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Rubber Research Institute of Sri Lanka

Annual Review

1999

Cover: A late wintering clone severely affected with *Oidium* due to wet weather prevailed at the time of refoliation. Clone in the background has escaped from the secondary leaf fall due to its early wintering character

Photograph by: Wimal Amaratunge

Rubber Research Institute of Sri Lanka

Annual Review - 1999

1st January 1999 to 31st December 1999

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RUBBER RESEARCH INSTITUTE OF SRI LANKA

DIRECTOR'S REVIEW

L M K Tillekeratne

Rubber Production in the country remained static during 1999 and the total production for the year was 96584.9 MT. The reason for this low production was the poor prices paid for all grades in the 1st three quarters of the year. However, the steady upward trends shown in the Singapore rubber prices in the last two months for year 1999, is an encouragement and it is hoped that a reasonable price will be offered for the rubber in year 2000.

In 1999, 29.6% of the total rubber production in Sri Lanka was sheet rubber (RSS). The latex crepe component was 40.7% a decline in comparison with the 1998 level. Centrifuged latex production had been 18.5% while TSR has fallen to the lowest percentage of 4.9 since 1975.

With this fast development of the rubber products industry if the rubber production is not increased, the date Sri Lanka has to import rubber to cater to the local products industry is not very far. Already most of the major BOI Companies producing rubber products have made requests from the BOI to permit them to import their rubber requirements from SEA Countries. If all those requests are allowed, the FOB price of all grades of Sri Lankan rubber will be affected badly. In order to overcome this situation, rubber plantation companies and smallholders must produce rubber at least to the level of 100-110,000 MT per year to cater to the local needs of rubber product manufacturers at least in the next 5 years. The only way to achieve this production target in the year 2000 itself is by fitting rain guards in estates and in small holdings which can guarantee a minimum of 20-25% increase in rubber production. If this is not done, there will be a shortage of required grades of NR in the country thereby forcing BOI Companies to import raw rubber.

It is expected that with the introduction of the Indo-Lanka Free Trade Agreement in March 2000; the rubber products manufacture will progress faster. According to this agreement, it has been possible for the Government of Sri Lanka to place 58 items such as natural rubber, reclaimed rubber, end products like thread and chord, tubes and reinforced threads, belts, pneumatic tyres and tubes, contraceptives, gloves and inflatable items in the Sri Lanka negative list; so that these items can only be imported subjected to normal duty rates. There are only 29 items in the India's negative list such as parts of textile machinery, articles of hard rubber, used or retreated tyres, solid tyres, floor covering mats and erasers, compounds and master batches and solution compounds. In addition to these, there are 43 items in India's residual list for which there will be an immediate 50% duty reduction and the balance 50% phased out in 3 years. These items include all kinds of pneumatic tyres inclusive of air craft tyres, cycle tyres, all kinds of tubes, sheath

contraceptives and all kinds of gloves. The number of items in the Sri Lanka's residual list is 14, inclusive of synthetic rubbers and lattices.

There is a remarkable drop in the TSR production last year from 8000 MT to 4000 purely due to the low price of TSR grades in the International market and due to the increased COP of TSR under the prevailing high electricity and fuel costs.

We have still not been able to see a remarkable improvement in clonal balances in estates as recommended by the RRI. Most of the estates have planted a fairly high proportion of clone RRIC 100 and about 6% of clone RRIC 102. Extent of RRIC 121 is also far below the acceptable 20% at present. PB 28/59 and PB 217 in Group 1 and recommended for estates receiving slightly lower rain fall has not been planted at all in many estates. This is a dangerous situation and if a pathogen affecting RRIC 100 enters Sri Lanka, like what happened to clones RRIM 600 and GT 1 in SEA major rubber producing countries, the rubber industry in the country might come to a halt within a couple of years.

Planting oil palm in the South of Sri Lanka without properly studying the influence of this crop on the environment is a matter of concern to everybody. Though, oil palm is known to produce lot of bio-mass, they are useless as firewood in comparison to rubber wood. Hence, if oil palm is planted in the traditional rubber fields, not only the ground water levels may drop; people will start felling trees in the limited forest reserves available for firewood. If that happens there will be a severe water shortage in the country which ultimately will cause power shortage as well. However, before planting oil palm, a full study of the pros and cons of planting it in those areas, very especially the ecological aspects should be carried out.

Though oil palm utilize less labour and more profitable compared to rubber while its gestation period too is less; decision to diversify rubber lands into oil palm has to be done after a careful analysis of the possible hazards of the same to the environment.

Research

Three new clones have been identified as promising latex - timber clones. Among the new genotypes tested, eight showed potential for future recommendations.

Brown budding technique was adopted in 2-3 year old clearings to introduce crowns showing resistance to leaf diseases. Within a clone more vigorous plants out-yields less vigorous ones. ½ s d/3 tapping with 4 rounds of stimulation per annum achieves ½ s d/2 yield levels. It appears that clones RRIC 100, 102 and 121 may be tapped at ½ s d/2 from initial year of tapping. TPD trees not recovered following a rest period can be tapped with a ¼ s (↑) on HO panels.

Girthing and bark thickness are affected when planting density is increased from 500 to 800 ha. Nevertheless, tappable trees/ha, increases upto a density of 700 trees/ha..

Double row systems of planting rubber with adequate spacing within a paired row is beneficial for the intercrop. Cardamom Rubber cropping system at low elevation appear to be economically viable.

Wet weather experienced during refoliation period predisposed susceptible clones to *Oidium* and *Colletotrichum* and hence diseases caused by *Phytophthora spp.* were negligible. Clone RRISL 203 is susceptible to *Phytophthora* leaf fall. Among the fungicides tested eleven were found to be effective against *Phytophthora spp.* while 12 were effective against *Drechslera hevea.* RRISL 224, a potential clone was discarded due to its susceptibility to *Corynespora* leaf fall.

A mixture of *Flemingia congesta* and *Crotolaria anagyroides* would produce sufficient biomass for mulching rubber clearings. Material from *Flemingia* could be used from year 2 until the end of immature period of rubber whereas material from *Crotolaria* can be used from 3 months after planting until the end of year 2.

Application of pre-emergence weedicide diuron at the rate of 1 kg per hectare could control weeds effectively for a period of 3 months in a seedling nursery. The chemical weeding using post-emergence weedicides or weedicide combinations with pre-emergence weedicides with supplementary manual upkeep is more effective and economical than exclusive manual weeding during the initial six months following planting rubber.

The RRI provided a revised fertilizer recommendation for all rubber estates for the year 2000 on the basis of samples collected in 1998. as a temporary economic measure. On this exercise the estates received a cost effective and a site specific fertilizer recommendation from the RRI free of charge.

The Raw Rubber Process Development and Chemical Engineering Department was involved in solving quality problems in raw rubber processing. They were able to prove that the reason for the quality deterioration of crepe rubber is not due to the poor quality of the bleaching agent used; but due to the delaying of processing latex in factories where central processing is done. They have also been engaged in implementing treatment systems for crepe rubber factory effluents and also for the centrifuged latex factory effluents. Based on a request made by the Coconut Development Authority, a treatment system for D.C. Factory effluents has also been initiated and the unit is now nearing completion at Sanhinda Desiccated Mill, Kirimetiyana. They have also been able to observe that sulphate ions in centrifuged rubber factory effluents has an adverse effect on the anaerobic digestion process of proteinous material. Based on the assistance given by this department, another crepe rubber factory at Padukka Estate has been granted ISO 9002 registration by the SLSI. They have also been able to conduct a workshop on "Waste Water Treatment" to a delegation of scientists from Thailand.

Project on DPNR/BR blends and NR/NBR blends have also been conducted by both the Polymer Chemistry Department and the RRPD & CE Department. NBR/BR projects have yielded good results for a blend containing 40% BR in the blend used in tyre treated. DMA and NMR analysis on vulcanized and raw rubber

samples of NR. NBR conducted jointly with the Griffith University, Australia, have shown valuable results.

An important Round Robin Cross Check was carried out by the Chemistry/Technology Departments in Colombo for the purpose of standardizing all the test equipment used in rubber products manufacture. From the results of these tests, it has been possible to unify the test results given by the testing equipment used in products manufacturing factories in the country.

Formulations developed by the Polymer Chemistry Department for conductive rubber pads in muscle toning machines were able to receive international recognition. They are now being used in the Army Hospital, Colombo North Hospital and at Ranawiru Sewana.

Another project carried out by this Department to utilize buffing dust in large quantities than the 10% used at present in tyre trend formulation after a fatty acid derivative treatment has been successful. This Department engaged in successfully solving the blooming problem in rubber foot-wear, which has been a major problem faced by the rubber products industries during the past.

The Rubber Technology and Development Department has been able to extend the modified Lowry procedures for the analysis of leachable proteins in Natural Rubber. This technique yielded lower leachable protein levels below 50μg/g in local dipped rubber products and in crepe rubber. The Department has been able to develop techniques for making latex coated fabric gloves and adhesive suitable for the manufacture of rubberised coir based baskets and casting systems suitable for making decorative flowers out of latex.

The number of TSR samples received by the Raw Rubber and Chemical Analysis Department has been low during the year. However, they have been heavily engaged in testing of latex and raw rubber for export certification purposes. Under the raw rubber quality control programme, they have been engaged in the analysis of the quality of water and chemicals used in the production of all grades of rubber. Further, they have been heavily engaged in the promotion of rain guards in the rubber plantations in Sri Lanka using the low cost brushable sealant developed by the department.

The main focus of the Bio-Chemistry and Physiology Department has been the development of appropriate technology for environmental friendly management of rubber factory wastes. Their Ditch System of treating rubber factory effluents has also been implemented in a couple of places during the year.

OVERSEAS VISITORS

Mr Sournet Dominiyne, France
M/s K Vaillant Flaing, France
M/s Coustier Maries Francoise, France
Mr Leboeg Reine, France
M/s Raea Tiene, France

Mr Grandsean Feom, France
Mr Rorgroe Bernard, France
Mr Obergtecl Friedbert, Germany
M/s Mariella Marzang, United Kingdom
Mr Hans Peter Berger, Germany
Mr Didin Suwardin, Indonesia
Mr Pichet Chairanich, Thailand
Mr Devaraj Veerasamy, Malaysia
Mr Ngnyen Ngoc Bich, Vietnam
Mr Earong Mainh Erung, Vietnam
Mr Hotelier Bruno, France
Mr Sommat Seengpradus, Thailand
Mr Chacxri Launram, Thailand
Mr Bodee Navawong, Thailand
Mr A K Gauba, India
Mr M H Mahajan Shetti, India
Mr S Ramakrishna, India
Mr V Subramanian, Singapore
Mr A F S Budiman, Indonesia

GENETICS AND PLANT BREEDING

D P S T G Attanayaka

SUMMARY

Experimental results showed eight new promising genotypes for future recommendation. Three new clones have been identified as promising latex- timber clones. The two vigorous clones PB 235, PB 260 and the clone BPM 24 gave the highest second year yield figures from the foreign clone trials.

A well -equipped laboratory was commissioned to undertake research on *Hevea* molecular biology. No significant association between the two forms of the PCR amplified *ref* gene and the morphological traits studied was detected among the progeny individuals of the PB 260 x RRIC 130.

DETAILED REVIEW

Staff

The Head of the Department, Dr D P S T G Attanayaka, Development Officer, Mr K B Karunasekera, Experimental Officers, Mr K W Rupatunga and Mr I D M J Sarath Kumara, Senior Experimental Assistant, Mr B M S G Peries, Technical Officers, Miss A K Gamage, Mr T M S K Gunasekera, Mr H P Peiris and Clerk/Typist, Mrs S D P K L Pieris, were on duty throughout the year. Mrs S P Herath left the island on 5th April for postgraduate studies at the University of Nagoya, Japan. Mrs S P Withanage, Assistant Geneticist and Plant Breeder was on maternity leave from 6th August to 8th December.

Meetings and Workshops

Dr D P S T G Attanayaka attended the following meetings and workshops.

- Central Scientific Committee.
- Committee on Specialist Group on Plant breeders, Tissue culturlists and Biotechnologists
- Indo-Sri Lanka Science & Technology Cooperation Joint workshop on "Agriculture and Plant Biotechnology including Fisheries and Livestock" 26-28 October 1999. Dr D P S T G Attanayaka spoke on the "present status of the biotechnology in relation to rubber" in this workshop.

Research students/training

Mr S W Abeynayake a final year student from faculty of Agriculture, University of Ruhuna completed his research training and submitted a report on "Investigation of the rubber elongation factor *(ref)* gene in *Hevea brasiliensis* and its possible application in *Hevea* breeding and selection" under the supervision of Dr D P S T G Attanayaka.

LABORATORY INVESTIGATIONS

Molecular biology of *Hevea* GPB/MM/97

A well-equipped laboratory was commissioned on 7th January 1999 to undertake research work on *Hevea* molecular biology. This laboratory was constructed using Rubber Research Board (RRB) funds.

Clone identification work using RAPD technique was continued. *ref* gene was amplified from 50 progeny individuals derived from a cross between PB 260 x RRIC 130 and digested with four restriction enzymes. *Eco*R I fragments shows a polymorphism of the *ref* gene amplified from the progeny individuals. The results confirmed the two *Eco*R I forms of the *ref* gene segregation according to 1: 1 Mendelian ratio. Morphological traits studied were not significantly different between the two groups but it was observed that the high yielding individuals to be included more in the *Eco*R I digested category (D P S T G Attanayaka, S W Abeynayake and Anusha Gamage).

FIELD EXPERIMENTS

Hand pollination (HP) programme for 1998 (GPB/BST/HP/98)

PB 260 clone from the Malaboda division and PR 255, PB 255, IAN 45/710 clones from the Neuchatel estate were selected as mother trees for cross pollination programme. The HP programme was disturbed by the rainy weather prevailed during flowering. The number of pollinations done in each cross, number of pods produced and seedlings obtained are given in Table 1.

Table 1. *Details of 1999 hand pollination programme*

Cross	No. of Pollinations	Fruit set after		No. of seedlings
		4 weeks	8 weeks	
Malaboda division				
PB 260 x PB 235	200	10	07	14
PB 260 x IAN 45/710	228	07	03	07
PB 260 x IAN 45/873	110	09	06	17
Neuchatel estate				
PR 255 x PB 235	322	00	00	00
PR 255 x IAN 45/873	610	04	04	11
PR 255 x IAN 45/710	466	02	02	06
PB 235 x PR 255	172	11	11	32
PB 235 x IAN 45/710	46	01	01	03
IAN 45/710 x PB 235	812	258	57	136
IAN 45/710 x PB 260	163	22	11	25
Total	3129	324	102	251

Pollen parent of 27 fruits derived after crossing was not identified in the following cases.

Cross	Fruit set		No. of seedlings
	4 weeks	8 weeks	
PB 235 x (not known)	01	01	03
PB 260 x IAN (unknown)	02	01	03
PB 260 x (not known)	12	05	15
IAN 45/710 x (not known)			06

Seedlings derived from these pods will be tested as half-legitimate seedlings (D P S T G Attanayaka, K B Karunasekera, S Withanage, I D M J Sarath Kumara and T M S K Gunasekera).

Evaluation of hand pollinated progenies

Small scale clone trials

An index of the hand pollinated progenies produced, since 1975 is given below (Table 2).

Table 2. *Details of the small scale clone trials to-date since 1975*

HP year	Site	Planting date
1975	Clyde – Doret	18 May 1982
1976	Hillstream – Tempo	13 May 1982
1977	No pollination programme	
1978	Payagala	Trial discontinued
1979	Eladuwa	Trial discontinued
1980	Eladuwa – Miturugama	Trial discontinued
1981	Eladuwa – Malaboda	Trial discontinued
1982	Clyde – Kethhena	September 1987
1983	No pollination programme	-
1984	No pollination programme	-
1985	Hillstream – Tempo	May 1989
1986	Kuruwita	May 1990
1987	i. Clyde – Kethhena	May 1993
	ii. Galawatta	June 1988
1988	Dartondfield	July 1993
1989	No pollination programme	-
1990	Not yet planted	
1991	Not yet planted	
1992	Dartonfield	May 1993
1993	Pollinations not successful	
1994	Pollinations not successful	
1995	Sorana	June 1998
1996	Kuruwita – I	May 1999
	Kuruwita – II	May 1999

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

Only the girth measurement was taken on the selected clones. In this trial, tapping on panel C has commenced in 1997 February and completed at the end of 1999. No test tappings were recorded in this year. After 13 years of very high intensity tapping, no TPD affected trees of clones RRISL 204 (out of thirteen trees) were detected. Two trees of clone RRISL 205 (out of eleven trees) succumbed to TPD. Table 3 shows the mean girth of the selected clones.

Table 3. *Mean girth in cm*

Clone	Mean girth
RRISL 204	78.03
RRISL 205	105.5
RRIC 130	60.35
RRIC 121	87.16
RRIC 100	66.00

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

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

Yearly girth and the test tapping data were recorded from the eight new clones selected and the two control clones (RRIC 100 and RRIC 121). Table 4 summarises the mean yield based on seven test tappings and the girth of these clones.

Table 4. *Mean yield in grams per tree per tapping (g/t/t) and mean girth of promising and the control clones (GPB/BST/HPS/76/1)*

Clone	Mean Yield (g/t/t)	Mean girth (cm)
76-121	34.88	69.37*
76-158	59.62	77.08
76-182	99.09	86.5
76-198	55.61	80.18
76-52	75.59	86.66
76-8	75.08	96.42
76-82	65.70	82.25
76-9	55.41	72.15
RRIC 100	57.34	75.90
RRIC 121	80.07	90.95

* Remarks three trees were lost from the experimental plot of clone 76-121

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

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

In this trial 61 new clones are being tested along with five control clones. One test tapping was possible during the year, which is the third year of tapping. Table 5 shows the mean yield and the girth of three new promising selections along with the performances of the control clones.

Table 5. *Mean yield and mean girth of promising H.P. Seedlings Clyde Estate (GPB/BST/HPS/82/2)*

Clone	Mean yield g/t/t	Mean girth cm
82 – 15	57.93	78.68
82 – 140	56.47	75.36
82 – 110	39.78	77.02
RRIC 100	28.08	65.42
RRIC 102	38.03	70.58
RRIC 121	42.84	73.73

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

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

Only one test tapping was possible in this trial (third year of tapping) during the year (D P S T G Attanayaka, K W Rupatunga and K B Karunasekera).

Evaluation of 1986 H.P. Selections - Kuruwita Sub station. (GPB/BST/HPS/86)

Sixth year girth measurement and the results of the Duncan's multiple range test of promising clones are given in the table 6. Test tapping of this trial was commenced in October last year. Eight test tappings were recorded for this year. Table 7 shows the mean test tapping data and the results of the Duncan's multiple range test.

Table 6. *Mean girth in cm of promising H.P. clones*

Clone	Mean girth and DMRT grouping
86-81	68.40 ^{A}
86-21	65.95 ^{AB}
RRIC 121	65.73 ^{AB}
87-77	65.18 ^{AB}
86-87	61.95 ^{BC}
86-76	60.57 ^{BCD}
RRIC 110	60.35 ^{BCD}
86-24	60.22 ^{BCDEF}
86-22	59.60 ^{BCDEF}

Table 7. *Mean yield g/t/t of promising H.P. clones*

Clone	Mean yield and DMRT grouping
RRISL 110	52.28 ^{A}
86-87	48.37 ^{AB}
86-22	47.46 ^{ABC}
RRIC 121	45.35 ^{ABCD}
86-39	44.89 ^{ABCD}
86-32	44.64 ^{ABCD}
BPM 24	42.15 ^{BCDE}
86-11	39.68 ^{BCDEF}
86-82	39.65 ^{BCDEF}

(D P S T G Attanayaka, H P Pieris and K B Karunasekera).

Evaluation of 1987 H.P. Selections - Clyde Estate (GPB/BST/HPS/87/1)

Girth measurement and the results of the Duncan's multiple range test (DMRT) are given in Table 8. This trial was opened for tapping at the end of 1999. Test tappings will be commenced from the next year.

Table 8. *Mean girth and the results of DMRT of the 1987 H.P. selections*

Clone	Girth in cm	DMRT grouping
87-370	59.46	A
RRIC 110	57.15	A B
RRIC 121	55.87	B C
87-371	55.43	B C
RRIC 100	53.89	C D
87-372	53.40	C D E
87-375	52.11	D E F
87-382	51.96	D E F
RRIC 102	50.45	E F G

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

Evaluation of 1987 H.P. Seedlings - Galewatta Division (GPB/BST/HPS/87/2)

Part of the seedlings derived from the 1987 HP programme has been planted in this trial in 1988. Progeny size, mean girth and the mean yield of the families are given in the Table 9. Yield data of each family are based on five test tappings.

Table 9. *Mean girth and mean yield of the 1987 HP seedling families*

Family	Progeny size	Mean girth (cm)	Mean yield (g/t/t)	
			1998	1999
RRIM 600 x RRIC 101	10	66.15	18.58	24.30
RRIC 101 x GT 1	30	55.8	13.12	15.72
RRIC 100 x GT 1	53	69.45	19.88	39.20
RRIC 100 x RRIC 101	10	63.3	17.48	39.19
RRIC 100 x RRIC 110	12	67.87	21.35	50.00
RRIC 100 x RRIC 121	34	67.52	19.98	35.68
PB 86 x RRIC 121	13	63.88	14.54	31.28
RRIC 102 x GT 1	04	65.12	13.65	49.56
RRIC 121 x RRIC 110	25	65.00	17.76	34.28
RRIC 110 x RRIC 100	08	62.25	16.32	49.40
RRIC 110 x RRIC 121	01	71.00	16.93	6.62

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

Evaluation of 1988 H.P. Selections - Dartonfield Estate (GPB/BST/HPS/88)

The sixth year girth measurement was recorded in this trial. The mean girth arranged according to the Duncan's multiple range test is given in Table 10.

Table 10. *Mean girth in cm of the 1988 HP progeny*

Clone	Mean girth and DMRT grouping
88-36	54.54 A
88-32	52.50 AB
RRIC 100	50.67 BC
88-31	49.89 BCD
88-28	49.48 BCD
RRIC 110	48.04 CDE
88-8	47.83 CDEF
88-40	47.43 CDEFG
88-39	46.66 CDEFGH
88-16	46.05 DEFGHI

(D P S T G Attanayaka and K W Rupatunga)

Evaluation of 1992 H.P. Seedlings Dartonfield Estate (GPB/BST/HPS/92)

The trees of this trial have been marked for tapping. The girth measurement taken at 150 cm from the ground level is given in Table 11.

Table 11. *Family means of the girth measurement of the 1992 HP progeny*

Family	Girth (cm)
RRIC 100 x RRIM 712	49.93
RRIC 100 x PB 255	56.72
RRIC 121 x PR 255	48.51
RRIC 121 x PB 255	53.14
RRIC 102 x PB 255	49.67
BPM 24 x RRIM 712	47.75
RRIC 100 x PR 309	49.59
RRIC 121 x PR 255	45.61
RRIC 102 x PR 309	50.50
RRIC 121 x PR 309	40.00

(D P S T G Attanayaka, A K Gamage, K W Rupatunga and T M S K Gunasekera)

Evaluation of 1995 H.P. Seedlings Sorana Estate (GPB/BST/HPS/95)

In this trial 41 test entries along with two control clones are being tested in a randomized block design with four replicates. Plot size of each clone consists of eight plants. A diameter measurement was recorded in this trial (D P S T G Attanayaka, I D M J Sarath Kumara and K B Karunasekera).

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

Yearly girth measurement and the test tappings were done in this trial. Table 12 shows the mean girth and the yields obtained from each site. Clones PB 260, PB 235 and BPM 24 continued to show high yields in the second year of tapping as well in Atale, Salawa and Kuruwita.

Table 12. *Mean girth (cm) and yield (g/t/t) obtained from SRRP clone trials*

Clone		Eladuwa	Salawa	Kuruwita	Atale	Bentota	Yatawatta
PB 260	Girth	55.98	53.18	53.71	61.76	62.02	55.32
	Yield		47.39	58.41	46.19	48.07	
PB 235	Girth	60.54	57.11	59.65	61.53	65.02	49.55
	Yield		42.72	59.57	43.29	35.86	
BPM 24	Girth	54.59	49.7	46.57	54.79	50.71	46.08
	Yield		44.45	44.44	52.52	37.12	
PR 255	Girth	50.28	50.15	46.07	58.55	47.99	45.73
	Yield		33.83	46.60	36.30	28.90	
PR 261	Girth	51.17	51.13	44.23	57.04	48.87	39.31
	Yield		34.98	51.77	23.65	27.96	
RRIM 712	Girth	52.09	46.33	44.36	59.79	43.51	48.13
	Yield		34.29	57.51	46.68	33.31	
RRIC 121	Girth	58.08	55.3	57.14	69.98	58.92	52.61
	Yield		25.95	40.60	36.66	31.48	
RRIC 100	Girth	56.92	55.14				
	Yield		32.0				
RRIC 110	Girth	54.23	54.25				
	Yield		41.38				
PB 217	Girth	53.59	53.34				
	Yield		34.0				

The experiment planted at Monaragala has to be abandoned due to loss of majority of experimental plants caused by dry weather (D P S T G Attanayaka, K W Rupatunga, I D M J Sarath Kumara, B M S G Peiris, H P Peris and K B Karunasekara).

Development of latex-Timber clones (GPB/BST/LTC/97)

Clear bole volume was taken from the potential new clones for timber production. The RRISL 205, 76-8, 76-52 have been identified as promising Latex-Timber clones. Estimated bole volume of the new genotypes is given in the Table 13.

Table 13. *Estimated clear bole volume of potential RRISL clones for timber production*

Clone	Parentage	Age (years)	Clear bole volume (m3/tree)
RRISL 205	82 x 82	18	0.68
76-8	RRIC100 x RRIC101	14	0.42
76-52	RRIC100 x RRIC101	10	0.36
76-82	RRIC100 x RRIC101	14	0.327
76-182	82 x RRIC 101	14	0.322
82-140	IAN45/710x PB 28/59	12	0.236
82-15	PB 28/59x IAN45/710	12	0.207

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

Genotype environment interaction (G X E) studies (GPB/GE/98)

The plants of the experimental plot at Nalanda estate were damaged by wild elephants. This experiment was re-established during the year. Diameter measurements were taken from the rest of the experimental sites, *i.e.* 8 sites (D P S T G Attanayaka, K B Karunasekera, K W Rupatunga, I D M J Sarath Kumara, H P Peiris and S P Withanage).

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

The *Hevea* germplasm collection was maintained by adopting routine agronomic practices (D P S T G Attanayaka, S P Withanage and K B Karunasekera).

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

This trial was handed over to the Soils and Plant Nutrition Department (D P S T G Attanayaka, S Dharamakeerthi, K B Karunasekera, K W Rupatunge and I D M J Sarath Kumara).

New planting

I) ***GPB/BST/HPS/96/01 and GPB/BST/HPS/96/02***

Two Small Scale Clone Trials were planted at Kuruwita estate on 8th July 1999, to test the HP clones derived from the 1996 HP programme. In the experiment

GPB/BST/HPS/96/01, 27 HP clones and in the experiment GPB/BST/HPS/96/02, 23 HP clones were planted with three control clones PB 260,RRIC 121 and RRISL 205 in a Randomized Block Design with four replicates. Each treatment plot consists of 15 plants (D P S T G Attanayaka, S P Withanage, H P Pieris and K B Karunasekera).

II) ***Estate/ RRI collaborative clone trials GPB/BST/ECT/99/Sa***

Six new promising RRISL 200 series clones each with one tapping task in extent were planted at Salawa estate using polybagged planting material to observe their performance in commercial plantation conditions. The clones planted are, RRISL 201, RRISL 206, RRISL 215, RRISL 220, RRISL 221, RRISL 226. This kind of ECT trials will in future replace the large scale clone trials hither to conducted by the RRI.

III) ***Multi-clonal stands GPB/MCS/98/KU***

An experiment was planted to study the effect of the multi-clonal stands on the performance of the growth and the per hectare yield of rubber. Four clones were planted as monoclonal blocks, all possible combinations of bi and tri clonal mixtures in a randomized block design comprising of four blocks. This study will be carried out in collaboration with the Plant Science Department.

New clones

Eight (08) new genotypes selected from hand pollinated seedlings generated from 1976 up to 1982 (inclusive of both years) have been identified as promising clones for large scale testing. These clones will be included in the future list of clone recommendation to be tested under the Estate/RRI collaborative clone trials (ECT programme).

PLANT SCIENCE

A Nugawela

SUMMARY

Two to three year old clearings can be crown budded to replace the foliage with a different genotype if necessary. g/t/t increase with increasing girth generally in all clones. Further within a clone g/t/t is higher in more vigorous plants than in less vigorous plants. Girthing, after commencement of tapping is relatively less in RRIC 100 than in RRIC 121 and RRIC 130. Productivity levels achieved by ½S d/3 + E* is comparatively less than with ½S d/2 and this is due to the inability to carryout recommended rounds of stimulation. Four rounds of stimulation per annum will help to increase productivity to ½S d/2 levels. With ½S d/1 tapping, the decline in g/t/t is less in RRIC 100 than in RRIC 102, 121 and 130. Tapping panel BI-1, with a renewed period of 10 years, gave better intakes than exploiting higher virgin panels.

Incidence of TPD is associated with tapping intensity, stimulation and clones. TPD trees not recovered following a rest period can be tapped with a ¼S(↑) cut on higher virgin panels.

Girthing, bark thickness declines with increasing density, *i.e.* 500-800 trees/Ha. Anyhow, tappable trees/Ha. increase upto 700 trees/Ha.

East West tapping of rubber improves performance of intercrop. Double row system of planting rubber land the intercrop due to wider alley space, but spacing within the paired row should reduce infra-specific competition within the paired row. Growing timber with no fertiliser inputs in the double row system can bring about a competitive effect on rubber. Cardamom, Rubber cropping systems at low elevations appear to be economically viable.

DETAILED REVIEW

Staff

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

Dr V H L Rodrigo, Botanist visited Rubber Research Institute of India during 13.12.1999 to 22.12.1999.

Mr T U K Silva, Mr M K P Perera and Mr M N de Alwis were promoted to the post of Experimental Officer with effect from 01.02.1999, 01.03.1999 and 21.05.1999 respectively.

Mr R B Gunaratne, Experimental Officer was promoted to the post of Developmental Officer and transferred to the Adaptive Research Unit with effect from 17.02.1999.

Research students

Mr W M P T Ariyaratne from the University of Peradeniya completed her final year project on "Seedling shoot tip culture of *Hevea brasiliensis* Mull Arg." under supervision of Dr (Mrs) P Senevirate.

Miss J C W Jayásuriya from the University of Ruhuna completed her final year project on "Optimizing the shoot proliferation of mature origin *Hevea* and acclimatization of juvenile plantlets of *Hevea*" under supervision of Dr (Mrs) P Senevirate.

Mr W G N Karunaratne of Aquinas College, Colombo, completed a study on "budwood nurseries" as a partial fulfilment of the Diploma in Agriculture under the supervision of Dr (Mrs) P Seneviratne.

Mr M J Perera of Aquinas College, Colombo, completed a study on "preserving budwood" as a partial fulfilment of the Diploma in Agriculture under the supervision of Dr (Mrs) P Seneviratne.

Mrs E S Munasinghe from the University of Peradeniya completed her final year project on "The level of variation in yield and yield determining factors and their relationship in different *Hevea brasiliensis* Muell. Arg. Clones" under the supervision of Dr A Nugawela.

Meetings and Conferences

The Head of Department addressed at the following meetings:

- Scientific Committee Meetings. Dr (Mrs) P Seneviratne, Dr V H L Rodrigo and Mr L S S Pathiratna also participated.
- Policy on replanting cycles. Discussion with the Management of Bogawantalawa Plantation Ltd.
- Meetings with RDD Officials on revised subsidy scheme.
- Seminar on Plantation Management for next millennium.

The Department Staff also conducted the following programmes.

- Dr V H L Rodrigo attended the Fruit co-ordinators Meeting, Department of Agriculture, Gannoruwa.

- Dr (Mrs) P Seneviratne attended the Panel Discussion on Biodiversity at SLAAS.
- Mr L S S Pathiratna attended a Seminar on Cinnamon Cultivation and Processing at University of Ruhuna.
- Dr V H L Rodrigo and Mr W Seneviratne attended the workshop on Indigenous Technical Knowledge (ITK).
- Nursery and Planting Techniques, Four programmes for Plantation Managers and Fourteen programme for the Field Staff.
- Exploitation and Rainguards. Seven Programmes for Plantation Management and Thirty two programmes for the Field Staff.
- University students and NDT Trainees.

LABORATORY INVESTIGATIONS

Tissue culture

Experiments were carried out to opitimize the growth medium, *i.e.* growth regulators to enhance the shoot proliferation rate of juvenile origin explants.

Explant manipulation seems to be the key factor for success rate of mature origin material. When the stock plants were grown in incubators, culture establishment was easier but no difference was observed in the shoot proliferation rate during the initial phases (P Seneviratne and G A S Wijesekera).

