW RUBBER PROCESS DEVELOPMENT AND CHEMICAL ENGINEERING

W M G Seneviratne

SUMMARY

Effluent treatment plants based on Anaerobic coupled with aerobic mechanism developed by the department has been commissioned and in full operation in five factories during the year.

On the success of the treatment system developed during the last five years in term of its cost effectiveness and the high level of efficiency, attention was paid to extend this system for the treatment of other industrial waste water also.

A treatment plant installed to treat textile waste water is now in operation at J.L. Industries at Wadduwa which is one of the largest towel manufacturing factories in Sri Lanka.

Under a pilot plant project funded by Coconut Development Authority, a treatment system has been designed for one of the desiccated coconut mills at Pothupitiya and construction is scheduled to commence early next year.

Distillery and meat processing waste water which contains high level of organic matter were also found to be readily digested under properly acclimatized anaerobic conditions.

A research project on 'developing an efficient and cost effective treatment system for treatment of skim serum and the use of bio-gas generated by this system as a source of energy' funded jointly by NARESA and Energy Conservation Fund will be commenced in January next year.

In a study carried out in collaboration with the University of Moratuwa, it was found that a system efficiency of 17% could be achieved with the portable green house type dryer developed for drying of sheet rubber.

Ground work preparation has been completed to obtain ISO 9002 accreditation for Dartonfield and Padukka rubber factories. A new quality management system was introduced in the Dartonfield rubber factory in order to effectively implement the ISO 9002 Quality Assuarance Scheme.

A fully equipped laboratory was set up to carry out tests for effluent quality parameters of industrial waste water. The laboratory is being upgraded to obtain ISO 25 Laboratory Accreditation and the related documents are being prepared.

As one of the major functions of the department, advisory services were rendered in connection with factory development and quality related matters in the manufacture of crepe rubber.

Staff

Dr W M G Seneviratne, Head, of the Department was on duty throughout the year.

Mr Susantha Siriwardane, Assistant Rubber Chemist and Mr Upul Ratnayake, Research Assistant were on duty throughout the year.

Mr P P Jayasinghe, Development Officer was on duty throughout the year.

Mr P H Sarath Kumara, Experimental Officer was on duty throughout the year.

Messrs C D Senanayake, T A S Siriwardena and Mrs W K C Nalini Technical Officers were on duty throughout the year.

Mr C Mahesh Gamage, Technical Officer was transferred to the department on 06th March.

Mrs S A Paranavitane, Clerk/Typist, Mrs L Rukmani, Stores Assistant were on duty throughout the year.

Messrs U Dharmasena and N L D Priyantha were also on duty throughout the year.

Training

The following students from University of Moratuwa were trained under the Apprenticeship Board In-Plant Training Scheme.

Mr Wajira Abeysinghe.	NDT
Miss N M Dilani Dilrukshi	- do -
Miss Hemanthi	- do -
Mr R A L P Rajapakse	- do -
Miss T Varaluxmy	Engineering
Miss J Seelika	- do -

W M G Seneviratne and P H Sarath Kumara supervised a project on "Ways of quality improvements of latex concentrate and study of various problems' carried out by Mr D U H Bulugahapitiya, the Superintendent, Sunnycroft Estate, Waharaka to prepare his dissertation as a partial fulfillment of the Diploma in Plantation Management of Sri Lanka.

Meetings seminars, lectures, and training programmes

Head of the department attended the following:

* Delivered a lecture on Waste water treatment technology at the seminar on waste minimization organized by the Industrial Development Board held in Hotel Trans Asia.

* Delivered a lecture on DRC determination for small holders organized by the rubber development Department.

* A seminar on environmental management conducted by ITCAD

* Two sittings of the evaluation panel of the professional examination in rubber manufacture and factory practice held at NIPM.

* Three scientific committee meeting of RRB held at SLAAS

* Participated in 2nd International workshop on renewable energy application to plantation and other industries, April 9-11, Indian Institute of Technology, Madras and Mudurai Kamraj University between 12-14th of April 1997

* Five committee meetings of the Educational Sub Committee of the Plastic and Rubber Institute

Dr W M G Seneviratne[1], Susantha Siriwardena[2], Upul Ratnayake[3] and P H Sarath Kumara[4] attended the following:

* Delivered lectures for Diploma in Agricultural extension course conducted by NIPM[1.2.3 & 4]

* Seminar on Rubber as an Environmental Friendly Raw Material and Renewable Resource organized by RRISL and RDD [1.2 & 3]

* Delivered lectures for the 6th Professional examination in Rubber Manufacture and factory practice conducted by the National Institute of Plantation Management. [1.2.3 & 4.]

* Delivered a lecture on Institutional support for pollution minimization organized by the Industrial Development Board at Trans Asia Hotel[3].

* Discussion a recent advances in Rubber Research and Development held at Dartonfield[3].

* Seminar on Importance of ISO - 9000 management standards organized by PRI at Agrarian Research Training Institute. [3 & 4]

* Workshop on "Plantation Management Practices" for the staff of Watawala Plantations held at Naikiadeniya Rubber factory. [1 & 4]

* Participated in 2nd International workshop on renewable energy application to plantation and other industries. April 9-11, Indian Institute of Technology, Madras and Mudurai Kamraj University between 12-14th of April 1997 [1&2]

Advisory visits

The following rubber factories and other industries were visited during the year in order to investigate into their problems with regard to processing and manufacturing of raw rubber, factory development work and waste water disposal problems.

1. *Raw Rubber Processing and Manufacturing*

1. Ayre Estate - Padukka.
2. Neuchatel Estate - Naboda.
3. Udapola Estate - Polgahawela.
4. Rattota Estate - Matale.
5. Bible Estate - Bible.
6. Sorana Estate - Horana.
7. Perth Estate - Ingiriya.

2. *Waste water treatment and disposal*

The following rubber factories and other industries were visited during the year to look into waste water disposal problems and also for necessary advice to improve efficiency of the existing treatment plants.

1. Pimbura Rubber Factory, Agalawatte.
2. Lak Latex Centrifuged (Pvt) Ltd., Baduraliya.
3. Ellakanda Rubber factory, Horana.
4. Mackwoods, Ja-Ela.
5. Glenross rubber factory, Neboda.
6. Eheliyagoda Estate, Eheliyagoda
7. Dipped Products Ltd., Brahamanagama, Kottwa and Weliweriya.
8. Rannagala estate, Neboda.
9. Glenross Centrifuged Factory, Neboda.
10. J. L. Industries - Wadduwa.
11. Pothupitiya D. C. Mills, Kalutara.
12. Premier Rubber Products, Ingiriya.
13. Culloden estate, Neboda.
14. Kumarawatte estate, Moneragala.
15. Bible estate, Bibile.
16. SRMEC, Baduraliya
17. Paiyagala estate, Payagala
18. Kiribathgala estate, Ratnapura
19. Bosang Latex Company Limited, Katana.
20. Dasin Glove Company, Makandura.
21. Degue Textile company, Divulapitiya.
22. Devalakanda and Kiriporuwa Rubber Factories.
23. Rambukkanda and Galatura Rubber Factories.

Rubber effluent treatment based on Anaerobic coupled with aerobic mechanism developed by the department has been fully implemented and commissioned in the following factories during the year.

1. Lak latex centrifuge limited - Baduraeliya
2. SRMEC Lanka Products foam rubber factory -Horana
3. Kiriporuwa rubber factory - Yatiyantota
4. J L Industries Textile factory - Wadduwa
5. Eheliyagoda Crepe rubber factory

Suitable waste water treatment systems were forwarded to the following rubber factories and other industries

1. Suraal Centrifuged Latex Factory - Yatiyantota.
2. Century Centrifuged Latex Factory - Ingiriya.
3. Midellamulahena Skim Rubber Factory - Horana.
4. Nakiadeniya Crepe Rubber Factory - Nakiadeniya, Galle
5. Dewalakanda Crepe Rubber Factory
6. SRMEC - Baduraliya
7. Pothupitiya D.C Mills - Kalutara
8. Totamune Rubber mills - Ingiriya
9. Culloden rubber factory - Neboda
10. Pussella estate
11. Arapolakande estate
12. Paiyagala estate - Paiyagala.
13. Kiribathgala estate - Ratnapura.

Testing of processing water and waste water

37 Processing water samples and 26 waste water samples have been tested during the year for effluent quality parameters and test reports were issued.

LABORATORY AND FIELD INVESTIGATIONS

Use of solar energy for drying of rubber

The green house type drier developed for drying of sheet rubber in the previous year has given the promising results. It could be used for the purpose without any adverse effects on physical properties of raw rubber. However, following practical problems were observed.

* Handling of portable two solar flat plate collectors to maintain the temperature at desired levels was a cumbersome operation.

* The cover material which is polythene of 1000 gauge decayed within 6-9 months.

To solve the first problem the two flat plate collectors were removed and control of temperature was achieved by adjusting the opening of the drier. The second problem was overcome by replacing 1000 gauge polythene by 700 gauge.

A research study was carried out using the drier developed in collaboration with the University of Moratuwa. Drying of normal rubber sheets was carried out and they could be dried within four days. The results of this study shows that the drier has a system drying efficiency of 17%.

By inspecting the dried samples it can be concluded that the conditions inside the drier is ideal for drying of sheet rubber. The required temperature for drying could be very easily achieved and control of temperature inside the drier could be done by providing ventilation using natural air draught created by the chimney (W M G Seneviratne, Susantha Siriwardane, T A S Siriwardane, C D Senanayake and Mahesh Gamage).

