



ANNUAL REVIEW 1996

RUBBER RESEARCH INSTITUTE OF SRI LANKA



Cover photographs :

Proven effluent treatment techniques for factory wastes, developed
by the R.R.I.S.L.

Photographed by : Wimal Amaratunge

Rubber Research Institute of Sri Lanka

Annual Review - 1996
1st January 1996 to 31st December 1996

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Assistant Field Officer

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** On no pay leave overseas

RUBBER RESEARCH INSTITUTE OF SRI LANKA

DIRECTOR'S REVIEW

L M K Tillekeratne

The favorable weather conditions that prevailed in the first half of the year were conducive in sustaining a high level of rubber production during this year. The total rubber production in 1996 is expected to be over 110,000 metric tons. The growth of the rubber sector can be regarded as a vital plus factor to the growth of the Sri Lankan economy considering the severe draw back experienced in the industrial sector due to power cuts. Fortunately, the rubber processing sector is not much affected due to power cuts unlike in the tea sector. The power is needed for rubber processing mainly in the milling stage of the coagulum. Hence, the rubber factory officers were able to arrange their milling times accordingly thereby minimizing the impact of power interruption.

Rainguards

Some of the large rubber plantations as well as smallholder's used rain guards in their plantations to minimize rain interruption on harvesting. The experiments carried out on commercial scale in Dartonfield Estate of the Rubber Research Institute have shown very attractive results. For instance, the rain guard sealant mixed and made by the ordinary sundry labourers were of extremely high quality. ~~There was~~ **Not** even a single case of bark infection caused by leaking rain guards have been reported in the whole of Dartonfield Estate. The total number of tapping days in Dartonfield Division (with rain guards) was 327 whereas in the adjoining Divisions of Nivitigalakele and Gallewatta which had not been used rain guards have reported only 290 and 284 tapping days respectively due to the interference of rain.

Problems faced by the clones RRIC 110

The Clone RRIC 110 which falls into the Group II of the Clones recommendation list was permitted to be planted up to a maximum of 10 ha. in estates. This particular clone was severely attacked by *Corynespora* leaf disease and *Gloesporium* leaf diseases in certain micro climatic locations where the moisture levels were very high. However, the same clone planted in dry and hilly parts of the same estate performed extremely well and some times even slightly better than any other RRIC 100 series clones. Nevertheless, a decision was taken at the Ministry

level to condemn this clone and remove it completely from the Group II of the clone recommendation list. It was also observed that some of the smallholder's too in Kegalle District had planted this clone which was generally recommended for large plantations. Hence, action was taken by the Ministry of Plantation Industries to uproot and destroy all disease affected RRIC 110 clone trees to overcome this problem.

Action will be taken by the middle of 1997 to promote 3 clones viz. PB 235, RRIC 117 and RRIC 130 to fill the vacancy created by withdrawing RRIC 110 from group II, once the yield data analysis of the 3 clones are completed. Even PB 260, which is a good latex yielding clone will also be considered for promotion to group II if the resistance of the same to *Corynespora* leaf disease as reported from other rubber producing countries is good.

Tapper shortage

This problem of tapper shortage was very acute even during this year. The Rubber Development Department jointly with the Rubber Research Institute conducted training classes at the village level to train a large number of tappers. Yet, it was observed that most of the people who completed the training program successfully were more keen in finding some other jobs rather than working as tappers. Some of the sociologists felt that the main reason for village youths not to engage in this profession is due to dignity of labour. Hence, even the name "Tapper" was changed to "Exploitation Technician". Aprons were given to wear while tapping is being done.

The s/2, d/3 tapping system was implemented in the plantation sector to minimize this problem of tapper shortage. It was also observed that in most small and medium level private rubber holdings tapping was done on crop sharing basis and hence the income levels of tappers are much better now in such areas. It is expected that the wage rate for tappers will further increase with the increase in demand for raw rubber in both local and world markets and hence this problem of tappers shortage will also be solved accordingly.

Effluent treatment

The cost effective anaerobic/aerobic effluent treatment system developed by the RRI Scientists has now been fully accepted by the Central Environmental Authority and is implemented in many rubber factories in the country. After calling for tenders, the implementation of this process was offered to M/s. Puritas Ltd.

Rubber prices

In general, the rubber prices continued to prevail at attractive levels during this year. Yet, there was a slight depression shown in the market towards the last quarter of the year. The average price paid for crepe rubber in 1996 was around Rs. 75/- per Kg. It is believed that the prices will improve for all grades of natural rubber at least upto year 2000 with slight fluctuation shown occasionally.

Centrifuged latex production

Centrifuged latex production during the year, increased to over 20,000 MT mark from the 46 centrifuging machines already installed in the country. Almost the entire quantity of this concentrated latex was consumed by the latex based products manufacturers. It is believed that the production of centrifuged latex in 1997 will be even more in order to cater to the fast growing dipped products industry in the country.

The consumption of dry rubber by the rubber based industries in the country has also increased vastly during this year and with the effort taken by the Ministry of Industrial Development to promote rubber based industries in the country, the day we will consume more rubber internally than what is exported in raw form, is not very far away.

Rubberwood industry

While taking every effort to improve the quality of planting material given, action was also taken to promote the rubberwood based industries in the country. This will improve the economic viability of rubber plantations by generating a realistic price for the old uprooted trees at the time of replanting. With the gradual development of the rubberwood based down-stream industries the income from selling of old trees alone will become sufficient to cover the cost of replanting.

IRRDB Meeting and Symposium

The 25th Meeting of the International Rubber Research and Development Board was held in Hotel Eden, Beruwala from 5th to 8th of November 1996 with the participation of members of 14 out of 15 member countries. This meeting was inaugurated by the Hon. Minister of Public Administration, Home Affairs, Plantation Industries and Parliamentary Affairs. All the key figures of the IRRDB including its Chairman Tan Sri Dato Dr Othmann, Secretary Dr P W Allen, Director MRPRI Dr C S L Baker, Director RRI Malaysia Tan Sri Abdul Aziz, Director RRI India Dr

M R Sethuraj, Director RRI Thailand Mr Charuck Boonsrirat, Director RRI Indonesia Dr Asril Darussamin, Director CIRAD Dr H D Livonnire, Deputy Chairman IRRDB Mr Jean Campagnolle and the Directors and Scientists of all other Natural Rubber Producing Countries were present at this meeting. Nearly, 50 research papers covering wide range of fields such as agronomy, farming systems and rubber technology were presented at this symposium held on the first 2 days of the conference. Approximately 250 Sri Lankan planters and policy makers in the plantation sector, also participated at this Conference. Another special feature of the meeting held in Sri Lanka was that the Chairman, IRRDB Tan Sri Dato Dr. Othmann, made his first appearance as the Chairman, while Dr P W Allen who served the IRRDB in the capacity of Secretary for one and a half decades relinquished his duties.

Research

In studies on plant molecular biology, the REF gene and some repetitive DNA sequences were identified as polymorphic DNA probes in detecting genetic differences of rubber clones.

Green budwood if sterilized and kept in low temperature maintains the grafting success rate for about a week. Healthy 1 - 2 year old clearings could be crown budded successfully in case of a disease out-break. Use of healthy budwood and early germinators is essential for raising quality young budding plants. Among the various planting materials recommended, young buddings are superior in establishment and growth. Opening at lower girth results in poor yields. Girthing after commencement of tapping is influenced by the clone and the girth at opening. Among the low frequency tapping systems tested, $\frac{1}{2}$ S d/3 + E(4/y) performed best. Increasing the number of stimulations per annum, in $\frac{1}{2}$ S d/3 tapping, will not give a corresponding yield increase. Incidence of TPD is significantly influenced by the clone and stimulation.

In high density trials, girthing is not affected even after four years growth. The cost of the rainguard could be significantly reduced by fixing it horizontally on the trunk. Different spatial arrangements tested to facilitate intercropping have not adversely affected the growth of rubber. Planting timber species and cocoa with rubber does not influence the growth of rubber. It appears that in Moneragala and Bibile districts rubber could be intercropped with sugarcane successfully.

Residual effect of mulching with rice straw on latex production was seen in the virgin panel BO - 2. It may be possible to obtain higher growth and early tappareability with increased level of potassium in comparatively drier areas, under field condition. *Flemingia congesta*, *Crotalaria anagyroides* and *Tephrosia vogellie* 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, although the growth rate of *Flemingia congesta* during the early stages appears to be slow. It was also observed that the first lopping of *Crotalaria anagyroides* may be done 4 months after planting and it may be possible to do 2 - 3 loppings during the 1st six years when climatic conditions are favourable. A creeping type of legume, *Mucuna bracteata*, appears to take about 6 months to establish fully in Kalutara District.

It was decided to recommend the use of Eppawela Rock Phosphate as the source of phosphate either during the 5th and 6th year of the immature phase or during the last 02 years of the immature phase which ever is later.

For young budding, application of fertilizers in liquid form has been found to be more effective than applying fertilizer in granule form. It was also found that this liquid formulation could be applied at fortnightly intervals. However, when the application frequency is reduced further to monthly application, the incidence of die back of scion shoots was significantly higher.

The soil and foliar survey programme provided data for fertilizer recommendations for 12,600 hectares in the estate sector. The soils and foliar survey programme was extended to the smallholder sector also covering more than 750 holdings in the Horana Division and fertilizer recommendations were sent for the years 1997, 1998 and 1999 to these smallholdings.

Systemic fungicide, Anvil was found to be effective against white root disease caused by *Rigidoporus lignosus*. At the same time, trials were conducted to develop a biological control method to reduce the incidence of white root disease using *Trichoderma spp.*

Studies on enzyme production by *C. quinqueseptatum* showed that pectic enzymes play a minimal role in disease development while cellulolytic enzymes probably play a nutritive role.

Arrangements were made to establish potential clones from Rubber Research Institute of Sri Lanka 200 series for screening purposes at eight localities representing all rubber growing agroclimatic zones. Observations of three consecutive years showed that the clones RRIC 130, RRIC 119, RRIC 133, RRIC 110, RRIC 112, RRIC 114, PB 86, RRIC 117, RRIM600 and RRIC 132 are highly susceptible to bark rot caused by *Phytophthora sp.* Whereas clones: BPM 24, RRIM 717, RRIC 116, PB 260, RRIC 121 and RRIC 100 are resistant to the same disease.

Culture characteristics and reproductive morphology of the *Hevea* isolate of *Natrassia mangiferae* were established. The fungus *Colletotrichum acutatum* was also shown to be the main cause of *Colletotrichum* leaf disease on rubber in Sri Lanka.

A suitable formulation for wood filling was developed for possible commercialization. Briquettes were prepared using waste material such as saw dust, coir dust and non toxic binders. These briquettes are to be used in drying of tea

leaves in place of fire wood in the factories. Epoxidised Natural Rubber (ENR) was used in the preparation of adhesives and these showed good bonding in rubber to cotton adhesion in the shoe industry. A new self-adhesive type latex based rainguard (sticker) was developed. Work on preparation of Constant Viscosity rubber by the latex method was also continued. Positex and high viscous Bitumen emulsion were blended in different ratios to obtain a smooth finish as a water proofing paint. Samples with good surface finish and low drying time were sent for evaluation. A latex based formulation for the manufacture of biodegradable shopping bags was developed.

A road trial with a latex/bitumen emulsion prepared by using a positex modified with a colloidal stabiliser was successfully completed. Irradiated latex films with improved technological properties were produced after proper calibration of the radiation source. Room temperature curing NR latex compound, suitable for coating of coir mattings, was developed. There seem to be a big market for these coir mattings in Japan. Two latex compounds suitable for carpet under linings, a few latex foam compounds suitable for making latex foam masks, two latex casting compounds suitable for making ornamental coir brushes and a dry rubber based compound ideal for the manufacture of feet of artificial limbs, were also developed.

Effluent treatment plant based on anaerobic/aerobic treatment principle installed at Dartonfield to treat the raw rubber processing waste water generating from the factory has already proven its success and cost effectiveness to treat rubber factory waste water. Organic removal in the region of 80-90% could easily be achieved from the anaerobic stage with nearly two days retention. Remaining 10 to 15 organics are removed from the aerobic process using a efficient fine bubble aeration mechanism. As a result of high rate anaerobic digestion, cost involved in the aeration process is drastically reduced.

A low cost solar assisted green house type dryer has been fabricated for drying of RSS and Air Dried Sheets (ADS). Preliminary studies reveal that there is no significant impact on the physical properties of the rubber dried in the drying chamber.

OVERSEAS VISITORS

Mr & Mrs Michael Lane, UK
Mr K J Mathew Ias, India
Dr A F S Budiman, Indonesia
Mr Somporn Krisanasap, Thailand
Miss Wipa Sawettaganit, Thailand
Miss Pakwimon Vardhanabbuti, Thailand
Dr Ramli Othman, Malaysia

Ms Lucy Palm. Holland
Ms Kastina van Dingen. Holland
Mr K M Lih. MAITA
Mr H P Berger. Hamberg
Mr Levan Binh. Vietnam
Mr Mai Van Son. Vietnam
Mr Lal Van Lam. Vietnam
Dr C S L Baker. England
Dr P W Allen. England
Dr M R Sethuraj. India
Dr Ayoola B Fasina. Nigeria
Dr ABD Aziz S A Kadir. Malaysia
Prof. Chen Quibo. China
Dr C Ratanawahara. Thailand
Dr S Somnark. Thailand
Dr Chairil Anwoor. Indonesia
Dr Ahmad Faiz. Malaysia
Dr Asril Darussumin. Indonesia
Dr Keli Z Jules. Ivory Coast
Dr Eric Pemci. Ivory Coast
Dr S S Beure. France
Mr Chen Ying. China
Mr Pongthep Kajornchaiyakul. Thailand
Mr Prawit Wongsukon. Thailand
Mr Wathana Panmanee. Thailand
Mr Jean Chmpaignolle. UK
Mr Mokoko Simon. Cameroon
Mr Ramie Eschabach. France
Mr N Tin Hue. Vietnam
Mr Charuck Boonsrirat. Thailand

GENETICS AND PLANT BREEDING

D P S T G Attanayaka

SUMMARY

The CARP funded molecular biology project was completed in this year. The REF gene and some repetitive DNA sequences were identified as polymorphic DNA probes in detecting genetic differences of rubber clones. RRIC 110 which was found to be susceptible for *Corynespora* leaf disease was removed from the clone recommendation. Nine new trials were established to evaluate RRISL 200 series clones.

DETAILED REVIEW

Staff

Head of the Department, Dr N E M Jayasekera, resigned from the institute with effect from 30 November 1996. Dr D P S T G Attanayake, Geneticist and Plant Breeder, Mrs S Herath, Assistant Geneticist and Plant Breeder, Mr K B Karunasekera, Development Officer, Mr K W Rупatunga, Experimental Officer, Mr B M S G Peries, Senior Experimental Assistant, Messrs I D M J Sarath Kumara and R A S K Ranatuge Technical Officers were on duty throughout the year.

Meetings

Head of the Department and Dr D P S T G Attanayaka attended the scientific committee meetings.

Dr D P S T G Attanayaka attended the Biotechnology working group meeting organized by CRI.

Workshops Seminars and Conferences

Research and the technical staff of the department attended the IRRDB conference held on 5th-7th, November 1996.

Dr D P S T G Attanayaka spoke on

"Molecular cloning nucleotide sequencing and characterization of Rubber Elongation Factor gene from *Hevea brasiliensis*" at the research colloquium held at IFS Kandy.

"Application of DNA technology on the improvement of Rubber tree" at the seminar on Agricultural Biotechnology in Sri Lanka organized by NARESA.

Research students/training

Miss C P Gunasekara and Miss V N Amarasekara, undergraduate students from the University of Peradeniya, completed their final year research projects on "Partial characterization of repetitive DNA sequences from *Hevea brasiliensis*" and "Investigation on the expression of rubber elongation factor gene from *Hevea brasiliensis*" under the joint supervision of Dr D P S T G Attanayaka and Prof. Eric H Karunanayake of the Colombo Medical faculty.

Head of the Department and Dr Attanayaka served as lecturers for the Diploma course conducted by the NIPM.

LABORATORY INVESTIGATIONS

Molecular biology of *Hevea* (CARP Project 12/192/165)

The research activities under the CARP funded project on *Hevea* molecular biology were concluded in the month of December.

In the course of this work

Methods for extraction of nucleic acid from the rubber tree including RNA from rubber latex were developed.

A representative gene library of the rubber tree was constructed.

The REF gene was identified as sufficiently polymorphic in identifying high yielding RRIC 100 series clones by having more copies of the gene.

A part of the gene library was used to isolate about 100 repeated sequences of *Hevea* and these sequences were grouped into four different classes. Among the group III clones investigated, clones 151, 42-3 and 2-3 were identified as polymorphic clones for genetic differentiation of rubber clones. Analysis of the mRNA levels of the REF gene showed a tissue specific expression pattern. The level of REF gene expression was about 100 fold higher in the laticifers than in leaves. Also the level of expression was varied among the rubber clones showing significant abundance of REF transcripts in the high yielding clone RRIC 121 (D P S T G Attanayaka, S Herath and E H Karunanayake).

FIELD EXPERIMENTS

Hand pollination programme for 1996 (GPB/BST/HP/96/2)

This year the hand pollination programme was carried out at Dartonfield Group. The crosses attempted, the number of pollinations done in each cross, number of pods harvested and seedlings obtained in each cross are given in Table 1 (N E M Jayasekera and K B Karunasekera).

Table 1. *Details of 1996 hand pollination programme*

Cross	No. of pollinations	No. of pods harvested	No. of seedlings
RRIC 121 x GPS 1	774	20	58
RRIC 100 x PB 260	145	05	08

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 registered the highest girth also. With respect to girth RRISL 201 continued to register the highest girth among promising genotypes (N E M Jayasekera, 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)
74-12 (RRISL 200)	66.3	82.0
74-41 (RRISL 201)	66.5	86.0
74-135 (RRISL 202)	71.8	83.0
74-193 (RRISL 203)	47.3	67.0
74-139	42.3	62.0
74-180	37.0	66.0
74-205	54.4	71.0
RRIC 121 (control)	96.6	91.0

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

Only two test tappings were carried out. Average yield of two RRISL clones, 205 and 204 recorded 53.6 and 40.8 (g/t/t) respectively.

With respect to girth RRISL 205 had a mean girth of 97.05 cm while RRISL 204 recorded a mean girth of 77.03 cm.

The control clone RRIC 121 yielded 38.4 (g/t/t) and its mean girth was 82.0 cm (N E M Jayasekera and I D M J Sarathkumara).

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

In this trial, 10 selected clones, including the three control clones (RRIC 100, RRIC 102 and RRIC 121) are tested. Table 3 summarizes the results of the analysis of variance for girth and yield data collected from this trial.

Table 3. Analysis of variance of girth and yield data. (GPB/BST/HPS/76/1)

	Girth			Yield		
	DF	MS	P	DF	MS	P
Clone	10	196.67	***	10	118.48	*
Block	3	90.42	*	3	382.84	*
Error	26	21.89			95.36	

< Probability level

*** = < 0.001

* = 0.01-0.05

Highly significant differences between clones for girth were detected.

Duncan's Multiple Range Test (DMRT) was done on data collected for both traits. With respect to girth, DMRT grouped 11 clones into 4 groups.

DMRT analysis of yield data produced only two groups with considerable overlapping (N E M Jayasekera and K W Rupatunge).

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

Average yield over previous 09 years, 1996 average yield and mean girth (1996) of this seedling population are given in Table 4.

Table 4. *Average yield of previous 9 years, including 1996 average yield and girth (GPB/BST/HPS/79/1)*

Clone	Average Yield Previous years g/t/t	Average Yield 1996 g/t/t	Mean Girth cm
79-347(RRISL 207)	48.79	88.33	87.50
79-457	58.98	38.66	72.50
79-42	59.99	65.50	79.00
79-337	49.32	38.25	72.00
79-292	56.03	47.50	74.50
79-293	49.14	17.66	61.00
79-458	33.28	31.16	80.00
79-145	36.11	44.66	73.50
79-466 (RRISL 209)	39.56	54.66	80.50
79-255	32.27	19.16	72.50
79-269	24.93	42.80	66.00
79-341	28.70	33.16	87.50

(N E M Jayasekera and I D M J Sarathkumara)

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

Average yield over previous 06 years, 1996 average yield and mean girth (1996) of this seedling population are given in Table 5.

Table 5. *Average yield of previous 6 years, including 1996 average yield and girth*

Clone	Average Yield for Previous 6 years (g/t/t)	Average Yield for 1996 (g/t/t)	Mean Girth 1996 cm
RRISL 212	63.89	40.25	83.00
RRISL 213	61.62	45.50	85.50
RRISL 214	57.34	20.12	73.50
RRISL 215	71.39	55.75	106.00
RRISL 216	68.10	33.25	84.00

(N E M Jayasekera and I D M J Sarathkumara)

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

This progeny too has mother plants of some clones registered under RRISL 200 series. Mean girth for 1996, mean yield of first six years (including 1996) and 1996 mean yield are given in Table 6. RRISL 200 series clone numbers are given in parenthesis.

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

Clone	Mean yield first 6 years g/t/t	Mean yield 1996 g/t/t	Mean girth cm
81-8 (RRISL 217)	63.87	51.92	82.00
81-50 (RRISL 219)	81.73	61.50	77.00
81-192 (RRISL 222)	68.03	93.28	82.00
81-65 (RRISL 226)	92.08	60.90	91.00
81-203 (RRISL 227)	93.67	33.14	84.00
81-111 (RRISL 220)	82.29	61.21	90.00
81-207 (RRISL 224)	78.71	51.57	76.00
81-30 (RRISL 218)	81.00	32.50	97.00
81-178 (RRISL 221)	76.90	32.35	85.50
81-69	88.63	106.07	89.50
81-197	85.43	51.07	99.50

(N E M Jayasekera, I D M J Sarathkumara and K B Karunasekera).

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

Analysis of girth data based on plot means collected from 66 clones, including 5 control clones *viz.* RRIC 100, RRIC 102, RRIC 110, RRIC 121 and RRIC 600 indicated significant differences between clones (Table 7)

Table 7. *Analysis of girth data of 1982 H.P. selections - Clyde Estate (GPB/BST/HPS/82/2)*

Source	D.F.	MS	P
Clones	65	217.96	***
Blocks	3	10.53	NS
Error	191		

Probability - P
 <0.001 = ***
 NS = Not Significant

DMRT grouped the 66 clones into 14 groups with considerable over lapping. Clones in group A and their over lappings with other groups are given in Table 8.

Table 8. *Clones in group A and over lapping groups according to DMRT. (GPB/BST/HPS/82/2)*

Clone	Mean girth cm	Group
82-163	71.86	A
82-51	69.68	AB
82-110	69.22	ABC
82-43	69.01	ABCD
82-132	68.85	A BCD
82-140	67.81	A BCDE
82-54	67.67	A B CDE
RRIC 102	66.45	A B C DEF
82-152	66.02	A B C D EFG

LSD for 5% level = 5.29

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

In this field experiment, 55 clones including five control clones (RRIC 100, RRIC 102, RRIC 110, RRIC 121 and BPM 24) are tested. Test tapping of these clones were started in this year. The results of the analysis of variance on girth data are presented in Table 9. Highly significant differences between clones were detected.

Table 9. *The analysis of variance results of girth data*

Source	D.F.	M.S.	P
Clones	54	563.82	***
Blocks	3	459.78	***
Error	825		

P = probability
<0.001 = ***

DMRT produced 19 groups with considerable over lapping. The 10 clones with highest mean girth and their DMRT grouping are given in Table 10 (N E M Jayasekera, K W Rupertunge and K B Karunasekera).

Table 10. *Ten clones with highest mean girth and their DMRT groups.
(GPB/BST/HPS/85/2)*

Clone	Mean girth cm	Group
85-82	63.60	A
85-60	62.31	A B
85.25	61.91	A B C
85-33	61.66	A B C
RRIC 110	61.53	A B C
85-59	61.20	A B C
85-14	60.35	A B C D
85-13	60.20	A B C D E
85-18	60.00	A B C D E
85-26	59.60	A B C D E F

LSD for 5% level = 4.62

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 11. 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 11. *Mean girth in cm*

Clone	Eladuwa	Salawa	
		P1	P2
PB 217	41.70	36.99	40.15
RRIC 110	47.16	41.96	43.36
PB 260	46.22	37.25	42.60
PR 255	36.37	34.36	37.60
PR 261	36.81	39.00	34.10
PB 235	50.70	42.12	41.55
RRIC 121	47.02	40.88	40.04
BPM 24	43.77	38.97	37.90
RRIC 100	48.87	42.87	40.90
RRIM 712	39.93	29.64	35.14

Mean girth of clones in four small experiments (Three 25 tree plots per clone per site) are given in Table 12.

Table 12. *Mean girth (cm) of clones in four experimental sites*

Clone	Yatawatta	Bentota	Kuruwita	Atale
RRIC 121	36.46	46.72	40.69	51.10
PB 260	35.55	50.93	40.75	50.91
PB 235	33.49	54.69	43.03	51.74
RRIM 712	31.38	34.17	30.22	48.46
PR 255	30.55	35.26	29.91	46.43
BPM 24	30.02	40.03	31.43	46.74
PR 261	21.57	38.13	27.83	46.92

Girth census showed that at the site of Atale clones PB 235, PB 260 and RRIC 121 have reached to the tappable standard having tappareability percentages of 68.42, 63.41 and 62.16 respectively. At Bentota clone PB 260 and at Eladuwa clone PB 235 have reached to the tappable stage having 62.66% and 64% of tappable trees respectively (N E M Jayasekera, K W Rupertunga, I D M J Sarathkumara, B M S G Peiris, R A S K Ranatunga and K B Karunasekara).

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 was found affected with *Corynespora* leaf disease (N E M Jayasekera, S Dharamakeerthi, K B Karunasekera, K W Rupertunge and I D M J Sarathkumara).

New planting

Observation plots of RRISL 200 series clones

Following observation plots, each with 300 plants were established in 1996. Details of the observation plots established are given in Table 13.

Table 13. *Details of observation plots established in 1996*

Clone	Estate/Site	No. of Tapping tasks
RRISL 201	Tempo Division	01
RRISL 204	do	01
RRISL 215	do	01
RRISL 201	Moralioya Estate	01
RRISL 202	do	01
GPS 1	Nakiyadeniya Est.	01
RRISL 200	do	01
RRISL 203	do	01
RRISL 220	do	01

PLANT SCIENCE

A Nugawela

SUMMARY

Green budwood if sterilized and kept in low temperature maintains the grafting success rate for about a week. Healthy 1-2 year old clearings could be crown budded successfully in case of a disease out-break. Use of healthy budwood and early germinators are essential for raising quality young budding plants. Among the various planting materials recommended young buddings are superior in establishment and growth. Opening at lower girth results in poor yields. Girthing after commencement of tapping is influenced by the clone and the girth at opening. Among the low frequency tapping systems tested $\frac{1}{2}S$ d/3 + E (4/y) performs best. Increasing the number of stimulations per annum, with $\frac{1}{2}S$ d/3 tapping, will not give a corresponding yield increase. Incidence of TPD is significantly influenced by the clone and stimulation.

In high density trials girthing is not affected four years after establishment. With apron type rainguards around 80 additional tapping days and an yield increase of up to 21% could be recorded in the Kalutara district. The cost of the rainguard could be significantly reduced by fixing it horizontally on the trunk. Different spatial arrangements tested to facilitate intercropping have not adversely affected the growth of rubber. Planting timber species and cocoa with rubber does not influence the growth of rubber. In Moneragala and Bibile districts rubber could be intercropped with sugarcane successfully. More than 8000 budded stumps were distributed to the Estate and Smallholder Sectors to establish budwood nurseries.

DETAILED REVIEW

Staff

The Head of Department, Dr A Nugawela, Dr (Mrs) P Seneviratne, Botanist, Mr L S S Pathiratna, Assistant Botanist, Mr R B Gunaratne and Mr L S Kariyawasam, Experimental Officers, Mr R P Karunasena and Mr K A G B Amaratunge, Senior Technical Officers, Mr S Wilbert, Senior Experimental Assistant, Mrs C W Ranasinghe, Mr U S Weerakoon, Mrs R K Samarasekera, Mr L P Vitharana, Mr M K P Perera, Mr T U K Silva and Mr M de Alwis, Technical Officers and Mrs D E Jayawardena, Clerk/Typist were on duty throughout the year.

Mr V H L Rodrigo, Botanist, proceeded to UK on the 6th March to continue his post-graduate studies. Mr L S S Pathiratna, Assistant Botanist was promoted to

Research Officer Grade 1 with effect from 20th November. Mrs G A S Wijsekera. Senior Technical Officer was on maternity leave from 10.04.1996 to 13.06.1996. Mr H P Peiris assumed duties as a Technical Officer on 20th May. Mr T U K Silva. Technical Officer was on no pay leave from 5th July. Mr A M W K Seneviratna and Mr K M G S N Kaluwewa. Assistant Botanists assumed duties on 1st November and 9th December respectively.

Research students

Miss C Jayakody, an under graduate student from the University of Peradeniya completed her final year project on "The effect of tapping during wintering period on yield and leaf nutrient status of Rubber" under supervision of Dr A Nugawela.

Mr P A Lukshman, an under graduate student from the University of Peradeniya completed his final year project on "Different stimulation methods to obtain economic yields from puncture tapping" under supervision of Dr A Nugawela.

Miss K N S Fernando, an under graduate student from the University of Ruhuna completed her final year project on "Incidence of Tapping Panel Dryness and its Distribution Pattern in *Hevea brasiliensis* Muell. Arg." under supervision of Dr A Nugawela.

Miss D P Abeygunawardena, an under graduate student from the University of Ruhuna completed her final year project on " Factors affecting rooting and root system of micro propagated plants of *Hevea brasiliensis*" under supervision of Dr (Mrs) P Seneviratna.

Mr M Chandrasekara, an undergraduate student from the University of Peradeniya completed his final year project on "The effect of age of budwood on the growth of grafted plants of *Hevea brasiliensis*" 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 also participated.
- * Estate Committee Meetings.
- * Seminars for Planting Executives of Namunukula Plantations Ltd., RPK Plantations Ltd., and Bogawantalawa Plantations Ltd.

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

Investigations were continued using successive grafted materials. *In vitro* study to test the degree of juvenility was affected by the insufficient number of replicates. Studies are being continued to see the clonal variation on establishment and shoot growth. Factors affecting the rooting and root system of micropropagated plants are also being looked into (P Seneviratne and G A S Wijesekera).

Preservation of budwood

Studies were conducted to see whether green budsticks could be stored without affecting the budgrafting success. Budsticks from clone RRIC 100 were used. They were kept at low temperature, *i.e.* 20°C in an incubator. To sterilize them, shoots were soaked in 10% chlorox solution for 5 minutes. Shoots of all treatments were sealed in polythene bags. Percentage grafting success for different treatments are summarized in Table 1.

Table 1. *The effect of different treatments tested on bud grafting success (n=6)*

Treatments	Storing Period (Days)				
	5	7	11	12	13
1. Non Sterilized + Room temperature	66	33	[0]	50	-
2. Non sterilized + low temperature	66	33	25	50	16
3. Sterilized + Room temperature	50	[0]	40	33	-
4. Sterilized + Low temperature	60	66	50	40	16

Buds already removed could not be stored using same treatments or in tissue culture media for more than 5 days (P Seneviratna and S P Withanage).

FIELD EXPERIMENTS

Seed production

An island-wide survey was conducted on the production of seeds of clones PB 86, RRIC 100 and RRIC 121. The effect of protecting flowers on seed production was also tested at Dartonfield Group, Rubber Research Institute. Data gathered from the seed survey are summarized in Table 2.

Table 2. *Seed production per hectare in different rubber growing regions*

Region	PB 86	RRIC 100	RRIC 121
Kalutara	3.718	9.243	-
Kegalle	11.466	23.131	815
Ratnapura	4.088	12.154	430
Gampaha	49.076	-	-
Homagama	6.199	10.432	-
Galle	10.266	3.866	-

(P Seneviratne, L P Vitharana and M N Alwis in collaboration with the Rubber Development Department. Study funded by the Smallholder Rubber Rehabilitation Project).

Rootstock nurseries

Significant differences on girthing and green budding success were not apparent among the three spacings, *i.e.* 6"x1.5', 6"x2' and 9" double row, tested. Brown budding success is being tested. Branch induction in stock plants did not significantly influence the girthing or grafting success (P Seneviratna, A Nugawela and K A G B Amaratunga).

Budwood nurseries

The poor quality and insufficient number of budwood nurseries in the country affects the adoption of young budding technique in the smallholder sector.

