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Rubber Research Institute of India

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Publisher
Dr. N.M. Mathew

Cover
Transgenic *Hevea* plants developed at RRII with integration of the gene coding for superoxide dismutase

Cover design
Mr. K.P. Sreerenganathan

November, 2001

* With particulars of personnel as on 31.03.2000

The Rubber Research Institute of India (RRII), under the Rubber Board (Ministry of Commerce and Industry, Government of India), had its inception in 1955. With a very modest beginning, the RRII is now capable of handling most of the problems associated with natural rubber (NR) production technology, primary processing and product development. The steady growth of the RRII in its scientific worth and research contributions has won it the recognition as an International Centre of Excellence on NR research.

Location

The RRII is located on a hillock 8 km east of Kottayam town in Kerala State and is easily accessible by road. Kottayam is connected to all major cities in the country by rail. The capital of the State is Thiruvananthapuram, 160 km south, where there is an international airport. The distance to New Delhi, the capital of the country, is 2950 km.

Functions

Undertaking, assisting and encouraging scientific, technological and economic research and dissemination of knowledge to the NR industry are the statutory functions of the RRII.

Organization

For the efficient discharge of its functions, the RRII has established major research divisions and research supporting sections at its headquarters and regional research establishments at appropriate locations where *Hevea brasiliensis* is commercially grown or is likely to be grown.

Continued on inside back cover

ANNUAL REPORT
1999-2000

RUBBER RESEARCH INSTITUTE OF INDIA
KOTTAYAM – 686 009, KERALA, INDIA
Website : www.rubberboard.com E-mail : rrii@vsnl.com

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THE RUBBER BOARD

The Indian Rubber Board was constituted under The Rubber (Production and Marketing) Act, 1947, which came into force on 19 April 1947. This Act was amended in 1954, 1960, 1982 and in 1994. The Act was again amended by The Rubber (Amendment) Act, 1994 (Act 33 of 1994), which is now in force.

Organization

The Chairman is the principal executive officer and exercises control over all departments of the Board. The Rubber Research Institute of India works under the administrative control of the Board, the Director being the head of the institution. Besides RRII, there are six departments under the Board, Administration, Rubber Production, Processing & Product Development, Finance & Accounts, Training & Technical Consultancy and Licensing & Excise Duty.

Chairman
Mr. S.M. Desalphine, IAS

Rubber Research Institute of India
Dr. N.M. Mathew
Director

Rubber Production Department
Dr. A.K. Krishnakumar
Rubber Production Commissioner

Administration Department

Secretary

Processing & Product Development
Dr. E.V. Thomas
Director

Finance & Accounts Department
Mr. Abraham Chacko
Director

Training & Technical Consultancy
Mr. K.S. Gopalakrishnan
Director

Licensing & Excise Duty Department
Mr. T. P. Sivankutty Achari
Director

ADVISORY PANEL OF EXPERTS

AGRONOMY/SOILS

1. Dr. R. Vikraman Nair
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   Kerala Agricultural University
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2. Prof. M.S. Iyer
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3. Dr. K.U.K. Nampoothiri
   Director
   Central Plantation Crops Research Institute
   Kasaragod - 671 124.

4. Prof. K.N. Ganeshayya
   Dept. of Genetics and Plant Breeding
   University of Agricultural Sciences
   Bangalore - 560 065.

5. Dr. Manikantan Nair
   Professor and Head
   Dept. of Plant Breeding and Genetics
   College of Agriculture
   Kerala Agricultural University
   Vellayani P.O., Trivandrum - 695 522.

MYCOLOGY AND PLANT PATHOLOGY

6. Dr. P.K. Koshy
   Jt. Director and Head
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   Regional Research Station
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   Kayankulam - 690 533.

7. Prof. S. Balakrishnan
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   Kerala Agricultural University
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8. Prof. D.J. Bhagyaraj
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11. Prof. A. Narayanan
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    Tamil Nadu.

13. Prof. K. Veluthambi
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    School of Biological Sciences
    Madurai Kamaraj University
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    Kunnukuzhy P.O.
    Trivandrum.

15. Dr. R.K. Matthan
    Polymer Consultancy Services (P) Ltd.
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    Chennai - 600 017.

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Medical College P.O.
Trivandrum - 695 011.

17. Prof. A. Damodaran
Dept. of Economics
Trade and Environment
Indian Institute of Plantation Management
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P.B. No.223, KSCMF Building
Block III, 4th Floor
Bangalore - 560 052.

DIRECTOR'S REVIEW

The achievements of the Indian natural rubber sector during the last five decades have been widely applauded in the academic and policy circles. The significant achievements made in various sectors of the NR industry are mainly the outcome of the well co-ordinated efforts initiated by the Rubber Board since its inception. In any crop, R&D efforts become meaningful only when the results reach the farmers' field. The Rubber Research Institute of India has, therefore, published a compendium of scientific information on NR production under the title "Natural Rubber : Agromanagement and Crop Processing", documenting particularly the latest developments in various aspects of rubber cultivation and primary processing. Organised in 34 chapters, this book is an attempt to comprehend and provide up-to-date information on agrotechniques and post-harvest technology of natural rubber, covering various aspects like history, botany, crop husbandry and harvesting, crop protection, processing and marketing, by-products, waste management, plantation management, labour legislation and eco-friendliness of the commodity. This book will prove to be a very useful asset to all those who are interested in the NR industry.

A major area of work in agronomy was on integrated nutrient management of rubber. The optimum dose of N, P_2O_5 and K_2O to ensure maximum yield in RRII 105 was found to be 30, 30 and 40 kg/ha. Adoption of integrated weed management involving cultural, physical and chemical methods appeared to be more cost effective and environmentally sound. In another experiment, 100 to 250 silt pits in the field could conserve 5 to 14 tonnes of soil per hectare. Experiments to compare the discriminatory fertilizer recommendation and diagnosis and recommendation integrated system (DRIS) have been in progress.

Transgenic plantlets were produced with the gene coding for superoxide dismutase and the antisense gene coding for ACC synthase. For the identification of disease tolerant genes RAPD analyses were carried out with random primers using the total DNA isolated from tolerant and susceptible lines. The effect of polyamines, glutamine, casein hydrolysate, gibberellic acid, light intensity, etc. on the frequency of somatic embryogenesis and plant regeneration have been studied in depth.

Investigations by the Botany Division revealed that during the sixth year of tapping the ten hybrid clones developed in 1982 and now in the pipeline continued to show superiority in yield over RRII 105, the yield improvement ranging from 10 to 56 per cent. The higher yield of other hybrid clones, compared to RRII 105, was evident from the results of small-scale trials obtained during the year. A disease screening programme was formulated for screening the wild germplasm for sources of resistance to the major leaf diseases. A laboratory was set up at CES Chethackal for the screening work.

During the year there was severe incidence of abnormal leaf fall disease and moderate incidence of powdery mildew and Corynespora diseases. New fungicides including systemics, were tested for their efficacy against major diseases. Special attention was given to Corynespora leaf disease. The isolates of *Corynespora* from Karnataka and Kerala showed wide variation in virulence.

Studies on drought stress in polyclonal plants have indicated that peroxidase activity

in the leaves may be related to drought tolerance. Further studies on low temperature stress confirmed the existence of high light induced down regulation of photosynthesis. Increased drain of resources including ATP through latex might be responsible for tapping induced loss of biomass that is not reflected in dry rubber yield. Field trials from the drought prone North Konkan have clearly established that the high intensity of solar radiation aggravated the adverse effect of drought on rubber plants.

Experiments on low frequency tapping confirmed the sustainable yield increase in high yielding clones under third daily tapping with stimulation. Fourth daily and weekly tapping with different levels of stimulation gave comparable yield. Low yield during the initial years of weekly tapping could be solved by adjusting the frequency of stimulation. Rainguarding was found essential for low frequency tapping systems.

Close interaction was maintained with footwear manufacturing units for the evaluation of styrene grafted natural rubber (SGNR) in microcellular soles. A process was standardized for deproteinization of NR latex using the enzyme preparation Anilozyme P. Incorporation of about 15 parts of epoxidised natural rubber in nitrile rubber-silica composites was found to improve the technological properties significantly. Necessary technical assistance was provided to M/s Kochi Refineries Ltd. for the commercial production of NR modified bitumen. A solar - cum - smoke dryer was installed at HBSS Nettana. The evaluation of the sheet cleaning machine being patented by the Institute indicated that over 60 per cent of the sheets can be upgraded and the process is found to be cost-effective.

A new methodology has been developed to assess the comparative commercial yield performance of *Hevea* clones. A study analyzing the consequences of economic liberalization on the Indian automotive tyre industry, has been completed.

Nutritional studies conducted in the North East India yielded positive response on growth and yield for application of N, P_2O_5 and K_2O up to 60, 60 and 40 kg/ha/yr. An extensive pests and disease survey carried out in the North East reported high incidence of powdery mildew disease and Secondary leaf fall (SLF) disease in most plantations. Brown root disease caused by *Phellinus noxius* was also noticed in some locations. Preliminary yield data from RRS, Nagrakatta revealed that rubber cultivation will be viable in northern parts of West Bengal. Rubber yield was significantly influenced by the interaction between P and K levels. Application of 20 kg P_2O_5 and K_2O per hectare resulted in higher yield. Intercropping of banana and pineapple with rubber was found to be profitable under Tripura conditions. Yield data from small-scale trials over eight years revealed clone PB 235 as the top yielder in the North East India. In the non traditional tract in North Konkan (Dapchari , Maharashtra) an annual yield of 1280 kg per hectare was obtained when 23 blocks were tapped third daily.

In the Research Component of the World Bank-Assisted Rubber Project, which has been under implementation from 1994, the seven research schemes yielded very useful results and the two consultancy projects were concluded. An amount of Rs.90 million was spent on research schemes and supporting services, training and technical assistance, consultancy projects and financial support to an NGO.

Indian Journal of Natural Rubber Research, Volume10, brought out during the year, contained 21 research articles. The Institute also maintained academic linkage with several universities and other institutions of research and learning.

AGRONOMY AND SOILS DIVISION

The Division continued to engage in the investigations on various crop management aspects of rubber cultivation aimed at reducing the immaturity period and improving productivity. Studies on the integrated nutrient management of rubber at various stages of growth constituted a major area of work of the Division. A field experiment being conducted with the high yielding clone RRII 105 indicated that the optimum dose of N, P_2O_5 and K_2O was 30, 30 and 40 kg/ha for maximum yield. Among the micronutrients, zinc (Zn) is reported to be low in many of the rubber growing soils and experiments were initiated to study the effect of Zn application on the growth of rubber seedlings.

An experiment was initiated to quantify the biomass production of popular legume ground covers *viz.*, *Pueraria phaseoloides* and *Mucuna bracteata* under different age groups. Experiments to find out the possibility of using waste from latex centrifuging and crumb rubber processing factories were in progress. The bowl sludge obtained from latex centrifuging factories was found to be a good source of phosphorus, for both young and mature plantations. Experiments on comparison of soil ecosystems under rubber and other systems and on characterization of soil organic matter were continued. Effect of liming on soil properties and plant growth was also under study during the period.

Investigations on the effect of density of planting on the growth of rubber were continued. During the initial years, plants in the higher densities registered relatively better growth. However, this trend was reversed during the later period of immaturity. Studies on the effect of silt pits on the growth and yield of rubber and on conservation of soil were also in progress. Another major area of research of the Division was weed management. Adoption of integrated weed management involving cultural, physical and chemical methods appeared to be more cost effective and eco-friendly. The Division continued its research activities for generation of ancillary income through intercropping.

The Division continued its service of offering discriminatory fertilizer recommendation to large Estates based on soil and leaf analyses and case history of individual fields.

1. Nutrient management

1.1 Nutritional studies

On the nutritional aspects of rubber, three field experiments are going on of which one is in seedling nursery and the other two on mature rubber. The nursery experiment was aimed at assessing the effect of Zn application on the growth of seedlings. Another experiment examined the effect of selected combinations of N, P and K fertilizers on growth and yield of rubber. The third experiment explored the possibility of sequential skipping of fertilizer application over seasons and years.

An experiment was initiated at Central Nursery, Karikkattoor, to study the influence of Zn application on the growth of rubber seedlings in ground nursery and the availability of Zn in soil. Different levels of Zn through two different sources were compared. The sources were $ZnSO_4$. $7H_2O$ (21.0% Zn) and ZnO (60-80% Zn) and the levels were 0, 2.5, 5.0, 7.5 and 10.0 kg Zn/ha as soil application. There was another foliar spray treatment at a concentration of 0.5% $ZnSO_4$.

The field experiment started in 1989 to study the NPK requirement of clone RRII 105 was in progress. Girth (2000) and girth increment (1991-2000) did not indicate any sig-

nificant difference between treatments. N, P_2O_5 and K_2O at the rate of 60:30:40 kg/ha recorded the highest yield (73.17 g/t/t) which was comparable with 60:60:40 kg/ha (63.85 g/t/t), 30:60:20 kg/ha (63.56 g/t/t) and 30:30:40 kg/ha (63.32 g/t/t) under 1/2S d/3 system of tapping.

The experiment to evaluate the effect of sequential skipping of fertilizers for one or more seasons/year, on the growth and yield of rubber continued. Observations on growth and yield were recorded.

1.2 Integrated nutrient management

Four experiments on the integrated nutrient management of rubber were in progress. They were aimed at evolving a nutrient management schedule for rubber, integrating organic and inorganic sources. In the first experiment, the effect of organic manure alone and in combination with chemical fertilizers on the growth of rubber was investigated. In the second experiment, organic matter under different ecosystems was characterised. The third experiment aimed at characterising the soil organic matter under different rubber based ecosystems. *P. phaseoloides* and *M. bracteata*, the most popular ground covers were compared in the fourth experiment. All the experiments progressed well during the period.

The experiment started at Shaliacary Estate, Punalur in 1994 to study the effect of organic manure alone and in combination with chemical fertilizers on the growth of rubber and soil properties was in progress. No significant difference was noticed on the growth of plants with and without organic manure.

Two experiments initiated in 1999 to characterise the soil organic matter under different ecosystems were in progress. In the first experiment, the disintegration pattern of litter from rubber, *P. phaseoloides* and *M. bracteata*, were compared. Litter bags were retrieved from the fields on a monthly basis and weight losses recorded (Table Ag. 1). The N content in the remaining *M. bracteata* litter increased till 94 days, and decreased slightly afterwards. In the case of *P. phaseoloides* litter, N content decreased till 73 days and after that an increase was noticed. All the other nutrients in both the species showed a decreasing trend. In the second experiment, surface soil and profile samples were collected from rubber, *P. phaseoloides*, *M. bracteata* teak and forest systems. Litter samples were also collected from all the systems. C^{13} NMR studies were undertaken for the samples and respiration rate and biomass were estimated. Total carbon (C) and nitrogen (N) were determined using CHN analyzer (Table Ag. 2).

Table Ag. 1. **Nutrient remaining in *M. bracteata* and *P. phaseoloides* litter**

Time (days)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
M. bracteata					
0	3.58	0.22	1.12	0.82	0.25
33	4.50	0.19	0.19	0.80	0.10
60	4.65	0.20	0.11	0.66	0.16
94	4.88	0.19	0.12	0.59	0.16
126	4.75	0.09	0.17	0.60	0.17
P. phaseoloides					
0	3.52	0.27	1.20	0.72	0.24
39	3.06	0.18	0.16	0.69	0.18
73	2.87	0.20	0.15	0.72	0.15
101	3.44	0.10	0.32	0.60	0.20

An experiment was initiated at Erumely Estate, Mukkoottuthara to fractionate and characterise soil organic matter under different rubber based ecosystems *viz.*, ten year old rubber plantation, rubber in immature phase in association with *P. phaseoloides* and rubber in immature phase in association with *M. bracteata*. Pre-treatment soil samples were collected and observation points were marked for collecting litter samples.

The experiment started at TR&T Estate, Mundakayam to quantify the biomass

Table Ag. 2. **Respiration rate, biomass C, total C and total N of litter and soil samples**

Samples	Respiration rate*	Biomass C**	Total C (%)	Total N (%)
Litter				
Rubber	0.3727	2.2681	54.77	1.45
P. phaseoloides	5.3561	49.8837	44.80	2.45
M. bracteata	1.8634	37.6673	43.60	2.98
Teak	3.7406	33.2791	49.21	0.86
Forest	0.4933	6.8854	48.59	0.97
Soil				
Rubber	0.017671	0.1591	4.42	0.24
P. phaseoloides	0.029646	0.3240	4.44	0.25
M. bracteata	0.016276	0.2474	3.54	0.22
Teak	0.040303	0.3653	4.30	0.30
Forest	0.103857	0.2690	6.36	0.38

* mmol CO_2/g/soil/hour

** mg C/g soil

production of *P. phaseoloides* and *M. bracteata* under different age groups and to study the effect of cover crop establishment on soil physico-chemical properties was in progress. The data on dry matter accumulation indicated that both *P. phaseoloides* and *M. bracteata* recorded the highest dry matter accumulation at the age of two years, which declined drastically in later years (Table Ag. 3). The data on nutrient accumulation (Table Ag. 4) indicated that accumulation of nutrients was significantly higher at the age of two years and then declined subsequently.

Table Ag. 3. **Dry matter production (t/ha)**

Age	*P. phaseoloides*	*M. bracteata*
1	3.34	2.63
2	5.46	7.62
3	3.43	5.41
4	2.60	3.92
5	2.45	3.32
SE	0.51	0.82
CD (P=0.05)	1.03	1.66

1.3 Forms and methods of fertilizer application

Under this major area of research, nine experiments were in progress. Effectiveness of bowl sludge, a waste product from latex centrifuge factory and sludge from crumb rubber factory, were evaluated in two experiments. The possibility of reducing the dose and frequency of fertilizer application through the use of controlled release fertilizers was explored in another experiment.

Another experiment explored the possibility of substituting potassium with sodium. Comparative efficiency of Rajphos (RAP) and Mussoorie rock phosphate (MRP) in immature and mature rubber was evaluated in two experiments. Other experiments in

Table Ag. 4. **Accumulation of nutrients (kg/ha) in biomass**

Age	N		P		K		Ca		Mg	
	P	M	P	M	P	M	P	M	P	M
1	112.13	84.60	9.68	5.20	82.15	32.14	32.02	19.90	14.06	7.25
2	174.17	236.21	13.08	15.21	103.84	79.08	65.35	55.71	18.03	14.57
3	100.70	169.60	7.39	9.62	67.32	59.17	30.19	41.67	7.99	10.68
4	95.23	140.51	6.30	8.95	47.87	63.90	27.07	35.34	9.76	12.27
5	81.07	97.99	5.15	5.18	47.54	31.34	23.59	21.57	7.66	8.37
SE	15.21	15.18	1.28	1.13	12.63	6.99	7.33	3.21	1.93	1.12
CD(P=0.05)	30.87	30.83	2.61	2.28	25.64	14.2	14.89	6.51	3.92	2.28

P : *P. phaseoloides* M : *M. bracteata*

nificant difference between treatments. N, P_2O_5 and K_2O at the rate of 60:30:40 kg/ha recorded the highest yield (73.17 g/t/t) which was comparable with 60:60:40 kg/ha (63.85 g/t/t), 30:60:20 kg/ha (63.56 g/t/t) and 30:30:40 kg/ha (63.32 g/t/t) under 1/2S d/3 system of tapping.

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* mmol CO_2/g/soil/hour
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Under this major area of research, nine experiments were in progress. Effectiveness of bowl sludge, a waste product from latex centrifuge factory and sludge from crumb rubber factory, were evaluated in two experiments. The possibility of reducing the dose and frequency of fertilizer application through the use of controlled release fertilizers was explored in another experiment.

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Table Ag. 4. **Accumulation of nutrients (kg/ha) in biomass**

Age	N		P		K		Ca		Mg	
	P	M	P	M	P	M	P	M	P	M
1	112.13	84.60	9.68	5.20	82.15	32.14	32.02	19.90	14.06	7.25
2	174.17	236.21	13.08	15.21	103.84	79.08	65.35	55.71	18.03	14.57
3	100.70	169.60	7.39	9.62	67.32	59.17	30.19	41.67	7.99	10.68
4	95.23	140.51	6.30	8.95	47.87	63.90	27.07	35.34	9.76	12.27
5	81.07	97.99	5.15	5.18	47.54	31.34	23.59	21.57	7.66	8.37
SE	15.21	15.18	1.28	1.13	12.63	6.99	7.33	3.21	1.93	1.12
CD(P=0.05)	30.87	30.83	2.61	2.28	25.64	14.2	14.89	6.51	3.92	2.28

P : *P. phaseoloides* M : *M. bracteata*

this area were evaluation of the utility of magnesium (Mg) contained in RAP and MRP, studies on the effect of different levels of P on growth and yield of rubber and downward movement of surface applied rock phosphate.

The experiment started in 1989 at TR&T Estate, Mundakayam to evaluate the effectiveness of bowl sludge, a waste product from latex centrifuging factories, as a source of P was in progress. No significant difference was observed between treatments with respect to girth increment. All the P sources *viz.*, Super phosphate, MRP and bowl sludge gave significantly higher yield over control (Table Ag. 5). No significant difference was noticed with respect to yield among the sources.

Table Ag. 5. **Effect of different P sources on yield (1999)**

Treatment	Yield (g/t/t)
Super phosphate	46.46
MRP	47.66
Bowl sludge	50.25
Control (No P)	28.03
SE	3.64
CD (P=0.05)	10.91

The sludge from crumb rubber factory contains three per cent N and two experiments were initiated to evaluate the effectiveness of this material as a source of N for rubber. An incubation study was started with urea and sludge at three levels and a control to find out the release pattern of N from the two sources (Table Ag. 6). The results indicated that inorganic N content in the treatments with urea increased during the first two weeks of incubation, while a steady but slow increase was noticed in the sludge treatments. When the N application was at the rate of 30 kg/ha, 78.78 ppm and 69.27 ppm was recovered as total inorganic N for urea and sludge respectively and when the rate of application was increased to 90 kg/ha, the increase in inorganic N was marginally higher for urea than sludge.

A nursery experiment was initiated at TR&T Estate, Mundakayam to explore the possibility of using sludge as a source of N in the seedling nursery.

The experiments started at CES, Chethackal and Kuzhimattom, Kottayam to study the effect of controlled release fertilizers on the growth of rubber were in progress. Data from the two experiments indicated the possibility of reducing the dose and number of splits of fertilizer application using controlled release formulations (Tables Ag. 7 and 8).

The field experiment started at Malankara Estate, Thodupuzha during 1998 substituting K with various levels of Na was in progress. Observations on growth and yield were recorded.

The experiments on immature rubber started at Boyce Estate, Mundakayam and Malankara Estate, to compare the efficiency

Table Ag. 6. **Mean value of total inorganic N as influenced by sources and levels of application (ppm)**

Source	Levels (kg/ha)	Days after incubation					Mean
		15	30	45	60	75	
Urea	30	127.96	70.98	58.08	53.35	83.53	78.78
Urea	60	142.77	75.75	62.61	57.85	94.07	86.61
Urea	90	146.49	107.14	121.61	73.37	151.69	120.06
Sludge	30	72.13	64.20	64.30	65.46	80.27	69.27
Sludge	60	79.48	74.20	73.30	67.43	119.46	82.81
Sludge	90	86.26	73.43	76.69	85.08	120.02	88.35
Control	0	34.30	32.08	39.68	36.92	45.75	37.75
SE		7.97	6.26	9.11	8.83	11.56	
CD(P=0.05)		22.89	17.96	26.16	25.35	33.20	

Table Ag. 7. **Effect of controlled release fertilizers on girth (Kuzhimattom)**

Treatment	Recommended dose (%)	Number of application	Girth *(cm)	Girth increment **(cm)
Prilled urea	100	Two	47.06	39.16
NPKMg pellets	75	Single	47.36	40.56
NPKMg pellets	75	Two	46.92	39.28
NPKMg pellets	50	Single	45.56	38.05
NPKMg pellets	50	Two	47.63	40.31
Nimin-coated urea	100	Two	46.96	39.76
Nimin-coated urea	75	Two	46.20	39.18
Neem cake mixed urea	100	Two	46.25	39.04
Neem cake mixed urea	75	Two	46.20	39.25
Control (no manure)			41.13	34.17
SE			1.12	1.14
CD (P=0.05)			3.33	3.39

*2000 **1995-2000

Table Ag. 8. **Effect of controlled release fertilizers on girth (CES, Chethackal)**

Treatment	recommended dose (%)	Girth * (cm)	Girth ** increment (cm)
Prilled urea	100	51.10	36.74
NPKMg pellets	100	53.56	38.17
NPKMg pellets	75	52.18	36.63
Nimin-coated urea	100	52.05	37.40
Nimin-coated urea	75	52.82	38.99
Neem cake mixed urea	75	53.39	38.71
Control (no manure)		46.82	32.48
SE		1.08	1.31
CD (P=0.05)		3.33	4.04

*2000 **1995-2000

of RAP and MRP, were in progress. Observations on growth did not indicate any significant difference among the treatments, at both the locations. The experiments initiated in 1997 at Boyce Estate and Malankara Estate, to evaluate the effect of Rajphos and MRP at different levels on growth and yield of rubber were in progress. Observations on growth and yield did not indicate significant difference among the treatments at both the locations.

A pot culture experiment was conducted to study the effect of different rock phosphates on dry matter production of *P. phaseoloides*. Application of rock phosphate alone or in combination with Mg increased the dry matter production of cover crop significantly over control (no P and Mg). However, no difference was noticed among the various forms of rock phosphates.

The experiment started at Mooply Estate, Palappilly during 1997 to study the effect of different levels of P on the growth and yield of rubber was in progress. Observations on growth and yield did not indicate any significant difference among the levels of P application.

An experiment was initiated to study the downward movement of P from surface applied rock phosphates. Soil samples were collected from two ongoing fertilizer experiments. In Experiment I, P is applied at four levels *viz.*, 0, 15, 30 and 45 kg/ha and in Experiment II, at five levels *viz.*, 0, 10, 20, 30 and 40 kg/ha and analysis of samples were continued.

2 Physical and chemical properties of soil

The experiment commenced in 1997 to establish the relationship between organic matter, organic C and available nutrients continued. Correlation matrices were worked out between organic C and available nutrients. Negative correlation was observed between organic carbon and available Ca and Mg. Positive correlation was noticed for available Ca with available Mg and K and also between available K and Mg.

The incubation experiment to study the nutrient release from different types of leaf litter and their combinations was in progress. The samples were analysed after six months of incubation. Organic C content did not increase even after six months of incubation of soil with litter of rubber, *P. phaseoloides*, *M. bracteata* or weed flora. Significant release of K was noticed from *P. phaseoloides* and *M. bracteata*. The combination of rubber with *M. bracteata* released more K than the other treatments except with inorganic fertilizers and the *P. phaseoloides* released higher Ca than other litter samples.

The experiment to study the soil solution chemistry and nutrition of *Hevea* continued. Soil and leaf samples were collected from Kodumon Estate, Adoor at monthly intervals and analytical data were generated.

An experiment was initiated to characterise the soil under rubber in upland paddy fields and low lying areas of Alleppey and Kottayam districts. Samples were collected from soils under rubber raised in upland paddy fields, low lying areas and sandy tracts of Kottayam and Alleppey districts for determination of physio-chemical properties.

The nursery experiments started to study the effect of liming on the growth of seedlings at two locations *viz*., Central Nursery, Karikkattoor and Regional Nursery, Perumpulickal were continued. Diameter of the plants recorded from the experiment at Perumpulickal indicated that application of NPKMg alone or in combination with various doses of lime were on par. Another experiment started in 1998 at Boyce Estate, Mundakayam to study the influence of lime application on the growth of rubber and availability of nutrients was in progress. Observations on growth of the plants did not indicate significant differences among the treatments. Liming did not influence the pH or availability of nutrients in surface and subsurface soil.

An incubation experiment was also initiated to study the changes in soil acidity due to liming and its effect on nutrient availability. The treatments were different levels of lime and a control without lime. The results indicated that pH increased significantly with increasing level of lime application and maximum pH was noticed when lime was applied at full rate of lime requirement. As incubation time advanced, pH decreased significantly. Availability of P, K and Mg decreased and availability of Ca increased with increasing levels of lime.

3. Soil and water conservation

Two experiments on mature rubber were in progress to study the effect of silt pits on the growth and yield of rubber. The extent of conservation of soil and moisture by the silt pits were also studied.

The experiment started in 1997 at TR&T Estate, Mundakayam to elucidate the effect of conservation pits on the yield of rubber and to quantify the soil and nutrients prevented from being lost through erosion was continued. Evaluation of yield data for 1998-99 did not indicate significant differences among the treatments. It was too early to expect an improvement in yield resulting from soil conservation. The experiment to study the influence of silt pits on the growth and yield of rubber and to explore the possibility of applying fertilizer in silt pits was in progress. Observations on growth and yield of rubber and the quantity of soil conserved in pits were continued.