Manufacture of different grades of sheet rubber

On a request made by an industry, very light colour sheets were manufactured as follows:

* Fractionated bleached rubber
* Unfractionated bleached rubber
* Fractionated unbleached rubber
* Unfractionated unbleached rubber

The above samples were dried in the green house type solar dryer and handed over to the customer for using them in commercial scale production of rubber bands and evaluation (Susantha Siriwardane, T A S Siriwardane and Mahesh Gamage).

Quality improvement of skim rubber

Centrifuged latex industry is a fast growing industry in Sri Lanka. Production of every nine dry kilograms of centrifuged latex gives one kilogram of skim rubber as a by product which is considered a low quality grade of rubber mainly due to its high nitrogen content and hence fetch a very low price.

In view of upgrading the quality and to be able to present as a special grade of rubber, a .project was designed to study physical properties and drying characteristics of skim rubber manufactured in crepe form by adopting certain quality improvement measures. A literature survey was carried out and the experiments will be carried out next year (Susantha Siriwardane and T A S Siriwardane).

Setting up of an effluent testing laboratory

A fully equipped laboratory was set up to carry out tests for effluent quality parameters of industrial waste water. This laboratory is being upgraded to the standard required for obtaining ISO 25 Laboratory Accreditation.

Preparation of slides to be used as visual aids for lectures

The staff of the department assisted the NIPM for preparation of slides which could be used as visual aids during the course of conducting lectures for NIPM courses (W M G Seneviratne, Susantha Siriwardane, Upul Ratnayake and P H Sarath Kumara).

ISO 9002 Accreditation Scheme

Very high priority was given for the implementation of ISO 9002 at Dartonfield and Padduka rubber factories. The documentation have been perfected. Ground work preparation is now complete and hopefully these two rubber factories will be able to obtain ISO 9002 accreditation in early 1998.

In order to effectively implement the ISO 9002 accreditation scheme at Dartonfield rubber factory, a new quality management system was introduced (W M G Seneviratne, Susantha Siriwardane and P H Sarath Kumara).

Effluent treatment and disposal

Effluent treatment system, based on anaerobic/aerobic treatment principle, installed at Dartonfield has been working satisfactorily during the year. A rubber trap tank and a new sand bed filter tank were also constructed in order to enhance the efficiency of the treatment. The improvement of the efficiency is being evaluated.

a. ***Waste water treatment for textile factory effluent***

Laboratory trials and experiments were carried out to find out a suitable method to treat the waste water discharged from J.L. Industries Wadduwa which is one of the largest towel manufacturing factory in Sri Lanka.

A treatment system based on chemical precipitation technique coupled with biological treatment process was proposed to treat the waste water discharged from the textile factory.

The proposed treatment system consists of the following:

1. Collecting tank.
2. Equalization tank.
3. Chemical treatment tank.
4. Anaerobic digester.
5. Aerobic tank.
6. Sand - bed filter tank.
7. Sludge drying bed.

The construction of the treatment plant has been completed and commissioned recently. Two operational methods are being currently evaluated in order to find out the most suitable operational method.

b. ***Generation of bio-gas from skim serum***

The project titled '*developing an efficient and cost effective treatment system for the serum water that is discharged when skim latex, a byproduct from centrifuged latex industry, is processed into skim rubber and also to use bio-gas generated in the process of treatment as a source of energy*' submitted to NARESA for funding has been approved as a viable project. The project will be funded jointly by NARESA and Energy conservation fund. The work on this project will commence in January 1998.

c. ***Treatment system for desiccated coconut (DC) mills***

Research work carried out to treat the DC effluent by using anaerobic coupled with aerobic system which is very effective for bio degradable waste water has been completed satisfactory. Based on research findings, a treatment system was designed to be constructed at Pothupitiya DC mills as a pilot plant for the treatment of desiccated coconut processing water. This project is funded by the Coconut Development Authority. The construction of the treatment plant will commence early next year.

d. ***Treatment of distillery and food processing waste water***

Distillery waste collected from Beruwala Distillery Plant and food processing waste water collected from M/s Elephant House were subjected to anaerobic digestion

under laboratory conditions with a view to study the effectiveness of the anaerobic treatment for these waste.

Distillery waste containing very high levels of organic matter was found to be readily digested under properly acclimatized anaerobic conditions whereas food processing (meat processing) was found to be mediocre towards anaerobic digestion under the same conditions (W M G Seneviratne, Upul Ratnayake, T A S Siriwardena, N M D Dilrukshi and Hemanthi).

ADAPTIVE RESEARCH

N Yogaratnam

SUMMARY

Adaptive research programmes on clone evaluation, soil and moisture conservation practices, organic manure, young budding are in progress. Adverse effect of excessive shading by rubber was observed on tea in an experiment on interplanting of Rubber with tea. Experiments are in progress with two rows of rubber at triangular spacing of 8ftx8ft and spacing of 60 and 70 ft between double rows to minimize at least to a certain extent the adverse effect of shade on tea.

DETAILED REVIEW

Staff

The Deputy Director (Research), Dr N Yogaratnam coordinated the activities of the Unit. Mr S M M Iqbal, Research Assistant in Agronomy, Mr P P Jayasinghe and Mr K B A Karunasekera, Development Officers were on duty throughout the year. Mr E A T Senadeera, Senior Technical Officer left to India on 6th August 1997 for a four months period of training at RRII which was partly funded by the IRRDB Project. Mr A Samarkoon, Technical officer of the Polymer Chemistry Department was transferred on a temporary basis to the Adaptive Research Unit from 6.8.97 and was stationed at Kegalle.

Temporary workers

The services of Mr L D Soyza Temporary Technical Assistant (CARP 12/30/21) was discontinued as the CARP 12/30/21 program was completed on 30th April 1997. Mrs S Dharmakeerthi Trainee Graduate discontinued her work from 6.8.97 as the training scheme of the Ministry of Youth Affairs and Policy Planning was terminated.

Meetings

The Adaptive Research Unit staff participated in the following:

* Research Meetings of the Institute and discussed the on going research programme in Adaptive Research.

* Joint meeting of Rubber Development Department and RRI Scientific Staff

* Monthly conferences of the Regional Rubber Development Department in Kegalle region.

* Tapper training, fixing of rainguards and rainguard sealant preparation programmes a Kegalle region.

Training programmes

Mr S M M Iqbal delivered a lecture on "Interplanting of rubber with tea" for the refresher training programme for Rubber Development Officers of the RDD and NIPM trainees.

FIELD INVESTIGATION

Clone evaluation

Four clones *viz*. RRIC 100, RRIC 102, RRIC 110 and RRIC 121 were tested under smallholder management practices (smp) and RRI recommended practices (RRI) at Kegalle and Kalutara regions. Rubber plants of clone RRIC 110 in the following sites were uprooted due to Corynespora leaf disease.

Site	Smallholder name & address	Extd	Clone
1.	Mr Piyadasa Abeywickrema Gonagala, Ruwanwella, Kegalle Region	0.3 ha	RRIC 100
2.	Mrs N D Babynona, Diyakaduwa, Mahagama, Kalutara region.	0.2 ha	RRIC 100

Clone RRIC 100 was supplied in these sites for replanting. Fertilizer was also issued to these plots by the Rubber Research Institute.

The following trials were selected to monitor the yield potential of these clones and it was decided to supply fertilizer and rain guard for the RRI management plots.

Site	Region	Clone	Treatment	Remarks
1.	Kegalle	RRIC 100	SMP	Advice on tapping
2.	Kegalle	RRIC 102	RRI	In tapping. Selected to fix rainguard and to mulch with paddy straw
3.	do	do	RRI/SMP	do
4.	do	RRIC 121	SMP	Advice on tapping
5.	do	do	RRI	In tapping. Selected to fix rainguard and to mulch with paddy straw
6.	do	do	RRI/SMP	In tapping. Selected to fix rainguard and to mulch with paddy straw
7.	Kalutara	RRIC 100	RRI	Selected to fix rainguard and to mulch with paddy straw
8.	Kalutara	RRIC 100	RRI/SMP	Selected to fix rainguard and to mulch with paddy straw
9.	do	RRIC 102	SMP	
10.	do	RRIC 121	SMP	
11.	do	do	RRI	Selected to fix rainguard and to mulch with paddy straw.

RRI - RRI management practice
SMP - Smallholder Management Practice

(D P S T G Attanayake, S M M Iqbal and K B A Karunasekera).

Use of rainguards

It was decided to fix rain guard on selected sites under the Clone Evaluation Program. See details in clone evaluation program (A Nugawela, N Kaluwewa, S M M Iqbal and E A T Senadeera).

Soil and moisture conservation practice

a) ***Effectiveness of bush/tree legumes***

b) ***Use of poultry litter***

The above programmes were in progress. Recording of girth was continued.

c) ***Use of paddy straw***

Three sites at Kegalle Region were selected for this program. See details in Clone Evaluation program (L Samarappuli, N Yogaratnam and E A T Senadeera).

Young budding

Programme - Planting techniques

Treatment	:	Young budded polybag plants (YB)
Control	:	Brown budded bare root plants (BR)

Girth measurements and information on management practices of three sites in Kegalle region and one site in Galle region for the year 1996 are given in tables 1 and 2.

Performance of both young budded polybag and brown budded bare root plants at the end of the year 1997 was assessed by measuring girth and annual girth increment of the plants selected randomly in 1996 (Annual Review 1996).

Out of the 17 trials in 6 rubber growing regions, 8 trials were assessed to date. Among the trials established in 1994, the highest mean girth (27.8cm) was recorded in YB plants at the site Haburugala and the lowest (21.1cm) was in BR plants at Uggalboda. Similarly, the mean girth was highest (24cm) in YB plants at Mattaka, while it was lowest (19.5cm) in YB plants at Pelmadulla among the trials established in 1995.