Therefore, arrangements were made to establish ca. 350 budwood nurseries each consisting of 25-50 RRIC 102 plants, in all rubber growing regions.

Arrangements are made to establish two young budding nurseries in each rubber growing region, for demonstration purposes in order to popularise it among the smallholder sector (P Seneviratna, A Nugawela, W S Seneviratna and M N Alwis in collaboration with the Rubber Development Department, Study funded by the Smallholder Rubber Rehabilitation Project).

Young budding

The effect of stock plant and the quality of budwood on budgrafting success and scion growth were looked at. It was found that use of early germinators by using a germination bed is essential to raise stock plants with good growth vigour. 100% grafting success could be obtained with young budding, if budwood is obtained from a well maintained nursery. Grafting success was below 50% when inferior quality budwood was used. The budgrafting success of all recommended clones was tested and found to be in the range of 90-100% (P Seneviratne, A Nugawela, G A S Wijesekera, S P Withanage, M N Alwis and L P Vitharana).

Polybag plants

Investigations carried out on the failures reported in polybag nurseries revealed that it is mainly due to the malpractices in bag preparation and type of soil used for filling the bags. It was also found that the growth up to the first whorl depends on the food reserves of the stock plant (P Seneviratne, A Nugawela and M N Alwis in collaboration with Soils & Plant Nutrition and Plant Pathology Departments).

Crown budding

Two trials were conducted at Uskvally and Padukka estates in order to rescue the clearings of RRIC 110 already affected by *Corynespora* leaf disease. Each trial consisted of approximately 1000 plants. Grafting success at Uskvally was very low due to the inferior quality of plants caused by the leaf disease. Grafting success recorded at Padukka Estate is given in Table 3.

Table 3. *Percentage budgrafting success of different crown clones on one year old RRIC 110 trunks*

Crown clone	% budgrafting success
RRIC 100	61
<i>H. spruciana</i>	64
RRIC 102	72
RRIC 117	86
RRIC 130	98

Mist propagation and rooted cuttings

Rooted cuttings produced under mist and hydroponic systems were transferred to the field for further studies on root growth (P Seneviratne, G A S Wijesekera and S P Vithanage).

Mixed planting

Three trials were initiated during the year at Dartonfield Group using young buddings of 2-3 clones (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 established during SW 1991. The percentage of trees that has reached tappareability, *i.e.* 50 cm girth at 120 cm from the union in different treatments are given in Table 4.

Though the mean girth in two whorled young buddings and brown buddings were similar the tappareability in young buddings is superior. This may be due to the uniformity of growth in young buddings (A Nugawela and K A G B Amaratunga).

Table 4. *The different types of planting material tested and the percentage of trees reached tappability*

Planting material	Establishment Success (%)	Tappability (%)
Two whorled young buddings	100	46
Two whorled brown buddings	100	38
Bare root brown buddings	88	40
Green buddings in polybags	96	35

Mohamadi (PT/92/1)

The trial was discontinued due to cattle damage.

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 3 years of growth are given in Table 5.

Table 5. *The different types of planting material tested and their establishment success and growth after 3 years.*

Planting material	Establishment Success (%)	Girth (cm)
Bare root green budding	91.0	22.9
Bare root brown budding	82.3	21.2
Green budding polybags	99.2	21.9
Young buddings	100.0	23.8
Brown budding polybags	98.8	23.1

Young buddings and brown buddings polybags are superior to other types in establishment and early growth (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 per clone.

Treatments

- T₁ Commencing tapping at GC1
- T₂ GC1 untapped trees
- T₃ Commencing tapping at GC2
- T₄ GC2 untapped trees
- T₅ Commencing tapping at GC3
- T₆ GC3 untapped trees
- T₇ GC1 trees to be tapped when reach GC 2
- T₈ GC 2 trees to be tapped when reach GC 3.

The mean yield g/t/t for different clones and girth classes are given in Table 6.

Table 6. *The mean yield, i.e. g/t/t when tapping commenced at different girths in different clones*

Clone	Girth Class		
	42-44 cm	44-46 cm	49-51 cm
RRIC 130	39.1	44.2	56.9
RRIC 121	14.3	15.2	19.5
RRIC 100	14.9	16.3	21.5
Mean	22.8	25.2	32.5

Generally, the yield increases with increasing girth in all 3 clones. The initial yield in RRIC 130 is significantly higher than in other two clones.

The girth increment after tapping is similar for all girth classes in clone RRIC 100 (Table 7). In clones RRIC 121 and RRIC 130 it increases with increasing initial girth (Table 6). Girthing, after commencement of tapping is less in clones RRIC 100 and RRIC 130 when compared with clone RRIC 121 (Table 7).

Table 7. Influence of girth at opening on the subsequent growth in clones RRIC 100, 121 and 130

Clone	Treatment (Girth Class)	Initial Girth (cm)	Increment (after 12 months) (cm)
RRIC 100	T ₁	41.9	4.5
	T ₂	41.7	8.2
	T ₃	44.6	4.8
	T ₄	45.1	8.8
	T ₅	50.2	3.7
	T ₆	49.3	9.3
	T ₇	42.0	8.3
	T ₈	45.0	8.9
RRIC 121	T ₁	42.2	5.1
	T ₂	42.6	6.3
	T ₃	44.9	5.2
	T ₄	44.6	6.6
	T ₅	49.6	6.2
	T ₆	49.6	7.6
	T ₇	42.6	7.1
	T ₈	44.7	6.1
RRIC 130	T ₁	42.9	4.9
	T ₂	42.4	8.1
	T ₃	44.6	5.7
	T ₄	45.1	8.8
	T ₅	49.5	5.7
	T ₆	49.8	9.6
	T ₇	42.6	8.2
	T ₈	44.7	8.5

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

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 the presently recommended $\frac{1}{2}S$ 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)

The dry rubber yield per tree per tapping (g/t/t) is highest in the $\frac{1}{2}S$ d/4 + E*(6/y) system. Anyhow, the two $\frac{1}{2}S$ d/3 + E* systems tested have given the highest annual yields among the different low frequency systems tested. Nevertheless, it is lower than in the conventional $\frac{1}{2}S$ d/2 system (Table 8). The treatment differences are not significant in either the girth or girth increment.

Incidence of Tapping Panel Dryness is similar in all treatments.

Table 8. *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)	Girth increment (cm)	
$\frac{1}{2}S$ d/2	44.4	7.99	81.8	4.1	5.0
$\frac{1}{2}S$ d/4 + E*(6/y)	58.2	5.24	77.3	3.1	4.8
$\frac{1}{2}S$ d/3 + E*(4/y)	49.8	5.98	78.1	3.0	4.0
$\frac{1}{2}S$ d/3 + E*(6/y)	50.2	6.02	76.6	3.0	4.9

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 $\frac{1}{2}S$ d/4 + E* (6/y) system. Nevertheless, the estimated total annual yield based on the maximum number of possible tappings per tree per year is high in the $\frac{1}{2}S$ d/3 + E* (4/y) and $\frac{1}{2}S$ d/3 + E* (6/y) systems (Table 9).

The treatment differences in girth are not significant.

The incidence of tapping panel dryness is generally high but similar in the different systems tested.

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

Table 9. *Effect of tapping systems on dry rubber yields, growth and mean number of dry trees (TPD) per plot of clone RRIC 102*

Tapping system	Yield		Girth	TPD	BCR
	g/t/t	kg/t/year	cm	(%)	(cm)
½S d/2	41.4	7.45	70.1	19.0	20.0
½S d/3	52.0	6.24	71.7	9.5	16.0
½S d/3 + E*(4/y)	68.6	8.23	72.0	12.9	16.2
½S d/4 + E*(6/y)	79.6	7.16	72.5	18.9	14.9
½S d/2 + E*(6/y)	72.9	8.75	72.1	14.4	15.9

*E 2.5% ET. Ba 1.6(2.5).

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

In the above trial stimulations and test tappings could not be done as scheduled during the year.

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

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

In clones RRIC 100 and PB 86, the g/t/t yield is high with low frequency tapping. Anyhow, clone RRIC 101 has not responded to it (Table 10). Similarly, for clones RRIC 100 and PB 86 the estimated annual yield per tree *i.e.* kg/t/year is highest with low frequency tapping with stimulation. Four and six rounds of stimulations per annum have given similar yields in all clones tested (Table 10).

In clone RRIC 101 the g/t/t and kg/t/year is highest with the conventional tapping.

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

Tapping System	Clones and Yield					
	RRIC 100		PB 86		RRIC 101	
	g/t/t	kg/t/year	g/t/t	kg/t/year	g/t/t	kg/t/year
½S d/2	22.6	4.01	19.3	3.47	47.9	8.62
½S d/3 + E*	44.0	5.28	31.9	3.83	42.0	5.04
½S d/3 + E**	39.6	4.75	32.5	3.90	41.3	4.96

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.* monthly with 1% ethrel, once every 2 months with 2.5% ethrel, once every 3 months with 2.5% ethrel is tested on clones RRIC 100, 102, 121 and 130.

The mean grammes per tree per tapping yields (g/t/t) recorded during 1996 for the 4 clones tested are given in Table 11.

Table 11. *Annual mean grammes per tree per tapping (g/t/t) for different frequencies of stimulation in clones RRIC 100, RRIC 102, RRIC 121 and RRIC 130*

Treatment	Clone and Yield (g/t/t)			
	RRIC 100	RRIC 102	RRIC 121	RRIC 130
1% ET.Ba 1.6(2.5)12/y	37.9	24.1	39.2	41.4
2.5% ET.Ba 1.6(2.5)6/y	47.5	24.5	44.6	48.2
2.5% ET.Ba 1.6(2.5)4/y	49.0	24.0	36.1	43.5

Treatment differences vary with the clone. Nevertheless, it appears that 2.5% ET. Ba 1.6(2.5)6/y will give the highest yield per tree per annum.

Dry trees were recorded only in clone RRIC 102 to-date (A Nugawela and R P Karunasena).

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. Mean yield per tree per tapping (g/t/t) and the annual girth increment (cm) are given in Table 12.

The g/t/t yields are low in the ½S d/1 tapping in all clones. Nevertheless, the total annual yield per tree (kg/t/year) is highest from ½S d/1 system. High intensity tapping, *i.e.* ½S d/1 has not influenced the girth increment. Additional fertilizer has not improved the yields or the growth in all treatments tested.

Table 12. *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	32.4 (3.2)	31.1 (3.1)	29.7 (2.4)	35.0 (5.4)
	Level -2	29.5 (2.4)	30.2 (3.1)	37.5 (3.6)	29.0 (5.5)
½S d/2	Level -1	32.6 (2.2)	37.6 (3.4)	37.5 (3.0)	45.0 (4.6)
	Level -2	37.4 (3.2)	30.8 (3.1)	43.9 (3.6)	36.4 (3.5)
½S d/2 + E*	Level -1	39.1 (3.4)	38.5 (2.5)	37.2 (2.9)	39.0 (3.8)
	Level -2	46.7 (2.7)	35.3 (1.9)	40.0 (3.9)	32.5 (3.3)
½S d/3 + E*	Level - 1	44.5 (3.2)	43.4 (2.1)	42.7 (2.8)	48.8 (3.1)
	Level - 2	54.3 (3.3)	30.1 (2.8)	54.1 (4.0)	49.9 (4.7)

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

Incidence of dryness is highest with $\frac{1}{2}$ S d/1 and $\frac{1}{2}$ S d/2 + E systems. Clone RRIC 130 is more susceptible to dryness whilst incidence of dryness is very low in clone RRIC 121. Fertilizer levels have no influence on the incidence of dryness (Table 13) (A Nugawela and R P Karunasena in collaboration with the Soils and Plant Nutrition Department).

Table 13. *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	
$\frac{1}{2}$ S d/1	Level -1	0	0	0	14.3	3.6
	Level -2	12.5	37.5	0	0	12.5
$\frac{1}{2}$ S d/2	Level -1	0	0	0	0	0
	Level -2	12.5	0	0	14.3	6.7
$\frac{1}{2}$ S d/2 + E*	Level -1	12.5	0	0	14.3	6.7
	Level -2	0	12.5	0	25.0	9.4
$\frac{1}{2}$ S d/3 + E*	Level -1	12.5	0	0	14.3	6.7
	Level -2	0	0	0	0	0
	Mean	6.3	6.3	0	10.3	

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 annual mean yield, per tree per tapping *i.e.* g/t/t for each year since the commencement of the two trials for different tapping treatments are given in Table 14.

Table 14. *The dry rubber yield (g/t/t) of the different treatments in trials ERB/93/1 and ERB/93/2*

Treatment	Year and mean annual yield (g/t/t)							
	ERB 93/1				ERB 93/2			
	1993	1994	1995	1996	1993	1994	1995	1996
T ₁ Panel BI-1	38.4	38.7	45.9	48.9	49.6	35.1	48.3	42.5
T ₂ 6" above BI-1	27.3	30.8	37.0	41.7	32.8	30.7	41.0	31.5
T ₃ Upper Virgin Bark (↑)	37.3	27.8	27.3	35.4	58.7	42.0	45.9	29.6
T ₄ Upper Virgin Bark (↓)	30.8	29.9	36.2	36.1	45.4	33.3	39.5	27.2
T ₅ Upper Virgin Bark (Puncture Tapping)	14.2	24.3	36.2	30.4	21.2	31.5	38.6	28.7

The above data clearly indicates tapping panel BI-1 commencing from the original height of opening gives highest yields. The percentage incidence of tapping panel dryness for treatments T₁, T₂, T₃ and T₄ above are 10.4, 12.5, 4.2 and 6.3 cm respectively. The incidence of tapping panel dryness is significantly low on upper virgin bark cuts (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 mean annual yield per tree per tapping (g/t/t), girth increment and % incidence of tapping panel dryness for different treatments and clones are given in Table 15.

Table 15. *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	RRIC 100			RRIC 110		
		g/t/t	GI (cm)	TPD %	g/t/t	GI (cm)	TPD %
Rainguarding	1	34.4	1.9	13.3	35.2	0.9	13.3
	2	38.9	2.5	13.3	34.7	2.2	13.3
Rainguarding and Stimulation	1	35.5	1.4	6.7	40.0	2.0	40
	2	38.7	2.7	13.3	43.3	1.9	27
Stimulation	1	35.4	1.6	0	36.5	0.2	20
	2	33.6	0.8	13.3	44.3	1.8	13.3
Control	1	31.9	2.7	20.0	30.4	1.8	6.7
	2	37.8	2.9	13.3	36.4	2.1	6.7

The incidence of tapping panel dryness recorded at the end of each year since 1994 is given in Table 16 to study the influence of different agronomic practices.

Table 16. *Effect of different agronomic practices on the percentage incidence of TPD*

Practice	Treatment	TPD (%)		
		1994	1995	1996
Rainguarding	With	10.0	6.7	17.5
	Without	13.3	6.7	11.7
Stimulation	With	16.7	9.2	16.7
	Without	6.7	4.2	12.5
Fertilizer	Normal	10.0	7.5	15.0
	Double	13.3	5.8	14.2
Clone	RRIC 100	16.7	5.0	11.7
	RRIC 110	6.7	8.3	17.5

The incidence of dryness is high in stimulated trees and it is consistent throughout the study. Relatively higher incidence of dryness in clone RRIC 110 (Table 15) may be due to its susceptibility to *Corynespora* leaf disease (A Nugawela and C W Ranasingha).

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

Millewa, 1977 Replanting - CD/77/1

The mean annual yield per tree per tapping, girth and incidence of tapping panel dryness for different density treatments in both clones studied are given in Table 17.

Table 17. *The yield, girth and % TPD of clones RRIC 101 and PB 86 planted at different densities*

Density (trees/ha)	Yield (g/t/t)		Girth(cm)		TPD (%)	
	RRIC 101	PB 86	RRIC 101	PB 86	RRIC 101	PB 86
400	23.7	21.8	78.5	66.5	39.5	27.0
533	17.1	18.5	69.9	72.4	33.3	18.1
666	22.9	20.0	59.7	67.8	22.2	14.8
800	21.9	15.9	61.6	63.0	18.2	13.6
771*	15.6	17.6	61.4	67.1	14.9	17.5
920*	18.6	15.7	62.5	61.8	17.4	15.1

* Triangular Spacing

The mean annual yield per tree per tapping (g/t/t) and girthing of trees appear to decline with the increasing density.

The incidence of TPD tend to decline with the yielding capacity of the tree, *i.e.* g/t/t. The yield per hectare when calculated assuming a complete stand and 150 tappings per tree per annum increases with increasing density (Table 18).

Table 18. *The yield per hectare (YPH,kg) for different planting densities of clones RRIC 101 and PB 86*

Spacing (m)	Density(trees/ha)	YPH (kg)	
		RRIC 101	PB 86
1. 2.5 x 10	400	1422	1308
2. 2.5 x 75	533	1367	1479
3. 2.5 x 6	666	2287	1998
4. 2.5 x 5	800	2628	1908
5. 3.87 (Triangular)	771	1804	2035
6. 3.54 (Triangular)	920	2567	2166

(A Nugawela and K A G B Amaratunga).

Kuruwita 1992 Replanting - PD/92/1

Experimental details are reported in Annual Review 1992.

The girth measured at 90 cm from union reveals that plant growth has not so far been affected by the increase in plant density in all clones tested. Growth of clones RRIC 100 and RRIC 121 appear to be superior than in clone RRIC 110 (Table 19).

Table 19. *Girth of rubber plants at a) different planting densities and b) in different clones at the end of each year after planting.*

a).

Density (Plants/Ha)	Girth (cm) and year			
	1 st	2 nd	3 rd	4 th
500	8.4	15.5	26.5	33.3
600	8.3	15.4	28.3	34.6
700	8.4	15.6	28.8	34.5
800	8.6	15.7	28.2	34.1

b).

Density (Plants/Ha)	Girth (cm) and year			
	1 st	2 nd	3 rd	4 th
RRIC 121	8.9	16.4	28.9	35.2
RRIC 100	8.4	15.2	27.1	34.3
RRIC 110	7.9	14.9	27.9	32.9

(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*

Clones RRIC 121, RRIC 133 and PB 260 which have a potential for girthing were selected with clone RRIC 100 for the study.

Planting densities of 350, 425 were tested together with the presently recommended 500 and a slightly higher density of 575 plants per hectare.

A split plot design, *i.e.* density main plot and clones sub-plot was used (A Nugawela, L S Kariyawasam and U S Weerakoon).

Rainguards

Both gutter and skirt type rainguards were fixed in five smallholdings in the Kalutara District.

The number of extra tapping days recorded per tapping block *i.e.* per tree is given in Table 20.

Table 20. *Monthly distribution of extra tapping days recorded in holdings fixed with rainguards*

Holding	Type	Month and No. of extra days tapped									Total
		A.	M.	J.	J.	A.	S.	O	N	D	
1	Skirt	-	2	5	8	0	5	3	3	0	26
2	Skirt	-	1	2	4	2	2	5	4	3	23
3	Skirt	-	2	2	7	3	1	1	3	0	19
4	Gutter	-	-	3	2	-	-	2	2	-	09
5	Gutter	-	1	2	2	4	3	4	-	1	17

Number of additional tappings per tree per annum varies from 9 to 26 in the smallholdings tested. This variation can be attributed to the interest shown by both the tapper and land owner.

Skirt type rainguards were fixed in the entire Dartonfield Division of the Dartonfield Group. The monthly distribution of additional tapping days are given below.

	Month												Total
	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.	
Additional Tapping Days	1	2	6	5	5	6	12	5	13	9	11	7	82

The number of additional tapping days recorded for the year is 82, which is about 41 additional tappings per tree (A Nugawela and R P Karunasena. The project is funded by the CARP Research Grant 12/176/150).

Nursery Inspection Unit

Inspections

One hundred and seven private commercial nurseries were inspected and reports were submitted to the Rubber Development Department for the issue of permits.

Issue of budded stumps for establishment of budwood nurseries

Budded stumps were issued to both Estate and Smallholder Sectors for the establishment of multiplication nurseries. 57 Estates belonging to 15 Plantation Companies were issued with plants during the year. Details are given in Table 21.

Table 21. *The clones and number of plants issued from each clone to both estates and Smallholder Sectors*

Clone	Number of budded stumps issued	
	Estate	Private Nurseries
BPM 24	122	
GPS 1	143	
PB 217	230	
PB 235	302	
PB 255	141	
PB 260	141	
PB 28/59	220	
PR 255	40	
PR 305	65	
RRIC 100	547	1010
RRIC 102	515	640
RRIC 117	190	465
RRIC 121	665	
RRIC 130	219	
RRIC 131	161	
RRIC 133	252	
RRII 105	108	
RRIM 717	50	
RRISL 201	535	
RRISL 202	660	
RRISL 217	211	
RRISL 218	138	
RRISL 219	231	
Total	5995	2125

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

Intercropping

Spatial arrangements

Different spacing systems for the rubber crop are tested to identify systems that will provide more light for a longer period to facilitate intercropping.

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

Experimental details are reported in the Annual Review 1992. There is no significant difference in the growth of rubber in different spatial arrangements being tested. However, system 4 continues to be superior than systems 2 and 3 as far as the growth of rubber is concerned (Table 22).

Table 22. *The mean girth of different spatial systems in 1996.*

System	Mean girth (cm)
1	32.7
2	30.4
3	30.1
4	34.4
5	32.0

(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 spatial arrangement was lower than those under the other two intercrops (Table 23). The growth or the yield of Coffee and the yield of grass was unaffected by the spatial arrangements up to now (Table 24).

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

Treatments	Girth of rubber (cm)
Rubber + grass	25.0
Rubber + Cinnamon	29.5
Rubber + Coffee	29.9
Rubber only	28.7
LSD	4.5

Table 24. *Effect of treatment on the growth of Coffee and the yield of grass and Coffee*

Treatments	Stem diameter of Coffee (cm)	Dry bean yield of Coffee (g/plot)	Yield of grass kg/ha
Row planting - Rubber + Grass	-	-	525.2
Row planting - Rubber + Coffee	2.8	625.8	-
Contour planting - Rubber + Grass	-	-	658.8
Contour planting - Rubber + Coffee	2.6	647.6	-

(L S S Pathiratna and M K P Perera)

Rubber and Timber

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

Ambatenna, 1992 Replanting - IC/RT/92/2

Experimental details appear in the Annual Review 1992. The growth of rubber has not been adversely affected so far by the timber crops or by planting rubber at high density (Table 25).

Table 25. *The girth of rubber plants measured at 90 cm from the union*

Spacing of Rubber	Intercrop	Usk Valley IC/RT/92/1	Ambatenna IC/RT/92/2
1. 8' x 27'	No timber	32.5	33.9
	Halmilla	29.4	33.0
	Alstonia	31.5	33.3
	Teak	31.9	30.7
	Mahogani	32.4	39.3
2. 8' x 8' x 54'	No timber	32.3	30.1
	Halmilla	35.3	33.0
	Alstonia	33.1	31.8
	Teak	33.9	29.9
	Mahogani	35.4	32.5
3. 8' x 17'	-	34.0	35.8
4. 8' x 15'	-	33.3	34.7

(V H L Rodrigo and L S Kariyawasam).

Rubber and Sugarcane

Details of the experiment are given in Annual Review 1992.

Intercropping rubber with sugarcane has not significantly affected the growth of rubber. Anyhow, non-significant complementary effect is apparent at the end of 4th year after planting (Table 26).

Table 26. *The girth of rubber plants each year after planting in different treatments*

Treatment	Year and Girth (cm. at 90 cm)			
	1	2	3	4
Rubber only	8.8	11.6	23.8	27.0
Rubber x Sugarcane (4 rows)	9.4	14.6	25.2	29.2
Rubber x Sugarcane (5 rows)	8.8	14.2	23.6	30.5

The cost of cultivation of sugarcane as an intercrop, the crop per hectare and the income (at Rs.1000 per MT) for each harvest are given in Table 27.

Table 27. *Cultivation cost, yield and income from different harvests separately for each treatment tested. The yield given is the mean for all varieties*

Treatment/Density		Harvest (Crop)		
		Plant	Rattan 1	Rattan 2
1. Sugarcane - 5 rows	Cultivation cost (Rs.)	35.526	20.305	17.670
	Yield (MT/Ha)	59.3	55.8	29.3
	Total Income (Rs./Ha)	59.300	55.800	29.300
	Net Income (Rs./Ha)	23.774	35.495	11.630
2. Sugarcane - 4 rows	Cultivation cost (Rs.)	28.077	16.047	13.965
	Yield (MT/Ha)	46.2	37.3	23.6
	Total Income (Rs./Ha)	46.200	37.300	23.600
	Net Income (Rs./Ha)	18.123	21.253	9.635

It is apparent that a significant income could be generated by sugarcane with no adverse effect to the growth of rubber. The sugarcane crop and growth of rubber will have to be further monitored to decide on the most economical density for sugarcane (A Nugawela, V H L Rodrigo in collaboration with SRI Udawalawe and Rubber Development Department. The Project is funded by CARP Research Grant 12/106/95).

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

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

The growth of grasses was adversely affected by the shade of rubber trees.

Different treatments have not affected the growth of rubber at this stage (Table 28).

Table 28. *Effect of intercropping systems on the growth of rubber*

Treatment	Growth of rubber (cm)
1. Rubber	48.0
2. Rubber + Panicum maximum (PM)	49.7
3. Rubber + Brachiaria brizantha (BB)	42.4
4. Rubber + Gliricidia	45.7
5. Rubber + Ipil Ipil	47.8
6. Rubber + PM+Gliricidia	48.9
7. Rubber + PM + Ipil Ipil	47.0
8. Rubber + BB+ Gliricidia	47.3
9. Rubber + BB+ Ipil Ipil	42.3

(L S S Pathiratna and M K P Perera)

Rubber and Cocoa/Cinnamom***Dartonfield - IC/CC/91/2***

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

The growth of rubber is not affected by the intercrops at this stage (Table 29)

Table 29. *Effect of intercrops on the growth of rubber (cm)*

Treatments	Girth of rubber (cm)
1. Rubber only	37.1
2. Rubber + Cinnamom (spacing 1)	41.4
3. Rubber + Cinnamom (Spacing 2)	38.6
4. Rubber + Cinnamom (Spacing 3)	41.0
5. Rubber + Cocoa (Spacing 1)	34.1
6. Rubber + Cocoa (Spacing 2)	32.6
7. Rubber + Cocoa (Spacing 3)	36.6

(L S S Pathiratna and M K P Perera)

Cocoa trials - Perth, Neuchetal, Tempo and Miriswatta

The pods were harvested in March and July and the bean dry weight was estimated. The growth of rubber is not affected by Cocoa in these trials (Table 30). The bean yield of cocoa was considerably low due to thieving of pods.

Table 30. *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)	70.2	62.9	68.4	71.4
	Bean yield (kg)	25.0	3.0	3.6	13.3
	No. of Cocoa plants	267	146	252	305
Rubber and Cocoa single row	Girth (cm)	68.3	63.4	70.6	70.1
	Bean yield (kg)	10.7	3.4	2.9	12.5
	No. of cocoa plants	179	97	134	162
Rubber only	Girth (cm)	65.4	64.7	67.8	66.0

(L S S Pathiratna and M K P Perera)

Rubber and Rattan - Kuruwita IC/RR/96/1

The objective of the trial is to look into the possibility of growing rattan economically under rubber with no adverse effect to the growth and upkeep of the main crop. Three indigenous species of rattan viz. *Calamus zeylanicus*, *Calamus ovoideus* and *Calamus pseudotenuis* were grown in a rubber clearing established in 1984. Planting distance for rubber is 9.1 m x 2.4 m. Rattan was planted in the rubber interrow at 3.0 m intervals. Each species of rattan was replicated six times in a randomized block experiment (L S S Pathiratna and M K P Perera).

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

The objective of the trial is to evaluate the long term performance of cardamom under the shade of rubber in the low country in terms of growth, yield, quality of the product and profitability.

Five Cardamom selections *i.e.* EC1/100, EC1/101, EC1/103, EC1/700, EC2 400MT suitable for the low country was established under mature rubber. Planting distance for rubber is 9.1 m x 2.4 m. Cardamom was planted in the interrow as single rows (at 2.4 m) and double rows (2.4 m triangular spacing). A split plot design was used with density and selections as main and sub-plots respectively (V H L Rodrigo and L S S Pathiratne) (Conducted in collaboration with the Department of Export Agriculture. The project is funded by CARP Research Grant 12/316/240).

Rubber Banana

Experimental details are given in Annual Review 1993. Growth of both crops were monitored and data suggests the possibility of increasing the presently recommended density of banana in the Rubber Banana system (V H L Rodrigo, R K Samarasekera and L S Kariyawasam. The project is jointly funded by the CARP Research Grant 12/156/125 and ODA).

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 of rubber beyond the traditional areas.

Clones RRIC 100, RRIC 102, RRIC 130 and PB 260 were planted, replicated 4 times to accommodate different micro-environmental conditions. In each replicate 250 plants were planted from a clone. Two whorled polybag plants were used for planting. The establishment rate and early growth of all clones are good in all sites (A Nugawela, R B Gunaratna, K A G B Amaratunga, S Wilbert in collaboration with all Biology Departments and Free Lanka Management Company Ltd. The Project is funded by CARP Research Grant 12/296/260)

successfully completing her post-graduate studies (MSc by research) at the University of Sydney, Australia.

Experimental Officers Messers D S Wettasinghe and E B Fernando were on duty throughout the year. Mrs J L P C Wettasinghe, Senior Technical Officer reported for duty on 22nd February 1996 after completing her training at the Rubber Research Institute of India. Technical Officers Mrs B I Tennakoon, 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.

Visits

The Department staff made 66 advisory visits, 210 for experimental and 164 for other purposes.

Mr C K Jayasinghe attended the Eleventh Meeting of the ANRPC Technical Committee and Workshop on South American Leaf Blight, held in Ho Chi Minh City, Vietnam, 28th to 30th May, 1996. Dr R Jayaratne and Miss W P K Silva participated the Asian International Mycological Congress held in Chiba, Japan from 3rd to 5th July and workshop on Corynespora leaf fall disease held in Medan, Indonesia on 16th and 17th of December 1996 respectively.

Staff of the Plant Pathology and Microbiology Department attended the International Rubber Research and Development Board Conference held in Beruwala, Sri Lanka from 5th to 6th November 1996.

Training/Lectures/Seminars

Mr 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 and NDT Trainees.

Committees

Mr C K Jayasinghe served as a member of Pesticides Technical and Advisory Committee and National Plant Quarantine Committee (NPQC). The main duty of the NPQC for the year 1996 was the revision of the existing Sri Lanka plant protection ordinance.

Mr C K Jayasinghe and Dr R Jayaratne attended the Scientific Committee Meetings of the Rubber Research Board.

PLANT PATHOLOGY AND MICROBIOLOGY

C K Jayasinghe

SUMMARY

Early wintering clones escaped from secondary leaf fall caused by *Oidium heveae* and *Colletotrichum* spp., but a moderate leaf fall on susceptible clones was noticed due to *Phytophthora* spp. towards the end of S.W. monsoon. The clone RRIC 110 was suspended from the list of recommendation as it was found to be susceptible to *Corynespora* leaf fall. Almost all existing RRIC 110 clearings in rubber plantations were inspected and recommendations were given depending on the microclimate and disease situation of the particular clearing.

Systemic fungicide, anvil was found to be effective against white root disease caused by *Rigidoporus lignosus*. At the same time trials were conducted to develop a biological control method to reduce the incidence of white root disease using *Trichoderma* spp.

Studies on enzyme production by *C. quinqueseptatum* showed that pectic enzymes play a minimal role in disease development while cellulolytic enzymes probably play a nutritive role.

Arrangements were made to establish potential clones from RRISL 200 series for screening purposes at eight localities representing all rubber growing agroclimatic zones. Observations of three consecutive years showed that the clones RRIC 130, RRIC 119, RRIC 133, RRIC 110, RRIC 112, RRIC 114, PB 86, RRIC 117, RRIM 600 and RRIC 132 are highly susceptible to bark rot caused by *Phytophthora* sp. whereas clones: BPM 24, RRIM 717, RRIC 116, PB 260, RRIC 121 and RRIC 100 are resistant to the same disease.

Culture characteristics and reproductive morphology of the *Hevea* isolate of *Natrassia mangiferae* were established. The fungus *Colletotrichum acutatum* was shown to be the main cause of *Colletotrichum* leaf disease on rubber in Sri Lanka.