FIELD EXPERIMENTS

Rooted cuttings

Root systems of cuttings taken from splitted seedlings show similar morphology when compared to their twin seedlings. Growth of these plants will be monitored and more pairs will be transferred to the field to confirm the results (P Seneviratna and G A S Wijesekera).

Branch induction

A trial was established at Pallegoda estate to see the effect of various treatments on branching and the effect of branches on the tree growth.

A two year old clearing of RRIC 121 was used for the study. The effect of leaf cap and leaf folding methods were compared with that of removing apex and removing leaves of the top whorl.

Observation after one month from introducing the treatments indicated faster and higher number of branches in plants with apex removed (P Seneviratne and U S Weerakoon).

Bare root budded stumps

An experiment was conducted to see the effect of the length of the tap root on the survival and growth of bare root budded plants. Brown budded stumps of RRIC 100 with 6", 12" and 18" tap root were planted in 9"x20" poly bags together with control treatment. Sprouting percentage for the three treatments three months after planting were 83%, 100% and 66% for 18", 12" and 6" long tap-roots respectively.

However, after the first whorl stage, the growth could not be maintained and survival rate after 1 year of the establishment was 50%, 55% and 20% for 18", 12" and 6" respectively.

Growth of the plants, after one year was similar in all 3 treatments (P Seneviratne and L Zoysa).

Polybag plants

In order to minimize the casualties due to transplanting polybag plants into the field and also to make transplanting easier, following treatments were tested, with polybag plants. Field planting,

T1 – Together with the polybag
T2 - Without base of the polybag
T3 - With out the base of the bag + 4 slits
T4 - With 4 slits on the bag
T5 - Whole bag removed as currently recommended.

Results after 7 months of transplanting indicates slightly better growth in plants of treatments 2,3 and 5 when compared to those of treatments 1 and 4 (P Seneviratna and U S Weerakoon).

Crown budding

RRIC 110, 1994 and 1996 Replantings - Padukka (CB/98/1)

Girth of RRIC 110 plants crown budded with clones RRIC 100, 102, 117, 130 and *Hevea spruciana* at Padukka Estate is given in Table 1.

Table 1. *Mean girth (cm) of RRIC 110 plants crown budded with RRIC 100, 102, 117, 130 and* Hevea spruciana

Clearing	Crown	Girth (cm)
1996 – RRIC110 Minnerigama Division	RRIC 100	29.9
	RRIC 102	33.1
	RRIC 117	27.2
	RRIC 121	31.0
	RRIC 130	30.4
	H. spruciana	31.4
1994- RRIC 110 Main Division	RRIC 100	38.1
	RRIC 102	38.6
	RRIC 117	35.6
	H. spruciana	36.7

As expected, the set back in growth is minimal when the plants are young, *i.e.* 1996, RRIC 110, and also the effect of the crown clone on the growth is not significant up to now (P Seneviratne and M N de Alwis).

RRISL 224, 1997 Replanting – Dartonfield (CB/98/2)

RRISL 224 clearing replanted in 1997 at Galewatta division in Dartonfield group was severely affected with *Corynespora* and repeated defoliation was observed. These plants were sprayed regularly as instructed by the Plant Pathology Dept. for a period of 3-4 months to improve the foliage and peeling quality to undertake crown budding. Clones RRIC 100, RRIC 121 and a species immune to SALB, *i.e. H. pauciflora*, were used for the crown. Bud grafting success was around 90% (P Seneviratne and M N de Alwis).

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)

Experimental details are given in the Annual Review 1995.

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

Table 2. *The mean yield, i.e. g/t/t in 1999 when tapping commenced at different girths in different clones*

	Clones and Mean g/t/t			
Treatment	RRIC 130	RRIC 121	RRIC 100	Mean
T1	51.94	30.44	33.16	38.51
T7	38.01	28.23	35.48	33.91
T3	56.69	30.37	36.34	41.13
T8	56.17	26.81	41.16	41.38
T5	67.34	41.90	33.52	47.59

Generally, in all clones the g/t/t increases with increase in girth class. Further, trees that reach a higher girth class later, continues to yield less than those reached the same girth earlier. Therefore, even within a clone vigorous trees yield better.

During 1999, *i.e.* fourth year of tapping, girthing of both tapped and untapped trees is less in clone RRIC 121 and it is heights in clone RRIC 100 (Table 3).

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

Clone	Treatment	Initial girth (cm)	Girth Increment (cm)			
			1st year	2nd year	3rd year	4th year
RRIC 100	T_1	41.9	4.5	3.5	4.8	4.09
	T_2	41.7	8.2	6.5	5.7	5.59
	T_3	44.6	4.8	3.5	4.8	4.50
	T_4	45.1	8.8	7.0	6.7	5.39
	T_5	50.2	3.7	4.5	5.1	5.19
	T_6	49.3	9.3	6.6	6.7	6.56
	T_7	42.0	8.3	3.9	3.4	4.79
	T_8	45.0	8.9	3.8	3.9	5.46
RRIC 121	T_1	42.2	5.1	4.3	4.1	1.9
	T_2	42.6	6.3	5.5	4.6	2.44
	T_3	44.9	5.2	4.2	3.8	1.42
	T_4	44.6	6.6	5.2	4.4	2.89
	T_5	49.6	6.2	4.5	4.2	2.20
	T_6	49.6	7.6	5.8	4.4	2.23
	T_7	42.6	7.1	4.1	4.1	2.02
	T_8	44.7	6.1	4.3	4.3	1.96
RRIC 130	T_1	42.9	4.9	4.2	2.2	2.77
	T_2	42.4	8.1	6.2	3.9	4.53
	T_3	44.6	5.7	5.5	2.1	4.28
	T_4	45.1	8.8	6.8	4.5	4.99
	T_5	49.5	5.7	5.0	1.5	4.36
	T_6	49.8	9.6	7.6	4.6	5.90
	T_7	42.6	8.2	3.9	2.0	3.50
	T_8	44.7	8.5	4.2	1.8	3.11

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

RRIC 100, 1992 Replanting - Yatadola

The experimental details are reported in the Annual Review of 1997. The mean yield per tree per tapping, *i.e.* g/t/t increases with that of girth. Girthing after tapping , *i.e.* percentage girth increase, is similar in all treatments (Table 4).

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

Treatment	Yield (g/t/t)	Girth increment (cm)
T_1	28.6	3.02
T_2	-	4.14
T_3	26.2	2.44
T_4	-	4.34
T_5	37.87	3.22
T_6	-	4.2
T_7	23.0	2.0
T_8	27.32	1.42

(A Nugawela, S Wilbert and R K Samarasekera)

Low frequency tapping

The objective of these trials is to reduce tapper requirement and tapping costs with no adverse effect on productivity.

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

Though the yield per tree per tapping (g/t/t) is highest in the Low Frequency Tapping System, the yield per tree per annum is highest with conventional tapping (Table 5). This is mainly because only 50% of the scheduled stimulation rounds were possible due to wet weather.

Incidence of TPD and girthing is comparable in both conventional and low frequency tapping systems (Table 5).

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

Tapping system	Yield		Growth		TPD
	g/t/t	kg/t/year	Girth (cm)	Increment (cm)	(%)
½S d/2	30.97	3.31	91.0	1.2	13
½S d/4+ E*(6/y)	43.0	2.28	85.7	0.9	9.7
½S d/3+E*(6/y)	34.1	2.52	85.2	1.2	10.3
½S d/3+ E*(4/y)	32.8	2.43	83.2	1.0	15.2

E* 2.5% ET, Ba 1.6(2.5)

(A Nugawela, S Wilbert and R K Samarasekera)

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

The annual mean dry rubber yield per tree per tapping (g/t/t) and the total annual dry rubber yield per tree are highest in ½S d/3 systems with stimulation (Table 6). Four rounds of stimulation had been possible during the year.

The annual girth increment is comparable in both conventional and low frequency tapping systems.

The incidence of TPD is relatively high RRIC 102 then in RRIC 100 and RRIC 121, but it is similar in both low frequency and conventional tapping systems.

Table 6. *Effect of low frequency tapping with stimulation on yield, growth and tapping panel dryness in clone RRIC 102*

Tapping system	Yield		Growth		TPD %
	g/t/t	kg/t/year	Girth (cm)	Increment (cm)	
½S d/2	20.48	2.46	73.9	1.7	17
½S d/3	33.79	2.57	75.4	1.6	7.4
½S d/3+E*(4/y)	49.25	4.04	75.8	1.3	4.7
½S d/4+E*(6/y)	39.69	2.54	75.9	1.8	19.1
½S d/3+E*(6/y)	58.51	4.62	75.7	1.9	12.6

E* 2.5% ET, Ba 1.6(2.5)

(A Nugawela and K A G B Amaratunga).

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

The mean annual yield per tree per tapping (g/t/t) is highest in low frequency systems with stimulation. Anyhow, the total annual yield of a tree is comparable in both conventional and low frequency systems (Table 7).

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

Tapping system	Yield		Growth		TPD
	g/t/t	kg/t/year	Girth (cm)	Increment (cm)	(%)
½S d/2	40.2	4.8	82.56	0.75	13.4
¼S d/2 + E*(6/y)	38.75	4.65	91.38	0.18	7.1
½S d/3 + E*(6/y)	56.6	4.30	88.62	1.48	13.3
½S d/4 + E*(6/y)	60.2	3.67	87.45	0.17	6

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

Incidence of dryness is similar in tapping treatments ½ S d/2 and ½S d/3+E* (Table 7) (A Nugawela, S Wilbert and R K Samarasekera).

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

½S d/3 system of tapping with different concentrations of the stimulant and frequencies of application was tested with the ½S d/2 system of tapping.

Treatments are as follows;

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

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

The total crop per tapper and the intake per tapper are both marginally high in the d/3 systems. Nevertheless, the ethrel concentrations and frequencies of application tested have not significantly affected the yields. The productivity per unit land area is high in the conventional ½S d/2 system (Table 8).

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

	Total Crop (Kg) per annum			
	Tapper	Block	IPT	g/t/t
½S d/3+E*(4/y)	1399.7	466.6	7.14	28.22
½S d/3+E**(4/y)	1382.7	460.9	7.05	28.42
½S d/3+E*(6/y)	1462.3	487.4	6.93	25.76
½S d/2	1346.9	673.5	6.23	22.09

E* 2.5%ET, Ba 1.6 (2.5)
E** 5%, Ba 1.6 (2.5)

(A Nugawela, S Wilbert and R K Samaraskera)

Low frequency tapping of clone PB 86 in the smallholder sector

The experimental details are given in the Annual Review 1998.

Low Frequency Tapping with stimulation has performed relatively well at Ratnapura than in Kegalle and may be due to the higher number of stimulations possible. It is apparent that with ca. 4 rounds of stimulations per annum productivity levels of ½S d/2 could be achieved ½S d/3 tapping (Table 9).

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

District	Treatment	IPT (kg)	Crop/Task (kg)	% TPD	BCR (cm)	Stimulation Rounds
Ratnapura	T1	6.72	638	4.5	21.9	0
	T2	10.9	732	5.3	17.0	3
	T3	10.9	679	6.4	16.5	5
	T4	6.8	442	6.8	16.5	5
Kegalle	T1	5.2	564	3.0	22.9	0
	T2	6.6	491	1.6	21.1	2
	T3	6.3	470	3.2	21.2	2
	T4	6.5	465	3.2	21.2	2

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.

The dry rubber yield per tree per tapping (g/t/t) is high with low frequency tapping with stimulation in all clones tested. Yields obtained through ½S d/2 tapping can be achieved with low frequency tapping with 4-6 rounds of stimulation per annum (Table 10). There is no evidence for treatment differences in TPD. This trial had to be terminated in September as the area was uprooted by the management for diversification.

Table 10. *Effect of different tapping systems on the yield per tree per tapping (g/t/t), annual yield per tree (kg/t/annum) and incidence of TPD (%) in clones RRIC 100, PB 86 and RRIC 101*

	RRIC 100			PB 86			RRIC 101		
Tapping System	g/t/t	kg/t/y	%TPD	g/t/t	kg/t/y	%TPD	g/t/t	Kg/t/y	%TPD
½S d/2	31.2	5.16	4.2	28.4	5.11	1.8	30.6	5.5	3.7
½S d/3 + E*	42.9	5.14	0.8	37.3	4.47	1.3	36.4	4.32	2.3
½S d/3 + E**	38.9	4.66	5.8	37.9	4.54	3.2	44.7	5.36	2.8

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

(A Nugawela and C W Ranasinghe).

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

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

The mean g/t/t recorded during 1999 and the number of stimulation rounds under taken for the four clones tested are given in Table 11.

Table 11. *Annual mean g/t/t for different frequencies of stimulation and the number of actual stimulation rounds undertaken for each of the four clones tested (Number of actual stimulation rounds are given within brackets)*

	Clone and Yield (g/t/t)			
Treatment	RRIC 130	RRIC 102	RRIC 121	RRIC 100
1% ET,Ba 1.6(2.5)12/y	50.4(9)	43.7(9)	40.7(9)	36.7(9)
2.5%ET,Ba 1.6(2.5)6/y	47.4(2)	41.2(2)	40.9(5)	46.2(5)
2.5%ET,Ba 1.6(2.5)4/y	53.7(2)	40.5(2)	36.3(3)	46.5(3)

Treatment differences are not consistent and may be due to the variation in the actual number of stimulations undertaken (A Nugawela and R P Karunasena).

High intensity tapping of virgin panels

The objective of the trial and the experimental details are described in the annual review 1993.

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

Generally, in all clones the g/t/t is lowest in ½S d/1 tapping system. Amongst the clones tested RRIC 100 and RRIC 102 has positively responded to ½S d/2 tapping with stimulation. All clones except RRIC 130 have given a higher dry rubber yield per tapping with ½S d/3 tapping with stimulation than from conventional ½S d/2 system (Table 12).

Treatment differences are not evident with regard to girthing in all clones (Table 12).

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
2S d/1	1	36.7 (2.6)	24.7(0.8)	27.9(0.9)	36.2(2.9)
	2	33.8(1.7)	27.1(1.1)	24.5(1.5)	28.6(1.7)
2S d/2	1	37.1(2.3)	33.2(1.2)	33.8(1.5)	46.0(3.7)
	2	49.7(3.2)	34.7(1.8)	46.8(2.1)	41.0(2.8)
2S d/2 +E*	1	52.6(3.7)	48.3(1.5)	39.5(1.4)	48.6(1.5)
	2	50.3(1.8)	37.2(1.1)	38.2(1.1)	37.2(2.4)
2S d/3+E*	1	43.9(0.8)	31.4(2.3)	45.5(1.8)	46.3(1.3)
	2	61.5(2.8)	33.0(1.3)	63.9(2.2)	42.3(3.6)

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

Clones RRIC 130 and RRIC 102 appear to be susceptible to TPD among the four clones tested. Further, incidence of TPD is marginally high with d/1 tapping (Table 13).

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	
2S d/1	1	14.3	28.6	28.7	14.3	21.5
	2	12.5	25.0	12.5	12.5	12.9
2S d/2	1	12.5	12.5	0	0	6.3
	2	0	14.3	0	28.6	10.4
2S d/2 +E*	1	0	0	0	14.3	3.6
	2	0	12.5	2.5	2.5	15.6
2S d/3+E*	1	0	12.5	0	12.5	6.30
	2	0	0	0	0	0
	Mean	3.6	13.2	8.3	13.4	

(A Nugawela and R P Karunasena in collaboration with the Soils and Plant Nutrition Dept.)

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 experimental details are given in the Annual Reviews of 1993 and 1997. Data gathered so far indicate higher yields could be obtained by tapping panel BI-1 (with a renewal period of 10 years) downwards rather than tapping higher virgin panels.

The tapping treatments tested previously were changed as follows from January 1999 to test whether resting of base panels, *i.e.* BI-1 and BI-2 whilst tapping higher virgin panels have improved the yield of the same.

Previous Treatment	New Treatment
T_1 - ½ S (↓) d/2 (Panel BI-1)	T_1 - ½ S (↓) +1/4 S (↑)d/2
T_2 – ½ S (↓) d/2 (6" above BI-1)	T_2 - ½ S (↓) +1/4 S (↑)d/2
T_3 – ½ S(↑) d/2 (Panel HO-1)	T_3 - ½ S (↓) d/2 (Panel BI-1)
T_4 – ½ S(↓) d/2 (Panel HO-1)	T_4 - ½ S (↓) d/2 (Panel BI-1)
T_5 Puncture Tapping (Panel HO-1)	T_1 - ½ S (↑)d/2 (Panel HO-1)
T_6 Puncture Tapping (Panel (HO-1)	T_1 - ½ S (↓)d/2 (Panel HO-1)

The mean dry rubber yield per tree per tapping (g/t/t) for treatments introduced from January 1999 are given in Table 14. Nevertheless, it is too early to comment on the effect of resting panel BI-1 on its subsequent yield.

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

	Annual Mean Yield (g/t/t)	
Treatment	ERB 93/1	ERB 93/2
T_1	53.8	48.5
T_2	40.7	33.7
T_3	36.9	39.7
T_4	39.1	28.7
T_5	41.7	39.6
T_6	35.9	37.1

(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 percentage incidence of tapping panel dryness for different treatments and clones are given in Table 15.

Table 15. *Effect of different agronomic practices on incidence of tapping panel dryness (% TPD) in clones RRIC 100 and RRIC 110*

		Clone and % TPD	
Treatment	Fert. Level	RRIC 100	RRIC 110
Rainguarding	1	0	6.7
	2	20	13.3
Rainguarding and stimulation	1	6.7	20.0
	2	0	13.3
Stimulation	1	13.3	6.7
	2	6.7	13.7
Control	1	0	13.3
	2	13.3	6.7

In both clones a correlation between agronomic practices and incidence of dryness is not apparent.

The percentage incidence of tapping panel dryness recorded for different treatments at the end of each year since 1994 is given in Table 16.

Table 16. *Effect of agronomic practices on the (%) incidence of dryness over a period of 5 years*

		Year and TPD (%)					
Practice	Treatment	1994	1995	1996	1997	1998	1999
Rainguarding	With	10	6.7	17.5	14.2	13.3	9.2
	Without	13.3	6.7	11.7	14.2	16.7	9.2
Stimulation	With	16.7	9.2	16.7	17.5	16.7	10.0
	Without	6.7	4.2	12.5	10.8	13.3	9.2
Clone	RRIC 100	16.7	5.0	11.7	10.8	6.7	7.5
	RRIC 110	6.7	8.3	17.5	16.7	23.3	11.7

Incidence of dryness is consistently high in stimulated trees and in clone RRIC 110. In clone RRIC 110 the foliage is poor due to its susceptibility to *Corynespora* Leaf Disease.

During the year 9 (nine) tree have fallen dry and 8 (eight) of them during April to July, *i.e.* during South West Monsoon (A Nugawela and C W Ranasingha).

Exploitation of dry trees

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

The objective and experimental details are described in the Annual Review of 1998.

The dry rubber yield per tree per tapping (g/t/t) and the % number of yielding trees for different treatments are given in Table 17.

Table 17. *The mean yield, i.e. g/t/t of exploited dry trees and percentage number of trees with latex (within brackets) for different treatments*

	Tapping Frequency		
Treatment	D/2	D/3	D/4
T_{1A} ¼S(↑)	26.0 (100)	24.1 (100)	26.2 (100)
T_{1B} (½S(↓)	19.6 (75)	16.8 (75)	13.9 (75)
T_2 Continuous Tapping	21.0 (25)	21.2 (63)	9.1 (50)
T_3 ½ S(↓) Opp. Panel	13.3 (50)	2.8 (25)	-
T_4 ¼S(↑) Opp. Higher Panel	19.4 (100)	19.3 (88)	16.8 (100)

Among the different treatments tested to exploit dry trees, the 1/4S (↑) cut on higher panels have given the highest yields. Further, 100% of the trees tapped using this system yielded through out the year (Table 17) (A Nugawela, N Kaluwewe, K A G B Amaratunga and S Wilbert) .

Planting density

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

High density

Kuruwita 1992 Replanting – PD/92/1

Details of the experiment appear in the Annual Review 1992. Similar to the performance in 1998, plant girth and bark thickness showed a significant difference ($P>0.05$) among different planting densities with lower values in higher densities (Table 18a and c). Tappability, *i.e.* % trees above 50cm girth, showed similar trend of declining, but this was not reflected by the tappable tree per hectare (Table 18 b). In general, tappable trees per hectare increased with increase in planting density up to 700 trees per hectare, except for clone RRIC 110 of which the highest value was at the highest density.

Poor girth, tappability and then, bark thickness in clone RRIC 110 reflected the infestation of *Corynespora* leaf disease. However, reasonable increase in girth and bark thickness of this clone over the previous year showed the effectiveness of fungicide application for the disease.

Table 18. *Growth and yield parameters of rubber in different densities and clones. In (a) plant girth at 90cm height, (b) tappable trees, i.e. trees above 50 cm at 120cm height, and in (c) bark thickness, BT at 150.*

(a)

Density (trees/ha)	RRIC 100			RRIC 110			RRIC 121		
	In 1998 (cm)	In 1999 (cm)	Girth increment (cm/yr)	In 1998 (cm)	In 1999 (cm)	Girth increment (cm/yr)	In 1998 (cm)	In 1999 (cm)	Girth increment (cm/yr)
500	50.59	58.76	8.17	48.11	54.43	6.32	50.69	58.03	7.34
600	51.30	57.32	6.02	46.02	50.76	4.74	49.53	55.59	6.06
700	48.95	54.80	5.85	44.70	50.13	5.43	49.14	55.42	6.28
800	48.67	54.25	5.58	43.16	48.03	4.87	47.48	52.94	5.46

(b)

Density (trees/ha)	RRIC 100		RRIC 110		RRIC 121	
	Tappability (%)	Tappable trees/ha	Tappability (%)	Tappable trees/ha	Tappability (%)	Tappable trees/ha
500	76.7	384	57.4	287	76.2	381
600	77.5	465	46.7	280	72.4	434
700	68.2	477	37.2	260	71.5	501
800	54.0	432	37.0	296	57.8	462

(c)

Density (trees/ha)	RRIC 100			RRIC 110			RRIC 121		
	In 1998 (mm)	In 1999 (mm)	Change in BT (mm/yr)	In 1998 (mm)	In 1999 (mm)	Change in BT (mm/yr)	In 1998 (mm)	In 1999 (mm)	Change in BT (mm/yr)
500	4.64	5.71	1.07	4.32	5.21	0.82	4.21	5.05	0.84
600	4.55	5.56	1.01	4.10	4.84	0.74	4.27	5.16	0.89
700	4.12	5.21	1.09	3.85	4.75	0.90	4.10	4.82	0.72
800	4.14	5.34	1.2	3.55	4.50	0.95	3.90	4.56	0.66

(V H L Rodrigo, A Nugawela, T U K Silva and L S Kariyawasam in collaboration with the Genetic and Plant Breeding Department)

Low density

The objective of the study is to findout 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
Nivitigalakale (Dartonfield Group) 1996 Replanting - PD/96/2

The experimental details are described in Annual Review of 1996. Girth measurements taken in 1988 are summarised in Table 19. Treatment differences are not apparent yet (A Nugawela, L S Kariyawasam and U S Weerakoon).

Table 19. *Girth measured at 120 cm for different densities and clones*

	Clones and Mean girth (cm)			
Planting density (tree/Ha.)	RRIC 100	RRIC 121	RRIC 133	PB 260
350	10.5	12.6	10.9	11.2
425	12.1	12.8	11.6	12.5
500	10.9	11.4	10.6	9.0
575	11.97	11.9	10.7	10.2

(A Nugawela and L S Kariyawasam)

Intercropping

Spatial arrangements

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

Details of the experiment appears in the Annual Review 1992. Poor performance of rubber was recorded in triple row system, though it provides the highest alley space (Table 20). Cluster planting systems, *i.e.* triangular and square performed similar to the traditional system of single row planting. Double row system, in general, appears to be better for intercropping due to its wider alley space, but spacing within the paired row has to be increased in order to reduce the intra-specific plant competition within the paired rows.

Table 20. *Effect of different planting systems on growth and yield parameters of rubber. Values with same letter (as the superscript) in each category, are not significantly different*

Spatial arrangement	Girth (cm)	Bark thickness (mm)	% tappable tree
Single row planting system	54.5^{ab}	5.95^{ab}	66.8^{ab}
Double row planting system	50.3^{bc}	5.67^{b}	46.8^{bc}
Triple row planting system	48.9^{c}	5.86^{ab}	34.8^{c}
Triangular planting system	57.7^{a}	6.22^{a}	79.1^{a}
Square planting system	54.8^{a}	6.19^{a}	65.5^{ab}

(V H L Rodrigo, L S Kariyawasam and T U K Silva)

Perth 1992 Replanting – IC/S/92/2

This experiment was established in 1992 and details are reported in annual review of same year.

The growth of the rubber trees is not affected significantly by the spatial arrangement, *i.e.* row or contour planting, but by the intercrop. The girthing of rubber in Cinnamon plots, irrespective of the spatial arrangement, was significantly higher than that in grass plots. The yield of rubber was also influenced by the intercrops irrespective of the spatial arrangement and the rubber in the grass treatment yielded significantly lower than those with the other two intercrops and the control (Table 21).

Table 21. *Effect of intercrop on the growth and yield of rubber*

Treatments	Yield g/t/t	Girth of rubber (cm)
Rubber + Cinnamon	22.4 A	57.3A
Rubber + Coffee	22.0 A	54.7AB
Rubber only	21.0 A	54.4AB
Rubber + Grass	15.2 B	51.8 B
(Values with the same letter are not significantly different)		

The growth of Coffee was not affected by the spatial arrangement, but by the closeness to the rubber row (Table 22). The yield of Coffee and Cinnamon was greater in east-west oriented rubber row treatment than in contours. Though the growth of grass was poor in all treatments its yield followed the same trend as those of Cinnamon and Coffee (Table 23) (L S S Pathiratna and M K P Perera).

Table 22. *Effect of closeness to the rubber row on the growth of Coffee*

Coffee row	Stem Diameter (cm)
1. Row next to the rubber row	4.16 B
2. Middle row	4.53 A
3. Middle row	4.28 AB
4. Row next to the rubber row	4.20 B
(Values with the same letter are not significantly different)	

Table 23. *The effect of spatial arrangement on the yield of coffee, cinnamon and grass*

Treatment	Dry bean yield of coffee, g/row	Bark yield of Cinnamon g/bush	DM yield grass, Kg/ha.
Row planting of rubber	384.2A	121.4A	392.4
Contour planting of rubber	262.3 B	86.7 B	306.8

Intercropping systems

Rubber and timber

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

Details of the experiment was reported in the Annual Review of 1992. Based on the decision made in previous year, Halmilla and Teak were replaced by Alstonia and Mahogani in Ambatenna estate, respectively. In Usk Valley estate, infilling was done with same timber species. In general, Alstonia performed better than other species. Although establishment of Mahogani was poor at the early stage of the experiment, reestablishment under the rubber shade appears to be successful in both sites. However, reestablishment of Alstonia under the shade was very poor.

Competition of timber crops on rubber growth was evident in Rubber/Alstonia intercrop showing the lowest rubber girth and bark thickness (Table 24). Poor establishment and growth of other timber species resulted in less competition to rubber. Growing Alstonia with no fertilizer inputs in the double row system showed the highest competitive effect on rubber (Table 25).

Table 24. *Effect of timber crops on growth and yield parameters of rubber. Values with same letter (as the superscript) within each category, are not significantly different*

Timber intercrop	Girth (cm)	Bark thickness (mm)
No timber plants	52.5^{b}	5.61^{a}
Halmilla	52.7^{b}	5.45^{ab}
Alstonia	49.0^{c}	4.79^{b}
Teak	52.3^{b}	5.36^{ab}
Mahogani	55.2^{a}	5.96^{a}

Table 25. *Performance of rubber under different cropping systems. Values with same letter (as the superscript) within each category, are not significantly different*

Cropping system	Girth (cm)	Bark thickness (mm)
Single row system (sole crop)	54.5^{a}	5.97^{a}
Double row system (sole crop)	50.5^{bc}	5.26^{ab}
Alstonia intercrop in single row system	51.0^{ab}	4.96^{b}
Alstonia intercrop in double row system	46.9^{c}	4.61^{b}
High density rubber-single row intercropping system	52.4^{ab}	4.87^{b}
High density rubber=double row intercropping system	51.9^{ab}	4.82^{b}

(V H L Rodrigo, L S Kariyawasam and T U K Silva)

Rubber and cardamom

This study aims to evaluate long term performance of cardamom at low elevations under rubber. Experimental plots were established in estate *i.e.* in Dartonfield and Hapugastenne estates and in smallholder, *i.e.* Morontotata conditions, in 1996. Based on the observations made, another rubber/cardamom observation plot was established in Elston estate in 1999 in medium scale at high density. Increasing planting density of cardamom, *i.e.* from single to double row systems, had no detrimental effect to either cardamom or rubber (Table 26 and 27). Instead, yield per hectare of cardamom increased with increase in the density.

Table 26. *Estimated yields (kg) per hectare of selected cardamom varieties at different planting densities and sites*

Cardamom variety	Dartonfield		Hapugastenne		Morontota	
	Single row	Double row	Single row	Double row	Single row	Double row
EC1/100	10.5	54	6	22	10	40
EC1/101	14	49	7	24	9	24
EC1/102	21	79	6.5	20	8.5	19
EC2/400MT	15	45	7.2	23	10.5	28
EC1/700	6.5	24	3.5	9	3	8

Table 27. *Growth and yield parameters of rubber in different sites of rubber/cardamom intercrop. Codes refer to G=girth at 150cm, BT=bark thickness and Y=rubber yield*

	Hapugastenne			Morontota			Elston	
	Control	Single row	Double row	Control	Single row	Double row	Control	With Cardamom
G (cm)	70	73	71	62	62	64	56	53
BT(mm)	8	8.4	8.3	7.5	7.4	7.1	5.6	5.3
Y (g/t/t)	38.7	39.4	36.0	40	39.2	39.2	38	35

(V H L Rodrigo, L S Pathiratne, T U K Silva and L S Kariyawasam. This is a collaborative project between the Department of Export Agriculture and the RRISL and funded by the CARP)

Intercropping project on rubber/Banana and smallholder on-farm trials

This is the second phase of the project. Objectives of the study are described in the Annual Review 1998 and the results of the first phase in Annual Review 1997. Research activities are on three directions, namely analyses of agronomic and socio-cultural factors influencing farming practice on smallholder rubber lands using on-farm trials and ethnographic studies, identification of key biological processes determining crop performance under shade conditions using on-station experiment and documentation of indigenous technical knowledge relating to smallholder rubber production and intercropping. This project was funded by the Department For International Development (DFID), UK and conducted in collaboration with Universities of Wales and Durham in UK and University of Sri Jayawardenapura, Sri Lanka.

On-farm trails on rubber intercrops

On –farm experiments were two fold, *i.e.* researcher - and farmer-led on-farm trials (RLEs and FLEs, respectively). The objective of the former was to evaluate the finding of the earlier project at smallholder conditions and also to refine them in accordance with farmers' need. The latter aimed to assess the farmers' priorities, needs and potential to maximize land use efficiency. In the establishment process of these on-farm experiments, in addition to the traditional areas for rubber (*i.e.* wet zone), the nontraditional areas (*i.e.* intermediate zone) of Sri Lanka were also focused with understanding of the potential for high rate of future expansion of rubber cultivation to these areas. During the year 1999, both RLEs and FLEs were established in the wet zone. Even in the intermediate zone, initial farmer interviews, site selection and preliminary land preparations were completed. Re RLEs in wet zone, four sites in Kegalle .egion (village Pannila) and three in Kalutara (adjacent to the village Kobawaka) were established. Treatments of RLEs were sole rubber and three intercrops comprising one to three banana rows between rubber rows. Since our earlier survey revealed that farmers do not fertilize banana in general when grown with rubber, banana of these on-farm experiments will be managed with three fertilizer regimes, *i.e.* at recommend level of fertilizer by the Agriculture Dept. of Sri Lanka, no inorganic fertilizer inputs and encouraging farmers to recycle banana trash after the harvest.

FLEs were confined to one village each in wet and intermediate zones. Decisions on crop selection and managements were taken by the farmer and researchers' involvement is mainly confined to the monitoring. (V H L Rodrigo, A M W K Senevirathna and P D Pathirana with collaboration with Universities of Wales and Durham in UK and University of Sri Jayawardenapura, Sri Lanka).

On-station shade experiment on rubber and banana

Primary objective of this study is to isolate the shade effect on both rubber and banana plants. Four shade levels, open area with 0% shade and three different mature rubber fields to simulate natural shades at ca. 25%, 50% and 75%, were selected from the Dartonfield estate for the study.

Genotypes, clone RRIC 100 of rubber and variety "Embul" of banana were used for the experiment. Planting under shade conditions was done as single rows in between two rubber rows. In order to avoid the root competition for water and nutrients among plants, both rubber and banana were planted in soil filled pits lined with two layers of polythene sheets (gauge 500). Diameter of each pit was six feet (1.8m) and depth five feet (1.5m) for rubber and three feet (0.9m) for banana. Original soil profile was maintained in the process of refilling the pits.