4. Density of planting

The experiment initiated at CES, Chethackal with five densities and two manuring regimes to study the effect of different densities of planting of rubber on the growth, canopy architecture and yield was continued. The trees in the higher densities had relatively higher girth during the initial years. This tendency gradually faded out as

the age advanced. During 1999-2000, trees under lower densities gave comparatively higher girth increments.

5. Cropping systems

The cropping system experiment started in 1993 at CES, Chethackal, was in progress. Growth of rubber in the cropping system was marginally superior to that of an adjacent pure stand of rubber under normal density (445 rubber trees per ha). About 75% of trees attained tappability six years after planting in the cropping system area compared to 68% in the monoculture area. Pepper plants have good vegetative growth, but flowering and fruit setting have been poor. Coffee plants have started bearing and 42 kg of fresh berries was harvested. Fodder grass planted along the boundaries gave a cumulative yield of 8.8 t since 1993.

6. Studies on pit size and incidence of wind damage

Two field experiments at Rajagiri Estate, Punalur were in progress. In experiment I, highest girth was recorded by the largest pit size, *viz.*, 90 x 90 x 90 cm, followed by the second largest pit size *viz.*, 75 x 75 x 75 cm. The block with no pits gave the third highest girth. In experiment II, the growth of the plants was not influenced by pit size.

7. Weed management

Weed control operations constitute a major share of the total cost of cultivation of rubber during immaturity period. Three field experiments were in progress to evolve effective and economic weed management schedules.

The experiment at Shaliacary Estate, Punalur, to evaluate different weed control methods in planting strips was in progress. Scraping and herbicide spraying in the entire platform gave significantly better weed control compared to other treatments. An integrated approach with herbicide spraying in the plant basins and slashing the interspaces also resulted in satisfactory control of weeds. Since this approach offers scope for reducing the quantity of herbicides applied and is comparatively less labour intensive, this method can be adopted for weed control in the planting strips (Table Ag. 9).

The experiment at TR&T Estate, Mundakayam to evaluate the relative efficiency of 'Touch down' and to compare the efficacy of Controlled Droplet Applicators (CDA) and Knapsack sprayers was continued. Weed infestation was lowest when the entire platform was scraped. During summer, the weed dry matter production (DMP) was less in plots sprayed with glyphosate (Round up) and sulphosate (Touch down) at 2 L/ha with CDA, followed by scraping and glyphosate and sulfosate application with CDA at the lower dose (1.5 L/ha). The weed density was maximum in paraquat

Table Ag. 9. **Effect of different weed management methods on percentage weed infestation (angularly transformed) and girth of rubber**

Treatment	Mean weed infestation (%) (January 99 to December 99)	Girth (cm)
Scraping entire platform	25.05	34.75
Slashing entire platform	41.81	33.00
Spraying Gramoxone + Fernoxone in planting strips	26.78	30.62
Spraying Glyphosate in planting strips	28.65	34.25
Slashing interspaces and scraping plant basin	34.27	33.75
Slashing interspaces and spraying Gramoxone + Fernoxone in the plant basin	31.28	33.00
Slashing interspaces and spraying Glyphosate in the plant basin	33.03	32.00
SE	1.59	1.46
CD (P=0.05)	4.72	NS

Table Ag.10. **Percentage weed infestation (angularly transformed) and weed dry matter production in different weed control treatments**

Treatment	Mean weed infestation (%) (Sept 98 – Dec 99)	Weed DMP one month after imposition of treatments (g/m2)	
		Summer	Rainy season
Scraping	33.82	3.20	12.65
Gramoxone + Fernoxone	39.71	26.40	46.90
Glyphosate 2 l/ha (Knapsack)	36.84	12.00	43.20
Glyphosate 2 l/ha (CDA)	33.79	1.75	22.85
Glyphosate 1.5 l/ha (CDA)	35.41	4.00	48.85
Sulphosate 2 l/ha (Knapsack)	36.15	11.80	44.40
Sulphosate 2 l/ha (CDA)	34.21	1.50	23.85
Sulphosate 1.5 l/ha (CDA)	36.90	4.95	40.80
SE	2.93	2.27	8.47
CD (P=0.05)	NS	6.70	4.91

(Gramaxone) + 2,4-D (Fernoxone) sprayed treatments. During rainy season, weed DMP was minimum in scraping followed by the treatments where glyphosate and sulfosate were applied with CDA at 2 L/ha (Table Ag. 10).

The experiment started during 1998 at TR&T Estate, Mundakayam to study the effect of herbicide rotation on the extent of weed control was in progress. Observation on weed infestation indicated that all the treatments were equally effective for weed control in planting strips, and the treatments need be repeated at 75% regeneration of weeds.

8. Discriminatory fertilizer recommendation

Discriminatory fertilizer recommendation based on soil and leaf analyses were offered to 695 fields belonging to 23 large Estates. A total of 1123 soil and 660 leaf samples were analysed during the period.

In Diagnosis and Recommendation Integrated System (DRIS) approach for fertilizer recommendation, leaf nutrient values and corresponding yield data from fields were collected. Compilation of leaf nutrient values and corresponding yield data available with the Economics Research Division was initiated for developing database.

BIOTECHNOLOGY DIVISION

Major research in the Biotechnology Division focussed on developing transgenic plants, *in vitro* propagation through shoot tip culture, somatic embryogenesis and *in vitro* micrografting, protoplast mediated genetic manipulation, development of *in vitro* haploid plants and *in vitro* fertilization techniques for controlled breeding, molecular control of growth and development, identification and characterisation of genes controlling tapping panel dryness (TPD), biotic and abiotic stress *etc.*, molecular control of gene expression and disease tolerance and tissue specific gene expression and characterisation of tissue specific promoters. Transgenic RRII 105 plantlets incorporated with the gene coding for superoxide dismutase were developed. Methods were developed for high frequency somatic embryogenesis and plant regeneration using immature anther and immature inflorescence as explants. DNA markers were identified for conferring tolerance to *Phytophthora*.

1. Micropropagation

Attempts to develop a more efficient micropropagation system through shoot tip and nodal cultures have resulted in multiple shoot induction and single bud sprouting in the nodal cultures of RRII 105 and RRIM 600. Multiple shoot formation from germinating somatic embryos of *Hevea* could be achieved in the presence of TDZ (2.0 µM) or high levels of BA (22.0 µM). Individual microshoots were rooted in hormone free medium. An average of 3 microshoots per explant could be induced by this system. The microcuttings of the shoots were cultured in elongation medium where axillary buds got elongated. Later these cuttings were rooted in medium fortified with IBA. An average multiplication rate of 10 per somatic plant could be achieved through this technique.

An efficient plant regeneration technique through somatic embryogenesis is a prerequisite to make the *Agrobacterium* mediated gene transfer technology a reality. Two separate pathways using explants from immature anther and inflorescence were developed, which achieved a low frequency somatic embryogenesis and plant regeneration. Improvement over the existing pathway was attempted by evaluating the influence of auxins (2,4-D, picloram, NAA, IBA & IAA), cytokinins (BA, 2ip, kinetin & zeatin), GA_3 and ABA and different concentrations of sucrose (58-350 mM). Embryo induction was favoured by both BA and zeatin in the presence of low levels of NAA or 2,4-D. Significant increase in embryo induction frequency was observed in the presence of GA_3. Percentage maturation of the somatic embryos was highest on hormone free medium with a high sucrose concentration. Plant regeneration frequency was highest on media fortified with BA and GA_3 along with a low sucrose concentration. The same protocol was extended to the explants of RRIM 600, RRII 208, PR 255, PB 280 and GT 1 and observed that different stages of the pathway were highly genotype specific.

Callus induction, somatic embryogenesis and plantlet regeneration using immature anther explants were achieved. Fifteen day old callus was found to be ideal for the first subculture to embryo induction medium. The best response of plant regeneration was obtained when the culture medium was supplemented with 50 mg/l adenine sulphate and the frequency decreased by increasing the concentration beyond 50 mg/l. To develop a high frequency continuous plant regeneration system, a long-term embryogenic system was initiated from the primary embryogenic cultures.

Work was also initiated to develop a system of plant regeneration through somatic embryogenesis / organogenesis from leaf explants. One week old leaves precultured in liquid medium favoured callus induction on transfer to semisolid medium. For obtaining good quality callus, optimum hormone concentration was found to be 1.0 mg/l BA and 1.5 mg/l 2,4-D.

2. Genetic transformation

Among the different methods attempted for the introduction of foreign genes into *Hevea*, *Agrobacterium* mediated genetic transformation system was found to be the most suitable one. To develop transgenic plants tolerant to drought and low incidence of tapping panel dryness, genes coding for sorbitol-6-phosphate dehydrogenase, superoxide dismutase, isopentenyl transferase and antisense ACC synthase were selected.

The selectable marker gene used in all gene constructs in the present study was npt II. This gene confers tolerance to four antibiotics – Kannamycin, Neomycin, Geneticin and Paromomycin. To use these antibiotics as alternative for the selection of transgenic calli without affecting the normal growth and development of the plantlets, kill curves were determined (Table Biotech.1).

Table Biotech. 1. **Optimum concentration required for the selection of transformed *Hevea* callus.**

Antibiotic	Concentration (mg/l)	Optimum concentration (mg/l)
Neomycin	100-500	Insensitive even at 500 mg/l
Kannamycin	100-500	300
Geneticin	50-250	100
Paromomycin	100-500	300

Low frequency plantlet regeneration was obtained from the transgenic embryos of RRII 105 with the gene coding for sorbitol-6-phosphate dehydrogenase. Though attempts were made to harden these plantlets, no plantlet survived.

Genetic transformation experiments were carried with the SOD gene under the control of 35S and 34S promoter. With the 35S promoter transformation experiments were performed and 14 new transgenic cell lines were developed. Embryo induction and plantlet regeneration were achieved. Ten plantlets were obtained and these are under acclimatisation for field transfer.

Genetic transformation experiments were also carried out with the SOD gene under the control of 34S promoter and experiments on the effect of stress on embryo maturation and plant regeneration are in progress. Water stress was induced with different concentrations of phytagel (0.2-1%) and osmotic stress using PEG, mannitol and sorbitol. Effect of cold treatment on embryo germination was also studied by maintaining the cultures at 10 °C for different time intervals of 7, 14, 21 and 30 days. Induction of osmotic stress at 6% PEG enhanced the frequency of embryo induction. However, no significant effect was noticed with cold treatment. Transgenic cell lines with the antisense gene for SOD were developed and embryogenesis obtained.

Seventeen transgenic cell lines were developed with the gene coding for isopentenyl transferase. Experiments were carried out with varying nutrient composition for embryogenesis from the transgenic calli. Embryogenesis could be obtained from three of these lines. A few normal embryos formed were tried for maturation and both shoot and root induction could be obtained, but further growth was found arrested. Attempts were made to increase the efficiency of embryogenesis and plant regeneration.

In order to regulate the ethylene biosysnthesis and thereby to reduce incidence of TPD, experiments were initiated to introduce antisense ACC synthase gene into clone RRII 105, which is susceptible to TPD. Many transgenic cell lines with antisense ACC synthase could be obtained. Only five cell lines have so far given rise to embryos. Mature embryos developed from two cell lines have germinated into full plantlets. Eventhough these plantlets were growing well in the initial stages, after reaching 2 or 3 whorls, senescence of the leaves followed by gradual drying up of the plants was observed.

3. Protoplast culture of *Hevea brasiliensis*

A system for plant regeneration *via* somatic embryo induction from protoplasts isolated from embryogenic cell suspension of *Hevea* has already been developed. Further studies to improve the efficiency of this system have resulted an enhanced embryo induction frequency with amino acids arginine and proline when incorporated at lower concentrations (50-100 mg/l). Maximum embryo induction was observed at 1.4 µM whereas the plant regeneration frequency was highest at 2.0 µM of GA_3.

4. Haploid plant production through microspore/ovule culture

For pollen culture, the isolation techniques, pretreatment of anthers and the nutrient media compositions for getting microspore division have been standardised. The late uninucleate stage was identified as

the ideal stage for microspore culture. A modified MS based nutrient medium containing growth regulators such as BA and 2,4-D were identified for the induction of calli from unpollinated ovule. Medium for calli proliferation as well as embryogenic calli formation also has been identified.

5. *In vitro* fertilization and plant recovery

Preliminary studies for establishing a successful *in vitro* fertilization system through different methods of *in vitro* pollination have been carried out. Enlargement of the ovary has been observed after *in vitro* stigmatic pollination. Fluorescent microscopic studies revealed the pollen tube growth and entry into the ovules between 24 - 48 hours after pollination.

6. Molecular biology of *Hevea*

A quick, simple and reliable method for the isolation of high quality intact total RNA from bark tissues was developed. The first strand cDNA was synthesized from this total RNA using RT-PCR kit. Various primers were designed and synthesized for further gene amplification and expression studies.

Attempts were made to isolate and clone the full gene corresponding to the RAPD marker identified earlier for conferring tolerance to TPD. In the preliminary experiments, the intensity of the amplified band was very poor. Further work was in progress to optimise the PCR conditions for amplification of the full gene. To understand the molecular mechanism of tolerance to leaf fall disease caused by *Phytophthora*, RAPD analyses were carried out with random primers using total DNA isolated from tolerant and susceptible lines. Among 100 random 10-mer primers, 8 were found to give good polymorphic bands. Further analyses using 8 primers have resulted in three bands associated with tolerant lines. Out of the three markers a 2.5 kb band, which is present in most of the tolerant clones was selected for further studies.

Work has been initiated to characterise the laticiferous specific promoters. A strategy was developed for the isolation of promoters. Primers were designed for the amplification of promoter by PCR. RAPD profile studies on 37 clones using 80 primers were conducted. Nine primers were identified to be very good for generating polymorphic bands for studying genetic linkage and identification of markers associated with agronomically important traits.

BOTANY DIVISION

The Division conducts research on hybridisation, ortet selection, clone evaluation, on-farm trials, anatomy, cytology and horticultural manipulation techniques for vegetative propagation of clonal material. Thrust area of activity of the Division is identification of clones having more yield and better secondary characteristics than RRII 105. In the research on hybridisation and selection, 28 experiments involving artificial hybrid clones, 15 ortet trials using the plus trees selected from open pollinated seed trees from different estates are in progress. Regarding the evaluation of both indigenously developed as well as imported clones, 13 large-scale trials and 12 on-farm trials are under way. The trials, being conducted both in the traditional and non-traditional regions are under various stages of evaluation. In the studies on anatomical investigations, five experiments on bark anatomy in relation to yield and TPD, two studies on wood anatomy and two collaborative experiments are in progress.

Apart from these, studies on cytology, stock scion interaction, floral biology and fruit set and morphological characterization of various clones are also in progress. Nine pipeline clones have been found to be better yielding than RRII 105.

1. Plant breeding

Under the project on evolving high yielding clones, 28 experiments involving artificial hybrid clones, 15 ortet trials and two trials with clones resultant of mutations, polyploidy and irradiation are in progress. The clones are in various stages of evaluation.

In the 1985 trials, where 63 hybrid clones and their parents are under evaluation, nine hybrids of the crosses between RRII 105 and RRIC 100 continued to show superiority in yield over RRII 105. The yield improvement ranged from 10 to 56% during the 6th year of tapping (Table Bot. 1). In the 1990 trial, four hybrids recorded yield on par with RRII 105 during the second year (Table Bot. 2).

In the 1988 trial, two ortets were found to be superior to RRII 105 during the second year of tapping (Table Bot. 3.) Out of 64 ortets under evaluation at Cheruvally Estate, four clones out yielded RRII 105 with a mean yield ranging from 49.85 to 56.93 g/t/t in the third year of tapping in the small-scale evaluation trial. Mean yield of RRII 105 was 47.8 g/t/t. In the Mundakayam Estate, six selections continued to show comparable yield with RRII 105 in the third year of tapping. At Koney Estate, out of 47 selections, 11 clones indicated better performance over RRII 105.

Table Bot. 1. **Yield and heterosis of the pipeline clones**

Clone	Yield (g/t/t)	Standard heterosis (%)
82/3	82.59	27.99
82/4	72.12	11.76
82/7	71.15	10.26
82/14	87.11	34.99
82/17	84.95	31.64
82/21	100.67	56.00
82/22	82.30	27.54
82/29	89.34	38.45
82/30	76.13	17.98
RRII 105	64.54	—

Table Bot. 2. **Performance of promising hybrids**

Clone	Girth (cm)	Yield (g/t/t)
29	63.08	50.84
213	57.65	46.43
347	69.71	45.25
758	51.00	45.00
RRII 105	58.29	48.20

The project on evaluation of clones comprises 13 large-scale trials and 12 on-farm trials being conducted in different regions of the traditional as well as non-traditional zones. In the 1985 trial at RRS, Dapchari, highest yield was observed for RRII 105 (1332 kg/ha) followed by RRII 208, PR 255, RRIM 605, RRIC 100 and RRII 6 during the second year of tapping (Table Bot. 4).

In trial-I of the multidisciplinary evaluation of clones (1989), RRII 5 was found to give significantly better yield and in trial-II, eight clones (PB 235, PB 255, PB 260, PB 280, PB 311, PB 312, PB 314 and KRS 163) showed significantly better yield than RRII 105.

In the onfarm trial at Manickal Estate, RRII 105 recorded a mean annual yield of 1846 kg/ha during the 6th year of tapping

Table Bot. 3. **Performance of ortets and hybrid clones**

Clone	Girth (cm)	Yield (g/t/t)	
		Annual	Summer
31	65.08	18.61	15.24
35	67.43	25.81	21.66
55	62.04	13.33	12.22
99	52.19	15.91	15.83
32/6	58.96	24.59	23.96
33/8	65.80	47.88	35.94
34/3	47.59	22.61	19.05
38/1	58.31	24.28	22.83
39/1	56.00	22.81	21.01
RRII 105	56.00	23.70	19.37
Grand mean	56.05	22.84	19.40
V.R.	5.14	7.26	8.29
C.D.	10.21	9.17	6.16

Table Bot. 4. **Girth yield and of clones at Dapchari**

Clone	Girth (cm)	Yield (g/t/t)
RRII 5	51.6	22.6
RRII 6	55.7	25.8
RRII 105	51.8	33.1
RRII 208	59.2	27.8
RRII 308	49.2	23.3
RRIM 605	51.3	25.1
PB 260	51.3	25.8
PB 310	51.5	20.5
PB 311	50.5	24.0
RRIC 52	57.2	16.1
RRIC 100	53.6	26.0
RRIC 102	54.7	21.5
RRIC 105	51.4	16.0
PR 255	50.4	27.0
PR 261	49.8	23.3

Table Bot. 5. **Yield of clones in the on-farm trial at Manickal Estate**

Clone	Yield (kg/ha/yr)
RRII 2	896
RRII 4	1384
RRII 105	1846
RRII 300	1084
RRII 308	880
PB 235	1036
PB 310	1124
GT 1	849

(Table Bot. 5). In the trial at Koney, clones PB 314 and PB 260 recorded 77 and 63.5 g/t/t while RRII 105 gave 53 g/t/t during the fifth year of tapping (Table Bot. 6).

2. Anatomical investigations

Five experiments on bark anatomy in relation to growth and yield, and TPD are in progress. Two studies on wood anatomy *viz.*, conduit dimensions of clones grown under two agroclimates and effect of ethrel stimulation on wood quality, and two collaborative experiments were also in progress.

The study on effect of debarking on 30 TPD affected trees each of RRII 105 and RRIM 600 from two locations continued. The dry unproductive bark was removed and wound dressing compound was applied.

Table Bot. 6. **Growth and yield of clones in the on-farm trial at Koney Estate**

Clone	Girth (cm)	Yield (g/t/t)
RRII 5	60.28	48.1
RRII 105	59.22	52.9
RRII 300	60.36	60.5
PB 260	68.03	63.5
PB 314	63.20	77.0
PR 255	58.52	55.0
PR 261	58.35	55.5
SCATC 88/13	55.71	47.0

Seasonal bark anatomical features were recorded from bark samples collected monthly from clone RRII 105 (Table Bot. 7). Number of LVR (Latex vessel rows) showed higher values during the winter period and least values were recorded during summer. Girth recording was carried out in untapped trees applied with 5% ethrel in order to study the effect of stimulation on the anatomy and histochemistry of untapped trees. Different methods of ethrel stimulation were imposed on eleven clones from a large-scale evaluation trial at CES, Chethackal, to study the clonal response to stimulation. Periodic observations on yield, DRC and panel length were carried out. Monthly bark application of ethrel (5%) was continued in two clones

Table Bot. 7. **Seasonal changes in bark anatomical characters**

Month	Thickness of bark (mm)		Latex vessel rows	
	S B	H B	S B	H B
Jul - 97	4.27	4.10	10.88	1.44
Aug- 97	3.40	4.27	8.96	3.04
Sep - 97	3.02	4.37	8.96	3.12
Oct - 97	3.01	4.16	9.63	5.20
Nov- 97	2.53	5.69	9.44	8.36
Dec - 97	2.85	5.35	9.56	5.92
Jan - 98	3.30	4.71	11.12	4.84
Feb - 98	2.45	6.09	8.44	4.92
Mar- 98	2.97	5.04	9.40	4.44
Apr - 98	2.83	5.54	8.08	4.72
May- 98	2.94	5.40	9.12	3.44
Jun - 98	3.29	5.43	10.16	4.92
CD	0.55	0.77	2.21	1.63
CV	15.41	13.39	9.47	37.91

SB : Soft bark HB : Hard bark

viz., RRII 105 and RRIM 600 to study the effect of long term ethrel stimulation on rubber wood quality.

Virgin and renewed bark samples were collected from the small scale evaluation of hybrid clones (1982). Number of latex vessel rows recorded high value for 82/3 (36.36) followed by 82/14 (34.33), 82/29 (29.66) and for RRII 105 (28). Xylem ray cell characteristics of three clones *viz.*, RRIC 52, RRII 105 and PR 261 from a drought prone region (RRS, Dapchari) were determined and compared with that of the traditional region (SFCK, Punalur) in order to study the conduit dimensions in relation to water translocation (Table Bot. 8).

Investigations on structural changes occurring in *Hevea* callus revealed that during the early phase, cells were active with abundant cytoplasm and prominent nuclei. Numerous developing embryos were also noticed. During the later phase, cells were inactive and mostly filled with phenolic contents.

A few light microscopic stains could be identified to improve the clarity of filler distribution pattern in rubber, under optical microscopy.

3. Propagation and planting methods

Girth recording and periodic observations were continued in the trial on budding height and depth of planting. In the comparative study on twin stock and single stock, no significant difference was observed both in growth and yield. In the study on delayed opening and pulling out on bud uptake and establishment of budded plants, maximum budding success and further establishment was noticed in the treatment which was opened 25 days after budding and pulled out after 10 more days. In the feasibility study on young budding technique in rubber, better scion growth was noticed after 10 months, in the young budded plants than the conventional green budded plants (Table Bot. 9).

In the trial to assess the performance of seven modern clones on different root

Table Bot. 9. **Growth of scion**

Budding technique	Height (cm)	Whorls
Young budding		
42 days old stock	135	2.9
49 days old stock	151	2.9
56 days old stock	161	3.5
Green budding (control)	121	2.9
CD	2.7	NS

Table Bot. 8. **Mean conduit dimensions in *Hevea* clones from two locations (L1 –Punalur, L2- Dapchari)**

	Depth*	Character	Clones		
			RRIC 52	RRII 105	PR 261
I	No/unit area	L1	20.80 ± 0.76	20.89 ± 1.25	26.12 ± 1.06
		L2	22.69 ± 0.76	23.91 ± 0.89	26.92 ± 0.67
	Height(μm)	L1	585.86 ±22.76	535.07 ± 23.35	474.35 ± 8.28
		L2	555.35 ±22.92	510.71 ± 22.07	546.85 ± 17.40
	Width (μm)	L1	60.41 ± 1.43	49.85 ± 4.21	41.35 ± 1.28
		L2	50.71 ± 1.71	41.43 ± 1.14	42.35 ± 1.07
II	No/unit area	L1	20.45 ± 0.35	21.58 ± 0.97	26.18 ± 1.03
		L2	21.98 ± 0.62	23.67 ± 0.39	24.84 ± 0.52
	Height(μm)	L1	547.33 ±13.16	580.40 ± 19.59	559.77 ± 18.68
		L2	533.21 ±14.14	491.21 ± 35.85	494.92 ± 17.42
	Width (μm)	L1	50.30 ± 1.35	45.45 ± 1.38	38.07 ± 1.72
		L2	50.92 ± 1.00	43.07 ± 1.85	38.42 ± 1.21

* I- just inner to the cambium II- towards the pith

Table Bot.10. **Performance of clones on different root systems**

Treatment (stock x scion)	Mean girth (cm)	Mean yield (g/t/t)
RRII 105 x RRII 105	74.08	73.09
RRII 118 x RRII 118	81.01	52.08
RRII 203 x RRII 203	82.59	52.35
RRII 208 x RRII 208	71.02	63.88
GT 1 x GT 1	76.42	55.37
GI 1 x GI 1	77.42	46.84
RRIM 600 x RRIM 600	73.63	50.64
AS x RRII 105	70.04	91.71
AS x RRII 118	83.03	47.68
AS x RRII 203	84.14	51.71
AS x RRII 208	70.52	59.84
AS x GT 1	73.35	46..15
AS x GI 1	71.13	42.08
AS x RRIM 600	71.88	49.20

AS : Assorted stock

systems, mean girth and yield of different treatments are given in Table Bot.10. Vigorous clones like RRII 203 and RRII 118 gained more girth and high yielding clones, RRII 105 and RRII 208 recorded more yield on all stocks.

4. Cytogenetical studies

The project envisages to understand the chromosome behaviour and pollen biology. Mitotic and meiotic studies were carried out in an induced polyploid of the clone PR 107. The somatic chromosome number was 2n=4x=72, confirming tetraploidy. Meiosis was highly irregular in this tetraploid showing the presence of univalents, bivalents, tri valents and tetravalents in varying proportion. Apart from the 3-zone colporate pollen grains, 4 zone colporate grains and micropollen were present. Pollen stainability was reduced (70.24%) as compared to the diploid (90.43%). Pollen germination studies on different clones were continued. The clones PR 255 and KRS 128 exhibited 38.36% and 42.67% pollen germination respectively.

GERMPLASM DIVISION

The division is mainly concerned with the introduction, collection, conservation and evaluation of *Hevea* germplasm. At present, the Wickham clones are being conserved in the field gene banks of one clone museum and five germplasm gardens, while the wild germplasm is being maintained in eight conservation-cum- source bush nurseries. Apart from the agronomic evaluation of the wild germplasm, screening for biotic and abiotic stress resistance and molecular characterization are also being carried out.

1. Conservation and documentation

1.1 Domesticated genepool

The clone museum consisting of 166 Wickham clones was maintained and one more clone was added to the existing collection. Data collection from the five-germplasm gardens comprising 125 Wickham clones established at CES, Chethackal was continued. Monthly cup lump yield was recorded from Garden II and III and annual girth was recorded from Gardens II, III, IV and V. As data recording in Garden I has been discontinued due to high wind damage, it was decided to replant two of the replications, while the third would be retained for conservation purpose. An experiment to examine the feasibility of ratooning in *Hevea* was designed in two replications before replanting this area. Accordingly, trees from two replications were felled at a height of 20 cms. Simultaneously, 39 clones of this garden were multiplied and raised in polybags. The sprouting and further growth in both the sets of plants will be monitored initially for a period of one year.

Among the 35 clones in Garden II, RRIM 703 had the highest annual yield in the thirteenth year, while RRIM 604, RRIM 701 and RRIM 607 recorded yield comparable with that of the control clone RRII 105 (Table Ger.1). Twenty two clones had an average annual girth comparable with or higher than RRII 105 over 13 years.

Table Ger .1. **Yield and girth of selected clones**

Clone	Yield (%)	Girth (cm)
RRII 105	100.00	87.70
RRIM 604	84.00	105.29
RRIM 701	85.00	90.60
RRIM 703	118.00	90.39
RRIM 607	92.00	105.86

The 16 clones in Garden III showed significant clonal differences for annual girth and yield. Among the clones, RRII 203, PB 311 and RRII 5 were the high yielders and RRII 118, RRII 300 and RRII 44 were the vigorous clones (Table Ger. 2).

In Garden IV, IRCA 111 and IRCA 130 had higher annual girth than RRII 105. Scoring of *Gleosporium* for one season indicated 50% resistance for IRCA 109 and IRCA 111. Growth of the clones in Garden V in the sixth year of planting was monitored in terms of the annual girth. Among the 20 clones, RRIC 100 showed the highest girth (32.35 cm) while RRIC 102 (28.22 cm) and RRII 178 (27.43 cm) were on par with RRII 105 (22.31 cm) (Table Ger. 3). The second round of visual scoring for *Oidium* resistance was carried out in collaboration with the Plant Pathology Division.