DETAILED REVIEW

Staff

Mr C K Jayasinghe, Head Plant Pathology and Microbiology Department, Dr R Jayaratne, Plant Pathologist, Mr K E Jayasuriya, Plant Pathologist, Mr W Amaratunge, Audio Visual Production Officer were on duty throughout the year. Miss W P K Silva, Plant Pathologist returned to Island on 3rd June 1996 after

GENERAL

Early wintering clones escaped from secondary leaf fall caused by *Oidium* sp. and *Gloeosporium* spp. due to dry weather that prevailed at the beginning of the year. However, incidence of these diseases were high on late wintering clones as favorable weather conditions were developed during the months of February and March. A moderate leaf fall on susceptible clones was noticed due to *Phytophthora* spp. towards the end of South West Monsoon.

The clone RRIC 110 was suspended from planting since 1996 as it was found that this clone is highly susceptible to *Corynespora cassiicola* especially in localities where micro-climate is favorable for the spread of the pathogen. All 110 clearing in rubber plantations were inspected and conditional reports were submitted to relevant managing companies.

It was brought to our notice that instructions given regarding eradication of *Corynespora* leaf fall during the RRI/ASD/RCD joint operation launched in 1987 to 1993 were not implemented by some of the rubber growers. Therefore, an Island wide campaign was carried out with the collaboration of Rubber Development Department to educate the smallholders on the danger of having extremely susceptible clones to *C. cassiicola* in their holdings.

Increasing number of estates reported that their polybag nurseries are severely affected with diseases during the early part of the year. All the affected nurseries were inspected and an interim circular entitled "Control of Nursery Diseases" was sent to all estate managing companies in January requesting them to be vigilant of nursery diseases and to follow our recommendations strictly.

Country Committee on South American Leaf Blight which was established in 1995 met on two occasions, on 30th April 1996 and 13th November 1996.

LABORATORY AND FIELD INVESTIGATIONS

Chemical Control of Economically Important Diseases of *Hevea*

A. Screening of fungicides against *Rigidoporus lignosus*

A1. Screening of 2-furaldehyde (furfural)

Small scale field experiment was carried out to evaluate the potentiality of 2-furaldehyde (furfural) to control the pathogen infection on young trees. Only 1 tree out of 8 trees treated (with more than 75% collar infection and mild foliar symptoms)

was recovered in the bud wood nursery in Elston estate. Puwakpitiya and 6 trees out of 7 trees (with 50% collar infection and mild foliar symptoms) were recovered in the budwood nursery in Frocester estate. Govinna. Further screening was suspended due to lack of data on toxicological properties of the chemical (K E Jayasuriya, D S Wettasinghe and B I Tennakoon).

A2. Screening of fungicides against Rigidoporus lignosus

Field trials laid out at Arapolakanda, Dartonfield and Padukka estates to ascertain the efficacy of fungicides Anvil and Tilt was continued. From these results arrangements have been made to recommend fungicide Anvil to manage white root of rubber as a drench application (R Jayaratne, C K Jayasinghe, P C Wettasinghe).

A3. Screening of clove oil

A series of experiments was carried out to evaluate the fungicidal properties of clove against white root disease. Clove oil was found to be very effective against *Rigidoporus lignosus* (200 ppm) when Poisoned Food Technique was used for evaluation purposes. Presently experiments are in progress to find a compatible solvent to dissolve clove oil to carry out further testing (C K Jayasinghe and E B Fernando).

B. Management of Corynespora leaf fall through spraying fungicides

B1. Spraying of fungicides against field plants

Fungicide spraying exercise was carried out at Moraliyoa Estate and Dartonfield estate using copper oxichloride, Dithane M 45 and Thiovit to determine the effect of these on mixed infection of *Oidium*, *Gloeosporium* and *Corynespora* on RRIC 110. Five rounds of fungicides in different combinations were applied in diesolene as the carrier oil.

Although the application of Dithane and Dithane + CuOCl gave an improvement in the canopies during chemical application period, no sooner the chemicals were stopped, the leaf fall due to *Corynespora* became severe. It was noted that semimature leaves were highly susceptible to *Corynespora* infection, although to the mature leaves too were affected.

Further this exercise was also carried out with the intention of familiarizing with the spraying operations with chemicals in the field for our technical staff members (R Jayaratne, C K Jayasinghe and D S Wettasinghe).

B2. Screening of fungicides against experimental plants

An experiment was commenced at two sites, Kuruwita and Salawa to find the possibility of the chemical control of *Corynespora* leaf fall disease on RRIC 110. The chemicals used are benomyl (150g/ha) and mancozeb (1 kg/ha). ASPEE Mist blowers were used for the spraying purposes. Experiment is in progress (C K Jayasinghe, R Jayaratne, D S Wettasinghe and E B Fernando).

B3. Testing of compatibility of mancozeb with diesolene

Small scale field experiment to carryout to determine the compatibility of Dithane M 45 w.p - with Diesolene as a spray oil. Diesolene was compared with water, Indian spray oil (mineral oil), and coconut oil after spraying on to leaf surfaces in a budwood nursery and the spores of *Corynespora* germination was used under laboratory conditions to determine the effectiveness of the chemicals used. Leaves were harvested from the nursery at 24 hours, 7 days and 14 day after spraying.

There were no phytotoxic effect observed from Diesolene whereas some toxic effects were shown by Indian oil. Spore germination inhibition of *Corynespora* in Dithane/Diesel was equally effective compared to Dithane/water and Dithane/Indian spray oil (R Jayaratne, D S Wettasinghe and D Siriwardene).

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

A. Biological control of white root disease (BC/89/1)

- a. Wood decaying basidiomycetes which were found antagonistic to *R. lignosus* *in vitro* were inoculated on the cut surface of rubber tree logs of an old clearing at Nivitigalakele sub-station. Number of old trees were cut down leaving logs (1-2 foot in length) above ground. Immediately after felling, fungi viz: *Trametes* sp. (isolate KIR8), *Schizophyllum commune* (isolate ISO12), *Lentinus squorasulus*, *Pycnoporus* sp. (isolate ISO17) and a *coprinus* sp. (isolate COPR1) were inoculated on to the cut surfaces by applying the fungal biomass grown on sterilized paddy straws. To protect the fungi from direct sun light, the surfaces were covered with pieces of papers. Assessments on the existence and their colonization of the fungi on the wood were taken after 1, 2, 3 and 4 months. It was noticed that, most of the tested fungi poorly colonized on the cut surfaces, but *Trametes* sp. (isolate KIR8) and *Pycnoporus* sp. (isolate ISO17) had colonized fairly well. However, the

fungus colonies were weakened after a prolonged dry period. Therefore, it was assumed that these wood decaying basidiomycetes are inefficient for competition with pathogenic basidiomycetes fungi such as *R. lignosus*, for available food resources in *Hevea* logs.

- b. Viable inocula of *Trichoderma harzianum* (strain P41.12) using vermiculite powder added with 3.3% rice bran (w/w) was produced in pelleted form. Fungal biomass was grown on sterilized 3% aqueous molasses, mixed with vermiculite/bran mixture and oven dried at 35°C. The weight to weight proportion of vermiculite:bran:fungal biomass was 100:3.3:15. In addition to the above ingredients, 5.10 and 15 ml of 50% sulphur dispersions were mixed with above proportions and pellets were produced. Determination of the shelf life of the inocula is in progress (K E Jayasuriya and B I Tennakoon).

A trial was established at Nivithigalakele division and at Dartonfield to test biocontrol methods to manage white root disease on young rubber plants. Bare root budded stumps were planted on beds at distance of 4' x 4' and artificially inoculated with rubber root pieces pre-colonized with *R. lignosus* (K E Jayasuriya and B I Tennakoon).

B. Biological control studies on rubber nursery pathogens

Fungal species antagonistic against rubber nursery pathogens were isolated from leaves of different plants including wild varieties. Their antagonism on culture medium and on living slides were tested. The antagonistic mechanism of *Trichoderma* spp. against the *Hevea* leaf pathogenic fungi was studied *in vitro* on slides as above.

T. harzianum (strain P41.12) conidial spore suspension in 3% molasses was sprayed to leaves against *C. gloeosporioides*, *C. cassicola* and *O. hevea* infection. The preparation contained 10^4 spores ml^{-1} . Investigations on interaction of germinated *Trichoderma* mycelium and above pathogenic fungi are in progress (K E Jayasuriya and B I Tennakoon).

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

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

Colletotrichum gloeosporioides has been described as the causal agent of *Colletotrichum* leaf disease of rubber in Sri Lanka and other parts of the world since

1905. A study carried out on vegetative and reproductive characteristics of 52 isolates from *Colletotrichum* leaf disease lesions on *Hevea brasiliensis* in Sri Lanka revealed that only 18 isolates belong to *Colletotrichum gloeosporioides* (Fig. 1). The remaining 34 isolates represented *C. acutatum* indicating that *C. acutatum* is the main cause of *Colletotrichum* leaf disease of rubber in Sri Lanka (C K Jayasinghe, T H P S Fernando and U M S Priyanka).

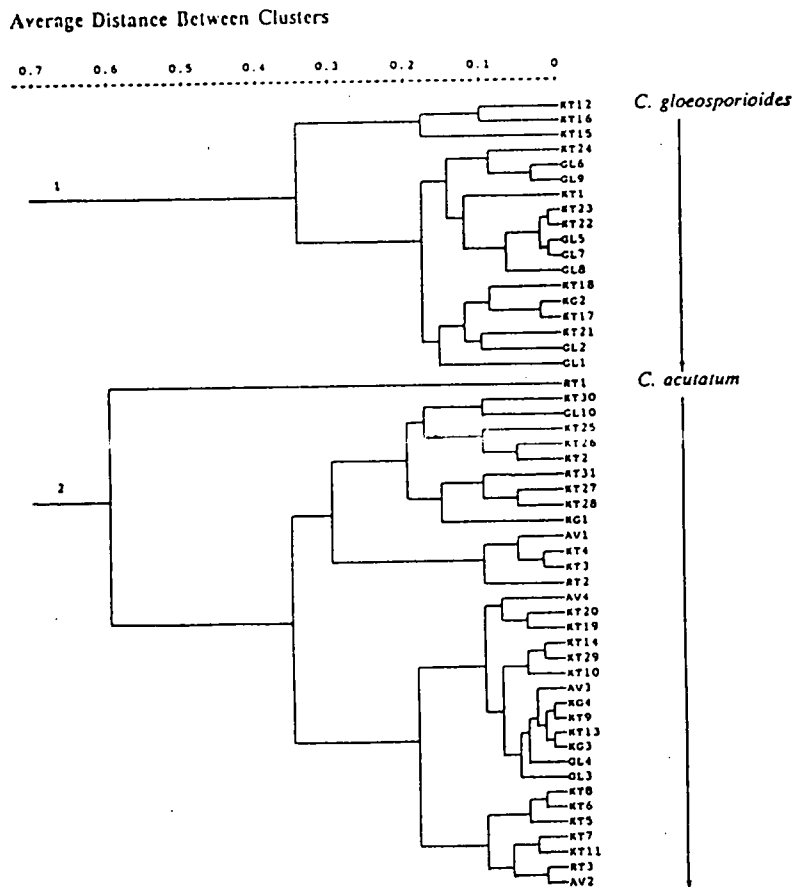


Fig. 1. Dendrogram showing the grouping of 52 *Colletotrichum* isolates based on the conidial morphology and the colony growth. The average linkage method of clusterine was applied to Euclidean distances

B. *Nattrassia mangiferae*: cultural characteristics and reproductive morphology of the *Hevea* isolate.

Nattrassia mangiferae (anamorph : *Scytalidium dimidiatum*), a wound invading pathogen of forest and fruit trees was reported to be the cause of foot canker of *Hevea brasiliensis* seedlings in Sri Lanka in 1992.

The cultural characteristics and the morphology of the reproductive structures: thallospores, pycnidia, pycnospores of *Hevea* isolate IMI 352075 were established and reported using the photomicrographs. Our investigations demonstrated that the isolate IMI 352075 from Sri Lanka resembles the isolates of *Nattrassia mangiferae* obtained from different hosts in other parts of the world (C K Jayasinghe, T H P S Fernando and U M S Priyanka).

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

A range of fungi were isolated from healthy leaves of rubber viz. *Curvularia*, *Colletotrichum*, *Fusarium*, *Mucor*, *Penicillium*, *Pestalotiopsis* and *Trichoderma*. Studies are in progress with the unidentified fungal cultures to authenticate them (C K Jayasinghe, O A N Pradeepika and T H P S Fernando).

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

C. cassiicola was isolated from papaw, manihot and cocoa. Cross inoculation studies indicated that papaw isolates were not pathogenic on *Hevea*. However, manihot and cocoa isolates were pathogenic on rubber (W P K Silva, C K Jayasinghe and U M S Priyanka).

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

A. Screening against bark rot caused by *Phytophthora meadii*

Observations for three consecutive years since 1992 collected at five localities were statistically analyzed. This analysis (Fig. 2) clearly indicated that a great deal of variation occurs among the *Hevea* clones grown in the Eastern hemisphere in susceptibility to bark rot caused by *Phytophthora* sp. The clones RRIC 130, RRIC 119, RRIC 133, RRIC 110, RRIC 112, RRIC 114, PB 86, RRIC 117, RRIM 600 and RRIC 132 were found to be highly susceptible to bark rot whereas clones such as BPM 24, RRIM 717, RRIC 116, PB 260, RRIC 121 and RRIC 100 were resistant to the same disease.

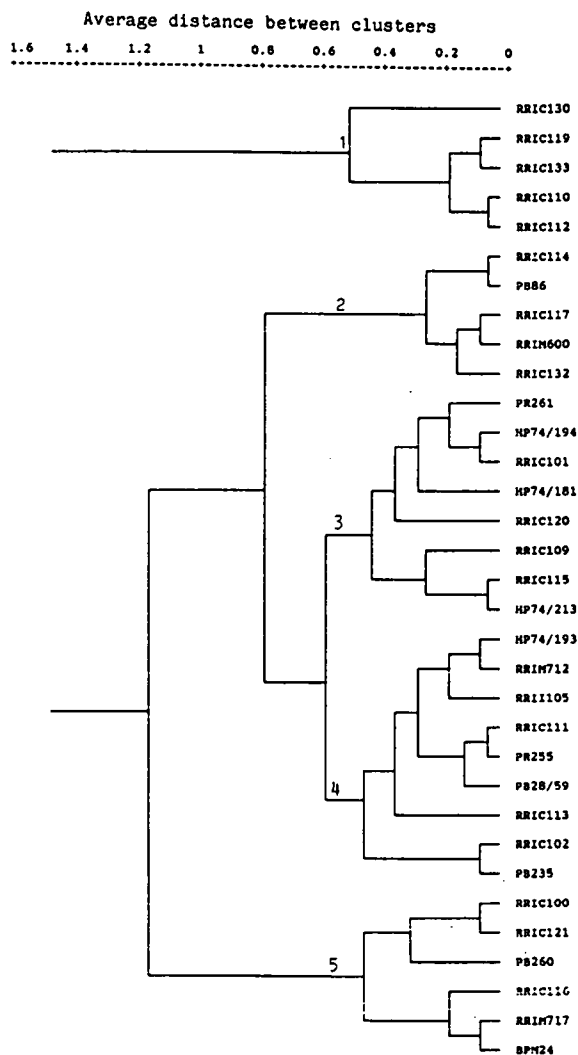


Fig. 2. Dendrogram showing the grouping of 33 *Hevea* clones based on the susceptibility to bark rot caused by *Phytophthora meadii*. The average linkage method of clusterine was applied to Euclidean distances.

Screening of the clones against bark rot in the international clone exchange programme was continued during 1996 also and results are presented in Table 1. Unlike in the last year, site to site variation was obvious and the experiment to be repeated during 1997 (C K Jayasinghe and D S Wettasinghe).

B. Establishment of RRISL 200 series clones for screening purposes

Arrangements have been made to establish new clones *viz.* RRISL 201, 202, 205, 206, 216, 217, 218, 219 and GPS 1 together with few already recommended clones in eight localities representing all rubber growing agroclimatic zones in Sri Lanka. Bud grafting and preparation of sites have been completed. Establishment of plants at different localities will commence during the South West monsoon of 1997 (W P K Silva, C K Jayasinghe and D S Wettasinghe).

Table 1. Testing of proven foreign clones under SRRP 2: Clonal susceptibility to bark rot caused by *Phytophthora meadii*.

Hevea clone	Susceptibility* to bark rot at different locations			
	Salawa	Atale	Kuruwita	Bentota
PR 261	14.65 ab	20.09 a	12.71 e	15.42 ab
PB 217	12.67 bcd	NA	NA	NA
PB 260	12.10 dc	17.38 bcd	13.45 bc	17.33 a
PR 255	15.12 ab	19.77 ab	15.10 ab	17.21
RRIC 110	16.64 a	NA	NA	NA
RRIC 121	14.04 bc	18.39 abc	18.84 b	13.24 b
RRIC 100	12.70 bcd	NA	NA	NA
RRIM 712	10.91 d	18.18 abc	14.86 b	13.88 b
PB 235	14.34 abc	15.07 d	16.82 a	13.49 b
BPM 24	13.78 bc	15.84 cd	13.79 bc	13.36 b

* Resulted lesion area after inoculation with *Phytophthora meadii*.

VA Mycorrhizal studies - (M/86/1)

1. The field experiment initiated to ascertain the effect of two mycorrhizal fungi namely *Gigaspora margarita* and *Acaulospora* sp. in competition with natural population of VAM fungi on *Hevea* seedlings under field conditions continued. The seedlings inoculated with the fungus *Gigaspora margarita* showed a marked increase in diameter and the budgrafting success (Table 2).

Table 2. *Diameter of seedlings (mm) at a height of 4" above ground level after 8 months of growth*

	N o n - mycorrhizal	Gigaspora margarita	N a t u r a l population	Acaulospora sp.	Mean
+ P	69	90	76	79	78.50 ±21.3
- P	72	89	78	77	79.0 ±9.1
Mean	70.50 c ±29.5	89.50 a ±6.9	72.00 b ±4.9	78.0 b ±10.5	

± SD Means with the same letter are not significantly different at 0.05% level by DMRT

Table 3. *Percentage success of budgrafted plants in the nurseries*

	N o n - mycorrhizal	Gigaspora margarita	Naturals	Acaulospora	Mean
+ P	81.8	93.0	84.2	83.4	85.47 ± 8.5
- P	73.4	88.3	83.5	83.3	82.12 ± 10.05
Mean	72.60 ±10.9	90.7 ±9.4	83.85 ±5.1	83.35 ±8.9	

± SD, +P - with added P, -P - No addition of P

These plants will be planted in the field at Dartonfield and the performance of plants will be monitored.

MISCELLANEOUS

A. Effect of rainguard on the development of bark rot

Gutter and skirt type rainguards were fixed during the first quarter on 100 trees of the clone PB 86 at Neuchatel estate to evaluate the effect of rainguards on the

prevention of bark rot infections during S.W. monsoon. However, experiment has to be discontinued as bark rot incidence were extremely low during this year (C K Jayasinghe and E B Fernando).

B. Cell wall degrading enzymes of common *Hevea* pathogens

Studies on enzyme production by common pathogens viz. *Phytophthora* and *Corynespora* are in progress. It was noticed that cellulolytic enzymes play an important role in pathogenesis (C K Jayasinghe and T H P S Fernando).

C. Cell wall degrading enzymes of *Cylindrocladium quinqueseptatum*

This study was completed in the year 1996.

Only one isolate (Kp) of *Cylindrocladium quinqueseptatum* secreted polygalacturonase (PG) when grown in liquid culture. None of the isolates secreted pectin lyase (PL). All isolates secreted cellobiase and β -glucosidase.

The extracts of clove and rubber leaf tissue, inoculated and infected with the Kp isolate of *C. quinqueseptatum* did not show any PG and PL activity. The leaf tissue did not have the ability to inhibit *C. quinqueseptatum* PG produced in culture. Binding of the PG to leaf tissue was also not detected.

All isolates of *C. quinqueseptatum* secreted cellulases viz. cellobiase and β -glucosidase in culture. A marked increase in the activity of cellobiase was detected in the inoculated, infected rubber leaves. Activity of β -glucosidase, an inherent enzyme of *Hevea* leaves, also increased rapidly following infection.

The results indicate that pectin enzymes play a minimal or no role in disease development of *C. quinqueseptatum* infection in cloves and *Hevea*. Thus cellulolytic enzyme probably play a nutritive role (C K Jayasinghe and T H P S Fernando).

D. RRI/RDD joint operation on eradication of clones extremely susceptible to *C. cassiicola*

The above programme initiated in the year 1997 was successfully completed by 1993. However, it was brought to our notice that instructions given during this operation were not implemented by few smallholders. Under the light of this situation an island-wide campaign was launched with the collaboration of Rubber Development Department to educate the smallholders on the danger of having extremely susceptible clones to *C. cassiicola* in their holdings. It was agreed that follow up action should be taken by Deputy Directors of Ratnapura, Homagama, Kalutara and Kegalle regions (C K Jayasinghe, R Jayaratne, K E Jayasuriya, D S Wettasinghe, E B Fernando with the collaboration of Rubber Development Department).

E. *Corynespora* leaf fall incidence on RRIC 110

The *Hevea* clone RRIC 110, a clone recommended in group 2 for the estates became susceptible to *C. cassiicola* in 1995 creating an unrest among the rubber growers. Steps were taken immediately to inspect all the RRIC 110 clearing in Sri Lanka and to issue the conditional reports for each clearing individually.

Twenty eight estates from Avissawella, Kegalle, Kalutara and Ratnapaura were reported to consist rubber clearings with the clone RRIC 110 and estimated total hecterage of RRIC 110 was around 160 ha. The observations of the surveys made during 1996 indicated that clearings in ten estates are severely affected with *Corynespora* and defoliation has commenced due to the disease (C K Jayasinghe, R Jayaratne, K E Jayasuriya, D S Wettasinghe and E B Fernando).

SOILS AND PLANT NUTRITION

Lalani Samarappuli

SUMMARY

Residual effect of mulching with rice straw on latex production was seen in the virgin panel BO-2. It may be possible to obtain higher growth and early tappable with increased level of potassium in comparatively drier areas, under field condition. *Flemingia congesta*, *Crotalaria anagyroides* and *Tephrosia vogellie* 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, although the growth rate of *Flemingia congesta* during the early stages appears to be slow. It was also observed that the first lopping of *Crotalaria anagyroides* may be done 4 months after planting and it may be possible to do 2-3 loppings during the 1st six years when climatic conditions are favourable. A creeping type of legume, *Mucuna bracteata*, appears to take about 6 months to establish fully in the Kalutara District.

It was decided to recommend the use of Eppawela rock phosphate as the source of phosphate either during the 5th and 6th year of the immature phase or during the last 02 years of the immature phase which ever is later. If this revised recommendation is fully implemented by the rubber sector, Eppawela rock phosphate consumption is likely to increase by 2620 MT per year which would cost approximately 9.44 million rupees only, resulting in a saving of 8.44 million rupees per year to the rubber sector.

For young budding, application of fertilizers in liquid form has found to be more effective than applying fertilizer in granule form. It was also found that this liquid formulation could be applied at fortnightly intervals. However, when the application frequency was reduced further to monthly application the incidence of die back of scion shoots was significantly higher.

The soil and foliar survey programme provided data for fertilizer recommendations for 12,600 hectares in the estate sector. The soil and foliar survey programme was extended to the small holder sector covering more than 750 holdings in the Horana Division and fertilizer recommendations were sent for the years 1997, 1998 and 1999 to these small holdings.

DETAILED REVIEW

Staff

The Head of the Department, Dr (Mrs) Lalani Samarappuli, Soils Chemist, Dr D M A P Dissanayake and Assistant Soils Chemist, Mr S Dharmakeerthi were on duty throughout the year.

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

Senior Technical Officers Mr S N Silva and Mrs C Maheepala were on duty throughout the year. Technical Officers Messrs P Karunadasa, U Mitrasena, T B Dissanayake, A N Yakandawela, V Edirimanne and D Senaratne, Senior Testing Officer Mr T M Ahamadeen and the English stenographer Mrs L Rupasinghe were on duty.

Technical Officer Miss C Jayalath resigned from the services of the RRI in July. Miss A Thevarapperuma joined the institute as a Technical Officer in August.

Research students

Mr N Herath, an undergraduate student from the University of Peradeniya, completed his final year project on "An assessment of discriminative fertilizer application to mature rubber in relation to yield" under the supervision of Dr (Mrs) Lalani Samarappuli.

Miss P Dias, an undergraduate student from the University of Ruhuna, completed her final year project on "Use of leaf and soil sampling for diagnosing nutritional requirement of mature *Hevea*" under the supervision of Dr (Mrs) Lalani Samarappuli.

Mr P Gunawardana, an undergraduate student from the University of Ruhuna, completed his final year project on "Sulphur status of rubber plantations in relation to fertilizer application" under the supervision of Dr D M A P Dissanayake.

Visits

Dr Lalani Samarappuli participated in the Interregional training course on "The use of nuclear techniques in studies of soil/plant relationships with emphasis on soil water management organized by the IAEA/FAO from 28th May to 5th July, held at the IAEA Laboratories, Seibersdorf, Vienna, Austria.

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 seminars:

Joint Symposium on "Improvement of Degraded Soils of Sri Lanka" organized by the Soil Science Society of Sri Lanka and SLAAS. Section B on the "Improvement of Degraded Rubber Lands in Sri Lanka."

IRRDB Seminar on Agronomy. Farming Systems and Technology on the "Possibilities of growing rubber in marginal dry areas."

Dr D M A P Dissanayake addressed the following seminars/workshops:

Seminar on "Rock phosphate use in rubber and recent developments in the use of root bioassay technique for assessing P requirement of plants" organized by the NRESA.

Seminar on "Eppawela Rock Phosphate as a source of P for rubber" organized by the Lanka Phosphate Ltd.

IRRDB Seminar on Agronomy. Farming Systems and Technology on the "Sri Lankan rock phosphate: A useful source of P for rubber."

Workshop on "Fertilizer use in rubber" organized by the NFS/FAO for fertilizer dealers.

Mr S Dharmakeerthi addressed the workshop on "Fertilizers to rubber nurseries" in Ratnapura Region organized by the Rubber Development Department.

Dr (Mrs) Lalani Samarappuli¹, Dr D M A P Dissanayake² and Mr S Dharmakeerthi³ attended the following seminars, meetings workshops and training:

* Fertilizer Advisory Committee¹.

* The Working Group on Fertilizer Mixtures of the Sri Lanka Standards Institution¹.

- * Central Scientific Committee^{1,2}.
- * Training programme on implementation of ISO 9000 in crepe rubber factories, organized by the Rubber Research Institute of Sri Lanka³.

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.
- * Assistant Superintendents of Plantation Management Companies.
- * 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 Agronomic practices in relation to moisture conservation

1.1 *Use of live and dead mulch*

1.1.1 *Comparison of different management practices*

Study on the residual effect of, mulching during the immature period, on latex production and girthing of trees was continued in experiment SM/82/5. The residual effect of treatments on yield in the virgin panel BO-2 and girth increment during the 7th year are given in Table 1 and 2, respectively. Yield of latex was higher in mulched plots compared to other soil management practices.

Table 1. *Residual effect of different soil management practices on yield in panel BO-2*

Treatment	Yield (panel BO-2)		Relative Increase (%)
	(g/t/t)	(kg/ha/yr)	
Legumes	21.41 ^a	349 ^a	100
Naturals	18.68 ^a	1177 ^a	87
Dead mulch	27.56 ^b	1736 ^b	129

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

Treatment	Girth (cm)	Girth Increment (cm)
Legumes	63.73 ^a	2.76
Naturals	61.70 ^a	0.58
Dead mulch	68.42 ^b	1.25

1.1.2 *Optimum N P K levels for rubber mulched with rice straw*

In this experiment (SM/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.

Yield data obtained indicated that when P level was increased to double the recommended level there had been a reduction in yield in comparison with the currently recommended level. Yield of latex was higher in mulched plots compared to no mulched treatment (Table 3). The effect of application of paddy straw on girth and girth increment during the 7th year are given in Table 4. This indicates that it is possible to obtain higher girth increments in the region of 1.58 cm/yr by application of paddy straw (L Samarappuli, P Karunadasa and U Mitrasena).

Table 3. *Effect of different P levels and mulching on yield of Hevea*

P Level	Yield		Treatment	Yield	
	(g/t/t)	(kg/ha/yr)		(g/t/t)	(kg/ha/yr)
P ₀	20.97	1321	C ₀	19.11 ^a	1203 ^a
P ₁	22.79	1435	C ₁	22.74 ^b	1432 ^b
P ₂	19.02	1198			
LSD	2.38	149			

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

1.2 Fertilizer practices for overcoming moisture stress

A field experiment (SM/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. In the dry area, under field condition, there was a significant increase ($P < 0.001$) in girth and tappareability with the increase in the level of K (Table 5).

Table 5. *Effect of different levels of K on growth and tappareability (%) of rubber plants at the end of 8 years in a dry area*

Treatment	Girth (cm)	Tappareability (%)
K ₀	38.1	17.88
K ₁	45.0	50.97
K ₂	49.0	71.21
LSD	4.69	20.59

In experiment SM/88/1, with and without K, girth, girth increment and yield data indicated higher girthing and higher yield (Table 6) with potassium at K₁ level. In another field experiment (SM/95/1), the effect of both potassium and mulching on moisture stress, growth and latex production 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 18 months after planting are given in Table 7 (L Samarappuli, P Karunadasa and U Mitrasena).

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 (SM/93/1) and monitoring of soil moisture content using Neutron Probe was done. The soil moisture profiles under rubber and tea multi cropping system are given in Fig. 1 (unrehabilitated) and Fig. 2 (rehabilitated).

Access tubes were also installed in each plot in the experimental area on multicropping of rubber with tea at Perth estate, Ingiriya (SM/96/1) and monitoring of soil moisture content was done. The difference in soil moisture content between the different spacings of rubber & tea and between positions of rubber and tea plants are given in Table 8 and 9 (L Samarappuli, N Yogaratnam, S M Iqbal, P Karunadasa and U Mitrasena).