Soil physical and chemical properties were analyzed and pre-treatment measurements such as initial height and stem diameter at 10cm height and leaf area of both plant types, were conducted. No pre-treatment difference among treatments was observed. In addition, the initial plant dry matter and total feeder root length were assessed.

This experiment was established towards the end of the year. Growth and development of both plant types under different shade conditions and their physiological responses will be monitored (A M W K Senevirathna, V H L Rodrigo, P D Pathirana with collaboration with University of Wales, UK)

Documentation of indigenous technical knowledge

Data gathering began on indigenous/local knowledge relevant to rubber and rubber based farming systems of smallholder farmers through on-farm interviews in the two major rubber growing agroclimatic zones, *i.e.* wet and intermediate zone. Using the data gathered in the first round of knowledge acquisition process, a knowledge base was developed using the Win AKT software. Subject areas were,

1. Growth and yield performance, planting disease, distances resistance of the crops: rubber, banana cinnamon, passionfruit and vegetables,
2. Soil moisture and conservation, soil fertility and fertiliser application, soil erosion and conservation, and role of cover crops,
3. Shade effects on development and yield of the crops: rubber, banana cinnamon passionfruit and vegetables, were acquired from the first interviews done in the wet zone.

The precision of the identified relationships is to be improved in the next round of interviews. Also, knowledge distribution among different categories of the village community will also be studied (A M W K Senevirathna and V H L Rodrigo with collaboration with Universities of Wales and Durham in UK and University of Sri Jayawardenapura, Sri Lanka).

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

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

Treatment effect on the growth of rubber was not apparent. The rubber trees in this area are now in tapping. The shade of rubber has completely eradicated the grass. This experiment is terminated from the year end (L S S Pathiratna and M K P Perera).

Rubber and Cocoa/Cinnamon

Dartonfield - IC/CC/91/2

This trial was established in 1991 to investigate the possibility of intercropping Cinnamon and Cocoa with rubber.

The growth of rubber is not affected by the intercrops at this stage (Table 28). This experiment was badly damaged from the inception by cattle (L S S Pathiratna and M K P Perera).

Table 28. *Effect of intercrops on the growth of rubber*

Treatments	Girth of rubber (cm)
1. Rubber only	57.1
2. Rubber + Cinnamon (spacing 1)	56.6
3. Rubber + Cinnamon (Spacing 2)	59.6
4. Rubber + Cinnamon (Spacing 3)	57.9
5. Rubber + Cocoa (Spacing 1)	52.5
6. Rubber + Cocoa (Spacing 2)	55.2
7. Rubber + Cocoa (Spacing 3)	53.4

Cocoa trials - Perth, Neuchatle, Tempo and Miriswatta

No measurements were taken in these trials during the year.

Rubber - Rattan/intercropping trial - Kuruwita Sub-station

This trial was established in October 1996 with three indigenous species of rattan (Annual Review 1996). The growth of rattan was good as apparent from the height of the stem (Table 29).

Table 29. *The height of stem of rattan (cm)*

Rattan	Height of stem (cm)
Species 1	37.8
Species 2	62.4
Species 3	37.5

(L S S Pathiratna and M K P Perera)

Possibilities of intercropping cinnamon under rubber

Two trials at the Kuruwita RRISL Sub station and one trial in a smallholding at Kamburupitiya were initiated and details are given in Annual Review 1998.

The growth of both rubber and cinnamon was satisfactory in all experiments and did not show any treatment effect at this stage. The mean girth of rubber and height of Cinnamon in the main experiment (IC/RC/98/1) was 20.5 mm and 97.5 cm respectively.

In the other experiment where Cinnamon was established under mature rubber, *i.e.* 1984 clearing, the growth of cinnamon was very poor when compared to the monocrop cinnamon under full sunlight. In Cinnamon under mature rubber the .91m x .61m treatment had a better growth compared to the conventional spacing of 1.2m x .91m (Table 30).

Table 30. *Effect of spacing on the growth of Cinnamon under mature rubber and full sunlight*

Treatment Cinnamon Spacing	Under Rubber Plant DM (g)	Under full sunlight Plant DM (g)
1.2 m x .91m	70.8 B	957.5
.91 m x .61 m	107.1 A	1135.5
1.7 m x 1.2 m	96.4 AB	1168.5
1.1m Δ lar spacing	72.0 B	1090.5

(L S S Pathiratna and M K P Perera, In collaboration with Dept. Export Agriculture with CARP funding. CARP Grant 12/378/285).

Nursery Inspection Unit

Estate Sector:

A survey was conducted to gather information on the clones and the number of plants available from each clone in budwood nurseries of estates managed by Plantation Companies. This was done with the objective of regularising the issue of budded stumps to establish budwood nurseries and to improve the general condition of budwood nurseries.

The percentage of each clone in budwood nurseries of 132 estates are shown in figure 1.

It was also observed that the number of budwood plants in estates is excessive and their condition is below standard. Most of the nurseries consisted mixed clones, withdrawn clones, seedlings and over mature budwood. Data gathered were analysed

and reports were sent to the management of each of the 17 plantation companies for information and necessary action.

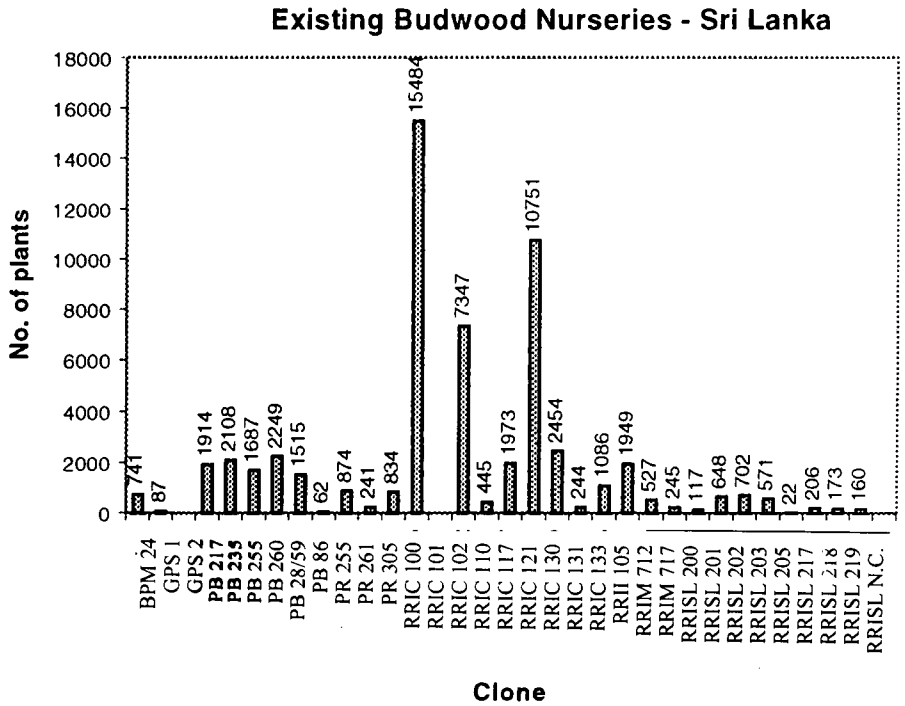


Fig. 1. Percentage of each clone in budwood nurseries of 132 estates

Smallholder Sector: There were only six requests for inspection during the year as compared to 171 in the previous year. Budwood nurseries of the Rubber Development Department nurseries at Egaloya, Gurugoda, Karpincha and Meerigama too were inspected.

Issue of budded stumps

Budded stumps were not issued for this purpose as it was revealed from the survey carried out that the clone distribution did not give expected results. This matter was discussed with management companies and a revised system will be implemented in the year 2000.

PLANT PATHOLOGY AND MICROBIOLOGY

C K Jayasinghe

SUMMARY

Wintering and refoliation were delayed during this year. Wet weather experienced during this period predisposed the susceptible clones to attack of *Oidium* and *Colletotrichum*. As flowers were also affected with *Oidium*, diseases caused by *Phytophthora* spp. were negligible except on the clone RRISL 203 which was severely affected with *Phytophthora* leaf fall during the latter part of the SW monsoon. Eleven fungicides were shown to be effective against *Phytophthora* spp. while 12 chemicals were found to be effective against *Drechslera hevea*. 7-hydroxy-6 methoxy coumarin which inhibited the conidial germination of *Corynespora cassiicola* was isolated from both infected and healthy rubber leaves. The molecular weight of the pectin lyase from *Colletotrichum acutatum* was recorded as around 24,000 Da and secretion of a thermo stable toxic metabolite by *C. acutatum* was reported. RRISL 224, a potential clone was discarded as it succumbed to *Corynespora* leaf fall.

DETAILED REVIEW

Staff

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

Experimental Officers, Mr D S Wettasinghe was promoted to a post of Research Assistant with effect from 17.2.1999 and transferred to the Adaptive Research Unit. Mr E B Fernando, Mrs J L P C Wettasinghe, Mrs B I Tennakoon, Experimental Officers were on duty throughout the year. Miss T H P S Fernando, Experimental Officer submitted her thesis entitled "Studies on the biology of the *Hevea* isolate of *Colletotrichum acutatum*" on 25.10.99 for MSc degree in the University of Colombo. Mrs D Wijeratne, Mrs S Gunasekera and Mr C Wijeratne, Technical Officers continued to work in the Department. Clerk Typist Mrs P Amarasekera was on duty throughout the year. Mrs H S L de S Rajapakse, Temporary Technical Officer worked for the CARP project 12/373/299 while Temporary Technical Officer Miss K D S Samararatne was discontinued with effect from 30th June 1999 as CARP Project 12/364/263 was terminated since 30th June. Mr R P D Vijitha, undergraduate from the University of Ruhuna successfully completed

his final year project entitled "Studies on the biology of the fungus *Phellinus noxius* and *in vitro* screening of selected fungicides against it" under the supervision of Dr R Jayaratne.

Visits

The Departmental staff made 42 advisory visits, 255 for experimental and 172 for other purposes.

Training/Lectures/Seminars

Dr C K Jayasinghe attended the 5th International Conference on Plant Protection in the Tropics from 15-18th March, 1999 held in Kuala Lumpur, Malaysia and presented a paper entitled "Significance of the factors affecting spore germination in the spread of *Colletotrichum acutatum* in rubber plantations of Sri Lanka".

Mr K E Jayasuriya participated in the International Training Course on Crop Protection at South China Agricultural University (CICAT), China from 5th May to 6th July 1999.

Dr C K Jayasinghe and Dr R Jayaratne served as resource persons in more than 20 training programmes for Superintendents, Asst. Superintendents, Field Officers, Undergraduates, Post-graduates and NDT Trainees. Messers D S Wettasinghe and E B Fernando covered the practical aspects of disease management while all the staff members extended their fullest cooperation in educating students from Universities, Technical Colleges and schools on the diseases of the rubber tree.

Dr C K Jayasinghe delivered two special lectures entitled "*Corynespora* leaf disease of rubber" (National Workshop on Challenging Problems of Plant Health in Sri Lanka, 9th August 1999, TRI Mid Country Station, Kandy) and "Rubber diseases to be cautious in the next millenium" (Seminar on Pest Control in the Next Millenium, 13th August 1999, SLAAS, Colombo).

Committees

Dr C K Jayasinghe served in several national committees; Pesticide Technical and Advisory Committee, Steering Committee on National Plant Quarantine (present Chairman) and Specialist Committee on Plant Protection.

Dr C K Jayasinghe, Dr R Jayaratne, Mr K E Jayasuriya and Miss W P K Silva attended the Scientific Committee Meetings of the Rubber Research Board.

Dr C K Jayasinghe continued to be a Visiting Lecturer in the University of Ruhuna while Dr R Jayaratne was appointed a Visiting Lecturer in the University of Ruhuna and University of Colombo.

GENERAL

The wet weather that prevailed at the beginning of the year delayed the occurrence of wintering. Depending on the locality and the clone wintering extended into early March. Refoliation was uneven and protracted over several months. Intermittent showers and morning mist favoured the spread of *Oidium hevea* and *Colletotrichum acutatum/gloeosporioides* causing secondary leaf fall specially on late wintering clones such as PB 28/59, RRIC 121 and RRIM 712. Consequently incidence of *Phytophthora* leaf fall and bark rot was mild. However, clearings of RRISL 203 were moderately affected with *Phytophthora* leaf fall in the latter part of the monsoon period. No new clones succumbed to *Corynespora* leaf fall. White root disease continued to be the major root disease. Requests made to fell the old trees at the collar region and treat the stumps with fertilizer/weedicides were rejected merely due to the high incidence of "Fomes patches" present in the rubber clearings of Sri Lanka. It was brought to the notice of interested parties that though the Malaysians recommend felling of trees at the collar region, mechanical clearing which involves removal of the roots by bulldozing is a must in clearings where the "Fomes patches" are present.

Preparation of the final drafts of three major publications namely, "Check List of Rubber Pathogens in Sri Lanka: Year 1900-2000"; "A Literature Guide to Rubber Pathology in Sri Lanka" and "Prevent, Diagnose and Control Rubber Diseases" has been completed.

The primary objective of the first publication is to present pathogens recorded on rubber tree in Sri Lanka since the establishment of rubber plantations in the latter part of the 19th century. Author surveyed available literature since 1900 and every effort was made to present a complete list of pathogens with the reference for the first published record. It is hoped that this checklist will be of valuable guide to Academics, Plant Pathologists and Quarantine Officers to search for pathogens recorded in Sri Lanka for their teaching, research and quarantine requirements.

The second presentation lists all the research articles published in Sri Lanka with regard to the pathology of rubber tree since its establishment in late 1800s. It is expected that this bibliography will help immensely to avoid repetition of experiments and direct the user to the sources of all findings in the discipline of *Hevea* pathology in the country.

The third publication was undertaken with the view of presenting up-to-date information with colour illustrations on identifying and managing all diseases reported to Rubber Research Institute of Sri Lanka during the last two decades. It is hoped that this will fulfil a long felt need and will serve as a valuable guide for Academics, Plant Pathologists, Quarantine Officers, Estate Managers and Extension Agents to diagnose and control diseases effectively.

LABORATORY AND FIELD INVESTIGATIONS

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

A. *Screening of fungicides against* Rigidoporus microporus

The monitoring of the field experiment laid down at Malaboda estate, Matugama to ascertain the efficacy of fungicide "Folicur" was continued. The results further confirmed that the fungicide "Folicur" is quite effective as a curative treatment for white root disease even 22 months after initiation of the experiment.

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

Estate	Pre-treatment assessment					Assessment after 22 months					
Disease score	0	1	2	3	4	0	1	2	3	4	D
Malaboda (No. of trees)	-	11	5	2	-	18	-	-	-	-	-

Two assessments were taken during the year in the experiments initiated at Devalakanda and Madeniya Estates for testing the effectiveness of the fungicide "Folicur" as a drench application.

Table 2. *Effectiveness of "Folicur" under field conditions after 14 months*

Estate	Pre-treatment Assessment					Assessment after 14 months					
Disease score	0	1	2	3	4	0	1	2	3	4	D
Dewalakanda (No. of trees)	-	8	13	14	4	27	-	-	-	-	12
Madeniya (No. of trees)	-	10	23	8	1	40	-	-	-	2	-

Disease Score

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

(R Jayaratne, C K Jayasinghe and P C Wettasinghe).

B. *Screening of fungicides against* Phellinus noxius – *Brown root causing fungus*

Nine fungicides were evaluated against this fungus using Poison Food Technique (PFT) and the soil fungicide screening test (SFST). The fungicides used were, Monceren (pencycuron), Folicur (tebuconazole), Bayfidan (triadimenol), Antracol (propineb), Dithane M 45 (mancozeb), benlate (benomyl), Captan (captan), Folpet (folpan), Baycor (bitertanol). From this study it was concluded that Folicur and Bayfidan can be used effectively under field conditions as an effective fungicide to control the Brown root disease (R Jayaratne, R P D Vijitha and P C Wettasinghe).

C. *Screening of fungicides against* Corynespora cassiicola

Management of the disease in clearings

Spraying of fungicides; benomyl, mancozeb and thiophanate methyl was continued at four locations namely; Dartonfield, Lagos, Salawa and Kuruwita estates. This long term experiment was initiated in 1997 and the clone under investigation is RRIC 110 (C K Jayasinghe, R Jayaratne, E B Fernando and C Wijeratne).

D. *Screening of fungicides against nursery diseases*

D_1 *Phytophthora* spp.

Phytophthora spp. are responsible in causing die-back of nursery plants specially during SW monsoon period. Several new chemicals have been introduced to the Sri Lankan market recently as potential fungicides in controlling *Phytophthora* spp. In view of this situation total of 17 fungicides were evaluated employing two screening techniques; conidial germination inhibition test (CGIT) and Poisoned Food Technique (PFT). Eleven fungicides, *viz.* propineb, propineb 56% + oxadixyl 10%, mancozeb, metalaxyl 8% + mancozeb 64%, captan, Copper 21% + mancozeb 20%, folpan, triadimenol, tebuconazole, mancozeb 56% + oxadixyl 10% and copper oxychloride reached the EC_{100} within the tested concentrations in both screening techniques (Table 3). These potential chemicals will be subjected to *in vivo* screening tests during the SW monsoon season of the year 2000 (C K Jayasinghe, E B Fernando and C Wijeratne).

Table 3. *Effectiveness[a] of fungicides against* Phytophthora meadii *as evaluated by two test procedures*

Fungicide	CGT[b]	PFT[c]
benomyl (Benlate)	200	NA
pencycuron (Monceren)	800	NA
propineb (Antracol)	100	200
triadimefon (Bayleton)	100	NA
propineb 56% + Oxadixyl 10% (Fruvit)	25	100
mancozeb (Dithane)	10	25
metalaxyl 8% + Mancozeb 64% (Ridomil)	10	25
captan (Captan)	2	100
chlorothalonil (Daconil)	25	NA
copper 21% + mancozeb 20% (Trimiltox)	5	200
thiophanatemethyl (Topsin)	NA	NA
folpan (Folpet)	2	200
triadimenol (Baytidan)	50	1600
tebuconazole (Folicur)	10	100
epoxiconazole (Opus)	10	NA
mancozeb 56% + Oxadixyl 10% (Sandofan)	5	50
copper oxychloride (Cobolight)	ND	800

[a] - Lowest concentration (µg/ml) required to inhibit 100%,
[b] - Conidial germination test.
[c] - Poisoned food technique
NA - EC_{100} was not achieved at the tested range.
ND - Not determined

D_2 *Drechslera heveae*

Drechslera heveae, which is also known as *Helminthosporium heveae* and *Bipoloris heveae* is identified as a serious pathogen of *Hevea* seedlings in many rubber growing areas of the world including Sri Lanka. A total of 21 fungicides were screened against *D. heveae* employing two screening techniques, conidial germination inhibition test (CGIT) and poison food technique (PFT) to evaluate the efficacy of inhibiting conidial germination and mycelial growth, respectively. Twelve chemicals have been identified as potential fungicides in management of *Drechslera heveae* as they reached the EC_{100} under both test procedures (Table 4) (C K Jayasinghe, S L Hewavitharana and T H P S Fernando).

Table 4. *Effectiveness* of 21 fungicides against* Drechslera hevea *as evaluated by two test procedures*

Fungicide	Test Procedure	
	CGT	PFT
copper oxychloride (Cobox)	5	400
oxadixyl 10% + mancozeb 56% (Sandofan)	5	800
pomarsol forte (Thiram)	5	800
metalaxyl 18% + mancozeb (Ridomil)	10	200
mancozeb (Dithane M 45)	10	1600
propineb (Antracol)	10	NA
captan 50% (Captan)	50	800
captan 80% (Captan)	5	1600
chlorothalonil (Daconil)	25	NA
folpan (Folpet)	25	NA
propineb 56% + oxadixyl 10% (Fruvit)	50	100
copper 21% + mancozeb 20% (Trimilto x Forte)	50	400
propiconazole (Tilt)	100	25
tebuconazole (Folicur)	200	100
tridemorph (Calyxin)	400	25
benomyl 50% (Benlate)	NA	NA
epoxiconazole (Opus)	NA	50
bitertanol (Baycor)	NA	50
carbendazim (Bavistin)	NA	NA
sulphur 80% (Maxel)	NA	NA
thiophanate methyl 70% (Topsin)	NA	NA
pencycuron (Monceren)	NA	NA

(a) * Lowest concentration (µg/ml) required to inhibit 100%
(b) ** Conidial germination test
(c) *** Poisoned Food Technique
(d) NA, EC_{100} were not achieved at the tested range

Biology of common pathogens (BCP/90/1)

A. Phytophthora *spp*

A_1 *Morphological studies of* P. meadii *isolates obtained from petiole infected sites of different* Hevea *clones*

Thirty-three *Phytophthora meadii* isolates were obtained from different *Hevea*

brasiliensis clones grown in different climatic regions in Sri Lanka. Growth, morphology and pathogenicity of the isolates were compared. Growth and pathogenicity levels varied among the isolates. Some isolates obtained from moderately susceptible rubber clones were highly pathogenic, than isolates obtained from resistant clones. Highly pathogenic isolates produced higher number of sporangia on agar at 27±2 °C. It was impossible to group isolates according to the clone or the region from where they were obtained (K E Jayasuriya, R L C Wijesundera, C K Jayasinghe and B I Tennakoon).

A_2 *Preliminary studies on anatomical and biochemical reactions involved in* Hevea *plants to* Phytophthora *infections*

Scanning electron microscope (SEM) studies revealed that the petiole surface of the tolerant clone (RRIC 100) showed a smooth surface when compared to susceptible clones (RRIM 600 and PB 86). In susceptible clones (RRIM 600 and PB 86) the petiole surface consists of many cavities and crevices. Petiole extracts with C_2H_5OH and $CHCl_3$ which showed antifungal activity against *Phytophthora* spore germination had Rf value of 0.08 (R Jayaratne, C K Jayasinghe, R L C Wijesundera and P C Wettasinghe).

A_3 *Studies on molecular variation of* P. meadii *isolates obtained from different* Hevea *clones*

DNA was extracted from twelve different *P. meadii* isolates. RAPD-PCR works are in progress (K E Jayasuriya, D P S T G Attanayake and R L C Wijesundera).

A_4 *Studies on cell wall degrading enzymes produced by* P. meadii *isolates*

Enzyme producing patterns were studied and further studies are in progress for determination of molecular weights of enzymes (K E Jayasuriya, R L C Wijesundera, C K Jayasinghe and B I Tennakoon).

A_5 *Studies on the accumulation of Pathogenesis related proteins (PRP) in* Hevea *petioles at* P. meadii *infection sites*

PRP were extracted from petioles of different *Hevea* clones at *P. meadii* infection sites and measured by Spectrophotometer. Further studies are in progress by using SDS-PAGE technique (K E Jayasuriya, R L C Wijesundera and B I Tennakoon).

B. Corynespora cassiicola

B_1 *Molecular characterization of* Corynespora cassiicola

42 isolates of *Corynespora cassiicola* collected from different clones of rubber and non rubber alternate host-plants grown in around rubber plantations throughout Sri Lanka were used in this study. Using RAPD-PCR analysis the isolates were clustered into different genetic groups. Rubber isolates clustered into three (A,B,C) genetically distinct groups. All the papaya isolates were in one group which is closely related to rubber group (C). Sweet potato, cocoa, tomato and manihot isolates were genetically distinct from each other and from rubber isolates (W P K Silva, E H Karunanayake and U M S Priyanka).

B_2 *Antifungal activity of* Hevea *leaf extract*

7-hydroxy-6methoxy coumarin which inhibited the conidial germination of *Corynespora cassiicola* was isolated from uninfected mature leaves and infected immature leaves of *Hevea brasiliensis*. The structure of the compound was determined by ^{1}H, $^{13}C_{nmr}$ spectra and mass spectra, UV and IR spectra. Scopoletin also inhibited the conidial germination of several other pathogens of *H. brasiliensis*. No correlation was observed between the scopeletin accumulation and clonal susceptibility (W P K Silva, R L C Wijelsundera, S A Deraniyagala and U M S Priyanka).

B_3 *Pathogenesis related proteins in* Corynespora cassiicola *infection process*

Production of PR proteins in the clones RRIC 100, 102, 121, RRIM 600 and RRIC 130 were investigated. This experiment is in progress (W P K Silva, R L C Wijesundera and U M S Priyanka).

B_4 *Production of pectic enzymes by* C. cassiicola

Corynespora cassiicola isolates, collected from papaw, tomato and rubber which belongs to three different genetic groups (according to the experiment B1) were used in this study. Since all the isolates tested produced PG and PL in liquid culture media, the molecular weights were determined using gel filtration chromatography. The results showed that there is no variation of the type of enzyme produced by different isolates. However some isolates produced higher concentration of enzymes than others (W P K Silva, R L C Wijesundera and U M S Priyanka).

C. Colletotrichum acutatum

C_1 *Cell wall degrading enzymes*

Investigations on cell wall degrading enzymes were completed. The molecular weight of pectin lyase (PL) was recorded as around 24,000 Da (T H P S Fernando and C K Jayasinghe collaborative project with Prof. R L C Wijesundera, University of Colombo).

C_2 *Toxic metabolite*

Observations from studies carried out on toxin production revealed that toxic metabolite produced by *C. acutatum* is thermostable and it is effective at a concentration of 3500 µg/ml on rubber leaves while it produces characteristic lesions even at a concentration of 700 µg/ml on polyalthia. Further studies are in progress (C K Jayasinghe and T H P S Fernando).

D. Rigidoporus microporus

Molecular characterizations of different isolates are being carried out in collaboration with Genetics and Plant Breeding Dept. (R Jayaratne, T Attanayake and P C Wettasinghe).

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

A. *Maintenance of recommended and potential clones in different agroclimatic zones*

Weeding, fertilizer application and numbering were done at Atale, Polatagama, Padukka, Pitiyakande, Nakiyadeniya, Bibile, Hapugastenna and Dartonfield estate nurseries (C K Jayasinghe and C Wijeratne).

B. *Field surveys for* Corynespora *leaf fall*

No new field infections were detected on any of the recommended clones in groups I, and II. However, the clone PB 235 showed a slight infection in an immature clearing at Uskvally estate, Lathpandura. RRISL 224, a potential clone was discarded due to high susceptibility to *C. cassiicola* (C K Jayasinghe and B Fernando).

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

An island-wide survey was conducted on fruit trees cultivated in rubber plantations to check whether fungus *Colletotrichum acutatum*, a newly recorded pathogen on rubber, is responsible in causing anthracnose disease symptoms on these crops. *C. acutatum* was isolated from "Katu lovi" and authentified with the collaboration of CAB International UK (IMI 381378). Pathogenicity of the fungus was proved and cross inoculation tests confirmed that IMI 381378 is capable of infecting rubber as well (C K Jayasinghe and T H P S Fernando).

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

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

The above experiment initiated in 1993 at Halwatura, Sirikandura, Eladuwa and Padukka estates was concluded and the results are being processed (R Jayaratne, C K Jayasinghe, D Siriwardene and U Mitrasena).

B. Poisoning of stumps to improve the methods of clearing of old stand during replanting

This experiment was initiated at Sapumalkanda estate in collaboration with the senior manager of the estate.

The chemicals used were, 2-4 D, Urea, Triclopyr, Glyphosete and Grammaxone. The stumps were poisoned with the above chemicals soon after they were cut at 6 inches above the ground level. Fungal colonization rates and the decaying rates will be monitored at regular intervals (R Jayaratne, C K Jayasinghe, A Perera, B Fernando and N Madawela).

Another experiment was initiated at N'kele division to determine decaying rates of split roots after poisoning with above chemicals. The decaying rates will be monitored by determining the weight loss at 6 monthly intervals (R Jayaratne and D Siriwardene).

Studies on arbuscular mycorrhiza (M/86/1)

The field experiment initiated to ascertain the effect of inoculating Arbuscular mycorrhiza on the natural populations were continued. The growth of the plants were monitored twice during this period (Table 5).

Table 5. *Mean diameter (cm) of the field established plants after 28 months (Mean of five replicates consisting 10 plants per replicate)*

Mycorrhizal type	+P (addition of P)	-P (No addition of P)
1. *Gigaspora margarita*	16.83 A	16.19 A
2. *Acaulospora* sp.	11.48 B	11.17 B
3. Natural population	11.67 B	10.72 B
4. Non-mycororhizal (initially)	11.22 B	10.12 B

(Means with the same letter are not significantly different at P = 0.05 using DMRT)

Gigaspora margarita inoculated plants are growing at a significantly faster rate than other treatments (R Jayaratne and D Siriwardene).

SOILS AND PLANT NUTRITION

Lalani Samarappuli

SUMMARY

It is proved that *Flemingia congesta* and *Crotolaria anagyroides* could be grown successfully between the rows of rubber plants which would provide sufficient biomass for mulching. The growth of *Crotolaria anagyroides* was much higher than the other species during the first year of planting. It was also observed that the growth rate and recovery after lopping of *Flemingia congesta* is much higher than the other species during the latter stages, although the growth rate during the early stages appeared to be slow. It is, therefore, confirmd that a mixture of *Flemingia congesta* and *Crotolaria anagyroides* would provide sufficient biomass for mulching; *Flemingia* from the beginning of year 2 until the end of immature period of rubber and possibly even during the mature phase whereas *Crotolaria* from 3 months after planting until the end of year 2.

The data reveals that application of pre-emergence weedicide diuron at the rate of 1 kg per hectare at planting could control weeds effectively for a period of 3 months in a seedling nursery. The chemical weeding using post-emergence weedicides or weedicide combinations with pre-emergence weedicides with supplementary manual upkeep is more effective and economical than exclusive manual weeding during the initial six months following planting rubber.

The foliar nutrition study suggested that currently recommended soil application of soluble fertilizer formulation is more effective and economical compared to soil application with commonly used commercial foliar feeds in relation to plant growth.

The RRI provided a revised fertilizer recommendation for all the rubber estates for year 2000 on the basis of the samples collected in 1998 and before as a temporary economic measure. It was based on the prevailing latex prices as well as on the results of soil and foliar survey carried out in the previous years. In this exercise the estates received a cost-effective and site specific revised fertilizer recommendation from the RRI at free of charge. As a result, the estate sector has not incurred any expenditure in carrying out the soil and foliar survey programme for the year 1999.

The soil and foliar survey programme for the small holder sector was not commenced as an economy measure due to the very poor trading condition prevailing in the country.

DETAILED REVIEW

Staff

The Head of the Department, Dr (Mrs) Lalani Samarappuli and Soils Chemist, Dr D M A P Dissanayake were on duty throughout the year. Assistant Soils Chemist, Mr S Dharmakeerthi continued his post graduate studies in Canada. Mr N Wickramasinghe joined the Department in June as an Assistant Soils Chemist.

The Experimental Officer, Mr A M A Perera was promoted as Development Officer of the Adaptive Research Unit in February. The Experimental Officers, Messrs G de Mel, H D S P Perera, R Hettiarachchi, C Maheepala, S N Silva, P Karunadasa, U Mitrasena, A N Yakandawela and T B Dissanayake were on duty throughout the year. Technical Officers, Messrs V Edirimanne, A Thevarapperuma, P R Puhambugoda and K Jayanetti and the English Stenographer Mrs L Rupasinghe were on duty throughout the year. Senior Testing Officer Mr T M Ahamadeen retired from the services of the Institute on 2nd August. Technical Officer Mr J A Sarath Chandrasiri was transferred to the Department from the Raw Rubber and Chemical Analysis Department in August.

Research students

Mr U L A N Kumara an undergraduate student from the University of Peradeniya completed his final year project on "Effect of growing different tree legumes on soil chemical properties and their influence on the performance of immature *Hevea brasiliensis*" under the supervision of Dr (Mrs) Lalani Samarappuli.

Mr Sundaramurthy Sureshsundar an undergraduate student from the Eastern University of Sri Lanka completed his final year project on "Effect of poultry litter on the chemical characteristics of the soils and their effect on the performance of immature *Hevea brasiliensis*" under the supervision of Dr (Mrs) Lalani Samarappuli.

Mr Tharmalingam Nagarajah an undergraduate student from the Eastern University of Sri Lanka completed his final year project on "Some aspect of Sulphur nutrition of *Hevea brasiliensis*" under the supervision of Dr D M A P Dissanayake.

Visits

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:

- National workshop on Weed Management for Agriculturists in Sri Lanka organized by the Sri Lanka Council for Agricultural Research Policy, on "Integrated weed management in rubber plantations".
- Scientific Committee Meeting on" Economy measures to be considered under the present adverse trading conditions for rubber".
- Planting Executives of Horana Plantations Ltd. on "Fertilizer Application for Mature Rubber".

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

- Annual General Meeting of the Institute of Biology of Sri Lanka[1].
- Annual General Meeting of the Soil Science Society of Sri Lanka[1].
- Technical Committee Meeting of the Tender Board for the Rubber Development Department[1].
- Fertilizer Advisory Committee[1].
- The Working Group on Fertilizer Mixtures of the Sri Lanka Standards Institution[1].
- Central Scientific Committee[1,2].