Table Ger. 2. **Yield and girth performance of 16 Wickham clones**

Clone	Mean Yield (g/t/t)	Girth (cm)
RRII 1	48.99	85.28
RRII 2	33.96	66.49
RRII 3	53.79	86.92
RRII 4	71.92	71.25
RRII 5	82.59	80.84
RRII 6	55.62	88.92
RRII 44	57.45	102.79
RRII 118	50.89	110.21
RRII 203	91.80	101.65
RRII 206	77.00	99.20
RRII 208	52.61	78.56
RRII 300	56.32	104.33
RRII 308	73.01	80.47
PB 260	59.26	79.30
PB 310	82.55	87.05
PB 311	86.93	75.08
CD (P = .05)	41.75	18.68

Table Ger. 3. **Girth of 20 Wickham clones (Sixth year after planting)**

Clone	Girth (cm)	Clone	Girth (cm)
RRII 12	25.42	RRIC 36	18.11
RRII 15	18.33	RRIC 100	32.35
RRII 20	20.93	RRIC 102	28.22
RRII 22	21.26	PB 255	25.41
RRII 23	25.72	RRIM 609	27.30
RRII 27	19.81	RRIM 618	15.41
RRII 105	22.31	SCATC 88 - 13	20.90
RRII 108	19.73	SCATC 93 - 114	22.74
RRII 168	24.30	Haiken 1	22.87
RRII 178	27.43	PR 255	14.25
CD (P = 0.05)	7.90		

Statistical analysis of the data on the mature plants from the experiment on multivariate analysis in 25 young and mature clones of *Hevea*, revealed that girth, rubber yield, dry rubber content (DRC), plugging index (PI), single leaf area (SLA), specific leaf weight (SLW), total chlorophyll content and biochemical parameters like thiols, inorganic phosphorous (Pi), sucrose and magnesium in the latex, showed highly significant clonal differences (at 1% level), while total solids content (TSC) in latex was significant at 5% level. Relatively high genotypic coefficient of variation (GCV) was seen for the four latex biochemical traits and yield. Medium to high heritability (H^2-broad sense) followed by high genetic advance (GA) was exhibited by yield, sucrose, thiols and magnesium (Table Ger. 4). Anatomical observations of bark and leaf samples are in progress.

1.2 Wild genepool

A total of 3617 wild accessions are being conserved in eight source bush nurseries. Another 200 accessions from the non-tradi-

Table Ger. 4. **Genetic parameters for 12 traits in 25 Wickham clones in the mature phase**

Traits	PCV	GCV	H^2GA	GA (as % of mean)
Yield**	39.76	28.87	52.74	43.19
Girth**	18.26	13.95	58.40	21.96
DRC**	8.90	5.93	44.48	8.15
TSC*	7.51	3.88	26.78	4.14
Thiols**	33.19	23.58	50.48	34.51
Pi**	29.92	22.60	57.08	35.18
Sucrose**	43.00	35.29	67.39	59.66
Mg**	45.21	29.45	42.42	39.51
PI**	26.73	17.99	45.30	24.95
SLA**	26.09	15.61	35.81	19.24
SLW**	17.91	11.08	38.25	14.11
Tot. Chl**	23.46	16.78	51.15	24.71

*and ** Clonal differences significant at 5 and 1% levels respectively

tional region of NE India (Guwahati), were multiplied and established in a polybag nursery at RRII main campus, Kottayam, along with three controls for field planting in the ensuing season. Twenty accessions with distinct morphological variations were multiplied and planted in a polybag nursery for establishing a demonstration plot at RRII main campus.

In a study involving 75 wild accessions in one of the nurseries, girth, bark thickness and total number of laticifer rows showed relatively high correlation with yield. Path analysis showed that total number of laticifer rows had the highest direct effect on yield. Six accessions with promising juvenile yield were identified from three of the nurseries.

Herbarium specimens of 126 genotypes were prepared in the current year. In order to induce flowering in the remaining accessions, ring barking of 1100 trees was carried out.

2. Characterisation and preliminary evaluation

445 wild accessions are under evaluation at CES, Chethackal, in various evaluation trials. Yield was recorded from the 1990 preliminary evaluation treal (PET). Four clones (MT 196, AC 163, AC 716 and 7.111) showed relatively higher yield among the wild germplasm. Average cup lump yield in the first year of opening was recorded in the peak season in the two PETs planted in 1992. The data showed significant clonal variation. The yield of AC 654 (10.98 g/t/t) and MT 1056 (16.36 g/t/t) were statistically on par with that of the control clone in the two experiments. (9.72 g/t/t and 16.13 g/t/t respectively). Several genotypes were found to be more vigorous in growth than the control clone RRII 105. Fifteen genotypes had a girth value more than 40.00 cm in comparison to 32.40 cm for the control clone in the first experiment, while 12 clones in the second experiment had values above 40.00 cm compared to 37.25 cm for the control clone (Table Ger. 5).

Table Ger. 5. **Girth of selected clones**

	Experiment A			Experiment B	
Sl No	Genotype	Girth (cm)	Sl No	Genotype	Girth (cm)
1	MT 1030	40.28	1	MT 454	40.07
2	MT 948	40.41	2	RO 303	40.46
3	RO 287	40.47	3	RO 329	40.66
4	RO 338	40.60	4	MT 1056	40.78
5	RO 322	41.31	5	RO 401	40.95
6	RO 868	41.35	6	RO 273	41.28
7	RO 352	41.81	7	MT 1032	41.38
8	RO 859	42.28	8	RO 292	42.41
9	AC 1043	42.31	9	MT 1022	44.12
10	AC 626	42.45	10	RO 271	44.38
11	AC 650	42.81	11	RO 297	44.77
12	RO 364	44.60	12	RO 272	48.97
13	RO 328	44.80	13	RRII 105	37.25
14	MT 944	45.16			
15	MT 1025	49.25			
16	RRII 105	32.40			

Among the 35 clones in Garden II, RRIM 703 had the highest annual yield in the thirteenth year, while RRIM 604, RRIM 701 and RRIM 607 recorded yield comparable with that of the control clone RRII 105 (Table Ger.1). Twenty two clones had an average annual girth comparable with or higher than RRII 105 over 13 years.

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RRII 3	53.79	86.92
KRII 4	71.92	71.25
RRII 5	82.59	80.84
RRII 6	55.62	88.92
RRII 44	57.45	102.79
RRII 118	50.89	110.21
RRII 203	91.80	101.65
RRII 206	77.00	99.20
RRII 208	52.61	78.56
RRII 300	56.32	104.33
RRII 308	73.01	80.47
PB 260	59.26	79.30
PB 310	82.55	87.05
PB 311	86.93	75.08
CD (P = .05)	41.75	18.68

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DRC**	8.90	5.93	44.48	8.15
TSC*	7.51	3.88	26.78	4.14
Thiols**	33.19	23.58	50.48	34.51
Pi**	29.92	22.60	57.08	35.18
Sucrose**	43.00	35.29	67.39	59.66
Mg**	45.21	29.45	42.42	39.51
Pl**	26.73	17.99	45.30	24.95
SLA**	26.09	15.61	35.81	19.24
SLW**	17.91	11.08	38.25	14.11
Tot. Chl**	23.46	16.78	51.15	24.71

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4	RO 338	40.60	4	MT 1056	40.78
5	RO 322	41.31	5	RO 401	40.95
6	RO 868	41.35	6	RO 273	41.28
7	RO 352	41.81	7	MT 1032	41.38
8	RO 859	42.28	8	RO 292	42.41
9	AC 1043	42.31	9	MT 1022	44.12
10	AC 626	42.45	10	RO 271	44.38
11	AC 650	42.81	11	RO 297	44.77
12	RO 364	44.60	12	RO 272	48.97
13	RO 328	44.80	13	RRII 105	37.25
14	MT 944	45.16			
15	MT 1025	49.25			
16	RRII 105	32.40			

Annual girth increment was recorded from the three PETs planted in 1994. Sixteen genotypes in the first one had girth comparable with or higher than that of the control (Table Ger. 6). AC 757 recorded the highest girth followed by MT 940 and RO 867. Of the 24 clones, MT 1012, MT 940 and RO 263 recorded relatively high test tap yield, though much less than that of RRII 105.

Table Ger. 6. **Accessions with girth comparable with or higher than that of RRII 105**

Accession	Girth (cm)	Accession	Girth (cm)
AC 442	29.07	MT 1012	32.22
AC 649	28.99	RO 263	29.20
AC 664	33.20	RO 853	30.62
AC 666	32.42	RO 867	34.25
AC 757	37.25	RO 871	32.10
MT 930	31.99	RO 895	34.20
MT 938	31.79	RO 938	31.61
MT 939	30.75	RRII 105	28.79
MT 940	35 .37		
CD (P=0.05)	4.75		

In the second PET, 6 accessions had their girth values on par with RRII 105. In the third PET planted in 1994, 11 genotypes showed higher girth values comparable with or higher than that of the control (Table Ger. 7). Six clones *viz.*, RO 893, AC 465, AC 645, RO 278, RO 846 and AC 605 had a higher girth than the control. RO 274, RO 278 and RO 846 were relatively high juvenile yielders though not on par with RRII 105.

Table Ger. 7. **Accessions with girth comparable with or higher than that of RRII 105**

Genotype	Girth (cm)
AC 465	32.70
AC 605	30.56
AC 645	31.28
AC 651	29.91
AC 649	28.21
AC 849	28.24
RO 278	30.16
RO 274	28.12
RO 893	35.06
RO 884	29.08
RO 846	30.28
RRII 105	24.78
CD (P = 0.05)	5.31

A preliminary evaluation trial comprising 46 ortet clones along with three controls, was planted in a simple lattice design with four replications. Adequate measures were taken to ensure proper establishment and to provide summer protection to the young plants.

Planting materials for two new PETs consisting of 168 wild genotypes each, to be planted at RRS, Padiyoor, were multiplied and established in polybags.

3. Further evaluation and selection

Out of 80 wild accessions, 22 genotypes showed higher annual average girth over the control RRII 105 at the age of five years. Maximum girth was recorded by AC 635 (23.75 cm) whereas RRII 105 had an average girth of 16.5 cm. Test tapping at the age of four years showed that only one genotype MT 1707 (9.72 g/t/t) had comparable yield with that of the control clone RRII 105 (9.40 g/t/t). Forty three genotypes had higher bark thickness over the control RRII 105. The genotype MT 68 recorded maximum value (3.63 mm) whereas RRII 105 had a bark thickness of 2.5 mm. Visual scoring for pink disease incidence was carried out. Two Mato Grosso (MT 1674 and MT 191), two Rondonian (RO 1347 and RO 136) and one Acre genotype (AC 668) showed an indication of field tolerance to pink disease which will be further confirmed in subsequent seasons.

4. Screening

4.1 For biotic stress resistance

A laboratory was set up at CES, Chethackal for routine screening of germplasm genotypes. The first round of scoring for resistance to *Oidium* was carried out in collaboration with Pathology Division in all the source bush nurseries. Wide variability for the disease reaction was observed. A few promising accessions with desirable levels of resistance were identified, which will have to be confirmed in the subsequent seasons.

Field screening of the genotypes for resistance to *Oidium* sp. was carried out in the statistically laid out field trials too. In the two 1992 trials, five genotypes (RO 316, AC 644, RO 254, RO 256 and RO 319) in the first experiment and four genotypes (RO 297, AC 457, AC 977 and RO 306) in the second experiment showed relatively less infection which will be further confirmed. Preliminary data from the 1994 PET revealed that seven genotypes showed less than 30% disease incidence of which AC 757 and AC 666 showed the least incidence of 7.5 and 17% respectively. All the nine ortets in PET (Ortet) 1994 trial were highly susceptible.

Among the Wickham clones screened in the Germplasm gardens, RRII 2 exhibited relatively low disease incidence followed by PB 310 among the 16 clones in garden 3. All the IRCA clones in garden 4 were found to be highly susceptible.

4.2 For abiotic stress resistance

Screening for drought tolerance in wild germplasm was continued with the selection of 10 wild genotypes along with three controls (RRII 105, RRIM 600, and Tjir 1) based on the results of thermostability analysis carried out in the previous year. Morphological characters like plant height, girth, number of leaf whorls, total number of leaves, total leaf area and specific leaf weight were recorded. The physiological parameters recorded under controlled conditions were transpiration rate, stomatal conductance, leaf temperature, photosynthetic activity by chlorophyll fluorescence, leaf water potential and soil water potential. The data is being analysed.

For the screening of cold tolerance, 126 wild genotypes, selected on the basis of vigour and other superior traits from both traditional and non traditional areas, have been multiplied and raised in polybags at RRS, Nagrakatta, West Bengal and were field planted.

4.3 For timber latex traits

Based on growth vigour, bole habit and branching habit 19 genotypes were selected, multiplied and established in a polybag nursery at RRS, Padiyoor, along with six control clones for laying out a field trial in the ensuing season.

5. Molecular characterization

Genetic relations among 60 wild genotypes through RAPD studies have been completed in collaboration with the Genome Analysis Laboratory. The genotypes have been grouped based on the genetic distance. The results indicated geographical distinction between the three provenances of Acre, Rondonia and Mato Grosso. All the genotypes showed genetic distinctiveness without any duplication. Mato Grosso genotypes showed maximum genetic divergence compared to other two provenances.

A new experiment on RAPD profiling and evaluation of genetic diversity in wild *Hevea* accessions was proposed.

MYCOLOGY AND PLANT PATHOLOGY DIVISION

The Division concentrated its research activities on crop protection, microbial manipulation of soil fertility, pollution control and investigations on agrometeorological basis for disease occurrence. The overall disease situation during the year under report was the severe incidence of abnormal leaf fall (ALF) disease moderate incidence of powdery mildew and Corynespora diseases. The studies on Gloeosporium leaf disease showed that the isolates of the fungus causing raised spots were *Colletotrichum*

acutatum and those causing papery lesion and anthracnose symptoms were *C. glocosporioides*. The isolates of *Corynespora* from Karnataka and Kerala showed wide variation in virulence. Studies on molecular mechanism of host pathogen interaction indicated the involvement of β-1, 3 glucanase in the resistance of certain clones to the pathogen. Among the stem diseases, pink disease received more attention. Evaluation of germplasm and pipeline clones for tolerance to disease was also attempted.

The entomology unit concentrated on the management of insects and non-insect pests of rubber. Bee keeping was another area of investigation and *Apis mellifera* was compared with *Apis indica* in its performance. The microbiology unit conducted studies on microorganisms involved in soil fertility and crop management. The unit also undertook studies on pollution abatement. The presence of a low molecular weight RNA was implicated to be associated with TPD syndrome.

The agrometeorological studies included evaluation of the rainfall pattern of the traditional rubber growing tracts for the last 22 years. Relationship of environmental conditions with progress of Corynespora disease in HBSS, Nettana and powdery mildew disease at CES, Chethackal were also studied.

1. Leaf diseases

1.1 Abnormal leaf fall

For the control of ALF, an experiment to evaluate new formulations of spray oil was laid out in areas planted with clone RRIM 600 in three locations *viz.*, Kulathupuzha Estate, Punalur; Cheruvally Estate, Erumeli and Boyce Estate, Mundakayam. Aerial spraying was carried out in four hectare plots at each location using the new formulation of IPOL spray oil for dilution of oil dispersible copper oxychloride (COC). Standard IOC spray oil, now recommended, formed the diluent in the control plots. A dosage of 8 kg COC per ha diluted in 40 l of respective oils was followed at all locations. The leaf retention recorded at the different locations is presented in Table Path.1. IPOL spray oil was observed to be as useful as IOC spray oil for rubber spraying.

Table Path. 1. **Evaluation of spray oil formulations for leaf retention (%)**

Location	Spray oil		t-test
	IPOL	IOC	
Kulathupuzha	14.39	13.13	NS
Cheruvally	69.80	69.74	NS
Boyce	58.80	67.80	NS

Rubber seed oil (RSO) was evaluated as a carrier for copper fungicides in Pudukad Estate in the clone RRIM 600. A 1:2 mixture of RSO and mineral oil was tried. COC was added at the ratio 1:5 to the mixture of oils and sprayed using micron sprayers. Use of COC in normal spray oil and unsprayed areas were kept as controls. Percentage of leaf retention showed maximum value for spray oil alone (55.52), followed by RSO plus spray oil (50.07) and unsprayed (17.72) treatments respectively.

In the experiment to evaluate the crop loss due to ALF laid out at CES, Chethackal in clones RRIM 600, RRII 105, GT 1 and RRII 118, the long term effect of leaving unsprayed, year after year, on the disease incidence and crop loss were assayed. A pre-monsoon spraying with COC in oil at the recommended dose using micron sprayer was done every year. Leaf retention was affected in RRIM 600, GT 1 and RRII 118 and severe crop loss recorded in RRIM 600 (Table Path.2).

Evaluation of the effect of dosage of COC on the disease severity and its effect on crop was carried out in an experiment laid out at Chemoni Estate, Trichur in the clone RRII 105. A pre-monsoon micron spraying was done with 2,4,6 and 8 kg COC per ha in one hectare plots. There was no apparent difference

Table Path. 2. **Evaluation of crop loss due to abnormal leaf fall disease**

Clone	Leaf retention (%)		Yield (g/t/t)	
	Sprayed	Unsprayed	Sprayed	Unsprayed
RRIM 600	42.11	14.87	79.34	52.91
RRII 105	71.02	69.61	60.98	75.13
GT 1	57.13	32.88	42.22	44.35
RRII 118	80.79	72.49	50.09	46.23

in leaf retention between 6 and 8 kg dosages. The effect on the crop was only marginal in dosages of 2, 4 and 6 kg. There was significantly higher yield when the dose was 8 kg/ha (Table Path. 3).

Table Path. 3. **Effect of COC on leaf retention and yield**

Treatment (kg/ha)	Leaf retention (%)	Yield (kg/240 trees)
2	60.84	881.70
4	63.36	881.70
6	61.05	827.75
8	62.73	1139.00

The experiment to improve the efficacy of Bordeaux mixture by the addition of RSO was continued. The evaluation of leaf retention indicated that addition of 1% RSO to 1% Bordeaux mixture gave the maximum disease control (62% leaf retention) as reported in the previous year. However, addition of 1% RSO to 0.5% Bordeaux mixture was found as good (54%) as the recommended 1% Bordeaux mixture (55%) in controlling the disease.

Crown budding has been undertaken on clones such as RRIM 600, RRIM 628 and GT 1 with *Phytophthora* resistant crowns like RRII 33, Fx 516 and F 4542. The latex samples collected from the experimental areas (Punalur, Calicut, Thodupuzha - 1970 trial) were analysed for dry rubber content (DRC), specific gravity, TS, Po, PRI, Mooney viscosity, *etc.* and compared with the control. The specific gravity of latex was not found to be affected by crown budding. The DRC of latex from crown budded plants in clone RRIM 628 was lower than control, whereas that from the clone GT 1 recorded lower DRC compared to the crown budded. The PRI of latex from crown budded plants was higher in RRIM 600, lower in RRIM 628 and at par in GT 1.

In another experiment in which PB 311 was crown budded with resistant clones like RRII 33 and Fx 516 at Malankara Estate, Thodupuzha, yield recording was continued. The observations on incidence of ALF disease and powdery mildew were recorded. ALF disease was negligible on crowns Fx 516 and RRII 33. *Oidium* incidence was moderate except in Fx 516 in which it was mild. The analysis of the latex samples collected indicated that the specific gravity was on par for crown budded and control (PB 311). The PRI was higher in crown budded plants (Table Path. 4).

To evaluate clones for ALF, leaf retention assessment was carried out in two trials at RRII Farm. In Trial I, high leaf retention was recorded in RRII 105 and the lowest in RRIM 600. In Trial II high leaf retention was recorded in KRS 128 and the lowest in PB 280.

1.2 Shoot rot

An experiment on shoot rot was taken up

Table Path. 4. **Latex properties in crown budded and control plants of clone PB 311**

Parameter	Crown		
	PB 311	RRII 33	Fx 516
Specific gravity	0.981	0.981	0.983
DRC (%)	36.8	34.9	33.9
TS (%)	39.1	37.6	36.7
Magnesium	0.048	0.05	0.084
Sludge	trace	trace	trace
Copper (ppm)	7.0	8.0	8.0
Iron (ppm)	1.8	2.0	1.0
Manganese (ppm)	nil	nil	nil
Acetone extract (%)	3.3	3.6	2.9
Ash content (%)	0.27	0.32	0.24
Nitrogen (%)	0.59	0.62	0.49
Po	52	55	48
PRI	65	67	75
Accelerated Storage Hardening	28	27	27
Mooney viscosity	76	76	63

to evaluate the efficacy of a systemic fungicide, Benlate and Bordeaux mixture (1 and 0.5%) mixed with 1% RSO. The results indicated that spraying of 0.5% Bordeaux mixture with 1% RSO was as effective as 1% Bordeaux mixture in checking the disease (Table Path. 5). The quantity of copper retained was maximum on leaves sprayed with 1% Bordeaux mixture + 1% RSO, whereas the control recorded the lowest. Compared to Bordeaux mixture, disease incidence was more in Benlate sprayed plots.

Table Path. 5. **Copper retention and incidence of shoot rot disease**

Treatment	Copper (ppm)	PDI
1% Bordeaux mixture	764.0	28.0
1% Bordeaux mixture + 1% RSO	872.0	25.0
0.5% Bordeaux mixture + 1% RSO	422.0	30.0
Benlate	233.0	38.0
Unsprayed control	152.0	50.0

1.3 Powdery mildew

A preliminary survey was carried out to assess the intensity of powdery mildew disease in Kanyakumari District. Thirty two locations were surveyed. An assessment scale of 1-5 was used based on the intensity of defoliation. Severe disease intensity was noticed only in 11 locations.

Observations were made on the incidence of powdery mildew disease in the eight evaluation trials of Germplasm Division and also in five source bush nurseries. The incidence of powdery mildew disease on the pipeline clones planted in RRII Farm and in Cheruvally Estate was also recorded. For the multidisciplinary evaluation of clones, observations on powdery mildew disease were made from two trials of 13 clones each planted in RRII Farm. In trial I, lowest disease incidence was noticed in RRII 5 and highest incidence was noticed in PB 261. In Trial II, lowest disease incidence was noticed in PB 255 and highest incidence in PB 312.

1.4 Colletotrichum leaf disease

The field trial for the evaluation of different fungicides at Manikal Estate was continued for the third year. The experiment was laid out with eight fungicidal treatments, *viz.*, Mancozeb (0.20%), Carbendazim (0.025%), Hexaconazole (0.02%), two concentrations of Metalaxyl + Mancozeb (0.02% and 0.01%), Bordeaux mixture 1% and alternate use of Mancozeb and Carbendazim and their combination and an unsprayed control. All the fungicides tested significantly reduced the disease incidence when compared to unsprayed control. Alternate use and a combination of Carbendazim and Mancozeb were comparable to their separate use in controlling the disease.

Experiment to evaluate the efficacy of weekly and fortnightly application of six fungicides laid out at Kaliyar Estate showed that all the fungicides were on par in controlling the disease (Table Path. 6). But in general, weekly application was superior to fortnightly application.

In a study for the comparison of variability of *Colletotrichum* isolates, infected leaf samples which showed different types of symptoms on different clones were collected from Kottayam, Kaliyar and Mundakayam and single spore isolations were made from these samples. Isolates derived from anthracnose lesions and from papery lesions exhibited similar growth rate but faster than those from raised type lesions on media. Colony

Table Path. 6. **Incidence of Colletotrichum leaf disease (PDI)**

Fungicide	Spraying	
	Weekly	Fortnightly
Hexaconazole (0.02%)	17.04	28.62
Metalaxyl + Mancozeb (0.2%)	8.42	30.79
Bordeaux mixture (1%)	17.69	30.60
Carbendazim (0.05%)	18.00	31.24
Mancozeb (0.2%)	11.67	18.08
Hexaconazole (.01%) + Mancozeb (0.1%)	11.25	28.52
CD 12.57		

colour of anthracnose and papery lesions isolates was light grey to dark grey while isolates from raised spots were pink on PDA. Conidial shape of isolates from anthracnose and papery lesions were cylindrical while isolates from raised spots were fusiform. Isolate with fusiform conidia were identified as *C. acutatum* and with cylindrical conidia as *C. gloeosporioides* by IMI. Molecular analysis carried out also clearly distinguished them into two major groups. While RAPD profiles of isolates from anthracnose and papery lesions were almost similar they differed from the isolates from raised spots. However, variability could be detected within each group.

1.5 Corynespora leaf disease

For studies on variability of *Corynespora cassiicola* isolates, infected leaf samples were collected during the disease season from various locations of Kerala and Karnataka, the pathogen isolated and purified. Virulence of these isolates was tested by detached leaf technique on the five clones *viz.*, RRII 105, RRIM 600, GT 1, PB 260 and Haiken 1 by spraying the conidial suspension. One isolate each from Sullia, Teekoy and Adoor exhibited more virulence than the others. Some of the isolates from Nettana, Sullia, Sampaji, Karmayee, Kolichal, Panathady and Karikattor also showed almost similar virulence pattern on tested clones except on GT 1.

A study was initiated to identify the molecular mechanism of host-pathogen interaction in *Hevea*. Pathogenesis related protein β -1, 3-glucanase activity in response to infection of *C. cassiicola* was tested in four clones of *Hevea*, *viz.*, GT 1, RRII 105, PR 107 and RRIM 600. The β -1, 3-glucanase activity was estimated and isozymes were detected in PAGE gels. Variation in symptom expression was observed between the clones. In RRII 105 and PR 107, the initial symptom appeared in 24 h and visible symptom was observed in 48 h. In GT 1 hypersensitive area appeared in 48 h. after induction. In RRIM 600, the lesion development was observed in 72 h. Very limited lesion formation was observed in GT 1, while susceptible reaction was recorded in all the other clones tested.

Three major β -1, 3-glucanase isozyme bands (G1, G2 and G3) were detected in induced leaves of GT 1 at 96 h. No positive reaction was detected in other clones on both induced and control leaves. The β -1, 3-glucanase activity was maximum in GT 1, where a typical tolerant reaction to *Corynespora* was observed.

To study the physiology of resistance to *Corynespora*, five different isolates (three from Karnataka and two from Kerala), and two *Hevea* clones RRII 105 and GT 1 were selected. Leaves were inoculated with 10 µl drops of spore suspension (2.3×10^4 conidia / ml). After 72 h of inoculation the lesion size on the leaves were recorded. Toxin activity was studied by leaf wilting bioassay and leaf puncture bioassay. The pathogenecity of isolates could be correlated to their toxin production. The culture filtrate showed toxic activity only on the susceptible clone. There was not much variation between the tested isolates in their virulence.

2. Stem diseases

2.1 Pink disease

The experiment to evaluate the efficacy of systemic fungicides such as thiophosphate, validacin and hexaconazole and the recommended chemicals such as thiram in controlling pink disease was continued. Their efficacy in different carriers such as Vinofan, Indtron and Rubberkote was also compared. The systemic fungicides validacin and hexaconazole were the most effective fungicides, whereas there was no significant difference among carriers. The percentage recovery of trees in various treatments is presented in Table Path. 7.

Table Path. 7. **Effect of fungicides and carriers on pink disease control**

Fungicide	Recovery (%)		
	Indtron	Rubber kote	Vinofan
Thiophosphate	33	83	50
Validacin	58	100	83
Hexaconazole	67	91	92
Thiram	58	67	67
Bordeaux paste (control)		50	-

In another study fungicide such as validacin, hexaconazole, thiram and Bordeaux mixture were sprayed on loci of infection and the disease control assessed. The disease progress was monitored periodically. Complete control was not achieved by spraying these fungicides.

2.2 Patch canker

An experiment was initiated to study the effect of various fungicides on the control of patch canker. The treatments were applied onto the wound by incorporating the fungicides in rubber kote at the dosages indicated. The fungicide treatments with Mancozeb, Ridomil and Kitazin have given slightly higher percentage of recovery, than the presently recommended Bordeaux paste (Table Path. 8).

Table Path. 8. **Control of patch canker disease**

Treatment	Dose per kg Rubber kote	No. of trees		
		A	B	C
Akomin (ml)	5	11	9	81.8
Benlate (g)	4	11	10	90.9
Bordeaux paste (%)	10	11	9	81.8
Mancozeb (g)	10	11	11	100.0
Ridomil MZ (g)	4	11	11	100.0
Kitazin (ml)	4	11	11	100.0

A : Treated B : Recovered C : % recovery

3. Root diseases

3.1 *Poria* root disease

The field trial for the control of *Poria* root disease at Kumbazha Estate was continued. The base and the soil around the collar of the infected and two neighbouring plants were drenched with fungicide solution. Treatments imposed were Calixin (1%), Calixin (0.5%), Tilt (0.1%), Contaf (0.05%) and Thiride (0.75%). All the fungicides tested were equally effective in protecting the neighbouring plants.