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

K levels	Girth (cm)	Girth Increment (cm)	Yield	
			(g/t/t)	(kg/ha/yr)
K ₀	49.7	3.5	23.3	1468
K ₁	54.3*	3.4	30.9*	1947*
LSD	1.3	ns	2.9	183

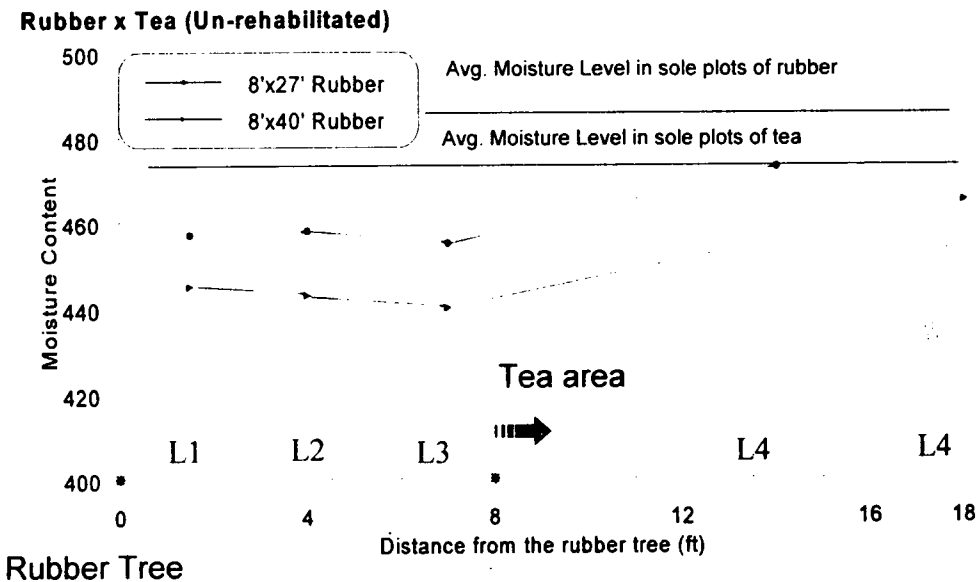


Fig. 1. The soil moisture profile under rubber and tea multi cropping system (unrehabilitated)

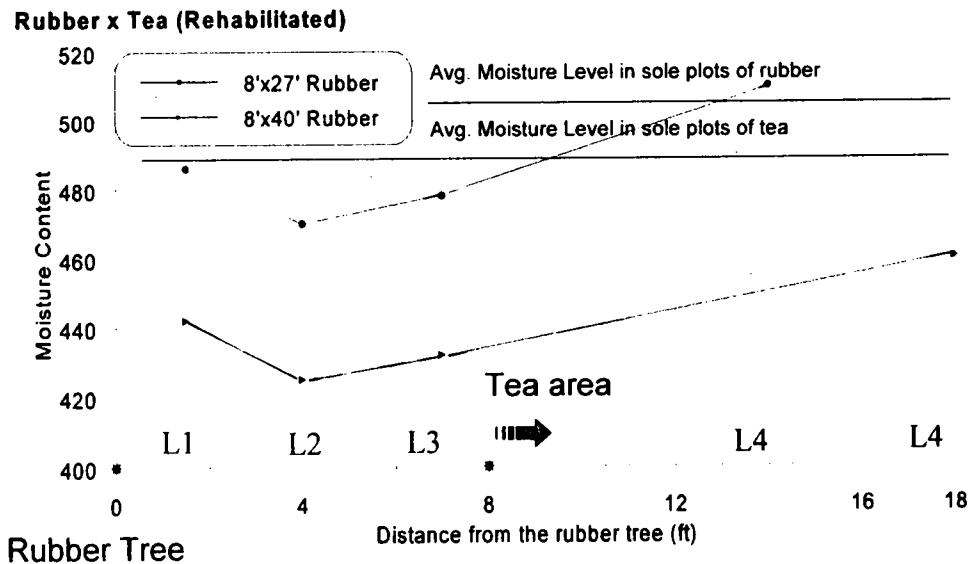


Fig. 2. The soil moisture profile under rubber and tea multi cropping system (rehabilitated)

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

Treatment	Girth (cm)
K ₁ M ₀	12.58 ^a
K ₁ M ₁	12.85 ^a
K ₂ M ₂	12.93 ^a
K ₃ M ₂	12.95 ^a
K ₁ M ₂	13.00 ^a
K ₂ M ₁	13.10 ^a
K ₄ M ₂	13.15 ^a
K ₁ M ₀	13.20 ^a
K ₃ M ₀	13.28 ^a
K ₃ M ₁	13.30 ^a
K ₂ M ₀	13.45 ^a
K ₂ M ₁	13.58 ^a

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

Treatment	Moisture content (kg/M ³)
Rubber only	439.5
Tea & rubber (8'x8'x46')	390.5
Tea & rubber (8'x8'x60')	460.5
Tea & rubber (8'x8'x70')	438.3
Tea & rubber (8'x60')	404.8

Table 9. *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	390.5	435.3	438.3	404.8
Between rubber & tea plants	393.0	429.7	419.3	422.0
1 st row of tea plants	371.0	434.0	376.0	419.5

1.4 Fertilizer and soil moisture requirement of rubber under different densities

An experiment (SM/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 diameter of rubber plants at the end of 6 months from planting is presented in Table 10 (L Samarapuli, P Karunadasa and U Mitrasena in collaboration with the Plant Science Department).

Table 10. *Effect of different plant densities on diameter of rubber plants*

Treatment	Diameter (mm)
500 trees/ha [4.5m x 4.5m]	14.84 ^{ab}
600 trees/ha [4.2m x 4.2m]	13.52 ^b
700 trees/ha [3.8m x 3.8m]	13.86 ^b
800 trees/ha [3.5m x 3.5m]	15.73 ^a

2. Ground cover management, land degradation and nutrient recycling.

2.1 Ground cover management

2.1.1 Comparison of different cover types

Experiment. SM/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 of rubber is given in Table 11 (L Samarappuli, P Karunadasa and U Mitrasena).

Table 11. *Effect of different types of legumes on girth and yield of Hevea*

Treatment	Girth (cm)	Yield (g/t/t)	Yield (kg/ha/yr)
<i>Pueraria</i> (Creeping type)	54.43 ^a	20.71 ^a	1304 ^a
<i>Desmodium</i> (bush type)	50.63 ^b	18.12 ^a	1141 ^a
<i>Srylosanthus</i> (bush type)	50.96 ^b	18.23 ^a	1149 ^a
<i>Tephrosia</i> (tree type)	49.15 ^b	18.51 ^a	1166 ^a

2.1.2 Comparison of different tree legumes

Experiments C/92/1 and C/93/1. were started to study the performance of leguminous trees and their effect on soil and moisture conservation, growth and yield of *Hevea* plants. Girth of rubber plants under different management practices are presented in Table 12. Girth was higher in trees under *Crotolaria anagyroides* and *Tephrosia vogellie* compared to trees under other species viz. *Pueraria phaseoloides*, *Sesbania aculeata* and *Gliricidia sepium* (L Samarappuli, P Karunadasa and U Mitrasena).

Table 12. *Effect of different tree legume species on girth of rubber plants*

Treatment	Girth (cm)
<i>Crotolaria anagyroides</i>	23.85 ^a
<i>Tephrosia vogellie</i>	23.46 ^{ab}
<i>Pueraria phaseoloides</i>	22.47 ^b
<i>Sesbania aculeata</i>	18.93 ^c
<i>Gliricidia sepium</i>	17.38 ^c

Another field experiment (C/96/1), was started to study the comparative efficiency of *Tephrosia vogellie*, *Crotalaria 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. According to initial observations, growth rate of *Flemingia congesta* during the early stages appears to be slow. It was further observed that the first lopping of *Crotalaria anagyroides* may be done 4 months after planting depending on the weather conditions. It may be possible to do 2-3 loppings of this species during the 1st six months when climatic conditions are favourable (Table 13). Effect of different types of tree legumes on diameter of rubber plants at the end of 6 months from planting is presented in Table 14 (L Samarappuli, P Karunadasa and U Mitrasena).

Table 13. Some characteristics of tree legumes as successful species

Characteristic	Months after planting		
	<i>Tephrosia vogellie</i>	<i>Crotalaria anagyroides</i>	<i>Flemingia congesta</i>
Flowering	6	3	6
1st lopping	12	4	-
2nd lopping	-	5	-
3rd lopping	-	6	-
Biomass (kg/ha)	1045	6625	-

Another field experiment (C/94/1), was started to study the effectiveness of tree legumes under rubber in Kegalle District. Treatments consisted of three types: *Tephrosia vogellie*, *Crotalaria anagyroides* and *Flemingia congesta*. Effect of different species on girth of rubber plants at the end of 2 years after planting is presented in Table 15 (L Samarappuli, N Yogaratnam and E A T Senadeera).

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

Treatment	Diameter (mm)
<i>Tephrosia vogellie</i>	12.22 ^a
<i>Crotalaria anagyroides</i>	11.86 ^{ab}
<i>Flemingia congesta</i>	11.32 ^b

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

Treatments	Girth (cm)
<i>Flemingia congesta</i>	25.50
<i>Crotalaria anagyroides</i>	24.17
<i>Tephrosia vogellie</i>	22.57

2.1.3 New cover crop species

A field experiment (C/94/2), was started to study the comparative efficiency of *Mucuna bracteata* on nutrient enrichment and other desirable characteristics in comparison with *Pueraria*. Visual observations on growth rate of this cover crop during both dry and wet periods appear to indicate higher rate than *Pueraria*.

At Perth Estate, Horana another experiment (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 diameter of rubber plants at the end of 6 months from planting is presented in Table 16 (L Samarappuli, P Karunadasa and U Mitrasena).

Table 16. *Effect of two different legume species on diameter of rubber plants*

Treatment	Diameter (mm)
<i>Mucuna bracteata</i>	12.20 ^a
<i>Pueraria phaseoloides</i>	11.59 ^a

2.2 Assessment of land degradation in rubber plantations

In a field experiment (SM/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 17). (L Samarappuli, P Karunadasa and U Mitrasena).

Table 17. *Effect of different slopes on girth and yield of rubber plants*

Slope	Girth (cm)	Yield	
		(g/t/t)	(kg/ha/yr)
6%	65.49 ^a	26.38 ^a	1662 ^a
12%	62.81 ^b	20.95 ^b	1320 ^b

A comparison between soils under rubber plantations and forest was done for some chemical and physical parameters to study the land degradation in rubber plantations (Table 18 & 19). This data shows that in general there is no significant difference in soil chemical and physical properties under rubber and natural forest condition (L Samarappuli and N Herath).

Table 18. *Average soil nutrient contents between rubber and forest soils*

Soil Nutrient	Rubber soil	Forest Soil
Soil N (%)	0.347	0.231
Soil P (ppm)	18.38	10.17
Soil K (ppm)	42.74	61.80
Soil Ca (ppm)	89.97	133.69
Soil Mg (ppm)	20.84	37.52
Soil Organic Carbon (%)	1.52	1.88

Table 19. *Some physical properties of soil under different vegetation systems*

Vegetation	Depth (cm)	Bulk density (g/cm ³)	Porosity (%)	Water storage capacity (cm/m)
Rubber	0-15	1.11	59	24.6
	15-30	1.22	56	21.2
Natural forest	0-15	1.09	60	26.3
	15-30	1.20	57	22.8

2.3 Nutrient recycling in rubber plantations

2.3.1 Sludge as a potential fertilizer for Hevea

Three experiments were started at Payagala estate to evaluate sludge as a fertilizer for immature rubber (OM/93/2 & OM/93/3), and for legume covers (OM/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, 21 and 22 (L Samarappuli and A M A Perera).

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

Treatment	Girth (cm)
Without sludge	21.4 ^a
With sludge	23.2 ^a

Table 21. *Effect of application of sludge and fertilizers on girth of rubber plants*

Treatment	Girth (cm)
No fertilizer + sludge (1/2 kg/plant)	23.61 ^a
No fertilizer + sludge (1 kg/plant)	22.68 ^a
Fertilizer (1/2 level) + sludge (1/2 kg/plant)	19.69 ^a
Fertilizer (1/2 level) + sludge (1 kg/plant)	23.38 ^a
Fertilizer (normal level) + sludge (1/2 kg/plant)	19.49 ^a
Fertilizer (normal level) + sludge (1 kg/plant)	21.46 ^a

Table 22. *Effect of application of sludge to covers on girth of rubber plants*

Treatment	Girth (cm)
No P fertilizer	21.65 ^a
IRP (recommended level)	21.71 ^a
Sludge (normal level)	22.36 ^a
Sludge (double level)	21.24 ^a

3. Weeds and weed control

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) & legume covers. Herbicides were sprayed according to the experimental design (L Samarappuli, P Karunadasa and U Mitrasena).

4. NPKMg requirement of rubber

4.1 *Fertilizers to nursery plants*

4.1.1 *Evaluation of fertilizer mixtures for young budding*

4.1.1.1 Application frequency

An experiment was conducted at the Eladuwa Estate in order to evaluate the effectiveness of reducing frequency of liquid fertilizer application for "young budding". Recommended liquid fertilizer mixture for Boralu series soils was applied at weekly, biweekly and monthly intervals with a no fertilizer control. Statistical analysis of plant diameter (mm) at different ages, indicates that applying liquid fertilizer is significantly better than not applying fertilizer, even though the top soil is used. Further, there were no significant difference in plant diameter among other treatments at different ages tested (Fig 3).

Budded % is significantly higher in fertilizer applied treatments than in no fertilizer control. Budding success is significantly higher when fertilizers were applied at biweekly intervals than when they were applied monthly. Die back % increases with the reduction of frequency, yet there were no significant difference among the fertilizer applied treatments (Table 23). Therefore, it is possible to apply liquid fertilizer mixture at biweekly intervals for young budding (R S Dharmakeerthi and S N Silva).

4.1.1.2 Requirement of a basal application when young buddings are planted in the field

This experiment was initiated to evaluate the necessity, if any, of a basal application when young buddings were planted in the field. Following treatments

(Table 24) were allocated in a completely randomized block design at Eladuwa Estate in May/June 1996. Growth parameters such as plant diameter (mm) plant height (cm). No. of leaves at six months intervals and leaf and soil nutrient levels at yearly intervals will be measured (R S Dharmakeerthi, S N Silva and D Senaratne).

Table 23. *Effect of frequency of fertilizer application on various aspects measured in young budding*

Treatment	Buddable %	Budded %	Budding success %	Die back %	Recovery % at planting
No fertilizer	52.9 ^a	43.1 ^b	92.9 ^a	0.00 ^b	33.5 ^b
Weekly	88.4 ^a	82.6 ^a	78.9 ^b	4.2 ^{ab}	61.8 ^a
Biweekly	92.1 ^a	85.8 ^a	87.6 ^{ab}	8.0 ^{ab}	68.7 ^a
Monthly	91.0 ^a	87.1 ^a	72.6 ^c	13.5 ^a	56.1 ^a

* All % values were analyzed after arcsine transformation.

Table 24. *Treatments for the experiment*

Treatment Number	Planting hole application	Age (months) at which fertilizer due for the 1st year was applied
T ₁	Nil	2.5.7.10
T ₂	Nil	1.4.7.10
T ₃	100g IRP, 50g NPK, 25g kieserite	2.5.7.10
T ₄	50g IRP, 25g NPK, 12.5g kieserite	2.5.7.10

4.2 Fertilizer requirement of new clones

This experiment was continued for the fourth year and in this year a significant interaction in the mean plant girth ($P < 0.05$) between clones and fertilizer levels was observed. Except PB 260 all other clones tested showed a significantly positive response to the fertilizer application compared to no fertilizer applied

control. However, there were no significant differences among the fertilizer applied plants in these clones. In the clone PB 260, a significant increase in plant girth was observed only when the fertilizer level was increased up to 1½ time the currently recommended level. Further there were no significant difference among the fertilizer applied treatments in this clone (Table 25).

Under zero fertilizer level clones PB 260 and RRIC 110 have achieved better girth than the clone 74-193. However, there were no significant difference among PB 260, RRIC 110, RRIC 121, RRIM 712 and also among RRIC 121, RRIM 712, 74-193 at this level. When the fertilizer level increased to ½ recommended level there were no significant difference in plant girth among clones. At currently recommended level RRIC 110 have performed better than RRIM 712 and RRIC 121. Further, there were no significant difference among RRIC 110, PB 260 and 74-193. When the fertilizer level further increased up to 1½ times the currently recommended level, RRIC 110 has responded significantly better than all other clones. In clones PB 260 and 74-193 a significantly higher growth was observed than that in clones RRIC 121 and RRIM 712 (Table 25). (R S Dharmakeerthi, S N Silva, A N Yakandawela and D Senaratne).

Table 25. *Effect of different fertilizer levels on the girth (cm) of some high yielding clones*

Fertilizer level	Clone					mean
	RRIC 110	RRIC 121	PB 260	RRIM 712	74- 193	
No fertilizer (control)	31.2 _a ^b	28.7 _{ab} ^b	33.4 _a ^b	27.2 _{ab} ^b	20.8 _b ^b	28.3
½ rec. level	37.6 _a ^a	34.3 _a ^a	36.7 _a ^{ab}	34.1 _a ^a	36.0 _a ^a	35.7
Rec. level	41.4 _a ^a	35.7 _b ^a	38.6 _{ab} ^{ab}	36.3 _b ^a	39.1 _{ab} ^a	38.2
1½ rec.level	43.6 _a ^a	37.3 _c ^a	41.0 _b ^a	35.8 _c ^a	40.7 _b ^a	39.7
Mean	38.5	34.0	37.4	33.3	34.2	

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

5. Micro nutrients

Micronutrient status and distribution profile of micronutrients along the soil depth were studied for different rubber soil series: *Parambe, Boralu, Agalawatta* and

Homagama (M/96/1). *Parambe* soils recorded the highest concentrations of acid-extracted micronutrients (Fig. 3). In general the micronutrient contents in soil showed an increase with increase in depth of soil (Fig. 4) (L Samarappuli and H K Lalantha).

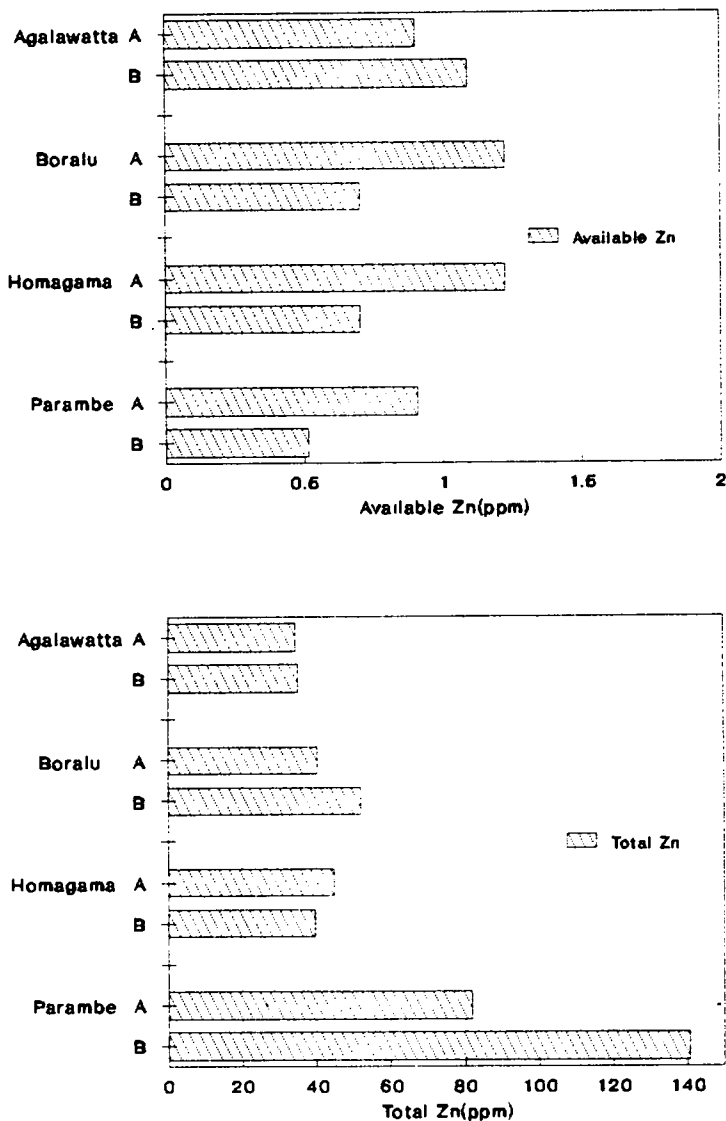
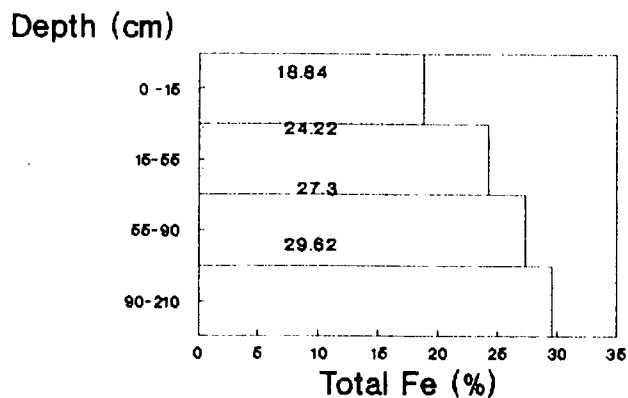
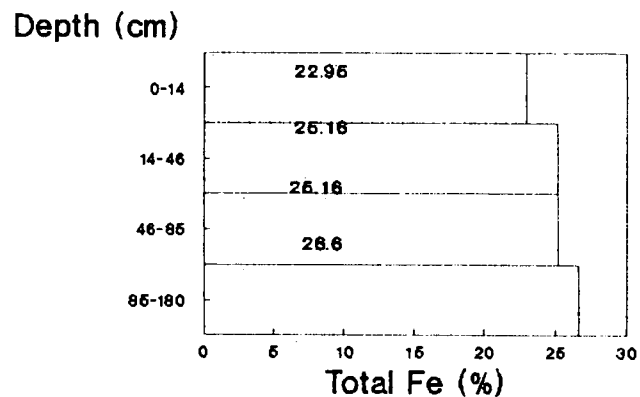


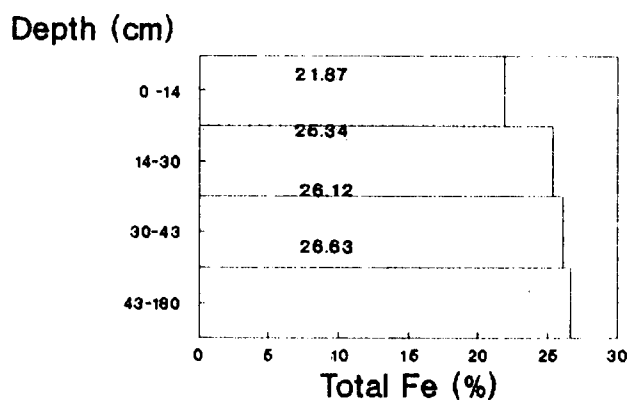
Fig. 3. Zn status in different horizons of rubber growing soils



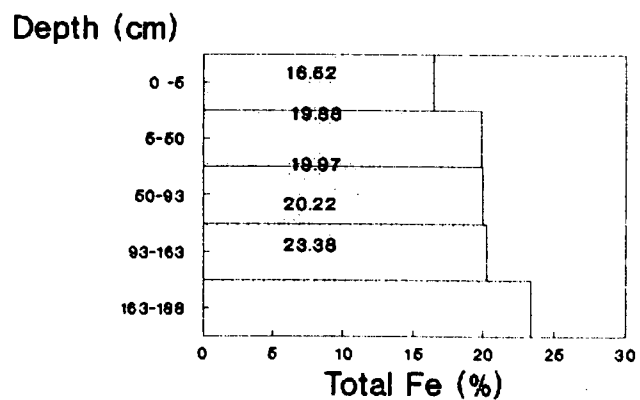
Agalawatta Series



Homagama Series



Parambe Series



Boralu Series

Fig. 4. Distribution profile of Zn along the depth of soil

6. Organic fertilizers

6.1. Use of organic materials in poly bagged nursery plants

An experiment (OM/95/1), is in progress 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 & sub soil (1:1), (c) sub soil & coir dust (1:1), (d) sub soil & paddy husk (1:1), (e) sub soil & poultry litter (2:1), (f) sub soil & saw dust (1:1), (g) sub soil, saw dust & poultry litter (1:1:1), (h) sub soil, paddy husk & poultry litter (1:1:1), (i) sub soil, coir dust & poultry litter (1:1:1) and sub soil & refuse tea (1:1). Plant diameter at 4 months after planting under different treatments is presented in Table 26. Growth was higher in plants under most of the treatments compared to the control treatment (top soil) (L Samarappuli and R Hettiarachchi).

Table 26. *Effect of different organic material substitutes on diameter of rubber plants*

Treatment	Diameter (mm)
Top soil (control)	8.03
Top soil & sub soil (1:1)	8.13
Sub soil & coir dust (1:1)	8.64
Sub soil & paddy husk (1:1)	7.60
Sub soil & poultry litter (2:1)	8.07
Sub soil & saw dust (1:1)	7.67
Sub soil, saw dust & poultry litter (1:1:1)	7.23
Sub soil, paddy husk & poultry litter (1:1:1)	7.76
Sub soil, coir dust & poultry litter (1:1:1)	7.25
Sub soil & refuse tea (1:1)	8.10

6.2. Use of animal wastes in rubber cultivations

A field experiment (OM/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 ($\frac{1}{2}$ recommended level) + poultry litter, (c) Inorganic fertilizer ($\frac{1}{4}$ 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 of rubber plants at the end of 18 months are given in Tables 27 (L Samarappuli, P Karunadasa and U Mitrasena).

Table 27. *Effect of different treatments on girth of rubber plants*

Treatment	Girth (cm)
Inorganic fertilizer (recommended level)	12.52 ^a
Inorganic fertilizer (1/2 recommended level) + poultry litter	12.46 ^{ab}
Inorganic fertilizer (1/4 recommended level) + poultry litter	12.39 ^{ab}
Poultry litter + IRP + paddy straw	12.08 ^{ab}
Poultry litter only	11.84 ^{ab}
Poultry litter only with natural cover	11.43 ^b
Poultry litter + IRP + MOP	11.17 ^c
No fertilizer (control)	8.53 ^d

6.3 *Use of green manure and straw in rubber cultivation*

Field experiment (OM/94/1), at Culloden Estate, Neboda which was started to study the effect of leguminous cover materials as an organic manure for rubber, was terminated. A new site was selected at Gallewatta Division, Dartonfield Estate to start this experiment and blocking was completed. Treatments consisted of (a) Control (recommended level of chemical fertilizers), (b) Chemical fertilizer (substitute level) with green manure and (c) Chemical fertilizer (substitute level) with straw (L Samarappuli, P Karunadasa and U Mitrasena).

7. Other fertilizers and fertilizer recommendations

7.1 *Reduced frequency of fertilizer applications*

A field experiment (F/Ap/95/1), is in progress to 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 18 months are given in Table 28 (L Samarappuli, P Karunadasa and U Mitrasena).

7.2 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 Yogaratham, P Karunadasa and U Mitrasena).

- T₁ No fertilizer from the first year of panel C
- T₂ No fertilizer from the second year of panel C
- T₃ No fertilizer from the third year of panel C
- T₄ No fertilizer from the fourth year of panel C
- T₅ Fertilizing throughout the panel C

Table 28. *Effect of different treatments on girth of rubber plants*

Treatment	Girth (cm)
20 applications/immature six year period (SA based)	12.43 ^a
25 applications/immature six year period (urea based)	12.35 ^a
14 applications/immature six year period (SA based)	11.67 ^a
14 applications/immature six year period (urea based)	11.63 ^a
14 applications/immature six year period (urea based)	11.41 ^a
No fertilizer	9.26 ^b

7.3 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. Leaf Ca, Mg and yield data obtained during the last year are given in Table 29 (L Samarappuli, S M M Iqbal, P Karunadasa and U Mitrasena).

Table 29. *Effect of different sources of Mg fertilizer on leaf Ca, Mg and yield of rubber plants*

Treatment	Leaf Ca (%)	Leaf Mg (%)	Yield		Relative yield (%)
			(g/tree/tapping)	(kg/ha/yr)	
Kieserite	0.847 ^a	0.393 ^a	22.07 ^a	1390 ^a	100
Dolomite	0.999 ^b	0.336 ^b	18.10 ^b	1140 ^a	82

7.4 *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 30) (L Samarappuli, N Yogaratnam and J G de Mel).

Table 30. *Effect of different fertilizer mixtures on girth of rubber plants*

Treatment	Girth (cm)
Control (no fertilizer)	14.30 ^a
Urea based	21.22 ^b
SA based	20.72 ^b
Sulpomag based	20.72 ^b

7.5 *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 presented in Table 31 (L Samarappuli, K G K de Silva, R Hettiarachchi and M Wijesekera).

Table 31. *Effect of different fertilizer treatments on the growth of rubber plants*

Treatment	Plant diameter (mm)	Plant height (cm)
Normal application of fertilizer only	6.77	36.83
Normal application of fertilizer + 2 coir blocks	7.44	38.85
Normal application of fertilizer + 4 coir blocks	7.55	39.45
Normal application of basal fertilizers + coir block encapsulated with higher dose of NPKMg fertilizers	7.97	44.64
100g IRP + coir block encapsulated with higher dose of NPKMg fertilizers	7.99	41.14
All fertilizers encapsulated in the coir block	8.68	46.61

8. Soil and foliar survey programme

8.1 Assessment of soil and foliar survey programme

An assessment (F/SF/95/1), of the effectiveness of the discriminative fertilizer application to mature rubber in relation to yield was done for the Kalutara, Ratnapura and Kegalle regions. Yield data of the last 15 years collected from different locations clearly showed the appropriateness of the soil and foliar survey based fertilizer recommendations for mature rubber in these regions and further confirms the observations made for Avissawella region (L Samarappuli and N Herath).

8.2 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 Yogarathnam, W Wijesuriya, V Edirimanne, P Karunadasa and U Mitrasena).

8.3 Soil and foliar survey programme - Fertilizer recommendation

Estate sector

The soil and foliar survey programme for 1996 commenced in July and approximately 12600 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 smallholder sector was extended to Horana Division of the Kalutara Region. 4 ranges *viz.* Horana, Millewa, Arakawila and Uduwa, which consisted of more than 750 holdings, was covered under this scheme and distributed fertilizer recommendations for the years 1997, 1998 and 1999. Fertilizer formulations recommended for different RDO ranges are given in Tables 32 and 33 (L Samarappuli, A M A Perera, V Edirimanne, A Thevarapperuma, G de Mel and T Ahamadeen).

Table 32. *Recommended Fertilizer Schedule for 1997, 1998 and 1999 for Uduwa and Horana ranges*

Year	Fertilizer Quantity (gram/tree/year)			
	Urea	Muriate of Potash	Eppawela Rock phosphate	Kieserite
1997	200	200	-	-
1998	200	200	-	-
1999	200	200	200	-

Table 33. *Recommended Fertilizer Schedule for 1997, 1998 and 1999 for Millewa and Arakawila ranges*

Year	Fertilizer Quantity (gram/tree/year)			
	Urea	Muriate of Potash	Eppawela Rock phosphate	Kieserite
1997	200	200	-	-
1998	200	200	-	-
1999	200	200	-	-

9. Phosphate Nutrition

9.1 *Rubber soils*

9.1.1 P fixation in rubber soils

Soils collected to represent all the rubber growing areas were analyzed for some of physical and chemical parameters. Under this Parambe, Boralu, Homagama and Agalawatta soils were subjected to determine available P contents, organic matter and clay contents (A Dissanayake, T Dissanayake, C Maheepala and C Jayalath).

9.2 *Nursery plants*

9.2.1 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 continued. Girth measurements were made at the age of 4 and 6 months. No significant effect of the P fertilizer treatments on girdling of rubber plants was observed. Therefore this experiment was further extended for a period of one year. After completion of one year plants were uprooted. Fresh and dry weights of roots and shoots of plants were measured in addition to chemical analysis of plant samples (A Dissanayake, T Dissanayake and Peter Perera).

9.2.3 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. Fertilizers were applied according to the experimental treatments (A Dissanayake, C K Maheepala and Peter Perera).

9.3 *Immature rubber*

9.3.1 Effect of different sources and levels of P

This experiment (P/IM/87) was continued.

Experimental plots were sub divided into two sub plots to study the residual effects of rock phosphates applied during the immature period on yield and fertilizer treatments were applied according to the new arrangement. Assessments of yield was continued in addition to chemical analysis of leaf and soil samples (A Dissanayake, T Dissanayake and Peter Perera).

9.3.2 Ability of different clones to utilize ERP

Experiment P/IM/93-01

This experiment started at Devalakanda Estate was continued. Fertilizers (ERP, IRP and ERP and IRP mixture) were applied according to the experimental treatments to supply phosphate at zero, normal and double the recommended level.

Girth measurements made after the completion of three years showed that there is no significant difference between rock phosphate sources (Table 34). But plants responded positively to phosphate application.

Table 34. *Effect of different source of P on plant girth*

Sources	Mean Girth (cm)
IRP	21.02 ^a
ERP	18.83 ^a
IRP + ERP (50:50)	20.60 ^a

A significant increase ($P < 0.05$) in girth was recorded when plants received P fertilizers. But, no significant differences were observed in plant girth between the recommended level (L1) and double the recommended level (L2) at this stage (Table 35).

Table 35. *Effect of different P levels on plant girth*

P level	Mean girth (cm)
P0 (No P fertilizer)	18.67
P1 (rec.level)	20.88 ^c
P2 (doub.rec.level)	20.89 ^c
LSD	1.98

Experiment P/IM/94

This experiment started at Lagos Division, Payagala Estate to study the ability of different RRIC clones (RRIC 110 & 121) in utilization of ERP was continued for the 3rd year. Fertilizer treatments, ERP, IRP, IRP + ERP (50:50) mixture were applied according to the experimental design. Girth measurements were made after completion of 3 years. Leaf and soil samples were also collected and analysis of leaf samples were completed (A Dissanayake, T Dissanayake, Peter Perera, C Maheepala and C Jayalath).

Experiment P/IM/96 - 01

A new 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. Pre treatment soil samples were collected before applying fertilizers (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. Fertilizer treatments were applied for the 4th year also.

Girth measurements made after completion of 4 years showed that there is no significant difference between fertilizer treatments. Leaf and soil samples also collected and chemical analysis of leaf samples were completed (A Dissanayake, T Dissanayake and Peter Perera).

9.4 Agronomic practices to increase the availability of P from ERP

9.4.1 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. Fertilizer treatments were applied according to the experimental design. Rice straw and lime were also applied around the base of the rubber trees. Girth measurements were made at the age of 3 years. Soil and leaf samples were also collected at this stage (A Dissanayake, L Samarappuli, T Dissanayake and Peter Perera).