Training programmes

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

- Worker Skill Development Programme organized by the NIPM for Pussellawa Plantations Ltd.
- Skill Development Training Programme organized by the Pussellawa Plantations Ltd. for Superintendents, Assistant Superintendents, Field Officers and Asst. Field Officers on the following subjects:
  - Integrated Plant Nutrient System - Superintendents and Assistant Superintendents
  - Soil and Moisture Conservation and Fertilizer Use - Asst. Field Officers
  - Soil Conservation - Asst. Field Officers
  - Fertilizer Use in Immature and Mature rubber - Field Officers
  - Soil Management and Fertilizer Use - Field Officers
  - Fertilizers for Nurseries - Field Officers

- Superintendents and Assistant Superintendents for the Diploma Course in Plantation Management organized by the NIPM.
- Rubber Development officers for the Diploma Course in Crop Management and Processing organized by the NIPM.
- Trainee Assistant Superintendent of Agalawatta Plantations Ltd. on All Aspects of Soils and Plant Nutrition.
- University Students/ NDT Trainees

LABORATORY AND FIELD INVESTIGATIONS

1. Soil fertility and Moisture conservation

1.1 *Agronomic practices in relation to moisture conservation*

1.1.1 *Use of live and dead mulch*

1.1.1.1 Comparison of different management practices

In experiment SMC-Ag/M/88/1, application of mulching was continued during mature phase. The effect of this treatment in relation to with and without K, indicated a higher leaf K content with potassium at K1 level (Table 1). Continuation of mulching in comparison with the residual effect of mulching on yield of rubber plants is given in Table 2. No significant difference was observed among the two treatments for yield (L Samarappuli, P Karunadasa and U Mitrasena).

Table 1. *Effect of different soil management practices and potassium on leaf K content*

Treatment	Leaf K content (%)	
	K0	K1
Legumes	0.77^{a}	1.09^{a}
Mulching discontinued	1.07^{ab}	1.29^{a}
Mulching continued	1.22^{b}	1.30^{a}

Table 2. *Effect of different soil management practices on yield*

Treatment	Yield	
	(g/t/t)	(kg/ha/yr)
Legumes	25.46[a]	1604[a]
Mulching discontinued	27.34[a]	1722[a]
Mulching continued	28.55[a]	1799[a]

1.1.1.2 Different mulching materials

A field experiment (SMC-Ag/M/97/1) is in progress at Sapumalkanda estate, Deraniyagala to study the effect of different quantities of refused tea and wood ash on growth of *Hevea* plants. Treatments consisted of three quantities of refused tea and wood ash; no refused tea (T0), ½ kg refused tea/plant (T1), 1kg refused tea/plant (T2), no wood ash (W0), ½ kg wood ash/plant (W1) and 1kg wood ash/plant (W2). Plant girth at two and a half years after planting is given in Table 3 (L Samarappuli, P Karunadasa and U Mitrasena).

Another field experiment (SMC-Ag/M/99/1) is in progress at Nottinghill estate, Kahapathwela to study the effect of different mulching materials on growth of *Hevea* plants in a comparatively drier area. Treatments consisted of four mulching materials and a control: no mulching (M0), paddy straw (M1), coir dust (M2), paddy husk (M4) and green manure (M5). Plant diameter at six months after planting is given in Table 4 (L Samarappuli, P Karunadasa and U Mitrasena).

Table 3. *Effect of refused tea and wood ash on girth (cm) of rubber plants*

Level of Tea Dust	Level of Wood Ash		
	W_0	W_1	W_2
T_0	14.75[a]	14.90[a]	13.15[a]
T_1	14.28[a]	14.73[a]	14.13[a]
T_2	13.33[a]	13.75[a]	13.33[a]

Table 4. *Effect of different mulching materials on diameter of rubber plants*

Treatment	Diameter (mm)
No mulch	22.50[a]
Paddy straw	24.38[a]
Coir dust	23.05[a]
Paddy husk	24.18[a]
Green manure	24.43[a]

1.1.2 *Fertilizer practices for overcoming moisture stress*

A field experiment (SMC-Ag/F/88/3) is in progress at Nalanda Estate, Ulpotha to study the effect of different levels of potassium on growth and yield of *Hevea* plants in a comparatively drier area. The effect of different K levels on girth and girth increment is given in Table 5. Test tapping was not done during the year 1999 (L Samarappuli, P Karunadasa and U Mitrasena).

In experiment SMC-Ag/M/88/1, with and without K, yield data indicated higher yield (Table 6) with potassium at K1 level (L Samarappuli, P Karunadasa and U Mitrasena).

In field experiment (SMC-Ag/F/95/1), the effect of both potassium and mulching on moisture stress and growth of *Hevea* was studied. Treatments consisted of three mulching techniques; no mulch (M0), surface mulching (M1) and sub surface mulching (incorporation) (M2) and four potassium levels; half the recommended level (K1), recommended level (K2), one and half the recommended level (K3) and double the recommended level (K4). Girth measurements at four and a half years after planting, girth increment during last year and leaf NPK contents are given in Table 7, 8, 9, 10 and 11, respectively (L Samarappuli, P Karunadasa and U Mitrasena).

Another two field experiments (SMC-Ag/F/98/1 and SMC-Ag/F/99/1) are in progress at Bibile Estate, Bibile and Nottinghill estate, Kahapathwela to study the effect of both potassium and mulching on moisture stress and growth of *Hevea* plants in comparatively drier areas. Treatments consisted of two mulching techniques; no mulch (M0) and surface mulching (M1) 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). Plant diameter at fourteen months and six months after planting are given in Table 12 and 13, respectively (L Samarappuli, P Karunadasa and U Mitrasena).

Table 5. *Effect of different K levels on girthing of* Hevea

Treatment	Girth (cm)	Girth Increment (cm)
K_0	58.3	6.6
K_1	58.7	6.9
K_2	58.2	6.8
LSD	4.0	-

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

K levels	Girth (cm)	Yield	
		(g/t/t)	(kg/ha/yr)
K_0	55.1	25.57	1606
K_1	58.6	29.72*	1872*
LSD	1.1	3.25	205

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

Mulching	Level of K			
	K_1	K_2	K_3	K_4
M_0	40.33[a]	40.38[a]	42.15[a]	40.93[a]
M_1	41.73[a]	41.13[a]	40.93[a]	42.68[a]
M_2	40.35[a]	41.55[a]	40.18[a]	40.63[a]

Table 8. *Effect of potassium and mulching on girth increment (cm) of rubber plants*

Mulching	Level of K			
	K_1	K_2	K_3	K_4
M_0	9.65[a]	8.83[a]	9.88[a]	8.65[a]
M_1	9.30[a]	8.55[a]	7.53[a]	9.05[a]
M_2	7.83[a]	9.10[a]	8.23[a]	8.43[a]

Table 9. *Effect of potassium and mulching on leaf N content (%) of rubber plants*

Mulching	Level of K			
	K_1	K_2	K_3	K_4
M_0	2.88[a]	2.96[a]	2.74[a]	3.00[a]
M_1	2.99[a]	3.05[a]	2.79[a]	2.99[a]
M_2	3.04[a]	2.99[a]	3.08[a]	3.02[a]

Table 10. *Effect of potassium and mulching on leaf P content (%) of rubber plants*

Mulching	Level of K			
	K_1	K_2	K_3	K_4
M_0	0.193[a]	0.200[a]	0.199[a]	0.195[a]
M_1	0.194[a]	0.197[a]	0.193[a]	0.200[a]
M_2	0.204[a]	0.200[a]	0.197[a]	0.214[a]

Table 11. *Effect of potassium and mulching on leaf K content (%) of rubber plants*

Mulching	Level of K			
	K_1	K_2	K_3	K_4
M_0	0.429[a]	0.537[a]	0.467[a]	0.468[a]
M_1	0.437[a]	0.477[a]	0.435[a]	0.476[a]
M_2	0.499[a]	0.497[a]	0.504[a]	0.522[a]

Table 12. *Effect of potassium and mulching on diameter (mm) of rubber plants*

Mulching	Level of K			
	K_1	K_2	K_3	K_4
M_0	19.95[a]	21.22[a]	21.18[a]	19.73[a]
M_1	23.63[b]	20.90[a]	19.43[b]	21.60[b]

Table 13. *Effect of potassium and mulching on diameter (mm) of rubber plants*

Mulching	Level of K			
	K_1	K_2	K_3	K_4
M_0	24.53[a]	25.10[a]	24.43[a]	25.58[a]
M_1	23.08[a]	24.28[a]	24.43[a]	25.83[a]

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

Two experiments are in progress at the RRI Sub Station in Kuruwita (SMC-Ag/I/93/1) and at Perth estate, Ingiriya (SMC-Ag/I/96/1) to study the water use efficiency of rubber plants when multicropped with tea. These experiments were continued (L Samarappuli, N Yogaratnam, S M Iqbal, P Karunadasa and U Mitrasena).

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

An experiment (SMC-Ag/D/96/1) was started at Mucalana Division, Sirikandura Estate to study the fertilizer and soil moisture requirement of rubber under different densities. Treatments consisted of (a) Four different densities: (i) 500 trees/ha [4.5m x 4.5m], (ii) 600 trees/ha [4.2m x 4.2m], (iii) 700 trees/ha [3.8m x 3.8m] and (iv) 800 trees/ha [3.5m x 3.5m] (b) Three fertilizer treatments: (i) recommended level (F1), (ii) reduced level (F2) and (iii) 1st three years recommended level and thereafter reduced level (F3). Effect of different densities on girth of rubber plants at the end of three and a half years from planting is presented in Table 14 (L Samarappuli, P Karunadasa and U Mitrasena in collaboration with the Plant Science Department).

Another experiment (SMC-Ag/D/97/1) was also started at Dorset Division, Clyde Estate to study the fertilizer and soil moisture requirement of rubber under different densities with same treatments. Effect of different densities on girth of rubber plants at the end of two and a half years from planting is presented in Table 15 (L Samarappuli, P Karunadasa and U Mitrasena in collaboration with the Plant Science Department).

Table 14. *Effect of different plant densities and fertilizer treatments on girth (cm) of rubber plants*

Planting Densities	Fertilizer Levels		
	F1	F2	F3
500 trees/ha [4.5m x 4.5m]	29.7[a]	29.0[a]	29.1[a]
600 trees/ha [4.2m x 4.2m]	28.8[a]	27.0[a]	29.0[a]
700 trees/ha [3.8m x 3.8m]	28.1[a]	28.1[a]	29.3[a]
800 trees/ha [3.5m x 3.5m]	30.4[a]	30.2[a]	31.0[a]

Table 15. *Effect of different plant densities and fertilizer treatments on girth (cm) of rubber plants*

Planting Densities	Fertilizer Levels		
	F1	F2	F3
500 trees/ha [4.5m x 4.5m]	19.2[a]	19.2[a]	19.0[a]
600 trees/ha [4.2m x 4.2m]	19.7[a]	19.3[a]	19.0[a]
700 trees/ha [3.8m x 3.8m]	18.8[a]	18.8[a]	19.3[a]
800 trees/ha [3.5m x 3.5m]	19.6[a]	19.1[a]	19.1[a]

1.2 *Feasibility of growing rubber in drier areas*

Field experiments (SMC-Ag/F/88/3), (SMC-Ag/F/98/1), (SMC-Ag/F/99/1), (SMC-Ag/M/99/1), (SMC-GC/TL/98/1) and (SMC-GC/C/99/1) are in progress at Nalanda Estate, Ulpotha, Bibile Estate, Bibile, Nottinghill estate, Kahapathwela, Kumarawatta estate, Monaragala and Nottinghill estate, Kahapathwela, respectively, to study the same with different soil management and fertilizer practices (L Samarappuli, P Karunadasa and U Mitrasena).

1.3 *Ground cover management and nutrient recycling*

1.3.1 *Ground cover management*

1.3.1.1 Comparison of different cover types

Experiment, SMC-Ag/M/88/1, was started to study the influence of creeping, bush and tree legumes on some soil characteristics and their effects on the performance of rubber in *Boralu* series soils. Effect of different types of legumes on girth and rubber yield is given in Table 16 (L Samarappuli, P Karunadasa and U Mitrasena).

Another field experiment is in progress at Perth Estate, Horana to compare the effectiveness of tree legumes with the conventional creeping type *Pueraria phasioloides*. Effect of these legumes on girth of rubber plants at the end of two and a half years from planting is presented in Table 17 (L Samarappuli, P Karunadasa and U Mitrasena).

Table 16. *Effect of different types of legumes on girth and yield of Hevea*

Treatment	Girth (cm)	Yield (g/t/t)	Yield (kg/ha/yr)
Pueraria (Creeping type)	57.9[a]	25.6[a]	1613[a]
Desmodium (bush type)	55.8[ab]	26.0[a]	1638[a]
Stylosanthus (bush type)	55.7[ab]	23.5[a]	1481[a]
Tephrosia (tree type)	53.5[b]	20.6[a]	1298[a]

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

Treatment	Girth (cm)
Pueraria phasioloides	28.3[a]
Crotolaria anagyroides	31.1[b]
Flemingia congesta	31.2[b]
Tephrosia vogellie	28.0[a]

1.3.1.2 Comparison of different tree legumes

A field experiment (SMC-GC/TL/96/1), was started to study the comparative efficiency of *Tephrosia vogellie, Crotolaria anagyroides and Flemingia congesta* as successful tree legume species that can be grown between the rows of rubber plants which could provide enough material for mulching. The growth of *Crotolaria anagyroides* was much higher .than the other two species during the first year of planting. It was also observed that the growth rate and recovery after lopping of *Flemingia congesta* is much higher than the other two species, although the growth rate during the early stages appeared to be slow. The quantity of biomass provided for mulching under different tree legume species are presented in Table 18 (L Samarappuli, P Karunadasa and U Mitrasena).

Table 18. *The quantity of biomass provided for mulching under different tree legume species*

Treatments	Quantity of biomass (kg/ha)			
	1st year	2nd year	3rd year	Total
Crotolaria anagyroides	23	20	8	51
Flemingia congesta	10	36	48	94
Tephrosia vogellie	3	8	2	13

1.3.1.3 Phosphate fertilizers for cover crops

A field experiment, (SMC-GC/P/97/1) was started in Weniwella estate, Kegalle to study the effectiveness of Eppawela rock phosphate as a source of P for leguminous ground covers, both creeping and bush/tree types. Treatments consisted of three P sources: no P (O), ERP (E) and IRP (I) and two cover types: *Mucuna bracteata and Flemingia congesta.* Effect of these treatments on girth of rubber plants at the end of two and a half years from planting is presented in Table 19 (L Samarappuli, A Dissanayake, N Yogaratnam, P Karunadasa, U Mitrasena and E A T Senadeera).

Table 19. *Effect of different sources of phosphate on girth of rubber plants*

Treatment	Girth (cm)
R_0C_0	17.8
R_0C_I	17.1
R_0C_E	17.0
R_IC_0	19.3
R_IC_I	19.6
R_IC_E	19.0
R_EC_0	17.5
R_EC_I	19.6
R_EC_E	17.7

R- Rubber C - Cover

1.3.1.4 New cover crop species

At Perth Estate, Horana an experiment (SMC-GC/C/96/1)) was started to study the efficiency of *Mucuna bracteata*, on growth, nutrient enrichment and other desirable characteristics in comparison with *Pueraria*. Effect of two different types of legumes on girth of rubber plants at the end of three and a half years from planting is presented in Table 20 (L Samarappuli, P Karunadasa and U Mitrasena).

At Sapumalkanda estate, Deraniyagala an experiment (SMC-GC/C/97/1)) was started to study the efficiency of *Wedelia biflora* (Arunadevi), on growth, nutrient enrichment and other desirable characteristics in comparison with *Pueraria*. Effect of this cover crop on girth of rubber plants at the end of two and a half years from planting is presented in Table 21 (L Samarappuli, P Karunadasa and U Mitrasena).

Another field experiment (SMC-GC/C/98/1), was started to study and identify leguminous cover crop species with multiple advantages and which would satisfy a dual function of being a cover crop and a cash crop at the same time. Effect of these treatments on diameter of rubber plants at the end of 15 months from planting is presented in Table 22 (L Samarappuli, P Karunadasa and U Mitrasena).

Table 20. *Effect of two different legume species on girth of rubber plants*

Treatment	Girth (cm)
Mucuna bracteata	28.8[a]
Pueraria phaseoloides	28.3[a]

Table 21. *Effect of Wedelia biflora (Arunadevi) on girth of rubber plant*

Treatment	Girth (cm)
Pueraria phaseoloides + P	13.5[a]
Wedelia biflora + P	13.7[a]
Wedelia biflora + NPKMg (level 1)	15.3[a]
Wedelia biflora + NPKMg (level 2)	15.5[a]

Table 22. *Effect of different legume species on diameter of rubber plants*

Treatment	Diameter (mm)
Pueraria phaseoloides	23.28[a]
Mucuna bracteata	27.68[a]
Flemingia congesta	23.08[a]
Crotolaria anagyroides	26.85[a]
Flemingia + *Crotolaria*	25.65[a]
Legume cash crop	25.25[a]

1.3.2 *Nutrient recycling*

1.3.2.1 Sludge as a potential fertilizer for *Hevea*

An experiment was started at Payagala estate to evaluate sludge as a fertilizer for immature rubber (SMC-GC/RC/93/2 & SMC-GC/RC/93/3), and for legume covers (SMC-GC/RC/93/1). Different levels of fertilizer and sludge were applied according to the design. Effects of treatments in experiment SMC-GC/RC/93/1 on girth of rubber plants are given in Table 23 (L Samarappuli, A M A Perera, U Mitrasena, A Thevarapperuma and S Chandrasiri).

Table 23. *Effect of application of sludge to covers on girth of rubber plants*

Treatment	Girth (cm)
No P fertilizer	51.68[a]
IRP (recommended level)	53.05[a]
Sludge (normal level)	53.10[a]
Sludge (double level)	53.30[a]

1.4 ***Soil conservation and development of degraded lands***

This project was continued (L Samarappuli, N Yogaratnam, P Karunadasa and U Mitrasena).

1.5 *Weeds and weed control*

1.5.1 *Weed control in rubber nurseries*

A field experiment was started to study the effects of different weed control methods in rubber seedling nurseries. Treatments consisted of six different weed control practices: manual weeding, manual weeding + mulching, Diuron as pre-emergent weedicide + mulching, Diuron as pre-emergent weedicide + Diuron after 3 months, manual weeding + post-emergent weedicide (Glyphosate) after 3 months and Diuron as pre-emergent weedicide + post-emergent weedicide (Glyphosate) after 3 months. Effect of different treatments on weed coverage (Table 24), plant diameter, buddability and budding success of seedling plants (Table 25) are presented (L Samarappuli and V Edirimanna).

Table 24. *Effect of different treatments on weed coverage (%) of a seedling nursery*

Treatment	Month after application					
	1	2	3	4	5	6
Manual weeding	42	48	40	39	40	42
Manual weeding + mulching	22	42	18	28	40	18
Diuron* +mulching	11	20	41	18	25	38
Diuron+Diuron	07	15	30	50	03	10
Manual weeding + Glyphosate**	10	14	25	48	03	09
Diuron+Glyphosate	43	09	28	48	03	04

* Diuron at the rate of 1 kg per hectare
* Glyphosate at the rate of 1.2 litres per hectare

1.5.2 *Weed control in immature rubber*

A field experiment was started to study the performance of different weed management systems on weed control during the immature stage of rubber. Treatments consisted of manual weeding, manual weeding + application of post-emergence weedicide, application of pre-emergence weedicide + manual weeding and application of pre-emergence weedicide + post-emergence weedicide. Effect of different treatments on the cost of establishment of legume cover during the initial 6 months period is given in Table 26 (L Samarappuli and V Edirimanna).

Table 25. *Effect of different weed control systems on plant diameter, buddability and budding success of seedling plants*

Treatment	Diameter (cm)	Buddability (%)	Budding success (%)
No control	0.53	24.6	63
Manual weeding	0.92	65.1	85
Manual weeding + mulching	0.98	66.4	88
Diuron*+mulching	1.00	72.3	82
Diuron+Diuron	0.94	68.0	79
Manual weeding + Glyphosate**	0.92	67.8	77
Diuron+Glyphosate	0.92	66.9	75

* Diuron at the rate of 1 kg per hectare
* Glyphosate at the rate of 1.2 litres per hectare

Table 26. *Effect of chemical weeding on the cost of establishment of legume cover during the initial 6 months period*

Treatment	Cost (Rs\ha)			As a percentage (%)
	Manual	Weedicides	Total	
Manual weeding	13,547	-	13,547	100
Manual weeding + application of post-emergence weedicide	6,774	3,152	9,926	73
Application of pre-emergence weedicide + manual weeding	11,690	1,576	13,266	98
Application of pre-emergence weedicide + post-emergence weedicide	6,774	4,606	11,380	84

2. Fertilizer use and plant nutrition

2.1 *NPKMg requirement of rubber*

2.1.1 *Fertilizers to nursery plants*

2.1.1.1 Application frequency

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

Treatment 1 - no fertilizer (control)
Treatment 2 - 50g RP + biweekly application of currently recommended liquid formulation
Treatment 3 - 50g RP + monthly application of currently recommended liquid formulation
Treatment 4 - 75g RP + biweekly application of SA/SOP/CES liquid formulation
Treatment 5 - 75g RP + Monthly application of SA/SOP/CES liquid formulation

(R S Dharmakeerthi, L Samarappuli and S N Silva).

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

This experiment was continued (R S Dharmakeerthi, L Samarappuli, S N Silva and A Yakandawela).

2.1.2 *Fertilizer Requirement of new clones*

This experiment was continued (R S Dharmakeerthi, L Samarappuli, S N Silva and A N Yakandawela)

2.2 ***Phosphate nutrition***

This project was continued (A Dissanayake, Peter Perera, T Dissanayake, C K Maheepala and R Puhambugoda).

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

2.2.1.1 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, was completed.

Dry matter production of plants was recorded and nutrient analysis of plant samples were completed. Statistical analysis of the experimental data are in progress (A Dissanayake, C K Maheepala and Rukmal Puhambugoda).

2.2.1.2 Immature rubber

2.2.1.2.1 Effect of different sources and levels of P

a. Assessment of yield and chemical analysis of leaf and soil samples were completed to represent the experimental plots that were sub divided into two sub plots to study the residual effects of rock phosphates applied during the immature period. This experiment (P/IM/87) was continued (A Dissanayake, T Dissanayake and Peter Perera).

b. The experiment started at Vogan Estate to study the possibility of using both Eppawala and imported rock phosphates in different combinations was continued. Fertilizer treatments were applied and nutrients present in both soil and leaf samples collected from experimental blocks were analyzed.
Girth measurements indicated that there is no significant difference between fertilizer treatments (A Dissanayake, Peter Perera, Sarath Chandrasiri and T Dissanayake).

2.2.1.3. Mature rubber

2.2.1.3.1. Residual effect of added rock phosphates

Soil samples collected to study the residual effect of rock phosphate added were analyzed and P availability in relation to time period after discontinuation of different P sources are given in Table 27.

Table 27. *P availability in relation to different P sources (ppm)*

Treatment	Year 1	Year 2	Year 3	Year 4	Year 5
Nil	4.5	3.41	8.3	8.4	3.4
IRP - Level I	56.7	18.1	15.2	28.4	41.5
IRP - Level 2	74.4	19.29	23.56	38.50	63.7
ERP - Level 1	26.0	14.8	18.2	20.2	33.9
ERP - Level 2	45.0	40.9	32.58	30.80	44.15

2.2.2. *Evaluation of clonal differences in phosphate utilization*

Experiments started at Devalakande (P/IM/93/-01), Payagala (1/IM/94-01) and Ambadeniya (P/IM/96-01) estates to study the ability of different RRIC clones (RRIC 100,102,110 and 121) in utilization of ERP were continued. P fertilizers were applied according to the experimental treatments. Both soil and leaf samples were collected for chemical analysis and girth measurements were recorded (A Dissanayake, T Dissanayake, Peter Perera and Chitra Maheepala).

2.2.3 *Availability of P from ERP*

2.2.3.1 Mulching and liming

The experiment started to study the effect of different agronomic practices on availability of P from ERP at Culloden Estate (P/Ag/93) was continued. The recommended amount of Rice straw and lime were also applied in two applications. Soil and leaf samples were analyzed for P, Ca and Mg. Girth of rubber plants were recorded (A Dissanayake, L Samarappuli, Peter Perera and Sarath Chandrasiri).

2.2.3.2 Suitability of ERP to cover crops (Mycorrhizal aspect)

The experiment started to study the effect of mycorrizae on the efficiency of P uptake from Eppawela rock phosphate by rubber plants grown in poly bags was completed. Stem growth of rubber plants was recorded and nutrients present in shoots and roots of plants were determined. Soil samples were analyzed to determine pH, exchangeable cations and phosphorus content (A Dissanayake, R Jayaratne, C Maheepala and Rukmal Puhambugoda).

2.2.3.3 Use of isotopic technique to evaluate the agronomic efficiency of ERP

A pot experiment with rubber as the test plant was established in the glass house to evaluate the short term P availability of commercially available, partially aciduated and selectively mined ERP in comparison with IRP and TSP. The role of rubber factory effluent was also studied in dissolution of ERP. ^{32}P labelled phosphate was received from IAEA, Vienna under the Technical Corporation Project SRL/5/032. Due to unforeseen reasons plants had to be harvested after a period one month. Plant samples were prepared for counting ^{32}P activity at the laboratory of Coconut Research Institute and results are being summarized (A Dissanayake, T Dissanayake and L L W Somasiri, CRI).

2.3 ***Sulphur nutrition***

This experiment was continued (A Dissanayake, T Dissanayake and Peter Perera).

2.3.1 *Effect of sulphur on growth of young rubber*

The experiment started at Pallegoda Estate to study the effect of three different sources of Sulphur on the performance of young rubber was continued. Fertilizers were applied according to the treatments and soil leaf samples were collected and girth measurements were recorded (A Dissanayake, Peter Perera, Sarath Chandrasiri and Chitra Maheepala).

2.3.2 Current status of sulphur nutrition

A field level survey was carried out in the estate sector to evaluate sulphur status of immature rubber plantations which received different quantities of sulphur through different S containing fertilizers. Records available on fertilizer application obtained from selected estates were used to establish different ways and means of sulphur addition.

The role of added sulphur on performance of young rubber plants was evaluated in relation to continuous use of urea, sulphate of ammonia based N, P ,K, Mg fertilizer mixtures and S containing kieserite.

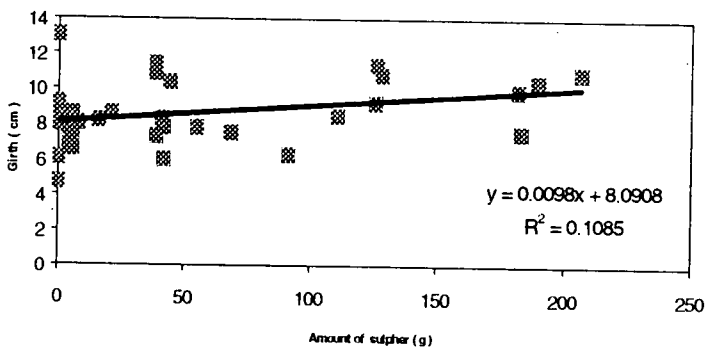
Application of sulphur in the form of kieserite with urea and SA significantly influenced the plant girth during the first and 2nd years of the age.

Table 28. *Effect of sulphur addition on girth of rubber plants*

Treatment	Girth (cm)	
	1st year	2nd year
Urea + Kieserite	10.58a	19.34a
Urea (No S)	9.43b	15.99b
Urea + Kieserite <25%	8.57b	16.55b
SA + Kieserite	7.60c	12.55c
Mixed	-	16.08b

A significant relationship was evident between amount of added sulphur and girth of young plants indicating that S is a limiting factor for some of the vigorously grown clones (Fig. 1).

1st year



2nd year

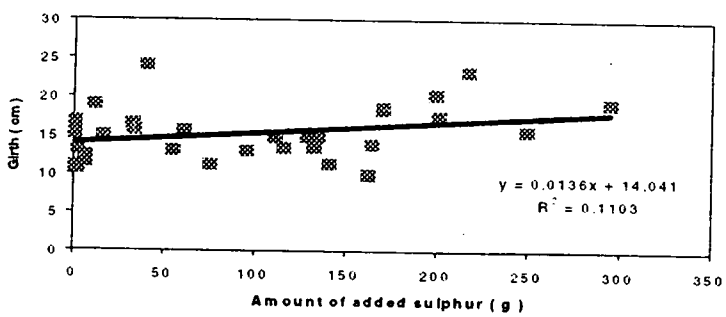


Fig. 1. Relationship between amount of added sulphur and plant girth

2.4 *Micro nutrients*

Effect of different soil management practices on the contribution of micro nutrients to the soil was studied in this experiment. Some micro nutrient contents under different soil management practices are presented in Tables 29, 30, 31 and 32 (L Samarappuli, A Thevarapperuma, U L A N Kumara and S Suresh).

Table 29. *Effect of different tree legume species on soil Mn content*

Species	Soil Mn content (mg/kg)			
	Inter-row area		Clean weeded circle	
	0-15 cm depth	15-30 cm depth	0-15 cm depth	15-30 cm depth
Pueraria	0.870[a]	0.897[a]	0.425[a]	0.523[a]
Tephrosia	0.840[a]	0.870[a]	0.852[b]	0.866[b]
Crotolaria	0.834[a]	0.836[a]	0.850[b]	0.840[b]
Flemingia	0.846[a]	0.852[a]	0.858[b]	0.882[b]

Table 30. *Effect of different tree legume species on soil Zn content*

Species	Soil Zn content (mg/kg)			
	Inter-row area		Clean weeded circle	
	0-15 cm depth	15-30 cm depth	0-15 cm depth	15-30 cm depth
Pueraria	1.02[b]	1.06[b]	0.73[b]	0.98[a]
Tephrosia	0.98[b]	1.00[b]	1.00[a]	1.00[a]
Crotolaria	0.97[b]	1.00[b]	0.98[a]	1.00[a]
Flemingia	0.99[b]	1.01[b]	1.00[a]	1.01[a]

Table 31. *Effect of different tree legume species on the leaf micro-nutrient content of rubber (mg/kg)*

Treatment	Mn	Zn	Cu	Fe
Pueraria	74.22[b]	25.93[b]	19.47[a]	100.10[a]
Tephrosia	74.93[b]	23.16[b]	17.08[b]	98.63[a]
Crotolaria	78.73[b]	27.09[b]	18.81[ab]	83.84[b]
Flemingia	77.13[b]	25.08[b]	19.33[a]	91.85[ab]

Table 32. *Effect of different treatments on soil and leaf Mn (mg/kg) of rubber plants*

Treatment	Soil 0-15cm	Soil 15-30cm	Leaf
Inorganic fertilizer (recommended level)	116.1	53.4	101.9
Inorganic fertilizer (½ recommended level) + poultry litter	108.5	66.1	97.2
Inorganic fertilizer (¼ recommended level) + poultry litter	103.4	62.8	126.9
Poultry litter only	147.7	59.3	109.3
Poultry litter + IRP + MOP	105.5	73.3	108.3
Poultry litter + IRP + paddy straw	124.8	84.3	122.0
Poultry litter only with natural cover	132.4	66.7	126.2
No fertilizer (control)	35.2	23.3	105.8

2.5 *Foliar nutrients*

Effect of commonly used commercial foliar fertilizer; Maxicrop on the performance of rubber plants raised by young budding technique was studied in this experiment with a randomized block design with five replicates. The effect of Maxicrop on the growth of rubber plants is presented in Table 33 (L Samarappuli and A Thevarapperuma).

Table 33. *Effect of foliar fertilizer: Maxicrop on diameter of rubber plants*

Treatment	Diameter (mm)
No fertilizer	5.8[a]
Soluble fertilizer (control)	8.1[b]
Soluble fertilizer + Maxicrop	8.7[b]
Maxicrop only	7.7[c]

2.6 *Use of rubber factory effluent*

The field experiment started at Eladuwa Estate to study the possibility of using rubber factory effluent as a fertilizer was continued. One liter of rubber factory effluent was applied weekly per plant and N P K Mg fertilizers were applied according to the treatments. Soil and leaf samples were collected and girth measurements were recorded. Arrangements have been made to compare the rooting pattern of young rubber plants in relation to with and without effluent application (A Dissanayake, T Dissanayake, Rukmal Puhambugoda and N Wickremasinghe).

2.7 *Organic fertilizers*

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

An experiment (FPN-Org/99/1), was started to study the possibility of using organic materials in the nursery stage and also to study the effect of these organic manures on the performance of rubber plants raised by young budding technique in poly bagged nursery plants. Treatments consisted of (T1) no fertilizer, (T2) inorganic fertilizer (recommended level), (T3) inorganic fertilizer (recommended level) + ¼ cowdung, (T4) inorganic fertilizer (¾ recommended level) + ¼ cowdung, (T5) inorganic fertilizer (½ recommended level) + ½ cowdung, (T6) cowdung only (no inorganic fertilizer), (T7) inorganic fertilizer (recommended level) + ¼ poultry litter, (T8) inorganic fertilizer (¾ recommended level)+ ¼ poultry litter, (T9) inorganic fertilizer (½ recommended level)+ ½ poultry litter and (T10) poultry litter only (no inorganic fertilizer). The effect of different treatments on growth of rubber plants is presented in Table 34 (L Samarappuli and A Thevarapperuma).