3.2 Purple root disease

Budded stumps from the infested nursery showing fruiting bodies at the collar region were uprooted and their shoot and root pruned. The root portion was dipped in any one of the fungicide solutions *viz.*, Calixin (0.25%), Tilt (0.1%), Contaf (0.01%), Thiride (0.75%) and planted in polythene bags. When treated at the initial stages all the fungicides used were equally effective in controlling the disease but plants treated with fungicides in the advanced stage showed only 50% recovery. In another experiment, rubber plants were uprooted from infested nursery beds and beds were treated with the above fungicides and 10 budded stumps were planted in each bed. Results showed that all the fungicides were on par in controlling the disease in the nursery bed.

4. Retention and residual studies of copper in rubber plantations

An experiment was initiated at Pudukad Estate, Trichur and CES, Chethackal to study the retention and residual effect of copper in rubber plantations. At Pudukad, treatments included (1) 1% Bordeaux mixture, (2) 1% Bordeaux mixture + 1% RSO, (3) RSO : Spray oil : COC at 5 : 10 : 3, (4) Spray oil : COC at 15 : 3 and (5) Control (unsprayed). At CES, Chethackal the treatments were (1) COC : Spray oil at 1:5 (sprayed) and (2) Control (unsprayed). These treatments were imposed in four blocks, covering four clones (RRII 105, RRII 118, RRIM 600 and GT 1). Apart from the analysis of copper residue, soil microflora is also being monitored.

5. Pests of rubber

The insecticides such as chlorpyriphos, fenvalerate and endosulfan at various concentrations were tried against termite (*Odontotermes*

Table Path. 9. **Post-treatment percent termite re-infestation in rubber plants**

Treatment	Dosage (% ai)	After 4 months	After 16 months
Chlorpyriphos	0.06	61	71
Chlorpyriphos	0.10	57	62
Chlorpyriphos	0.14	52	66
Chlorpyriphos	0.20	41	67
Fenvalerate	0.02	46	65
Fenvalerate	0.04	40	54
Endosulfan	0.10	64	74
Endosulfan	0.175	60	71
Control		90	76
CD (P=0.05)		6.09	12.32

obeses). Chlorpyriphos (0.2%) and fenvalerate (0.04%) were effective for the control of termites for four months (Table Path. 9).

Against crickets, *(Gryllacrys* sp.) damaging rainguards, application of different insecticides namely neem oil 10 ml/L, malathion (0.1%), methyl parathion (0.1%), dimethoate (0.1%), fenvalerate (0.02%), BHC (0.2%) and phorate 2 g/L was done after dilution in water. Neem oil application has resulted in decrease of damage.

Eco-friendly repellents such as castor oil, kerosene + neem oil, phenyl, used engine oil, mineral turpentine, neem oil, maroti oil and cashew kernel oil were also tried against *Gryllacrys* sp. Used engine oil, cashew kernel oil and maroti oil were found effective.

Borer beetle infestation on rubber trees was observed during September-October. The experiment for the control of borer beetles revealed that a combination of carbaryl + quinalphos and carbaryl + chlorpyriphos were effective. The treatment with carbaryl + malathion and lindane + quinalphos were the next effective combinations.

The population of root-knot nematodes and total nematodes from soil samples collected from different rubber growing locations was assayed. The relative density of root-knot nematode *M. incognita* was found to vary in soil samples collected from different regions. The infectivity of the soil samples was tested on highly susceptible plants such as tomato by evaluating the gall indices.

The prior establishment of vesicular arbuscular mycorrhiza (VAM) fungi by a week or two, tended to mitigate the effect of *M. incognita* on the plant growth of *Pueraria phaseoloides*. The presence of root-knot nematodes interfered with mycorrhizal root infection and spore production. The gall formation by *M. incognita* and the multiplication of nematodes were also found to be hampered by the early establishment of VAM.

6. Pathological aspects of tapping panel dryness

Tapping panel dryness (TPD) is widespread in all rubber growing areas and is a matter of serious concern. Work done so far has only attributed TPD to physiological changes and generally believed to be not caused by any biotic agents. A study on the detection of etiology of TPD was undertaken in collaboration with Indian Agricultural Research Institute (IARI), New Delhi. Electrophoresis done by the technique of R-PAGE showed the presence of a low molecular weight RNA associated with TPD affected trees.

Chemical treatment experiments for symptom remission in TPD affected trees (RRII 105 and PB 235) conducted at Malankara (Thodupuzha) and Vaniampara (Trichur) Estates were continued. As in the case of the previous year, no significant effect of the treatments was observed.

As part of the molecular and biochemical studies on the etiology of TPD, total nucleic acid extracts purified from leaf and bark tissues of affected trees, were analysed by polyacrylamide gel electrophoresis under denaturing conditions of low salt and high temperature. This showed the presence of nucleic acids similar in electrophoretic mobility to low molecular weight (LMW) RNA, of 359 nucleotides such as potato spindle tuber viroid (PSTVd). The LMW nucleic acid detected from TPD affected samples was found to be RNA based on its sensitivity to

RNAase and insensitivity to DNAase, phenol and heat treatments. The LMW-RNA was purified and cloned in a PVC 19 derived vector using primers specific to PSTVd. The cloned DNA, when random labelled and used as probe, reacted specifically to nucleic acid extracts from TPD affected trees but not from healthy tissues in dot-blot hybridisation assays. Based on the above findings, a viroid etiology for TPD syndrome was proposed.

A symptamatology study was initiated in 1999 when TPD affected plants of clone RRIM 605 with special symptoms of bark cracking were observed near Anchal in Kollam District. Out of the 134 plants, 20% showed the bark scaling symptoms with pink colour at the time of opening. The nucleic acid analysis of the samples from these trees was carried out and the presence of LMW-RNA was observed. The latex yield and the DRC were less in affected trees. All the trees showing this particular symptom originated from a single nursery. A survey was conducted in the nearby plantations where the planting materials were supplied from the nursery. All the 28 smallholdings surveyed had trees with same syndrome.

7. Bee keeping in rubber plantations

Survey on bee keeping in rubber plantation and associated problems was carried out in rubber growing areas in Kottayam and Kasaragod Districts. Cost of equipment and inputs such as bee hives, bee stand, bee colony, honey extractor, bee veil, bee net, comb foundation sheet (only for *Apis mellifera*), labour expenses, artificial feeding (sugar, bengal gram) were studied. The various sources of income from bee keeping namely honey, wax and bee colony were also recorded for the two types of domesticated honey bees *viz.*, *Apis indica* and *Apis mellifera*. The incidence of diseases, attack due to predators and parasites were also recorded. The total cost per hive was Rs. 755 and Rs. 2900 and the total income per hive was Rs. 800 and Rs. 3500 for the two kinds of bees which showed only a marginal profit.

8. Vermiculture

Vermicomposting units were established successfully at Malankara Estate, Thodupuzha and Palampra Estate, Kanjirapally.

9. Microorganisms for improving growth of rubber and cover crops

In the study on nitrogen fixing microorganisms, periodic observations were taken on growth and spread of *Mucuna bracteata* in the *Bradyrhizobium* inoculated and uninoculated plots at RRS, Padiyoor. Dense growth of *M. bracteata* plants and suppression of weeds were observed in plots inoculated with *Bradyrhizobium*.

The tolerance of five isolates of *Azotobacter* to the weedicide diuron was studied under laboratory conditions at the concentrations of 250 to 5000 ppm. The bacteria were found to survive in these concentrations. But none of the isolates survived exposure to glyphosate at a concentration of 100 ppm.

A survey on the occurrence of *Beijerinckia* in different locations of Kerala was carried out. Twenty six soil samples were screened and 10 *Beijerinckia* isolates were collected.

A pot culture study was conducted to find the effect of coinoculation of *Beijerinckia* with *Pseudomonas*, the plant growth promoting rhizobacteria (PGPR) and VAM at different levels of N and P. After 10 months growth, dual inoculation of *Beijerinckia* with VAM or PGPR at 100% N and P gave significant improvement in girth and height of the plants compared to control (NPK 100%) and at 50% N and P it was on par with the control (Table Path. 10).

To study the improvement in phosphate uptake of rubber and cover crops through micro-organisms and to find out the effect of mycorrhizal inoculation on rubber seed-

Table Path. 10. **Growth of plants after 10 months**

Treatments	Height (cm)	Girth (cm)
Beijerinckia + 50% N + 100% P	143.33	12.33
Beijerinckia + 100% N + 100% P	138.67	12.00
Beijerinckia + PGPR + 50% N + 50%P	102.33	9.00
Beijerinckia + PGPR + 100% N + 100% P	143.33	13.00
Beijerinckia + VAM + 50% N + 50% P	112.33	11.67
Beijerinckia + VAM + 100% N + 100% P	148.00	13.67
Beijerinckia + PGPR + VAM + 50% N + 50% P	125.67	11.00
Beijerinckia + PGPR + VAM + 100% N + 100% P	138.00	12.67
100 % NPK - Control	115.33	10.67
CD (P = 0.05)	21.01	26.00

lings under sterile condition, a pot culture study was initiated. Eleven isolates of VAM were used under three different levels of rock phosphate application (50, 75 and 100% of recommended levels). Growth of the plants was monitored up to one year. Study revealed that rubber seedlings responded more to VAM inoculation when the phosphate level was low. Only a few isolates showed improvement in growth of rubber seedlings at higher levels of phosphate application.

Genetic engineering of beneficial microbes was another area of study. Mutation was induced on *Azotobacter* and *Beijerinckia* using physical mutagens (UV rays 254 nm) and the mutants were obtained. Growth and nitrogenase activity at different pH and biochemical characters of both parents and mutants of *Azotobacter* and *Beijerinckia* were studied. The effect of curing on stress tolerance of the parent and mutant strains was observed.

10. Waste management in rubber processing

For the evaluation of the modified effluent treatment system of crumb rubber factory, effluent samples from soaking tank, rubber trap, composite tank, aerator, clarifier 1, clarifier 2, filler 1 and final water after filler 2 were collected monthly and analysed for pollution parameters. The final effluent after the treatment was within the safe limit specified for discharge into the environment.

To study the performance of large size anaerobic immobilized growth digester, digesters having 10 and 15 m^3 capacity attached with aerobic pond were constructed in the RPS group processing centres. The digesters were fitted with fixed film assembly in order to enhance the surface area for the micro-organisms to act. These digesters were daily fed with 1500 L RSS effluent. The effluent samples from various points were collected and analysed for different parameters. The quantity and quality of biogas generated were also monitored. The biogas generated contained 62% methane and was used for the drying of sheets. The colour of the RSS produced using this gas was golden yellow. A special system for the burning of biogas in the smoke house was developed. Reduction in the various pollution parameters was noted after the anaerobic digestion and also after the aerobic treatment.

Water samples from the nearby wells of RSS, TSR, latex concentrate and crepe processing factories were collected and analysed for indicator bacteria and other pollution parameters. The pollution parameters were within the prescribed limits for drinking water in most of the samples tested. However, some samples showed the presence of indicator bacteria.

Modification of the anaerobic digester specific for rubber processing waste water was also initiated. In a laboratory study,

natural rubber granules from TSR processing and polythene shade net pieces were used as fluidised beds in the anaerobic digester as a carrier matrix for the bacteria. The effluent before and after the treatment was analysed for various pollution parameters. Biogas generation and the time taken for the treatment were also monitored. NR granules served, as a good carrier matrix for the bacteria and hydraulic retention time in the reactor was considerably low than the conventional anaerobic digester.

PLANT PHYSIOLOGY DIVISION

The Division is carrying out research in six major areas, *viz.*, environmental physiology, physiology of growth and yield, stock–scion interaction, tapping panel dryness, secondary metabolism and ecological impact of natural rubber cultivation covering both traditional and non-traditional zones. Under each area, several experiments are underway addressing both fundamental and applied aspects of *Hevea* tree physiology.

Studies on drought stress in polyclonal rubber plants have indicated that peroxidase activity in the leaves may be related to drought tolerance. Additional studies on low temperature stress confirmed the existence of high light induced down regulation of photosynthesis. Investigations on tapping induced stress have showed increase in both alternative and cytochrome c oxidative pathways of respiration. Increased drain of resources including ATP through latex might be responsible for tapping induced loss of biomass. Field trials have been initiated at RRS, Nagrakatta and CES, Chethackal for studies on the ecological impacts of natural rubber cultivation.

1. Environmental physiology

1.1 Drought tolerance

A study has been going on at RRS, Dapchari for physio-biochemical comparison of drought tolerant and susceptible clones. Leaf and bark samples were collected from the polyclonal trees with high girth and yield and low girth and yield during peak summer and stress free post-monsoon seasons. Biochemical composition of leaf and bark (aminoacids, phenols, glutathione, sugars and protein) and activities of some critical enzymes (peroxidase, polyphenol oxidase, ascorbate peroxidase and superoxide dismutase) were analysed with an objective to relate any of these with drought tolerance. The results showed that peroxidase and ascorbate peroxidase remained higher in the leaves in high yielding trees than low yielding trees both during summer and stress free periods. Leaf peroxidase was also high in high girth trees than low girth trees in both the seasons. In the bark, polyphenol oxidase activity was less in high yielding trees than low yielding trees in both stress and stress free seasons. High peroxidase and ascorbate peroxidase in the leaf and low polyphenol oxidase activity in the bark are suitable markers associated with drought tolerance in *Hevea*.

1.2 Combined effect of drought and high light

The effect of different light regimes on growth, photosynthesis and transpiration of young rubber plants were studied in four clones (RRII 105, RRIM 600, GT 1, PR 255) using polybag plants. Three treatments (open sun, 70% and 30% sun light) were imposed. In general, the plant height and girth were significantly high at 70% sun light. There was 24 and 34% increase in leaf area per plant in 70 and 30% light levels, respectively compared to open sun. Specific leaf

weight (SLW) of plants decreased significantly under low light. The SLW decreased by 14% in 70% light and 26% in 30% light compared to plants receiving full sun light. Total chlorophyll content increased significantly in all the clones grown under low light conditions.

Though chlorophyll fluorescence index, Fv/Fm in the dark adapted state in three seasons did not show any clonal variations, significant seasonal variations ($p<0.05$) were observed under different light regimes (Table Phy. 1). At 100% light the seasonal variations were not noticed except in clones RRII 105 and PR 255, where Fv/Fm ratios significantly differed in the months of November and March. However, in 70% and 30% light regimes, significant differences in Fv/Fm ratios were observed in all the clones between different seasons. The Fv/Fm ratio was found low in the month of March and maximum in November.

When diurnal variations in Fv/Fm were measured in the forenoon (9 AM) and afternoon (3 PM) hours (Table Phy. 2), significant differences were observed only in plants grown under open sunlight. Under drought stress a significant difference in diurnal Fv/Fm was observed in plants grown under open sunlight as well as 70% light. An increase in initial fluorescence (Fo) and a decrease in maximum fluorescence (Fm) was observed in drought stressed plants compared to non-stressed plants especially in the afternoon.

Table Phy. 1. **Seasonal variations in dark adapted Fv/Fm ratios under different light regimes**

Clone	August	November	March
open sun			
RRII 105	0.79±.004	0.81±.003	0.78±.007
RRIM 600	0.80±.005	0.81±.013	0.80±.004
GT 1	0.78±.005	0.78±.008	0.77±.005
PR 255	0.79±.003	0.81±.004	0.78±.005
70% light			
RRII 105	0.78±.001	0.82±.003	0.82±.002
RRIM 600	0.78±.002	0.83±.001	0.83±.006
GT 1	0.78±.005	0.80±.004	0.80±.002
PR 255	0.78±.005	0.82±.003	0.80±.002
30% light			
RRII 105	0.79±.001	0.82±.001	0.82±.002
RRIM 600	0.80±.001	0.83±.002	0.83±.002
GT 1	0.80±.003	0.82±.003	0.81±.003
PR 255	0.80±.002	0.82±.003	0.83±.003

In a study to determine the structure and function of photosynthetic apparatus of young rubber plants in relation to its adaptation to high light and drought stress, CO_2 exchange rate (A) was measured during morning hours periodically covering three

Table Phy. 2. **Diurnal variations in dark adapted Fv/Fm ratios in *Hevea* grown under different light regimes under irrigated and unirrigated conditions**

Clone	Irrigated		Unirrigated	
	Forenoon	Afternoon	Forenoon	Afternoon
open sun				
RRII 105	0.80±.003	0.76±.014	0.75±.005	0.72±.010
RRIM 600	0.81±.004	0.77±.005	0.75±.007	0.73±.005
GT 1	0.77±.010	0.70±.020	0.74±.009	0.70±.007
PR 255	0.81±.004	0.79±.007	0.74±.004	0.70±.009
70% light				
RRII 105	0.82±.002	0.81±.002	0.77 ±.006	0.74±.009
RRIM 600	0.82±.002	0.82±.003	0.80±.008	0.75 ±.009
GT 1	0.79±.001	0.79±.007	0.78±.006	0.74±.007
PR 255	0.82±.004	0.79±.005	0.76±.007	0.73±.006
30% light				
RRII 105	0.82±.002	0.81±.003	0.80±.005	0.78±.003
R RIM 600	0.83±.002	0.81±.005	0.80±.004	0.79±.004
GT 1	0.82±.001	0.81±.002	0.78 ±.002	0.78±.002
PR 255	0.82±.002	0.81±.004	0.80±.002	0.78±.003

different seasons, during August, November and March (Table Phy. 3). During the monsoon period (August) there was no difference in photosynthesis among the clones grown under open sunlight except a slight reduction in CO_2 assimilation rate in clone PR 255. In August, at 70% light, GT 1 recorded maximum photosynthesis rate compared to other clones. But at 30% light a substantial reduction in photosynthesis was observed in all the clones. In general, photosynthesis during November was same as in August.

During summer (March) the open sun grown plants recorded less A than other seasons. The clones GT 1 and PR 255 showed less A than RRII 105 and RRIM 600. There was no significant difference between open and 70% light grown plants in March. Shade had only a modest effect on A in different months. But significant reduction in A was recorded in unirrigated plants (44 -57%). The magnitude of drought mediated inhibition in photosynthesis was more in open sunlight grown plants than shaded plants indicating aggravating effect of high light intensity.

The chloroplast polypeptides were prepared from leaves developed at different photosynthetic photon flux densities (PPFD) and resolved on a 12% SDS PAGE. The gels stained with comassie blue were scanned for quantifying the interested bands, *viz.*, the large and small subunits of Rubisco (55 & 13 kDa) and light harvesting chlorophyll binding proteins LHCP (25-27 kDa). In general, the relative amounts of the large and small sub units of Rubisco progressively decreased as the growth light intensity decreased and the concentration of the LHCP increased in the shade treatments. This is an adaptive feature of photosynthetic apparatus to low light condition in order to harvest maximum light for photosynthetic reactions. Further experiments are in progress.

1.3 Low temperature stress studies

A study has been going on to investigate the harmful effects of concomitant occurrence of low temperature and high solar radiation on young rubber plants. A total of 150 young polybag plants belonging to 14 *Hevea* clones were grown in a nursery at Mattupetty, a hill station in the Western

Table Phy. 3. **Variation in leaf photosynthetic rate (A) of young *Hevea* plants in different light intensity**

Clone & light	Carbon dioxide exchange rate (A) (μ mol $m^{-2}s^{-1}$)					
	August	November	March	April		% inhibition
				Irrigated	Unirrigated	
100% light						
RRII 105	11.47±0.380	11.63± .25	10.06±0.30	9.24 ±0.42	4.15±0.25	55
RRIM 600	11.82±0.430	11.01± 0.45	10.14±0.60	9.64±0 52	4.18±0.13	57
GT 1	10.22±0.440	10.62± 0.35	9.05±0.35	9.11±0.33	3.88±0.15	57
PR 255	9.62±0.217	11.3± 0.38	8.94±0.45	8.68 ±0.34	3.7 ±0.24	57
70% light						
RRII 105	10.66± 0.60	11 ± 0.52	9.41±0.25	9.06±0.28	4.76±0.08	49
RRIM 600	11.85± 0.81	11.5± 0.43	10.8±0.30	9.44±0.54	4.9 ± 0.3	47
GT 1	13.5± 0.50	9.3 ± 0.53	9.8±0.31	9.02 ±0.36	4.4 ±0.15	51
PR 255	10.9± 0.65	9.6 ± 0.44	8.86±0.32	8.26 ±0.59	4.2±0.13	49
30% light						
RRII 105	9.49± 0.60	7.2 ± 0.26	6.7 ±0.60	7.1± 0.26	3.27±0.13	54
RRIM 600	9.95± 0.65	7.2± 0.32	6.68 ±0.34	7.1±0.39	3.9±0.11	45
GT 1	7.7± 0.60	7.11± 0.34	5.93±0.30	6.45 ±0.37	3.14±0.13	51
PR 255	6.8± 0.58	6.3 ± 0.37	5.46±6.00	6.5 ±0.36	3.70±0.24	44

± SE is shown, n=6-8

Ghats, in the farm of Kerala Livestock Development Board with a set of plants at RRII, Kottayam as control. Initially all the plants in both the environments were pruned to equal height from the bud union to bring uniformity in growth.

In spite of having successful sprouting in all the clones, a distinct impact of low temperature stress was noticed at Mattupetty. The average height of the plants at Mattupetty was only 14.3 cm in contrast to 64.8 cm at Kottayam after four months of growth. Almost all the plants grown in the warm climate of Kottayam were in the two whorl stage, while their counterparts in the low temperature climate failed to develop a complete whorl except in 15 plants. To understand the mechanistic insights of such low temperature effects on gas exchange, chlorophyll fluorescence and biochemical studies were conducted during December 1999 – January 2000. The CO_2 assimilation rate (A) of *Hevea* was significantly lower at Mattupetty both at low and high PFDs (Table Phy. 4). Also, *Hevea* grown at Mattupetty showed much smaller A than several native species such as Rose, Seteria, Napier and clover adapted to the Mattupetty conditions. The maximum potential quantum yield of PS II photochemistry as studied from the ratio of the maximum to variable chlorophyll fluorescence (Fv/Fm) in the dark adapted state was also significantly reduced in the rubber plants grown at Mattupetty.

Although effective PS II quantum yield (ϕ PS II) at a given PFD was lower at Mattupetty, there was relatively more electron transport rate (ETR) across PS II in the leaf for every mole of CO_2 assimilated in the low temperature grown plants (Table Phy. 5). This indicated low temperature induced photoinhibition of photosynthesis, which explains the stunted growth observed in plants at Mattupetty.

Table Phy. 5. **Effect of low temperature on PS II quantum yield of young *Hevea* plants**

PPFD (μmol m^{-2} s^{-1})	Yield (Ø PS II)	ETR (μmol m^{-2} s^{-1})
Mattupetty		
145.0 ± 5.7	0.239 ± 0.020	13.58 ± 0.80
536.4 ± 21.8	0.068 ± 0.011	15.59 ± 3.69
RRII, Kottayam		
141.6 ± 5.6	0.581 ± 0.006	35.33 ± 1.62
712.7 ± 12.9	0.191 ± 0.008	56.58 ± 2.39

2. Physiology of growth and yield

Six experiments on the physiology of growth and yield of *Hevea* are in progress.

Table Phy. 4. **Comparative effects of low temperature on gas exchange of young *Hevea* plants at low and high PPFD**

PPFD (μ mol m^{-2} s^{-1})	Gas exchange parameters: Leaf temperature (TL) (°C)	Stomatal conductance (gs) (mol m^{-2} s^{-1})	Transpiration (E, mmol m^{-2} s^{-1})	CO_2 Assimilation rate (A) (μmol m^{-2} s^{-1})	A/gs
Mattupetty					
199.1 ± 25.2	22.3 ± ~~20.9~~ 0.3	0. 123 ± 0.009	1.10 ± 0.34	1.02 ± 0.18	7.69 ± 1.04
1206 ± 30.9	30.2 ± 0.4	0.098 ± 0.007	2.12 ± 0.08	0.60 ± 0.24	6.85 ± 1.79
RRII, Kottayam					
214.4 ± 12.6	31.2 ± 0.3	0.50 ± 0.033	5.52 ± 0.16	5.70 ± 0.26	13.00 ± 0.63
1100.5 ± 15.9	34.6 ± ~~0.499~~ 0.2	~~0.43 ± 11.08~~ 0.499 ± 0.014	~~9.73 ± 0.2~~ 9.23 ± 0.21	~~0.014 ± 0.21~~ 11.08 ± 0.23	~~0.25 ± 0.68~~ 23.73

2.1 Yield and yield components

In the ongoing study on yield and yield components, observations from 12 clones at CES, Chethackal were recorded. The clone PB 235 recorded the highest girth (94 cm) followed by RRII 118 (90 cm) and the lowest in PR 107 (68 cm). RRII 105 continued as the highest yielder (56.8 g/t/t) and RRIM 612 was the lowest yielder (25.7 g/t in 1/2S d/2 system). Clone RRII 105 showed higher initial flow rate (IFR) and dry rubber content (DRC). Clone RRIM 612 recorded higher mean plugging index (PI) and very low DRC. The PI values of clones GT 1, PB 235, RRIM 600 and RRIM 703 ranged between 4.5 and 4.7 whereas that of Gl 1, PR 107 and Tjir 1 ranged between 7.5 and 8.5.

2.2 Mechanism of tapping induced loss of biomass

A project was initiated in July 1997 with five clones in a 1987 plantation at HBSS, Nettana to find out the mechanism of loss in biomass of a rubber tree subjected to regular tapping. The trees were opened for tapping during July 1997 and one set of trees was left untapped as control. The girth increment during the second year of tapping in d/2 tapped trees was lesser than the control in all the clones. Diversion of carbon sources to rubber biosynthesis explains the loss of biomass in tapped trees. The reduction in tapping induced girth increment was more in RRII 105 (59%) and less in PB 311 (30%).

The dark respiration mediated oxygen uptake rate was measured in soft bark tissue from tapping panel area of the d/2 tapped trees and from the corresponding point in the untapped trees during May 1999 and November 1999 representing summer and post monsoon, respectively. During the post monsoon season of 2000 onwards, the measurement of respiration was also extended to RRII 105 and PB 235 under d/3 tapping. The tapping panel respiration rate was significantly higher than untapped control trees. The high rate of respiration recorded in the tapping panel area could be due to the increased rate of metabolism for biosynthesis of rubber molecules as well as possible wound induced maintenance respiration. There was seasonal changes in the respiration rate of tapped trees. Respiration was higher in post monsoon (November) than summer (March) in all the clones. Among the tapped trees, clones PB 235 and RRII 105 recorded the maximum respiration during summer and post monsoon, respectively and clones PB 260 and RRII 300 recorded the minimum respiration (Table Phy. 6). In clone PB 235, d/3 tapped trees recorded significantly less respiration than d/2 tapped trees indicating that low frequency of wounding leads to small respiratory activity. The total sugar content in tapping panel area was higher than untapped trees in all the clones in summer season but the difference was not significant in post monsoon. There was no difference in starch content between tapped and untapped control trees in both the seasons.

Table Phy. 6. **Dark respiration rate of soft bark tissues in tapped and untapped *Hevea* clones**

Clone	Respiration rate (n mole O_2 g^{-1} dry wt. min^{-1})				
	Summer		Post monsoon		
	Untapped	d/2	Untapped	d/2	d/3
RRII 300	269.3 ± 08.30	423.6 ± 27.0	339.4 ± 29.00	497.0 ± 42.4	---
RRII 105	295.8 ± 05.14	534.8 ± 29.3	311.4 ± 19.60	708.4 ± 16.1	681.7 ± 16.0
PB 235	210.3 ± 06.70	541.3 ± 18.2	360.0 ± 33.80	682.0 ± 46.8	557.8 ± 21.1
PB 260	271.13 ± 14.60	472.9 ± 17.1	178.0 ± 08.87	479.0 ± 21.4	---
PB 311	253.5 ± 13.00	527.3 ± 17.7	255.0 ± 08.50	692.14 ± 46.0	---

± SE; n = 6-10

Table. 7. **Rate of various pathways of dark respiration and ATP content in tapped and untapped trees**

Parameter	Untapped tree	Tapped tree
Total respiration (n moles O_2/g dry wt/min)	266.9 ± 16.9	644.73 ± 33.8
Cytochrome-c oxidase	236 ± 15	386.5 ± 25.6
Alternative oxidase	47.3 ± 4.4	258.3 ± 10.05
Residual respiration	9.8 ± 2.9	168.6 ± 3.2
ATP content in soft bark (n mole /g fresh wt)	347 ± 129	47.3 ± 3.04
ATP in C- serum (n mole/ml)	551 ± 72	2532 ± 77

± SE; n= 8

2.3 Tapping induced respiration and ROS scavenging

A study was taken up for examining the interrelationship between the rate of respiration, ATP content and ROS scavenging activities in tapped and untapped *Hevea* trees. The rate of dark respiration was measured in soft bark tissue of tapped and untapped trees of RRII 105 with different inhibitors, namely, KCN to inhibit cytochrome pathway and Salycylhydroxamic acid (SHAM) to inhibit alternative oxidase (AO) pathway. The tapped trees recorded significantly higher rates of total cyt-c oxidase, cyanide resistant alternative oxidase and residual respiratory activities compared to the untapped tree (Table Phy. 7). The ATP content in untapped bark tissue was found to be seven fold higher than that in tapped trees when the samples were collected after harvesting the latex. Contrary to this, a very high ATP content was noticed in C-serum of tapped tree. The result indicated that a metabolically active tapped rubber tree (as indicated by increased respiration) produces enormous amount of ATP, which is lost through serum and hence not detected in the soft bark tissue. A tapped tree is also loosing considerable amount of resources through the non-phosphorylating AO pathway.