9.4.2 *Suitability of ERP to cover crops*

9.4.2.1 Mycorrhizal aspect

The experiment started to study the effect of mycorrhizae on the efficiency of P uptake from Eppawela rock phosphate by rubber plants grown in poly bags was discontinued. The growth of plants were poor irrespective of the treatments and fairly large number of plants were died due to unknown reasons. Therefore, arrangements have been made to repeat this experiment ((A Dissanayake, R Jayaratne, T Dissanayake, C Jayalath and C Maheepala).

9.5 *Mature rubber*

9.5.1 *Residual effect of added rock phosphates*

This experiment (P/M/76) was continued for a further period of one year. Assessments of yield were done but not regularly due to interference by rain. Soil and leaf samples were collected. No P fertilizer was applied during this year also. But uniform application of N,K and Mg fertilizers were made. Chemical analyses of leaf samples were completed (A Dissanayake, T Dissanayake and Peter Perera and C Maheepala).

10. Sulphur nutrition

10.1 *Sulphur status of rubber soils*

Sulphur (S) status in both immature and mature rubber plantations were evaluated in relation to the continuous use of urea based NPK fertilizer mixtures recommended by the Rubber Research Institute of Sri Lanka. The impact of sulphur on yield and plant girth was also studied. Both, leaf and soil sulphur levels were decreased when urea was used for a considerable period as the only source of nitrogen for mature rubber (Fig. 5 & 6). Although, application of urea resulted lowering the leaf and soil sulphur during the early immature phase, this effect was not seen during the later part of the immaturity (Fig. 7 & 8).

A significant relationship, ($P < 0.05$) was evident between leaf sulphur and girth of young plants. This indicate that sulphur is a limiting factor for their growth (Fig. 9). However, the latex yield of rubber plant was not influenced by the soil and plant sulphur (A Dissanayake, T Dissanayake, Peter Perera and C K Maheepala).

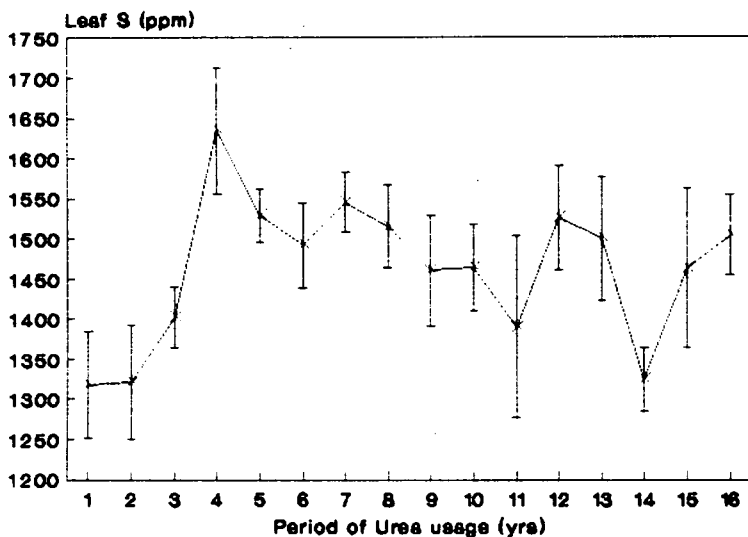


Fig. 5. Changes of leaf S with urea application during the mature stage

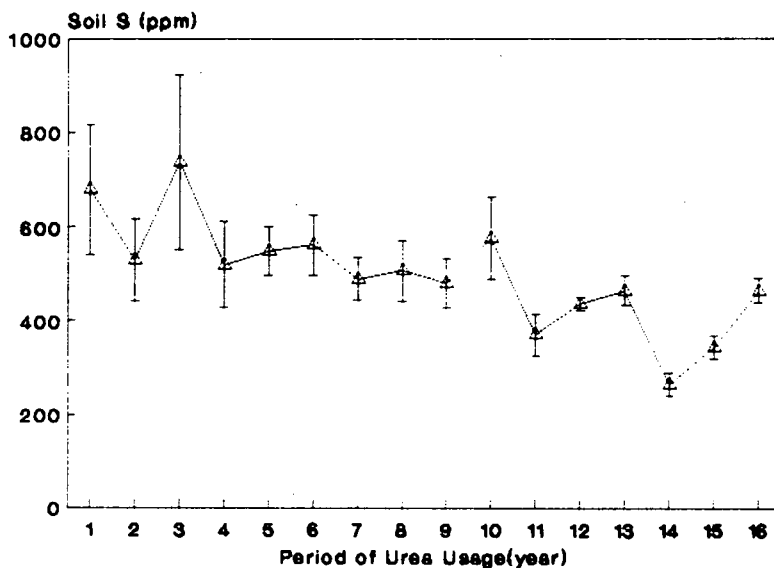


Fig. 6. Changes in soil S with urea fertilization during the mature stage

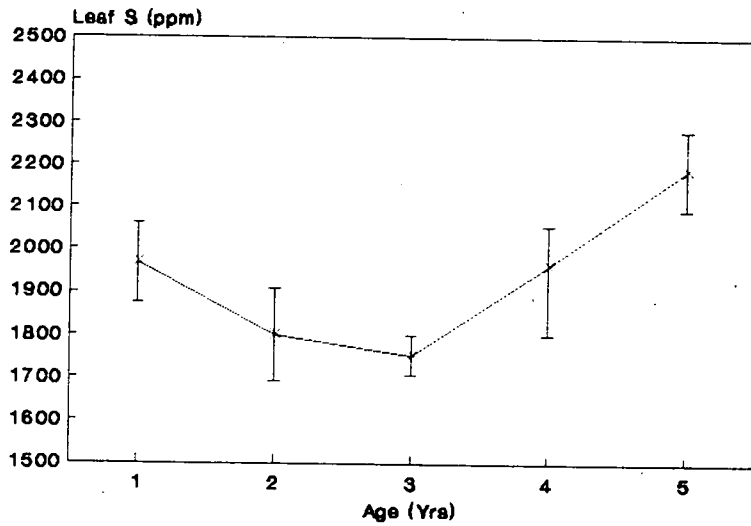


Fig. 7. Changes in leaf s with urea application during the immature period

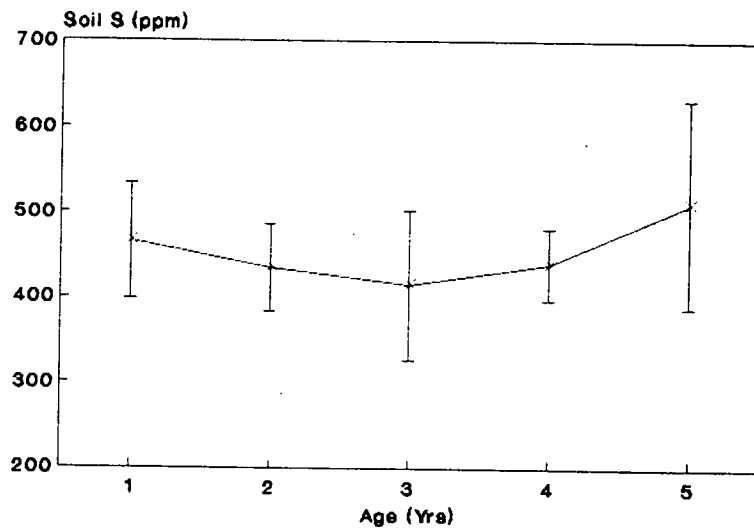


Fig. 8. Soil S levels in relation to urea fertilization during the immature stage

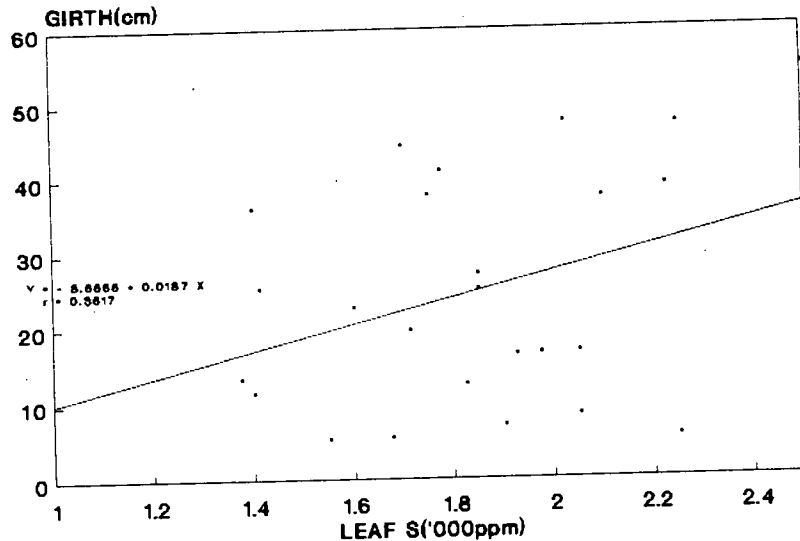


Fig. 9. Relationship between leaf S and plant girth of immature rubber

10.2 Sulphur nutrition of immature rubber

A new experiment was planned to start 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) will be tested in a randomized block design with 4 replicates (A Dissanayake, T Dissanayake and Peter Perera).

11. Use of rubber factory effluent

A new 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. Soil samples were collected prior to commencement of the experiment (A Dissanayake, T Dissanayake, and C K Maheepala).

12. Soil survey and classification

12.1 *Assessing of important chemical properties of rubber growing soils*

Important chemical parameters such as pH, Organic Carbon, Total N, Total P, Ca, Mg, K, Na, available P, Total S, CEC and exchangeable cations were estimated for four major rubber growing soils classified by the Rubber Research Institute of Sri Lanka. Initially, the study was confined to Boralu, Homagama, Parambe and Agalawatta soils. Locations to represent each soil series were marked and soil pits were made. Soil samples were taken after identification of horizons and subjected for determination of above parameters.

Boralu soils contain the lowest amount of total nitrogen compared to other soils. The four major soils are fell into two sub groups in relation to total phosphate content. Soil can be categorized into two groups by considering total magnesium content also. Profile distribution of total N,P,K, Mg and S were studied and values were presented as percentages. Both, total N and total S contents are influenced by the soil depth. Generally, total N content of A horizon was significantly higher than that of B horizon. But, sulphur behaved in the opposite way showing higher value in the B horizon. Also, variations in some of the chemical parameters are governed by both type and depth of the soil together (A Dissanayake and C K Maheepala).

Variation in some chemical characteristics of rubber growing soils

Soil acidity, total nitrogen, phosphorus, magnesium and available calcium were significantly influenced by soil series. pH (1N KCL) in Boralu soils was significantly different from other 3 soil series and it was the highest. Lower soil pH in 1N KCl was recorded in Parambe series soil.

Also, similar results were observed in relation to soil acidity measured by using 0.01M CaCl₂.

Total N content in Boralu soils was significantly lower than that of other three soils series. But it was clearly observed that the total phosphorus content in Parambe soils was significantly higher than that of other soil series.

However, both Agalawatta and Boralu soils contained the lowest amount of total magnesium. According to the total magnesium contents of different rubber soils studied can be categorized into two groups where Homagama and Parambe was fallen into one group and Agalawatta and Boralu was fallen into another group.

In addition, Calcium availability also significantly higher in Parambe soils than in other soils (Table 36).

Table 36. *Some chemical characteristics of rubber growing soils*

Soil series	pH (KCl)	pH (CaCl ₂)	Tot. N%	Tot. P ppm	Tot. Mg ppm	Avai. Ca ppm
AGALAWATTA	4.0482 ^B	3.7600 ^B	0.1531 ^A	213.01 ^B	57.9 ^B	184.13 ^B
HOMAGAMA	3.9587 ^B	3.8008 ^B	0.1677 ^A	190.44 ^B	683.1 ^A	183.02 ^B
PARAMBE	3.4583 ^C	3.6267 ^C	0.1478 ^A	343.97 ^A	881.3 ^A	450.91 ^A
BORALU	4.4753 ^A	3.9978 ^A	0.1067 ^B	241.02 ^B	70.4 ^B	208.64 ^B

(Mean values with similar letters are not significantly different at P 5% level)

Variation in some chemical characteristics in relation to horizons of rubber growing soils

Soil acidity measured by using 0.01M CaCl₂ was significantly lower in B horizon of all the soil series than in A horizons (P < 0.05).

A horizon of all the rubber soils contained significantly (P < 0.001) higher amount of total N than B horizon. But this was observed in the opposite way in relation to total sulphur content showing that B horizon consisted with higher amount than A horizon (Table 37).

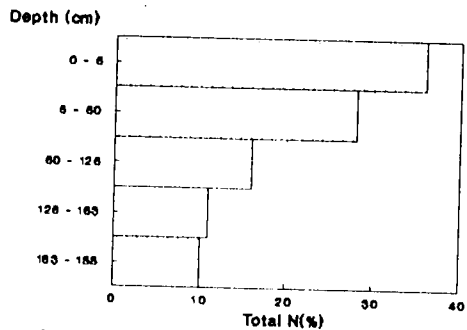
Table 37. *Variations in some chemical characteristics in relation to horizon of rubber growing soils*

Horizon	Mean values		
	pH (CaCl ₂)	Tot. N	Tot. S
A	3.7492 ^B	0.1914 ^A	292.59 ^B
B	3.8435 ^A	0.0962 ^B	394.70 ^A

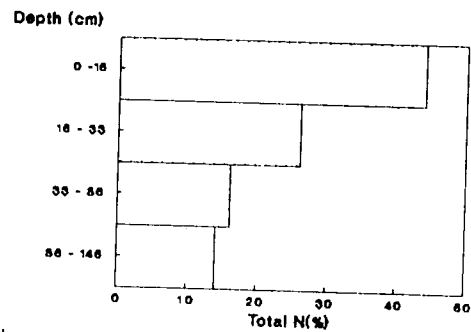
Profile distribution of nutrients in different rubber soils

Total nitrogen contents of different rubber soil series were generally decreasing along the soil profile. Also, it was observed that the top soil layer contained the highest amount of total nitrogen in all the soils series (Fig. 10).

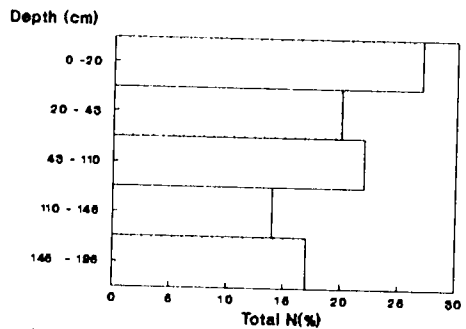
Total phosphorus contents were also generally decreasing along the soil profile except in Parambe series soil (Fig. 11).



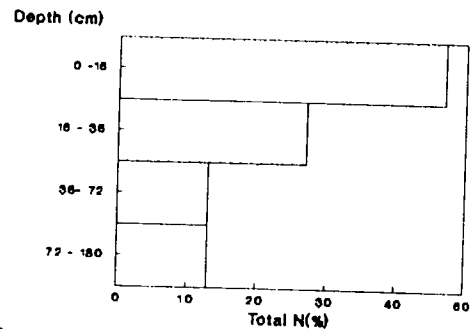
Boralu Series



Homagama Series

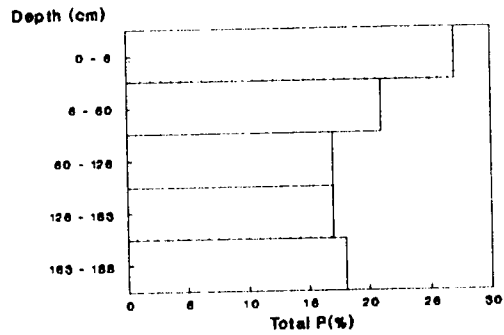


Agalawatta Series

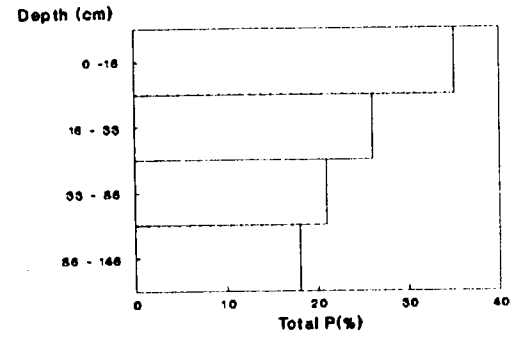


Parambe Series

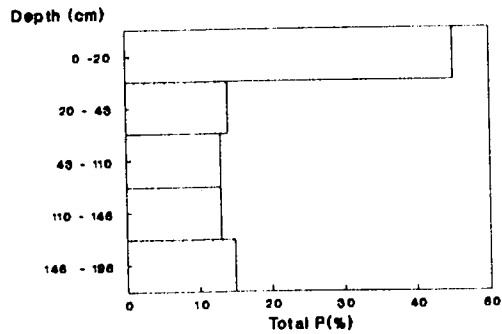
Fig. 10. Profile distribution of total Nitrogen



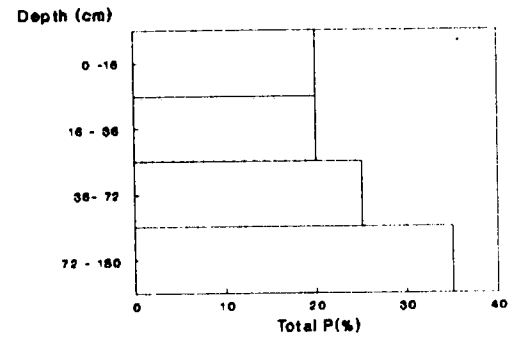
Boralu Series



Homagama Series



Agalawatta Series



Parambe Series

Fig. 11. Profile distribution of total Phosphorus

But when the total potassium contents of soil profiles was considered it was evident that it is generally increasing except in Boralu series soil (Fig. 12).

Total magnesium contents were generally increasing in Parambe and Homagama soils along the profile but it is generally decreasing in Agalawatta and Boralu series soils (Fig. 13).

Profile distribution of total sulphur indicated increasing trend along the soil profiles in all the soil series (Fig. 14) (A Dissanayake and C K Maheepala).

13. Chemical analysis

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).

14. Adaptive Research Programme

14.1 *Effectiveness of bush/tree legumes*

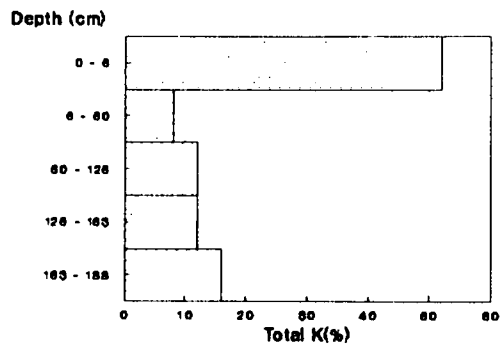
Experiments were started to compare the effectiveness of growing bush/tree legumes with the current practice of growing creeping legumes on soil and moisture conservation in smallholdings in Kalutara and Kegalle Districts (L Samarappuli, N Yogaratnam, S M M Iqbal and E A T Senadeera).

14.2 *Use of poultry manure*

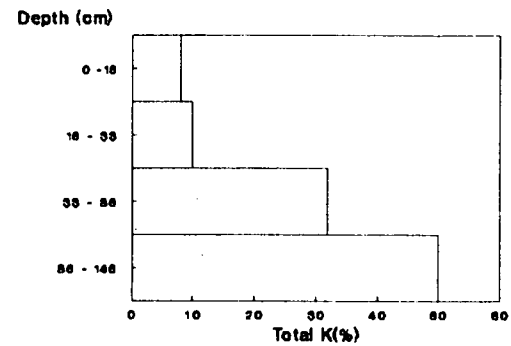
Use of poultry manure as a substitute for inorganic fertilizer in immature and mature rubber smallholdings is also being studied under Adaptive Research Programme (L Samarappuli, N Yogaratnam, S M M Iqbal and E A T Senadeera).

14.3 *Mulching with rice straw*

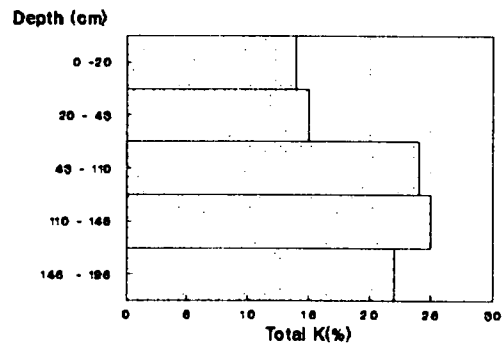
A new set of experiments was started to evaluate the effectiveness of mulching with rice straw in smallholdings (L Samarappuli, N Yogaratnam, S M M Iqbal and E A T Senadeera).



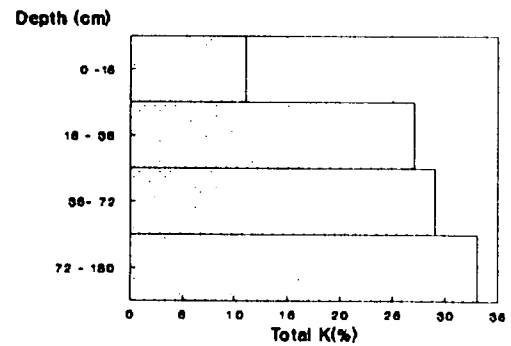
Boratu Series



Homagama Series

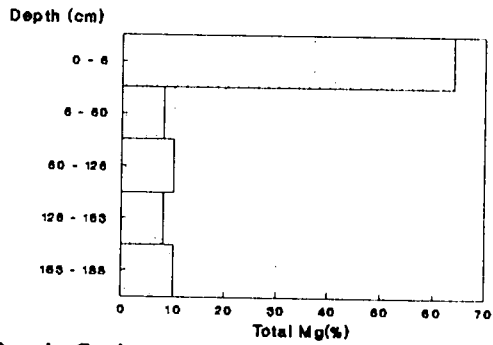


Agalawatta Series

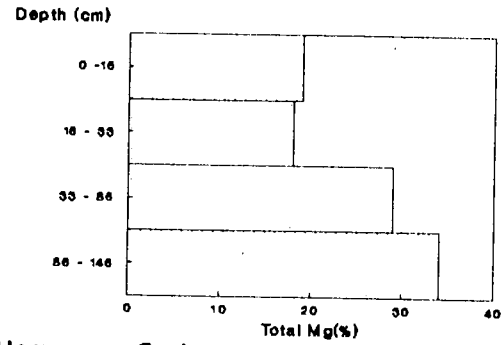


Parambe Series

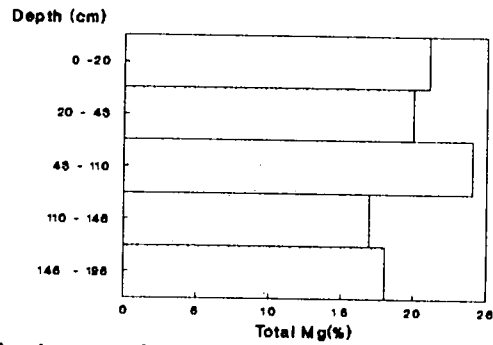
Fig. 12. Profile distribution of total Potassium



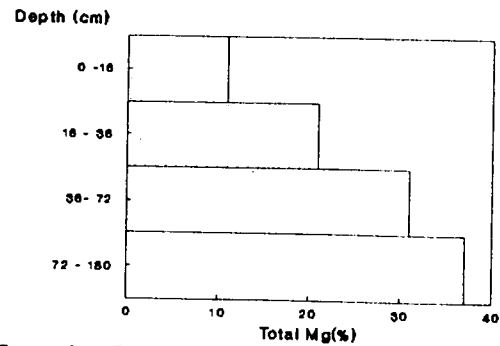
Boralu Series



Homagama Series

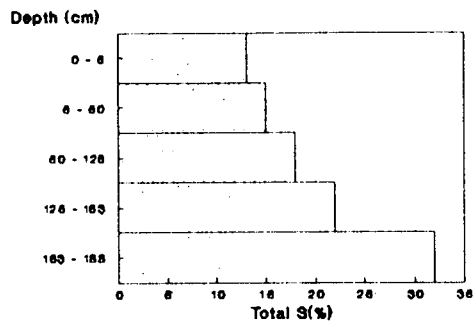


Agalawatta Series

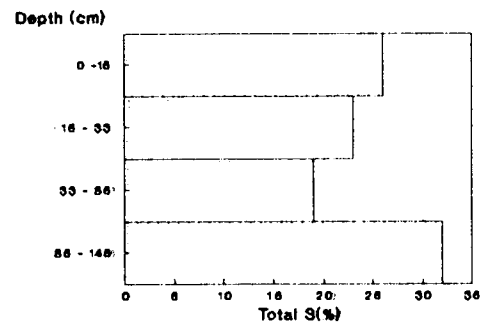


Parambe Series

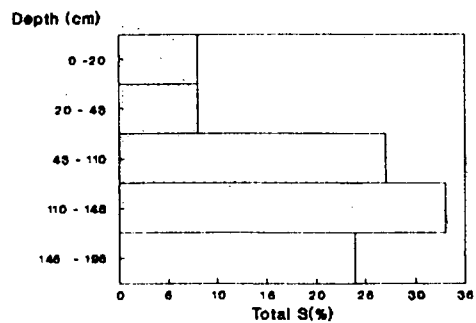
Fig. 13. Profile distribution of total magnesium



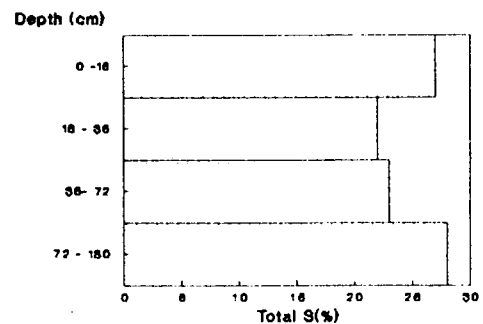
Boralu Series



Homagama Series



Agalawatta Series



Parambe Series

Fig. 14. Profile distribution of total sulphur

14.4 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).

14.5 Evaluation of ERP

Experiments started in smallholdings to evaluate the effectiveness of ERP and IRP mixture (50:50) on the performance of immature rubber were continued (A Dissanayake, N Yogaratnam, S M M Iqbal and Peter Perera).

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 research work of the department was mainly focused on treatment and utilization of rubber factory wastes.

DETAILED REVIEW

Staff

Mr M T Warnakula, Assistant Biochemist; Mr M D C Senevirathne, Miss K V V S Kudaligama, Mr D Ramawickrama, Technical Officers and Mr P D J Rodrigo, Specification Assistant were on duty in the year 1996. Mr M T Warnakula left for Australia in March to continue his post graduate studies and returned back in May. Mr M D C Senevirathne helped the Adaptive Research Unit in new program on interplanting Rubber with Tea.

LABORATORY AND FIELD EXPERIMENTS

Treatment and utilization of rubber factory waste

Experiments on treatment and utilization of rubber factory wastes were continued.

Rubber factory effluents as fertilizer

The experiments carried out at Culloden estate, Neboda, investigating the effectiveness of the rubber factory effluents as a source of fertilizer was handed over to the department of soils and plant nutrition, for further investigations.

Development of a new medium

Continued work on development of a medium using coconut fiber was successful. A new medium was developed for high rate biological waste water treatment. The medium is made out of coconut fiber, where the fiber is arranged in a mechanically stable, systematic way for holding optimum amount of active

microorganisms in both 'Anaerobic' and 'Aerobic' treatment reactors. This medium costs very much less than the other available media, but all ideal characteristics are necessary for high rate biological treatment. By using this medium it is possible to perform biological waste water treatment at much lesser cost than that of conventional systems (M T Warnakula, K V V S Kudaligama, D Ramawickrama, P D J Rodrigo).

An application was made for receiving patent rights for this medium.

A low cost system configuration

A low cost, full scale rubber factory effluent treatment system was designed for 'Rayigam' estate rubber factory and it was agreed to built and monitor the system in collaboration with M/S Puritas Ltd.

The major part of the system is confined to several covered earthen ditches. This system configuration is an adaptation of covered anaerobic lagoons. In addition to covered anaerobic lagoon system, for increasing the reactivity and the treatment efficiency per unit volume of the ditches, previously mentioned medium is arranged in the ditches. Because of the increased treatment efficiency the required volume of the ditches is reduced. The ditch configuration is adapted to suit to the topography of rubber plantations of Sri Lanka where flat land for a lagoon is hardly available. If necessary one can lay these kind of ditches in contours in a hilly land. The ditch configuration also over comes several inherent drawbacks of lagoon systems (M T Warnakula, K V V S Kudaligama, D Ramawickrama, P D J Rodrigo).

A possibility of reducing the waste volume

Studies were continued successfully to investigate the possibility of reducing the volume of crepe rubber factory effluents without affecting the quality of the rubber. The objective of this reduction of the waste volume was to reduce the transport cost of waste, if a central treatment system for several factories are built or if the wastes are used for making an other product. The aim was to limit the waste only to the volume of serum in the coagulating tanks and in the coagulum. Serum of the coagulating tanks was used to sprinkle at the maceration step instead of using fresh water. From the next step onwards normal procedure was followed and the waste levels of wash water from the entire process was found to be bellow the CEA limits.

The produced crepe rubber was compared with the crepe rubber produced by the normal method from the same batch. The comparison was conducted chemically for selected non rubber serum solids remaining in rubber and visually by the experienced graders of rubber of a leading rubber broker company in Sri Lanka. No

significant difference between the two products at 0.05 confidence level was observed in chemical analysis for remaining serum solids and no difference was observed in the comparison done by professional grade. This is a good indication of the possibility of reducing the waste volume, but it is necessary to investigate further, before making a recommendation (M T Warnakula, K V V S Kudaligama, D Ramawickrama, P D J Rodrigo).

A new medium for growing antagonistic fungi

Collaborative work with the Department of Plant Pathology and Microbiology was commenced, 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).

Trouble free coagulation of skim latex with organic acids

Experiments were conducted to ensure trouble free coagulation of skim latex using organic acids. The objective of this experiment was to avoid usage of sulphuric acid in coagulation process in order to get the produced waste with lesser amount of sulphur. If the waste is with low sulphur level, it can be treated in a low cost anaerobic system, easily (M T Warnakula, K V V S Kudaligama, D Ramawickrama and P D J Rodrigo).

Coagulation of latex for RSS using skim serum

Experiments were conducted for coagulating latex using skim serum for small scale domestic RSS manufacture. Normal practice in coagulating latex is to use extra sulphuric acid there by lowering pH to very low levels in the mixture. The pH of this serum produced is low enough to coagulate a fresh latex batch when mixed in certain proportions. The quality of the RSS produced using the coagulant should remain unaffected if the exponent is a success. The objective of this is to disperse the waste in small quantities there by minimizing damage to the environment (M D C Senevirathne, K V V S Kudaligama, D Ramawickrama, P D J Rodrigo and M T Warnakula).

An RSS-grade of rubber with skim latex

Experiments were conducted for developing a coagulating technique for skim latex for small-scale manufacturing of RSS type rubber. The objective of this is to

generate self employment opportunities to unemployed people while distributing the waste in small quantities where the waste can be treated in a low cost in small treatment systems (M T Warnakula, K V V S Kudaligama, D Ramawickrama and P D J Rodrigo).

Coir-coirdust mat bound with skim rubber

Experiments were carried out to produce a Coir-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 making a valuable product where the serum is not separated as a waste (M T Warnakula, K V V S Kudaligama, D Ramawickrama and P D J Rodrigo).

RUBBER TECHNOLOGY AND DEVELOPMENT

N M V Kalyani Liyanage

SUMMARY

A road trial with a latex/bitumen emulsion prepared by using a positex modified with a colloidal stabiliser was successfully completed.

Irradiated latex films with improved technological properties were produced after proper calibration of the radiation source.

Room temperature curing NR latex compound suitable for coating of coir mattings was developed. There seems to be a big market for these coir mattings in Japan.

Two latex compounds suitable for carpet underlinings were developed.

A few latex foam compounds suitable for making latex foam masks were developed.

Two latex casting compounds suitable for making ornamental coir brushes were developed.

A dry rubber based compound ideal for the manufacture of feet of artificial limbs was developed.

DETAILED REVIEW

Dr (Mrs) N M V Kalyani Liyanage, Head, Rubber Technology and Development Department 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 proceeded to Takasaki Radiation Chemistry & Research Establishment, Japan for a one year training programme on Radiation Pre-vulcanisation of Natural Rubber Latex on September 1996.

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

Research students

Miss Sandamali Weerakoon, NDT student was trained on various aspects of Latex form rubber manufacture.

Meetings, Seminars and Lectures

Dr (Mrs) N M V Kalyani Liyanage and Mrs Madupani Jayasooriya participated in the following:

Committee meetings of the Sri Lankan Research group on "Radiation Pre-vulcanisation of Natural Rubber Latex" held at the Atomic Energy Authority.