Significant girth increment of YB was observed in the sites Badugama and Baduraliya. Although the difference of the mean girth increment of YB and BR was not significant in the sites at Elapatha and Mattaka, more than 10cm girth increments were shown by those sites. However the highest girth increment (10.8cm) was recorded in YB plants at Elapatha.

Table 1. *Mean girth of the rubber plants in young budding trials*

Region	Site	Year of planting	Mean girth (cm)		t-value at 5%	Conclusion	% Casualties	
			YB, n=20	BR,n=20			YB	BR
Kegalle	1	1994	15.7	17.2	1.875	* Not signif.	5	3
	Dehiowita	Aug	+2.6	+2.4				
	2	1995	9.1	8.2	2.343	# Significant	2	8
	Kotiyakumbura	Jul	+1.1	+1.3				
	3	1995	13.8	8.9	9.57	Significant	4	30
	Ambakote	Jul	+1.7	+1.6				
Galle	4	1995	13.8	11.8	2.84	Significant	2	0
	Akuressa	Jul	2.2	2.2				

* BR is superior
\# Girth is not satisfactory

Table 2. *Suplimentary data collected from the young budding programme*

Region	Site	Weeding		Ground Cover		Fertilizing	Remarks	
		Type	Response	Crop	Situation		Manag.	Record.
Kegalle	1	Circle	Moderate	*Pueraria*	20%	Regular	Moderate	Moderate
	2	Strip	Poor	*Pueraria* Vetivar	10%	Not regular	Moderate	Moderate
	3	Circle	Poor	*Pueraria*	35%	Regular	Poor	Moderate
Galle	4	Circle	Moderate	*Pueraria*	30%	Not regular	Poor	Poor

Table 3. *Mean girth and girth increment of rubber plants in the young budding trials*

Region	Site	Year of	Mean girth 1997		Girth increment		T-	Observation
			YB (n=20)	BR (n=20)	YB (n=20)	BR (n=20)		
Kalutara	1	1994	24.2	23.2	9.1	7.8	2.155	Significant
	Badugama	Aug						
	2	1994	25.2	21.1	8.4	8.6	0.329	Not
	Uggalbada	Aug						significant
	3	1995	22	21.5	9.5	9.5	0.059	Not
	Morapitiya	Jul						significant
	4	1995	21.2	19.4	9.4	8	2.027	Significant
	Baduraliya	Jul						
	5	1995						
	Horana	Jul						
Galle	1	1994						
	Kamburupitiya	Aug						
	2	1994	27.8	22.5	8.3	6.8	1.997	Not
	Haburugala	Jul						significant
	3	1995	24	23.7	10.2	10.3	0.102	Not
	Mattaka	Jul						significant
	4	1995						
	Akuressa	Jul						
Ratnapura	1	1994	23.6	23.4	10.7	10.6	0.1404	Not
	Elapatha	Sep						significant
	2	1995	19.5	19.6	9.3	9.6	0.4089	Not
	Pelmadulla	May						significant
Colombo	1	1994						
	Padukka	Aug						
	2	1995						
	Gampaha	Jul-Aug						
	3	1995						
	Polgasowita	Jul						
Kegalle	1	1994						
	Dehiowita	Aug						
	2	1995						
	Kotiyakumbura	Jul						
	3	1995						
	Ambakote	Jul						

(P Seneviratne. A M W K Seneviratne and S M M Iqbal)

Inorganic fertilizer (Eppawala Rock Phosphate)

Suitability of Eppawala rock phosphate as a phosphorus source for smallholdings

Three trials were continued in Kalutara regions. Field visits were made to the above trials. Fertilizer was applied according to the RRI recommendation. Girth measurements of rubber plants were recorded. Statistical analysis of these data was is progress (A Dissanayaka, and H D S P Perera).

Intercropping of rubber with cinnamon

Programmes on intercropping of rubber with cinnamon were in progress at Ratnapura, Galle and Kegalle regions. Growth of the Rubber in these areas were satisfactory. Harvesting of cinnamon is being continued. Poor growth of cinnamon was observed in these trials due to the following reasons.

* Domestic problems of the smallholder.
* Poor smallholder response.

(L S S Pathiratna)

Interplanting of rubber with tea

State sector I (1985)

Girth of the rubber plants were recorded in 2 observation trials at Kegalle and Kalutara (Table 4) regions. Shade measurements were recorded. Yield data of tea were also collected.

Table 4. *Girth of rubber in the rubber and tea interplanting experiments (State sector 1) in 1997*

Estate	Rubber spacing	Mean Rubber Girth (cm)		Remarks
		Rubber only	Rubber x Tea plot	
Perth	8'x30'	73.13	76.50	N.S.
Kiriporuwa	8'x40'	68.90	74.93	N.S.

N.S. - Not significant

(N Yogaratnam and S M M Iqbal).

State sector II

Experiment 1 (RRISL Sub Station - Kuruwita)

The following were done:

a) Recording of tea yield.
b) Measurement of rubber girth.
c) Collection of leaf samples.
d) Test tapping of rubber

Girth of the rubber plants measured at 5ft from the bud union in 1996 is given in Table 5.

Table 5. *The effect of multicropping of rubber lands with tea on girth of rubber after 5 years of growth*

Treatments		Mean Girth (cm)
Rubber Only		56.80 A
Tea (Rehabilitated) Rubber 8' x 27'	+	57.67 A
Tea (Unrehabilitated) Rubber 8' x 27'	+	56.24 A
Tea (Rehabilitated) Rubber 8' x 40'	+	57.89 A
Tea (Unrehabilitated) Rubber 8' x 40'	+	59.00 A

Means followed by a common letters are not significantly different.

Yield of tea in unrehabilitated plots were recorded in 1996 (Table 6).

Table 6. *The effect of multicropping of rubber lands with tea on yield of tea planted without rehabilitation.*

	Made tea yeild	
Treatments	Actual	kg/bush
Rubber 8'x27'+ Tea	816	0.103A
Rubber 8'x40'+ Tea	1355	0.145A

Yield of tea in rehabilitated plots were recorded in 1996 (Table 7).

Table 7. *The effect of multicropping of rubber lands with tea on yield of tea planted after rehabilitation (Pruning Year)*

	Made tea yield	
Treatments	Actual kg/ha	kg/bush
Tea only	1313	0.105A
Rubber 8'x 27'+ Tea	429	0.054B
Rubber 8'x 40'+ Tea	532	0.057B

Means with the same letters are not significantly different.

Tapping of rubber trees commenced in February 1996. Yield of rubber in this experiment was presented in table 8.

Table 8. *The effect of multicropping of rubber lands with tea on yield of rubber*

Treatments	Rubber yield		
	g/t/t	kg/ha (calculated)	kg/ha (Actual)
Rubber Only 12'x 18' 100%	32.39A	1311.3	1311.3
Rubber 8'x 27' 100% + Tea (rehab) (4 rows) 65%	33.17A	1343.4	1343.4
Rubber 8'x 27' 100% + Tea (unrehab) (4 rows) 65%	31.48A	1275	1275
Rubber 8'x 40' 70% + Tea (rehab) (7 rows) 75%	32.41A	1312.5	985.80
Rubber 8'x 40' 70% + Tea (unrehab) (7 rows) 75%	31.52A	1273.8	956.7

Means with the same letters are not significantly different (N Yogaratnam, S M M Iqbal in collaboration with TRI).

Experiment II - (RRISL - Agalawatta)

Experiment II started at RRISL. Gallewatta Division to study the effect of Interplanting of Rubber with tea on the growth and yield of Rubber with tea.

Girth of the rubber plants were recorded in 1996 (Table 9).

Table 9. *The effect of multicropping of rubber lands with tea on growth of rubber*

Treatments	Mean Girth (cm) 1996
Rubber Only 12'x 18' 100%	43.51A
Rubber 8'x 27' 100% + Tea	47.11A
Rubber 8'x 32' 85% + Tea	46.47A
Rubber 8'x 36' 78% + Tea	44.17A
Rubber 8'x 40' 70% + Tea	45.31A
Rubber 8'x 44' 65% + Tea	45.08A

Means with the same letters are not significantly different.

Growth measurements of tea

Bush diameter at the ground level, height and tipping weight were recorded in 1996. These growth assessments were not affected by treatments (Table 10).

Table 10. *The effect of multicropping of rubber lands with tea on growth of tea (at the 2nd cut)*

Treatments	Height (m)	Diameter (cm)	Tipping wt kg/bush
Tea only 2'x4'100%	2.088A	2.310A	0.2295A
Rubber 8'x 27' 100% + Tea	1.962A	2.418A	0.2215A
Rubber 8'x 32' 100% + Tea	2.083A	2.500A	0.1518A
Rubber 8'x 32' 85% + Tea	2.148A	2.640A	0.1831A
Rubber 8'x 36' 78% + Tea	2.025A	2.383A	0.1397A
Rubber 8'x 44' 65% + Tea	2.112A	2.433A	0.2427A

Means with the same letters are not significantly different.

Girth of rubber and bush thickness, height, tipping weight of tea in this experiment were not effected by treatments.

Yield

Plucking of tea was started in July 1996. Yield of tea in this experiment is presented in table 11. Yield data shows no significant difference between treatments.

Table 11. *The effect of multicropping of rubber lands with tea on yield of tea*

Treatments	Made tea yield Jul-Dec 1996 kg/bush	Jul-Dec 1996 Actual kg/6m
Tea only 2'x4'100%	0.05862A	732.752
Rubber 8'x 27' 100% + Tea	0.05595A	454.59
Rubber 8'x 32' 85% + Tea	0.05083A	432.06
Rubber 8'x 36' 78% + Tea	0.05770A	526.51
Rubber 8'x 40' 70% + Tea	0.05703A	534.65
Rubber 8'x 44' 65% + Tea	0.06870A	687.70

Means with the same letters are not significantly different.