2.4 Clonal variation in ATP pool and latex regeneration

A project was started in November 1999 at RRII to study the clonal variation and effect of stimulation in the adenylate content, its biosynthesis and regulation in the latex regeneration mechanism and thereby yield. Clones RRII 105, RRIM 600 (high yielders), RRII 38 and HP 20 (low yielders) were selected. Latex samples were analysed for sucrose, inorganic phosphorus and adenylates. H^+ ATPase activity was determined from lutoids and pH of C serum, B serum and latex was measured. The initial results of this study showed significant correlation of ATP content, ATPase activity and C-serum pH with yield irrespective of clones. This study is in progress.

2.5 Physiological changes in leaves during wintering and refoliation

The project to study the changes in leaf biochemical parameters of untapped and tapped trees of *Hevea* during wintering and refoliation was continued. The changes in total chlorophyll, soluble protein, free amino acid, sugar, starch, MDA and per cent membrane damage during refoliation phase were recorded. Correlation coefficients of various leaf biochemical parameters from pooled data of untapped and tapped trees of *Hevea* during wintering are presented in Table Phy. 8. The chlorophyll content during the post maturation and wintering phases was positively correlated with the contents of soluble protein, sugar, starch contents of the leaf and was negatively correlated with free amino acid, MDA and per cent leakage. The free amino acid content during wintering phase was negatively correlated with the soluble protein content. Soluble protein content showed a positive correlation with sugar and starch contents and it showed a negative correlation with

Table Phy. 8. **Inter-relationships among biochemical properties during wintering phase**

	Protein	FAA	Sugar	Starch	MDA	% leakage
Chlorophyll	+0.95 **	-0.74 **	+0.85 **	+0.89 **	-0.95 **	-0.96 **
Protein		-0.62 *	+0.93 *	+0.97 **	-0.84 **	-0.95 **
Free AA			-0.50 *	-0.57 *	+0.74 **	+0.72 **
Sugar				+0.98 **	-0.67 **	-0.83 **
Starch					-0.73 **	-0.88 **
MDA						+0.92 **

* Significant at 5% level ** Significant at 1% level

MDA and per cent leakage. Free amino acid was negatively correlated with sugar and starch contents and positively correlated with MDA and per cent leakage. Sugar was positively correlated with starch and was negatively correlated with MDA and per cent leakage. Starch showed a negative correlation with MDA and per cent leakage. A positive correlation was observed between MDA and per cent leakage during wintering.

The correlation coefficients of various leaf biochemical parameters from pooled data of untapped and tapped trees of *Hevea* during refoliation phase (Table Phy. 9) showed a positive correlation among the various parameters during refoliation phase.

2.6 Intraclonal variations in yield and yield attributes

An experiment was conducted to study the intraclonal variations in yield, yield attributes and their associations in RRII 105 in a plantation at Vennimala, Kottayam. Twenty three healthy trees of the clone RRII 105 were selected at random from 400 trees, which were planted in 1985 and opened for tapping in 1992. The parameters *viz.*, yield per tree per tap, DRC and concentrations of sucrose, thiol and inorganic in the latex were recorded monthly for a period of two years. The mean dry rubber yield per tree per tap varied from 12 to 126 g and the coefficient of variation of the monthly mean rubber yield ranged from 22 to 46%. The mean DRC varied from 29 to 50% and its coefficient of variation ranged from 4 to 11%. There were large variations in the mean PI computed for each month. The concentrations of sucrose, inorganic P and thiol present in the latex also showed fairly large coefficient of variation for their respective means computed for every month. Among the variables studied here, DRC showed relatively smaller coefficient of variation through out the year.

Path coefficient analysis with yield as the dependent and DRC, PI, sucrose, inorganic P and thiols as the independent variables was made. Results revealed that direct and indirect effects of the variables PI and inorganic P were significant. DRC has moderate influence on yield, while the other two variables sucrose and thiols have no influence on yield. Inorganic P was found to be a crucial parameter in assessing the yield capability of a clone just similar to PI. The results of the study show the existence of large tree-to-tree variation not only in yield and yield attributes such as DRC but also in the biochemical composition of the

Table Phy. 9. **Inter-relationships among biochemical properties during refoliation phase**

	Protein	FAA	Sugar	Starch	MDA	% leakage
Chlorophyll	+0.75 **	+0.78 **	+0.72 **	+0.70 **	+0.89 **	+0.70 **
Protein		+0.83 **	+0.59 **	+0.56 *	+0.81 **	+0.62 **
Free AA			+0.75 **	+0.68 **	+0.93 **	+0.75 **
Sugar				+0.88 **	+0.83 **	+0.75 **
Starch					+0.73 **	+0.81 **
MDA						+0.71 **

* Significant at 5% level ** Significant at 1% level

latex within the clone RRII 105 grown in the traditional rubber growing area.

3. Stock-scion interaction

An experiment was initiated at RRII Farm in May 1999 to observe the interclonal variability in growth and yield. Monthly recordings of yield, PI, DRC, *etc.* of 13 clones were made from the first month of opening the trees. Girth recording once in three months, was also done. Biochemical analysis was carried out in seven of the above clones. Considerable coefficient of variation was observed in all these parameters among the trees within each clone suggesting genetic heterogeneity of the root stock as the source of the variations.

The experiment on upward (high panel) and normal tapping of healthy and TPD affected trees was continued in the clone RRII 105 at CES, Chethackal. The study is being conducted to find out whether translocated type of incompatibility exists in TPD affected trees.

3.1 Scion - scion interaction

To study the performance of budded plants having the rootstock and scion of the same clone (for a homogenous condition for stock and scion) a seedling nursery was raised at RRII comprising of polyclonal and monoclonal seedlings. Clones selected were RRIM 600, GT 1 and PB 86. Now the seedlings are ready for budding and replanting in polybags.

The project on scion-scion communication in terms of the wintering behaviour of *Hevea* is in progress. After field planting of single and double budded plants percentage survival of plants of each clone was noted. Gap filling was done to compensate the casualty. Pruning was carried out in a uniform manner.

4. Tapping panel dryness

Tapping panel dryness (TPD) decreases the ability of the *Hevea* tree to synthesise rubber and thus reduces the productivity of the crop. Susceptibility to TPD was reported to be related to high exploitation of the tree. Despite the investigations on cytological and pathological aspects as well as the latex physiological and biochemical characteristics associated with the onset of TPD, the real cause of this disorder remains unclear. Earlier studies have shown that the availability of carbohydrate substrates for cis-polyisoprene biosynthesis was not a limiting factor. Instead, the metabolic conversion of sugars, the primary processor for rubber biosynthesis, into IPP which is an extremely energy consuming process was probably affected.

4.1 Biochemical changes

A study initiated in 1999 to assess the biochemical changes associated with TPD continued and biochemical components were analysed in the normal and affected trees of RRIM 600. The high peroxidase activity and accumulation of phenols in the soft bark tissue of *Hevea* trees indicate possible oxidative stress in the TPD affected tissue. The other free radical scavenging systems like superoxide dismutase (SOD), peroxidase (Px), thiols and phenols along with sugars and proteins in the soft bark tissue from the wet and dry stretches in the tapping panel and its back side in TPD affected trees in comparison with normal trees (Table Phy. 10) were analysed. The over expression of some of the free radical systems was noticed during the advanced stages of TPD. The bark tissue of RRIM 600 also indicated the possible oxidative stress during the onset of TPD as shown earlier in clone RRII 105. Thus the bark tissue are metabolically damaged due to the oxidative stress, which inhibited the metabolic conversion of sucrose into rubber during TPD.

4.2 Respiration and ATP status

Studies were conducted in the clones GT 1, RRIM 600 and RRII 105 to examine the

Table Phy. 10. **Biochemical composition of the soft bark in RRIM 600**

Parameter	Normal tapping panel (TP)		TPD tapping panel		
	TP	Back of TP	Dry stretch	Wet stretch	Back of TP
Soluble protein (mg/g fresh wt.)	15.50 ± 1.05a	14.30 ± 1.60a	21.50 ± 0.97b	25.60 ± 2.43c	16.10 ± 1.5 a
Soluble sugars (mg/g fresh wt.)	31.60 ± 1.26a	25.30 ± 2.37b	38.10 ± 1.44c	40.10 ± 0.58c	31.80 ± 1.64a
Thiols (mg/g fresh wt.)	0.59 ± 0.05 a	0.52 ± 0.06 b	0.81 ± 0.04 c	0.73 ± 0.03 c	0.52 ± 0.05 a
Phenols (mg/g fresh wt.)	3.50 ± 0.11 a	3.40 ± 0.18 b	3.90 ± 0.12 b	4.00 ± 014 b	3.60 ± 0.22 a
Melondialdihyde (m mol x10^{-5}g dry wt.)	1.52 ± 0.08 a	2.25 ± 0.14 a	1.19 ± 0.09 c	1.56 ± 0.08 a	1.47 ± 0.21 a
Peroxidase (U/mg protein/min)	1.52 ± 0.15 a	1.55 ± 0.41 a	4.32 ± 0.48 b	4.59 ± 0.42 b	4.97 ± 0.71 c
SOD (U/mg protein/min)	1.76 ± 0.23 a	1.17 ± 0.14 b	0.92 ± 0.07 b	0.99 ± 0.12 b	1.11 ± 0.12 b

Values indicated with similar alphabets are not significantly different

respiratory rates of the bark tissue from TPD affected and normal trees and relate them to the carbohydrate status of the tissue and the ATP content of the cytosol. The soft bark tissue of TPD affected trees had more sugar and starch contents in the tapping panel than the healthy trees. Concomitant with an increase in the total sugars, sucrose and starch contents, there was an increase in the respiration rates in the bark tissues of the affected trees compared to healthy trees (Table Phy.11). The respiratory rates were almost similar between the yielding and non-yielding stretches of the tapping panel of the TPD trees. The total soluble sugars and starch contents in the wet and dry stretches of the tapping panel of the TPD trees showed significant clonal variations.

A study on the tissue respiration in RRII 105 and RRIM 600 confirmed that the enhanced bark respiration noticed in TPD trees was due to the accelerated alternative pathway (cyanide resistant respiration) (Table Phy. 12). Simultaneous with the increase in alternative pathway in the bark tissues of TPD trees, there was also a remarkable reduction in the ATP content in the latex. It appeared that the increased respiratory activity in the bark and the decreased ATP status in the cytosol were due to an increase in the cyanide resistant alternative respiration in the TPD affected trees. Intermedi-

Table Phy. 11. **Respiration rate and total soluble sugar and starch contents of the soft bark tissue from the normal and TPD affected trees (n = 7-10) ±S.E.**

Parameter	Normal		TPD		
	Tapping panel	Back side of the panel	Non-yielding stretch	Yielding stretch	Back side of the panel
Clone RRII 105					
Respiration (n moles O_2/g dry wt/min)	647 ± 34	549 ± 30	772 ± 7	849 ± 17	459 ± 26
Total soluble sugars (mg/g fresh wt)	42.7 ± 2.50	52.3 ± 3.85	51.3 ± 1.30	62.8 ± 7.6	57.1 ± 8.85
Starch (mg/g fresh wt)	47.1 ± 1.10	50.5 ± 2.29	57.7 ± 3.11	60.3 ± 3.67	58.0 ± 1.09
Clone GT 1					
Respiration (n moles O_2/g dry wt/min)	669 ± 55	465 ± 20	927 ± 10	901 ± 52	659 ± 55
Total soluble sugars (mg/g fresh wt)	43.5 ± 1.44	66.7 ± 4.7	83.7 ± 6.17	65.0 ± 8.67	68.8 ± 4.64
Starch (mg/g fresh wt)	45.8 ± 2.33	81.1 ± 6.70	66.7 ± 0.98	61.2 ± 5.72	90.8 ± 5.43

Table Phy. 12. **Different types of respiration in soft bark tissue of *Hevea* clones**

Respiration (nM O_2/min/g dry wt.)	RRII 105		RRIM 600	
	Normal	TPD	Normal	TPD
Total	558 ± 19	670 ± 25*	572 ± 27	686 ± 31*
SHAM inhibited (Cytochrome)	361 ± 27	368 ± 25	365 ± 22	385 ± 18
KCN inhibited (AO)	275 ± 22	346 ± 22*	316 ± 20	403 ± 20*
Residual	194 ± 08	221 ± 14	147 ± 4.48	166 ± 24

ates of isoprene pathway such as HMG CoA and mevalonate were found at a higher concentration in TPD affected tissues. It appears that poor conversion of mevalonate to IPP due to the poor supply of ATP may be the cause of retarded rubber biosynthesis in TPD trees. Investigations are in progress.

5. Secondary metabolism

Photosynthates are converted into different secondary metabolites in plants. Inositols are one of the secondary metabolites found in rubber latex. A project was initiated to study the inositols in *Hevea* latex.

5.1 Inositols

An experiment was carried out with 13 clones *viz.*, RRII 5, RRII 105, RRII 118, RRII 208, RRII 300, RRII 308, RRIM 600, RRIM 703, PR 255, PR 261, SCATC 88-13, SCATC 93-114 and Haiken 1 to determine the seasonal and clonal variations in total inositol content in latex. Yield, DRC, total latex volume and initial flow rate were also recorded. Total inositol content in latex, estimated monthly ranged from 0.16 to 0.89% by weight and varied with the clone and season. Clonal variation in inositol-1-phosphate synthase was also observed. The study is in progress.

6. Ecological impact of *Hevea* cultivation

The first phase of this interdisciplinary study to assess the impact of rubber cultivation on the microenvironment is nearing completion. Studies on water consumption by rubber and other forest tree species, microclimate changes inside different monoculture plantations, soil nutrient status, litter production, decomposition *etc.* have been carried out.

RUBBER CHEMISTRY, PHYSICS AND TECHNOLOGY DIVISION

The focus of research of the Division was on natural rubber (NR) processing, chemical modification, rubber composites, elastomer blending/compatibility and latex technology, evolving of methodologies to upgrade the quality of different forms of NR and identification of new areas of consumption.

Pilot plant production of styrene-grafted natural rubber (SGNR) was initiated and the material was supplied to a premier footwear manufacturing unit for evaluation. Epoxidised natural rubber (ENR) was identified as a reinforcement modifier in silica-filled elastomers *viz.*, NR, SBR and NBR and efforts were made to patent the above findings. Collaborative studies were initiated with a major clay manufacturing industry on the application of chemically modified clays. By adopting the already developed enzymatic deproteinization process, pilot plant-scale trials were carried out to produce low protein latex. Attempts were also made to develop functionalized NR lattices for biomedical application.

A study was initiated to analyse the quality and level of consistency of sheet rubber being produced in four major rubber growing regions. The effect of storage of

field coagulum under various conditions prior to its processing to TSR, was also studied.

1. Primary processing and storage

1.1 Primary processing

The study to assess the effect of drying sheet rubber under direct sunlight was concluded with five replications. It was observed that though plasticity, mooney viscosity and gel content of the rubber dried under sunlight, fully or partially were high, significant differences were not observed in the breakdown behaviour. Comparatively lower plasticity retention index (PRI) was observed for sun dried samples and a slight excess exposure to sun deteriorated the quality/appearance of the sheet rubber. Drying in sunlight during the initial period with subsequent drying in smoke house render sheets conforming to grades not less than RSS 4.

A study to find the factors affecting coagulation of fresh NR latex with the objective to standardise a method for rapid estimation of the dry rubber content (DRC) of fresh NR latex was initiated. It was observed that fresh NR latex coagulates quickly by addition of acids in presence of definite quantities of higher fatty acid soaps. The efficiency of fatty acid soaps in increasing the coagulative power of acid depends on its solubility in water. Other factors which were examined for their role in coagulation of latex were pH and DRC of latex and concentration of metal ions present in latex. Based on a series of experiments a calibration graph was made. The DRC of NR latex can be obtained directly from the calibration curve by noting the value of DRC corresponding to the volume of acid required for coagulation. Action was taken to refine the method.

A study was undertaken to identify a coagulant which is as effective as formic acid but cheaper and having less adverse effect on properties of rubber. The preliminary observations of the coagulum mixture in comparison to formic acid are given in Table Chem. 1.

The major marketable form of NR available in India is the ribbed smoked sheet (RSS), that is predominantly produced by the small grower sector. The visual grading system has constraints in assessing the quality and level of consistency of the sheet rubber. Therefore, a study has been initiated to assess the above parameters of RSS 4 grade sheets produced in the major rubber growing regions. Regions and centres of collection were identified and a method of sampling with statistically sound layout was derived. Sample collection has been initiated.

1.2 Storage of NR

Longer storage of NR leads to hardening which adversely affects its processing behaviour. Also it could lead to mould growth on the surface of the sheet, making it unacceptable in the market. The factors such as humidity, temperature and mode of stacking could influence the storage behaviour of rubber. In the present context, different storage spells could be expected at the level of farmer/dealer/other procurement agencies. Hence, a study was initiated to investigate the effect of storage on the properties of NR and to optimize the conditions of storage.

Table Chem. 1. **Comparison of coagula**

Parameter	Coagulant	
	Formic acid	Coagulant mixture
Minimum maturation time required for sheeting the coagulum	7 h	4.5 h
Clarity of serum	Clear serum	Almost clear (like control)
pH of serum	4.7	5.1
Drying time of sheet	-	Same as control

The properties of the NR samples stored in different environment of temperature and humidity were tested periodically. Mooney viscosity and gel content were observed to increase as the storage period increased. Plasticity (Po) value recorded an increase up to 6 months and then remained more or less the same. PRI of samples kept in low humidity region remained more or less constant whereas a reduction in PRI was observed for samples kept in a high humidity condition. Acetone extractables were observed to decrease with storage period. Volatile matter of sheets kept in both locations increased and the increase was more pronounced in the low humidity region. Sheets stored in high humidity area were affected by mould growth after three months. The samples are proposed to be stored for a period of two years.

To evaluate the effect of preprocessing conditions on the quality of NR, latex samples were allowed to auto coagulate and the coagulum was processed into crepe rubber periodically. Samples were dried and the PRI and initial plasticity were determined. It was observed that the PRI of samples decreased with increase in storage period. Immersing the coagulum in different alkaline media did not improve the raw rubber properties. GPC measurements have shown that the molecular weight of samples stored for four weeks prior to processing reduced considerably with low molecular weight fractions predominating.

2. Chemical modification

NR could be modified into different forms to make it suitable for specific applications. ENR, thermoplastic NR, graft copolymers and chlorinated NR are the commercially significant chemical modifications of NR. Focusing was initiated on two modified forms of NR *viz.*, SGNR and NR modified with functional monomers.

In the project on graft copolymerisation of styrene onto NR, the effect of age of field latex, stabilizers and sensitizer on the grafting efficiency was studied. The technology for the production of SGNR was transferred to P&PD Department and necessary technical support was offered during its production. As a process of seed marketing, SGNR was supplied to one of the premier footwear manufacturing units. The material is being evaluated as a reinforcement modifier in microcellular soles.

In the study to develop a process for the production of functionalized NR lattices for biomedical applications, initial trials were conducted to graft copolymerise glycidyl methacrylate (GMA) onto NR in latex stage using gamma irradiation. The stability of the modified latex was observed to be comparatively less when the monomer content was above 10 phr. Efforts were started to improve the same using different antioxidant combinations.

3. Blends / Compatibilizers

Elastomer blends have gained much importance due to their superior properties compared to single elastomers. The blending of small amount of ENR with NR, SBR and NBR was found to substantially improve the dispersion of silica and therefore the technological properties of the filled system. The focus was to explore the possibility of using ENR as low cost modifier in place of the costlier silane coupling agents which are being used at present.

Studies to ascertain the effect of ENR as a reinforcement modifier in NR-silica composites were continued. Rheological characterization of NR-silica composites were done in a capillary rheometer. Lower viscosity was noticed for the ENR modified samples, especially at lower shear rates. Experiments were also initiated to study the effect of ENR in SBR-silica composites. Cure characteristics, technological properties and resistance to ageing were found to be improved with incorporation of ENR.

The NBR-silica system containing ENR as a reinforcement modifier were compared with ISAF and silica filled systems contain-

ing silane coupling agent. Two accelerator systems in the above compounds *viz.*, CBS and CBS/DPG were evaluated. Both single and binary accelerated systems showed improvement in properties with ENR addition. To assess the rubber-filler interaction, bound rubber content was measured and the same for few typical mixes are given in Table Chem. 2.

Table Chem. 2. **Effect of modifiers on the bound rubber content**

Mix	Bound rubber
NBR-Silica	27.16
NBR-10ENR-Silica	40.44
NBR-15ENR-Silica	41.59
NBR-2%Si69	29.12
NBR-8%Si69	31.36
NBR-IASF	34.82

NBR-silica system containing ENR as the modifier was observed to have higher bound rubber content. Also these compounds exhibited ageing resistance comparable to those modified with conventional coupling agent.

4. Rubber composites

Various rubber composites are being used for different applications. The potential of NR modified bitumen asphalt mixes to improve the service life of highways have been well established. To overcome the constraints experienced in carrying out the bitumen-latex blending at the work site, it was proposed to effect the blending at the refinery level. This ensures more effective control of the processing conditions and hence better consistency for the modified bitumen.

Necessary technical support was given to Kochi Refineries Limited for the production of rubber modified bitumen on a pilot plant at the refinery. The quality parameters required for the latex to be used for modifier were finalised.

Coconut shell powder (CSP) at present finds application as a flooring material and as a component for hard/smoothly finished thermoplastic mouldings. A study was initiated to evaluate the use of the same as a filler in rubber compounding. It was observed that the Hexamethylene/Resorcinol/Silica treated CSP improved all properties of the vulcanizates in comparison with the untreated CSP and other semi-reinforcing non-black fillers. Also the incorporation of CSP was observed to impart high abrasion resistance, low heat build up and better electrical resistance.

As clays are mostly semi-reinforcing and have lower cost than other fillers, any attempt to improve its reinforcing potential deserves attention. The surface modifications of clays can significantly improve the properties of resulting vulcanizates. The study was proposed in collaboration with a major clay manufacturing unit. The amino silane and mercapto silane modified clays were observed to have improvements in properties compared to the conventional clays. Evaluation of less costlier grades of modified clays was initiated.

5. Latex technology

NR latex products are facing serious challenges owing to the allergic effects of extractable proteins (EP). Several techniques are being adopted for manufacturing product with very low EP content, so that allergic effects can be minimised. Use of low protein centrifuged latex could substantially reduce the EP content of the products. Action was taken to standardise a method for production of deproteinised latex using a proteolytic enzyme in a single centrifuging process.

Sulphur vulcanization essentially requires accelerators which may lead to residual nitrosoamines. Radiation vulcanization has been suggested to overcome the above problem. However, inferior strength properties of radiation vulcanized NR latex (RVNRL), compared to sulphur vulcanizates imposes limitations on its wider applica-

tions, especially in the biomedical field. Efforts are being carried out to overcome the above aspects.

5.1 Enzymatic deproteinization of NR latex

Pilot plant studies were carried out at Pilot Latex Processing Centre, Chethackal, adopting the method standardised earlier.

Compounds were prepared using the above lattices and tensile properties and ageing characteristics of the film were determined. The EP content of the films were determined before and after wet/dry gel leaching (70 °C for 2 min). The properties of the raw latex and latex film vulcanizates were found to be satisfactory. EP content of vulcanizates from the low protein latex was low, even before leaching.

The enzyme treated sample has comparable level of EP content with double centrifuged latex. Also the former was found to be suitable for dipping operations and the vulcanizate properties of the same were satisfactory.

Towards upgradation of the quality of RVNRL, the effect of maturation on the properties of RVNRL was attempted. The RVNRL films were prepared, dried at room temperature and leached for 24 hours. The properties of the films were evaluated. The initial studies showed that the storage period of latex up to 45 days before irradiation showed better strength properties.

6. Characterization of molecular parameters of lattices of different clones

Collection of three sets of samples was completed and the characterization of molecular parameters of the selected 13 clones was continued.

AGRICULTURAL ECONOMICS DIVISION

The Division concentrated on studies pertaining to economic aspects of natural rubber cultivation, processing, marketing, end uses, ancillary sources of income and by-products. Inter-divisional collaborative studies were also undertaken to analyse the economic viability of experimental findings.

During the period under review four major projects were completed by the Division, which included one interdivisional collaborative project. Results and findings of two major projects were published by the Division as monographs, *viz.*, (1) 'Commercial yield performance of *Hevea* clones in India: A comparative analysis' and (2) 'Indian Rubber Products Manufacturing Industry: Evolutionary Dynamics and Structural Dimensions.' These monographs are expected to be valuable sources of reference material for planters, researchers, policy makers as well as those interested in the development of Indian rubber products manufacturing industry. The Division has eleven ongoing projects.

1. Commercial yield performance of *Hevea*

The study was undertaken with the objectives of (a) analysing the trends in yield and related factors of *Hevea* clones during different decades (b) comparing the yield performance and other factors during different phases (c) examining the clonal stability in yield over seasons, locations and age of the tree and (d) assessing the overall performance of clones in a comparative perspective of the planting material recommendations in India *vis-a-vis* Malaysia. A comprehensive report has been published in the form of a monograph covering yield and related aspects of 27 clones under commercial cultivation in India. The study forms part of a continuous commercial yield evaluation scheme initiated by the Rubber Research Institute of

Table Age.1. **Yield and related variables over decades (1-10 year phase)**

Variables	1950s	1960s	1970s	1980s
Yield (kg/ha)	1100	1229	1389	1514
Yield/tree (kg)	3.62	3.7	4.15	4.5
Tappable stand (no./ha)	304	332	335	336
Share of field coagulum (%)	29.2	31.1	27.3	26.6
Tapping intensity (%)	94	88	82	77
Immature phase (years)	8.4	8	7.9	6.9

India in 1974. Information on yield per ha, yield per tree, share of field coagulum, tapping intensity and tappable stand of different clones were analysed for different phases. The reported mean duration of immature phase of the 27 clones was 8.01 years, the clonal difference being 5.7 years in the case of PB 260 to 9.3 years in the case of PB 5/63 and RRIM 628. Information on yield was supplemented with an analysis of seasonal and locational yield stability. The peak season (October to January) and lean season (February to March) accounted for 45.4 and 19.6% of the annual yield respectively. The high yielding clones reported lower seasonal stability compared to low yielders. Except in the case of Gl 1, PB 235, RRII 105 and PB 217, which are reported to have higher level of locational stability during the 1-5 year phase, all other clones showed a steady increase in locational stability in the 5-10 year phase.

Mean yield and related attributes of the plantations belonging to the 1-10 year phase, established during the decades between 1950 and 1980 are given in Table Age.1.

Mean yield during the 1-10 year phase was 1100, 1229, 1389 and 1514 kg/ha respectively during the four decades. The steady increase in yield/ha over the decades can be attributed mainly to the adoption of modern high yielding varieties and improved cultural practices.

2. Rubber products manufacturing sector

A comprehensive report in the form of a monograph was published analysing the origin, evolutionary growth and current status of Indian rubber products manufacturing industry and its structural dimensions. The analysis on the evolutionary growth identified the historical, economic and political factors contributing to the development of the nascent industry. The major structural dimensions of the industry were analysed from sectoral and regional perspectives so as to draw relevant guidelines for appropriate policy inputs. Based on the relative shares in the total consumption of NR in the country during 1996-97, the important NR consuming states were grouped as high, medium and low propensity states (Table Age.2). The main objective of the classification was to assess the growth potential of NR consumption in the country.