Progress control meetings of the Road Development Authority to discuss the work on Latex/Bitumen project.

Central Scientific Committee meetings of the RRI.

An Industrial exhibition organised by the Industrial Development Board held at the BMICH.

A seminar on "Implementation of ISO 9000 in Crepe Rubber Factories" organised by the RRISL held at the Hotel Taj Samudra on 2nd August 1996.

A committee meeting of "Polymers and Polymer Products" held at the Sri Lanka Standards Institution on 2nd August 1996.

Inauguration of ANRPC meeting of Rubber producing Countries held at Hotel Sinbad, Kalutara on 16th July 1996.

A course on "Rubber Products Manufacture" held at Daraniyagala electorate organised by the Central Bank, Matale on 24th and 25th November 1996.

A workshop on the "Process and quality control in Radiation Processing" held at the Takasaki Radiation Chemistry and Research Establishment, Japan in August 26-30, 1996.

Training Programmes

A training course on "Rubber Products Manufacture" was successfully conducted at the Daraniyagala Maha Vidyalaya for above sixty trainees selected from Daraniyagala Electorate by the Central Bank, Matale on 24-25 November, 1996.

LABORATORY INVESTIGATIONS

1. Latex Technology

1.1 *Latex bitumen emulsion in road construction*

A batch of 5000 litres of latex/bitumen emulsion was prepared at the emulsion plant of Road Construction and Development Company by using a positex modified with a colloidal stabiliser. However, some clogging of the emulsion was observed in the emulsion distributor during the application of the batch in a sand sealing. Therefore, it was decided to perform the sand sealing manually for this particular batch. The service performance of the sand sealing was found to be good.

A second batch of 800 litres of latex/bitumen emulsion was prepared by using the same type of latex and no practical problems were experienced during the application in a sand sealing with an emulsion distributor. Performance characteristics of this trial were also found to be good (N M V Kalyani Liyanage, Madupani Jayasooriya, Manel Mahanama and Sriyani Yapa).

1.2 *Radiation prevulcanisation of Natural Rubber Latex*

The Head, Rubber Technology and Development Department was given an opportunity to attend a workshop on the "Dosimetry Practices in Quality Control in Radiation Processing" held at the TRCRE, Japan Atomic Energy Research Establishment. The importance of adapting proper dosimetry practices in radiation processing was discussed at length at this workshop. As such, it was felt that the poor physical properties observed for RVNRL films may be due to an error in the calibration of the radiation source. A proper calibration was done using some Ceric/Cerous dosimeters obtained from Ansells Lanka Limited. A new set of irradiated latex films was prepared and the physical properties of the films were found to be improved (N M V Kalyani Liyanage, Manel Mahanama and Samantha Kulatunga (Atomic Energy Authority).

1.3 *Room temperature curing compound for coir mattings*

A cost effective NR latex compound suitable for coating of coir mattings was developed to meet a request made by an industrialist. It was informed that these coir mattings were produced to meet an export order made by Japan. The formulation suggested by us was said to be very good for this application (N M V Kalyani Liyanage, Manel Mahanama and Sriyani Yapa).

1.4 *Latex compounds for carpet underlinings*

Two latex compounds suitable for carpet underlinings were prepared to meet a request made by Chemanex Limited (N M V Kalyani Liyanage, Sriyani Yapa and K M U Mithrananda).

1.5 *Latex foam based masks*

A request for a suitable formula was made by an individual who was very enthusiastic in making foam based masks to be used in documentary films made by Nature Foundation. A few small scale trials have produced very satisfactory results (N M V Kalyani Liyanage and Manel Mahanama).

2. Dry rubber technology

2.1 *Variation of cure-behaviour of dry rubber compounds*

It was informed by one of the leading shoe manufacturers in the country that the cure behaviour of rubber compounds used in foxing tapes of their canvas shoes varies at times with no change in the compound formula. A few trials were carried out to identify the cause for the problem and some measures for perfecting the processing conditions were suggested (N M V Kalyani Liyanage and Manel Mahanama).

2.2 *Cure behaviour of sheet rubber*

Preliminary studies have been carried out to evaluate the effects of smoking on the rheological and technological properties of natural rubber vulcanisates. Previous studies based on gum compounds indicated that the smoking process of sheet rubber has a significant effect on the cure rate of gum compounds especially at low curing temperatures. However, it was found that this effect could be minimised or even eliminated by using a conventional vulcanising system for vulcanisation of rubbers which were subjected to different smoking periods. As a result there are not any significant differences in rheological and technological properties of NR vulcanisates based on sheet rubber prepared by varying the length of smoking period (L M K Tillekeratne, Madupani Jayasooriya, K M U Mithrananda and Sriyani Yapa).

2.3 NR based compounds in making artificial limbs for disabled soldiers

A request came from "Ranaviru Sevana", Ragama, for a suitable NR based compound to prepare feet of artificial limbs used by the soldiers who were disabled at the war front. A few trials were conducted and one NR based compound was found to produce a feet of much lighter weight. A large batch of this compound was prepared and was sent for further trials (N M V Kalyani Liyanage and K M U Mithrananda).

Industrial Extension

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

Lanka tyre Retreaders	Testing of tread and cushion gum compounds
Midland retreads (Pvt.) Ltd.	Testing of raw rubbers
Road Development Authority	Testing of latex/bitumen emulsions
Associated Motorways Ltd.	Testing of tread compounds
Helanka Horticulture	Testing of chemicals
D. Samson Industries	Testing of chemicals
Microcells	Preparation of various test pieces
Kandy Tyre House	Testing of cushion gum compounds
Rathnayake Rubber Industries	Testing of tread compounds
Ceytra Limited	Testing of rubber bands
Ceyesta	Testing of latex compounds
Atomic Energy Authority	Testing of latex gloves
Sri Lanka Standards Institute	Testing of tread compounds
Various small industrialists	Advice on latex compounds, moulded rubber articles <i>etc.</i>

POLYMER CHEMISTRY

K G Karnika de Silva

SUMMARY

Preparation of ISO 9000 Quality Manuals for ten plantation companies and for the Dartonfield Estate. Agalawatte received high priority. These quality manuals which consist of 73 pages describe the steps to be taken by the management to maintain the quality of latex and raw rubbers produced in the rubber factories. All the necessary steps to implement the documented process for quality improvements, maintenance *etc.* are discussed under 20 main headings.

Analysis of latex proteins in rubber gloves using Bradford Assay and elastomer and bloom analysis and chemical purity using FTIR Spectrophotometer were carried out for various industries.

Several samples of conductive rubbers were prepared and tested to match conductive rubber pads used in muscle toning machines developed in UK. These machines consist of 10 such conductive rubber pads and the IDB has undertaken commercial scale compounding using the formulation developed by this institute. The machines are being sold locally and the manufacturer has received foreign orders too. Semi-commercial scale batches of MG rubber were prepared for C W Mackie for export and Chamara Products for fabrication of large rollers used in the printing industry. A royalty payment was made to this Institute for using the patented process in this manufacture. Controlled release fertilizer encapsulates were tested in water and soil in different conditions to study the efficiency of membranes based on natural rubber and coir dust. The Soils and Plant Nutrition Department is conducting the field trials and study their effectiveness.

A project report on rubber wood was prepared and submitted to Diriya Foundation and Woodman Exports (Pvt.) Ltd. and several small industrialists were advised on technical matters relating to rubber wood treatment and on setting up of treatment plants.

A suitable formulation for wood filling was developed and handed over to Sinwa (Pvt.) Ltd. for possible commercialization. The preparation of briquettes using waste material such as saw dust, coir dust and non toxic binders was done on a request made by a plantation company. These briquettes are to be used in drying of tea leaves in place of fire wood in the factories. Use of Epoxidised Natural Rubber (ENR) in adhesives has been looked into. Adhesives prepared from ENR showed good bonding in rubber to cotton adhesion in the shoe industry.

A new self - adhesive type latex based rainguard (sticker) was developed. Work on preparation of Constant Viscosity rubber by the latex method was continued. Positex and high viscous Bitumen emulsion were blended in different ratios to obtain a smooth finish as a water proofing paint. Samples with good surface finish and low drying time were sent to a manufacturing firm for evaluation.

A latex based formulation for the manufacture of biodegradable shopping bags was developed and handed over to an interested party for commercial implementation. The trials have been successful and the commercial production will commence in 1997.

DETAILED REVIEW

Staff

Dr K G Karnika de Silva, Head of the Polymer Chemistry Department and Dr Pushpa Goonetilleke, Rubber Chemist were on duty throughout the year. The services of Mr S M C E Silva, Assistant Rubber Chemist was terminated with effect from May 96 for not returning to the country at the end of approved leave period. Mr H N K K Chandralal, Experimental Officer was on no pay leave in Saudi Arabia.

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

Mrs Chitra Kuruppu, Senior Technical Officer returned from India in May 1996 after a period of training at RRI, India, on a partly funded IRRDB project. Mr S L G Ranjith, Technical Officer was on no pay leave in Saudi Arabia.

Mrs Renuka Wijeratna, Clerk/Typist, Messes S Weerasiri and P R Sigera, Laboratory Attendants and Messrs L L Piyasena and W D S Dharmawardena, Laboratory Labourers were on duty throughout the year.

Seminars/Lectures/Meetings

- * Dr K G Karnika de Silva served as a lecturer for third year undergraduate students on Industrial Polymers at the University of Colombo, Affiliated University students and for the NIPM course. She also served as a moderator for Kotalawela Defence Academy.

Dr K G Karnika de Silva participated at the followings.

- * Two Scientific Committee meetings
- * Seminar on implementation of ISO 9000 in Crepe Rubber factories

- * Seminar on Research on NARESA awards at NARESA
- * Seminar on Polymers for Sri Lankan Industries held at the University of Colombo
- * Inauguration of An Industrial exhibition Organized by IDB at the BMICH.
- * Inauguration of ANRPC meeting at Sindbad Hotel Kalutara
- * Two committee meetings on ADB Funding for Polymer Technology held at the CISIR
- * Two day workshop on commercialization of R&D results held at Hotel Taj Samudra from 18 - 20 Sept. 1996.
- * Meeting with consultants and officers from Elston Estate about the possible cost reduction in rubber processing.
- * Discussion with officials and consultants from Woodman Lanka on Rubberwood utilization for BOI approved project.
- * Discussion with Mal Lanka Officers about poor adhesion of NR latex and coir fibers.
- * Two day workshop on Scientific Writing held at the SLAAS
- * Seminar on ISO 9000 organized by the PRI.
- * Discussions on ISO 9000 with SLSI Officers
- * Delivered a lecture on the Small and Medium Scale Rubber Industrialists at Sausiripaya.
- * Dr Pushpa Goonetilleke served as a lecturer for MSc students on Analytical Chemistry at the University of Colombo and for NIPM course and as a moderator for Kotalawela Defence Academy.

Dr Pushpa Goonetilleke participated at the followings.

- * Two Scientific Committee meetings
- * Seminar on implementation of ISO 9000 in Crepe Rubber factories
- * Seminar on Research on NARESA awards at NARESA.
- * Seminar on Polymers for Sri Lankan Industries held at the University of Colombo.

Conductive natural rubber

Development of conductive natural rubbers used in muscle toning machines was done on a request made by a foreign collaborator who wanted to match a British product. Several samples of conductive rubbers were prepared and tested for their

conductivity by using an ameter. The most suitable formulation to achieve the required conductivity was obtained with 60 phr of a conducting filler in the sample.

The machine consists of 10 such conductive rubber pads and the IDB has undertaken the commercial scale compounding using the formulation developed by this institute. The machines are being sold locally at a competitive price and the manufacturer has received a foreign order from Indonesia for 2000 such machines. A report on the non-toxicity of the product was also issued (K G Karnika De Silva and S S Warnapura).

Slow release fertilizers

Experiments on slow release fertilizers were continued. The advantages of using these are to minimize wastage, possible pilferage, adulteration and labour costs and to provide a steady supply of nutrients to the plant.

Slow release effect on fertilizers through polymeric membranes and composites were continued in water and soil. Over 150 samples of slow release fertilizer encapsulates were tested in water and soil under different conditions to study the efficiency of membranes based on natural rubber and coir dust. The trials were extended to the field and done in collaboration with the Soils and Plant Nutrition Department.

A paper titled "Controlled Release of Nutrients through Membranes based on a NR Coir Dust" was presented at the IRRDB meeting held in November 1996 (K G Karnika de Silva, Lalani Samarappuli, Indra Denawake and Medhavi Wijesekera).

ISO 9000

Eleven ISO 9000 Quality Manuals were prepared and distributed among the plantation companies who have paid the initial payment of Rs.10,000. The quality manual prepared for Dartonfield factory has been forwarded to SLSI for evaluation. A workshop on Implementation of ISO 9000 was organized for the senior management of plantation companies to educate them on how to implement ISO 9000 in the factory floor. Over 60 persons from Plantation Management Companies actively participated in this workshop. Officials from SLSI and from the private sector delivered lectures on different aspects and talked on their experiences on implementing ISO 9000 in factories (K G Karnika de Silva and P P Jayasinghe).

Epoxidized natural rubber (ENR)

Methods on the preparation of epoxidised natural rubber was perfected. Commercial implementation of this specialty rubber is under investigation. Use of

ENR as a footwear adhesive was evaluated. Two types of adhesives were prepared with pure gum rubber and vulcanisable rubber of ENR and RSS by dissolving in a solvent mixture. Adhesives were tested by means of Rubber to cotton, Rubber to Rubber and Rubber to PVC at 180°C peel test using the tensile tester. Vulcanisable ENR adhesives show highest peel strength in Rubber to cotton system for buffed and smooth surfaces. A sample of vulcanisable adhesives was given to Bata Shoe Company for testing.

Adhesives prepared from ENR with different amounts of Cumerone Indene (CI resin) were compared with an adhesive obtained from Bata Shoe Co. The peel strength of the ENR adhesive containing CI resin was found to be superior to the adhesive obtained from Bata Shoe Company.

Several samples of ENR 25 and ENR 50 were prepared and characterized by NMR and FTIR spectroscopy. Use of ENR in a tyre tread formulation was also evaluated. The properties of ENR compounds in semi EV, EV and conventional vulcanizes systems have been tested.

Further experiments are underway to compare the properties of ENR based adhesives with commercially available footwear adhesive (Pushpa Goonetillke, Ruwanthi Athukorala (NDT student) and Ananda Samarakoon).

Constant viscosity rubber

CV 60 rubber was prepared by the procedure adapted in the previous experiments. Drying of the samples were carried out at C W Mackies factory, Nathupana. Drying time employed for the rubber prepared in the factory is too high for the experimental samples as the samples tend to overdry. Hence we had to fabricate a special unit to place the rubber coagulum in hot air oven for drying under control.

Physical properties of CV rubber prepared by the latex method was evaluated in comparison to SMR5 using ACS1 and tread mix formulations. In the ACS1 compound the tensile strength of CV rubbers were found to be higher than the conventional rubber before and after ageing for two weeks. Hardness values were comparable in both samples. In the tread compound, CV rubber shows very good physical properties such as tensile strength, elongation at break, modules at 300% and 600% before and after ageing (Pushpa Goonetillke, Chithra Kuruppu and A Samarakoon).

Rubber wood and wood fillers

A project report on rubber wood was prepared and submitted to Diriya Foundation and Woodman Exports (Pvt) Ltd. and several small industrialists were advised on matters relating to rubber wood treatment. A suitable formulation for wood filling was developed and handed over to Sinwa (Pvt.) Ltd. for possible commercialization (K G Karnika de Silva and S S Warnapura).

Utilization of waste materials

Use of waste materials such as saw dust, coir dust and buffing dust from retreading industry in useful applications were under study. Trials on the preparation of briquettes using saw dust, coir dust and non toxic binders were successful. These were made on a request made by a plantation company for drying tea leaves in place of fire wood (K G Karnika de Silva and S S Warnapura).

MG rubbers

A large batch of MG rubber was prepared at Dartonfield on a request made by a customer. The rubber has been tested and used in fabricating large rollers used in the printing industry. The required specifications such as hardness without much fillers added could be achieved by using MG rubber. Two semi-commercial scale batches of MG 30 and MG 45 rubber were prepared and handed over to C W Mackies (Pvt.) Ltd. for export. A royalty payment was also included in the payment made to this institute (K G Karnika de Silva, S S Warnapura and A Samarakoon).

Bloom analysis/ageing of rubber thread

Analysis of bloom on a rubber mat sent by microcells Ltd has been studied and a report has been sent for necessary action. Ageing behaviour of rubber thread has been studied and the samples have been handed over to Palma (Pvt) Ltd.

Bloom analysis of rubber products for Microcells Chemicals Analysis for DSI and Mal Lanka, ageing properties of rubber thread for Palm (Pvt.) Ltd. and elastomer analysis for IDB and Prasanna Cushion Works have been studied (K G Karnika de Silva, S A Pushpa Goonethilleke and Indra Denawake).

Rubberized coir pads

Factory visits were made to Mal Lanka (Pvt) Ltd to solve a problem of poor adhesion of natural rubber latex to coir fibers. The procedure of mixing certain

chemicals into latex seemed to be incorrect. Some fillers were found to be stirred as powders in to latex but not ball milled. Also these chemicals are added to latex without any dispersing agent. Compounded latex used in some occasions was found to be prevulcanised. The coir pads are cured at high temperature for 11/2 hours and this long curing time could result in reversion of crosslinking. Suitable modifications were suggested for improving the quality of the rubberized coir pads used for mattresses *etc.* (K G Karnika de Silva and Chithra Kuruppu).

Adhesives

Adhesives to laminate PVC sheets to MDF boards manufactured using rubber wood chips and dust were tested for Malindu Timber (Pvt) Ltd. NR based tar mastics were found to be suitable adhesives for this purpose. Several adhesives samples from Sinwa Adhesives Ltd. were tested (K G Karnika de Silva, S S Warnapura and A Samarakoon).

Latex properties and applications

Evaluation of latex properties on storage has been done in order to monitor the behavior of latex properties with time. A rubberized latex - bitumen paint has been developed for water proofing applications. Technique of preparation of creamed latex using tamarind seeds is under investigation. A new formulation based on NR latex for fabric coating was developed and technical know how was passed on to The In's System for commercialization. The production will commence in the 1st quarter of 1997. Experiments on preparation of Constant Viscosity rubber (CV rubber) from NR latex was continued.

Latex for printing

Suitable formulations have been tested as suitable base for printing of textile bags using screen printing techniques. Same formulations have been used to get a smooth and stiff texture used for application on textiles used for bag making. This research was initiated on a request made by a young inventor who is keen in promoting biodegradable shopping bag manufacture as a cottage industry (K G Karnika de Silva and Chithra Kuruppu).

Rubberized/bitumen for water proofing

Positex and high viscous Bitumen emulsion were blended in different ratios to obtain the correct finish as a water proofing paint. The sample with good surface finish and low drying time was chosen and a sample out of the same composition was sent to Lankem Ltd. for their evaluation (Pushpa Goonetilleke and Chithra Kuruppu)

Variation of latex properties during storage

(a). The LATZ samples incorporated with a viscosity stabilizer and an antioxidant were stored for upto 18 weeks and gel content was determined. Results show that the antioxidant has no control on gel formation in this particular experiment while the viscosity stabilizer, HNS reduces the gel significantly. Further experiments are underway to monitor this behaviour of latex (Pushpa Goonetilleke, Indra Denawake)

(b). The effect of storage of different lattices LATZ and HACL on prevulcanisation has been studied. The properties such as gel content and viscosity of latex were evaluated in two weeks time intervals for both lattices followed by prevulcanization and the tensile properties will be evaluated (Pushpa Goonetilleke, Indra Denawake and Anuja Ratnasekera-NDT student).

Creaming of latex

Research on the use of tamarind seed powder as creaming agents for natural rubber latex has commenced. This was initiated as a result of the knowledge gained by Mrs W C M Kuruppu on a recent visit to RRII on a training course. Initial trials have shown separation of rubber and aqueous layers within an hour of addition of tamarind seed extract into field latex. Further studies are underway in this project (K G Karnika de Silva and Chitra Kuruppu).

Industrial extension

IDB	Elastomer Analysis, MG Rubber
Mal Lanka	Elastomer Analysis, foam pads, coir pads
Palma (Pvt) Ltd.	Ageing and heat resistance and elasticity of latex thread
Bata Shoe Co.	Adhesives

Sinwa Holdings Ltd.	Adhesive Solvents. adhesives
Plantation Companies	ISO 9000 Quality Manuals
Private Companies	Rubber Wood
Charama Products	Rollers with MG Rubber
Prasanna Cushion Works	Elastomer Analysis
Textrip	Latex film properties
Richard Peries	Analysis of Foam Rubber. Dipped Products.
Lalan Rubbers (Pvt) Ltd.	Latex Protein Analysis
Slim Quest	Conductive Rubbers
C W Mackies	MG Rubber
Woodman Lanka	Rubber Wood
Malindu Timber Works	Adhesive for Wood

RAW RUBBER AND CHEMICAL ANALYSIS

L M K Tillekeratne

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 (*eg*: 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 rain guard sealant for smallholders, and officers of the Rubber Development Department.
- i. Assistance was rendered to other departments in their research and extension work by analysing dry rubber, latex, chemicals and water samples.
- j. The following research projects were in progress:
 - * Sealant for rainguards.
 - * Evaluation of raw rubber and latex properties of currently recommend clones.
 - * Production of briquets out of saw dust for fuel purposes.

- k. Services were rendered to eliminate problems such as adulteration of raw rubber with skim rubber and contamination of iron in water soluble bleaching agent.

DETAILED REVIEW

Staff

Mr L Karunanayake, Assistant Specifications Officer, returned to the country on 29th April 1996, after completing the practical part of his PhD project at the University of North London, UK and continued writing of his PhD thesis, thereafter. Since then he continued to be the Officer in Charge of the Department.

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, Mr Gamini Wanigatunga, Mr P L Perera, Mr Mahesh Gamage and Mr P Lelwela, Instrument Technician were on duty throughout the year.

Mrs Champa Lokuge, Technical Officer, who was on no-pay leave resumed duties on 8th April, 1996.

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

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

Mr Sirisena Gallage, the Laboratory Attendant and Mr G H Somasiri, Laboratory Labourer were on duty throughout the year.

Mr J A Dayaratne, Laboratory Labourer was transferred to Rubber Technology Dept., with effect from 3.10.96. Mr Piyatissa Vithanage, Laboratory Labourer, resumed duties on 3.10.96.

Workshop

Mr P L Perera attended a one day work shop on productivity and machinery maintenance organized by Plastic and Rubber Institute.

Meetings, Seminars and Lectures

Mr Laleen Karunanayake participated in the following:-

- * Committee meeting of the National Laboratory Accreditation Committee of the Sri Lanka Standards Institution.
- * Two Committee meetings on Standardization of Metrolac ready reckoner chart. organized by SLSI.
- * Presented a paper on RVNRL at the IRRDB conference.
- * Delivered a lecture on manufacturing of rainguard sealant in a workshop organized by Central Bank Matale branch for recipients of "Surathura" Loan Scheme.

Training

The following Officers and students. were trained on latex and raw rubber testing:

Organization	Name
Department of Chemistry University of Colombo	Miss R S Weragala Miss T K W T P Premaratne
Associated Speciality Rubbers (pvt) Ltd	Miss Udeni Malkanthi Nikapitiya Mr A K S Thajin
Wendale Estate Ruwanwella	Mr W G K Seneviratne Mrs W A Indrani Dayalatha
Ansell Lanka (pvt) Ltd., Paiyagala	Miss B T D Perera

LABORATORY INVESTIGATION

Sealant for rainguards

Island wide educational and demonstrational campaign was continued to educate the smallholders on the method of manufacturing rainguard sealant developed by this department (L M K Tillekeratne, Nimal Karunatileke and W Vithanage).

Evaluating the raw rubber and latex properties of currently recommended clones

Experiments and surveys were carried out to evaluate the properties of clones such as RRIC 100, RRIC 102, RRIC 121, RRIC 103, RRIM 600, RRIC 160, PB 217 and PB 28/59. Collection of data was concluded. The analysis of data is being continued (W M G Seneviratne, L Wanigatunga, P L Perera and C Senanayake).

Manufacturing of briquets out of saw dust

Cylindrical briquets were prepared by incorporating 8% starch with saw dust and by applying pressure to reduce the volume four times. These briquets can be packed easily utilizing a small space and thereby transportation cost can be reduced remarkably. These briquets can be utilized in place of fire wood as a less expensive alternative (L M K Tillekeratne, P L Perera and N Karunatileke).

Electrically controlled filling and auto zero adjustable attachment for burettes used in non aqueous titration

An electrically controlled filling and auto zero adjustable attachment for burettes has been invented.

The filling of the burette with the titrant is carried out with a simple vibration type compressor pump attached to a capillary tube. The same capillary tube is used to set zero of the burette attached, by using the gravitational force to remove the excess amount of titrant remaining above the zero point of the burette. Any type of glass burette can be used with this attachment since the auto zero adjustable facility which can be moved vertically is not fixed to the burette. An application for patent has been submitted for this innovation (P L Perera).

Inspection visits

Inspection visits were made to Shermans Block Rubber Factory, Ceymac Block Rubber Factory and Statcon Block Rubber Factory (P L Perera, G Wanigatunga, M Gamage and N Karunatileke).

Analytical service

Table 1. *Number of samples tested from each TSR factory*

Producer	No. of samples
Statcon Block Rubber Factory, Getahetta	1825
Sherman Block Rubber Factory, Ingiriya	1405
Ceymac Block Rubber Factory, Horana	3602
Total	6832

Table 2. *Miscellaneous samples tested from each TSR factory*

Rubber samples	677
Latex samples	221
Chemical samples	233
Master batch samples	425
Gloves samples	38
Water samples	14
Polythene samples	05
Total	1613

RAW RUBBER PROCESS DEVELOPMENT AND CHEMICAL ENGINEERING

W M G Seneviratne

SUMMARY

Effluent treatment plant based on anaerobic/aerobic treatment principle installed at Dartonfield to treat the raw rubber processing waste water generating from the factory has already proven its success and cost effectiveness to treat rubber factory waste water. Organic matter removal in the region of 80-90% could easily be achieved from the anaerobic stage with nearly two days retention.

Remaining 10 to 15% organics are removed from the aerobic process using a efficient fine bubble aeration mechanism. As a result of high rate anaerobic digestion, cost involved in the aeration process is drastically reduced.

A low cost solar assisted green house type dryer has been fabricated for drying of RSS and Air Dried Sheets (ADS). Preliminary studies reveal that there is no significant impact on the physical properties of the rubber dried in this drying chamber. Further studies are underway to improve efficiency of the drying system.

Work on implementation of ISO-9000 quality assurance certification scheme for rubber factories was in progress through out the year. Revised procedures and quality manuals for two crepe rubber factories were completed. Final assessment studies in those factories were being carried out in view of obtaining the ISO 9000 accreditation.

As one of the main functions of this department, Advisory services were provided to raw rubber manufacturing industries to help them to overcome their day to day problems related to rubber processing and quality of their products.

Staff

Dr W M G Seneviratne, Head of the department returned to the country on 24th July 96 and resumed duties at the RRI after completing his post doctoral study leave in CISIRO and RMIT, Melbourne Australia.

Mr Susantha Siriwardena, Assistant Rubber Chemist resumed duties on 1st April 1997 after successfully completing his post graduate studies at the University of Melbourne in Australia.

Mr Upul Ratnayake, Assistant Rubber Chemist was on duty throughout the year. Mr P P Jayasinghe, Development Officer was on duty throughout the year.

Mr P H Sarath Kumara, Experimental Officer and Messrs C D Senanayake, T A S Siriwardena and Mrs W K C Nalini, Technical Officers were on duty throughout the year.

Mr S Somasiri, Temporary Research Assistant and Mr K A D Sirimal and Miss S W Wijesuriya, Temporary Technical Officers were on duty in the department and worked on the effluent treatment project at Dartonfield funded by CARP. Mr Sirimal left the department in October, 1996.

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

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

Training

The following students from University of Moratuwa were undergone in-plant training at this department under the National Apprenticeship Board Scheme.

H N Vithanage	Eng. Student
M Yoheshwaran	Eng. Student
V Thangavadivel	Eng. Student
E T Kanapathipillai	Eng. Student
J A D S S Ranasinghe	NDT. student

Three undergraduate students from the University of Colombo under went two weeks training in the department.

Meetings, Seminars, lectures and training programme

The Head of the department participated in the following:-

- * A workshop on Research & Development Commercialisation organized by the Ministry of Science and Technology.
- * Two Scientific Committee meetings of RRB held at SLAAS.

Dr L M K Tillekeratne¹, Dr W M G Seneviratne², Mr Susantha Siriwardena³, Mr Upul Ratnayake⁴, Mr P P Jayasinghe⁵, Mr Sarath Kumara and Sarath Siriwardene⁷ participated in the following.

- * Two meetings with SLSI officials regarding ISO 9000 Quality Assurance Scheme.^{1, 4, 5 & 6.}

RAW RUBBER PROCESS DEVELOPMENT

- * A meeting at CEA organized by the Planters' Association to discuss the rubber effluent treatment and disposal problems and law enforcement with regard to same ^{4&6}
- * Delivered lectures on Manufacture of Concentrated latex for two batches of Rubber Development Officers. ⁶
- * Demonstration on rubber processing and manufacturing at Dartonfield rubber factory for three officers from Walahandura Laboratory ^{4&6}.
- * A meeting at Kalutara District Secretariat organized by National Youth Council to discuss the possibility of getting assistance from various institutions for vocational training for Youth in Kalutara area⁶
- * A seminar on effluent sampling and Analysis organized by Central Environmental Authority and held at CISIR. ^{4 & 6}.
- * Delivered lectures for a batch of planters who were following the 8th Diploma in plantation management conducted by National Institute of Plantation Management (NIPM) ^{2,3,4 & 6}
- * A seminar on ISO 9000 implementation organized by RRISL and held at Taj Samudra. ^{1,2, 3, 5 & 6}
- * A workshop on Research and Development work evaluated Indo - Sri Lanka Sub commission administered by the Ministry of Science and Technology. ^{2 & 3}
- * The Steering Committee on Energy at NARESA to discuss on the project on Bio - gas production ^{2 & 4}.
- * Delivered lectures on manufacture of centrifuged latex for 3 batches of Rubber Development Officers at the training centre at Matugama. ⁶
- * Two meetings to discuss on standardization of Metrolac chart at SLSI⁶
- * A demonstration on centrifuged latex manufacture at Glenross factory for a batch of planters who followed the Diploma course in Plantation Management conducted by the NIPM^{3,4}.
- * National seminar on Demand-side Management in Integrated Resource Planning organized by Ceylon Electricity Board at Hotel Taj-Samudra, Colombo^{2&3}.
- * Delivered lectures for a group of teachers from National Institute of Education to assist in preparing a teachers' Guide on rubber industry. This was organized by National Institute of Education in collaboration with Rubber Development Department^{3,6}.
- * Delivered lectures at the induction course for newly recruited Rubber Development Officers at Matugama Training Centre^{3,4,6}.

- * Delivered a talk on Effluent treatment and disposal for Gramasevaka Officers in Agalawatta AGA division on a request made by the Divisional Secretary of Agalawatta^{2&.6}.
- * Attended the meeting convened by the Director, RRI to discuss environmental pollution problems caused by rubber factory effluent and the measures to be adopted to solve the situation. The meeting was attended by the chief executives of plantation companies, A. S. P., M. O.H., Divisional Secretaries of the area^{4&.6}.
- * Training programme on rubber base products and related industries organized by the Central Bank for unemployed youths in Kegalle district at Sirisaman Vidyalaya, Deraniyagala ^{3.4.6}.
- * Conducted one day training programme on rubber grading and packing for seven officials from Aitken Spence Insurance (Pvt) Limited^{3.4.6}.
- * Conducted an intensive training course on RSS grading and packing for officers at co-operative societies in rubber growing areas in the country ^{2.3.4.6.7}.
- * Delivered lectures on promotion of sun drying and fuel substitutes and RSS manufacture for four batches of rubber Extension Officers ^{3.6}.
- * Energy Management group meeting organized by Ceylon Electricity Board held at Taj Samudra Hotel^{3.4}.

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. Five estates in Balangoda Plantation Limited-Ratnapura District. (Millawitiya, Paradise, Mahawilla, Galatura & Mutuwagala).
2. Neuchatel Rubber factory - Neboda.
3. Nakiadeniya Rubber Estate.
4. Narangoda estate -Palmadulla.
5. Paiyagala estate - Kalutara.
6. Pambegama Rubber Factory - Eheliyagoda.
7. Pallegoda estate, Matugama.