Rubber and Tea leaf samples were also collected (N Yogaratnam, S M M Iqbal, C Seneviratne and Mr G D Piyathilake, Tea Inspector, TSHDA, Matugama).

Experiment III - Perth Estate, Horana (Meenapalana Division)

This experiment was in progress.The following were carried out.

* Manuring of rubber and tea
* Growth assessments of tea and rubber
* Collection of leaf and soil samples
* Centering of Tea bushes.

(S M M Iqbal and N Yogaratnam).

Experiment IV

Another new experiment was also planned to be started in May /June 1998 at Vogan Estate Matugama with the following treatments, in split-plot design replicated 4 times.

Treatments

Main Treatments

M1 - Tea with rehabilitation
M2 - Tea without rehabilitation

Sub Treatments

Fertilizer Levels:

F1 - ½ of the recommended rubber fertilizer
F2 - normal recommended rubber fertilizer
F3 - 1 ½ of the recommended rubber fertilizer

Cropping systems:

T1 - Rubber only 12' x 18' 100%
T2 - Rubber 8'x 8' x 46' 100% (double row) + Tea (8 rows) 66%
T3 - Rubber 8'x 8'x 60' 80% (double row) + Tea (12 rows) 76%

A sole plot of tea (4'x2') with standard agro management practice also included in each main plot (T4) (S M M Iqbal and N Yogaratnam).

Smallholder sector

Smallholder trials at the Kegalle and Ratnapura Region were in progress. Girth of the rubber and yield of tea were collected. Table 12 give the yield details of tea in Smallholder sites.

Table 12. *Tea yield details of interplanting of rubber with tea programme at the Kegalle and Ratnapura Regions*

	Site	Clone & Year of Planting	Made tea yield (kg)
01	Mr W Higgoda, Undugoda, Kegalle.	TRI 2026 1992 N.P.	1827/ha
02	Mr P K M G Karunathilake, Kiriwana - Higgoda, Kegalle	TRI 2026 1993 NP	1165/ha
03	Mr A R Samarasekara Dela Ratnapura	TRI 2025 1994 NP	1172/ha

(N Yogaratnam, S M M Iqbal and E A T Senadeera).

AGRICULTURAL ECONOMICS

P H M U Herath and I N Samarappuli

SUMMARY

Studies undertaken include; future direction of Sri Lankan rubberwood industry; economic assessment of land degradation; economic and environmental feasibility of converting degraded tree crop lands into alternative farming systems; global trends in NR industry; adoption of technologies in rubber smallholdings; a policy study on rubber products sector, environmental linkages of rubberwood industry, present status and factors affecting intercropping; some problems related to rubber latex market; role of credit in rubber marketing and economic impact of subsidy scheme on rubber.

Other studies in progress are; economic lifespan of *Hevea*, social cost associated with rubber effluent; gender issues and impact on rubber industry; cost of production under farmer managed conditions; issues related to decline in total rubber extent; participation of youth in rubber cultivation; strategies adopted in other countries to develop rubber sectors; and impact of trade blocks, exchange rate liberalization and macro-economic policies on rubber sector, information dissemination in rubber sector; comparative study of management at estate and smallholder sector; factors affecting local consumption of rubber; labor economics in rubber sector and modelling farmer behavior at micro level.

DETAILED REVIEW

Staff

Assistant Agricultural Economists, P H M U Herath, I N Samarappulli and A K B Naranpanawa were on duty throughout the year.

Presentations/Seminars/Meetings

Dr I N Samarappuli made the following presentations.

* "Environmental linkages of rubber wood industry" at a seminar on "Rubber as an Environment-friendly raw material and renewable resource" organized by RRISL and RDD - held at SLAAS.

* "An overview of the Sri lankan rubber plantation industry with special reference to wood sector" at Rubber Research Institute of India, Kottayam.

* "Present situation of the rubber wood industry in Sri Lanka" at Scientific Committee Meeting - February 1997.

* "The Global price situation of NR" at Scientific Committee Meeting - December, 1997.

* "Economic consequences of land degradation in rubber plantations" at a seminar on "Land degradation" organized by the MPI and La Trobe University - held at TRI, Hantana.

* "Modelling the affects of land degradation in rubber plantations" at a Technical workshop on "Land degradation and policy option in Sri Lanka" organized by MPI and La Trobe University - held at Taj Samudra, Colombo.

* "Economic and Environmental feasibility of converting unproductive tree crop plantations in to forest plantations and agro-forestry systems" at a Technical Workshop on "Land degradation and policy option in Sri Lanka" organized by MPI and La Trobe University - held at Taj Samudra, Colombo.

* "Trends in world Natural Rubber Industry" at a seminar on "Strategic management approach for improved performance in Natural Rubber" organized by the National Institute of Plantation Management - held at Taj Samudra, Colombo.

* "The role of rubber goods manufacturing sector in the industrialization program of Sri Lanka" presented to the Ceylon Chamber of Commerce.

* "Rubber goods manufacturing sector: Proposal for indicative planning and policy formulation (1996-2000)" - Presented to the Industrialization Commission, at Ministry of Finance.

* "Why Policy Reforms for Thrust Industries: The case of Rubber Product sector" at the 11th Annual Technical Sessions of the Plastics and Rubber Institute of Sri Lanka - held at Sausiripaya, October 1997.

* "Future direction of rubber wood industry in Sri Lanka" at a progress review seminar for research grantees (Agricultural Science) organized by the Steering Committee on Agriculture and Animal Husbandry, NARESA, November, 1997.

* P H M U Herath addressed the Scientific Committee Meeting on 'Plantation Sector Past, Present and future' - held in December, 1997.

* P H M U Herath attended the bi monthly meetings of the Socio Economists and Policy Analysis group of the CARP.

Training

Mr A K B Naranpanawa attended a Training on information for agricultural research managers (INFORM) conducted by CARP held at ICT, University of Colombo on 29.10.97.

Research students/Lectures/Committees

Miss P N Subasinghe, an undergraduate student from the University of Peradeniya completed her final year research project on "Economic analysis to determine the optimum lifespan of *Hevea*" under the supervision of Dr I N Samarappuli.

* P H M U Herath served as a visiting Lecturer for the Plantation Management specialization course of the Faculty of Agriculture of the Rajarata University.

* P H M U Herath served as an economic consultant to the Sri Lanka - NRI (UK) research group working on Rubber/Banana Marketing in Sri Lanka.

* Dr I N Samarappuli was appointed to serve as a visiting lecturer at Department of Agricultural Economics, University of Ruhuna.

* Dr I N Samarappuli served as a member of the Standing Committee on Research Programmes and Projects, Sri Lanka Council for Agricultural Research Policy.

RESEARCH

Micro economic policies and their impact on the plantation sector of Sri Lanka

This study that was undertaken to quantify the impact of different policy measures on the plantation sector development was continued. The necessary data collection since 1948, on different policy measures and the sector performances in terms of land and labour productivity, contribution to the gross national production, employment generation, foreign exchange earnings and land utilization was completed. A study was initiated on the impact of different land policies of the rubber sector (P H M U Herath).

Developing a simulation model for rubber industry in Sri Lanka

An explanatory model was designed as a pre requsite to develop a simulation model. The process of developing a simulation model to the whole sector is complicated. Therefore, model devlopment was segregated according to the main aspect of the production. The enviromental aspects of the production was studied and an explanatory flow chart was developed. Developing mathematical relationships was continued (P H M U Herath).

Rubber latex market: Some related problems

Development of latex based industries lead to a new market channel in rubber marketing system. This facilitates some of the smallholders immensely as this system provides them easy access to the market and also considerably higher prices compared to sheet rubber. The system is well established as it is connected to the rubber based end product system. However, a survey conducted in Kalutara district shows that the monopoly in the end product sub system leads to high susceptibility of the system to any negative development in the end product sub system. Further this survey revealed the importance of product diversification of the rubber factories and the quality improvement in the latex production to stabilize this new market segment (P H M U Herath).

Future direction of the rubberwood industry in Sri Lanka

A field survey was carried out to study the future direction of the Sri Lankan rubberwood industry with particular reference to supply and demand, technological status, constraints and investment opportunities (I N Samarappuli, L M K Tillekeratne, K G K de Silva and C S Wickramaratne).

Economic assessment of land degradation

A mathematical model was developed to assess the impact of land degradation on rubber yields using experimental data (I N Samarappuli, L Samarappuli and A Ekanayake).

Economic and environmental feasibility of farming systems on degraded lands

A study was undertaken to assess the economic and environmental feasibility of converting unproductive tree crop plantations into forest plantations and agro-forestry systems using secondary data and field observations (I N Samarappuli, A Ekanayake and A K B Naranpanawa).

Global trends in NR industry

Global trends pertaining to both NR and SR production, consumption, exports, prices and Government policies were studied using secondary data to assess the future direction of the rubber industry (I N Samarappuli).

Adoption of technologies in rubber smallholdings

A study was conducted to determine the adoption pattern of some technologies in rubber smallholdings using a logistic regression approach. Data gathered from a field survey conducted in 1995 were used for the analysis. The preliminary findings of this study were presented at the 53rd Annual sessions of the SLAAS (B W Wijesuriya and I N Samarappuli).

Policy studies on rubber products sector

A study was undertaken to formulate appropriate policies to develop the rubber products sector as a Thrust Industry. The full report of the preliminary study was submitted to the Industrialization commission (I N Samarappuli, L M K Tillekeratne, Tilak de Zoysa, Nanda Fernando, P de Silva, L P Mendis, A Mitra, K Rajapaksha, D Dharmasena and Stig Wanni).

Further investigations are in progress to study the missed linkages of the rubber product industry and to estimate value addition and producer margins according to product types (I N Samarappuli, L M K Tillekeratne and A K B Naranpanawa).