Table 34. *Effect of organic manures on diameter of rubber plants*

Treatment	Source of organic manure	
	Poultry	Cow dung
Inorganic fertilizer (recommended level) only	8.5^{ab}	8.5^{ab}
Inorganic fert. (rec. level) + ¼ organic manure	9.2^{a}	8.3^{ab}
Inorganic fert. (¾ rec. level) + ¼ organic manure	8.4^{b}	8.7^{ab}
Inorganic fert. (½ rec. level) + ½ organic manure	9.2^{a}	8.9^{a}
Organic manure only	8.1^{b}	8.2^{b}

2.7.2 *Use of animal wastes in rubber cultivations*

A field experiment (FPN-Org/An/95/3), is in progress at Dorset Division, Clyde Estate to study the effect of poultry litter as an organic manure for rubber. Treatments consisted of (a) Inorganic fertilizer (recommended level), (b) Inorganic fertilizer (½ recommended level) + poultry litter, (c) Inorganic fertilizer (¼ recommended level) + poultry litter, (d) Poultry litter only, (e) Poultry litter + IRP + MOP, (f) Poultry litter + IRP + paddy straw and (g) Poultry litter only with natural cover. Effects of treatments on girth and girth increment of rubber plants at the end of four and a half years are given in Table 35 (L Samarappuli, P Karunadasa and U Mitrasena).

Table 35. *Effect of different treatments on girth of rubber plants*

Treatment	Girth (cm)	Girth Increment (cm)
Inorganic fertilizer (recommended level)	39.8	8.7
Inorganic fertilizer (½ recommended level) + poultry litter	41.3	8.9
Inorganic fertilizer (¼ recommended level) + poultry litter	42.3	9.2
Poultry litter only	41.5	9.7
Poultry litter + IRP + MOP	40.6	8.8
Poultry litter + IRP + paddy straw	42.4	9.5
Poultry litter only with natural cover	39.4	9.3
No fertilizer (control)	31.9	8.2

2.7.3 *Use of green manure in rubber cultivation*

Two field experiments (FPN-Org/Gm/97/1) and (FPN-Org/Gm/97/2) are in progress at Dartonfield estate (*Agalawatta* series) and Dorset Division, Clyde estate (*Boralu* series) to study the effect of plant materials as an organic manure for rubber. Treatments consisted of combinations of three sources of N *viz* full inorganic, ½ inorganic + ½ green manure and full green manure and three sources of K *viz* full inorganic, ½ inorganic + ½ straw and full straw. The nine different treatment combinations were applied in a randomized block design with four replicates. Effects of treatments on girth of rubber plants at the end of two and a half years are given in Tables 36 and 37 respectively (L Samarappuli, P Karunadasa and U Mitrasena).

Table 36. *Effect of different treatments on girth of rubber plants in Agalawatta series soils*

Sources of N	Sources of K		
	K1	K2	K3
N1	14.48[a]	11.25[a]	12.90[a]
N2	12.68[b]	14.13[b]	13.20[a]
N3	9.7[c]	12.15[a]	10.25[b]

Table 37. *Effect of different treatments on girth of rubber plants in Boralu series soils*

Sources of N	Sources of K		
	K1	K2	K3
N1	19.15[a]	19.05[a]	19.83[a]
N2	20.83[a]	18.73[a]	20.53[a]
N3	18.35[a]	19.38[a]	18.98[a]

2.7.4 *Organic rubber*

An experiment is in progress to develop a sustainable system which is commercially suitable for plantation as well as for small holders to produce an environmental friendly new grade of rubber (organic rubber) to meet the increasing demand for "bio-market". No adverse effects were observed in growth of rubber plants in the field by using only organic and natural (mined) fertilizers (Table 38) (L Samarappuli, N Yogaratnam, L M K Tillekeratne, P Karunadasa and U Mitrasena).

Table 38. *Effect of different treatments on girth of rubber plants*

Treatment	Girth after planting (cm)	
	1 ½ years	2 ½ years
Chemical fertilizer only	7.2	13.8
Organic fertilizer only	8.4	11.9

2.8 *Efficiency of fertilizer utilization*

2.8.1 *Reduced frequency of fertilizer applications*

A field experiment (F/Ap/95/1), is in progress to the study the effect of reduced frequency of fertilizer applications during the immature period on the growth of rubber plants. Treatments consisted of (a) 25 applications/immature six year period (urea based), (b) 20 applications/immature six year period (SA based), (c) 19 applications/immature six year period (urea based), (d) 14 applications/immature six year period (SA based) and (e) 14 applications/immature six year period (urea based). Effects of treatments on girth and girth increment of rubber plants at the end of four and a half years are given in Table 39 (L Samarappuli, P Karunadasa and U Mitrasena).

Table 39. *Effect of different treatments on girth and girth increment of rubber plants*

Treatment	Girth (cm)	Girth increment (cm)
20 applications/immature six year period (SA based)	38.9[a]	8.7
25 applications/immature six year period (urea based)	39.3[a]	9.0
19 applications/immature six year period (urea based)	37.1[a]	9.1
14 applications/immature six year period (SA based)	37.9[a]	9.3
14 applications/immature six year period (urea based)	38.3[a]	9.5
No fertilizer	31.1[b]	8.2

2.8.2 *Economics of fertilizer use in mature rubber*

This experiment was continued (L Samarappuli, N Yogaratnam, P Karunadasa and U Mitrasena).

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

An experiment (F/Mg/94/1), is in progress in Dorset Division, Clyde Estate to study the feasibility of using Dolomite even during the mature stage. Treatments consisted of kieserite throughout the immature and mature period, kieserite in immature period and dolomite in mature period, dolomite throughout the immature and mature period, dolomite in immature period and kieserite in mature period. Latex samples collected during the year are being analyzed (L Samarappuli, P Karunadasa, U Mitrasena and V Edirimanna).

2.8.4 *SUL-PO-MAG based fertilizer mixtures*

An experiment (F/SPMg/94/1), was started in Culloden Estate, Neboda to study the effectiveness of SUL-PO-MAG based mixtures in comparison with the conventional mixtures 12:14:14 and 7:9:9:3 in immature rubber. SUL-PO-MAG based treatment was formulated by adding urea, rock phosphate and muriate of potash to SUL-PO-MAG to meet the nutrient ratios of N,P,K and Mg recommended for rubber in conventional mixtures. Growth was significantly higher in plants that received fertilizers compared to no fertilizer treatment. However, there was no significant difference in girth between the three fertilizer treatments. Similar results were observed for the tappability of rubber trees taken at the end of 5 years after planting (Table 40) (L Samarappuli, N Yogaratnam and J G de Mel).

Table 40. *Effect of different fertilizer mixtures on girth of rubber plants*

Treatment	Tappability (%)	Girth (cm)
Control (no fertilizer)	6.0[a]	48.3[a]
Urea based	34.6[b]	53.1[b]
SA based	24.8[b]	53.9[b]
Sulpomag based	27.4[b]	53.5[b]

2.8.5 *Slow release fertilizers*

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

2.8.6 *Nutrient requirement of rubber based cropping systems*

Arrangements have been made to commence experiments at estate and small holder sectors to study the nutrient requirements of rubber based cropping systems (A Dissanayake, L Samarappuli, N Wickremasinghe, U Mitrasena and Sarath Chandrasiri).

2.9 *Soil and foliar survey programme*

2.9.1 *Improvements to soil and foliar survey programme*

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

2.9.2 *Soil and foliar survey programme - Fertilizer recommendation*

Estate sector

The RRI provided a revised fertilizer recommendation for all the rubber estates for year 2000 on the basis of the samples collected in 1998 and before as a temporary economic measure. It was based on the prevailing latex prices as well as on the results of soil and foliar survey carried out in the previous years. In this exercise the estates received a cost-effective and site specific revised fertilizer recommendation from the RRI at free of charge. As a result, the estate sector has not incurred any expenditure in carrying out the soil and foliar survey programme for the year 1999.

The criteria followed in this revised scheme is outlined below.

Panel A -	Full dosage of the recommended fertilizers as per the soil and foliar survey
Panel B -	Revised programme (a cut down in fertilizer)
Panel C -	Fertilizer application to be discontinued

(L Samarappuli and V Edirimanne).

Small holder sector

The soil and foliar survey programme for the small holder sector was not commenced as an economy measure due to the very poor trading condition prevailing in the country (L Samarappuli and V Edirimanne).

2.10 *Survey on agronomic practices in rubber lands*

2.10.1 *Model fitting on factors affecting fertilizer utilization*

A field level survey was carried out with the aim of modelling the factors affecting fertilizer adoption in the Estate sector. Social, economic, institutional and other factors were included for this study and statistical analysis of data collected from seventy estates under 19 plantations companies are in progress.

2.10.2 *Performance of young rubber relation to agronomic practices*

Around 300 of immature rubber fields of these estates were physically observed simultaneously to investigate the effect of fertilizers on performance of rubber plants.

Plants were randomly selected to represent each field and girth measurements were recorded and leaf samples were taken. Rating of some important agronomic practices were also exercised and details of fertilizer applications were obtained on field basis from estate offices and the quantities of nutrients applied were calculated. Leaf samples were analyzed to determine N,P,K,Mg and S.

Girth of rubber plants was compared with general standards and it was observed that the girth was not up to the expected level showing a negative deviation of 15 -27% from standards during the immature period (Table 41).

Table 41. *Girth of immature rubber*

Age	Girth (cm)		Deviation (%)
	Actual	Standard	
1	8.3	10.0	16.7
2	14.5	20.0	27.6
3	23.8	30.0	20.5
4	32.3	40.0	19.2
5	42.4	50.0	15.2
6	46.2	55.0	16.1

In comparison made with the RRI general fertilizer recommendation, it was evident that more than 60% and 84% of immature fields were not fertilized with the recommended dosage of NPK and Mg respectively (Table 42) (A Dissanayake, N Yogaratnam, L Samarappuli, W Wijesuriya, Rukmal Puhambugoda and Vidura Abeywardana).

Table 42. *Deviation of NPK & Mg compared to RRI general recommendations*

Year/Age	NPK					Mg					
	% mean Qty		% fields			% mean Qty		% fields			
	+	-	+	-	Exact	+	-	+	-	100% (-)	Exact
1	14	21	38	42	20	14	21	9	73	9	9
2	28	27	25	68	7	18	28	18	71	11	0
3	13	26	38	62	0	0	82	0	28	72	0
4	11	32	44	56	0	33	48	8	63	29	0
5	9	28	30	70	0	21	42	24	48	12	16
6	12	26	32	68	0	12	25	12	63	25	0
Average (immature period)	15	27	34	61	5	16	41	12	58	26	4

3. **Land use planning**

3.1 ***Soil survey and classification***

Initially soil samples were collected from locations to represent four major rubber growing soils and arrangements have been made to collect samples from remaining soil series and Bibile, Moneragala area. Soil samples were chemically analyzed with the aim of assessing the important chemical properties and studying the variation among soil series. Profile distribution of nutrients in different rubber soils was also evaluated and general percentage distribution of N,P,K,Mg and S within top 50 cm of the profile is given in Table 43 (A Dissanayake and C K Maheepala).

Table 43. *% distribution of nutrients within 50 cm of the soil profile*

Soil series	%				
	N	P	K	Mg	S
Agalawatta	47	59	29	41	16
Boralu	65	48	60	72	28
Homagama	70	63	18	38	49
Parambe	74	40	38	32	49

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

4. Analytical services and techniques

4.1 *Analytical service*

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. Details are presented in Table 44.

Table 44. *Details of the analysis done during the year 1999*

Organization	Plant	Soil	Fertilizer	Other*	Total
Experimental	3000	1500			4500
Other Departments of RRI	-	220	-	10	230
Research Institutes	-	306	-	-	306
Rubber Development Department	-	-	390	-	390
Plantation Management Companies	-	520	150	20	690
Other Private Companies	-	-	60	50	110
Total	3000	2546	600	80	6226

* - water/bleaching agents/chemicals/rubber

4.2 **Analytical techniques:**

- **Developed a new procedure for the analysis of particle size distribution of soils in order to analyse more number of samples in a shorter time with the same accuracy (N Wickramasinghe and L Samarappuli).**
- **Initiated preliminary work on preparation of a Laboratory Manual for the Soils and Plant Nutrition Department (N Wickramasinghe and L Samarappuli).**

4.3 Quality of rubber fertilizers

Analytical determinations of 133, 230 and 42 samples of straight fertilizers conventional fertilizer mixtures and special mixtures respectively received during the period of last six years from plantations companies, fertilizer companies and Rubber Development Dept. were used in this study in comparison with general fertilizer standards.

It is clear that a share of 46% of analytical determinations carried out for plantation companies were under estimated indicating that a fairly significant number of fertilizer samples analyzed for plantation companies were inferior. The situation with regard to both RDD and Fertilizer Companies was also similar showing that a considerable number of fertilizer samples contain low contents of nutrients (Fig. 2)

Variations of nutrient determinations made for N,P, and K in special rubber fertilizer mixtures recommended under the soil and foliar survey programme was significantly higher than that of conventional fertilizer mixtures (Fig. 3) (A Dissanayake, N Wickremasinghe and R Puhambugoda).

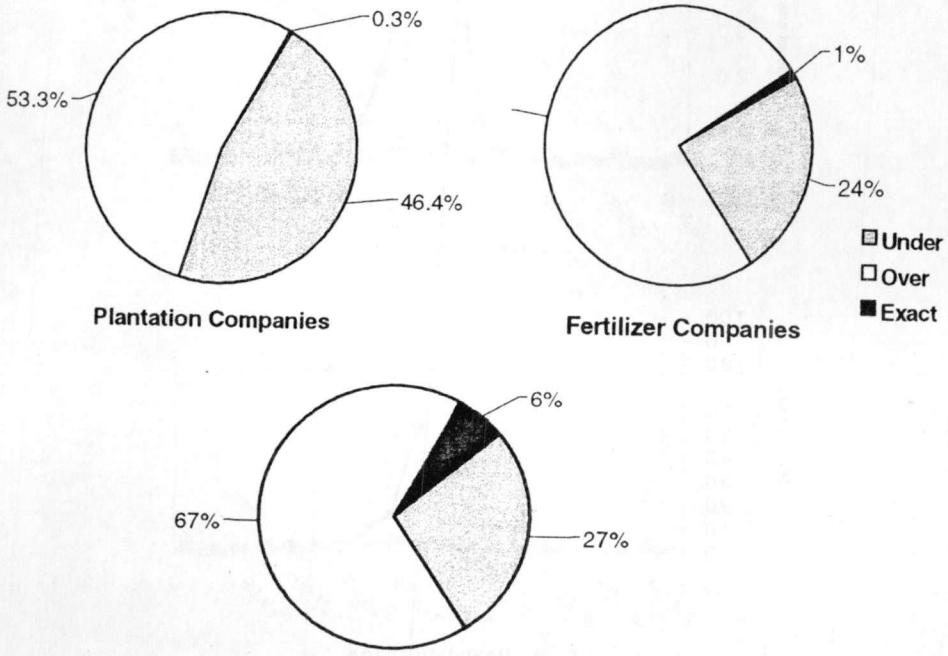


Fig. 2. Pattern of nutrient determinations in relation to different organizations

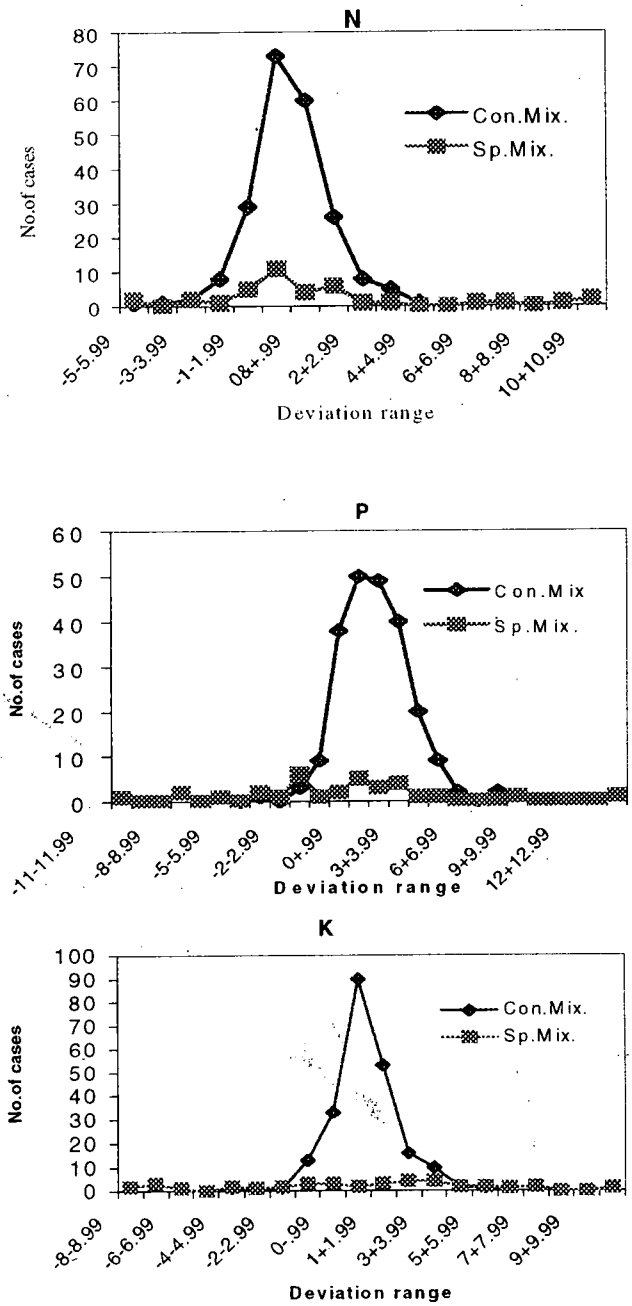


Fig. 3. Variation of analytical values of conventional and special fertilizer mixtures

BIOCHEMISTRY AND PHYSIOLOGY

Thurul Warnakula

SUMMARY

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

Staff

Assistant Biochemist, Mr M T Warnakula was on duty throughout the year. Miss K V V S Kudaligama, Technical Officer was promoted to Experimental Officer with effect from 01.03.1999 and was on duty through out the year. Mr P D J Rodrigo and Mr D Ramawikrama, Technical Officers, were on duty throughout the year.

Research students

Miss D J Liyanage, MSc Student from Sri Jayawardenapura University carried out her project on rubber factory effluent treatment in the department.

Patent applications

The patent application submitted on "*In situ* coir based biological odour filter for controlling the odour from waste water treatment facilities and polluted natural environments" was awarded.

A patent application on "Coir pieces as the stationary media for Fluidized Bed reactor" was submitted.

LABORATORY AND FIELD EXPERIMENTS

1. Appropriate technology for environmental friendly management of rubber factory waste

Research and development

Bio-Brush media

Several technological possibilities were investigated to upgrade the production of Bio-Brush media. Further research was carried out to improve the efficacy of rubber waste treatment with Bio-Brush media (M T Warnakula, K V V S Kudaligama, P D J Rodrigo and D Ramawikrama).

Odour filter

Further research on development of coir based odour filter was continued. All the treatment systems developed by the Department of Biochemistry were covered with the odour filter and this reduces the high costs for covering the anaerobic reactors (M T Warnakula, K V V S Kudaligama, P D J Rodrigo and D Ramawikrama).

Low cost treatment configurations

An advanced type of "Covered Activate Ditch (CAD)" system was developed and implementations were continued on factory scale effluent treatment systems (M T Warnakula, K V V S Kudaligama, P D J Rodrigo and D Ramawikrama).

Deammoniation and continuous coagulation of skim latex

Developing appropriate techniques for removing ammonia from skim latex and continuous coagulation of skim latex with organic acids were continued. Several possibilities were identified (M T Warnakula, K V V S Kudaligama, P D J Rodrigo and D Ramawikrama).

Implementation of new developments

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

Rayigam estate Crepe Rubber Factory

Supervision and the analytical assessments were commenced. In both systems COD and BOD of treated effluent always met CEA standards with anaerobic treatment alone (M T Warnakula, K V V S Kudaligama, P D J Rodrigo and D Ramawikrama).

Pallegama estate Sole Crepe Rubber Factory

The effluent treatment system for the factory was functioning successfully. Supervision and the analytical assessments were carried out. COD and BOD of treated effluent met CEA standards. Factory also received the Environmental Protection License (M T Warnakula, K V V S Kudaligama, P D J Rodrigo and D Ramawikrama).

Kiripooruwa estate Centrifuge Factory

Construction of the effluent treatment system was completed. Supervision and the analytical assessments were carried out. A polishing pond was constructed to facilitate final polishing of effluent. The system was mature enough to treat the full waste capacity of the factory (M T Warnakula, K V V S Kudaligama, P D J Rodrigo and D Ramawikrama).

Yatadola estate Crepe Rubber Factory

Construction of the effluent treatment system was completed. Supervision and the analytical assessments were done from the fourth quarter of the year. The full waste capacity of the factory was directed to the system for treatment and it was noted that the treated effluent met the standards required by the CEA to grant Environmental Protection Licenses (M T Warnakula, K V V S Kudaligama, P D J Rodrigo and D Ramawikrama).

Siriniwasa estate Crepe Rubber Factory

Detailed engineering design and relevant documents were submitted to a Management Company for construction of an effluent treatment system for the factory. A complete anaerobic biological treatment system was designed using the existing tanks of an abandoned treatment system. Covered Activated Ditches available the reserved as the reactors where the major part of treatment of effluents was achieved. An anaerobic polishing pond was designed for the final treatment of effluent (M T Warnakula, K V V S Kudaligama, P D J Rodrigo and D Ramawikrama).

Elladuwa Crepe Rubber Factory

Detailed engineering design and relevant documents were submitted to the Management Company for construction of the effluent treatment system for the factory. A Covered Activated Ditch type anaerobic treatment system was designed and an anaerobic polishing pond was designed for final treatment of effluent (M T Warnakula, K V V S Kudaligama, P D J Rodrigo and D Ramawikrama).

Other methods of waste utilization and disposal

Several commercial possibilities of waste utilization/disposal were identified. Practicability of these is being studied (M T Warnakula, K V V S Kudaligama, P D J Rodrigo and D Ramawikrama).

2. Utilization of rubber wood

Biological and Biochemical treatment of rubber wood

Studies on biological and biochemical treatment of rubber wood were continued. Possibility of selective staining of rubber wood for masking the blue stain formed due to fungal attack was further investigated (M T Warnakula, C K Jayasinghe, K G K de Silva, K V V S Kudaligama, P D J Rodrigo and D Ramawikrama).

Chemical bleach of rejected treated rubber wood

Further development of the technique for bleaching treated rubber wood, was discarded as the fungal staining was continued. Subsequently, a simplified environmental friendly bleaching method was developed. By this new technique, leach out of preservating chemicals from treated wood and bleaching chemical residues left over in bleached wood, is minimal. Further development of this technique would be possible for commercial use (M T Warnakula, Anusha Perera, K V V S Kudaligama, P D J Rodrigo and D Ramawikrama).

Biological and biochemical carving of rubber wood

Only a little work was done on this project during the year 1999 (M T Warnakula, K V V S Kudaligama, P D J Rodrigo and D Ramawikrama).

RUBBER TECHNOLOGY AND DEVELOPMENT

N M V Kalyani Liyanage

SUMMARY

Modified Lowry procedure for the analysis of leachable proteins in NR latex was extended towards the lower levels of concentrations since most of the extractable protein levels detected for local latex based products as well as for local crepe rubber samples, the values were found to be below <50μg/g of rubber.

Two techniques suitable for making latex coated fabric gloves were developed.

A latex based adhesive suitable for the manufacture of rubberised coir based baskets was developed.

A casting technique suitable for making decorative flowers out of latex was developed.

The projects on latex based cement and latex/C-black masterbatches were revitalised.

A few more batches of rubber compounds were supplied to the 'Ranaviru Sevana' for the manufacture of artificial limbs of disabled soldiers.

A program was initiated to analyse the total extractable protein content in all the grades of crepe rubber produced in Sri Lanka.

An interlaboratory cross-check program was performed with twelve local testing laboratories.

Effects of proteolytic enzymes on the proteins and physical properties of RVNRL and conventionally vulcanised latex were evaluated.

Two batches of ENR-25 and ENR-50 were synthesised according to a patented procedure and a formula for the correlation between the reaction time and the extent of epoxidation was developed.

DETAILED REVIEW

Staff

Dr (Mrs) N M V Kalyani Liyanage, Head, Rubber Technology and Development was on duty throughout the year.

Mrs M M Jayasooriya, Assistant Rubber Chemist was on duty throughout the year.

Dr A C M Rizmi, Assistant Rubber Chemist assumed duty on the 15th of February.

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

Research Students

Mr P G S C Gallage, Samantha Wijenayake, G D M P Kumara, S Karunaratne, Rohan Senanayake, students from the University of Moratuwa under the Apprenticeship Board In-Plant Training Scheme, and Mr S Mahagama and Mr R A P N Perera, undergraduates from the University of Colombo were trained on various aspects of Latex Technology and Dry Rubber Technology.

A Dissanayake and R Balasundaram, MSc students from the University of Sri Jayawardenapura successfully completed their research projects under the supervision of the Head of the Department.

Meetings, Seminars and Lectures

Dr (Mrs) N M V Kalyani Liyanage,[1] Mrs Madupani Jayasooriya[2] and Dr A C M Rizmi[3] participated in the following;

- Meetings of the Sri Lankan research group on "Radiation Prevulcanisation of Natural Rubber Latex" held at the Atomic Energy Authority and RRISL[1,2]
- Research Staff Meetings of the Institute held at the Directors Office, Dartonfield[1]
- The Diploma course on "Rubber Technology" organized by the Plastics & Rubber Institute as a lecturer[1]
- Central Scientific Committee Meetings held at the SLAAS on 6th February, 28th May and 30th August.[1,2]
- A seminar organised by Sri Lanka Association of Manufacturers and Exporters of Rubber Products (SLAMERP) and Sri Lanka GTZ Private Sector Project on "World Trends in Rubber Technology" by Dr Hermann Fries at Trans Asia Hotel on 5th and 16th March 1999.[3]
- A meeting organised by CARP on 'Assistance They Could Extend Towards The RRI Scientists' at RRISL, Dartonfield on 18th of May.[1,2,3]

- A seminar on "Effective Leadership to Make Things Happen" on 26th May at Trans Asia Hotel organised by Innovative Skills (Pvt.) Ltd.[3]

- A lecture organised by PRI on "PVA and Natural Rubber Blends" on 2nd June at Institute of Chemistry[3].

- A lecture organised by PRI on "Polyester Resins" (Eastman Kodak) on 22nd June at Taj Samudra Hotel.[3]

- A seminar organised by SLASS on "Product Diversification of Export Crops" on 2nd July.[1]

- A lecture organised by PRI on "Thermoplastic Elastomers" by S M Leong from Singapore Polymer Corporation (Pvt) Ltd. on 17th August at Galadari Hotel[3]

- A discussion on the project on "Radiolysis of *Hevea* proteins" with Dr Seneka Perera from the University of Queensland and Mr Sugath Amerasekera from Ansells on 23rd August at RRISL[1]

- A seminar on "Rubber Processing Oils" on 24th August at Hilton Hotel organised by CSL International.[1]

- A Staff Meeting of the Institute held at the Directors Office, Dartonfield on 1st September [123]

- A meeting organised by the Colombo Rubber Traders Association on "Protein Allergy Issue" on 3rd September at the CRTA Office.[1]

- 156th Technical Sessions of the American Chemical Society, Rubber Division held between 21st-24th September and the "Rubber Expo'99" held between 21st-23rd September at the Orange County Convention Center in Orlando, Florida, USA.[1]

- A Technology Exposure Programme organised by the Akron Rubber Development Laboratory (ARDL), held between 27th Sept - 1st Oct. at ARDL, Akron, Ohio, USA.[1]

- A lecture was delivered at AMW, Kalutara on "General Aspects of Tyre Re-treading" for the Factory Officers' on 21st October.[1]

- A lecture was delivered at Balangoda Plantations Ltd. on "The Manufacture of Rubberised Coir" on 2nd November.[1]

- Served in the panel of judges of the "Inter School Inventors Exhibition" organised by the Sri Lanka Inventors Commission at D S Senanayake Vidyalaya on 5th and 6th November.[1,3]

- A seminar on "Asia - Rubber Markets" organised by IBC Singapore Ltd. at Taj Samudra Hotel on 17th and 18th November.[1]

- A seminar on 'Rubber to Metal Bonding' organised by Chemlock (India) at Hotel Lanka Oberoi on 11th December.[3]

- Annual General Meeting of the Plastics & Rubber Institute held at Taj Samudra Hotel on 3rd December.[3]

- The Department organised a stall for an exhibition of the Horana Development Program organised by The Ministry of Plantation Industries at Ingiriya Maha Vidyalaya on 4th and 5th December.[1,2]

LABORATORY INVESTIGATIONS

1. Latex technology

1.1 *Latex bitumen emulsions in road construction*

A few lab scale trials were carried out to seek the possibility of incorporation of modified positex to CRS2 bitumen emulsion since it is the most widely used type of bitumen emulsion. Latex/bitumen blends containing various amounts of positex were prepared and the stability of resultant blends were noted. Since the normal positex itself was not found to give suitable latex/bitumen blends, a density modifier was incorporated into positex at various concentrations. The storage stability of resultant blends was observed and it was found that the modified positex separates as a white layer either on the top or bottom of the latex/bitumen blend after a few days. It became apparent that the inconsistency of stability characteristics of the latex/bitumen blends is due to batch to batch variation in density of the bitumen emulsions. As it will not be practical to alter the density of each batch of latex to match that of bitumen emulsions it was decided to alter the density of latex to 1.0

using a density modifier and go for a large scale plant trial to produce Latex/CRS II blend.

A batch of approximately 1200 litres of latex/bitumen blend was prepared at the RCDC emulsion plant using density modified positex. The resultant blend which was CRS-II type was then used in a sand sealing trial at a road stretch along Wijerama Mawatha, Nugegoda. The service performance of the applied blend is being evaluated.

A laboratory investigation of the same blend showed no separation of positex from CRS-II bitumen over a period of six days (N M V Kalyani Liyanage and M Rizmi).

1.2 ***Radiation prevulcanisation of natural rubber latex***

1.2.1 *Latex protein analysis*

The calibration curve used in the analysis of latex proteins by Modified Lowry procedure was replotted with a view to obtain more realistic values particularly at low concentration levels. A project on the effects of maturation period on the protein content of RVNRL was commenced and the variation of latex characteristics and the leachable protein contents were determined. Corresponding physical properties of the latex matured to various time intervals were also determined. It was not possible to observe a reasonable correlation between the leachable protein content and the maturation period.

As for the physical properties of the corresponding films, it was observed that as the latex matures the physical properties of the films after leaching increases and the extent of the increase depends upon the nature of the leaching medium (N M V K Liyanage, L Karunanayake, H N K K Chandralal, M Rizmi, M K Mahanama, S I Yapa and S S Kulathunge (Atomic Energy Authority).

1.2.2 *Radiolysis of* Hevea *proteins*

Variation of protein levels in HA centrifuged latex before and after irradiation and after deproteinisation via enzymatic treatments were evaluated.

A discussion was held with Dr Seneka Perera (University of Queensland) and Mr Sugath Amerasekara, Quality Assurance Manager, Ansells, regarding the possible co-operation of the Industry for this particular project. Dr Seneka Perera agreed to write the project proposal and submit to the relevant authorities to obtain the formal approval to commence the project (N M V Kalyani Liyanage, Manel Mahanama and S Perera (University of Queensland).

1.2.3 *Effects of proteolytic enzymes on the proteins/physical properties of RVNRL and conventionally vulcanised Latex*

Attempts were made to remove the water soluble proteins in RVNRL films, conventionally vulcanised latex films and in final products by leaching them in papain solutions. It was found that leaching in papain solutions not only helps to reduce the soluble protein content but also helps to improve tensile properties.

A modified technique for the protein analysis of papain treated RVNRL films and conventionally vulcanised NRL films was developed. A calibration curve was obtained by using Coomassie Brielient Blue G-250 as the dye. It was found that this technique could be used even for the detection of very low concentrations of water soluble proteins, *i.e.* less than 50μg/ml. The main drawback of this method was that the colour development with the dye tends to reduce with time due to the formation of particles. Hence the effect of time and temperature on the absorbance values of colour complex were evaluated (Madupani Jayasooriya, Sriyani Yapa, and Rohan Senanayake (NDT student).

1.2.4 *Effects of radiation to reduce the protein content in conventionally vulcanised latex*

Attempts were made to irradiate HA centrifuged latex to various radiation doses followed by prevulcanisation. Tensile properties as well as soluble protein content of these latex samples were determined. It was found that irradiation of latex samples without using any sensitizer helps to improve the green strength and tensile properties of latex and it was found to be superior than purely irradiated latex or prevulcanised latex. It was also found that it helps to reduce the N_2 content and soluble protein content in the final product (Madupani Jayasooriya, Sriyani Yapa and Rohan Senanayake).