2. *Technical feasibility reports (submitted to the Rubber Development Department on setting up of centrifuged latex factories)*

1. Hewij centrifuged factory - Welipenna.
2. Kobowela estate - Govinna.
3. SRMC - Mawanella.
4. Shed Lanka Rubberized coir factory - Kadawata.

3. *Rubber effluent disposal systems*

Following rubber factories and other industries were visited to look into their waste water disposal problem. A suitable treatment method was forwarded after studying the effluent discharged from the factory.

1. Panawatte Estate - Yatiyantota
2. SRMEC Rubber Factory - Baduraliya
3. Neuchatel Estate - Neboda
4. Maha-Oya Estate - Dehiowita
5. Pallegoda Estate - Matugama
6. Vol-Lanka
7. Rambukkande Estate - Ratnapura
8. Talduwa Estate - Avissawella
9. Pussella Estate - Eheliyagoda
10. Devalakanda Estate - Dehiowita
11. Mal Lanka Rubberized Coir and Foam Rubber Factory
12. Ceyfoam Industries Limited
13. Mahawella Estate - Ratnapura
14. Gattahetta Statcon Rubber Factory

LABORATORY AND FIELD INVESTIGATION

Effluent treatment and disposal

Effluent treatment plant based on anaerobic coupled with aerobic system installed at Dartonfield was functioning satisfactorily throughout the year. The results of the experiment show that the final discharge of the treatment plant comply to the Central Environmental Regulatory Standards.

80 - 90% of COD and BOD removal can be achieved at this high rate packed bed type, anaerobic digester within 2 days retention and the remaining organics are removed by the aeration process followed by clarification and sand bed filtration stages. Since substantially, less amount of organics that need to be digested would come to aerobic digester after the anaerobic treatment the cost involved in the aeration process was found to be negligible. Treatment efficiency of above system is as follows.

Summary of the overall removal efficiencies of COD, BOD, TS, TN and P. after treatment

Influent COD mg/l	COD Removal efficiency %	BOD Removal efficiency %	TS Removal efficiency %	TN Removal efficiency %	P Removal efficiency %
11200	99.2	-	88.9	94.3	-
15200	99	99.5	95.2	87.3	40
17440	98.6	-	94.6	84.1	77.9
10580	99.2	99.1	93	93.8	86.3
14000	99.4	99.2	94.6	92.1	85.9
10800	98.9	98.8	93.5	86.5	85.1
11040	97	99	92.9	91	86.5
13840	97.9	99.7	94.4	87.1	82.2
14920	98.3	97.1	85.5	64.2	73.6
9360	99.5	-	96.1	-	82.1
6800	97.6	-	-	95.8	90
6720	97.7	-	96.1	95.1	-
11600	99.3	99.7	97.4	84.8	-
6240	98.1	99.6	88.6	-	-
10160	98.4	98.9	91.3	86.5	-

Few commercial scale plants based on this technique are in operation in few places and some were in the process of implementing by the end of 1996. These plants are as follows;

1. Dartonfield rubber factory
2. Glenross Centrifuged latex factory, Aerobic & Anaerobic processes are in operation

RAW RUBBER PROCESS DEVELOPMENT

3. Mackwoods weedside and insecticides packing plant, Ekala
4. Lak latex Centrifuging Plant, Construction is almost completed
5. SLREMC Mawanella, Anaerobic Digester completed.
6. Nakiyadeniya Oil Palm factory
7. Rannagala estates, Anaerobic digester completed, Rest of the work is in progress
8. Sena Textile processing Plant, Moratuwa
9. Pimbura factory, Anaerobic digester is completed and is in operation

Following plants which are in operation designed and implemented by the BKH consultants in collaboration with the Department

10. Ellakanda Rubber factory, Anaerobic coupled RBC process
11. Eheliyagoda Rubber factory, Anaerobic coupled with Surface aeration process
12. Hanwella Centrifuging plants, Oxidation process

Further research has already been started on waste water discharged from textile factories. Preliminary studies were carried out on textile dyes to see whether the high rate packed bed type anaerobic digester can be used to remove the colours of the textile dye.

Bio - gas generation

(a). *Generation of Bio - gas from skim serum*

A project proposal on the development of an efficient and cost effective treatment system for skim serum and also to use the bio gas generated in the process of treatment as an alternative energy source was submitted to NARESA for funding. This was formally approved by the Energy committee of the NARESA and work in this project will be started soon.

(b). *Effluent from decicated coconut mills*

Preliminary research work was carried out to treat the DL effluent by using the Anaerobic/Aerobic digestive principal. It was found that the anaerobic digestion of DC mill effluent is extremely effective and generates substantial quantity of Bio-gas than what could be obtained from the natural rubber processing effluents. As the results of these preliminary studies were very promising it has been agreed by the

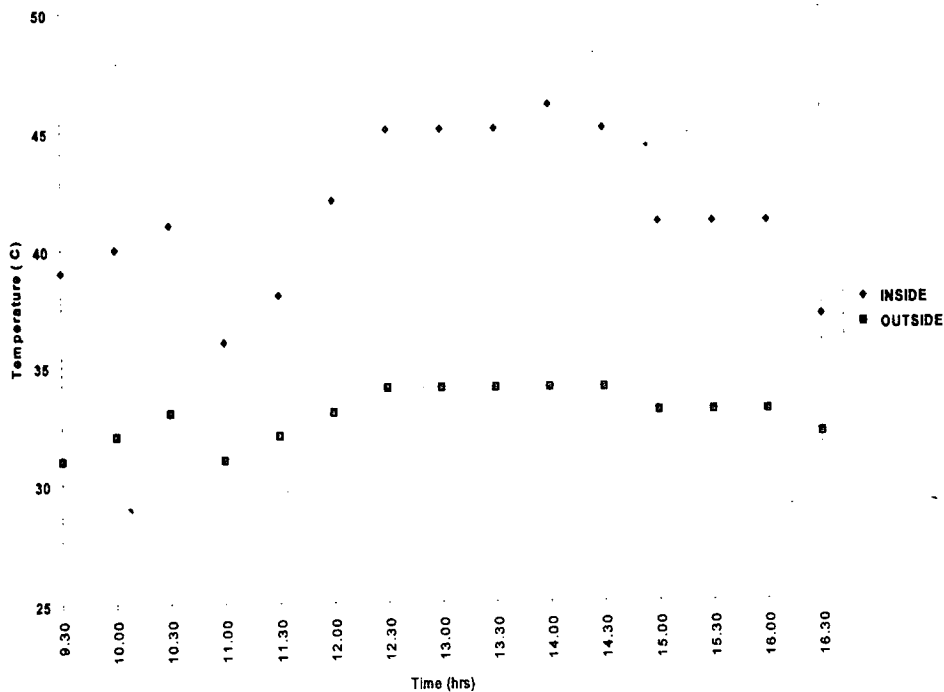
Coconut Development Authority and the Decicated Coconut Millers Association to construct a model treatment plant at Pothupitiya DC mills in Pothupitiya.

Greenhouse type dryer for RSS drying

A green house type solar dryer consisting of two solar air flat plate air collectors and a drying chamber was fabricated. Each flat plate air heater has area of 1 m². Galvanized iron sheets and polythene (Gauge 1000) were used for absorber plate and cover plate respectively. Drying cabinet has dimensions of 1.2 M length, 1.9 M height and 0.9 M width and can accommodate 60 normal size RSS sheets weighing up to 30 kilos. The chamber was made out of timber structure which is covered by polythene of gauge 1000.

Ambient air temperature (AT) and inside temperature (IT) of the dryer were measured. Following graph shows the AT and IT variation during the day time. IT was found to be always higher than the AT for more than 8 hours during the day minimum difference being 4 degrees while maximum is around 12 degrees.

THE VARIATION OF TEMPERATURE IN EMPTY DRYER DURING A NORMAL DAY TIME



RAW RUBBER PROCESS DEVELOPMENT

The dryer was installed and operated at the RRI premises at Ratmalana during the 4th quarter of the year during which period solar radiation was available without significant interruptions. Three batches of samples were dried in this dryer out of which a one batch was subsequently smoked in a smoke house and the physical properties were evaluated.

Batch No.	Thickness of the sheet	Sun dried period	Smoke period
1	1/8"	4 days	No.
2	1/8"	3 days	2 days
3	3/16"	7 days	No.

Table 1. *Average raw rubber properties of sun dried sheets and smoked sheets*

Batch No	V.M % wt	Wallace Plasticity (Po)	Plasticity Retention Index (PRI)
1	0.26	54	85
2	0.62	46	94
3	0.70	45	61

Results clearly show that sheets could be dried without any adverse effects on the raw rubber properties. However, it was observed that prolong drying in the chamber results in lowering the P_n and PRI of the rubber. It is also noted that, although direct exposure of solar radiation may cause lowering the said values, they still remain within the accepted limits. Colour of the sheets dried in this dryer is superior than that of the conventionally dried RSS or ADS which encourage the use of this type of dryer for drying of sheet rubber with subsequent smoking for a shorter duration in a conventional smoke house. Plans are underway to implement this economical way of drying technology at smallholder level.

ISO 9000 Quality Assurance Scheme

A training programme on implementation of ISO 9000 in crepe rubber factories was conducted during this year. This was attended by executives and senior management personnel from various plantation companies. Quality and Procedure

Manuals Prepared according to 1987 ISO document were revised according to the 94 ISO document. The revised quality and procedure manuals were completed for Dartonfield, Padukka, Rambukkanda and Madampe estates. Preparation of revised Quality and procedure manuals for Nakiadeniya estate was started.

Detailed discussions with the Superintendent, Factory and Field staff of Paddukka estate were held in connection with implementation of the ISO 9002 quality assurance scheme. An awareness programme was also conducted for factory and field workers at the estate.

ADAPTIVE RESEARCH

N Yogarathnam

SUMMARY

Adaptive research programmes on clone evaluation, soil and moisture conservation practices, organic manure, young budding and interplanting of rubber with tea were continued. Programmes on rainguard, intercropping rubber with banana were completed. It was found that girthing of rubber is higher in plots that were interplanted with rubber, in 1985.

DETAILED REVIEW

Staff

The Deputy Director (Research), Dr N Yogarathnam coordinated the activities of the Unit. Mr S M M Iqbal, Research Assistant in Agronomy and Mr E A T Senadeera, Senior Technical Officer were on duty throughout the year. Mr W C Dayaratne and Mr F P W Silva, Development Officers retired from the services of the Institute on 1st January 1996 and May 1996 respectively. Mr S Wijesekera, Senior Testing Officer passed away on 25th March 1996 due to sudden illness.

Temporary workers

Mr L D Soyza continued to work as Temporary Technical Assistant in CARP 12/30/21 funded programme. Mrs S Dharmakeerthi joined the Unit as a Trainee Graduate on 3rd June 1996 under the training scheme of the Ministry of Youth Affairs and Policy Planning.

Meetings

The Adaptive Research unit staff participated in the following :

- * Joint meeting of Rubber Development Department and RRI Scientific Staff
- * Monthly conferences of the Regional Rubber Development Department in Kalutara and Kegalle region.

- * Young budding and tapping programme in the Galle region.
- * Demonstration programme on fixing of rainguards, mulching with paddy straw, rainguard sealent preparation for smallholders in Kegalle and Galle regions.

Training programmes

Mr S M M Iqbal participated in the following:

- * Delivered a lecture on "Interplanting of rubber with tea for the refresher training programme for Rubber Development Officers, Planters and NIPM training programmes.
- * Workshop on IRDP interplanting of Rubber with tea programme, Kalutara region.

FIELD INVESTIGATION

1989 Integrated Programme

- (a) Field Establishment Practices
- (b) Clones
- (c) Planting Distances
- (d) Intercropping

The above programmes were continued in the following sites:

Regions	No. of smallholder sites
Ratnapura	10
Kegalle	12
Kalutara	24
Colombo	12
Galle	10

S₂d₃ tapping system was recommended where the sites reached tappable girth where clone RRIC 100 series was planted (A Nugawela, S M M Iqbal and E A T Senadeera).

Use of rainguards

The use of rainguard is being tested with the objective of increasing the number of tappable days eventually leading to higher crop in smallholdings. Gutter type rainguards were fixed in smallholdings. The small holders in the following two sites are successfully participated in this programmes. The number of extra tapping days recorded are given in Table 1.

Table 1. *Number of extra tapping days with the use of rainguards*

	Smallholder & Address	Period	No. of extra tapping days
01	Mr D D Gunaratne, Ekneligoda. Kuruwita, Ratnapura	Jan-July	18
02	Mrs T P Siriwardena, Kegalle	May-Sept.	13

(A Nugawela, L M K Tillekeratne, S M M Iqbal and E A T Senadeera).

Soil and moisture conservation practice

a) *Effectiveness of bush/tree legumes*

Kegalle Region

Four smallholder sites were selected to implement this programme in 1990. Only 2 sites were continued upto 3 years. Girth measurements were recorded and presented in the previous annual reviews. Observations on establishment, number of lopping per year, pest attack were made regularly. Re-establishment of bush legumes was started in 1994. But these trials were discontinued due to the poor follow up action by the farmer.

Kalutara Region

Seven smallholders were selected in 1990 and only one trial was continued up to 3 years. Most of the trials were not successful due to the poor soil condition (Boralu series soil).

b) Use of poultry litter

The above programmes were in progress. Recording of girth was continued. Poultry litter was applied by the smallholders according to the recommendations.

c) Use of paddy straw

Trials started in 1994 and 1995 at Kegalle region were continued. Application of paddy straw was done by the smallholders at the rate of 2 - 5kg in 2 application. It was decided to implement this programme in the 1990 clone evaluation trials with RRI practice, wherever the paddy straws are available. Recording of growth assessments were continued (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)

Results of the young budding/bare root trials established in 1994 and 1995 are presented in the table 02. These will be continued till they reach the tapable girth.

Performance of both young budded polybag and brown budded bare root plants at the end of the year 1996 was assessed by girth measurements taken from 20 plants, each selected randomly (Table 2).

Girth was taken at 120 cm (4 feet) height from the union of the plant, and the comparison of the data was done statistically by a paired t-test.

Supplementary data

Weed control practices, situation of the ground cover, fertilizer application, management of the clearing and the response of the smallholders were gathered by examination of the fields and also by interviewing the small holder (Table 3).

Three sites in Kegalle region and one site in Galle region are still in progress.

Table 2. Mean girth of the rubber plants in young budding trials

Region	Site	Year of Planting	Mean girth (cm)		t-value at 5%	Conclusion
			Y B n=20	B R n=20		
Kalutara	1	1994	15.1	15.4	0.315	*Not significant
	Badugama	Aug	±2.3	±3.5		
	2	1994	16.8	12.5	5.131	**Significant
	Uggalbada	Aug	±2.9	±2.3		
	3	1995	12.5	11.9	1.075	Not significant
	Morapitiya	Jul	±1.8	±1.4		
	4	1995	11.8	11.4	0.811	Not significant
	Baduraliya	Jul	±1.7	±1.3		
Galle	5	1995	13.9	12.6	2.434	Significant
	Horana	Jul	±1.7	±1.6		
	1	1994	17.6	16.5	1.41	Not significant
	Kamburupitiya	Aug	±2.3	±2.5		
	2	1994	19.5	15.7	4	Significant
	Hamburugala	Jul	±2.8	±3.1		
Ratnapura	3	1995	13.8	13.3	0.746	Not significant
	Mattaka	Jul	±2.1	±2.1		
	1	1994	12.9	12.8	0.146	Not significant
	Elapatha	Sept	±2.8	±2.8		
	2	1995	10.1	10	0.115	Not significant
Colombo	Pelmadulla	May	±1.5	±1.8		
	1	1994	21	19.4	2.033	Significant
	Padukka	Aug	±2.58	±2.35		
	2	1995	6.3	8.3	3.378	*#Significant
	Gampaha	Jul -Aug	±2.53	±4.32		
Polgasowita	3	1995	10.7	8.4	4.822	#Significant
	Polgasowita	Jul	±1.4	±1.5		

* BR is superior

** BR were planted 5 months later

Girth is not satisfactory

Table 3. *Supplementary data collected from the young budding programme*

Region	Site	Weeding		Ground cover		Remarks		
		Type	Response	Crop	Situation	Fertilizer	Manag	Record
Kalutara	1	Circle	Poor	Puraria	60%	Not regular	Poor	Moderate
	2	Circle	Moderate	Puraria	50%	Not regular	Moderate	Poor
	3	Circle	Moderate	Puraria	60%	Not regular	Moderate	Moderate
	4	Strip	Good	Puraria	70%	Regular	Good	Poor
	5	Circle	Moderate	Puraria	10%	Regular	Good	Good
Galle	1	Strip	Good	Puraria	80%	Regular	Good	Poor
	2	Strip	Good	Puraria	90%	Regular	Good	Moderate
	3	Circle	Moderate	Puraria	40%	Regular	Good	Good
Ratnapura	1	Circle	Poor	Puraria	25%	Not regular	Poor	Poor
	2	Circle	Poor	Puraria	75%	Not regular	Poor	Poor
Colombo	1	Circle	Moderate	Puraria	80%	Regular	Good	Moderate
	2	No	V. poor	No		Not regular	V. poor	Poor
	3	Strip	Moderate	No		Not regular	Moderate	Poor

Although the girth difference between YB and BR was significant in 6 experimental sites, only 3 sites: Horana, Haburugala and Padukka have been managed well.

Out of the 6 significant sites, girth of the plants of the sites: Gampaha and Polgasowita were not satisfactory, and also the BR of the Gampaha site was superior to that of YB. Although the girth difference was not significant in the site at Badugama, BR was superior to the YB. In contrast, the girth difference was significant in the site at Uggalboda, where BR were planted 5 months later (P Seneviratne, A M W K Seneviratne and S M M Iqbal).

Interplanting of rubber with tea

State sector I (1985)

Girth of the rubber plants were recorded in 6 observation trials at Kegalle and Kalutara (Table 4) regions. Shade measurements were recorded in December 1996. Yield data of tea were also collected from the estate record books.

Table 4. *Girth of rubber with tea interplanting experiments (State sector I) in 1996*

Estate	Rubber spacing	Mean Rubber Girth (cm)		Remarks
		Rubber only	Rubber x Tea plot	
Neuchatel	8'x30'	64.57	67.82	N.S
Perth	8'x30'	70.53	72.56	N.S.
Miriswatta	8'x30'	66.17	67.97	N.S.
Panawatta	8'x40'	63.80	72.72	***
Kiriporuwa	8'x40'	61.88	70.10	***
Ambadeniya	8'x40'	77.52	80.89	N.S.

N.S. - Not significant

*** - Significant at 0.1% level.

(N Yogaratnam and S M M Iqbal).

State sector II

Experiment I (RRISL Sub Station - Kuruwita)

The following were done :

- a) Recording of tea yield.
- b) Measurement of rubber girth.
- c) Collection of soil and leaf samples.
- d) Test tapping of rubber
- e) Pruning of Tea in rehabilitated plots.

Girth of the rubber plants measured at 3ft from the bud union in 1995 is given in Table 5.

Table 5. *The effect of multicropping of rubber lands with tea on girth of rubber after 5th year of growth*

Treatments	Mean Girth (cm)
Rubber Only	48.40 A
Tea (Rubber) + Rubber 8' x 27'	49.17 A
Tea (Unrehabilitated) + Rubber 8' x 27'	49.24 A
Tea (Rehabilitated) + Rubber 8' x 40'	47.18 A
Tea (Unrehabilitated) + Rubber 8' x 40'	48.67 A

Means followed by a common letters are not significant 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. Plucking of tea was started in June 1996. Girth of the rubber plants in December 1995 is given in Table 6.

Table 6. *The effect of interplanting of rubber lands with tea on girth of rubber in 1996*

Treatment	Mean Girth (cm) 1995
T ₁ - Rubber only	30.40 A
T ₂ - Rubber 8'x27' + Tea	37.16 A
T ₃ - Rubber 8'x32' + Tea	39.23 A
T ₄ - Rubber 8'x36' + Tea	35.67 A
T ₅ - Rubber 8'x40' + Tea	38.82 A
T ₆ - Rubber 8'x44' + Tea	36.80 A

Means with the same letter are not significantly different.

Following activities were done :

- Growth assessments of tea and rubber
- Collection of soil and leaf samples.

(N Yogaratnam and S M M Iqbal and C Seneviratne and Mr G D Piyathilake, Tea Inspector, TSHDA, Matugama)

Experiment III - Perth Estate, Horana (Meenapalana Division)

A new experiment was started in May - June 1996 at Perth Estate, Meenapalana Division, Horana. The following treatments are being tested in plots, ½ acre in size, with a randomized block design replicated 3 times.

Treatments

- T1 - Rubber only, 12' x 18' (100%)
- T2 - Tea only, 2' x 4' (100%)
- T3 - Rubber 8' x 60' (single row) (46%) + Tea (12 rows) (87%)
- T4 - Rubber 8' x 8' x 46' (double row) (100%) + Tea (8 rows) (65%)
- T5 - Rubber 8' x 8' x 60' (double row) (80%) + Tea (12 rows) (73%)
- T6 - Rubber 8' x 8' x 70' (double row) (70%) + Tea (14 rows) (78%)

Clone : Rubber - RRIC 100; Tea - 2026 and 2027

The following were carried out.

* Planting of tea and rubber was completed according to the experimental design.

* Manuring of rubber and tea

(S M M Iqbal and N Yogaratnam).

Experiment I and II were partially funded by the CARP under their Contract Research Programme 12/30/21 (N Yogaratnam).

Smallholder sector

Smallholder trials at the Kegalle and Ratnapura Region were continued. Girth of the rubber and yield of tea were collected. Table 7 give the girth details in smallholder sites. It was found that the management practices in site 3 was very poor.

Table 7. Mean girth of rubber plants and other details of interplanting of rubber with tea programme at the Kegalle Region

	Site	Clone & Year of Planting	Mean girth (in cm) 1996	N	Max	Min	Std. dev.
01	Mr W Higgoda. Undugoda. Kegalle.	RRIC 100 1992 R.P.	42.73	20	48.00	32.00	4.43
02	Mr P K M G Karunathilake. Kiriwana - Higgoda. Kegalle	RRIC 100 1993 R.P.	21.29	20	25.50	25.00	2.58
03	Mr W M D Samarawickrema. Bulathkohupitiya. Kegalle	RRIC 100 1993 R.P.	22.21	48	36.10	13.00	5.10

* N : No. of observations

* Max : Maximum

* Min : Minimum

* Std dev. : Standard deviation

(N Yogaratnam, S M M Iqbal and E A T Senadeera).

AGRICULTURAL ECONOMICS

P H M U Herath and I N Samarappuli

SUMMARY

Several studies were completed. These include: economics of reinvestment on rubber sector; economics of soil and foliar survey based fertilizer application; estimation of capital of rubber and extended cost-benefit analysis; major shifts in world NR industry; trends in demand for NR in major producing countries, variation in rubberwood prices at farm-gate level, market margin analysis of smallholder rubber sector and a study on some factors affecting replanting at smallholder rubber.

The studies that are being continued deal with issues such as: future direction of the rubberwood industry; economic life span of *Hevea* in relation to timber production; environmental linkages of rubberwood industry; economics of rubber based farming systems; statistical modelling of run-off studies; assessment of agro-climatic feasibility using computer modelling; economic assessment of land degradation; social cost associated with rubber effluents; socio-economic conditions of women workers; trade policies in conservation of rubber plantations and the impact of macro-economic policies on rubber sector.

DETAILED REVIEW

Staff

I N Samarappuli completed his PhD programme at the PGIA while performing his official duties in the unit. Mr A K B Naranpanawa and P H M U Herath were on duty throughout the year.

Seminars/Presentations

Mr A K B Naranpanawa delivered the following lectures:

- * "World rubber economy and new trends in the Sri Lankan NR industry" for the representatives of the National Institute of Education at the Training Center, Nivitigalakele.
- * "Cost of production of rubber and rubber statistics" for the new batch of rubber development officers at the Training Center, Nivitigalakele.

Dr I N Samarappuli presented the following papers:

- * "Econometric analysis of world rubber economy" at a research seminar held at PGIA.
- * "Variation in rubberwood prices at farm-gate level: a regression analysis" at 52nd Sessions of SLAAS.
- * "Major trends in consumption of NR with significant implications for the future" at 52nd Sessions of SLAAS.
- * "NR industry in transition" at IRRDB seminar on Agronomy and Farming systems held in Beruwala.

Dr I N Samarappuli delivered the key note address on "NR industry: Prospects and threats" at the Regional Meeting organised by the Avissawella District Planters' Association.

P H M U Herath attended a workshop on biodiversity and land utilization held on 22nd to 27th April 1996.

P H M U Herath present a paper on 'Some Factors Affecting replanting of smallholder rubber in Sri Lanka' at IRRDB seminar on Agronomy and Farming systems held in Beruwala.

RESEARCH

Economics of reinvestment on rubber in the estate sector

This study investigated the financial viability of reinvestment on rubber under estate conditions. The sample consisted of 135 rubber fields randomly selected from 15 large estates. The results will appear in the forth coming RRISL Journal (I N Samarappuli, C S Wickramaratne and D G S B Dias).

Major shifts in the natural rubber industry

Major transitions in the world rubber industry were studied with special reference to production, consumption, exports and trade. Time series data on annual basis were used in the analysis. The study period was confined to 1960 - 1990. The results were presented at the IRRDB conference held in Sri Lanka and the full paper will appear in the conference proceedings (I N Samarappuli, A Ekanayake and A K B Naranpanawa).

Major trends in demand for natural rubber

This study examined the major trends in the consumption of natural rubber and its research and policy implications with special reference to major NR producing countries. Time series data for a 20 - year period (1975-94) were used to estimate the trend equations and to make forecasts up to year 2000. The findings of this study were presented at the 52nd Annual Sessions of the SLAAS, Sri Lanka (I N Samarappuli and C S Wickramaratne).

Variation in rubberwood prices at farm-gate level

This study was undertaken to analyze the factors governing the price of uprooted rubber trees at farm-gate level. The study area consisted of rubber plantations located in the Kalutara district. Data were obtained on random basis from a cross sectional sample of 85 rubber fields uprooted in year 1995. The fields consisted of both estates and smallholdings. The results of this study were presented at the 52nd Annual Sessions of the SLAAS, Sri Lanka (I N Samarappuli, W R Perera and C Bogahawatta).

Economic assessment of Soil and Foliar based fertilizer application for mature rubber

A study was done to compare the cost of two alternative recommended methods of fertilizer application for mature rubber *viz.* the readily available conventional pre-mixed fertilizers against the site specific soil and foliar survey based fertilization. The sample consisted of 669 mature rubber fields in the Kegalle district. A scientific paper of this study will appear in the RRISL Journal (I N Samarappuli, C S Wickramaratne, L Samarappuli and N Yogaratnam).

Extended cost/benefit analysis and ecological capital of *Hevea*

A preliminary study was undertaken to estimate the ecological capital of rubber and to perform an extended cost/benefit analysis. The results were presented at the 1996 PGIA Annual Congress. The full paper will appear in the Tropical Agricultural Research Vol 8 (N Naranpanawa, A K B Naranpanawa, I N Samarappuli and C Bogahawatta).

Micro economic policies and their impact on the plantation sector of Sri Lanka

A study was planned to quantify the impact of different policy measures on the plantation sector development. 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 is being continued. Initially the study was focused on one of the major policies of the rubber sector the subsidy policy. An econometric model was developed to quantify the impact of this policy and the price of tea on replanting of rubber (P H M U Herath).

Future directions of the rubberwood industry in Sri Lanka

Several surveys are in progress to investigate the supply, demand, present status of technology and investment opportunities of the rubberwood industry. A preliminary report consisting of the initial findings of this study was submitted to the funding agency: NARESA (I N Samarappuli, L M K Tillekeratne and K G K de Silva).

Statistical modeling on run-off studies using econometric procedures

The runoff soil loss relationship was modeled in rubber plantations using soil physical and biological measurements for different management practices, slope levels and age of plantation. Subsequently, the relationships between soil loss against runoff were plotted to estimate the damage cost to the environment (I N Samarappuli, W Wijesuriya, L Samarappuli and N Yogaratnam).

A computer model to assess agro - climatic feasibility for rubber cultivation in Sri Lanka

An algorithm in the form of a structure chart was prepared for the full program. Steps will be taken to execute the model using LOTUS 123 release 5 (I N Samarappuli, W Wijesuriya, L Samarappuli and N Yogaratnam).

Economic assessment of land degradation in rubber holdings

Several mathematical functions were developed to quantify the relationship between land degradation and productivity of rubber holdings. This study is being carried out in collaboration with the Soils and Plant Nutrition Department of the RRISL (I N Samarappuli, L Samarappuli and A Ekanayake).

Economic life span of *Hevea* with special reference to timber production

Rubberwood is fast becoming attractive as a source of valuable timber as it provides the most promising solution to diminishing forest resources. Rubber trees are generally felled for replanting after about 30 years when latex production declines and tapping becomes uneconomical. This study investigates the optimum life span of *Hevea* with special reference to timber production. The data for this study are being gathered from commercial holdings (I N Samarappuli, L Samarappuli and A K B Naranpanawa).

Trade policies and conservation of forest resources in Sri Lanka: The case of rubber plantation sector

Past attempts to curtail the pace of diversifying rubber lands into other alternative ventures have been largely ineffective. This is partly due to insufficient attention focused on the multiple use functions of the rubber plantations.

This study investigates the multiple functions of rubber plantations in an economy wide context to formulate an appropriate policy environment for its full potentials to be realized (I N Samarappuli and A K B Naranpanawa).

Economics of rubber based farming systems

Few studies are in progress to evaluate the financial viability of rubber based alternative farming systems. Field data are being gathered from both smallholdings and estates. Multivariate techniques such as Logit, Probit and Discriminant functions are used at different stages of this study. Several indices were constructed to assess the adoption rates of different components of improved technology (I N Samarappuli, A K B Naranpanawa and W Wijesuriya).

Socio-economic conditions of women workers in the rubber sector.

A significant involvement of women labour is evident in different sub sectors of the rubber economy such as cultivation, processing and product manufacturing. The socio-economic status of these women workers will have a direct impact on the performance of these rubber based sub sectors in addition to the overall welfare status of the economy. This study attempts to identify the socio-economic status and the constraints faced by women employees in the rubber sector with a view of formulating appropriate policies to increase labor productivity while uplifting their welfare status (I N Samarappuli and K B Naranpanawa).

Impact of macro-economic policies (monetary and fiscal) on the performance of agricultural sector with special reference to natural rubber industry

The study of the indirect impacts of macro-economic and non-agricultural policies on the agric. sector is a recent development in agricultural economic research. An overvaluation or devaluation of exchange rates and expansionary fiscal and monetary policies are often blamed for distorting the economic activities in the agric. sector. This study focuses on the macro-economic linkage to agriculture with special reference to the natural rubber sub sector. An econometric model with an endogenous money supply mechanism is being constructed (A K B Naranpanawa).

Developing a simulation model for rubber industry in Sri Lanka

An explanatory model was designed as a pre requisite to develop a simulation model. The process of developing a simulation model to whole sector is complicated. Therefore, model development was segregated according to the main aspect of the production. Initially the biological aspects of the production was studied and an explanatory flow chart was developed. Developing mathematical relationships and the relevant computer programmes was continued (P H M U Herath).

Impact of exchange rate liberalization on the raw and manufactured rubber products sectors in Sri Lanka

The economic liberalization that had taken place in the country comprises some significant changes in the exchange rate (ER) regimes. These exchange rate liberalization process would have implications on the country's export sector. This study attempts to evaluate the impact of ER liberalization on the exports of raw and manufactured rubber sector, which is an important sub sector of the economy. An econometric model is being developed to identify the relationship in a partial equilibrium framework (A K B Naranpanawa).

International trade blocks and exports of raw rubber and manufactured rubber products of Sri Lanka

The development of "trading blocks" have been an important area that needs investigation to achieve a stable growth in the export sector of the country. Since natural rubber being primarily an export commodity, it is of vital importance to study these developments with respect to Sri Lankan rubber sector. In this regard, a study

is in progress to examine the implications of South Asian Preferential Trading Arrangement (SAPTA) on the Sri Lankan rubber industry (A K B Naranpanawa and I N Samarappuli).

Environmental and economic viability of the natural rubber industry

Valuation of non market variables in estimating the economic viability of industries is becoming increasingly important in the process of sustainable development of the country. A study has been planned to estimate the environmental values (costs and benefits) of the natural rubber industry under Sri Lankan conditions. As an introductory step, a study has been initiated in estimating the social cost of rubber effluents using the contingent valuation method. This study is being carried out in collaboration with the Biochemistry department of the RRISL (A K B Naranpanawa, I N Samarappuli and M T Warnakula).