Environmental and economic viability of the NR industry

This study emphasizes that depletion of natural resources such as rain forests or any unaccounted damage to the environment such as dis-charge of effluent should be considered in the computation of national output (*eg*. GNP) which is presently based only on the value of manufactured and marketed goods and services (I N Samarappuli, A K B Naranpanawa, L M K Tillekeratne, K G K de Silva and C S Wickremaratne).

Social cost of rubber effluent

A study initiated in estimating the social cost of rubber effluent is in progress. A structured questionnaire was developed to use in the contingent valuation of social cost of effluent. A pre-test was conducted under the field conditions and the questionnaire has been modified accordingly (A K B Naranpanawa, I N Samarappuli and M T Warnakula).

Environmental linkages of rubber wood industry

A preliminary study is in progress to investigate the environmental linkages of the rubber wood industry using both primary and secondary data (I N Samarappuli, A K B Naranpanawa, L M K Tillekeratne, K G K de Silva and C S Wickramaratne).

Economic lifespan of *Hevea*

This study investigates the optimum lifespan of *Hevea* with special reference to timber production. According to the preliminary results, the optimum lifespan is achieved at 19 years under the single production period (I N Samarappuli, A K B Naranpanawa, P N Subasinghe and H B Kotagama).

Socio-economic conditions of women workers in the rubber sector

This study attempts to identify the socio-economic status and the constraints faced by women workers in the rubber sector with a view of formulating appropriate policies to increase labour productivity while uplifting their welfare status (I N Samarappuli and A K B Naranpanawa).

Estimation of cost of production

A study has been designed to estimate the cost of production of rubber cultivation and processing under farmers technology adoption conditions in Sri Lanka (I N Samarappuli and A K B Naranpanawa and B W Wijesuriya).

Analysis of the decline in area under rubber cultivation

A substantial decline in the area under rubber cultivation has been observed, specially during the last two decades. in several rubber growing districts. A field study is in progress to examine this phenomenon in-depth including the merits of diversification of rubber lands in to other profitable ventures from a financial, economic. social and environmental perspective (I N Samarappuli and A K B Naranpanawa).

Participation of youth in rubber cultivation

It has become evident that the interest of youth to participate in rubber cultivation is declining. Several reasons may have influenced to discourage youth from seeking employment in rubber plantation sector. A study has been undertaken to examine the issues pertaining to the lack of interest of youth to participate in rubber plantation activities (I N Samarappuli and A K B Naranpanawa).

Strategies adopted in NR producing countries to develop rubber sector

This study examines the strategies adopted in other NR producing countries to develop the rubber sector and lessons for Sri Lanka (I N Samarappuli and A K B Naranpanawa).

Comparison of costs and returns of rubber cultivation between countries

This study intends to compare the costs and returns of rubber cultivation between the NR producing countries (I N Samarappuli and A K B Naranpanawa).

International trade blocks and exports of raw rubber and manufactured rubber products of Sri Lanka

A study that was initiated to investigate the implications of South Asian

Preferential Trading Arrangement (SAPTA) on the Sri Lankan rubber sector is in progress. The necessary data are being gathered (A K B Naranpanawa and I N Samarappuli).

Impact of macro-economic policies (monetary and fiscal) on the performance of agricultural sector with special reference to natural rubber industry

Under this broad area, a study has been initiated in identifying and quantifying the impacts of macro-economic policies (monetary, fiscal and exchange rate), producer prices and other relevant variables on supply of natural rubber in Sri Lanka. The study intends to adopt general to specific econometric methodology in developing the supply response model. Monthly data since January 1970 have been gathered and a supply response model is being fitted (A K B Naranpanawa).

Impact of exchange rate liberalization on the raw and manufactured rubber products sector in Sri Lanka

The study focuses on the relationship between real exchange rate and exports of raw and manufactured rubber products in Sri Lanka. The necessary data have been gathered and an econometric model is being developed to identify the relationship in a partial equilibrium framework (A K B Naranpanawa).

Factors affecting on intercropping at smallholder level

A logit model was fitted to quantify the factors affecting intercropping. Educational level, attitude towards intercropping and experience in growing rubber indicate significant impact on intercropping (P H M U Herath).

Economic impact of replanting and newplanting subsidy on rubber

The Rubber Replanting Subsidy Scheme (RRSS) has functioned for around 45 years since its inception in 1953. This is an in-depth study on the rubber subsidy scheme in terms of financial, economic and social gains to the sector. Also this study intends to recommend necessary improvements or alternatives to improve the rubber replanting and new planting. The secondary data on the different aspects of RRSS were gathered for this study. Economic criterions like cost of subsidy to the economy, the impact of replanting in monetary terms, the actual and the potential performances of the scheme in terms of area replanted, comparative study of actual and optimum replanting performances have been employed in this study (P H M U Herath).

Role of credit in rubber marketing at smallholder level

At present non institutional lenders play a major role in providing credits in agricultural production like rubber. This study revealed that rural and urban level dealers act as one of the major components in non institutional lenders. Most of the present rural agricultural production is either stagnated or deteriorated due to indebtedness of the farmers to these rural and urban money credit lenders. In some cases the market margin retained by dealers is higher than the price received by the producers. Also, with an increase in producer prices, the margin retained by the dealers increases very significantly. This clearly indicates that the open market phenomena is being obstructed by rural and urban level money lenders. The indebtedness of the farmers reduce their bargaining power. Therefore, price level received by the farmer is being mainly decided by the dealer and not by the open market interactions (P H M U Herath).

Information dissemination in rubber sector

A situation analysis was conducted on information dissemination in rubber sector. Based on the preliminary studies a detailed study was planned on the effectiveness of different modes, characterization of different modes, quantification intensity of farmer knowledge and adaption of selected practices, quatification of constraints and impact evaluation of adaptive research (P H M U Herath).

Comparative study of management at estate and smallholder sector

A project proposal on the feasibility of managing RDO ranges as an estate was prepared based on the information gathered by serveys conducted by the Agric Economics Unit. This Study intends to carryout finanacial economic and administrative aspects and the constraints based on production function frontier analysis of the sectors (P H M U Herath and V H L Rodrigo).

Factors affecting local consumption of rubber

Quantification of factors, future trends, potential areas to improve and the constraints on local consumption are planned to be studied under this program. Initialy consumption trend data were gathered since 1960 and with and without policy tecniques in regression analysis was employed to quantify the impact of open market policies implemented since 1977, on local consumption (P H M U Herath).

Labor economics in rubber sector

Present status of labor absorption, potential labor absorption of the sector, impact of labor migration, socio economic aspects of Indian tamil labor and determination of optimum wage rate policies were designed under this program. A preliminary study conducted using data from 3 estates shows that the present tapping wage rate is higher than the optimum wage rate suggested by marginal value product analysis. This result indicates the low tapper productivity in these estates. However, further investigations are necesary to generalize these results (P H M U Herath).

Modelling farmer behavior at micro level

This study focuses on characterization of producers, planting patterns, age and clone distribution, actual and potential production levels, dicarding and replanting pattern of rubber, net present values and timing of replanting. Primary and secondary data gathering is in progress (P H M U Herath).

BIOMETRY

Wasana Wijesuriya

SUMMARY

Support services to the research departments including experimental design, statistical analysis and interpretation of results of experiments done by these departments were among the routine responsibilities of the Biometry section. The services also include, development of computer programs, providing assistance in effective usage of word processing and graphic software and database management. The studies carried out during the year were focused on the theme "development, modification or application of established statistical methodologies".

DETAILED REVIEW

Staff

Ms Wasana Wijesuriya completed the MPhil programme at PGIA while attending to the official duties as the Assistant Biometrician. Senior Technical Officer, Ms Nandani Wanigatunga and Technical Officer, Ms Chintha Munasinghe, were on duty throughout the year. Mr Vidura Abeywardene joined the Biometry section as a Technical Officer with effect from 3rd June, and was on duty throughout.

Seminars, Meetings and Workshops

- Ms. Wijesuriya was awarded a fellowship under Rothamsted/IRRDB programme and worked on "statistical techniques related to rubber tree and intercropping trials" in the Statistics Department of the IACR/Rothamsted, UK from 01st October to 02nd December.
- Ms Wijesuriya presented a paper on;
  "Some socio-economic factors on level of adoption in rubber small holdings: A logistic regression approach" at the 53rd Annual Sessions of SLAAS held at University of Ruhuna.

SERVICES

1. Statistical analysis and interpretation

The statistical services include designing of experiments, analysis and interpretation of results for research departments in the Institute and for University

undergraduate and postgraduate students on their specialized training. The areas covered in statistical analyses were; analysis of variance and covariance, linear and non-linear regression, applied multivariate methods, categorical and non-parametric methods and time series techniques (B W Wijesuriya and N Wanigatunga).

2. Database management

AGROMET database which has daily meteorological observations of the Dartonfield station was maintained successfully and reports were sent to the Central Meteorological Station, Colombo on a monthly basis (C Munasinghe and V Abeywardene).

INFORM database with personal, project information and budgetary involvement was updated for 1997 and data collection is in progress for the year 1998 (B W Wijesuriya and A K B Naranpanawa).

The database on available literature on statistical methods, experimental designs and sampling was updated in DBASE with authors and years and coded according to main and sub categories of discipline for easy access (C Munasinghe and V Abeywardene).

RESEARCH

The following studies were completed during 1997.

1.Modelling binary data on technology adoption in young rubber plantations of small holder sector in Sri Lanka

Data gathered from a small-holder survey, covering four rubber growing regions; Kalutara, Kegalle, Ratnapura and Colombo were employed in this study. The sample comprised of 300 immature holdings (15 divisions x 2 ranges/division x 10 holdings/range). The technologies considered in this study were recommended fertilizer levels, high yielding clones, degree of weed control and state of ground cover management.