Table Age.3 shows the growth rates in NR and total rubber consumption across the states. The most important trend evident from Tables Age. 2 and 3 is that among the four states, which have recorded higher growth rates in NR consumption, three

Table Age. 2. **Classification of States based on NR consumption (1996-97)**

High propensity states (relative share above 10 %)	Medium propensity states (relative share between 5% and 10%)	Low propensity states (relative share less than 5%)
Punjab	Gujarat	Andhra Pradesh
Kerala	Haryana	Delhi
Uttar Pradesh	Rajasthan	Goa & Daman
Maharashtra	Tamil Nadu	Karnataka
	West Bengal	Madhya Pradesh

Table Age.3. **Compound rate of growth in the consumption of different types of rubber (1985-86 to 1996-97)**

State	NR	SR	RR	Total
Andhra Pradesh	9.26	14.08	13.44	10.6
Delhi	3.60	2.89	7.24	3.72
Goa & Daman	11.15	3.69	7.09	9.61
Gujarat	11.96	12.56	11.83	12.03
Haryana	3.29	0.94	4.27	2.79
Karnataka	4.41	2.40	5.56	4.05
Kerala	5.54	9.33	3.63	6.15
Madhya Pradesh	21.56	17.59	31.05	21.14
Maharashtra	3.28	3.17	2.31	3.15
Punjab	5.97	3.62	2.82	5.09
Rajasthan	9.77	5.07	6.79	5.63
Tamil Nadu	4.37	3.13	2.79	3.93
Uttar Pradesh	4.95	4.52	3.32	4.72
West Bengal	2.69	0.04	(-)0.04	1.88
Others	2.96	(-)14.40	5.57	(-)0.86
All India	5.53	4.55	3.53	5.14

states (Madhya Pradesh, Goa and Daman and Andhra Pradesh) belong to the low propensity group and the remaining one (Gujarat) in the medium propensity group. A positive aspect of the observed trend is that the combined share of these four 'high growth' states in total rubber consumption is only 15.49% and therefore, the potential for the growth of NR based industries is relatively higher in the new regions. Conversely, among the high propensity states, Kerala has achieved maximum growth in total rubber consumption (6.15 %) and it is important to note that the State has a higher growth rate in SR consumption (9.33 %) compared to that in NR consumption (5.54 %).

3. Impact of economic reforms on automotive tyre industry

The study is perceived in the backdrop of the ongoing process of economic reforms in Indian economy and the objective was to assess the impact of economic reforms on production, export and import of the major tyre segment, *viz.*, the truck and bus tyres.

The analysis indicated that there are well-defined limitations in sustaining the domestic demand-driven export growth to reap the advantages of scale economies. The tyre production sector in India is on the verge of a major shake up with the entry of multi-national corporations (MNCs) in the post-reforms phase with its concomitant consequences on the structure of production underlying the need for rationalization of product-mix favouring radial tyres with large-scale investment.

4. Rubber by-products sector

The studies on the production and consumption of ancillary products *viz.*, rubber wood, rubber seed and honey are continuous in nature. During 1999-2000 the estimated availability of rubber wood was 1.40 million m^3. But the actual production during the period was around 20% lower than the projected availability due to slackened demand and low prices. The stem wood, which forms 60 per cent of the total is used for industrial purposes and the branch wood as fire wood. The end use pattern of stem rubber wood shows that 56.50% of the stem wood is consumed by the packing case industry (Table Age.4)

Table Age.4. **Consumption pattern of stem rubber wood**

Consuming sector	Consumption (%)
Packing cases	56.5
Safety matches	3.0
Plywood	26.5
Processed wood *	12.0
Others	2.0

* includes rubber wood treated through diffusion process also.

The estimated production of rubber honey during the period remained 1750 t. The production of rubber seed oil and cake was estimated to be 2000 t and 3250 t respectively (Table Age. 5).

Table Age.5. **Production of ancillary products**

Production	Quantity
Rubber wood	1.12 ('000 m^3)
Rubber seed oil	2000 t
Rubber seed cake	3250 t
Honey	1750 t

Table Age.1. **Yield and related variables over decades (1-10 year phase)**

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4.1 Rubber seed processing industry

The study is based on primary surveys conducted during 1996 and 1999. During 1996, data was collected from 20 rubber seed dealers and 10 seed processing units in Kerala and Tamil Nadu. Data for the period from 1996-97 to 1998-99 was collected in 1999 from 10 processing units in Tamil Nadu. The study revealed that the rubber seed processing sector was enveloped by hurdles at procurement, processing and marketing front such as declining collection of seeds, difficulties in getting molasses, falling prices and declining demand for oil, competition from substitutes etc. Further, rubber seed processors cannot avail the benefits of promotional schemes enjoyed by other oil processors since rubber seed oil is still included in the category of hill products. The volume of rubber seeds collected is declining annually and most of the former full time processors have switched over to other non-edible oil seeds and rubber seed processing is confined to the slack season of other seeds. Due to the low procurement price of seed and high wage rates, the annual collection is expected to decline in the forthcoming years as well. The rising cost of processing and the difficulties at the marketing front also predict a bleak future for this industry. R & D activities to identify commercially sustainable uses are vital in improving the status of the rubber seed processing sector.

Other studies such as operational efficiency of rubber plantations under different levels of management, an investigation into the development and structural changes of Indian rubber plantation industry during the colonial era (1902-1947), analysis of stockholding practices of the rubber small growers in Kerala, analysis of the impact of price change of NR on investment and employment in rubber smallholdings sector and price stability and growth of rubber cultivation in Kerala are in progress.

WORLD BANK-ASSISTED RUBBER PROJECT RESEARCH COMPONENT

1. Exploitation studies

Low frequency tapping trials laid out in various estates and medium holdings as well as in experimental farm at RIT, Pampady progressed well during the period under report. In general, 15-30% sustainable yield increase is possible under d/3 frequency of tapping by judicious stimulation. In clones RRII 105 and PB 217 under d/3 frequency tapping, three stimulations in an year would give satisfactory yield improvement whereas and for GT 1 and RRIM 600, four stimulations were needed (Tables Wb. 1 & 2).

Under d/4 system, six stimulations were required in clone RRII 105 to get optimum yield, whereas, in clone GT 1 seven stimulations and in PB 217 five stimulations were needed to get profitable yield (Table Wb. 3). No adverse effect of stimulation could be noticed in the long-term trials carried out.

Table Wb. 1. **Yield performance (kg/400 trees/year) under d/3 frequency with stimulation in clone RRII 105**

Location	Panel	Control	T1	T2	T3
Tropical Plantation, Mundakayam	BO - 1	1768(100)	2066(117)	2110(119)	2224(126)
Kalarickal, Kottayam	BO - 2	2199(100)	2549(116)	2558(116)	-
Palampra Estate, Kanjirapally	BO - 1	2097(100)	2303(110)	2435(116)	-
TR&T Estate, Ambanad	BO - 1	1344(100)	1375(102)	1754(130)	-

Stimulation : Panel application 3-5; Mean of five years. There was no decline in response over 6 years

Table Wb. 2. **Yield performance (kg/400 trees/year) under d/3 frequency of tapping in other clones**

Location	Clone	Panel	T0	T1	T2	T3
HML, Cheruvally	PB 217	BO -1	1473(100)	1595(108)	1708(116)	1795(122)
New Ambadi, Kulasekharam	RRIM 600	BO -1	1573(100)	1936(123)	1827(116)	1991(126)
New Ambadi, Kulasekharam	GT 1	BO -2	1863(100)	2364(127)	2351(126)	2265(122)

Stimulation : PB 217 (3-5); RRIM 600 (4-6); GT 1 (5-7)

Table Wb. 3. **Yield performance (kg/400 trees/year) under d/4 frequency in the 5th year of tapping**

Location	Clone	Panel	T1	T2	T3
TR & T Estate*, Ambanad	RRII 105	BO -1	1713	1780	1865
Kannukuzhy, Kottayam	RRII 105	BO -1	2173	-	-
TR & T Estate, Ambanad	GT 1	BO -1	995	1143	1219*
New Ambadi, Kulasekharam	RRIM 600	BO -1	1949	2047	1913
HML, Konney	PB 217	BO -1	2054	2279	2292

* There was go slow during peak season

Under d/6 frequency of tapping, with monthly stimulation, there was higher yield from third year. Low yield during the initial years of tapping could be solved by adjusting the frequency of stimulation. Cost benefit analysis of the data from Vengathanam Estate showed that in clone RRII 105, in a tapping block of 400 trees, mean annual additional income generated was Rs.6634/- per block. Additional income for the tapper was Rs.604/- per block. In clone RRIM 600 (New Ambadi Estate), stimulation under d/3 frequency resulted in additional mean annual income of Rs.7414/- per block. Additional income for the tapper was Rs.706/- per block.

In the experimental farm at RIT, yield under d/3 and d/4 frequencies of tapping with stimulation was comparable. However, under weekly tapping there was significant yield depression during the initial two years.

Three year data on yield performance in the rain guarding experiment showed a significant yield reduction of 38% in the absence of rainguard under d/2 frequency of tapping. By stimulation, yield loss could not be reduced. Similar reduction in yield under d/3 frequency of tapping was 44% in the absence of rainguard, which could be significantly reduced (22%) by stimulation. Data from controlled upward tapping (CUT) experiment (clone GT1) showed that, under monthly stimulation, alternate daily tapping of 1/4S cut was more productive than third daily tapping. Results of the minicut experiment showed promising results and yield from stimulated minicuts were comparable to that of 1/2S d/3.

2. Latex diagnosis studies

Latex diagnosis studies conducted in smallholders' plots from North and South regions in the traditional area, showed maximum variation in thiol levels and were lower than the base value fixed under optimum yield in the Central region. The levels of inorganic phosphorous, sucrose and DRC could explain the differences in exploitation pattern practised in these two locations.

A TPD survey of RRII 105 under d/2 and d/3 frequencies in small holders' plots covering North, South and Central regions of the traditional rubber growing tract revealed that up to 5% of trees were affected by total dryness in the BO-1 panel, 5 to 9% in the BO-2 panel and upto 15% in the B1-1 panel. The trees affected by partial dryness were up to 10%, 12% and 20% in the BO-1, BO-2 and B1-1 panels respectively.

In an experiment laid out at RIT, Pampady with clone RRII 105 under 1/2S d/3 frequency in BO-1 panel, latex diagnosis parameters did not show any significant difference with the control

Table Wb. 4. **Growth and yield performance of clones**

Location	Clone	Year of planting	Yield (g/t/t)	DRC (%)	Girth (cm; Feb 2000)
Kamalghat	RRIM 600	1980	37.20	32.40	60.20
Fatikcherra	RRIM 600	1982	42.90	33.10	66.30
Taranagar	RRII 105	1982	42.80	36.80	65.10
Fatikcherra	RRII 105	1982	32.90	34.50	58.70
Kamalghat	GT 1	1980	38.96	37.00	67.80
Anandanagar	GT1	1985	20.50	28.20	56.20
Mean			35.88	33.67	62.38

suggesting that the stimulation treatment imposed did not affect the health of the tree.

3. Clone evaluation

In the1994 trial at Arasu Rubber Corporation, Keeriparai, Tamil Nadu, among the 11 clones, four clones recorded significantly higher yield than RRII 105. In the trial at RRS, Padiyoor, IRCA 230 showed the highest girth followed by PB 314. A new clone trial was initiated at Dhenkanal, Orissa and field planting for the trial was completed.

In the 1994 onfarm trial at Arasu Rubber Corporation, Keeriparai, six test clones recorded better growth rate than the control clone (RRII 105) of which PB 235 ranked first. Lowest girth was recorded for PR 261. In the onfarm trials at Pullengode and Thirumbadi Estates and in the smallholdings at Manappally, Suranadu, Vallikunnam and Thamarakkulam, recording of girth and disease occurrence was carried out. At Suranadu, Oidium was severe on PB 260 while at Vallikunnam, severe pink incidence was noticed in the test clone (RRII 351).

To study the performance of clones in the mature phase at Agartala, all the three Category 1 clones, *viz.*, RRII 105, RRIM 600 and GT 1 were selected from four different locations. The observations and results are given in Table Wb. 4. The results showed that clone RRIM 600 attained more girth than RRII 105 at Fatikcherra, while RRII 105 recorded better growth at Taranagar.

Mean dry rubber yield of the clones revealed that RRIM 600 at Fatikcherra and RRII 105 at Taranagar have comparable yield. Clone RRIM 600 ranks first in yield followed by RRII 105 and GT 1. In all the clones studied, November is the peak- yielding month regardless of the locations. Dry rubber content (DRC) declined from October onwards and it was lowest during January, in all the clones. Clone GT 1 at Kamalghat and RRII 105 at Taranagar showed the highest DRC, while that of GT 1 at Anandanagar was the lowest. Regardless of the clones, DRC was comparable at other places. Regardless of the clones DRC was comparable at other places. Poor yield and low DRC of GT 1 noticed at Anandanagar might be due to poor management of the plantation.

During immature phase, four clones, *viz.*, RRII 105, RRIM 600, GT 1 and PB 235 were selected from one location to study their performance. During immature phase GT 1 attained highest girth followed by RRIM 600 and RRII 105. Annual girth increment also showed GT 1 as the vigorous clone after seven years. Clone PB 235 attained a mean girth of 40.4 cm and an annual girth increment of 6.6 cm after six years (Table Wb. 5).

4. Biotechnology

The effect of polyamines, glutamine, casein hydrolysate, gibberellic acid, light *etc.* on the frequency of somatic embryogenesis and plant regeneration revealed no signifi-

Table Wb. 5. **Growth of planting performance of clones in immature phase**

Clone	Year	Girth (cm; Feb-2000)
RRIM 600	1992	46.8
RRII 105	1992	44.3
GT 1	1992	48.9
PB 235	1993	40.4
Mean	-	45.1

cant effect of polyamines. Embryo induction efficiency was promoted by supplementing glutamine at 150-200 mg/l and casein hydrolysate at 400 mg/l. Incorporation of low levels of gibberallic acid (2.0 mg/l) stimulated embryo induction and plant regeneration. Plantlet regeneration frequency increased at higher levels (3-5 mg/l), however, the transfer of germinated embryos to hormone free medium was required. Dark incubation favoured induction and proliferation of callus and embryogenesis.

Transgenic plants initially developed with the gene coding for sorbitol-6-phosphate dehydrogenase did not grow satisfactorily after the second leaf stage. Efforts are underway to overcome this problem. Transgenic plants transformed with SOD gene were produced successfully.

5. Germplasm evaluation

In the 1996, trial where 36 Brazilian germplasm clones were under evaluation at RRS, Sukma, Chathisgarh, significant variation in growth was observed among the clones. The Wickham clones showed more vigour, compared to the germplasm clones. High girth increment was recorded for RO 5554 (8.48 cm), MT 2594 (8.28 cm), RO 5363 (7.61 cm), RO 2635 (7.42 cm) and RO 2629 (7.12 cm). Low girth increment of 5.52 cm, 4.83 cm, and 4.50 cm was recorded in AC 685, AC 607 and AC 707, respectively.

In the trial for cold tolerance laid out at the RRS, Nagrakatta, Brazilian clone AC 68 showed highest girth in the second year of planting followed by RO 5408. The Wickham clones had less vigour and the girth ranged from 9.0 cm in GT 1 to 7.1 cm in RRII 105. The lowest girth recorded was for AC 607.

5.1 Genome analysis

RAPD profiling of 60 wild genotypes along with two cultivated clones (RRII 105 and GT 1) was done using 22 informative random primers and a database of the RAPD profiles was constructed from the images, for genetic analysis. The study indicated considerable genetic variation among the wild genotypes from three different provenences namely, Acre, Rondonia and Mato Grosso of Brazil. Primers have been identified which could detect geographic distinctness of the genotypes.

Two hundred primers (20 random primers from each OPA to OPJ series) were screened against *Phytophthora* tolerant (RRII 105) and susceptible (RRIM 600) clones, for identifying a marker for the disease. The primers, identified for polymorphism in tolerant clones, have been subjected to tests for the consistent polymorphic pattern for disease resistance against 15 genotypes, including 12 popular clones. Preliminary studies have indicated that a ≈0.6 kb RAPD fragment may be a marker for resistance to Phytophthora leaf fall disease. Further confirmatory studies are in progress.

A study on RAPD profiling of *Corynespora* isolated from different regions, has revealed the existence of seven different genotypes of *Corynespora cassicola* among the Kerala and Karnataka isolates. Considerable genetic variations were detected among the Kerala isolates, and three of them were expected to be different species. Putative virulence specific RAPD profile of *Corynespora* was identified among the isolates where the disease became epidemic.

In another study, the 26 isolates of *Glomerella* could be classified into two subgroups, which showed distinctness in relation to the type of disease symptoms. Wide genetic variability of the pathogen was observed among the isolates under each subgroup.

6. DRIS fertilization

Results from the experiments on application of fertiliser based on two types of recommendations, *viz.*, Discriminatory Fertil-

izer Recommendation (DFR) and Diagnosis and Recommendation Integrated System (DRIS), did not give significant difference. In the regional and satellite laboratories a total of 16152 soil and 1350 leaf samples were collected. 14736 soil and 1312 leaf samples were analysed and 8000 discriminatory fertilizer recommendations were offered. Beside these, 7411 latex samples were collected and 7207 samples analysed. Conducted 57 numbers of mobile soil testing programmes in central and regional laboratories at various places. Fertiliser recommendations were offered on the spot.

On the basis of the survey report on the rubber growing soils of Kerala and Tamilnadu, conducted by NBSS & LUP, a new project on "the refinement of DFR" was initiated. For this study, three locations at Kozhikode, Pala and Adoor were selected. Six smallholdings in each series were identified and initial work such as plot marking and tree numbering were completed.

7. Rubber based sustainable farming system

Four experiments under this project were in progress. All the trials except the 4th one, were laid out at Taranagar Farm, RRS, Agartala. The fourth trial was conducted at a farmer's field near Taranagar Farm. Annual crops were taken as intercrops in this trial. Pineapple and banana were planted as intercrops in model I & II and tea in model III.

Annual average yield of banana in alternate row intercropping over three years was 655 kg per hectare from of 416 plants. In strip intercropping combined with pineapple, the annual average yield was 688 kg per hectare from 476 plants. The annual average yield from a pineapple population of 2770 plant in alternate row intercropping was 1144 kg per hectare, whereas from strip planting of banana and pineapple the yield was 1350 kg per hectare from a population of 3572 plants/ha (Table Wb. 6).

Intercrops of banana and pineapple produced higher amount of biomass in model I. This was in comparison to that of model II and was mainly due to a higher stand per unit area. Nutrient recycling studies also revealed higher recycling of all nutrients except K and Ca in model I. In general, total nutrients added through fertilizer and manure exceeded the nutrient removal and maximum nutrient removal occurred in the case of K followed by N.

The commercial crop ginger was tried in the gaps available between two banana plant points in model II. Ginger produced 0.5 kg of rhizome per square meter. Tea leaf harvesting in experimental plots have been initiated in model III.

In the fourth experiment, chilli, groundnut, pigeon pea and sesame were intercropped with rubber. All the intercrops except chilli recorded high yield. Growth of rubber *i.e.*, girth and height increment was also highest in the intercropped plots which

Table Wb. 6. **Yield of intercrops in different years**

System	Year	Pineapple		Banana	
		No/ha	kg/ha	Bunch/ha	kg/ha
Model I	1997	1690	1294	240	1084
	1998	2271	1576	170	654
	1999	1873	1179	90	325
	Mean	1945	1350	167	688
Model II	1997	1437	1165	221	1030
	1998	1634	1226	151	645
	1999	1540	1041	74	289
	Mean	1537	1144	149	655

may be due to additional application of fertilizers in the intercropped area compared to a pure rubber stand.

The Benefit Cost Ratio (BCR) of banana in normal planting was found to be 2.74. However, for the strip planting it was higher than normal planting. The BCR of pineapple in normal planting was 1.47, which was higher than that in strip planting. The BCR will increase substantially if family labour is inducted. Yield and profitwise intercropping of banana and pineapple in strips in model I showed good prospect. The banana cultivation seemed to be more economic with round the year marketing facility.

8. R&D activities on NR processing

As part of the project on improvement of drying conditions of sheet rubber in smallholdings, establishment of solar cum smoke dryers at HBSS, Nettana was completed and that of Dapchari is in progress. In the trials on sun-cum-smoke drying of sheet, as the intensity of sunlight was low, the drying time of sheets during April to August varied between 5 and 6 days. Drying trials revealed that more than 50% firewood savings during summer season and 15-20% in rainy season could be accomplished with the new drying system. For popularising the design, demonstrations were conducted. Upgradation of low quality sheets by the sheet cleaning machine was tested by cleaning 500 kg of fungus affected sheets received from GAICO, Kuravilangadu. The sheets were graded before and after the cleaning.

Natural Rubber – Polypropylene blends having a blend ratio of 60 NR and 40 PP were prepared. To avoid the molecular weight mismatch of the components of the blend, natural rubber was masticated to different levels for reducing its molecular weight. GPC analysis showed that NR of molecular weight 7.5 lakhs can be reduced to 4.3 and 3.7 lakhs respectively by 10 and 15 minutes of mastication. Mastication of NR was found to improve the processability without affecting the technological properties of the blend. Dynamic vulcanisation of the rubber phase using DCP and sulphur improved the technological properties. However, reducing the molecular weight of NR to below 3 lakhs adversely affected the technological properties.

9. UPASI component

In the project being implemented through UPASI, 2152 soil and 352 leaf samples were analysed. Number of growers benefited was 1350. Training classes on soil collection and campaigns and exhibitions were conducted for popularising the discriminatory fertiliser application.

CENTRAL EXPERIMENT STATION, CHETHACKAL, KERALA

The Central Experiment Station was established in the year 1966 with the main objective of conducting experimental projects. The Station is situated at a distance of about 50 km from RRII, Kottayam. The Station has a total area of 254.79 ha and is divided into two divisions for efficient management. The entire area has been utilized for different trials, which include progeny trials, exploitation trials, intercropping trials, density trials, *etc.* In addition, the screening of over 4000 genotypes of wild Brazilian germplasm as well as their conservation is being undertaken in this Station.

During the period under report, total crop realized was 14724 t. A total of 297 tapping days was possible in the year and 19844 mandays were engaged for tapping. The total mandays engaged was 61616. The dispensary caters to the needs of the workers and the total patients attended during the reported year were 9742.

REGIONAL RESEARCH STATION, GUWAHATI, ASSAM

The thrust areas of research of the Station are evaluation of clones, assessment of nutritional requirement under different fertility status of soil, disease and pest management and evolving suitable exploitation systems. The research projects undertaken by the Station can be broadly classified into four categories, *viz.*, crop improvement, crop management, crop protection and exploitation studies. During the reporting period the Station had 14 projects under four different categories : three under crop improvement, six under crop management, four under crop protection and one under exploitation systems. Results revealed positive response on growth and yield up to the application of NPK @ 60:60:40 kg/ha/year. Insoluble forms of phosphatic fertilizer (MRP) were found better than soluble forms of P (SSP) for growth during immature phase. High dose of K (40 kg/ha) along with Mg (7.5 kg/ha) recorded better growth during immature phase over control. Maximum yield (72.3 g/t/t) was observed under 1/2S d/4 6d/7 with three months rest during winter. Clone RRIM 600 continued to be the best performer in terms of growth and yield.

1. Crop improvement

1.1 Evaluation of clones

In the 1985 clone trial, highest girth over 14 years was observed in clone RRIM 600 (69.07 cm) followed by RRII 118 (68.51 cm) and RRII 203 (68.28 cm) and the minimum in PB 5/51 (50.16 cm). Annual mean yield (g/t/t) recorded was highest in RRIM 600 (33.75) followed by PB 235 (32.63) and minimum in PB 5/51 (22.53). Maximum dry rubber content (DRC) was recorded in PB 235 (32.91) and minimum in GI 1 (29.35) (Table Nea. 1).

In the 1986 clone trial, clone RRIC 102 registered highest girth (72.27 cm) followed by PB 310 (64.97 cm) and minimum in RRII 5 (60.79 cm). The annual mean yield (g/t/t) recorded was highest in PB 311 (38.97) followed by PB 310 (32.92) and minimum in PR 255 (20.87). DRC recorded was highest in PR 255 (32.09) followed by PB 310 (31.98) and minimum in RRIC 105 (27.79) (Table Nea. 2).

Table Nea.1. **Growth and yield performance of ten *Hevea* clones (1986 clone trial)**

Clone	Girth (cm)	Annual mean	
		Yield (g/t/t)	DRC (%)
RRII 105	59.71	30.95	31.04
RRII 118	68.51	30.26	32.73
RRII 203	68.28	26.86	30.27
RRIM 600	69.07	33.75	32.28
RRIM 605	63.98	25.79	31.56
PB 86	67.94	26.29	30.51
PB 235	65.05	32.63	32.91
PB 5/51	50.16	22.53	30.24
GT 1	64.61	30.55	31.37
GI 1	55.11	25.28	29.50
SE	1.29	1.70	1.68
CD (P=0.05)	3.58	4.79	NS

Table Nea. 2. **Growth and yield performance of eight *Hevea* clones (1986 clone trial)**

Clone	Girth (cm)	Annual mean	
		Yield (g/t/t)	DRC (%)
RRII 102	72.27	23.60	30.56
RRII 105	63.33	23.23	27.79
RRII 208	64.45	27.56	29.34
RRII 5	60.79	27.66	31.54
PB 260	60.87	25.08	29.37
PB 310	64.97	32.92	31.98
PB 311	63.22	38.97	30.10
PR 255	62.92	20.87	32.09
SE	2.11	2.46	1.45
CD (P=0.05)	5.85	6.9	NS

1.2 Evaluation of polyclonal population

Out of the 278 polyclonal trees, 177 trees were tapped (1/2S d/2) and the crop efficiency (g/cm) of 15 selections in terms of yield was found to be promising (Table Nea. 3). The annual mean yield (g/t/t) recorded highest

Table. 3. **Performance of 15 seedling selections vis-à-vis polyclonal seedlings**

Selections Code No.	Girth (cm)	Annual girth increment (cm)	Yield (g/t/t)	Length of tapping panel (cm)	Crop efficiency (g/cm)
S1	68.7	2.3	111.89	41.0	2.72
S2	73.8	3.0	84.03	44.5	1.88
S3	76.5	2.5	88.24	47.0	1.87
S4	81.5	6.5	90.48	49.5	1.82
S5	82.5	4.3	84.24	48.0	1.75
S6	62.2	2.7	56.95	34.5	1.65
S7	62.5	3.7	61.74	38.0	1.62
S8	67.2	1.8	57.47	36.0	1.59
S9	60.5	3.4	53.40	34.0	1.57
S10	63.1	3.1	62.55	40.0	1.56
S11	68.5	2.4	61.18	40.0	1.52
S12	82.5	2.5	80.36	54.0	1.48
S13	70.0	4.5	68.40	47.5	1.44
S14	95.0	6.3	76.42	53.5	1.42
S15	56.6	0.9	48.85	34.6	1.41
*Polyclonal seedlings	62.3	2.6	21.62	37.5	0.57

in selection S1 (111.89) and minimum in selection S15 (48.85). The stability of increasing yield trend in 10 different selections out of 15 was also maintained for the last four years. Among the selections, S14 showed highest girth (95.0 cm) followed by S5 (82.5 cm) and minimum was in S15 (56.6 cm).

1.3 Evaluation of wild germplasm

Growth parameters were recorded during pre- and post-monsoon and also in pre- and post-winter periods for evaluation of vigour and cold tolerance among 150 out of the 200 wild genotypes raised in polybag nursery (100 each in 1997 and 1998). No indication of cold injury was noticed in 70 genotypes in 1997 polybag nursery. Symptoms of cold injury were noticed in 1998 polybag nursery where five genotypes out of 80 dried up. Cataloguing of 70 wild genotypes in 1997 polybag nursery was completed.

2. Crop management

2.1 Nutritional studies (Mature phase)

The 1987 nutritional trial at Nayekgaon in Kokrajhar, to find out the optimum requirements of N, P and K for the growth and yield of *Hevea* under the agroclimatic condition of Assam was continued. Results showed that treatments have significant effect on average girth and yield. Effect of N application on girth increased with higher doses but the significance is mainly confined to 40 kg N/ha. However, highest dose of N (60 kg/ha) resulted in highest mean yield. In the case of P, though application of highest doses (40 kg/ha) was found numerically superior in terms of average girth, its effect on average yield was not significant. In the case of K, significant increase in girth as well as in yield was observed due to imposition of the treatments. However, significance was more pronounced with application of 20 kg/ha (Table Nea. 4). It was also observed that the effect of treatments on annual girth increment was non-significant. Interaction effects among the treatments on growth, annual girth increment and average yield were calculated and found non-significant except N x P on yield.

2.2 Interaction effect of K and Mg on growth and yield

Growth data under both the trials (Sorutari and Nayekgaon) revealed that the effect of treatments on average girth and annual girth increment were non-significant.