Another study is in progress to investigate the environmental linkages of the rubberwood industry using both primary and secondary data (I N Samarappuli and A K B Naranpanawa)

A study on market margin in smallholder rubber sector.

A study on market margins was conducted in the smallholder rubber sector. The following table indicates the magnitude of marketing margin retained by the village and town dealers. This shows that compared to the 1991, the percentage increase in market margin is higher than the percentage increase in producer prices in other years. Therefore, the real benefit of the recent price incise in natural rubber was not transferred to the producers. The main reason for this situation is the indebtedness of the producers to the dealers. According to a survey conducted in 1991 around 90% of the smallholders depend on their dealers for their credit requirements. The indebtedness of the farmers reduces their bargaining power. Therefore, price level received by the farmer is being mainly decided by the dealer as the indebtedness reduced the bargaining of the producer (P H M U Herath).

Item	1991	1992	1993	1994	1995	1996
Producer Price (Rs/Kg) approximated by CPD Price of RSS3	21.11	26.41	31.69	44.50	63.58	62.63
Colombo Auction Price (Rs/Kg)						
RSS 1	23.58	29.29	35.66	50.34	72.45	71.28
RSS 2	23.02	28.89	34.46	49.59	70.20	69.10
RSS 3	22.39	28.53	33.38	48.03	69.40	67.90
Village and town dealers margin (Rs/Kg)						
RSS 1	1.28	2.12	1.69	3.53	5.82	5.27
RSS 2	2.47	2.88	3.97	5.84	8.87	8.65
RSS 3	1.91	2.48	2.77	5.09	6.62	6.47
Average market margin of village and town dealers (Rs)	1.89	2.50	2.81	4.82	7.10	6.80

Some socio economic aspects of immature rubber holders population in Sri Lanka

A Survey conducted (n=880) showed the following results on some important socio economic aspects of smallholder sector in Sri Lanka. A index was developed to measure management status by considering some important aspects of plantation management. These results should consider carefully for effective and efficient implementation of the policies for the better performance of the sector (P H M U Herath).

Variable	%
(a) Labour usages	
permanent labourers	17
family labourers	80
both permanent and family labourers	03
(b) Management	
owner cultivation (full time/part time)	93
by other means	07
(c) Ownership of land	
single ownership	85
share ownership	15
(d) Level of education	
no scowling	02
less than Ordinary level	50
Ordinary Level	32
Advanced Level	12
Diploma/Degree Level	04
(e) Immature rubber land size	
less than 1 acres	30
1-5 acres	57
greater than 05 acres	13
(f) Total rubber land area	
less than 1 acres	20
1-5 acres	56
greater than 05 acres	24
(g) Management status of the immature rubber holdings	
below average	44
average	48
above average	08
(h) Social participation	
actively participate in different societies	25
non participant	75
(I) Experience in intercropping	
no experience	61
1-10 years	34
more than 10 years	05
(j) Main decision maker	
male	88
female	12

Present status of intercropping with rubber

A survey (n=880) was conducted in Kegalle, Rathnapura, kalutara, Gampaha and Colombo districts to study the present situation of intercropping in rubber sector. The following table shows the results. Accordingly only few farmers practice intercropping systematically. Further analysis is in progress to study the factors affecting and the association of some socio economic aspects on intercropping (P H M U Herath).

District	intercroppers (%)	intercroppers who perform incropping systematically (%)
Kalutara	27	06
Kegalle	28	11
Ratnapura	12	03
Gampaha	28	13
Colombo	05	04

BIOMETRY

Wasana Wijesuriya

SUMMARY

The primary concern of the Biometry section is to provide support services to the research departments including experimental design, statistical analysis and interpretation of results of experiments done by the these departments. 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 mainly focused on further development, modification or application of established statistical methodologies in analysis of experiments, modeling of spatial variability, sampling methods and time series techniques.

DETAILED REVIEW

Staff

Assistant Biometrician, Ms Wasana Wijesuriya; Senior Technical Officer, Ms Nandani Wanigatunga; Technical Officer Ms Chintha Munasinghe, were on duty throughout the year.

Seminars, Meetings and Workshops

Ms Wijesuriya presented papers on;

“Use of covariates in improving precision of field experiments in rubber” at the 08th Congress of PGIA at the Plant Genetic Resource Centre, Gannoruwa, Peradeniya.

“Inter-relationships among Natural Rubber prices between Colombo and major overseas markets” at the 52nd Annual Sessions of SLAAS held at University of Kelaniya.

“Analysis of intercropping systems under rubber” at the Technical Sessions of the IRRDB Seminar.

Ms Wanigatunga and Ms Munasinghe attended the workshop on “Introductory Training on Agrometeorology - Observations and Data Entry” at Central Meteorological Station, Colombo on 28 and 29 March.

Services

Statistical

The 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 are: analysis of variance and covariance, linear and non-linear regression, applied multivariate methods, categorical and non-parametric methods and time series techniques.

Database Management

AGROMET database, daily meteorological observations of the Dartonfield station was maintained successfully. Reports were sent to the Central Meteorological Station, Colombo on a monthly basis.

INFORM database with personal, project information and budgetary involvement was updated for 1996.

Available literature on statistical methods, experimental designs and sampling were entered in REFLEX with authors and years and coded according to main and sub categories of research areas for easy access.

RESEARCH

The following studies were completed during 1996.

1. Inter-relationships between natural rubber prices in Colombo and major overseas markets

The Colombo FOB prices lag behind the prices of overseas terminal markets by a quarter. The Sri Lankan market can therefore be regarded as a 'price taker' in the global context. These time lags reflect the imperfect market conditions prevailing in the local trading system possibly in the form of 'direct trading' where a substantial volume of rubber bypassing the auction. In this instance, the reference price appears to be based on the leading prices quoted in official overseas markets despite the fact that direct trading has no pricing mechanism of its own. This study therefore suggests the necessity to strengthen the Colombo rubber auction to reflect transparency in all transactions.

2. Impact of production, consumption, exports and stocks on the price of Natural Rubber

A negative relationship was found in the seasonal behaviour of prices and production. Similar pattern of seasonal variation was observed for exports and prices. However, the strength of relationship between prices to production and stocks were comparable. An accumulation of stocks was observed towards the end of the year. Nevertheless, there was a tendency to consume more rubber during the latter part of the year. No significant relationships were found between consumption or stocks with auction prices. These variations clearly illustrate the seasonality in rubber product manufacture and oligopolistic nature of Sri Lanka's NR market.

3. Use of covariates in improving precision of field experiments in rubber

Pre-treatment yield is most effective as a covariate in adjusting post-treatment yield during the early years, but the efficiency declined with time. Pre-treatment girth which can be accurately and easily measured is comparatively more consistent in terms of efficiency with lapse of time. For experiments on immature rubber, measurement of seed weight and budded stump weight have reduced the initial variability to a substantial extent. No firm conclusions were made in favour of double covariance compared to single covariance analysis.

4. Analysis of intercropping systems under rubber

All the indices that quantify the beneficial effects of intercropping systems involve yields of both component crops. However, the beneficial or deleterious effect of intercrops on the growth of rubber has to be assessed in many instances. The main criterion of growth during the initial stages of rubber is girth or the girth increment. All the agronomic practices are therefore aimed at attaining the tappable girth (50 cm) as early as possible. Therefore, the following indices were suggested to quantify the effect of intercropping during the immature stage in a rubber based intercropping system.

$$\text{INDEX 1} = \frac{\text{Avg. girth of rubber in mixture}}{\text{Avg. girth of rubber in pure stand}} + \frac{\text{Yd. of intercrop in mixture}}{\text{Yd. of intercrop in pure stand}}$$

$$\text{INDEX 2} = \frac{\text{Annual girth increment of rubber in mixture}}{\text{Annual girth increment of rubber in pure stand}} + \frac{\text{Yd. of intercrop in mixture}}{\text{Yd. of intercrop in pure stand}}$$

For mature stages of rubber, when both component crops produce yields, the first part of the index is replaced by the following:

$$\frac{\text{Yield of rubber in mixture}}{\text{Yield of Rubber in pure stand}}$$

The yields were recorded in equal units of weight per unit area. The above indices are all based on the Land Equivalent Ratio (LER). Two other indices, namely Income Equivalent Ratio (IER);

$$\text{IER} = \frac{\text{Income from both crops in intercropping}}{\text{Income from the main sole base crop}}$$

and Monetary Advantage (MA);

$$\text{MA} = \text{Value of combine yield} \times \frac{\text{LER} - 1}{\text{LER}}$$

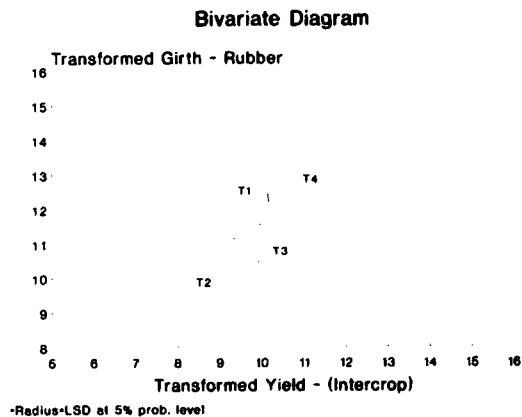
may also be employed directly for the mature stage of rubber. This can be modified for the immature stage of rubber in the following manner.

$$\text{MA} = \text{Value of the yield of other crop} \times \frac{\text{Index (1) or (2)} - 1}{\text{Index (1) or (2)}}$$

MA of this form is compared with zero, since immature rubber will not give any monetary value.

Bivariate Method

This method may also be employed in interpretation of results from intercropping trials. The resulting bivariate diagram provides a more realistic picture of the performance of different systems. A simple program segment was prepared by the Biometry Section to accomplish the tedious computations involved in this method.



The following studies are in progress.

1. **Comparative performance of rubber industry in the plantation sector**

A database was prepared on prices, exports, production and consumption of rubber, coconut and tea for the period 1980 to 1996. The intended analyses were to identify trends, seasonal and cyclical factors, and possible forecasting approaches.

2. **Modeling for spatial variability**

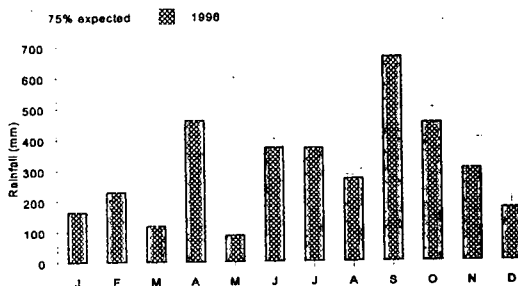
The objective of this study is to improve the efficiency of field experiments since unevenness of soil fertility or disease levels can seriously affect the quality of data from experiments, sometimes totally obscuring differences between treatments. If a large number of treatments are to be compared or if treatments need larger plots, blocking may not be effective. The idea is to apply *additive models* which avoid a formal model and simply smooth the data. This method can be used to express plot yield or any other variable of interest as a smooth function of the position of the plot in the field. Studies on nearest neighbour methods to control spatial variability have not shown any significant improvements. However, further studies are in progress on the use of nearest neighbour approach.

3. **Distributional properties of different measurements involved in experiments with rubber**

On several occasions, the final result obtained from an experiment is either a rating or a count. As a result, many parametric statistical procedures applied to normal distribution cannot be directly applied and many types of data transformations are practiced or non-parametric procedures are used in analyses. It is a known fact that a guaranty cannot be given to any method of transformation. Therefore, this study aims on modeling of data from different experiments which have counts or rates as the final observation.

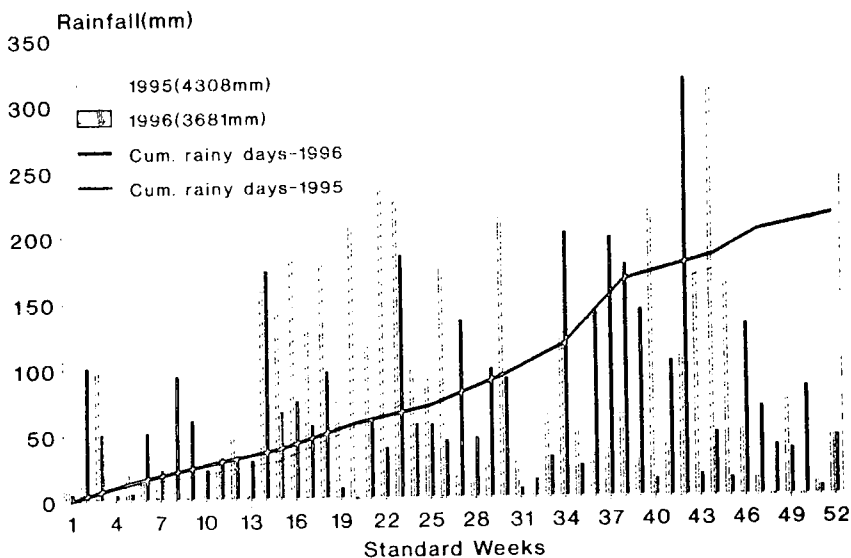
Meteorological Summary - 1996 Dartonfield Station

Unusual pattern of rainfall was observed in 1996 with a total of 3681mm, compared to the long-term average of 4243mm, a drop of 627mm compared to the previous year. The highest rainfall observed in September coincided with the second inter-monsoonal period (IM2). The lowest value was experienced in May 1996.



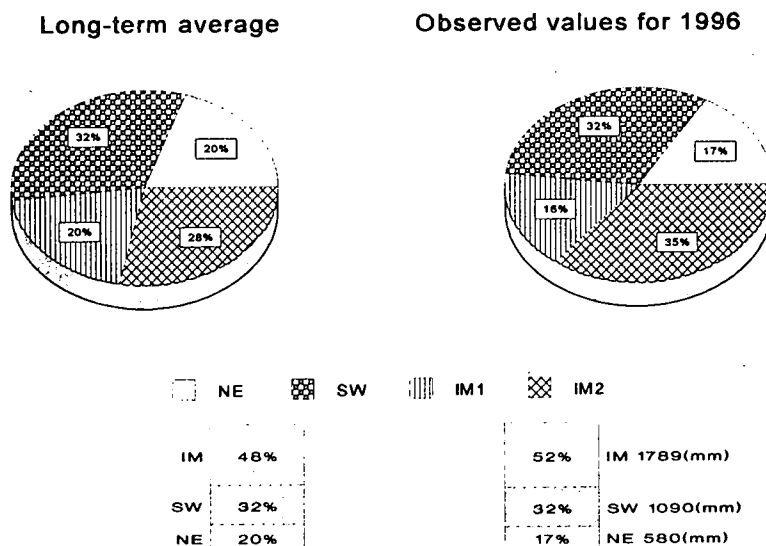
Monthly variation in rainfall

A comparison of weekly rainfall in 1995 and 1996 is given in the following figure. A fairly dry weather was observed during March and May but there was only a single dry week during the course of the year. Number of rainy days equaled 214 during this year.



Weekly distribution of rainfall and cumulative rainy days

The rainfall distribution in different seasons also exhibit slight deviations from the long-term average. Respective decreases of 3% and 4% in North-East and IM1 (mid March to mid May) rains and an increase of 7% in IM2 (Sep. to mid Nov.) rains were observed during 1996. In general, a greater proportion of rains (52%) have been experienced during inter-monsoonal seasons. These observations are presented in the following figures accompanied with the long-term averages.



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.

Table 1. *Monthly variation of rainfall and rainy days in 1996*

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	167.0	(121)	14	(10)	06	07	01
February	231.6	(116)	13	(09)	02	10	01
March	119.6	(252)	12	(17)	02	10	-
April	461.6	(449)	19	(21)	04	11	04
May	88.4	(629)	13	(24)	04	09	-
June	373.7	(440)	23	(24)	04	18	01
July	372.2	(299)	23	(22)	05	16	02
August	270.7	(257)	19	(21)	07	10	02
September	665.8	(391)	29	(22)	01	25	03
October	452.2	(476)	18	(22)	04	11	03
November	304.1	(448)	19	(20)	07	11	01
December	174.3	(282)	12	(17)	03	08	01
Total	3681.2	(4160)	214	(229)	49	146	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	Wind speed		Temperature (°c)			Relative Humidity (%)			Mean (kmph ¹)
	Mean Max	Mean Min	Mean	No. of days min temp < 20	Soil at 10 cm	8.30 am	No. of days RH 8.30 > 90%	3.30 pm	
Jan	32.7 (32.3)	20.8 (20.8)	26.8 (26.5)	03	25.8	87 (87)	12	66 (67)	1.6
Feb	32.9 (23.3)	20.9 (21.1)	26.9 (27.2)	02	26.1	90 (85)	17	70 (64)	1.6
Mar	32.8 (33.5)	21.1 (21.7)	27.0 (27.6)	01	27.2	85 (84)	06	63 (66)	1.9
Apr	32.8 (32.9)	22.7 (27.8)	27.8 (27.8)	-	27.2	85 (84)	04	80 (73)	1.8
May	32.7 (31.6)	23.3 (23.3)	28.0 (27.5)	-	28.0	86 (87)	06	71 (77)	2.1
Jun	30.8 (30.8)	22.8 (23.1)	26.8 (26.9)	-	27.1	90 (88)	16	78 (76)	2.1
Jul	30.3 (30.2)	22.7 (22.8)	26.5 (26.5)	-	26.8	91 (88)	19	79 (74)	2.4
Aug	30.7 (30.2)	22.6 (22.7)	26.7 (26.5)	-	27.2	88 (87)	12	72 (74)	2.8
Sep	30.0 (30.6)	22.6 (22.4)	26.3 (26.5)	-	26.4	90 (86)	19	81 (74)	1.7
Oct	31.2 (30.9)	22.1 (22.1)	26.7 (26.5)	-	26.6	83 (85)	08	74 (77)	1.9
Nov	32.1 (31.4)	21.0 (21.8)	26.6 (26.6)	01	27.2	84 (84)	06	73 (77)	1.5
Dec	32.5 (32.0)	21.4 (21.4)	27.0 (26.7)	02	26.6	86 (84)	10	67 (74)	1.6

** Average values for 1980-1992 are shown in parentheses

LIBRARY AND PUBLICATIONS

Kamani Perera

SUMMARY

The prime objective of the Library is to provide promptly, appropriate documents to its clientele to help gain knowledge to do research and to perform their work efficiently. The Library attempts to fulfil this objective by collecting and disseminating information on Natural Rubber and related areas. The other responsibility of the section is maintaining, processing and publishing of Institute's regular publications such as Annual Review, Journal, Bulletin, Rubber Puwath etc.

DETAILED REVIEW

Staff

Mrs Kamani Perera, Librarian & Publications Officer, Mrs Tilaka Dantanarayana, Library Assistant & Assistant Publications Officer (Colombo Office), and two Library Attendants were on duty throughout the year. Mrs Ramani Amaratunga, Clerk/Typist was promoted to the post of Library Assistant & Assistant Publications Officer with effect from 15th October 1996.

Resource Development Activities

Book/Serial acquisition

The Library stock increased to 4788 books and the bound volumes to 3191 by the end of the year.

The Library subscribed 64 journals and about 33 journals were also received as gift/exchange. RRISL is grateful to all those persons and organisations who donate documents to the RRISL Library collection.

Meetings/Seminars

Librarian & Publications Officer attended the seminar on New Information Technologies held on 26th July at the NARESA Auditorium in collaboration with CARP.

International Photocopy (BLDS/IFLA)/Reprint Service

Under this service 154 articles were requested for RRISL scientists.

ILL Service

82 articles were sent to various agricultural libraries on their request and vice versa 75 articles were requested for our users. Literature surveys based on *Hevea*/rubber were done using CD-ROM databases available at IIMI, CARP Libraries.

Equipment/Furniture

Every conceivable articles in the form of office equipment, furniture etc. were purchased during the year under review.

- * Godrej Sinhala Scripta Single Line Electronic Typewriter with 16 KB memory.
- * Steel Typist Table and Chair.
- * Home TS398 Vacuum Cleaner
- * Plain Paper Copier
- * 06 Nos. Book Shelves
- * Uninterrupted power supply (UPS) and diskette storage box
- * Glass fronted 6 shelves book case was transferred to Library from the Head Office.
- * Notice Board was fixed to display RRISL current publications.

Publications

The following publications were published during the year under review.

Annual Review 1995
RRISL Bulletin Vol.33, 1996
RRISL Bulletin Vol.34, 1996
RRISL Journal Vol.77, 1996
RRISL Journal Vol.78, 1996
Rubber Puwath Vol.18, 1995

Advisory Leaflets

Rootstock Nurseries	1996-01
Budwood Nurseries	1996-02
Young Budding	1996-03
Clone recommendations	1996-04
Bird's eye Spot disease	1996-05
Corynespora Leaf Fall Disease	1996-06
Gloeosporium Leaf Disease	1996-07
Phytophthora Disease	1996-08
White Root Disease	1996-09
Oidium Leaf Disease	1996-10
Pink Disease	1996-11
Interplanting Rubber with Tea	1996-12
Sorting Grading and Packing of Rubber	1996-13
Manufacture of RSS and Latex Crepe Rubber	1996-14
Performance of Rubber Industry	1996-15
Leaf and Soil Sampling	1996-16
Rainfall Pattern	1996-17
Intercropping	1996-18
Rainguards	1996-19
Polybag Plants (in Sinhala)	1996-20
Tapping (in Sinhala)	1996-21
Speciality Rubbers	1996-22

Library Automation

Librarian & Publications Officer created following databases using CDS ISIS package.

BIN	-	RRISL Bulletin Index 1966-95
LIB	-	Bibliography of Natural Rubber 1981-94
JNL	-	Serial Holdings
AGRI	-	Book Accessions from 1995
BOOK	-	Book Accessions from 1961-1994
RUB	-	Journal Analytical Entries
JIN	-	RRISL Journal Index from 1995
ARP	-	Annual Reports
MEM	-	Thesis Collection
PER	-	Journals Exchange
USI	-	User Records

Information Services

Computerized bibliographic data from year 1996 were sent to the National Library of Sri Lanka for compilation of the National Union Catalogue.

Contents of the current periodicals were distributed among the users.

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

A Nugawela

SUMMARY

A crop of 159329 kg were harvested during the year which is an increase of 3% above the previous year from same hectarage. The harvested crop is 93% of the estimated for the year.

The relative tapping intensity during the year in 100% tapped areas was 79%. The productivity of the Group was 953 kg per hectare per year and it has improved from the previous year figure of 928.

In the rainguarded Dartonfield Division a relative tapping intensity of 90% was recorded.

The average intake per tapper for 250 tree tapping tasks, is 6.0 kg. The highest intake per tapper recorded during the year was 18 kg from 250 trees in the 1986, RRIC 100 clearing at Gallewatta Division.

The average number of normal, late, and no tapping plus rain interference days were 234, 50, and 81 for non rainguarded Divisions whilst 316, 11 and 38 days were recorded for the rainguarded Division respectively. The relative tapping intensity, recorded for non rainguarded and rainguarded Divisions was 79 and 90% respectively.

A total rainfall of 3696.9 mm was recorded over 165 wet days. The total rainfall is 672.6 mm less than the previous year. The number of wet days are also less by 20.

The total cost of production and net sale average for the year were Rs.38.72 and Rs.70.49 respectively, which resulted in a profit of Rs.31.77 per kg and Rs.5.01 million from the entire revenue area. The profit recorded per hectare of revenue area is Rs.30,279.46 during the year.

The manufacture records reveal that the latex grade 1 percentage is around 95.7%. This was possible due to the manufacture of unfractioned unbleached rubber and have resulted in a high net sale average, of Rs.70.49.

DETAILED REVIEW**Staff**

Dr A Nugawela, Acting Estate Superintendent, Mr P Kannangara, Chief Clerk, Mr K K P Gunawardena, Senior Clerk, Mrs C Dissanayake and Mr A K D A Wickramasinghe Junior Clerks, Mr J A Wimalasena, Mr S K S de Silva and Mr T Somaratne, Field Officers, Mr S R Vadivel, Mr N L D Reggie and Mr H M Jayantha Premalal, Assistant 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 Attendant and Mr A K Piyasena Office Peon, were on duty through out the year.

Mr N L D Reggie, Assistant Field Officer was promoted as Field Officer with effect from 1st February, 1996. Mr T D Kularatne, Assistant Field Officer resigned with effect from 30th April 1996.

Miss S I K Pathirage was appointed as Junior Clerk with effect from 22nd March 1996.

The Group cadre stood at 20 at the end of the year, made as follows:

Senior Staff	01
Assistant Staff	18
Minor Staff	01
Total	20

Hectarage

A summary of the Hectarage is given in Table 1.

Table 1. *Land distribution (Ha) in Dartonfield Group*

	Dartonfield	Galewatta	Nivitigalakele	Total
Mature Area	24.42	97.85	44.84	167.11
Immature Area	15.96	52.93	2.93	71.82
Nurseries	7.27	-	7.69	14.96
Paddy Field/Deniya	-	1.22	-	1.22
Earth Slip Area	1.65	1.26	2.62	5.53
Rocks/Streams	0.14	1.8	1.21	7.46
Waste Land	0.19	0.18	-	0.37
Jungle	0.80	-	0.71	1.51
Roads	3.27	6.86	0.32	10.10
Buildings	18.67	5.07	7.79	31.53
Abandoned	-	-	5.13	5.13
State Land taken in	0.27	-	-	0.27
Uprooting	-	14.87	-	14.87
Total	74.29	184.35	73.24	331.88

Crop

A total crop of 159,329 kg was harvested from an extent of 167.11 ha. during the year. This is 93% of the estimated crop of 170500 kg and 3% above the previous years crop of 155,097 kg from same extent.

The yield per hectare for the past 5 years is 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 1992 to 1996*

Division	Year				
	1992	1993	1994	1995	1996
Dartonfield	605	943	1037	714	900
Galewatta	740	958	1077	1039	1073
Nivitigalakele	771	841	876	804	723
Group average	740	918	1012	928	953
Group Estimate	883	883	884	887	1020

The yield per hectare at both Dartonfield and Gallewatta Divisions have increased significantly. Nevertheless, it has declined at Nivitigalake Division and it could be attributed to poor tapper out-turn and age distribution of the clearings.

A monthly breakdown of the yield per hectare, separately for each division is given in Table 3.

Table 3. *The yield per hectare (YPH,kg) recorded during each month in 1996 in different Divisions*

Month	Dartonfield	Gallewatta	Nivitigalake
January	100	125	94
February	65	84	59
March	74	91	72
April	44	56	37
May	59	80	42
June	57	57	48
July	77	66	56
August	85	108	68
September	58	22	19
October	83	98	62
November	93	133	68
December	106	151	98

Around 47% of the annual crop is harvested during the cropping months of October, November, December and January.

Tapper productivity

The average intake per tapper division wise and for the entire group for the last 5 years is given in Table 4. The task size for 100% areas had been 250 trees for each year.

Table 4. *The average intake per tapper (kg) division wise for the last 5 years*

Division	Year				
	1992	1993	1994	1995	1996
Dartonfield	5.15	6.96	6.96	7.0	6.5
Gallewatta	4.78	6.06	6.35	6.7	6.2
Nivitigalakele	5.06	5.67	5.78	5.4	4.5
Group Average	4.90	5.97	6.21	6.20	6.0

The average intake per tapper for the Group has increased steadily since 1992. It has showed a slight decline in 1996 and this may be attributed to relatively more rain interference during the cropping months.

Manufacture

A summary of the manufacture records during the year is given in Table 5.

Table 5. *Details of the crop manufactured in Dartonfield Group during the year*

Grade	Amount (kg)	Grade (%)	Latex (%)	Scrap (%)
Crepe No.1	138.054	86.7	95.7	-
Crepe No.2	6 171	3.8	4.3	-
Scrape Crepe No.1	10 892	6.8	-	72.1
Scrape Crepe No.2	3 814	2.4	-	25.3
Scrape Crepe No.3	398	0.3	-	2.6

90.5 and 9.5% of the crop is latex and scrap respectively.

The grade 1 percentage in latex is 95.7% whilst that of scrap is 72.1%.

Weather

The annual rainfall (mm) and the number of wet days for the last 5 years are given in Table 6.

Table 6. Annual rainfall (mm) and the number of wet days for the last five years

	Years				
	1992	1993	1994	1995	1996
Rainfall (mm)	3974.4	4391.9	3884.7	4369.5	3696.9
Wet days	163	192	185	185	165

The annual rainfall and the number of wet days this year are relatively less than in the previous year.

The average number of normal, late, double and no tapping days for the last 4 years are given in Table 7. For current year the figures are based only on Nivitigalakale and Gallewatta Divisions. Further, the relative tapping intensity, average intake per tapper and the yield per hectare are also given for the same years to study the influence of wet weather on productivity.

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			
	1993	1994	1995	1996
1. Tapping days				
1.1 Normal	198	214	205	238
1.2 Late	52	57	54	49
1.3 Double	16	9	8	-
1.4 No	115	94	106	78
2. Relative Intensity	73	77	73	79
3. Average Intake Tapper (kg)	5.97	6.21	6.2	6.0
4. YPH (kg)	918	1012	928	953

The number of tapping days and the relative tapping intensity is comparatively high during 1996 than in the previous year. This may have resulted in the higher YPH recorded in 1996 than in the previous year.

During 1996 Apron type rainguards were fixed at Dartonfield Division and the tapping days recorded in this and at neighbouring Gallewatta Division (without rainguards) are given in Table 8.

Table 8. *Tapping days at Dartonfield (Rainguarded) and Gallewatta (Non-rainguarded) Divisions*

1. Tapping days	Division	
	Dartonfield	Gallewatta
1.1 Normal	316	234
1.2 Late	11	50
1.3 Double	-	-
1.4 No	38	81
2. Relative Intensity	90	78

The rainguarded division has recorded 82 more normal and 39 less late tapping days. Relative tapping intensity is 90% in the rainguarded division whilst it is 78% for the other.

Cost of production and profitability

Labour rate, a breakdown of cost of production, net sale average and profit made per kg for the last 5 years are given in Table 9.

Table 9. *Labour rate (LR, Rs) and a break down of cost of production (COP, Rs.), Net sale average (NSA, Rs.) and the profit per kg for years 1992, 1993, 1994, 1995 and 1996*

	1992	1993	1994	1995	1996
1. Labour rate	58.19	72.24	72.24	72.24	83.00
2. COP	44.68	35.15	33.45	36.60	38.72
2.1 Tapping	14.17	13.91	14.76	16.23	18.56
2.2 Manufacture	6.07	8.76	7.32	6.47	6.15
2.3 General Charges	19.07	6.57	7.34	9.17	9.09
2.4 Upkeep	5.37	5.35	4.03	4.03	4.92
3. NSA	35.15	39.01	55.22	80.73	70.49
4. Profit	(9.53)	3.86	21.77	44.73	31.77

The labour rate has increased by 15%, but the cost of production has increased by only 6% during 1996. The NSA has also dropped during 1996 and hence the profit per kg of rubber has declined from Rs.44.73 to Rs.31.77. The profit made during 1996 is Rs.5.06 million.

A breakdown in Total Tapping Cost for years 1994, 1995 and 1996 is given below:

Table 10. *A break-down in Total Tapping Cost*

Cost Item	Cost (Rs.)		
	1994	1995	1996
Tapping	13.28	14.36	16.90
Double Tapping	0.23	0.20	-
Kanganies	0.33	0.13	0.12
Over-kilos	0.68	1.17	1.12
Scrap Pay	0.18	0.28	0.32
Incentive to Field Staff	0.06	0.09	0.10
Total	14.76	16.23	18.56

Tapping Cost has increased by 18% and could be attributed to increased labour rates and marginal decline in intake per tapper during 1996.

The profitability per unit land area, *i.e.* ha during last 4 years is given in Table 11.

Table 11. *Total profit made from revenue extent, the revenue extent and profit per ha of revenue area for years 1993, 1994, 1995 and 1996.*

	Year			
	1993	1994	1995	1996
Mature Extent	155.59	144.42	167.11	167.11
Total Profit (Rs. Mn)	0.48	3.2	6.84	5.06
Profit/Ha (Rs.)	3064.16	22 031.69	40 957.59	30 2979.46

The profit per revenue hectare has declined by 26% in 1996 though the productivity has increased (Table 11). This could be attributed to a 13% decline in NSA and a 15% increase in labour rate during the year.

LIST OF PUBLICATIONS

Scientific journals

(Rubber Research Institute of Sri Lanka authors are shown in bold type)

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