The explanatory variables or categories involved in the study were;

a) different regions (R): Kalutara (0), Kegalle (1), Ratnapura (2) and Colombo (3),
b) type of land management (M): land-owner managed (M=0) or care-taker managed (M=1),
c) education level (E): initially taken as primary, secondary and higher but the last two categories were grouped together to form one due to lesser number of observations

in higher group. Therefore, the categories were (E=0) and (E=1) for low and medium educated groups, respectively; and

d) the income groups (I) were (i) < Rs. 3000 (ii) Rs. 3000-5000 (iii) Rs. >5000.

Logistic regression approach was employed in analysis using the procedure, Generalized Linear Models in GENSTAT. The deviance (residual chi-square statistic) was employed in assessing the model fit.

The sequence of model fitting followed a sequential approach starting from main effect models with a single explanatory variable and extended to models with 3-way interactions. The resulting changes in the deviances were used to select appropriate models. Using the fitted models, adoption curves were established for different socio-economic conditions with respect to the farmers income. A brief summary of results is given below.

Adoption of recommended fertilizer levels

The decisive factors affecting the rate of adoption of recommended fertilizer application were the type of land management and income. In owner-managed holdings, a steady increase in adoption was observed with the farmer's income. The probability of adoption increased from about 55% (in low income groups) to 70% (in middle income groups) and 85% (in high income groups). Besides, in care taker-managed holdings, the rate of adoption for fertilizer application is fairly low (<50%).

Adoption of recommended high yielding clones

The level of education was found to be the most decisive factor affecting adoption of high yielding clones. A high rate of adoption around 80% was observed when the education level is high in both management conditions. The farmer's income also seemed to play an important role in owner-managed holdings, when the education level is low. In general, in all combinations of M and E, the adoption rates were comparatively high, indicating that the farmers have considered the importance of planting high yielding clones in their holdings.

Adoption of recommended cover crop management practices and weed control measures

A similar behaviour of adoption with respect to the socio-economic conditions was observed for the technologies; cover crop management and weed control

measures. This indicated the complementary effect of cover crop management practices on weed control.

The education of the farmer seemed to be the most important factor on the adoption of both technologies. The adoption rate is comparatively low under selected socio-economic conditions for both these technologies. No significant effects were observed with respect to income when the education level is moderate (E1). The profiles of adoption in low education level were always below in the selected range of income.

This study highlighted that further in-depth research are needed to investigate the cause of low adoption rates in certain categories of socio-economic groups considered in this study, especially for the technologies; weed control and cover crop management practices. Moreover, the extension activities should aim at the technologies which showed relatively low adoption rates and socio-economic categories with low adoption rates for a better small holder sector in Sri Lankan rubber industry.

2. Analysis of repeated growth measurements in rubber

There were many reports on the yield-girth relationship of rubber. However, research on modelling girth with the ageing of tree have not been reported in great detail. Therefore, it is important to identify the behaviour of girth with age in different clones. Moreover, the behaviour of individual trees within clones is also of importance since there were evidences on different stock effects which probably create variation in tree growth. This study therefore attempted to identify the clonal and individual tree behaviour using standard model fitting techniques. Further, the study extended to provide appropriate guidelines to analysis of repeated measurement data in rubber.

Choice of Models

The following non-linear models were employed in fitting girth data of rubber.

a) Exponential Model $$Y_i = \alpha + \beta.\rho^{x_i}$$

b) Logistic Model $$Y_i = \alpha + \gamma \exp^{-\exp(\beta(x_i - \mu))}$$

c) Gompertz Model $$Y_i = \alpha + \frac{\gamma}{1 + \exp^{-\beta(x_i - \mu)}}$$

The following observations were made for different clones.

+ For the RRIC clones both Logistic and Gompertz models fit equally well, compared to the exponential model. A considerable improvement in behaviour of residuals was obtained by transforming of girth data using, $\sqrt{\text{girth}}+0.5$.

+ The Logistic and Gompertz models seemed to under estimate girths during the latter part of the age in both RRIC clones due to the observed depression in most of the trees after the commencement of tapping. The exponential model can be used with more confidence during the latter part of the age. However, it under estimate girths during early stages of growth.

+ For the other three clones *viz* RRIM 600, RRIM 623 and PB 86, the exponential model seemed to give a good fit despite of its simplicity. Logistic model failed to converge for girth data of RRIM clones. No marked improvement was observed between fits of Exponential and Gompertz. Satisfactory residual plots were obtained after the square root transformation of girth data for these clones

+ The depression in girth observed in RRIC clones caused a downward shift of the asymptote, especially in Logistic and Gompertz models. In such a situation, the use of random coefficient models would be an appropriate approach to model girth data in rubber. Preliminary studies were undertaken using individual tree girths of clone RRIC 101 to compare alternative models which can be used to analyze data on repeated measures by employing the restricted maximum likelihood (REML) procedure.

The following studies are in progress.

1. Distributional properties of indices poposed to evaluate the combine benefit of intercropping systems

The study of distributional properties is generally considered as important on statistical grounds as the statistical tests to be applied are based on certain assumptions. This study attempts to identify the distributions of the indices proposed for assesing the combined benefit of intercropping systems under immature and mature rubber holdings.

2. Variance heterogeneity modeling as a guide to analyse repeated measurement data

The objective of this study is to find an alternate method to the traditional approach of data transformation to cope up with heterogenous variability. Moreover, the use of split-plot or the compound symmetry (CS) model assuming uniform correlations among successive obseravtions makes the model, the most parsimonious but with definite lack of fit potential. On the otherhand, the unstructured variance model (UN) has best possible variance-covariance structure but with the maximum number of parameters. This study therefore attempts to seek for certain types of models between the above two which can bridge the gap between the extremes. The preliminary study on individual girth data of rubber revealed that the simple first order auto-regression model AR(1) is equally well compared to the UN model. Further studies are in progress to use this technique for different sets of data to model temporal and spatial variability using resticted maximum likelihood method.

3. Long term trends and seasonal behaviour of meteorological factors at Dartonfield

Analysis of records and preparation of a report and a poster are in progress.

LIBRARY AND PUBLICATIONS

Ramani Amaratunga and Thilaka Dantanarayana

SUMMARY

The main objective of the Library and Publications Unit is collection and dissemination of information on Natural rubber and related areas among researchers. The other functions of the section is maintaining, processing and publishing of the Institute's regular publications such as Annual Review, Journal, Bulletin, Rubber Puwath etc.

DETAILED REVIEW

Staff

Mrs Kamani Perera, Librarian & Publications Officer resigned with effect from 1st December 1997. Library Assistants & Assistant Publications Officers Mrs Thilaka Dantanarayana (Colombo Office), Mrs Ramani Amaratunga and two Library Attendants were on duty throughout the year. Dr N Yogaratnam, Deputy Director Research overlooked the functions of the section.

Seminars and Meetings

The Library Assistant & Assistant Publications Officer (Colombo Office) attended the following meetings:

* Annual General Meeting of SLSTINET on 31.01.1997 at NARESA auditorium.

* Seminar on Computerisation of National Union Catalogue (NUC) at Sri Lanka National Library Services Board, Colombo on 26.02.1997

Resource Development Activities

Book/Serial acquisition

The Library stock increased to 4898 books and the bound volumes to 3530 by the end of the year. The Colombo Library received 21 text books as new additions and the stock increased up to 1373 by the end of the year 1997.

The Library subscribed 64 journals and about 30 journals were also received as gift/exchange. RRISL is grateful to all those persons and organisations who donate documents to the RRISL Library collection.

International Photocopy Service (BLDS)

Under this service 5 articles were received for RRISL scientists.

ILL Service

48 articles were sent to various agricultural libraries at their request and vice versa 167 articles were requested for our users. Literature surveys based on *Hevea*/rubber were done using CD-ROM databases available at CARP and NARESA Libraries.

Publications

The following publications were published during the year under review.

Annual Review 1996
RRISL Bulletin Vol.35, 1997
RRISL Bulletin Vol.36, 1997
RRISL Journal Vol.79, 1997
RRISL Journal Vol.80, 1997 (in press)
Rubber Puwath Vol.19, 1996

Library Automation

Following databases were updated using CDS/ISIS package.

AGRI	-	Book Accessions from 1995
RUB	-	Journal Analytical Entries

* Library Assistant & Assistant Publications Officer (Colombo Office) prepared a bibliography on Constant Viscocity Rubber.

Information Services

Computerized bibliographic data of 1997 were sent to the National Library of Sri Lanka for compilation of the National Union Catalogue.

Content pages of the current periodicals were distributed among the users and provided photocopies of relevant articles.

AGRINET SDCP Services

Content pages of 60 Journal titles were received according to our user requirements and we also forwarded contents of 12 Journal titles to AGRINET Libraries.

DARTONFIELD GROUP

Anusha S Perera

SUMMARY

Dr A Nugawela relinquished his duties as Acting Superintendent of Dartonfield Group from 17th April, 1997 and I assumed duties on this day as Officer in Charge of Dartonfield Group.

The Dartonfield Group harvested 166527 kgs of rubber from 165.59 hectare When comparing with previous year there is an increase of 7198 kgs.

The yield per hectare was 1006 kgs per hectare which is an increase of 53 kgs above previous year. The average intake per tapper for the group is 6.5 kgs per tapper, increased by 0.5 kgs above last year. In September 1997 the tapping task was increased to 275 trees per tapper. As a result for the month of December, 1997 the group intake per tapper was recorded at 9.1 kgs. The highest crop brought in by a single tapper from a tapping task of 275 trees was 17 kgs. From 1981 clearing at Gallewatte.

The rainfall in the year 1997 was 4501.2 mm as against 3696.9 mm in the previous year.