1.3 ***NR Latex coated fabric gloves***

A request came from Chemanex Ltd. for a suitable technique to reduce the penetration of latex into the interior surface of latex coated fabric gloves during the coating process. Several techniques were tested to develop a more practical system to prevent the penetration of latex into the interior surface of the fabric gloves during the coating process. A cost effective technique was successfully developed by using two different types of latex which could produce rubber coated fabric gloves with superior peel strength properties. Finished products were forwarded to the Chemanex Ltd. for evaluation (N M V Kalyani Liyanage, M M Jayasooriya and Sriyani Yapa).

1.4 *Rubberised coir based baskets*

A request came from an Industrialist for a suitable fast curing NR latex based compound to be used as an adhesive in the manufacture of coir based baskets. A suitable formula for this purpose was developed and some techniques for reducing the weight of the product were also suggested (N M V Kalyani Liyanage and Madupani Jayasooriya).

1.5 *Latex based artificial decorative flowers*

A casting technique suitable for making artificial decorative flowers out of NR latex was developed. This technique was found to be suitable to produce a range of beautiful flowers and the appearance and the texture of these flowers were much better than that of plastics or fabric based flowers (N M V Kalyani Liyanage and M Mahanama).

1.6 *Latex based cement for tyre retreading*

A few attempts were made to prepare the latex based cement with a longer storage stability. The major drawback of the latex cement was the premature coagulation of the cement. The effects of variation of soap content, solvent content, DRC of latex etc. on the stability of latex were evaluated. Some correlation between solvent content, DRC of latex *etc.* on the stability of latex cement could be observed.

Associated Motorways Ltd. made some repeated requests for a large scale sample of the new latex based cement developed by the department having observed the superior bond strength characteristics of the cement. Arrangements have been made to meet their request as early as possible. Development work of this nature is rather slow as the Department has only a very limited staff (N M V Kalyani Liyanage, M Rizmi, L Karunanayake and S Weeraman).

1.7 *Latex/C-Black masterbatches*

A request came from a leading solid tyre manufacturer for a suitable latex/C-Black masterbatch. A series of masterbatches were prepared in laboratory scale. The percentage of incorporation of C black into the rubber phase was determined the and technical evaluation of the masterbatches in a tyre tread formula was done (N M V Kalyani Liyanage and M K Mahanama).

2 Dry rubber technology

2.1 *Artificial limbs for disabled soldiers*

Four 25Kg batches of rubber compounds were prepared at the IDB and handed over to "Ranaviru Sevana" for the manufacture of feet of artificial limbs of disabled soldiers. Further requests for the same compound came from "Ranaviru Sevana" could not be met as the milling facilities at the IDB was not available for this purpose (N M V Kalyani Liyanage and K M U Mithrananda).

2.2 *Epoxidised natural rubber*

A few batches of ENR was synthesised by using HA centrifuged latex as the starting material. Characterisation for the level of epoxidation was done by FTIR spectroscopy and the ^{1}H NMR spectroscopy. Formation of ring opened products was properly controlled by altering the reaction conditions. Two large batches of ENR25 and ENR50 were synthesised under carefully controlled conditions and their applicability in tyre tread compounds was evaluated. The correlation between the reaction time and the extent of epoxidation was formulated by performing a statistical evaluation. A report of the work on this work was submitted as a project thesis for an MSc to the University of Sri Jayawardenapura and was considered as one of the best project thesis which were submitted for assessment during this year. Arrangements are being made to publish two papers from this work (N M V Kalyani Liyanage, K M U Mithrananda and A Dissanayake (MSc student).

A further set of epoxidation reactions was carried out by using performic acid for latex samples containing different dry rubber contents with an aim of studying the effects of DRC of latex on the epoxidation rate. Epoxidation levels of ENR samples obtained at different time intervals were determined using FTIR spectroscopic method. It is found that the DRC of latex has a pronounced effect on epoxidation rate. Further attempts were made to synthesise ring opened products of ENR samples with different epoxidation levels (Madupani Jayasooriya, Sriyani Yapa and Rohan Senanayake).

2.3 *Oil extended natural rubber*

A few lab scale batches of OENR was prepared. Oil extension was carried out at the latex stage and the percentage of oil extension was determined by acetone extraction technique. Energy required for the mastication of each sample was determined by Brabender Plasticorder. Rheological characteristics of some tyre tread compounds synthsised using the OENR were evaluated and their technological properties were also studied. Based on the results of the laboratory evaluation two

selected compounds were prepared at factory scale at the Associated Mototways Limited. A report of the work on this was submitted as a project thesis for an MSc to the University of Sri Jayawardenapura (N M V Kalyani Liyanage, M Rizmi, K M U Mitrananda and R Balasundaram (MSc Student).

2.4 *Protein analysis of crepe rubber*

A program was initiated to analyse the total extractable protein content in all the grades of crapes produced in Sri Lanka. Some pale crepe samples from C W Mackies and Balangoda Plantations were analysed by BCA procedure. All the samples contained <50µg/g rubber of total extractable protein levels (N M V Kalyani Liyanage and M Rizmi).

2.5 *Inter-Laboratory cross check system*

An inter-laboratory cross-check program was initiated jointly with both public and private sector testing laboratories with a view to make each testing laboratory aware of the accuracy and the reliability of their test results.

A batch of 12Kg of tyre tread compound was prepared at IDB and sent out to total of 11 companies and Research Institutions to perform some specified tests following standard procedures. The results received were analysed statistically to check their accuracy with the average. The final report of the statistical analysis was sent out to participants (N M V Kalyani Liyanage, M Rizmi, A K B Narampanawa and K M U Mitrananda).

Industrial extension

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

Asia Industrial (Pvt.) Ltd.	Testing of shoe sole compounds
Richard Pieris & Company Ltd.	Testing of Foam Rubber Samples and analysis of migrating chemicals of Jar rings into olive oil
Hanwella Rubber Products	Testing of rubber gloves
Plymouth Industries	Testing of rubber compounds
Midland Retreads	Testing of tread compounds
Road Grip	Testing of tread compounds
EU-Retec (Pvt.) Ltd.	Testing of rubber compound

Associated Motorways Ltd.	Testing of rubber compounds
Quality Latex Products (Pvt.) Ltd.	Testing of rubber strips
Ceymac Rubber Co. Ltd.	Testing of rubber compounds
CISIR	Testing of rubber compounds
Elastomeric Industries (Pvt.) Ltd.	Testing of staining of rubber sheets
Ceytra (Pvt.) Ltd.	Testing of rubber bands
Mimara Limited	Testing of rubber compounds

POLYMER CHEMISTRY

K G Karnika De Silva

SUMMARY

Laboratories of both private and public sector rubber industries participated an inter laboratory cross-check program (Round Robin Test) initiated by the Polymer Chemistry department to standardize all physical testing equipment used in rubber products manufacture and procedures followed in testing rubber products. Samples of latex and compounded rubber for testing were distributed among them for the tests to be carried out. The results were statistically analyzed at the RRI to check their performance when compared with the results of other similar laboratories. The test reports were submitted with comments under a confidential code.

Rs.1.3 Million worth research grant was awarded to the Polymer Chemistry department by the National Science Foundation for the project titled Protective Measures for the Current Latex Protein Allergy Problem – *A serious threat to the NR industry*. The research assistant appointed to carry out research work on this subject at RRISL laboratories was registered at the University of Sri Jayawardenepura for a 3-year MPhil project.

Polymer Chemistry department also received "Spare Parts for Research Equipment Scheme" which cost over Rs.113,000.00.

The formulation developed by the department for conductive rubber pads in muscle tonning machines has now received international recognition. These units are now being used at the Army hospital, Ranaviru Sevana and Colombo North Hospital in Ragama.

Project on utilization of buffing dust, a by-product from the tyre retreading industry with NR was continued. The results showed that utilization of buffing dust could be increased upto 20% from its current 10% in industrial applications without any deterioration of properties provided the tyre crumbs are pre-treated with a fatty acid derivative. It has also been observed that the processing properties such as reversion resistance and physical properties such as abrasion resistance and resilience seems to improve with the addition of fatty acid treated tyre waste in tyre tread formulations.

Commercial scale production of self reinforced powdered rubber by an economically viable method is now available. Scanning Electron Micrographs were also obtained for some blends using facilities at the University of Colombo.

An industrial problem due to blooming on rubber foot wear was solved after carrying out trials at different temperatures and storage conditions. Several samples from the industry were tested for bloom upon storage. Suggestions to rectify this problem were submitted in the form of comprehensive reports.

Several samples from the industry were analyzed for their base elastomer using FTIR spectrophotometer.

Tests were conducted to identify polymer ratios of different rubber blends by using the peak ratios of the calibration curves of the authentic samples in FTIR spectra..

Projects on creaming of field latex using tamarind seed powder, Constant Viscosity (CV) rubber using non-toxic chemicals, PVC/NBR blends, Epoxidised Natural Rubber, property evaluation of NR/NBR & CR lattices, low viscosity rubbers with plant extracts and fatty acid based oil emulsions as preservatives for latex and Oil Extended NR were continued. Locally available plant based extracts were tested as stabilizers and/or processing aids in dry rubber processing. Certain materials were found to be very effective to replace the currently used imported materials.

A series of NR/NBR blends were made and DMA and NMR analysis were carried out on vulcanized and raw rubber samples in collaboration with University of Griffith, Australia. NMR investigations were carried out to analyze crosslink distribution between NR/NBR phases.

It was noted that some locally available fatty acids materials could replace stearic acid in compounding to yield better physical properties. Very high tear strength values were recorded by the samples containing new fatty acid based materials.

Research Officers in the departments supervised six MSc Projects and three undergraduate vacation-training projects on latex and dry rubber technology as outcome of these projects are beneficial to the rubber products industry. The department staff was also involved in research projects implemented under the scheme to link industry, university and RRISL. Eight students from NDT and NAITA worked on different aspects such as to improve quality, productivity, new formulation development and so on forwarded by the industry.

A Patent was obtained for "New preservative systems with fatty acid based oil emulsions to replace TMTD in natural rubber latex" under the names of K G Karnika de Silva and Chitra Kurruppu.

Dr K G Karnika de Silva was awarded a PRI merit award in appreciation of her contribution made to the Polymer Industry in Sri Lanka.

Information was forwarded to the Ministry of Plantation Industries on a request made, for funding small holder development projects by the German and Canadian Governments.

DETAILED REVIEW

Staff

Two Assistant Research Officers, Mrs Champa Wellappili and Mrs Nilmini Liyanage joined the Polymer Chemistry Department with effect from 15th February 1999.

Mrs Nilmini Liyanage went on maternity leave from 14th May-15th September 1999.

Messers H N K K Chandralal, S S Warnapura, Mrs Indra Denawake, Mrs W C M Kuruppu, Messers R S Wijesundara, S L G Ranjith and Ananda Samarakoon, Experimental Officers were on duty through out the year.

Mrs Renuka Wijeratne, Clear/Typist was on accidental leave since January - April 1999.

Messers Sunil Weerasiri, P R Sigera, L L Piyasena, W D S Dharmawardena, Laboratory Attendants were on duty through out the year.

Meetings/ visits/ seminars/discussions

Dr K G Karnika de Silva participated at the following meetings/visits/ seminars/discussions.

- Scientific Committee Meetings held at SLAAS auditorium.
- NIPM Technical Committee Meetings held at TRI auditorium.
- Three EPSOOL Committee Meetings.
- Three inspection visits to PVC pipe manufacturing plants and Rubber Retreading Industry on requests made by SLSI.
- Discussions on recent developments by the rubber technology departments and about the PRI Award to RRISL with the Editor of "Desathiya" magazine.
- Inauguration ceremony for exhibition/awards for inventor- organized by IDB at the BMICH.
- Asia Rubber Markets '99 organized by IBC Singapore Ltd. held at Hotel Taj Samudra.
- Two seminars on Agricultural crops and Effluent disposal held at Hotel Taj Samudra.
- A seminar on Rubber Processing Oils organized by CSL International held at Hilton Hotel.
- Inauguration of the International workshop on Effluent treatment held at Dartonfield.
- A meeting organized by CARP on Extension of assistance to RRISL scientists at Dartonfield, RRISL.
- Served as an external examiner for viva-vocal examinations of Polymer Science MSc course organized by University of Sri Jayawardenepura..
- Several discussions and factory visits to Mal Lanka on semi commercial scale experiment trials with neem stabilized latex.

- Discussions with Malwattavelly, Bogawanthalawa and Balangoda Plantations on product manufacturing factories. Project proposals were submitted to the requested parties.
- Several meetings with local and foreign representatives dealing with JICA, TIPS, ADB and PSP on project funding.
- Two seminars organized by PRI on Rubber based Products and Modified EPDM Rubber.
- Discussion at VET at Rajagiriya on training facilities and funds for NR based industries.
- Seminar on Plantation Management for 21st Century organized by RRI Associates held at Mount Berjaya Hotel.
- Seminar organized by ESSO chemicals on rubber processing oils held at Hotel Lanka Oberoi.

Mrs Champa Wellappili also participated at the following meetings/visits/ seminars/discussions

- ISO Standards and Good Laboratory Practices conducted by Sigma Chemicals held at Foundation Institute.

The department staff participated at a training programme on Basics in Rubber Compounding by Dr M R N Fernando, Director, Rubber Development, at the RRISL auditorium.

Visits

Dr K G Karnika de Silva left for Seoul, South Korea on 26th April to present a paper titled Blending of waste tyre crumbs and polypropylene - An ideal way to recycle used tyres at IRC'99 held from 27th April- 29th April 1999.

LABORATORY INVESTIGATIONS

Inter laboratory cross check programme

An inter laboratory cross-check programme was initiated to standardize test methods carried out by the centrifuged latex manufacture and latex based manufacturers. Eleven latex testing laboratories from both private and public sector participated in this exercise. As the preliminary step the Raw Rubber and Chemical Analysis Department distributed 11 latex samples among the participated laboratories. The laboratories were requested to carry out five tests, namely Dry Rubber Content, Total Solid Content, Alkalinity, Volatile Fatty acid and Mechanical stability Time in triplicate. The results received were analyzed statistically to check

their accuracy. Reports were prepared using the above data and analysis reports were sent to the participated laboratories with comments for improvements in the test methods and testing conditions and chemicals used. More laboratories have shown interest in participating in the second round of this programme (K G Karnika de Silva, L Karunanayake, A K B Naranpanawa, H Sriyanthi Weeraman, Champa Wellappili, Wasantha Gamage, Champa Lokuge and Geethani Rajapakse).

The efforts were extended to eleven dry rubber-processing factories by statistically analyzing their results on samples distributed by the Rubber Technology and Development Department (K G Karnika de Silva, N M V Kalyani Liyanage, M Rizmi, A K B Narampanawa and K M U Mitrananda).

Powdered rubber

Trials on powdered rubber were continued. Powdered rubber prepared by the method developed, offers the advantages such as low power consumption and possibility of injection moulding. High production rates are possible with powdered rubber due to thermoplastic nature introduced by the acrylic polymers used in processing.

Different types of synthetic lattices from the industry were used for this purpose and the blends with acrylic co-polymers gave powdered rubber on acid coagulation. Blends of specially prepared latex such as compounded, prevulcanized natural rubber latex, were also used in the preparation of powdered rubber.

Samples were compounded and blended with natural rubber and tested for their physical properties. Properties indicated that the co-polymers could introduce a self reinforcing effect on powdered rubber. Upto 20% of powdered rubber in the blends gave better abrasion resistance, tensile properties etc. when compared with conventional rubbers in standard formulations.

Samples of powdered rubber were handed over to Road Development Authority to check the usage with Bitumen. The performances with bitumen showed encouraging results and arrangements have been made to carry out field trials with the blends.

Further, the samples made with acrylic co-polymer were used to prepare tyre tread compounds as the results showed that with 20% powdered rubber better abrasion resistance, tensile properties etc could be achieved, when compared with conventional rubbers in standard formulations.

A thesis titled Development and property evaluation of granular natural rubber for value added applications by Harsha Sugathapala was submitted to University of Sri Jayawardenepura as a partial fulfillment of MSc degree.

Indian Rubber Institute extended an invitation to Dr K G Karnika de Silva to present a paper titled Self Reinforced Granular Natural Rubber at the plenary session of the RubbTec'2000 to be held in New Delhi from 27th – 29th February 2000 (K G

Karnika de Silva, Champa Wellappili, H K K Chandralal, S S Warnapura and Harsha Sugathapala - MSc student from the Open University).

Use of buffing dust in tyre treads

A project on utilization of buffing dust, a by-product from the tyre retreading industry in tyre treads was commenced as a joint project with AMW.

The results showed that utilization of buffing dust could be increased upto 20% from its current 10% in industrial applications without any deterioration of properties provided the buffing dust or tyre crumbs are pretreated with a fatty acid derivative. Processing properties such as reversion resistance and physical properties such as abrasion resistance and resilience seemed to increase with the addition of fatty acid treated tyre waste in tyre tread formulations. Arrangements have been made to carry out field trials with this new formulation.

A thesis titled Effect of buffing dust on the technological properties of rubber compounds by Malini Dharmathilaka was submitted to University of Moratuwa (K G Karnika de Silva, Champa Wellappili, Ananda Samarakoon and Malini Dharmatilake - IDB - MSc Project Student).

Tyre crumbs/Polypropylene blends

A paper titled "Blending of waste tyre crumbs and polypropylene - An ideal way to recycle used tyres" was presented at the International Rubber Conference held in South Korea from 23rd- 29th April 1999 (K G Karnika de Silva).

New preservative system for latex

The main purpose of this project is to find out a suitable alternative to replace high ammonia and low ammonia - TMTD/ZnO stabilizer system used as preservative systems for field and centrifuged latex. TMTD is well known as a thermal producing nitrosoamines and hence will be banned from all the industries in the future. Hence it is very important to find suitable alternatives for this purpose.

Different types of preservative/ stabilizer systems were used in this study and the stability of a few combinations of neem oil based systems were tested which also showed good performance. Further, the commercially available newly developed Struktol 219B as a bactericide in the absence of TMTD showed better results than the other two systems. The new system would not form any nitroso amine as in the case of widely used traditional system, Low ammonia - TMTD-ZnO (LATZ latex).
Production trials of rubberized coir, foam rubber were also carried out with the latex preserved with neem oil based preservative systems. The end products showed good performance and properties compared with the conventional system.

A thesis titled Development of an eco-friendly preservative system for natural rubber latex concentrates and determination of effectiveness of Tamarind seed

powder as a creaming agent by Dilani Nadeeja Wickramarachchi was submitted to University of Sri Jayawardenepura as a partial fulfillment of MSc degree (K G Karnika de Silva, Chitra Kurruppu and Nadeeja Wickramarachchi - MSc Project student).

Creaming of field latex

Creaming of NR field latex using sodium alginate and tamerind seed was continued. Systems with tamerind seed powder have shown better and faster creaming with slight modifications done to the latex medium.

Experiments were also conducted to see the performance of dried films, compounded and prevulcanized lattices using creamed latex.

Problem of destabilization of creamed latex was closely monitored and certain steps were taken to prevent this.

Smallholders dealing with the Kalutara Regional Office have shown interest in creaming latex and a few trials were conducted for them to be familiarized with the process. Arrangements were made to dispatch creamed latex to Mal Lanka where they use this latex in their trials in eco-friendly latex products manufacture trials (K G Karnika de Silva, Chitra Kurruppu and Nadeeja Wickramarachchi (MSc Project Student).

NR/NBR blends

Main objectives of this project are to obtain a homogeneous polymer blends system to be used in various applications. For instance these blends could be an ideal solution to the current NR latex protein allergy problems where a certain percentage of NR could be replaced with a non-protein allergic synthetic rubber latex while retaining the excellent film properties of natural rubber.

A series of blends was prepared changing the polymer composition and miscibility of polymers was monitored using FTIR spectral technique. Adding a homogenizer to the blend has shown to improve the performance of the blends.

Dipped films were prepared using the best compositions. Tensile strength, elongation of break and protein content of the films was measured. Determination of protein content was carried out.

A thesis titled Latex blends of natural rubber and nitrile rubber with chloroprene rubber by W N Lakmal de Silva was submitted to University of Moratuwa as a partial fulfillment of MSc degree (K G Karnika de Silva, L Karunanayake, W W Nandasena and W N Lakmal de Silva).

PVC/NBR/NR blends

PVC and NBR were mixed in the Brabender plasticorder. Blends were milled with NR in an open mill and physical properties were evaluated. The results showed that NBR blends with PVC gives better tensile properties, compression set, tear strength than NBR alone.

Several samples of NR/NBR/PVC blends with different percentages of components were prepared and the physical properties were tested. Particularly the abrasion resistance seemed to improve in the presence of PVC and which showed an optimum value (K G Karnika de Silva, Laleen Karunanayake, Champa Wellappili and S L G Rangith).

Bloom analysis

Bata Shoe Company Ltd., Plymouth Industries and Asia Industries faced bad experiences with their rubber slippers and/or shoe soles due to a white colour bloom appeared on the surface upon storage. Several tests were conducted using FTIR Spectrophotometer at different temperature conditions to solve this problem. Suggestions were submitted in form of a comprehensive report (K G Karnika de Silva, Nilmini Liyanage, H N K K Chandralal, Indra Denawake and Ananda Samarakoon).

Elastomer analysis

Several samples from Soledeal, DSI, Water Board, Rovin Tech and Sinwa Ltd. were analyzed for various elastomers used in product manufacture. In some instances the ratio of two or more elastomer blends were determined using calibration curves obtained with authentic samples. Brabender plasticorder was used to mill certain blends (K G Karnika de Silva, Nilmini Liyanage, Champa Wellappili, Indra Denawake and Ananda Samarakoon).

Constant viscosity rubber

A project was initiated to manufacture Constant Viscosity (CV) rubber using non-toxic chemicals. A literature survey was carried out to find alternatives to match the function of Hydroxyl Amine Neutral Sulphate (HNS) to see the possibilities of replacing HNS from the method of manufacture. Initial trials were conducted at Dartonfield and compared the performance with conventional samples from Associated Speciality Rubbers (K G Karnika de Silva, Nilmini Liyanage and L P Vitharana).

Low viscosity latex and rubber

The observations made with plant extracts that certain systems with NR latex give low viscosity than other stabilized systems used to get low Mooney rubbers. These systems show better storage stability than other systems.

Low viscosity latex systems were tested for their stabilility with high dosage of viscosity modifiers. The coagulum was dried and the dry rubber samples were tested for their low and constant viscosity values. Physical properties were tested and further work on the project is in progress (K G Karnika de Silva, Champa Wellappili and Ananda Samarakoon).

Latex protein analysis in latex products

National Science Foundation funded research grant was awarded to Polymer Chemistry department for the project titled Protective Measures for the Current Latex Protein Allergy Problem – A serious threat to the NR industry. The grant includes a research assistantship leading to a MPhil Degree, capital cost on SDS Page Analyzer, BCA kit, an ageing oven and a water bath. A research assistant assumed duties on this project to work at RRISL laboratories and registered for a MPhil Degree at the University of Sri Jayawardenepura.

A calibration curve was done using BCA method for quantitative analysis of proteins in latex gloves. Effect of leaching conditions was studied to reduce leachable proteins. Further work to study the possibilities of maximum reduction of extractable proteins is in progress (K G Karnika de Silva, Laleen Karunanayake, Champa Wellappili, Nilmini Liyanage and S L G Ranjit).

Latex proteins in raw rubbers

This project was initiated on a request made by Bogawanthalawa Plantations Ltd. as one of their buyers has requested protein free latex crepe rubber. As the possible protein levels of latex crepe grades are not found in literature it was thought that the levels could be very low due to extensive washing and millings carried out during the normal process of manufacture of crepe grades. However, it was found that the protein contents are higher than expected. The experiments to find the protein levels of all rubber grades are in progress (K G Karnika de Silva, Laleen Karunanayake and Nilmini Liyanage).

Different grades of rubber were milled according to the ACS 1 formulation to test the protein levels when compounded (K G Karnika de Silva, Champa Wellappili and M Rizmi).

Rubber mats

Formulations used by Microcells for rubber mats out of NBR for use in restaurants were modified by incorporating about 20% NR in to the formulations. To make the two NR and NBR phases compatible a small percentage of Chloroprene rubber was incorporated. Specifications of these blends satisfied the request of the customer who has placed an order with Microcells. Tests on oil, water and detergent resistance were carried out to issue the certificates. Routine analyses were conducted on samples from several batches (K G Karnika de Silva, S S Warnapura and H N K K Chandralal).

Muti-functional ingredients for rubber compounding

Research on this project was reactivated to find out the suitability of a fatty acid based natural ingredient to replace stearic acid used in rubber compounding. The initial trials showed that the new materials have multifunctional properties to act as an activator, accelerator and an anti-oxidant in the compounding formulation. Further work on the project is in progress (Karnika de Silva and Nilmini Liyanage).

Rubberized binders

Compounded latex was used as a suitable binding medium for two projects on expanded coir based coins (magic coins) and for the development of organic plant growing medium. These projects were initialed on requests made by Pro Flora (Pvt.) Ltd. and Tea Research Institute.

Several trials were conducted to get the right texture, expandability and storage stability of magic coins requested for the German market. Samples and formulations were given to the manufacturer for factory trials (K G Karnika de Silva, H N K K Chandralal and Nilmini Liyanage).

Research on utilizing organic wastes (tea refuse, coco peat, coir dust, saw dust *etc.*) based plant growing medium to match a commercially available, costly plant medium (oasis) was carried out. The trials include variations in compositions, binding medium, compression, processing technique *etc.* to get required water uptake to the medium (K G Karnika de Silva, T Mohotti (TRI) and S S Warnapura).

Industrial extension

Various samples were analyzed for the rubber based industries on request.

Microcells	NR/NBR blends, Mats
Ansell Lanka	Chemicals
Hanwella Rubber Products	Chemicals

Proflora	Magic coins
TRI	Oasis material
Bata Shoe Co.	Bloom analysis, Elastomer analysis
Bogawanthalawa Plantations	Quality reports and project proposals
Sigiri weaving mill	Rubber roller
Soliedeal rubber	Elastomer analysis
Waterr Board	Water seals, Elastomer analysis
Mal Lanka	Extracts of rubbers
Malwatte Vally Plantations	Project Report on moulded rubber goods
Balangoda Plantations	Tapping cups, Latex/dry rubber goods
Standards Institution	Bicycle tubes
AMW	Toxicity of rubber compounds
Lalan rubbers	Latex proteins
Proflora Pvt. Ltd	Magic coins out of coco-peat/rubber latex
Sri rub Elastomeric Techniques	Cot sheet
Work Wear Lanka	Chemicals
Arpitalian Compact soles	Physical properties
Rovin Tech	Water seals
Cedar International (Pvt) Ltd.	Rubber samples
Textrip (Pvt) Ltd.	Latex proteins
DSI	Elastomer analysis
City Cycle Stores	Elastomer analysis
IDB	Elastomer analysis
Textile Training Institute	Solvent resistant seals

RAW RUBBER AND CHEMICAL ANALYSIS

L Karunanayake

SUMMARY

The following activities were performed during the year:

a. Analysis, grading and issuing shipping certificates for all TSR produced in the country.
b. Recommendation of new chemicals for the industry.
c. Analysis and issuing quality certificates for latex, crepe, sole crepe and sheet rubber produced in the country for local industries and exports.
d. Analysis of chemicals and water used in the rubber processing and rubber products manufacturing industry .
e. Testing of finished products such as:
    1. Rubber gloves for sodium pentachloraphenate content
    2. Rubber content in vulcanized products
    3. Rubber and other polymer contents in foam rubber
    4. Contaminations of metal ions in dipped products
f. Participation in Round Robin cross check on standard dry rubber testing for regional laboratories conducted by Rubber Research Institute of Malaysia. Organizing and participation in inter laboratory cross check programme for latex testing laboratories in private factories and government sector.
g. Organizing demonstrations and work shops on preparation of new brushable rainguard sealant for plantation companies and small holder sector.
h. Analysis of dry rubber, latex, chemicals, finished products, *etc* on requests made by the other research departments.
i. The following research projects were in progress.
    1. New brushable sealant for rainguards
    2. Properties of reclaimed rubber and its blends
        a. Storage hardening of reclaimed rubber
        b. Technological properties of blends reclaimed rubber
    3. Effects of Mg^{2+} and phosphate ion levels on NR latex properties.
    4. Blends of NR latex with synthetic lattices.
    5. Effect of moderately high temperature and maturation on protein content and physical properties of NR dipped products.

DETAILED REVIEW

Staff

Dr L Karunanayake, Specifications Officer was on duty through out the year. Mrs Sriyanthi Weeraman, Mrs Leela Wanigatunga, Mrs H Vasantha Gamage, Mrs Champa Lokuge and Messrs. L P Vitharana, P L Perera, Experimental Officers were on duty through out the year.

Mrs N Baduge, Graduate Assistant (Technical) was on duty through out the year.

Mrs Geethani Rajapakse, Miss Medavi Wijesekera, Messrs B Gunasiri, W Vithanage, W W Nandasena, N Karunatilake, Technical Officers were on duty through out the year.

Mr P Lelwala, Instrument Technician was on duty through out the year.

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

Messrs Sirisena Gallage, G H Somasiri and P Vithana, Laboratory Attendants were on duty through out the year.

Meetings, Seminars and Lectures

Dr L Karunanayake attended the following:

- A discussion with TIPS on rubber products manufacturing industry organized by PRI.
- Scientific Committee Meetings of Rubber Research Institute .
- A meeting on quality of crepe rubber produced in Sri Lanka organized by CRTA with Planters, Chemicals Suppliers and Shippers.
- Annual General Meeting of the Association of Testing Laboratories.
- Two joint staff meetings held in Dartonfield, Agalawatta.
- Demonstration on the facilities available from CARP for the use of Scientists.
- A seminar organized by SLAAS on product diversification of export crops.
- A seminar organized by ESSO Chemicals on Rubber Processing Oils.
- A lecture organized by PRI on modified EPDM Rubbers .
- Served as a lecturer for two workshops organized by Bogawantalawa Plantations Ltd. on
    - Manufacture of rainguard sealant
    - Discolouration of crepe rubber.
- Delivered a lecture on quality of raw rubber used in the retreading industry at a workshop organized by AMW.

- Served as an external examiner for viva-vocal examinations of Polymer Science MSc course organized by University of Sri Jayawardenapura.
- Asia Rubber Markets, "99 organized by IBC Singapore Ltd. Mrs H S Weeraman also attended the Asia Rubber Markets, "99 organized by IBC Singapore Ltd.

Inspection visits

In order to resolve the discoloration problem in crepe rubber raised by the CRTA, all rubber chemicals used in the rubber industry were tested. As agreed at this meeting, surprise visits were made to the factories where bleaching agent is manufactured and also to ware houses where they are stocked and drew samples for analysis.

Recommendations and advise were given according to the findings (L M K Tillekratne, L Karunanayake, P L Perera and W W Nandasena).

Training programme

Following students/trainees carried out their projects/training in the department.

1. Lakmal de Silva	- MSc	- University of Moratuwa
2. Priyanthi Perera	- MSc	- University of Sri Jayawardenapura
3. Anura Perera	- MSc	- University of Sri Jayawardenapura

LABORATORY INVESTIGATIONS

New brushable rainguard sealant

Patent right was obtained for new brushable rainguard sealant developed in the department (Patent No 11698) (L M K Tillekeratne, N Karunatilake and L Karunanayake).

Effects of magnesium and phosphate levels on latex properties

The presence of Mg^{2+} is known to destabiliyze NR latex. Therefore, $(NH_4)_2HPO_4$ or NaH_2PO_4 is added to remove the excess Mg^{2+} ions present in latex. However, the addition of Phosphate ions in excess are reported to affect latex properties such as chemical stability which can give low physical properties to dipped products.

A series of latex samples with adjusted magnesium and phosphate levels were prepared by incorporating $MgSO_4$ and $(NH_4)_2HPO_4$. Latex properties and physical properties of dipped products manufactured out of them were evaluated (L Karunanayake, Wasantha Gamage and Priyanthi Perera).

Blends of NR, NBR with a homogenizer

Main objectives of this project are to obtain homogeneous polymer blends to be used in various applications. For instance these blends could provide an ideal solution to the current NR latex protein allergy problems where a certain % of NR could be replaced with a non- protein allergic synthetic rubber latex while retaining the excellent film properties of natural rubber.

A series of blends was prepared by changing the polymer composition and the miscibility of polymers was monitored using FTIR spectral techniques.

Dipped films were prepared using the best compositions. Tensile strength, elongation at break and protein content of the films were found. Determination of protein content is to be repeated due to some interferences observed in the presence of stabilizers used in the experiments (K G Karnika de Silva, L Karunanayake, W W Nandasena and Lakmal de Silva).

Storage hardening and other properties of reclaimed rubber

As in raw natural rubber, storage hardening of reclaimed rubber is a predominant problem encountered by the reclaimed rubber manufacturers. However, phenomenon for storage hardening is not well known for reclaimed rubber as it for raw NR.