Table Nea. 4. **Effect of NPK on average girth, annual girth increment and mean yield**

Nutrient level	Average girth (cm)	Annual girth increment (cm)	Mean yield (g/t/t)
Nitrogen (N)			
0	51.31	1.96	28.51
0	53.53	1.73	35.88
40	55.38	1.70	41.24
60	55.38	1.63	52.78
SE	0.57	0.13	1.53
CD (P=0.05)	1.57	NS	4.25
Phosphorus (P_2O_5)			
0	54.28	1.87	36.70
20	52.71	1.66	39.67
40	54.68	1.74	42.44
SE	0.49	0.11	1.32
CD (P=0.05)	NS	NS	3.68
Potassium(K_2O)			
0	53.10	1.69	36.76
20	54.47	1.81	40.15
40	54.35	1.78	41.89
SE	0.49	0.11	01.32
CD (P=0.05)	1.36	NS	3.68
CD (P=0.05)			
For			
NP	NS (0.982)	NS (0.22)	7.36 (2.64)
NK	NS (0.982)	NS (0.22)	NS (2.64)
PK	NS (0.850)	NS (0.19)	NS (2.30)
NPK	NS (1.700)	NS (0.38)	NS (4.60)

The values of SE are given in parenthesis for NP, NK, PK and NPK.

Highest doses of Mg (15 kg/ha) effected significant increase in yield in both the trials. However, significant increase in yield due to K application was restricted only to Sorutari. Interaction effect between K and Mg on average girth, annual girth increment as well as average yield was found non-significant (Table Nea. 5).

2.3 Rock phosphate and Super phosphate as source of P for mature rubber

Girth data under the two trials, which were laid out in two different locations

Table Nea. 5. **Interaction effect of K x Mg on growth, annual girth increment and yield**

Nutrient level (kg/ha)	Average girth (cm)		Girth increment (cm)		Average yield (g/t/t)	
	Sorutari	Nayekgaon	Sorutari	Nayekgaon	Sorutari	Nayekgaon
Potassium(K_2O)						
0	55.93	55.74	2.32	2.12	30.38	32.17
20	54.32	54.55	1.98	1.65	33.83	34.70
40	55.75	55.43	2.47	1.90	38.89	38.15
SE	1.51	0.59	0.25	0.20	0.55	1.96
CD (P=0.05)	NS	NS	NS	NS	1.65	NS
Magnesium(MgO)						
0	56.60	54.33	2.76	1.80	32.29	26.94
7.5	55.30	55.57	1.70	1.78	34.46	35.64
15	54.10	55.81	2.31	2.07	36.35	42.43
SE	1.51	0.59	0.25	0.20	0.55	1.96
CD (P=0.05)	NS	NS	NS	NS	1.65	5.87
SE for K x Mg	2.62	1.03	0.43	0.5	0.95	3.39
CD for K x Mg	NS	NS	NS	NS	NS	NS

(Sorutari and Nayekgaon) revealed that effect of treatments on average girth and annual girth increment was statistically non-significant. At Sorutari, the plants receiving water insoluble phosphatic fertilizer, registered highest average girth as well as highest annual girth increment compared to other treatments. In case of Nayekgaon, the treatment T_6 (water soluble P @ 60 kg/ha) is numerically superior in terms of average girth compared to other treatments whereas T_5 (water insoluble P @ 40 kg/ha) resulted in highest annual girth increment during the year reported upon. Effect of treatments on yield was statistically significant in both the experiments. It was also observed that application of rock phosphate effected significant increase in yield compared to other treatments. Significant increase in leaf nitrogen was observed at Sorutari (Table Nea. 6) due to imposition of treatments. However, effect of treatments on leaf P and K was non-significant.

Table Nea. 6. **Influence of treatments on leaf nutrients (%) at RRS Sorutari**

Treatment	N	P	K
T1	3.66	0.24	1.25
T2	3.46	0.22	1.10
T3	3.52	0.24	1.14
T4	2.97	0.22	1.13
SE	0.06	0.01	0.12
CD (P=0.05)	0.18	NS	NS

2.4 K dynamics in the rubber growing soils

Seventy two surface and subsurface soil samples were collected from three districts of Assam, *viz.*, Kamrup, Goalpara and Kokrajhar (24 samples from each district) and their physicochemical properties were analysed.

2.5 Effect of sulphur on growth of immature *Hevea*

Two experiments were carried out under this project. In the incubation study to assess the dissolution pattern of sulphur in soil, representative soil samples were collected at the depth of 0-30 cm from different rubber growing areas and pH, total and available sulphur were estimated. 2.5 kg each of the soil samples were filled in plastic containers. Different levels (0, 20, 40, 60, 80 and 100 ppm) of sulphur were applied. The soil moisture was maintained at about 27-30% (field capacity). Soil samples were collected from each pot at 15, 30, 60, 90, 120, 150 and 180 days interval for analysis of total and available sulphur and soil pH. In the second experiment, where effects of different concentration of sulphur to young rubber was studied, budded stumps of RRIM 600 were planted in polybags. Agricultural grade sulphur was applied in six different doses. Pre-treatment and post-treatment morphological parameters were recorded and presented in Table Nea. 7. The data revealed that effect of treatments on girth was significant, whereas it was non-significant with respect to plant height and number of whorls.

2.6 Comparative efficiency of cover crops

Objectives of this experiment were to compare the influence of the two cover crops, *viz. Pueraria phaseoloides* and *Mucuna bracteata* on soil nutrient enrichment, building up of microbial population, improving soil

Table Nea. 7. **Effect of sulphur on morphological parameters of young *Hevea***

Sulphur (ppm)	Morphological parameters		
	Average girth (cm)	Plant height (cm)	No. of whorls
0	4.01	147.2	4.0
20	3.83	133.4	3.6
40	3.76	140.6	3.8
60	4.39	152.4	4.0
80	3.89	141.3	3.8
100	4.83	182.4	4.4
SE	0.25	13.5	0.3
CD (P=0.05)	0.73	NS	NS

moisture retention, soil nutrient recycling, suppression of weeds and growth of *Hevea* during immature phase. The experiment was laid out at Jorhat, Assam, in 1999 as an on farm trial with clone RRIM 600. The plants were raised and cover crops established. Pretreatment soil samples were collected for nutrient analysis. Pretreatment girth data of *Hevea* plants were also recorded.

3. Crop protection

3.1 Survey of diseases and pests

Incidence and severity of various pests and diseases and the damages caused by them in non-traditional areas such as North-East and northern part of West Bengal are not similar to that of the traditional zone of rubber plantation. Therefore, a survey was carried out to highlight the association of pests and diseases with rubber in 88 locations covering 24 different rubber growing tracts in Assam, Meghalaya, Tripura, Arunachal Pradesh and Northern part of West Bengal. High intensity of powdery mildew disease was noticed in certain locations in Assam, Tripura, Meghalaya and northern part of West Bengal, which caused repeated premature defoliation, die-back of twigs and branches and drying of flowers. The incidence of secondary leaf fall disease was noticed on tender leaves in both mature trees and nursery plants during June to September in some of the locations in Assam, Meghalaya and northern part of West Bengal. The intensity of the disease was very high in nursery plants where severe premature defoliation was noticed. Leaf blight disease was noticed on tender leaves during November to March in nursery plants in most of the locations surveyed. In some locations in Assam and Meghalaya leaf blight also caused severe premature defoliation and dieback of shoots.

Purple root disease, which caused a total loss of affected plant, was noticed on one-year-old *Hevea* seedling in nursery at Jenggitchakgre in Meghalaya. Intensity of the disease at Jenggitchakgre was 45% and the incidence of the disease was a new report from North East region. Brown root disease was noticed in some plantations at Sorutari, Tulakona, Nagorlung and Subroom. The intensity of brown root disease at Subroom plantation (Tripura) was five per cent. Mild attack of weevil (*Hypomeces squamosus*) was noticed only in nursery plants at Sorutari (Assam) during February/March. Minor infestation of scale insects, termites, slugs and snails were also noticed in some plantations in Assam and Meghalaya.

3.2 Isolation, identification and maintenance of fungal pathogens

Isolation of fungal pathogens from various diseased samples collected from different locations during the survey was made in the laboratory and identified after cultural and microscopic studies. Fungal pathogens, *viz.*, *Corynespora cassiicola*, *Fusarium solani*, *Colletotrichum gloeosporioides*, *Phellinus noxius*, *Periconia heveae* and *Helicobasidium compactum* were cultured in the laboratory and studied under microscope for regional strain differentiation.

3.3 Control of powdery mildew disease

For evaluation of the economic efficacy of sulphur dusting in the control of powdery mildew disease, a trial was initiated in mature rubber (RRII 105) at RRS, Nagrakatta (West Bengal). Dusting of agricultural grade sulphur (85%) was carried out in other trials at Sorutari Farm (Assam) and completed by three rounds because of late wintering. After final round of dusting the incidence of powdery mildew disease was assessed and found below 20% except in 1985 clone trial.

To find out the role of zinc in the control of powdery mildew disease in RRIM 600 at nursery stage, a trial was initiated at RRS, Nagrakatta. Different treatments like untreated control, Chelazin 5 ml/L of water as foliar application, Chelazin 7.5 ml/L of

Table Nea. 8. **Variation in growth and yield of *Hevea* under different exploitation systems**

Treatment	Girth (cm)	Girth increment (cm)	Yield (g/t/t)
T1 - 1/2S d/2 6d/7 - regular tapping	59.96	1.16	31.2
T2 - 1/2S d/2 6d/7 - one month rest (Feb.)	56.49	1.09	38.22
T3 - 1/2S d/2 6d/7 - two months rest (Feb & March)	57.65	0.75	38.16
T4 - 1/2S d/2 6d/7 - three months rest (Jan-March)	61.26	1.36	42.26
T5 - 1/2S d/3 6d/7 - continuous tapping 5 Stim.	61.49	1.19	44.98
T6 - 1/2S d/3 6d/7 - one month rest -do-	65.53	1.23	51.71
T7 - 1/2S d/3 6d/7 - 2 months rest -do-	63.75	1.25	70.27
T8 - 1/2S d/3 6d/7 - 3 months rest -do-	63.55	1.35	60.35
T9 - 1/2S d/4 6d/7 - continuous tapping – 7 Stim.	62.87	1.27	59.49
T10 - 1/2S d/4 6d/7 - 1month rest -do-	63.13	1.33	59.84
T11 - 1/2S d/4 6d/7 - 2 months rest -do-	62.61	1.41	56.82
T12 - 1/2S d/4 6d/7 - 3 months rest –do-	63.32	1.62	72.83
Sem +	2.35	0.19	5.37
CD (P=0.05)	NS	NS	15.04

water in soil application near root base, Zn SO_4:Trasco zinc active (21%) 3g/L of water as soil application near root base, S_1 (no dusting of sulphur) and S_2 dusting with sulphur 85% agricultural grade were completed for the first year. After completion of all treatments for the first year, the incidence and severity of powdery mildew disease was assessed in different experimental plots. Plants under treatments T_2S_1 and T_2S_2 showed very low incidence of powdery mildew disease as compared to control and other treatments.

4. Exploitation systems

An experiment on tapping rest and frequency interaction studies in *Hevea* was initiated during 1999 with clone RRIM 600. Normal tapping (1/2S d/2 6d/7) with and without rest is being compared with other tapping systems, *viz.*, 1/2S d/3 6d/7 and 1/2S d/4 6d/7 where stimulation has been imposed. Details of treatments and data on average girth, girth increment and mean yield are presented in Table Nea. 8. The data revealed that treatments are non-significant with respect to girth increment. However, the yield was significantly influenced by the treatments. Maximum yield (72.83 g/t/t) was noticed for the treatment T_{12} followed by T_7 (70.27 g/t/t). Maximum annual average yield was obtained under the treatment T_2 (1391 kg/ha) followed by T_7 (1377 kg/ha).

REGIONAL RESEARCH STATION, AGARTALA, TRIPURA

The thrust area of research in the Station is the development of suitable agrotechnology for this region. Rubber based sustainable farming system experiments were in progress under World Bank assisted project. Studies on nutritional aspect, clone evaluation, physiology and embryo culture were also continued. Higher fertilizer dose up to 60:60:40 NPK kg/ha has shown positive response to growth and yield. The organic carbon (C) content of soil under rubber was found to be on par with that of forest soil and also substantially higher than in barren land. Clone PB 235 recorded highest

yield in the clone trial. Selected clones were taken for onfarm evaluation. In exploitation study, the higher yield was recorded in 1/2S d/2 system of tapping with 10-10 °C rest during winter. Efforts to predict yield by using antecedent atmospheric parameters were also in progress. The advisory service on fertilizer recommendation and processing technology continued.

1. Agronomy and soils

The experiments on the effect of different planting densities and fertilizer levels and the impact of rubber on physico-chemical properties of soil were continued. In the planting density trial, three densities with three NPK combinations were studied in two clones (Table Net. 1). During this year also, highest girth and yield per tree were recorded in the lowest density planting. Clone RRII 118 showed higher girth than RRII 105 whereas yield showed reverse trend.

Table Net. 1. **Effect of different densities and fertilizer doses on rubber under 1/2S d/3 system of tapping**

Planting density	Yield (g/t/t)
D1 (420 trees/ha)	42.5
D2 (606 trees/ha)	35.1
D3 (824 trees/ha)	27.8
CD (P=0.05)	3.67
M1 (40:40:20 kg/ha)	34.9
M2 (60:60:30 kg/ha)	36.7
M3 (80:80:40 kg/ha)	33.8
CD (P=0.05)	NS
C1 (RRII 105)	38.9
C2 (RRII 118)	31.3
CD (P=0.05)	2.25

In the nutritional trial, three combinations of NPK were experimented on clone RRIM 600. It was observed that 60 kg N and 60 kg P_2O_5 produced significantly higher yield whereas the effect of K_2O was not significant though increasing levels of K_2O increased the yield (Table Net. 2).

Table Net. 2. **Average yield at different nutrient levels**

Nutrient	Average yield* (g/t/t)		
	Nutrient levels		
	0	1	2
N	53.2	60.5	64.6
P	52.5	59.7	64.2
K	52.8	57.4	60.7
CD (P=0.05)	NS	8.13	NS

* under 1/2S d/3 system of tapping
total number of tapping days was 67

The study of changes in physico-chemical properties of soil under different plantations was initiated during the report period. Soil samples were collected from plantations of rubber (*Hevea brasiliensis*), teak (*Tectona grandis*) and gamai (*Gmelina arborea*) and barren land surrounding the area. Soil analysis showed that the organic C, available P_2O_5, Ca and Mg content were significantly higher in soils under rubber, teak and gamai compared to barren land. Significant differences were not observed in available K content and pH of soil under various plantations and barren land.

2. Biotechnology

Immature embryos (2-16 weeks old) of clones RRII 105, RRIM 600, GT 1 and SCATC 93-114 were excised out and cultured on media containing different concentrations and combinations of Kinetin, NAA and 2ip. It was observed that 7-8 weeks old embryos of all the clones responded very well in this experiment. Pre-treatment with Kinetin 1.0 mg/L for 10-20 days induced multiple shoot buds, which developed into multiple shoots when cultured on the medium containing Kinetin 0.5 + 2ip 1.0 mg/L. Higher per cent of immature embryos responded for clone RRII 105 (55-60%) followed by GT 1 (45-50%). Maximum number of shoots per explant were obtained by using clone RRII 105 (6-12) followed by SCATC 93-114 (6-10) and GT 1 (6-8). Healthy tap roots and few secondary roots were obtained when the cultures were transferred on the medium without cytokinins but with IBA (1.5 mg/L).

3. Breeding and selection

The programme for breeding and selection of suitable planting materials for the North East

region fall under four categories, *viz.* evaluation of exotic/indigenous clones, recombination breeding, evaluation of polycross progenies and conservation, evaluation and utilization of wild Brazilian germplasm.

3.1 Evaluation of clones

Four clone evaluation trials, two each in mature and immature phase were continued. Among the 20 clones being evaluated over the years, clone PB 235 continued to give highest yield. Other promising clones selected for onfarm trials were RRII 203, RRIM 600, RRII 208, RRII 118, RRIM 703, Haiken 1 and SCATC 88-13. Clone evaluation during immature phase revealed that clones 82/17 and 82/29 were promising.

Recombination breeding has resulted in sufficient number of hybrids involving Wickham and Amazonian accessions. Evaluation of polyclonal seedlings has resulted in identification of a few ortets for further evaluation. Two hundred and forty two wild Brazilian accessions were maintained in a gene pool garden and action was taken for field evaluation for secondary characters.

Trees of two clone trials, *viz.*, 1979 and 1987 were under tapping. Yield over ten years in the first clone trial recorded the highest yield for PB 235 followed by RRII 203, RRIM 600 and RRIM 703 (Table Net. 3). The weather variables like minimum temperature, wind speed and evaporation showed a negative correlation with yield. A regression analysis of dry rubber yield over environmental yield of two regimes was carried out with clones PB 235 and RRIM 600. The regressions were of cross over type, where the meeting points of regression lines represented the threshold yield (28 g/t/t). Estimation of coefficient of variation in yield over months found RRII 5, RRII 203, PB 235 and GT 1 as having the lowest values. A covariance analysis of yield data through bifurcating lean and peak yielding periods revealed RRII 5, RRIM 703, PB 5/51 and PB 235 as consistent over the periods.

Analysis of girth data from the second clone trial (1987) revealed Haiken 1, PR 107 and SCATC 93-114 to be with highest stability (Table Net. 4). Bifurcation of yield contributions during two regimes revealed RRII 208 to be with near equal contributions. Calculation of per cent yield contribution during regime I showed RRII 208 with least depression. RRII 208 exhibited an ascending trend from July onwards, which was a

Table Net. 3. **Projected yield of 15 clones over ten years**

Clone	Yield (kg/ha)									
	90-91	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-2000
PB 235	1554	1333	1844	1557	1785	1680	2030	2212	2845	1943
RRII 203	875	1102	1347	1477	1414	1193	1711	2117	2800	2021
RRIM 600	1085	1207	1501	1592	1417	1232	1466	1494	2250	1940
RRII 118	859	1001	1312	1291	1340	1326	1743	2033	1995	1615
RRIM 703	906	1053	1473	1074	1309	1053	1557	1666	2254	1496
RRII 105	1011	1092	1305	1120	1211	1053	1400	1344	1956	1403
PB 86	749	889	1092	1078	1092	976	1064	1211	1816	1231
RRIC 105	836	973	1116	955	1078	850	966	1326	1697	1266
RRIM 605	752	780	1211	1064	1032	780	1050	1169	1491	1379
GT 1	577	707	833	1001	969	864	1123	1169	1816	1458
RRII 5	665	710	861	840	808	777	1113	1155	1806	1266
RRIC 52	521	689	833	815	1018	833	931	1256	1711	1153
PB 5/51	665	717	854	787	1011	840	955	1067	1494	964
Harbel 1	472	707	766	689	742	357	717	878	1337	828
Gl 1	497	556	710	570	675	374	525	553	948	601

BO 2 Panel from October 1993; BI 1 Panel from September 1999; Tapping system : 1/2S d/2 6d/7; No. of tapping days : 100; Trees/hectare : 350; Data from large-scale clone trial; Season : May to January.

Table Net. 4. **Stability and yield of clones**

Clone	Stability variance for girth	Regression coefficient (*bi*) for yield	Mean yield over four years (g/t/t)	Unit yield (g/cm)
RRII 208	8.936	0.937	42.9	1.25
RRIM 600	7.979	1.353	28.2	0.62
PR 107	0.265	0.629	12.9	0.38
SCATC 88-13	4.116	1.153	26.3	0.81
SCATC 93-114	1.834	0.567	13.0	0.38
Haiken 1	0.226	1.360	27.9	0.80

desirable attribute since the clone assures higher yield during all months. These observations clearly demonstrated the utility of RRII 208 as a potential clone to be evaluated. Analysis of yield data through calculation of regression coefficient (*bi*) under two yielding regimes revealed RRII 208, SCATC 93-114 and PR 107 to be the most stable clones (Table Net. 4). Depiction of yield and regression coefficient rationalize the supremacy of RRII 208 in terms of stability and yielding potential. When parameters like girth and yield were considered, selection goes in favour of RRII 208, SCATC 88-13, Haiken 1 and RRIM 600.

In the third trial (1995) having 10 clones, analysis of girth data through calculation of regression coefficient (*bi*) revealed that SCATC 93-114 was the most stable for girth followed by SCATC 88-13, Haiken 1 and PB 311. In the fourth trial (1996), among the 13 clones the hybrid clone 82/29 attained the highest girth followed by RRII 203, 82/30 and PB 217. Test tap yield revealed 82/17 as the highest yielding clone (Table Net. 5).

Onfarm clone trials were undertaken for confirmation of the results from experiments for future planting material recommendations. A clonal block trial with 300 trees involving eight clones (RRII 118, RRII 203, RRII 208, RRIM 600, RRIM 703, PB 235, PB 260 and Haiken 1) was initiated at Bagafa (TFDPC Centre).

3.2 Evaluation of polycross progenies

A field trial of full sib progenies of 1993 hybridization programme was opened for test tapping and identified a few potential selections for further evaluation. A total of 75 hybrid progenies evolved from seven cross combinations during 1998 were maintained in the field and these attained a mean girth of 9.63 cm at a height of 50 cm. The progenies of 1999 season from 12 crosses were maintained in the polybag nursery for field planting.

Table Net. 5. **Performance of 13 clones in large-scale trial**

Clone	Girth (cm)	Yield (g/10 tapping)
RRII 5	19.9	57.0
RRII 105	18.1	61.3
RRII 176	18.7	54.4
RRII 203	21.5	56.4
RRIM 600	19.2	56.5
PB 217	20.3	52.7
PB 235	18.2	48.7
RRIC 100	16.5	39.5
82/14	19.9	42.0
82/17	18.4	78.6
82/22	17.6	50.7
82/29	23.3	60.7
82/30	20.5	59.4
Mean	19.4	55.2
CD (P=0.05)	3.01	24.01

Growth, yield and secondary attributes of a polyclonal seedling evaluation trial were compared with a multiclonal bud grafted population. Based on the yield performance of individual trees over five years, ten high yielding elite trees having secondary attributes were selected and multiplied for evaluation in small-scale trial with RRIM 600 as control. The trial with 49 half-sib revealed that progeny of PB 5/51 attained the highest girth. However, early yield revealed that

Table Net. 6. **Girth and test tap yield of female parents and their half-sib**

Female parent	Girth (cm)		Yield (g/t/t)	
	Parent	Progeny	Parent	Progeny
PB 5/51	28.0	37.50 (33.97)	3.61	8.08 (123.82)
PB 86	34.7	34.80 (00.29)	5.32	4.02 (-24.43)
GT 1	35.6	41.10 (15.45)	3.88	9.96 (156.71)
RRII 203	36.6	36.50 (-0.27)	4.54	6.82 (50.22)
RRIM 600	35.6	37.00 (10.40)	6.82	6.91 (1.32)

Values in parenthesis indicate per cent increment in girth and yield

progenies of clone GT 1 gave the highest yield in comparison with their parents (Table Net. 6).

3.3 Evaluation and utilization of wild germplasm

Two field trials were laid out with 87 wild genotypes and RRIM 600 as control. Early girth data showed that among the provenances Rondonia and Acre genotypes were vigorous than Matto Grosso genotypes. A screening programme for resistance to *Oidium heveae* involving various genotypes during nursery phase giving due importance to Amazonian clones has been envisaged through creation of epiphytotic conditions. Twelve wild germplasm accessions, nine oriental clones and three polyclonal selections showing various levels of resistance, judged through visual observations, have been multiplied and laid out in a nursery trial with susceptible clone PB 5/51 as spreader rows.

4. Physiological and exploitation studies

Low winter temperature is one of the stresses in the North East region. Late dripping is a common phenomenon during winter period which may lead to TPD syndrome. Experiments were conducted to fix the tapping rest during this period and also to increase yield during low yielding period by stimulation. The study on the response of scavenging enzymes in TPD affected and non-affected genotypes is also in progress.

4.1 Effect of different tapping systems in combination with tapping rest during winter

The experiment was continued and the annual yield data for three consecutive years showed that the 20-20 °C rest in any combination of tapping system had significantly low yield in comparison to that of the control (continuous tapping). Moreover, the 15-15 °C and 10-10 °C rest in 1/2S d/3 also showed significantly low yield. Data on TPD revealed that in all the combinations of 1/2S d/1, the percentage of TPD occurrence was higher than any other combination. Among 1/2S d/2 as control, the 10-10 °C and 15-15 °C combinations and 1/2S d/3 as control, 15-15 °C rest showed lowest TPD. Under 1/2S d/2 frequency rest during 15-15 °C was found optimum (Table Net. 7) whereas under d/3 frequency all the three rest periods resulted in lower yield. A similar study was conducted with clone RRII 105 in growers field, where the temperature rest treatments were 15-15 °C, 12-12 °C, 10-10 °C and 1/2S d/27d/7 system of tapping as control. From the last two years result, it was observed that there was significant difference among the treatments. However, no significant differences were observed in yield among the control, 12-12 °C and 10-10 °C temperature rests. However, the 12-12 °C

Table Net. 7. **Average annual yield kg/ha over three years (400 plants per ha)**

Tapping system	Control	10-10 °C	15-15 °C	20-20 °C
1/2S d/1	1871	1874	1700	1442
1/2S d/2	1872	2006	1839	1188
1/2S d/3	1967	1544	1356	987
CD (P=0.05)	-	246.4	-	-

treatments performed better when the occurrence of TPD was considered. This experiment was initiated at Tura and Nagrakatta also under 1/2S d/1, 1/2S d/2 and 1/2S d/3 tapping systems with four regimes of tapping rests based on minimum temperature of 20-20 °C, 15-15 °C, 10-10 °C and control.

4.2 Effect of stimulation

Another experiment was initiated to study the effect of stimulation during low yielding period with tapping rest during winter (rest below 12 °C) with five clones, *viz.*, RRII 105, RRIM 600, PB 235, RRII 203 and RRII 118. The preliminary result showed that the effect of stimulation on yield was more in clone RRII 105 compared to other clones. In the major yield component study in clone RRIM 600 the highest yield was observed during November. The initial flow rate, plugging index and dry rubber content have shown decreasing trend in cold stress period.

4.3 Biochemical studies on TPD

A study on isozyme banding pattern in C-serum of TPD tolerant and susceptible healthy genotypes was initiated during 1999 to know the variations in super oxide dismutase (SOD) and peroxidase (POX) – scavenging enzymes. Seasonal variations in the isozyme pattern of these two enzymes were noticed. DRC during winter was found to be lower in all the genotypes and occurrence of TPD increased with time.

5. Processing

The study on the processability of latex into forms other than sheets showed that the major portion of latex produced in the North East India is processed into sheets and only negligible quantity is processed into centrifuged latex and pale latex crepe (PLC). The latex produced in other north eastern states at present is insufficient to establish processing factories other than sheet processing. The study further revealed that the transportation of processed latex to other states and procurement of chemicals and other accessories is difficult in Tripura. Advisory services in processing and small-scale product development have been rendered to 13 growers/manufacturers during the reporting period.

6. Prediction of yield using atmospheric parameters

The antecedent and prevailing environmental parameters which significantly influenced daily yield during the winter and non-winter tapping periods were quantified and regression equations were formulated for five clones, *viz.*, RRII 203, RRII 118, RRIM 600, RRII 105 and GT 1 in the region. Optimum agrometeorological conditions for the five clones were found out. Dependence of yield on the observed and computed parameters were also studied by working out the means with respect to different lag periods from 1 to 30 days prior to tapping. The estimated soil moisture storage value was found to be the most important factor for predicting yield in rubber. The relative lag in soil storage corresponding to three days prior to tapping during the winter period showed higher association with yield compared to that of one day prior during the non-winter period. Clones RRIM 600 and RRII 105 with high yielding tendencies showed prime dependence on average temperature of the previous day of tapping during the non-winter period. Clones RRII 118 and RRII 105 were more susceptible to water deficit conditions during the winter tapping period, while RRIM 600 performed well under water stress conditions. During the winter tapping period, RRII 203 was found to be susceptible to water deficit conditions.

7. Advisory services

During the reporting period, 1096 soil samples and seven leaf samples were collected and analysed. Discriminatory fertilizer recommendations were given to 548 growers from South, North and West Tripura.

REGIONAL RESEARCH STATION, TURA, MEGHALAYA

The Station was established in 1985 to study various aspects of rubber cultivation under the agroclimatic conditions of this region.