During this season 10 hectare of re-planting was carried out.

In August, 1997 we undertook the task of upgrading and gearing the Dartonfield Group towards achieving ISO 9002 standard under the guidance of Dr L M K Tillekeratne, Director, RRISL, Dr Gamini Seneviratne, Head, Raw Rubber Process Development and Chemical Engineering Department and Mr Susantha Siriwardena, Assistant Rubber Chemist.

The Group cost of production for the season is Rs.39.74 after depreciation. Net sale average for the season is Rs.72.68, increased by Rs.2.22 above the previous season. The profit per hectare of the group is Rs.33126/-. The total profit realised is 5.48 million for the season.

DETAILED REVIEW

Staff

Mr Anusha S Perera, Officer in Charge, Mr P Kannangara, Chief Clerk, Mr K K P Gunewardena, Senior Clerk, Mrs C Dissanayake, Mr A K D A Wickramasinghe and Mrs S I K Pathirage, Junior Clerks, Mr J A Wimalasena, Mr S K S de Silva, Mr T Somaratne and Mr N L D Reggie, Field Officers, Mr J K

Nakandala, Mr K A Sarath Kumara, Mr B M Siriwardena and Mr N L D Nihal, Junior Assistant Field Officers, Mr D S K Ranaweera, Rubber Factory Officer, Mr W D D Senanayake, Assistant Factory Officer, Mrs C S Hettiarachchi, Creche Attendent and Mr A K Piyasene, Office Peon were on duty.

Mr N V Premawansa daily paid Tractor Driver was appointed as a monthly paid Staff with effect from 01st February 1997.

Dr A Nugawela relinguish his duties as Officer in Charge with effect from 17th April 1997.

Mr Anusha S Perera was appointed as Officer in Charge with effect from 17th April 1997.

The Group Cadre stood at 21 at the end of the year, made as follows:

Senior Staff	1
Assistant Staff	18
Minor Staff	2
Total	21

Hectarage

A summary of the hectarage is given in Table 1.

Table 1. *Land distribution (Ha.) in Dartonfield Group*

	Dartonfield	Gallewatte	Nivitigalakele	Total
Mature area	23.06	105.05	37.48	165.59
Immature area	15.96	57.39	4.04	77.39
Budwood nurseries	6.54		2	8.54
Seedling nurseries	0.73		5.69	6.42
Uprooting area		4.51	7.36	1187
Abandoned 53/54			3.06	306
State land taken	0.27			0.27
Paddy/Deniya		1.22	1.22	1.22
Waste land	0.19	0.18		0.37
Earth slipped area	3.01	1.26	2.62	6.89
Jungles	0.8		0.71	1.51
Rocks/Streams	2.14	2.81	2.17	7.12
Buildings	18.67	5.07	7.79	31.53
Roads	2.92	6.86	0.32	10.1
Others total	35.27	21.91	31.72	88.9
Grand total hectare	74.29	184.35	73.24	331.88
Grand total acres	183.57	455.53	180.98	820.08

Crop

A total crop of 166527 kg was harvested from extent of 165.59 during the year. When comparing with the actual last season (1996) there is an increase of 7198 kgs 1996 had a revenue hectarge of 167.11 hectare.

Yield per hectare

The yield per hectare of the past 5 years given in Table 2 for the entire group and separately for each division.

Table 2. *The yield per hectare (YPH Kg) at Dartonfield Group from 1993 to 1997*

Division	Year				
	1993	1994	1995	1996	1997
Dartonfield	605	1037	714	900	1059
Gallewatta	791	1077	1039	1073	1067
Nivitigalakele	841	876	804	723	800
Group average	794	939	912	953	1006
Group estimate	883	884	887	1020	1038

Table 3. *The yield per hectare (YPH Kg) recorded during each month in 1997 in different divisions*

Month	Dartonfield	Gallewatta	Nivitigalakele
January	88	118	89
February	56	83	54
March	77	93	63
April	70	65	34
May	57	39	24
June	83	92	53
July	71	51	36
August	183	114	80
September	79	71	52
October	125	75	86
November	110	120	78
December	117	150	101

Intake per tapper

Table 4. *The average intake per tapper (kg) division wise for the last 5 years*

Division	Year				
	1993	1994	1995	1996	1997
Dartonfield	6.96	6.96	7	6.5	6.9
Gallewatta	6.06	6.35	6.7	6.2	7
Nivitigalakeke	5.67	5.78	5.4	4.5	4.9
Group average	4.9	5.97	6.21	6.2	6.5

The intake per tapper has increased gradually in all 3 divisions.

Re-blocking was carried out in order to increase the tapping task from 250 to 275 trees per tapping block. The new tapping task was introduced in September, 1997. As a result the group intakes for the months of September, October, November and December increased in the following manner.

Month	1995	1996	1997
September	6.7	5.5	7.7
October	7.1	6.1	7.7
November	7.7	7.1	9.4
December	8	7.5	9.1

Tapping cost

Table 5. *A break-down in total tapping cost for 3 years*

Cost item	Cost (Rs.)		
	1995	1996	1997
Tapping	14.36	16.9	16.32
Double tapping	0.2	-	0.28
Kanganies	0.13	0.12	0.05
Over kilos	1.17	1.12	0.92
Scrap pay	0.28	0.32	0.29
Incentive to Field Staff	0.09	0.1	0.07
Total	16.23	18.56	17.93

The Tapping cost has decreased by -/63 cents per kg than last year.

Rain fall

Table 6. *Annual rainfall and the number of wet days for the last five years*

	Year				
	1993	1994	1995	1996	1997
Rainfall (m.m.)	4391.9	3884.7	4369.5	3696.9	4501.2
Wet days	192	185	185	165	164

Table 7. *The number of tapping days, relative tapping intensity, average intake per tapper and yield per hectare for the last four years in Dartonfield Group*

		Year			
		1994	1995	1996	1997
1.	Tapping days				
1.1	Normal	214	205	238	256
1.2	Late	57	54	49	29
1.3	Double	9	8		5
1.4	No	94	106	78	80
2.	Average intake tapper (Kg)	6.21	6.2	6	6.5
3.	YPH (Kg)	939	912	953	1006

Manufacture

Table 8. *The details of the crop manufactured during the year 1997*

Grade	Quantity Kgs.	Grade %	Lates %	Scrap
Crepe No.1	142097	85.3	94.2	
Crepe No.2	500	0.3	0.3	
Crepe No.3	8310	5	5.5	
Scrap Crepe No.1	11298	6.8		72.3
Scrap Crepe No.2	3976	2.4		25.5
Scrap Crepe No.3	346	0.2		2.2

The grade percentage in the above table are due to manufacture of unfractioned unbleached rubber throughout the season except in December where we had to manufacture crepe rubber due to lack of unfractioned unbleached orders during December.

ISO 9002[1]

In August, 1997 we undertook the task of upgrading the Dartonfield Rubber Factory according to the ISO 9002 standards, under the guidance of Dr L M K Tillekeratne, Director, RRISL and RRPD & CE Department. In order to achieve this standard, we are in the process of attending to the required machinery repairs upgrading the effiency of the drying tower, repairing and painting the factory building, providing the factory with protective lighting, upgrading and demarcating of the milling and packing sections according to the ISO requirement.

Inaddition to the above, we have introduced a new documentation and production monitering systems.

These are in accordance with the quality manual and the procedure manual which lays down the required standards for ISO 9002 certification.

Table 9. *Labour rate (LR,RS) and a break down of cost of production (COP)*

		* 1993	* 1994	***1995	*1996	***1997
1.	Labour	72.24	72.24	72.24	83	83
2.	COP	35.15	33.45	36.6	38.72	39.74
2.1	Tapping	13.91	14.76	16.23	18.56	17.93
2.2	Manufacture	8.76	7.32	6.47	6.15	5.38
2.3	General charges	6.57	7.34	9.17	9.09	12.75
2.4	Upkeep	5.35	4.03	4.03	4.92	5.28
3.	NSA	39.01	55.22	80.73	70.49	72.68
4.	Profit	3.86	21.77	44.73	31.77	32.94

* Accounts computed without depreciation
*** Accounts computerd with depreciation

[1]ISO 9002 Quality System Certificate has now been awarded to the Dartonfield Rubber Factory (June, 1998)

Table 10. *Comparative statement of the mature extent, profit per kg and profit per hectare*

	Year			
	1994	1995	1996	1997
Mature extent	144.42	167.11	167.11	165.59
Total profit (Rs.Mn.)	3.2	6.84	5.06	5.48
Profit/Ha (Rs.)	22031.69*	40957.59***	302979.5*	33126.4***

Profit per kg and profit per hectare has increased remarkebly in the year 1997.

* Profit without depreciation

*** Profit with depreciation

Meteorological Summary - 1997
Dartonfield Station

Wasana Wijesuriya

A total of 4040 mm of rain experienced during the year 1997 compared to the long-term average of 4243mm. The highest rainfall observed in September coincided with the second inter-monsoonal period (IM2). The lowest value was experienced in January. The rainfall exceeded the 75% expected value in May, July, September and December. A fairly dry weather was observed until April.

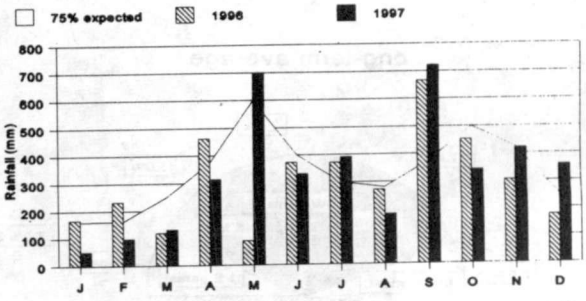


Fig 1. Monthly variation in rainfall

A comparison of weekly rainfall in 1997 together with 75% expected value and long term average are given in the following figure. A fairly dry weather was observed during January to April with 7 dry weeks. Number of rainy days equaled 209 during this year.