Formation of active functional groups such as carbonyl and peroxide groups during devulcanization of reclaimed rubber is a known phenomenon .

There are three possible ways of occuring storage hardening in reclaimed rubber.

i.e.
a. through carbonyl and amine groups as it happens in raw NR.
b. through peroxide vulcanization due to presence of groups formed during the devulcanization process.
c. through normal sulphur vulcanization due to the presence of free sulphur and other vulcanization chemicals.

A research project was carried out to study the remedial measures for the above problem (L Karunanayake, L P Vitharana and Anura Perera).

Properties of skim rubber

It was observed that skim rubber usually records low values for PRI. However, concentration of Mn and Cu ions which are responsible for lowering PRI of some skim

samples, were found to be below the recommended level, even though they record low values. Therefore, a study was commenced to find out the relationship between PRI value and other parameters such as phosphate ion and Fe ion contents, *etc* (L Karunanayake, H S Weeraman and W W Nandasena).

Inter laboratory cross check programme

An inter laboratory cross-check programme was initiated to standardize the test methods used by the centrifuged latex manufacturers and latex based dipped products manufacturers. Eleven latex testing laboratories from both private and public sector participated in this exercise. As the preliminary step 11 latex samples were distributed among the participated laboratories. They were requested to carry out five tests, namely. Dry Rubber Content, Total Solid Content, Alkalinity, Volatile Fatty Acid number and Mechanical Stability Time in triplicate and report back. The results received were analyzed statistically to check their accuracy. Analysis reports were sent to the participated laboratories with comments, for improvements in test methods, conditions and chemicals (K G Karnika de Silva, L Karunanayake, A K B Narampanawa, H Sriyanthi Weeraman, Champa Wellappili, Wasantha Gamage, Champa Lokuge and Geethani Rajapakse).

Effect of maturation of latex at elevated temperatures on latex properties

A project carried out at Birmingham University has shown that storage of NR latex at elevated storage temperatures give lesser amounts of leachable proteins when used in dipped products.

However, the use of higher temperatures for latex storage might affect latex properties such as MST and viscosity and thereby physical properties of dipped products produced out of them.

Hence, a study was started to monitor the effect of latex maturation temperature on properties of latex (L M K Tillekeratne, L Karunanayake, L P Vitharana and R G Keckwick).

Analytical services

Table 1. *The number of samples tested from each TSR factory during this year*

Producer	No. of samples
Statcon Block Rubber Factory, Getahetta	1555
Ceymac Block Rubber Factory, Horana	2931
Total	4486

Table 2. *Other samples tested during this year*

Rubber samples	459
Latex samples	196
Chemical samples	181
Master batch samples	52
Gloves samples	61
Water samples	122
Bleaching agent	277
Soils	02
Total	1350

Table No 3. *Instruments repaired at Electronic Repair Unit during the year*

Instrument	Inventory No.	Date of request	Fault	Completed date and comments
Gallenkamp Oven	CA/003-1	23.05.99	Not heating	25.05.99 Temperature control board was out of order and repaired using some parts obtained from a rejected oven
Gallenkamp Oven	CA/003-2	25.05.99	Not heating	27.05.99 Temperature control board was out of order and repaired using some parts obtained from a rejected oven
Brabender Machine oil bath	RT – 328-2	20.04.99	Not heating	05.05.99 Temperature control unit was out of order and p.c.b. was repaired. (above temperature control unit was repaired without a service manual)
UV spectro photometer	SP-0276	25.03.99	Memory out of order	05.04.99 Power supply unit (memory section) was out of order

Instrument	Inventory No.	Date of request	Fault	Completed date and comments
Computer printer	RT 404	02.02.99	not printing	11.02.99 Power control and distribution PCB was out of order and the repair was completed replacing some spare parts.
UV-Spectrophoto meter	SP-0276	21.01.99	Monitor reading out of order	26.01.99 Motor P.C.B. out of order and the repaired was carried out replacing some I.C.s.
Abrasion Tester Machine	RT-101	01.09.99	Sample Holder not working	02.09.99 The motor belt was repositioned and the machine was serviced
A Grant water bath	RC/0387		Temperature reading out of order	14.12.99 A new thermostat was fixed and temperature range was calibrated
A Viscosity Testing machine	CA/26	01.02.99	Meter reading value out of order. Rotating disk cannot insert properly and nobs inside the machine, also air leak	07.07.99 Viscometer was serviced fully
Mechanical stability machine	SP/187	23.06.99	Wrong speed	29.06.99 The repair was carried out replacing new brushes and serviced the instrument fully..
Two roll mill	CA/019	18.6.99	Big noise in electrical control panel and cracked motor belt	Replaced the motor belt and repaired the control panel using new parts, also fully serviced the machine
Brabender Machine Inter Face Unit	RT 328	01.06.99	Temperature reading out of order	Temperature controlling PCB was out of order. Replaced some I.C.s. and fully serviced (above interface unit repaired without service manual).

RAW RUBBER PROCESS DEVELOPMENT AND CHEMICAL ENGINEERING DEPARTMENT

W M G Seneviratne

SUMMARY

As the main function of the department, advisory visits were made to nine crepe rubber factories to solve quality problems connected with raw rubber manufacture.

Thirty-three rubber and other industrial sites were visited to look into the problems associated with the disposal and treatment of effluent generating from respective manufacturing processes and to give necessary advice in implementing a suitable treatment facility. Two other industries were visited for industrial extension work. Effluent treatment plants at four crepe rubber factories commenced operation during the year. Proposals for waste water treatment systems were forwarded to five crepe rubber factories and two centrifuged latex factories. Construction work of the waste water treatment plant at Sanhinda Desiccated mills at Kirimetiyana was nearing completion at the end of the year and the project is fully funded by the Coconut Development Authority.

Results of a series of experiments carried out showed that sulphate ions in skim effluent generating from centrifuged latex processing has an adverse effect on the anaerobic digestion process. In contrast, when sulphate less effluent is digested anaerobically, it was shown that a maximum gas volume of approximately 230 ml per gram of COD is produced from satisfactory digestion.

Studies on blends of DPNR/BR showed that good all round properties can be expected from a tyre tread in which 40% of BR incorporated in a blend of DPNR and BR.

Padukka crepe rubber factory was accredited for ISO 9002 by the SLSI. This is the second crepe rubber factory in Sri Lanka to receive this registration. Implementation of the ISO 9002 quality system in Padukka rubber factory was assisted by the department.

Workshop on methodologies of waste water treatment was conducted to a delegation from Thailand. Waste water testing laboratory functioned as usual and 93 waste water samples were analyzed during the year. ISO/TC 25 laboratory manual draft for this laboratory was completed.

DETAILED REVIEW

Staff

Head of the Department visited South Korea between the period 25th - 30th April to participate an International Rubber Conference IRC '99 held in Seoul and presented a paper on "Cost Effective Waste Water Treatment System based on high rate Anaerobic septic tank digester coupled with aerobic mechanism for the treatment of rubber and allied industrial effluents." He served as a session chairman of the forum of Environment and Recycling at this conference. He visited the Polymer Technology Department of University of Science in Penang, Malaysia between the period 30th April and 7th of May. He also visited USA to attend Annual Exhibition and Technical Conference on "Water Quality and Waste Water Treatment' (WEFTEC 99') held during the period between 9th and 14th of October at New Orleance, Lousiana USA.

Mr Susantha Siriwardena, Rubber Chemist, left for Malaysia on 25th of January to read for his PhD at University of Science in Penang.

Mr Upul Ratnayake, Assistant Rubber Chemist, reported for duty on 26th July after completing one year of his research project on "Radiation Processing of Natural Rubber Latex" at Takasaki Radiation Chemistry Research Establishment, Japan Atomic Energy Research Institute.

Mr P H Sarath Kumara was promoted to the post of Assistant Rubber Chemist with effect from 15th February.

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

Messrs C D Senanayake, T A S Siriwardane and Mrs Chandrika Nalini, Experimental Officers were on duty throughout the year.

Mr A K D Warnajith and Miss V C Rohanadeepa, Technical Officers were on duty throughout the year.

Mrs Imali Koralage, Temporary Research Assistant continued to work on a National Science Foundation (NSF) funded research project on 'Developing an efficient and cost effective treatment system for the serum water that is discharged when latex is centrifuged and also to use the bio gas generated in the process of treatment as an energy source'.

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

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

Students

Mr Upul Herath, NDT student from University of Moratuwa completed his training on 15th June.

Seminars, meetings, lectures and workshops

Head of Department attended the following:

- Delivered a lecture on Waste Water Treatment in rubber factories, organised by the SPCD at the Seminar on Cleaner Production.
- Conducted an international workshop on 'Rubber Factory Waste Water Treatment and Disposal' sponsored by the IRRDB between 7th and 13th of March at the Rubber Research Institute of Sri Lanka.
- Four Scientific Committee meetings.
- Two CRTA meetings.
- Seven Management Committee meetings and six Educational sub committee meetings of PRISL.
- Two NIPM technical committee meetings held at Tea Board.
- Delivered a lecture on waste water treatment of industrial effluents conducted by the SMED at Hotel Renuka, Colombo.
- One NLAC meeting held at the SLSI.
- Participated at the PRI awards ceremony.
- Participated in a two day seminar on Asia Rubber Markets - 1999 conducted by IBC, Singapore Ltd. at Taj Samudra, Colombo.
- Participated in a ½ day seminar on CHEMLOK adhesives at Hotel Lanka Oberoi, Colombo.
- Conducted visiting lectures at the Rajarata University on "Rubber Manufacture and Processing"
- A seminar on Agricultural Management conducted by the University of Ruhuna at SLAAS.
- Delivered a lecture on Waste Water Treatment for Officers from Pussellawa Plantations Ltd. at a workshop held at Dartonfield.

Dr W M G Seneviratne[1], Dr Laleen Karunanayake[2] Messrs Upul Ratnayake[3], P H Sarath Kumara[4], T A S Siriwardane[5] and A K D Warnajith Prasad[6] attended the following:

- Delivered lectures on Important Aspects of Rubber Manufacture and Usage of Chemicals at Low Country Managers Meeting at Bogawantalawa Plantations Ltd., held at Maha Oya Group. [1 & 4]
- Meeting at Malwatte Valley Plantations Ltd.[4]

- Addressed the Managers, Field Officers and Factory Officers of Bogawantalawa Plantations Ltd, at Udabage Rubber Factory on "General aspects of manufacture with special attention to prevention of down grading of crepe rubber. [4 & 5]
- Meeting at CEA to discuss the present situation of Ellakande Effluent Treatment Plant[4 & 5]
- Participated at a workshop on waste water treatment & disposal conducted by CEA at SLAAS auditorium and CISIR laboratories.[5]
- Accompanied IRRDB participants of the workshop on waste water treatment, to plants in operation at Kiriporuwa crepe rubber factory, Eheliyagoda crepe rubber factory, Pussella crepe rubber factory, Hanwella Rubber Products centrifuged latex factory and Ellakande crepe rubber factory [1 & 5.]
- Two Joint Staff meetings held at Dartonfield.[1,3 & 4]
- A Seminar on ISO 14000 conducted by Somaratne Consultants Ltd. at Hotel Lanka Oberoi.[1, 4 & 5]
- Delivered lectures on Rubber Manufacture for Rubber Factory Officers of Pussellawa Plantations Ltd. at a workshop held at Dartonfield. [4, 5 & 6]
- Delivered lectures on Rubber Manufacture for Asst.Rubber Factory Officers of Pussellawa Plantations Ltd. at a workshop held at Dartonfield. [4, 5 & 6]
- Working group meeting on tolerance limits for effluents from palm oil and coconut kernel based industry held at Sri Lanka Standards Institution.[3]
- Workshop on Rubber Processing for Asst. Superintendents of Pussellawa Plantations Ltd. held at Dartonfield. [3 & 4]
- Addressed the rubber factory workers on 'Present situation of the rubber industry and the role of the employees' at 4 workshops held at Pussella, Eheliyagoda, Elston and Penrith rubber factories.[4, 5 & 6]
- Delivered lectures for rubber factory officers' skill development programme at NIPM.[4]
- Addressed the managers and rubber factory officers at a seminar/discussion held at Udapolla Estate, Deraniyagala.[2 & 4]
- Addressed the Rubber Factory Officers of the Pussellawa Plantations Ltd. on ISO 9000 concept at a workshop held at Elston rubber factory.[4 & 6]
- Delivered a lecture on 'Collection of latex and DRC determination' for Rubber Field Officers at a workshop conducted by NIPM at Dartonfield.[4]
- Delivered a series of lectures for Asst. Superintendents of Pussellawa Plantations Ltd. on ISO 9000 series of standards at a workshop held at Dartonfield.[4]
- A seminar on ISO Standards and good laboratory practice organized by Sigma Chemicals (Pvt.) Limited at Sri Lanka Foundation Institute.[3]
- Meeting on Research project RG/98/EP/01 at National Science Foundation. [3]
- Conducted lectures on 'Plantation Rubber" and 'Latex Technology' at the University of Moratuwa for part-time course in 'Polymer Technology'. [4]

Advisory Visits

The following estates and rubber factories were visited during the year in connection with factory development and quality improvement of raw rubber.

1.	Paiyagala Rubber Factory	- Dodangoda
2.	Neuchatel Rubber Factory	- Thebuwana
3.	Pambegama Rubber Factory-	- Ehaliyagoda
4.	Sirikandura Estate	- Matugama
5.	Elpitiya Rubber Factory	- Elpitiya
6.	Delkeith Estate	- Baduraliya
7.	Elston Rubber Factory	- Puwakpitiya
8.	Lanka Products Ltd.	- Waulugala, Horana
9.	Silverdale Rubber Factory	- Dodangoda

The following rubber factories and other industries were visited during the year to look into the aspects connected with wastewater treatment and disposal. Among these some were visited to provide assistance to improve the existing treatment facility and the others to submit proposals and designs or to inspect the progress of the construction, which are being carried out.

1.	Lak Latex Centrifuged Pvt Ltd.	-	Baduraliya
2.	SRMEC Crepe rubber Factory	-	Baduraliya
3.	Dipped Products Ltd.	-	Brahamanagama, Kottawa
4.	Venigross Factory	-	Weliweriya
5.	Hanwella Rubber Products Ltd.	-	Hanwella
6.	Glenross Centrifuged Latex Factory	-	Neboda
7.	Padukka Estate	-	Padukka
8.	Ellakanda Rubber Factory	-	Horana
9.	Kahathuduwa Rubber Mills	-	Kahathuduwa
10.	Rambukkanda Estate	-	Ratnapura
11.	Galatura Estate	-	Galatura
12.	Maha Oya Estate	-	Dehiowita
13.	Densworth Estate	-	Kiriporuwa
14.	Coconut Development Authority		
15.	Paiyagalla Estate	-	Dodangoda
16.	Morontota Crepe Rubber Factory	-	Morontota
17.	Dalkeith Estate	-	Baduraliya
18.	Sanhinda DC Mills	-	Kirimetiyana
19.	Elston, Salawa, Halpe Estates	-	Avissawella

19. Elston, Salawa, Halpe Estates	-	Avissawella
20. SRMC Foam Rubber Factory	-	Waulugala, Horana
21. Ceysta Factory	-	Undugoda
22. Mackwoods Weedicide Factory	-	Ja-Ela
23. SRMEC Centrifuged Latex Factory	-	Elpitiya
24. Ranweli Hotel	-	Waikkal
25. Ceymac Rubber Co. Ltd.	-	Nartupana
26. Lalan Rubbers Ltd.	-	Warakapola
27. Atale Crepe Rrubber Factory	-	Atale
28. Kiriporuwa Crepe Rubber Factory	-	Kiriporuwa
29. Devalakanda Rubber Factory	-	Dehiowita
30. Panawatte Rubber Factory	-	Yatiyantota
31. SRMC Foam Rubber Factory	-	Elpitiya

Subsidy visits

Following three Latex centrifuging factories were visited in view of inspecting the progress of the construction of effluent treatment facility which is a prerequisite to enable them to qualify for the subsidy under the factory development scheme for installation of centrifuging machines.

1. SRMEC	- Mawanella
2. Surral Lanka (Pvt) Ltd.	- Yatiyantota
3. Premier Rubber Products Ltd.	- Ingiriya

Other visits

- Visited Carnival Ko - Lanka Ltd., Katana to solve problems connected with rubber masks and water quality.

- Visited Union Carbide factory at Ekala, Ja-Ela for air velocity measurements of the laboratory fume cupboard.

Exposure tour of Thai delegation on effluent treatment

A Thai delegation comprising 4 scientists from Rubber Research Institute of Thailand and its affiliated institutions visited Sri Lanka for an exposure tour on familiarisation of waste water treatment methodologies practiced in Sri Lanka. They visited Dartonfield, Kiriporuwa, Atale waste water treatment plants designed by the department and Colombo Rubber Auction.

Sample testing

Ninety three factory waste water samples were tested and certificates were issued during the year. In addition to that water samples were also tested and seven certificates were issued during the year.

ISO 9002 Quality Assurance Scheme

Three MRC meetings were held at Dartonfield and at SLAAS, Colombo to discuss the quality related matters in connection with ISO 9002 quality system of Dartonfield rubber factory in January, June and December respectively.

Three Internal Quality Audits were carried out at Dartonfield rubber factory by the Officers of the department.

Two surveillance audits were carried out at Dartonfield rubber factory by the SLSI Auditors in April and November.

Padukka rubber factory was accredited for ISO 9002 by the SLSI. This was possible with the assistance extended by Officers of the department.

Assistance was extended to Padukka Rubber Factory for the preparation of surveillance audit and to make amendments to existing documents to correct non-conformities which have been raised at the surveillance audit carried out in July. Also two internal Quality audits were carried out at Padukka Rubber Factory by the Officers of the department.

Manuals are being prepared at Statcon Rubber Factory to go for ISO 9002 under the direction and assistance of the department (W M G Seneviratne, P H Sarath Kumara and A K D Warnajith Prasad).

Laboratory Accreditation - Waste water testing laboratory

Drafting of ISO/TC 25 Laboratory Manual was continued. Some of the chapters on Equipment and their Maintenance, Job Description and Allocation of Tests had to be redrafted to suit the changing conditions in the staff and test capabilities of the Department. The Manual on methods was also studied in detail and necessary changes were effected. The Manual draft was completed at the end of the year and the final touches are being effected (P P Jayasinghe).

LABORATORY AND FIELD INVESTIGATIONS

Waste water treatment and disposal

Detailed description of the waste water treatment process primarily developed

for the treatment of the rubber and allied industrial effluents by the department has been published by the Third World Network of Scientific Organization (TWNSO) publication of "Sharing Innovative Experiences" Volume I in the year 1999. TWNSO is the special unit of the UNDP for the technical co-operation among developing countries. The main aim of this exercise by the UNDP is to introduce such innovative and effective technologies in other countries.

Four treatment plants constructed and designed as per the specifications submitted by the department have commenced operation during the year. They are Effluent treatment plants at;

1. Galatura crepe rubber factory - Daily liquid flow $90m^3$
2. Rambukkanda crepe rubber factory - Daily liquid flow $90m^3$
3. Paddukka crepe rubber factory - Daily liquid flow $80m^3$
4. Atale crepe rubber factory - Daily liquid flow $90m^3$

Treatment plant at Paiyagalla crepe rubber factory is almost completed and commissioning of the plant is yet be done. Similarly construction wok of the plant at Morontota rubber factory designed to treat the centrifuged latex effluents generating from Ms Surral Lanka centrifuged plant, Yatiyantota too is nearing completion.

Construction work of the waste water treatment plant at SRMC foam rubber factory at Elpitiya was completed and the operation will be commenced early next year. The treatment plant is to treat 40 m^3 of waste water per day and made into a compact design in order to reduce the cost of construction and to minimize the utilization of space.

Construction work of the proposed treatment plants at Devalakande ($90m^3$) and Pannawatte ($80m^3$) crepe rubber factories belonging to Kaleni Vally Plantations were commenced and will be ready for commissioning within the 1st quarter of next year.

Detailed proposals including BOQ and structural details of the construction have been sent to the following factories during the year in view of installing treatment facilities in those factories.

1. Halpe Crepe Rubber Factory
2. Salawa Rubber Factory
3. Elston Rubber Factory
4. Talduwa Rubber Factory
5. Sunnycroft Crepe Rubber Factory
6. Vincit Centrifuged Latex Factory
7. Glenross Centrifuged Latex Factory for completion of the existing plant
8. Delkeith Rubber Factory

Most of these factories are in the process of making arrangements to obtain loans from the National Development Bank under the Bank's loan scheme allocated for environmental pollution control known as E-friends.

The surface aerators used in the aeration tanks are fabricated by a local firm under the guidance of the departmental staff. The effectiveness of these aerators is found to be as effective as much more expensive imported aerators.

Constructional work of the pilot effluent treatment plant for the treatment of DC mill waste water was started at Sunhinda DC mill, Kirimetiyana during the early part of the year. The designs were based on the laboratory scale experiments conducted at the laboratory. The project is fully funded by the CDA. Most of the construction work were completed by the end of the year. Commissioning will be done after the fabrication of the surface aerator. Certain modifications were carried out at the existing plant at the Lak Latex centrifuging plant, Badureliya. These modifications were found to be required due to the excessive processing of concentrated latex than the previous years.

Structural improvement has been introduced for Pussallawa, Kiriporuwa, Atale, SRMC and Rambukkanda effluent treatment plants inorder to cut down the cost of construction of each plant. This was done by constructing the major components of the treatment plants together to make it a compact system.

It was found that the efficiency of the treatment in compact system is same as that in non-compact system (W M G Seneviratne, Upul Ratnayake, T A S Siriwardane and A K D Warnajith Prasad).

Generation of bio - gas from skim rubber

The project titled 'Developing an efficient and cost effective treatment system for the serum water that is discharged when latex is centrifuged and also to use the bio gas generated in the process of treatment as an energy source' funded by National Science Foundation was continued.

Micro-biological studies in the aerobic and anaerobic systems were conducted at the Department of Micro-Biology at University of Kelaniya.

Comparative studies between effluent generated from crepe rubber factories and from centrifuged latex factories were started using newly constructed medium scale pilot plant made out of transparent material in order to study the treatment efficiency of skim effluent.

Experiments were carried out to study the effect of sulphates and pH on anaerobic digestion since the skim effluent contains high SO_4^{2-} and low pH when compared to crepe rubber effluent. The results showed that SO_4^{2-} content in the effluent has adverse effect on anaerobic digestion. BOD and COD removal efficiencies were

measured in sulphate rich and sulphate less skim effluent in order to find out the optimum feeding load to the treatment system without any detrimental effect on the anaerobic digestion.

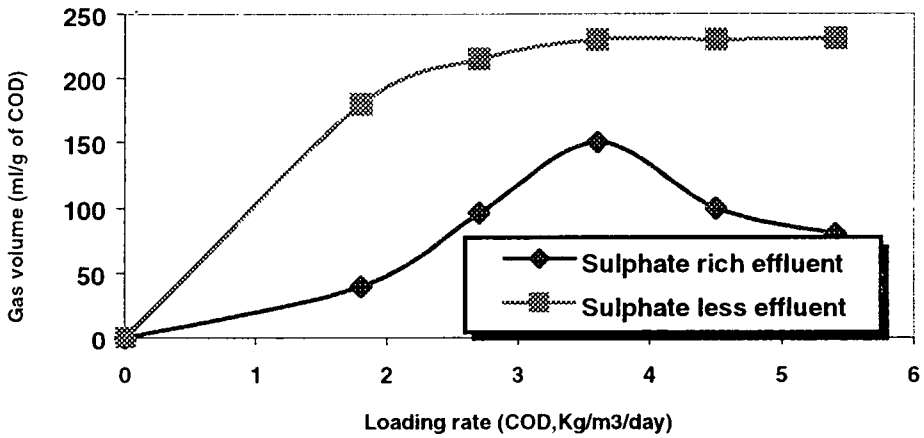


Fig. 1. Gas production in anaerobic digester with different loading rates of skim rubber effluent

The above graph shows the gas volume produced in relation to various loading rates of sulphate rich and sulphate less effluent when subjected to anaerobic digestion in laboratory scale experiments. The experimental results show that 230 ml of gas volume is produced per gram of COD digested when sulphate less effluent is digested anaerobically. This indicates that sulphate less effluent is more effective in producing bio-gas when compared to sulphate rich effluent in anaerobic digestion process.

Further experiments have been planned to reduce SO_4^{2-} content in the skim effluent and to measure the bio-gas volume generated from anaerobic digestion (W M G Seneviratne, Upul Ratnayake, T A S Siriwardane and Imali Koralage).

Survey on bio-mass consumption by the rubber industry

Studies were carried out by the NERD centre in collaboration with the department on the drying towers at Dartonfield, Pallegoda and Vogen rubber factories in a survey on above (Upul Ratnayake and P H Sarath Kumara).

Evaluation of physical properties of different grades of NR and DPNR/NR blends

These studies were carried out by an MSc student under the supervision of the Head of the department. The grades of NR used for this study were RSS 1, RSS 2, RSS 3, SLR L, SLR 20, SLR 50, UFUB crepe, FB crepe, YF crepe, skim rubber and DPNR.

The physical properties of vulcanisates of different grades of rubber compounded to a standard tyre tread formulation indicate that DPNR has high resilience while showing excellent tensile properties comparable with that of RSS, SLR grades and high quality crepes. As expected, BR showed the highest resilience, but tensile properties were observed to be poor.

Studies on Blends of BR with NR show that poor tensile properties of BR can be remarkably improved if blended with NR.

Best heat build up properties were observed in DPNR. Moderate heat build up was observed in a blend of DPNR/BR 60:40 combination.

Overall results indicate that good all round properties can be expected of a tyre tread where around 40% of BR is incorporated in a blend of DPNR and BR. Higher concentration of BR reduce the strength properties of vulcanisates quite remarkably even though the resilience and wear resistance are improved (W M G Seneviratne and U D Vandabona).

ADAPTIVE RESEARCH

S M M Iqbal

SUMMARY

Experiments on interplanting of Rubber with Tea in estate and small holder sectors were in progress. A detailed study was initiated to identify the limitations to productivity in rubber -tea interplanting systems. A study on bee keeping under rubber plantations was initiated under the adaptive research program. Programs on clone evaluation, soil and moisture conservation practices organic manure and young budding were discontinued due to the lack of interest shown by the growers as well as extension staff.

DETAILED REVIEW

Staff

The Deputy Director (Research), Dr N Yogaratnam coordinated the activities of the Unit till 20th May 1999. Mr S M M Iqbal, Research Assistant in Agronomy proceeded to UK on 24th August 1999 and returned in December after an initial training for a split postgraduate programme. Mr K B A Karunasekera and Mr P P Jayasinghe, Research Assistants and Mr E A T Senadeera, Experimental Officer were on duty throughout the year. Research Assistants Messers A M A Perera, R B Gunaratna and D S Wettasinghe assumed duties on 17th February 1999.

Meetings

The Adaptive Research Unit staff participated in the following:

- Research Meetings of the Institute.
- Joint meeting of Rubber Development Department and RRI Scientific Staff.
- Monthly conferences of the Regional Rubber Development Department in Kegalle region.
- Advisory visits to tea/rubber plantations.

Training programs

Mr S M M Iqbal delivered a lecture on "Interplanting of rubber with tea" under a training program conducted by NIPM.

FIELD INVESTIGATIONS

Bee keeping in rubber smallholdings and private sector estates.

The objective of the study is to improve the income levels of rubber growers through bee keeping in rubber lands. Sites were selected and relevant Field Officers were trained (D S Wettasinghe, and L M K Tillekeratne in collaboration with Training and Extension Division Department of Agriculture, Peradeniya).

Clone evaluation

The trials established in Kegalle and Kalutara districts were terminated and mainly due to the poor adoption of agronomical practices by the smallholders (D P S T G Attanayaka, S M M Iqbal and K B A Krunasekara).

Soil and moisture conservation practice

a) ***Effectiveness of bush/tree legumes***

b) ***Use of poultry litter***

c) ***Use of paddy straw***

The above trials were discontinued due to the lack of interest shown by the smallholders (Lalani Samarappuli and E A T Senadeera).

Young budding

Treatment	:	Young budded polybag plants (YB)
Control	:	Brown budded bare root plants (BR)

Programmes started in 1994 and 1995 were discontinued (P Seneviratna and W Seneviratna).

Inorganic fertilizer (Eppawala Rock Phosphate)

Trials started in Kalutara region were discontinued due to the poor follow up action by the farmers (A Dissanayaka, N Yogaratnam and H D S P Perera).

Intercropping of rubber lands with cinnamon

Programs on intercropping of rubber with cinnamon were discontinued due to the poor follow up action by the farmers (L S S Pathiratna).

Interplanting of rubber lands with tea

State sector I (1985)

Yield data of tea and rubber were collected.

State sector II

Experiment 1 (RRISL Sub Station - Kuruwita)

The following were done:

a) Recording of tea yield in sample plots
b) Measurement of rubber girth
c) Collection of leaf and soil samples
d) Test tapping of rubber

Yield of tea recorded in 1999 is presented in Tables 1 and 2.

Table 1. *Made tea yield in tea rubber systems*

System	Made tea yield kg/bush (without rehabilitation)
Rubber 8'x27'+Tea	0.0968a
Rubber 8'x40'+Tea	0.0936a

Table 2. *Made tea yield in tea rubber systems*

System	Made tea yield kg/bush (with rehabilitation)
Tea only	0.1076a
Rubber 8'x27'+Tea	0.0457b
Rubber 8'x40'+Tea	0.0528b

(Means with the same letter are not significantly different)

(S M M Iqbal and S Wettasinghe in collaboration with TRI).

Experiment II (RRISL, Agalawatta)

The above established to study the effect of Interplanting of Rubber lands with tea on the growth and yield of component crops is in progress.

Yield and Girth of rubber are recorded. Tea pruning was done in early June and yield data presented in Table 3.

Table 3. *Made tea yield in tea rubber systems*

System	Made tea yield kg/bush/year
1. Tea Only 12'x 18' 100%	0.3802A
2. Rubber 8'x 27' 100% + Tea	0.2213A
3. Rubber 8'x 32' 85% + Tea	0.2067A
4. Rubber 8'x 36' 75% + Tea	0.2046A
5. Rubber 8'x 40' 70% + Tea	0.1751A
6. Rubber 8'x 44' 65% + Tea	0.2048A

(Means with the same letter are not significantly different)

Rubber and tea leaf samples were analysed for nutrients (S M M Iqbal, N Yogaratnam and A M A Perera).

Experiment III - Perth estate, Horana (Meenapalana Division)

Growth assessments of both rubber and tea crops were taken (Table 4). Leaf and soil samples were analysed for nutrients.

Table 4. *Growth of rubber in tea rubber systems*

System	1999 Mean girth(cm)
1. Rubber Only 12'x 18'	22.94A
2. Rubber 8'x 60' + Tea	22.29A
3. Rubber 8'x 8' x 46' + Tea	22.69A
4. Rubber 8'x 8' x 60' + Tea	22.62A
5. Rubber 8'x 8'x 70' + Tea	22.74A

Means with the same letter are not significantly different (S M M Iqbal and R B Gunaratna).

Experiment IV - Vogan estate. Matugama

Growth assessments of both tea and rubber crops were taken. Leaf and soil samples were analysed for nutrients. Centering of tea bushes were done (S M M Iqbal and R B Gunaratna).

Smallholder sector

Smallholder trials in Kegalle and Ratnapura regions were continued (S M M Iqbal, A M A Perera and E A T Senadeera).

AGRICULTURAL ECONOMICS

A K B Naranpanawa

SUMMARY

During this year the Agricultural Economics Unit continued to provide the support services required by the other research departments. In addition, research studies on impacts of macro-economic policies and implications of trade blocks were carried out.

DETAILED REVIEW

Staff

Mr P H M U Herath resigned from the post of Agricultural Economist in June 1999. Assistant Agricultural Economist Mr A K B Naranpanawa was on duty throughout the year.

Presentations/Seminars/Meetings

Mr A K B Naranpanawa attended the following meetings during this year.

- Scientific Committee meetings
- Addressed the meeting on the laboratory cross checking held at the RRI Ratmalana office on the 12th July 1999'
- Committee meeting of the Socio-Economists and policy analysts group held at the CARP Office in Colombo on the 22 July 1999.
- Attended a seminar on "Implications of SAPTA on the Agricultural sector of Sri Lanka" organized by the socio-economists and policy analysts group of CARP held at TRI auditorium on the 8th March.
- Delivered a lecture on "Global rubber industry" for the students of NIPM diploma (Plantation Management) at the auditorium, Dartonfield, Agalawatta.
- Attended a symposium on Indu-Lanka trade agreement organized by the Centre for Law and Society, Colombo.
- Meeting on "Economic life span of rubber" held at the Bogawanthalawa Plantations head office on the 11th June 1999.
- Made a presentation on "Natural Rubber Market: Future Prospects" at the seminar on Plantation Management for the 21st Century, organised by the rubber Research Associates Consultancy Consortium in Colombo.