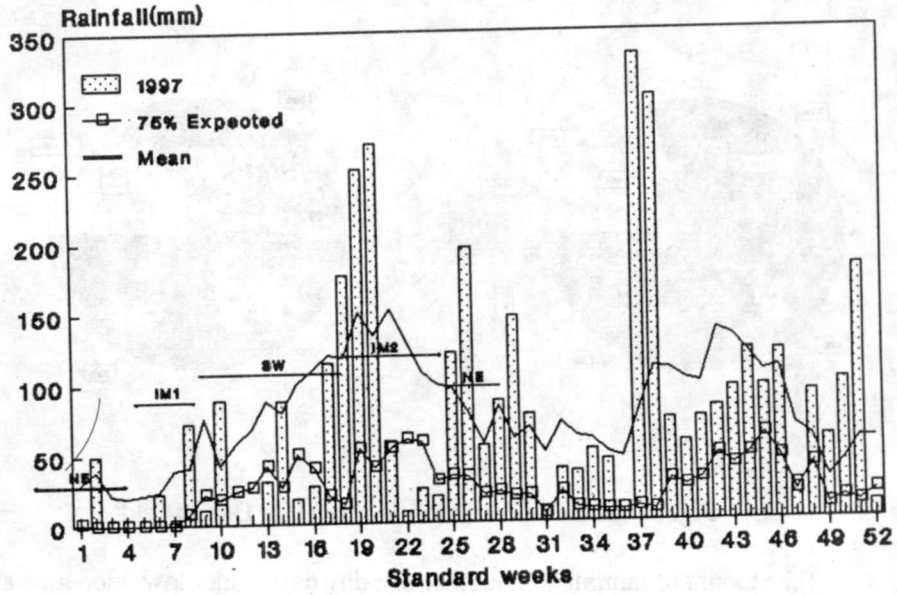


Fig. 2. Weekly variation in rainfall

The rainfall distribution in different seasons also exhibit slight deviations from the long-term average. Respective decreases of 1% and 2% in North-East and IM1 rains and an increase of 5% in IM2 rains were observed during 1997. In general, a greater proportion of rains (51%) have been experienced during inter-monsoonal seasons. These observations are presented in the following figures accompanied with the long-term averages.

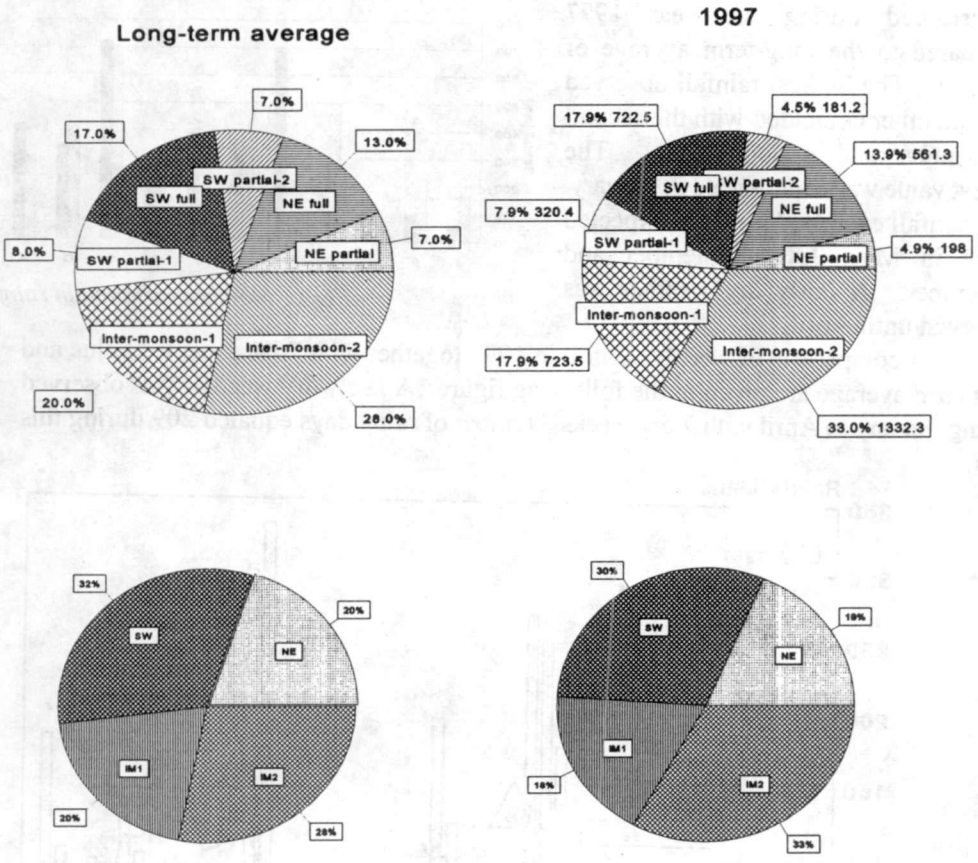


Fig. 3. Seasonal variation in rainfall at Dartonfield

The amount of rainfall and number of rainy days under low, moderate and high rainfall categories are listed in Table 1. Table 2 depicts the monthly values of some important meteorological observations together with averages for 1980 to 1992. The soil temperatures at four different depths are given in Table 3.

Table 1. *Monthly variation of rainfall and rainy days in 1997*

Month	Rainfall (mm)	Average** (mm)	No. of rainy days*	Avg.** days	No. of days under each category		
					0.3 - 2.5 (mm)	2.5 - 50 (mm)	>50 (mm)
January	50.2	(121)	03	(10)	01	02	00
February	98.2	(116)	06	(09)	03	02	01
March	130.3	(252)	08	(17)	00	07	01
April	313.9	(449)	17	(21)	02	14	01
May	699.7	(629)	22	(24)	03	14	05
June	331.4	(440)	16	(24)	02	12	02
July	391.1	(299)	26	(22)	07	18	01
August	181.2	(257)	23	(21)	09	14	00
September	722.4	(391)	22	(22)	04	13	05
October	342.3	(476)	26	(22)	04	22	00
November	420.0	(448)	21	(20)	03	18	00
December	358.7	(282)	19	(17)	03	13	03
Total	4039.4	(4160)	209	(229)	41	149	19

* Rainy days are defined as those with 0.3 mm or more ** Average values for 1980-1992 are shown in parentheses

Table 2. *Variation of observed meteorological factors at Dartonfield*

DARTONFIELD (Latitude 6°32': Longitude 80.09 E: Altitude 65.50 m)

Month	Temperature (°c)				Relative Humidity (%)			Wind speed
	Mean Max	Mean Min	Mean	No. of days min temp <20	8.30 am	No. of days RH 8.30>90%	3.30 pm	Mean (kmph^{-1})
Jan	33.8 (32.3)	19.5 (20.8)	26.7 (26.5)	18	85 (87)	06	57 (67)	1.9
Feb	33.8 (33.3)	20.3 (21.1)	27.1 (27.2)	11	84 (85)	06	61 (64)	1.9
Mar	33.9 (33.5)	21.0 (21.7)	27.5 (27.6)	09	85 (84)	01	61 (66)	1.8
Apr	33.6 (32.9)	21.9 (27.8)	27.8 (27.8)	-	83 (84)	04	66 (73)	1.6
May	32.2 (31.6)	22.8 (23.3)	27.5 (27.5)	-	88 (87)	12	77 (77)	1.3
Jun	32.0 (30.8)	23.1 (23.1)	27.6 (26.9)	-	87 (88)	11	72 (76)	1.4
Jul	30.9 (30.2)	23.7 (22.8)	27.3 (26.5)	-	90 (88)	16	77 (74)	1.3
Aug	31.4 (30.2)	23.2 (22.7)	27.3 (26.5)	-	88 (87)	14	73 (74)	2.1
Sep	31.2 (30.6)	22.6 (22.4)	26.9 (26.5)	-	87 (86)	12	77 (74)	1.5
Oct	32.4 (30.9)	22.4 (22.1)	27.4 (26.5)	-	84 (85)	02	82 (77)	1.1
Nov	32.3 (31.4)	22.3 (21.8)	27.3 (26.6)	-	83 (84)	05	79 (77)	1.5
Dec	33.0 (32.0)	22.2 (21.4)	27.6 (26.7)	-	83 (84)	07	74 (74)	1.2

** Average values for 1980-1992 are shown in parentheses

Table 3. *Soil temperatures recorded at different depths at Dartonfield - 1997*

Month	09.00hrs				16.00 hrs			
	5 cm	10 cm	20 cm	30 cm	5 cm	10 cm	20 cm	30 cm
January	27.6	27.1	28.3	28.7	36.1	32.9	30.1	28.8
February	28.4	27.6	28.7	29.2	37.1	34.0	30.8	29.2
March	29.3	28.4	29.4	29.8	37.4	34.7	31.6	29.9
April	29.5	28.6	29.5	29.8	36.5	34.2	31.3	30.0
May	28.4	27.6	28.2	28.5	33.2	31.7	29.8	28.7
June	28.7	28.1	29.0	29.1	35.0	32.4	30.4	29.2
July	27.9	27.5	28.0	28.2	32.4	30.8	29.4	28.6
August	28.7	28.1	28.8	29.0	33.9	32.2	30.4	29.4
September	28.1	27.4	28.1	28.3	33.3	32.0	30.0	28.5
October	28.9	27.6	28.2	28.4	32.4	31.6	30.1	28.8
November	28.2	27.2	27.8	28.2	32.0	30.9	29.5	28.5
December	27.9	27.2	27.9	28.2	32.5	31.4	29.6	28.6

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