P H M U Herath attended the following meetings

- Made a presentation on "Implications of SAPTA on the rubber sector" at the seminar organized by the socio-economists and policy analysts group of CARP held at TRI auditorium on the 8th March.
- Delivered a lecture on "Some local aspects of rubber industry" for the students of NIPM diploma (Plantation Management) at the auditorium, Dartonfield. Agalawatta.
- Attended a symposium on Indu-Lanka trade agreement organised by the by the Centre for Law and Society , Colombo.

RESEARCH

Impact of macro–economic policies (monetary and fiscal) on the performance of the natural rubber sector

The partial equilibrium model developed on the export supply was estimated using the general to specific econometric methodology. A distributed lag model was fitted on quarterly exports (log values) using local consumption, total production, real agricultural wages and real exchange rate as explanatory variables. Testing was done to ascertain the presence of any cointegration relationship among the variables. The multivariate cointegration testing procedure reveals that there are no cointegration relationships among the variables. Thus, a short run model was fitted. The model performed satisfactorily well with respect to statistical significance tests, diagnostic tests and parameter stability tests (A K B Naranpanawa).

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

A descriptive study was carried out to identify the possible implications of the South Asian Preferential Trading Arrangement (SAPTA) on the natural rubber sector of Sri Lanka (A K B Naranpanawa).

Study on the rubber market channel

In view of studying present structure, market margins, credits involvement and impact of removing cess, a detail study has been planned on the rubber market channel. This study intends to conduct a survey to cover all the elements of the channel inorder to obtain relevant information. Questionnaires were prepared and pretested for different elements of channel (P H M U Herath and A K B Naranpanawa).

Labour economics in rubber sector

Present status of labor absorption, potential labour absorption of the sector, impact of labour migration, socio economic aspects of Indian Tamil labour and determination of optimum wage rate policies was designed under this program. A preliminary study conducted by using data from 3 estates shows that the present tapping wage rate is higher than the optimum wage rate suggested by marginal value product analysis. This result indicates the low tapper productivity in these estates. However, further investigations are necessary to generalize these results (P H M U Herath).

BIOMETRY

Wasana Wijesuriya

SUMMARY

Biometry section continued providing support services to other research departments. These include experimental design, analysis and interpretation of experimental results. The main research focuses during this year were; development and application of statistical techniques for on-farm research, time series and categorical data analysis methods.

Database and the meteorological station at Dartonfield were maintained satisfactorily during the year. The personnel and project summary databases of the RRI scientists were updated.

DETAILED REVIEW

Staff

The staff of the Biometry section Ms Wasana Wijesuriya (Biometrician), Ms Chintha Munasinghe (Experimental officer) and Mr Vidura Abeywardene (Technical Officer) were on duty during the period under review. Ms Wijesuriya continued her postgraduate studies while attending to the services of the Biometrician.

Research students

Mr Chinthana Jayasekera, an undergraduate from the Faculty of Agriculture, University of Peradeniya, successfully completed his final year project on "Forecasting Natural Rubber Production in Sri Lanka" under joint supervision of Prof. R O Thattil and Ms Wasana Wijesuriya.

Committees

- Ms Wasana Wijesuriya attended the central scientific committee meetings and the management review meetings of the Dartonfield rubber factory. Ms Wijesuriya continued the services of INFORM coordinator to the CARP.

SERVICES

Statistical analysis and interpretation

Designing of experiments, analysis and interpretation of results for research

departments and statistical assistance to undergraduate and postgraduate students on their specialized training were among the statistical services. The areas covered in statistical analysis were; biometrical genetics, analysis of variance and covariance, linear and non- linear regression, applied multivariate techniques, categorical and non parametric methods and time series techniques.

Meteorological database management

Dartonfield meteorological station was maintained successfully and daily measurements were entered in the database. Monthly reports were sent to the Central Meteorological Station in Colombo. Data on meteorological factors were provided to several schools in the vicinity of the station, which showed an interest on studying the climatic behaviour for Advanced Level Projects.

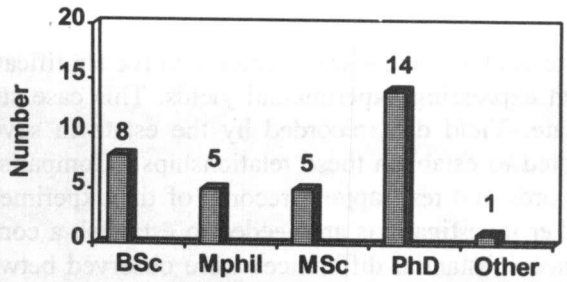
The upkeep of the meteorological station, maintenance of the database and documentation are responsibilities of Ms Chintha Munasinghe and Mr Vidura Abeywardene.

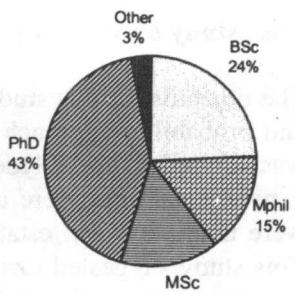
Management information

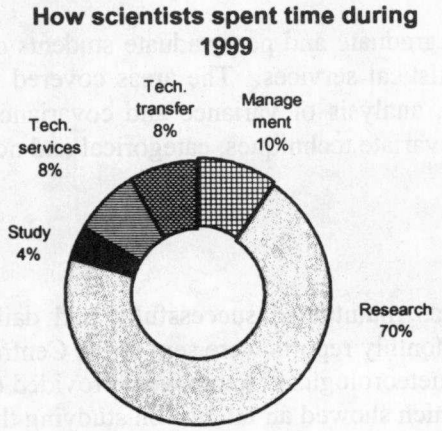
The INFROM database with personnel, project information and budgetary involvement was updated for the year 1999. The collected information was transferred to CARP to be included in the database of National Agricultural Research System (NARS).

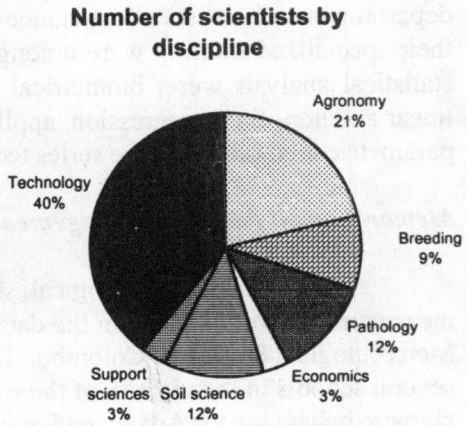
The following are some of the important features of the research system at RRI.

Scientists by highest qualification as at December 1999









RESEARCH

1. Development of statistical techniques for on-farm participatory research

This study is in progress. The logistic regression approach was successfully employed in modeling the adoption behaviour of technologies related to rubber cultivation. Further modeling will be carried out to investigate the adoption behavior for combinations of different technologies. Rank correlations were established for the 4 technologies studied. As expected, farmers who adopt correct cover management practices tend to adopt appropriate weed management practices also ($r=0.7451$, $p<0.001$). Those who adopt correct fertilizer application methods adopted new clones ($r=0.4588$, $p<0.001$) as well as correct cover management practices ($r=0.3214$, $p<0.001$). Majority of the farmers (37.3%) adopted all 4 technologies. Among the combinations of 2, there was a tendency towards fertilizer and new clones.

2. Case study on yield gap

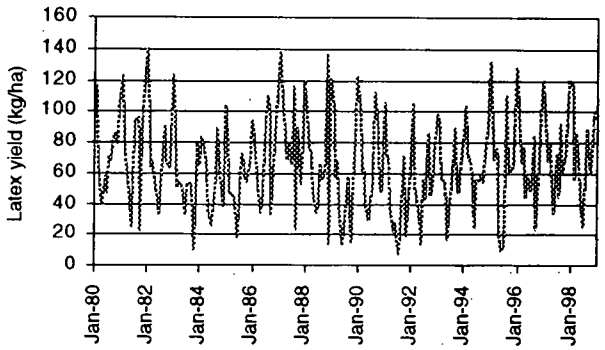
The objective of this study is to find a suitable way, which involve stratification and probability approach when expressing experimental yields. This case study was limited to the Clyde estate. Yield data recorded by the estate in several experimental sites were collected to establish these relationships. Comparisons were made between estate records and test tapping records of the experiments. This study suggested that further investigations are needed to establish a correct sampling process for yield since substantial differences were observed between experimental and estate yields when converted into a single measuring unit (W Wijesuriya, L Samarappuli and V Abeywardene).

3. **Forecasting natural Rubber production in Sri Lanka**

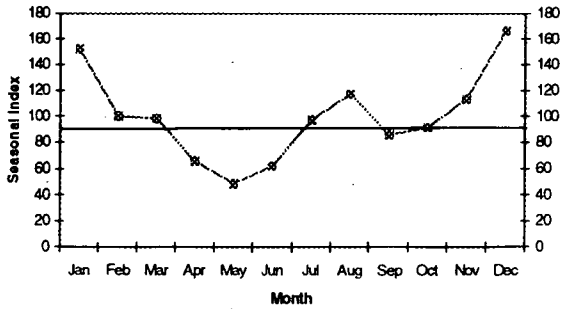
This study was carried out to identify the behavioural patterns, trend, seasonals and cycles of production and to select the best forecasting technique to predict NR production. Three forecasting approaches were employed; namely, trend fitting, decomposition and ARIMA approach. Decomposition and ARIMA approaches were found to be appropriate to forecast monthly NR production with sufficient accuracy (Y S S C Jayasekera, W Wijesuriya and R O Thattil).

4. **Behavioural pattern in Dartonfield yield records**

Twenty years of yield data on monthly basis were taken from secondary sources. The fluctuation in yield is shown in the following figure.



The usual seasonal behavior in latex yield was observed in Dartonfield records. The seasonal indices are depicted in the following figure.



The highest seasonal index was observed in December followed by January. The lowest seasonal index was observed in May, probably associated with loss of

tapping days due to rain. The improvement shown in August is associated with fair weather with more tapping days (Y S S C Jayasekera, W Wijesuriya and R O Thattil).

5. **Agronomic survey on adoption of fertilizer practices**

This study was carried out in collaboration with the Soils and Plant Nutrition department. The statistical analyses; modeling the adoption behaviour by logistic regression, multivariate analysis of different factors associated with adoption are in progress.

6. Factor productivity trends in fertilizer use

Factor productivity is the ratio of output value to the cost of the input. It may be, total factor productivity (TFP), *viz.* the ratio of total output value to the total cost of all inputs, or partial factor productivity (PFP), the ratio of output value to a specific input. TFP indices have gained greater attention in recent years as indicators of the long-term sustainability of agricultural systems. PFP indices, also considered important because they can provide useful information about the efficiency of individual inputs used. This study therefore, attempts to determine the benefit: cost ratio of fertilizer application and PFP trend for major nutrients in rubber culture (W Wijesuriya and L Samarappuli).

6. Long term climatic variability in the Dartonfield estate

A database is being maintained for all measured meteorological factors at Dartonfield recorded since 1968. Statistical analyses on these climatic variables were done in order to document a report on long term climatic variability in the Dartonfield station where majority of the experiments are been done. The documentation of the report is in progress.

LIBRARY AND PUBLICATIONS

Ramani Amaratunga

SUMMARY

The main functions of the Library and Publications Section were maintaining, processing and publishing of the Institute's regular publications such as Annual Review, Journal, Bulletin, Rubber Puwath *etc.* It was also engaged in collecting and dissemination of information on natural rubber and related areas.

DETAILED REVIEW

Mrs Tilaka Dantanarayana (Colombo Office) and Mrs Ramani Amaratunga, Library Assistants and Assistant Publications Officers, Mr P M Prema Jayantha, Library Clerk/Typist and a Library Attendant were on duty throughout the year.

Mr N L D Linton was appointed as a Library Attendant on 01.04.1999.

Resource Development

Book/Serial acquisition

With the addition of 43 acquisitions, book collection recorded at 4982 and the bound volumes to 3925.

The Library subscribed for 60 Journals and about 30 Journals were also received as gift/exchange. Subscribed Journals were received regularly except for few lapses due to limited allocation.

ILL Service

Thirty eight articles were sent to various libraries at their request whilst we received 47 photocopies of articles.

Literature surveys based on *Hevea*/rubber were done using CD-ROM databases available at CARP Library.

Equipment/Furniture

The following office furniture were purchased during the year.

- Computer Chair with arm
- Computer Table with paper collection tray
- Monitor filter for the new computer

Publications

The followings were published during the year under review.

- RRISL Bulletin Vol.38 (1998)
- RRISL Journal Vol.81 (1998)
- RRISL Annual Review 1998
- RRISL Bulletin Vol.39 (1999)
- Advisory Circulars:-
  - සුදුමල් රෝගය 1999/04
  - පැල තවාන් වල රෝග සහ මර්ධනය 1999/06
  - රබර් සඳහා පොහොර 1999/01
  - Fertilizer to Rubber 1999/01
  - Ethrel Stimulation 1999/09

Information Services

Computerized bibliographic data of 1999 were sent to the National Library of Sri Lanka for Compilation of the National Union Catalogue.

AGRINET SDCP Service

60 content pages of different Journals were received according to user requirement and we also forwarded 12 of the same to AGRINET.

Visitors

NAB trainees and University students were given the opportunity to use the Library during their training period and every assistance was given to them for their training.

DARTONFIELD GROUP

Jehan Perera

SUMMARY

A crop of 138576 kgs was harvested from 190.26 hectares during season 1999. When comparing with last year there is a decrease of 19545 kgs.

The yield per hectare was 728 kgs and there is a decrease of 270 kgs per over last year.

The downfall of the crop and the yield per hectare were mainly due to heavy rains prevailed throughout the season 26.36 hectares coming into bearing may also have contributed to decline in yield per hectare.

The average intake per tapper for the group was 7.7 kgs an increase of 0.4 kgs above last year.

The annual rainfall was 4903.9 mm with 194 wet days as against 5790.1 mm with 184 wet days during last year.

The Group cost of production for the season was Rs.45.22. Net sale average for the season was Rs.44.81, a drop of Rs.8.46 per kilo over last year. Hence, the loss is =/41 cents per kilo and Rs.298.62 per hectare. The total loss realized was Rs.56816.16.

DETAILED REVIEW

Staff

Mr Jehan Perera, Estate Superintendent, Mr P Kannangara, Chief Clerk, Mr K K P Gunewardena, Senior Clerk, Mrs C Dissanayake, Mr A K D A Wickramasinghe and Mrs S I K Pathirage, Junior Clerks, Mr D S K Ranaweera, Rubber Factory Officer, Mr W D D Senanayake, Assistant Factory Officer, Mr J A Wimalasena, Mr S K S de Silva, Mr T Somaratne and Mr N L D Reggie, Field Officers, Mr H M J Premalal and Mr S R Vadivel, 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, Mrs C S Hettiarachchi, Creche Attendent, Mr N V Premawanse, Tractor Driver and Mr A K Piyasene, Office Peon were on duty.

The Group Cadre stood at 21 at the end of the year, made as follows:

Senior Staff	1
Assistant Staff	18
Minor Staff	2
Total	21

Hectarage

A summary of the hectarage is given in Table 1.

Table 1. *Land distribution (Ha.) in Dartonfield group*

	Dartonfield	Gallewatte	Nivitigalakele	Total
Mature area	26.51	131.91	31.84	**190.26**
Immature area	12.51	28.60	14.34	**55.45**
Budwood nurseries	6.54		2.00	8.54
Seedling nurseries	0.73		5.69	6.42
Uprooting area		4.51		4.51
Abandoned 53/54			3.06	3.06
Difference in fields			2.70	2.70
State land taken	0.27			0.27
Paddy/Deniya		1.22		1.22
Waste land	0.19	0.18		0.37
Earth slipped area	3.01	1.26	2.62	6.89
Jungles	0.80		0.71	1.51
Rocks/Streams	2.14	4.74	2.17	9.05
Buildings	18.67	5.07	7.79	31.53
Roads	2.92	6.86	0.32	10.10
Others total	35.27	23.84	27.06	**86.17**
Grand total hectare	74.29	184.35	73.24	331.88
Grand total acres	183.57	455.53	180.98	820.08

Crop

A total crop of 138576 kg was harvested from an extent of 190.26 hectares during the year. When comparing with the actual last season there is a decrease of 19545 kgs.

The yield per hectare of 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 1995 to 1999*

Division	Year				
	1995	1996	1997	1998	1999
Dartonfield	714	900	1059	790	649
Gallewatta	1039	1073	1067	926	713
Nivitigalakele	804	723	800	1106	858
Group average	912	953	1006	965	728
Group estimate	887	1020	1038	979	926

The yield per hectare of all 3 divisions and in the group have declined significantly during the year (Tables 2 & 3).

Table 3. *The yield per hectare recorded in 1999 division wise*

Month	Dartonfield	Gallewatta	Nivitigalakele
January	105	112	161
February	67	77	112
March	73	74	112
April	15	17	32
May	8	15	14
June	55	63	73
July	99	108	128
August	41	49	46
September	28	31	28
October	9	8	6
November	63	49	60
December	88	116	71

Intake per tapper

The average intake per tapper of the group has increased. Among the divisions, Dartonfield has shown an increase while there is a decrease in both Galewatte and Nivithigalakale (Table 4).

Table 4. *The average intake per tapper (kg) division wise for the last 5 years*

Division	Year				
	1995	1995	1997	1998	1999
Dartonfield	7	6.5	6.9	7.4	8.5
Gallewatta	6.7	6.2	7	7.9	7.5
Nivitigalakele	5.4	4.5	4.9	6.5	5.6
Group average	6.21	6.2	6.5	7.3	7.7

Tapping cost

There is a marginal decline in tapping cost during the season (Table 5).

Table 5. *A break-down in total tapping cost for 3 years*

Cost item	Cost (Rs.)		
	1997	1998	1999
Tapping	16.32	15.46	15.67
Double tapping	0.28	.48	.43
Kanganies	0.05	.03	.01
Over kilos	0.92	.92	.81
Scrap pay	0.29	.20	.14
Incentive to Field Staff	0.07	.07	.02
Total	17.93	17.24	17.08

Rain fall

The total annual rainfall has decreased, though there is an increase in wet days. (Table 6).

Table 6. *Annual rainfall and the number of wet days for the last five years*

	Year				
	1995	1996	1997	1998	1999
Rainfall (mm)	4369.5	3696.9	4501.2	5790.1	4903.9
Wet days	185	165	164	184	194

Tapping days

There is a decline in both normal and late tapping days. The number of non tapping days have increased from 135 to 168 during the season (Table 7).

Table 7. *The number of tapping days, average intake per tapper and yield per hectare for the last four years in Dartonfield group*

		Year			
		1996	1997	1998	1999
1.	Tapping days				
1.1	Normal	238	252	199	186
1.2	Late	49	29	30	11
1.3	Double	-	7	12	25*
1.4	No	78	80	135	168
2.	Average intake tapper (Kg)	6.0	6.5	7.3	7.7
3.	YPH (Kg)	953	1006	979	728

*Dartonfield division only

Manufacture

Table 8. *The details of the crop manufactured during the year 1999*

Grade	Quantity Kgs.	Grade %	Latex %	Scrap
Crepe No.1	116155	84	94	
Crepe No.3	7784	6	6	
Scrap Crepe No.1	8858	6		72
Scrap Crepe No.2	3105	2		25
Scrap Crepe No.3	389			3
Smoke Sheets	2289	2		

Unfractioned unbleached rubber was manufactured through out the season. However, on the requirement of the buyers 1X rubber was also manufactured

Cost of production and profitability

The cost of production has increased by Rs.1.97 per kg (Table 9) and the recorded loss is Rs.298.62 per hectare (Table 10) during the year.

Table 9. *Labour rate (LR,RS) and a break down of cost of production (COP)*

		1995	1996	1997	1998	**1999
1.	Labour	72.24	83.00	83.00	95.00	95.00
2.	COP	36.60	38.72	39.74	43.25	45.22
2.1	Tapping	16.23	18.56	17.93	17.24	17.08
2.2	Manufacture	6.47	6.15	5.38	8.75	7.98
2.3	General charges	9.17	9.09	12.75	11.21	12.01
2.4	Upkeep	4.03	4.92	5.28	6.05	8.15
3.	NSA	80.73	70.49	72.68	53.45	44.81
4.	Profit	44.73	31.77	32.94	10.20	(0.41)

Table 10. *Comparative statement of the mature extent, profit per kg and profit per hectare*

	Y E A R			
	1996	1997	1998	1999
Mature extent	167.11	165.59	163.90	190.26
Total profit (Rs.Mn.)	5.06	5.48	1.61	(0.06)
Profit/Ha (Rs.)	302979.50	33126.40	9840.00	(298.62)

Meteorological Summary - 1999
Dartonfield Station

Wasana Wijesuriya

A total of 4957mm of rain experienced during the year 1999 compared to the long-term average of 4243mm. This accounted for an increase of 334 mm compared to the preceding year. The distribution followed the usual bimodal pattern as shown in Fig. 1. The highest rainfall was observed in October, a departure of nearly 594 mm from the long-term average for this month. A fairly dry weather was observed during the first quarter of the year and June to September preriod, with the lowest value experienced in July.

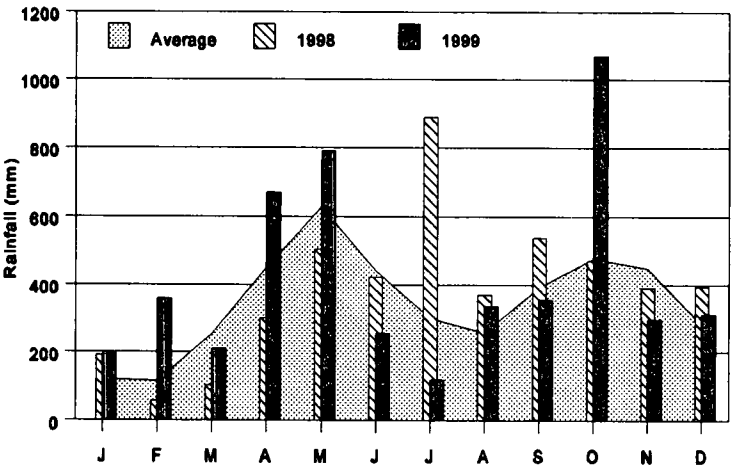


Fig.1. Monthly variation in rainfall

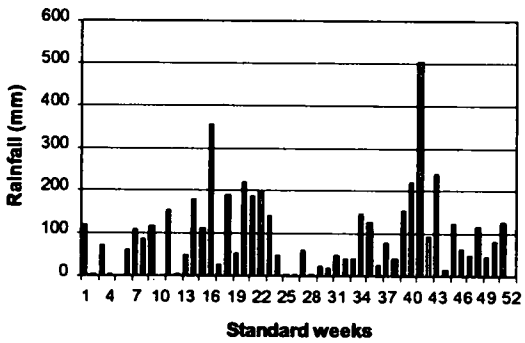


Fig. 2. Weekly variation in rainfall

The distribution of weekly rainfall is depicted in Fig. 2. Only 3 dry weeks were observed in this year. The highest rainfall experienced during the 41st standard week (early October) coincided with the North East monsoon period.

The rainfall distribution in different seasons also exhibit deviations from the long-term average. Substaintial decrease of around 6.5% was observed in South-West (SW) rains. The first and second inter-monsoonal periods (IM1 and IM2) were slighty increased by 2.8 % and 3.6 %, respectively (Fig. 3). Percentage rain experienced in the period, under the influence of the North-East (NE) monsoon was 20%, which is equal to the long term average.

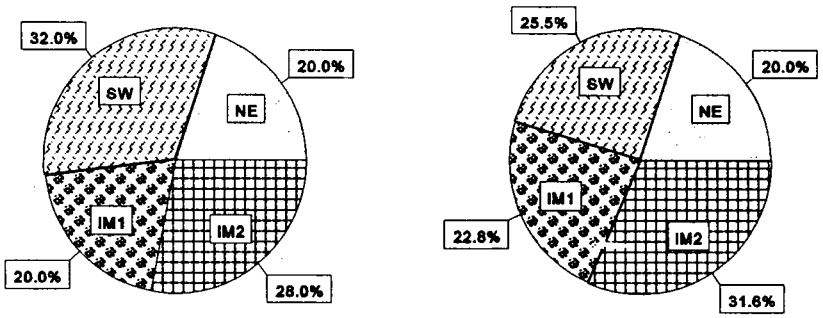


Fig.3. Seasonal variation in rainfall

The amount of rainfall and number of rainy days under low, moderate and high rainfall categories are listed in Table 1. Number of rainy days for this year equaled 231 with 6 months exceeding 20 rainy days. In October, 8 days have exceeded 50 mm of rain per day.

Intensity of rainfall

High intensity showers with short durations were common in South-West monsoon period. The highest rainfall intensity recorded was 260 mm/hr, but lasted only for 3 minutes. The 3 highest intensity records, their duration and time of occurrence and the average intensity for each month are presented in Table 2.

Table 3 depicts the monthly values of some important meterological observations together with averages for 1980 to1992. Minimum temperature dropped below 20°C for 5 days in January and 3 days in December. The lowest value for sun shine was observed in October due to overcasted conditions due to heavy rains. The

average morning RH exceeded 85% in all months, except November and December. The highest number of days with morning RH greater than 90% was observed as 21 in August and 19 in May, July and October. The soil temperatures at 4 different depths are given in Table 4.

Diurnal Variation in Temperature and Relative Humidity

Relative humidity (RH) and temperature were measured during October and November period, once a week for the whole day and presented in Fig. 4. The observed RH values fell below 90% only for 10 hours during the day.

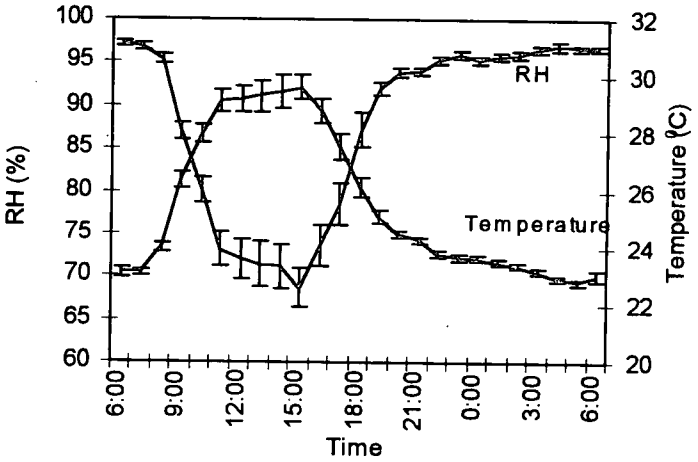


Fig. 4. Diurnal variation in temperature and RH during October/November period

Table 1. *Monthly variation of rainfall and rainy days in 1999*

Month	Rainfall mm	Average** mm	No. of rainy days*	Avg.** days	No. of days under each category			Evaporation
					0.3 - 2.5 mm	2.5 – 50 mm	>50 mm	(mm)
January	194.4	(121)	09	(10)	00	07	02	52.7
February	358.6	(116)	13	(09)	02	08	03	47.8
March	208.4	(252)	11	(17)	04	05	02	78.6
April	670.0	(449)	23	(21)	03	18	02	45.6
May	790.4	(629)	27	(24)	03	20	04	47.8
June	253.5	(440)	16	(24)	03	13	00	65.3
July	118.3	(299)	19	(22)	07	12	00	52.5
August	334.7	(257)	25	(21)	02	22	01	56.2
September	353.7	(391)	25	(22)	06	18	01	37.4
October	1069.8	(476)	30	(22)	05	17	08	30.2
November	295.2	(448)	23	(20)	09	13	01	56.3
December	310.3	(282)	10	(17)	01	08	01	63.1
Total	4957.3	(4160)	231	(229)	45	161	25	633.5

* Rainy days are defined as those with 0.3 mm or more ** Average values for 1980-1992 are shown in parentheses

Table 2. *Rainfall intensity recorded at Dartonfield meteorological station*

Month	Date	Intensity (mm/hour)			
		3 highest records	Time interval	Duration (min)	Average
January	19/01	23.40	14.25 to 14:45	20	6.51
	19/01	21.90	15:00 to 16:30	90	
	01/01	19.10	15:10 to 17:50	160	
February	26/02	52.14	14.10 to 15.20	70	
	20/02	42.25	16.55 to 18.15	80	12.48
	17/02	39.41	18.10 to 19.35	85	
March	16/03	40.90	16.20 to 18.00	100	
	29/03	34.00	16.45 to 17.45	60	11.23
	17/03	29.07	18.45 to 21.15	150	
April	06/04	40.00	08.45 to 08.47	2	
	19/04	38.00	08.15 to 09.10	55	9.06
	06/04	30.00	17.42 to 17.45	3	
May	16/05	260.00	01.00 to 01.03	3	
	07/05	50.00	09.44 to 09.45	1	8.46
	07/05	43.33	07.12 to 07.15	3	
June	08/06	40.00	23.50 to 00.00	10	
	02/06	28.00	17.45 to 17.55	10	11.46
	06/06	28.00	08.45 to 09.00	15	
July	05/07	114.00	19.10 to 19.15	5	
	16/07	68.00	03.25 to 03.30	5	12.91
	26/07	42.00	13.35 to 13.45	10	
August	30/08	39.00	21.15 to 21.45	30	
	24/08	36.67	01.40 to 02.10	30	9.97
	12/08	34.29	12.40 to 12.47	7	
September	29/09	66.00	14.40 to 14.50	10	
	29/09	36.67	12.10 to 12.25	15	9.62
	15/09	36.67	04.10 to 04.25	15	
October	28/10	34.40	17.00 to 17.45	45	
	13/10	33.00	15.15 to 18.25	190	6.56
	16/10	22.50	16.55 to 17.15	20	
November	06/11	22.40	02.40 to 03.55	75	
	26/11	17.38	15.15 to 16.20	65	4.87
	29/11	15.75	14.45 to 15.25	40	
December	01/12	26.67	14.30 to 16.00	90	
	23/12	22.30	18.30 to 19.30	60	6.50
	14/12	15.00	17.30 to 18.30	60	

Table 3. *Variation of observed meteorological factors at Dartonfield*

DARTONFIELD (Latitude 6°32'; Longitude 80.09 E; Altitude 65.50 m)

Month	Temperature (°c)			Sun shine		Relative Humidity (%)		Wind speed	
	Mean Max	Mean Min	Mean	No. of days min temp <20	hours	9.00 am	No. of days RH 9.00 am >90%	4.00 pm	(Kmph)
January	32.3 (32.3)	21.6 (20.8)	27.0 (26.5)	05	5.2	89 (87)	12	69 (67)	0.80
February	33.5 (33.3)	21.8 (21.1)	27.7 (27.2)	-	6.7	87 (85)	08	69 (64)	1.20
March	33.5 (33.5)	22.3 (21.7)	27.9 (27.6)	-	6.7	87 (84)	11	65 (66)	1.20
April	31.2 (32.9)	23.2 (22.7)	27.2 (27.8)	-	4.2	89 (84)	11	78 (73)	1.40
May	30.4 (31.6)	23.3 (23.3)	26.9 (27.5)	-	4.4	92 (87)	19	80 (77)	1.70
June	31.0 (30.8)	22.7 (23.1)	26.9 (26.9)	-	6.2	89 (88)	12	73 (76)	2.40
July	30.9 (30.2)	23.3 (22.8)	26.8 (26.5)	-	5.5	91 (88)	19	82 (74)	2.30
August	30.3 (30.2)	23.0 (22.7)	26.7 (26.5)	-	7.0	91 (87)	21	75 (74)	1.90
September	30.3 (30.6)	22.5 (22.4)	26.5 (26.5)	-	5.7	90 (86)	15	74 (74)	1.70
October	29.9 (30.9)	22.5 (22.1)	26.2 (26.5)	-	4.1	90 (85)	19	81 (77)	1.50
November	32.0 (31.4)	22.3 (21.8)	27.2 (26.9)	-	6.4	85 (84)	06	74 (77)	1.50
December	32.1 (32.0)	22.6 (21.4)	26.9 (26.7)	3	6.4	80 (84)	01	65 (74)	1.40

Average values for 1980-1992 are shown in parentheses

Table 4. *Soil temperatures recorded at different depths at Dartonfield - 1999*

Month	09 .00 hrs				16.00 hrs			
	5 cm	10 cm	20 cm	30 cm	5 cm	10 cm	20 cm	30 cm
January	26.6	26.3	27.0	27.4	32.3	29.7	28.8	27.7
February	27.2	26.8	27.6	27.9	34.4	31.5	29.9	28.2
March	28.2	27.4	28.2	28.7	37.2	32.9	31.0	29.0
April	27.4	26.8	27.2	27.5	31.9	30.1	28.9	27.8
May	27.4	26.8	27.3	27.7	32.1	30.6	29.0	27.9
June	27.5	26.9	27.5	27.9	34.3	31.9	29.5	28.1
July	27.6	27.2	27.9	28.3	33.4	32.0	29.8	28.6
August	27.3	27.1	27.7	28.1	32.4	31.7	29.8	28.4
September	27.8	27.2	27.8	28.4	33.0	32.0	30.0	28.7
October	26.8	26.2	26.5	27.1	30.8	29.9	28.4	27.3
November	27.6	27.1	27.4	27.9	32.3	31.3	29.8	28.3
December	26.6	26.4	27.2	27.8	32.9	31.4	29.5	28.1

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