1. Evaluation of clones

Results from the 1985 trial at Ganolgre Farm indicated highest girth in RRIM 600 (75.12 cm) followed by RRII 118 (73.93 cm), PB 235 (73.63 cm) and RRII 203 (72.58 cm) while for yield, RRIM 600 (43.8 g/t/t) ranked first among the ten clones followed by RRII 203 (33.6 g/t/t) and RRII 118 (33 g/t/t). In the 1986 trial highest girth was recorded in RRIC 105 (75.23 cm), PB 311 (73.67 cm), RRII 118 (72.13 cm) and PB 310 (71.83 cm) while lowest girth was recorded in PR 255 (58.95 cm). On the basis of yield, PB 311 (38.2 g/t/t), RRII 208 (31.1 g/t/t) and RRII 118 (30.9 g/t/t) were performing better than the other clones.

Girth data were recorded at monthly intervals from the polyclonal seedlings planted in 1999, in an area of 0.25 ha at a spacing of 3 x 3 m at 600 m altitude. Population average girth was 50.38 cm. Even seedlings, in the population showed vigorous growth and were under observation for their performance. On the basis of growth, bark thickness, disease resistance, TPD and yield performance, ten trees from the plantation at Bagapha (1967 plantation, 400 m msl) and fifteen mother trees were selected from an area of two ha plantation at Tebrongre (1974 plantation, 620 m msl). Establishment of a budwood nursery of the selected trees was in progress.

2. Rubber based cropping system

This trial was started in 1987 with rubber (RRIM 600, spacing 6.6 x 3.3 m; no. of plants 125), tea (spacing 60 x 90 cm; total no. of plants 3000) and orange (spacing 15 x 15 ft, no. of plants 300) planted in separate block (each block of 0.25 ha) to assess the performance. In the current year, 388.5 kg green tea leaves worth Rs.2331/- were harvested. Girth and yield were collected from RRIM 600 clone and it has been noticed that plants attained an average girth of 60.2 cm while maximum yield was recorded in September and October. Generally it has been noticed that rubber and tea are performing better in terms of growth and yield while orange plants showed poor growth.

3. Plant physiology

During 1992, a project was initiated to find out the effect of low temperature on growth, yield and foliage pattern of *Hevea* at 600 m altitude of Garo Hills. It was noticed that when average air temperature dropped below 10 °C, growth and yield of all clones were adversely affected. All clones defoliated in the second week of February and remained so till air temperature rose to 15 °C which normally observed up to second week of March in the region.

An experiment was laid out during 1992 in 1987 block plantation to assess the effect of different aspect of slopes. One hundred plants of RRIM 600 clone has been selected from two different aspect of slopes, *i.e.*, West South West and North North East to find out the suitable aspect of slope for the region. Girth data were recorded at quarterly intervals from both the slopes and the results indicated that plants growing in West South West aspect of slope attained an average girth of 64.3 cm while plants growing in North North East aspect of slope attained an average girth of 60.5 cm.

During the year 1998, an experiment was initiated to find out the low temperature effect on growth, yield and yield components of *Hevea* clone at 600 m altitude. Three hundred plants of RRIM 600 were selected for monthly girth data recording and 35 plants

treatments performed better when the occurrence of TPD was considered. This experiment was initiated at Tura and Nagrakatta also under 1/2S d/1, 1/2S d/2 and 1/2S d/3 tapping systems with four regimes of tapping rests based on minimum temperature of 20-20 °C, 15-15 °C, 10-10 °C and control.

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The Station was established in 1985 to study various aspects of rubber cultivation under the agroclimatic conditions of this region.

1. Evaluation of clones

Results from the 1985 trial at Ganolgre Farm indicated highest girth in RRIM 600 (75.12 cm) followed by RRII 118 (73.93 cm), PB 235 (73.63 cm) and RRII 203 (72.58 cm) while for yield, RRIM 600 (43.8 g/t/t) ranked first among the ten clones followed by RRII 203 (33.6 g/t/t) and RRII 118 (33 g/t/t). In the 1986 trial highest girth was recorded in RRIC 105 (75.23 cm), PB 311 (73.67 cm), RRII 118 (72.13 cm) and PB 310 (71.83 cm) while lowest girth was recorded in PR 255 (58.95 cm). On the basis of yield, PB 311 (38.2 g/t/t), RRII 208 (31.1 g/t/t) and RRII 118 (30.9 g/t/t) were performing better than the other clones.

Girth data were recorded at monthly intervals from the polyclonal seedlings planted in 1999, in an area of 0.25 ha at a spacing of 3 x 3 m at 600 m altitude. Population average girth was 50.38 cm. Even seedlings, in the population showed vigorous growth and were under observation for their performance. On the basis of growth, bark thickness, disease resistance, TPD and yield performance, ten trees from the plantation at Bagapha (1967 plantation, 400 m msl) and fifteen mother trees were selected from an area of two ha plantation at Tebrongre (1974 plantation, 620 m msl). Establishment of a budwood nursery of the selected trees was in progress.

2. Rubber based cropping system

This trial was started in 1987 with rubber (RRIM 600, spacing 6.6 x 3.3 m; no. of plants 125), tea (spacing 60 x 90 cm; total no. of plants 3000) and orange (spacing 15 x 15 ft, no. of plants 300) planted in separate block (each block of 0.25 ha) to assess the performance. In the current year, 388.5 kg green tea leaves worth Rs.2331/- were harvested. Girth and yield were collected from RRIM 600 clone and it has been noticed that plants attained an average girth of 60.2 cm while maximum yield was recorded in September and October. Generally it has been noticed that rubber and tea are performing better in terms of growth and yield while orange plants showed poor growth.

3. Plant physiology

During 1992, a project was initiated to find out the effect of low temperature on growth, yield and foliage pattern of *Hevea* at 600 m altitude of Garo Hills. It was noticed that when average air temperature dropped below 10 ^{0}C, growth and yield of all clones were adversely affected. All clones defoliated in the second week of February and remained so till air temperature rose to 15 ^{0}C which normally observed up to second week of March in the region.

An experiment was laid out during 1992 in 1987 block plantation to assess the effect of different aspect of slopes. One hundred plants of RRIM 600 clone has been selected from two different aspect of slopes, *i.e.*, West South West and North North East to find out the suitable aspect of slope for the region. Girth data were recorded at quarterly intervals from both the slopes and the results indicated that plants growing in West South West aspect of slope attained an average girth of 64.3 cm while plants growing in North North East aspect of slope attained an average girth of 60.5 cm.

During the year 1998, an experiment was initiated to find out the low temperature effect on growth, yield and yield components of *Hevea* clone at 600 m altitude. Three hundred plants of RRIM 600 were selected for monthly girth data recording and 35 plants

for yield and yield components analysis at monthly intervals. Results indicated that RRIM 600 has attained an average girth of 60.2 cm but girth increment was lowest (0.01 cm) when air temperature dropped below 10 °C for three months (December - February). Similarly, minimum yield (9.0 g/t/t), latex volume (50 ml/t/t) and DRC (26%) were recorded from December to February. During winter period, low temperature adversely affected growth and yield of *Hevea* clone under agroclimatic conditions of Garo Hills.

4. Pathology

The secondary leaf fall (SLF) disease caused by *G. alborubrum* was noticed affecting the young rubber plants. However, the PDI calculated was always negligible.

During March-April, a severe outbreak of Powdery mildew disease was noticed infecting newly flushed leaves leading to defoliation. During a survey, 86.4% of PDI was recorded at DDC, Jungitchakgre where repeated defoliation was noticed. In other private holdings, the recorded PDI varied from 9.7 % at Chibragre to 80.8% at Danakgre in West Garo Hills.

A new root disease, commonly known as purple root disease, caused by *Helicobasidium compactum* was noticed infecting the seedling nursery at DDC, Jenggitchakgre. The disease has been occurring in a severe form and as a result a number of seedling died off. An experiment with different fungicides to control the disease are in progress.

Soil samples from forest, rubber, bamboo stands and barren land were collected to assay the qualitative and quantitative distribution of microbial population. It was observed that the minimum population was recorded during January and thereafter the population increased gradually. A few saprophytic fungal species were found to be very common and widely distributed. Among the species, *Penicillium* spp., *Mucor hiemalis*, filamentous yeast, *Cladosporium herbarum* and *Fusarium* spp. were isolated with a very high percentage of relative abundance. There was not much difference in the distribution of microbial population and the above ground vegetation does not seem to exert any influence in the composition of fungal species.

To assay the role of *Rhizobium* sp. on the growth of leguminous cover crops, an experiment was initiated in polybags. The soil samples were sterilized by autoclaving and cover crop (*Pueraria phaseoloides*) seeds were sown. After germination, the seedlings were thinned to four per polybag and *Rhizobium* sp. were inoculated. Monthly harvesting will be done and various growth parameters will be recorded. The study is in progress.

REGIONAL RESEARCH STATION, KOLASIB, MIZORAM

The Station is conducting experiments mainly to identify suitable clones of rubber for the Mizoram region. In addition, the station is also engaged in finding out suitable tapping systems, optimum fertilizer dose to make rubber cultivation more economical.

1. Nutritional trial

This experiment was initiated in 1998 to find out optimum fertilizer dose with NPK combinations in foothill condition. There are four fertilizer treatments in RBD with clone RRIM 600. Girth data were recorded at monthly interval and is presented in Table Nez. 1.

2. Evaluation of clones

This experiment was initiated in 1998 to identify the clones suitable for Mizoram con-

Table Nez. 1. **Effect of different doses of fertilizers on growth**

Nutrients (N:P:K kg/ha)	Girth (cm) in Feb. 2000	Annual girth increment (cm)
0:0:0	44.0	5.8
20:20:20	44.7	5.9
35:35:35	46.9	6.9
50:50:50	45.5	7.2
CD (P=0.05)	NS	NS

ditions in different land forms. The performance of these clones in different land forms *viz.*, foot hill, mid hill and hill top were recorded in terms of growth (girth) and yield. The highest mean girth was observed in mid hill condition and the clones SCATC 93-114 showed the highest girth among the clones. The highest yield was observed under foot hill with respect to mid hill and hill top condition (Table Nez. 2). Among the clones, PB 235 performed well in foot hill and hill top condition.

Table Nez. 2. **Yield of clones in different land forms under 1/2S d/2 system of tapping**

Clones	Yield (g/t/t)		
	Foot hill	Mid hill	Hill top
SCATC 93-114	35.0	38.1	24.2
PB 235	44.6	28.2	36.8
RRII 300	37.1	39.1	25.7
GT 1	28.2	32.9	29.5
RRII 118	33.2	33.5	21.3
RRII 105	27.1	31.9	24.2
RRIM 600	33.5	25.3	22.1
Mean	34.1	32.7	26.2

3. Effect of tapping systems on yield

The principal objective of this experiment was to identify a suitable tapping system under Mizoram conditions. The average dry rubber yield (g/t/t) of the seven blended clones for seven months under different tapping systems is presented in Table Nez. 3. The highest yield per tree was obtained in 1/2S d/3 system, however, the annual yield was high in 1/2S d/1 system of tapping due to more number of tapping days.

Table Nez. 3. **Yield under different tapping systems**

Tapping system	Yield (g/t/t)
1/2S d/1	32.0
1/2S d/2	34.2
1/2S d/3	42.9

REGIONAL RESEARCH STATION, NAGRAKATTA, WEST BENGAL

Research priorities of the station are to find out the suitable clones for the region, evolving appropriate fertilizer recommendations and development of suitable exploitation system for the region. Ten experiments are in progress, out of which four are on clone evaluation, two on nutritional studies and one each on clone blending, Genotype x Environment interaction and exploitation system.

1. Nutritional studies

Yield data during the third year of tapping from the nutritional requirement trial (1989) indicated no significant effect. Higher doses of N showed depressing effect on rubber yield. NPK combination at 30 kg N, 0 kg P and 40 kg K/ha recorded maximum yield (32.31 g/t/t) while 0 kg N, 20 kg P and 0 kg K/ha recorded the lowest yield (13.34 g/t/t). In the trial on split fertilizer application also, significant effect was noticed on girth.

A study on of intercropping rubber with tea was initiated. Rubber was planted at five different spacing (5 x 5 m, 10 x 2.5 m, 10 x 5 m, 12 x 2.5 m and 3 x 3 x 18 m). All cultural operations were completed for planting tea during June 2000.

2. Evaluation of clones

Observations from the 1990 trial, where 11 clones were under evaluation, highest

girth (58 cm) was recorded for RRIM 703 and the lowest (47.07 cm) for PB 5/51. Clones SCATC 93-114, Haiken 1, RRII 203, and RRII 118 recorded similar girth. Yield recorded for different clones produced significant effect. Among the different clones, SCATC 88-13, PB 235 and PB 311 recorded significantly higher yield during the second year of tapping compared to other clones. Clones Haiken 1, RRIM 703 produced lowest yield (Table Nag. 1).

Table Nag. 1. **Clone wise girth, girth increment and mean rubber yield during second year**

Clone	Girth (cm)	Yield (g/t/t)
PB 311	54.10	31.67
RRII 300	52.97	23.49
Haiken 1	57.80	14.72
SCATC 88-13	54.80	35.92
GT 1	52.93	19.77
SCATC 93-114	57.97	20.11
RRII 203	56.43	19.77
RRIM 703	58.00	17.14
PB 5/51	47.07	23.82
RRII 118	56.28	21.87
PB 235	56.23	35.71
SE	1.61	3.87
CD (P=0.05)	4.76	11.38

In another trial, where seven clones were under evaluation, RRIM 612 recorded the highest girth (59.33 cm) while PR 107 recorded the lowest girth (51.43 cm). In the second year of tapping differences in yield was not statistically significant (Table Nag. 2).

In the 1991 trial, PB 235 recorded highest girth (54.77 cm) and SCATC 93-114, RRIM 600, PB 86, RRII 208, PB 310 recorded almost similar girth and PR 107 recorded lowest girth (45.86 cm). In 1993 trial, RRIM 600 and RRII 105 recorded significantly higher girth (42.6 cm), while RRIC 104 and RRII 308 recorded lowest girth (310 cm).

Table Nag. 2. **Clone wise girth, girth increment and mean rubber yield during second year of tapping**

Clone	Girth (cm)	Mean yield (g/t/t)
PB 86	56.33	19.45
RRII 105	54.07	20.10
RRIM 605	57.50	14.40
RRIM 612	59.33	15.23
RRII 208	55.60	19.88
GI 1	52.87	15.92
PR 107	51.43	15.64
SE	0.92	1.66
CD (P=0.05)	0.92	NS

Among the different genotypes in the 1996 multi-locational trial, RRII 203 recorded significantly higher girth (44.58 cm) during the fourth year of planting. Similar girth was recorded in RRII 51, RRII 105, RRIM 600, PB 217, 82/14, 82/17 and 82/30.

3. Exploitation system

An experiment on the effect of combination of tapping systems (1/2S d/1, 1/2S d/2, 1/2S d/3) with tapping rest based on temperature regime (18-18 ^{0}C, 15-15 ^{0}C and 12-12 ^{0}C) and control without rest was started and treatments were imposed. The design of the experiment was split plot with tapping system as main plot and temperature rest as sub plot treatment.

4. Evaluation of germplasm

A trial to evaluate the *Hevea* germplasm (4 Wickham, 4 Mato Grosso, 6 Acre and 11 Rondonia accessions) for cold tolerance was planted in 1998 in simple lattice design with two replications. During the second year no significant effect on girth was noticed.

REGIONAL RESEARCH STATION, DAPCHARI, MAHARASHTRA

Major thrust areas of this station are development of suitable planting materials and location specific agrotechnology for this drought prone region. Experiments to evaluate low frequency tapping systems, studies on the growth and yield potential of various clones / polyclones and a clone evaluation trial with 15 clones including

RRII 105 are being carried out. The total crop production during the period was 18950 kg from 23 blocks. The total number of labourers engaged in 1999-2000 was 11425 (mandays).

1. Environmental physiology

The research concentrated on evaluation of suitable clones for this agroclimatic region with desired characters like tolerance to water and high temperature stress. Three irrigation-based experiments were conducted to study the effect of irrigation and irrigation system on yield of rubber.

The irrigation experiment started in 1987 with ETc based Basin (1.00 ETc, 0.75 ETc and 0.50 ETc) and drip (0.75 ETc, 0.50 ETc, 0.25 ETc) irrigation treatments in clone RRII 105 continued. The objective was to standardize and evaluate the advantages of drip irrigation system over basin irrigation in terms of water saving and total economy in the quantity of water and methods of irrigation. From February 2000 onwards the 0.75 ETc basin and 0.50 ETc drip were reduced to 0.25 ETc (basin and drip) with an objective to test whether irrigation requirement can be further reduced. Observations on the fortnightly cup lump weight, monthly girth measurements and seasonal DRC, PI, TP were recorded.

A trial to study the effect of different levels of irrigation (1.00 ETc, 0.75 changed to 0.25 ETC from February 2000 onwards and 0.50 ETc) on yield and yield components of clones indicated that clone RRII 118 performed better in terms of growth while RRII 105 showed better yield and yield parameters in response to different levels of irrigation treatments.

In the cost evaluation trial, the expenses incurred towards various inputs, farm practices and irrigation were monitored since 1987 in irrigated and unirrigated trees of RRIM 600. No significant reduction in block yield and growth was observed in mature trees even after reducing the irrigation level to 50% of that under immature phase, which indicated that irrigation level can be reduced to minimum after attaining maturity if the soil depth is good (Table Dap.1).

Table Dap. 1. **Yield of clone RRIM 600 under different levels of irrigation (Feb-May 2000)**

Irrigation	Project yield (kg/ha)	Yield (g/t/t)
Unirrigated	295.4	22.3 ± 17
1.00 ETc (shallow soil)	651.3	49.0 ± 4.1
ETc (deep soil)	707.5	53.1 ± 4.7

2. Exploitation studies

Based on the evaluation of low frequency tapping system (1/2S d/3), two experiments were laid out to identify exploitation system suitable to North Konkan conditions.

Two trials were initiated for evolving the optimum stimulation schedule under 1/2S d/3 tapping system in RRII 105 (Trial I) and RRIM 600 (Trial II) under irrigation. Trial I was started in December 1999 with RRII 105. Stimulation treatments T0 (control, no stimulation), T1 (2/y), T2 (4/y) and T3 (6/y) were implemented as per schedule under irrigation (0.50 ETc). Observations on DRC before and after stimulation, annual girth increment and TPD were monitored. Among the various treatments cumulative yield kg/tree/ha was highest in T3. Results indicated high rubber yield in the ethephon treated plants as compared to control. With a low incidence of TPD, ethephon stimulation (6/y) appeared to be optimum without any significant effect on growth under irrigation in this non-traditional agroclimatic region. No change in DRC was noticed after stimulation.

Trial II was started in February 2000 with clone RRIM 600. (BO1 panel) under 1/2S d/3 system of tapping. Stimulation treatments T1 (2/y), T2 (4/y), T3 (6/y), and T4 (8/y) were implemented as per schedule under irrigation (0.50 ETc) to all treatments. Observations on DRC before and after stimulation, annual girth increment and annual scoring of TPD were recorded.

An experiment was started in 1999 to study the tapping rest-cum-stimulation interaction under low frequency tapping system (1/2S d/3) in clone RRII 105 under rainfed condition with an objective to find out best tapping rest period during summer. Higher yield was observed in treatment with tapping rest in May and June with four stimulations/year, without any significant effect on the growth of trees. Results indicated that stimulation did not affect the DRC at all.

3. Plant breeding

The clone evaluation trial, started in 1985 with an objective to evaluate growth and yield performance of 15 modern clones indicated that clone RRII 208 performed better in terms of growth, whereas RRII 105 was better in terms of yield (Table Dap. 2). In another trial, promising polyclonal trees selected during 1996 were categorized as high girth, low girth, high yielder and low yielder trees. The selected trees were cut back to generate sprouts, which were used for multiplication through budding. Observation on fortnightly yield, seasonal girth, soil moisture and yield components were recorded. The growth and yield of latex were pooled and stable high yielders were identified for further selection. Selected mother trees with good yield throughout the year including drought season were studied.

Table Dap. 2. **Growth and yield of *Hevea* clones (March 2000)**

Clone	Mean girth (cm)	Mean yield (g/t/t)
RRII 5	53.30	28.40
RRII 6	57.19	31.49
RRII 105	52.84	33.16
RRII 208	60.12	36.15
RRII 308	50.91	24.02
RRIM 605	52.03	26.32
PB 260	53.08	30.12
PB 310	53.67	26.33
PB 311	52.36	22.65
RRIC 52	58.97	17.03
RRIC 100	55.29	29.34
RRIC 102	55.88	24.00
RRIC 105	52.61	17.41
PR 255	51.75	29.02
PR 261	51.32	26.05
SE±	2.35	3.26
CD (P=0.05)	4.81	6.67

4. Plant pathology

Experiment was started to evaluate the susceptibility / tolerance of various *Hevea* clones and polyclonal seedlings to powdery mildew. Results indicated no incidence of powdery mildew disease in this region. This might be due to prevailing high temperature.

REGIONAL RESEARCH STATION, DHENKANAL, ORISSA

The Station concentrates its research activities on agromanagement techniques, water conservation and evaluation of clones tolerant to drought condition existing in the region.

1. Evaluation of clones

In the clone trial planted in 1987, with three elite clones (RRIM 600, GT 1 and RRII 105), significant difference in girth was observed. Both GT 1 (51.5 cm) and RRIM 600 (50.1 cm) recorded significantly higher girth than RRII 105 (46.6 cm).

Regular observations were collected from the polyclonal seedlings planted in 1989. Variations in girth was very high. Tapping of the trees that have attained tappable girth was started. Twelve promising seedlings have been identified. The highest average yield was recorded for tree 26 (76.4 g) and minimum in tree 280 (23.3 g) during 1998-99.

In the 1990 clone trial, no significant difference in girth was recorded. Maximum girth was recorded in SCATC 93-114 (52.0 cm), followed by RRII 208 (50.5 cm) while SCATC 88-13 recorded the lowest girth (41.5 cm).

Another trial was initiated in 1991 to compare the performance of different *Hevea*

clones with polyclonal seedlings. Clones did not differ significantly on girth while polyclonal population recorded highest girth (49.5 cm). Lowest girth was observed in PR 255 (35.7 cm). Maximum girth increment was noticed in PR 261 (21.5%) and PR 255 (19.8%).

2. G x E interaction in *Hevea*

An onfarm trial was started at Regional Research Laboratory campus, CSIR, Bhubaneswar and 12 clones were planted during 1996. Three years after planting, maximum girth of 19.4 cm was recorded in clone PB 217 and RRIC 100 followed by 82/30 (19.3 cm), 82/17 and RRII 203 (19.0 cm). Clones 82/14 and RRII 176 showed the lowest girth of 16.7 and 17.5 cm respectively. The result showed that 82/30, RRIC 100, PB 217, RRII 203, 82/17, RRIM 600 and RRII 105 were stable clones.

The World Bank assisted project on clone evaluation was laid out in 1999-2000, to evaluate the growth and yield performance of few modern clones of *Hevea* under the environmental condition of Orissa. Growth and morphological parameters were collected. The trial is under progress.

3. Nutritional studies

The experiment was laid out to assess the nutritional requirements and the efficiency of N and P biofertilizers on the growth of *Hevea* seedlings. The treatments included N and P biofertilizers alone and in combination with FYM, having NPK fertilizer in three levels (0, 25 and 100%) of the recommended dose. All the growth parameters were recorded during the period. Soil and leaf samples were collected for microbial and chemical analysis.

Treatments N1P1K1 found superior for all the growth parameters (growth, height and number of whorls). Maximum girth and number of whorls in seedling nursery was observed at 75% doses each of N, P and K fertilizers along with the biofertilizers (Azospirillum and PSM), height of the plants were on par among them. It saved 25% each of N, P and K fertilizer.

Trial was laid out with RRIM 600, to study the effect of water soluble and water insoluble forms of P on growth of *Hevea* and the effect of higher dose of NPK fertilizer with appropriate number of split application needed for optimum growth of rubber in Orissa. During the period under report all growth parameters were recorded (Table Ori. 1). The trial is under progress.

4. Disease management

An observation trial to study the status of powdery mildew disease in rubber plantations of non-traditional areas was started in 1998. The objective was to evaluate the susceptibility/tolerance of various *Hevea* clones and polyclonal seedlings planted in these areas against powdery mildew disease. Till now rubber plantation was not affected by powdery mildew disease. Experiment is under progress.

Table Ori. 1. **Effect of water-soluble and water insoluble forms of P fertilizers on the growth of *Hevea***

Treatment (NPK)	Stem diameter (cm)	Whorls (cm)	Height
T1 - 0:0:0	1.04	1.87	124.40
T2 - 40:40(20):16	1.16	1.97	144.20
T3 - 40:40:16	1.12	1.63	124.70
T4 - 60:60(30):24	1.09	1.93	144.70
T5 - 60:60:24	0.93	1.85	121.90
T6 - 80:80(40):32	0.92	1.49	118.30
T7 - 80:80:32	1.19	2.03	141.00
SE	0.10	0.18	13.05
CD = (P=0.05)	NS	NS	NS

REGIONAL RESEARCH STATION, SUKMA, CHATTISGARH

The major research activities of the Station are identification of suitable planting material for the region and refinement of agromanagement recommendations for optimal growth and yield of rubber. To meet these objectives, experiments on performance of modern clones, polyclonal seedlings and germplasm material are in progress.

In the trials initiated during 1990, 1992 and 1993, girth was recorded at regular intervals. In the 1990 trial, an average girth of 56 and 50 cm were recorded for RRII 105 and RRIM 600 respectively. Polyclonal seedlings planted in 1997 were growing satisfactorily and have attained an average girth of 20 cm.

The trial on screening of *Hevea* germplasm for drought tolerance showed wide variations in growth and adaptability. Morphological and phonological studies also showed significant variations suggesting good scope for selection of genotypes with desired traits for the region. Budded stumps of *Hevea* germplasm were generated at the station for a trial on screening for cold tolerance at RRS, Nagrakatta. A study on phenology and architecture of *Hevea* germplasm was conducted. Significant variation was observed among the clones. Branching behaviour varied significantly. The lowest number of primary branching was observed in AC 707 and highest in RO 5069 and MT 196 respectively.

REGIONAL RESEARCH STATION, PADIYOOR, KERALA

The Station was established in 1994 in an area of 40 ha in Kannur District with the major objective of developing clones suitable for the region and for screening of clonal tolerance to drought/disease incidence. The long-term field trials initiated include evaluation of Brazilian germplasm, investigations on Genotype x Environment interaction, clone evaluation, large scale testing of potential hybrid clones, multiclone blend trial and disease evaluation.

1. Physico-chemical properties of soil

The experiment was initiated in 1998 with the objective of building a database on soil physico-chemical properties. Survey of the entire experimental area has been completed. Grouping the area into different slope classes using the Abney level is in progress.

2. Water requirement in seedling nursery

The purpose of this experiment is to study the water requirement of *Hevea* seedlings in the nursery. The treatments comprised of five irrigation regimes, *viz.*, irrigation at 0, 25, 50 and 75% depletion of available soil moisture (dasm) and an unirrigated control. Observations on growth and soil moisture were carried out at periodic intervals. Fifty per cent depletion of available soil moisture was found to be the optimum level of moisture depletion for growth of rubber seedlings (Table Pad. 1).

Table Pad. 1. **Plant diameter (cm) at periodic intervals**

Treatment	Interval after treatment imposition (months)				
	Pre-treatment	1	2	3	4
0 dasm	0.42	0.58	0.74	0.93	1.12
25 dasm	0.46	0.60	0.75	0.93	1.03
50 dasm	0.47	0.62	0.76	0.91	1.01
75 dasm	0.46	0.57	0.67	0.79	0.89
Unirrigated	0.48	0.59	0.64	0.69	0.79
SE	0.02	0.02	0.02	0.03	0.04
CD (P=0.05)	NS	NS	0.06	0.09	0.12

HEVEA BREEDING SUB-STATION, NETTANA, KARNATAKA

The experimental farm comprises an area of 47.6 ha wherein different trials on clone evaluation and other breeding trials have been laid.

1. Yield and exploitation systems

Two experiments are constituted in this trial, one planted in 1987 and the other in 1988 to compare the effect of different systems of exploitation on the yield of the constituent clones and also the growth of clones. Each experiment comprised of five clones planted in a split plot design. In the first experiment, clone PB 235 was superior in growth in terms of average girth (74.73 cm) while RRII 300 was poor in girth (60.48 cm) (Table Kar. 1). The percentage contribution to the annual growth was more during the second quarter (40.41 %) followed by the first quarter (30.41 %). The last quarter contributed the least to the growth (12.58 %). In the second experiment, clone RRII 118 showed better growth by means of average girth (72.22 cm) while PR 255 was poor in girth (52.83 cm). The highest percentage contribution to growth was by the third quarter (30.58 %) while it was lowest during the last quarter (21.84 %).

The trial initiated during 1987 was under third year of tapping. The data on dry rubber yield is being recorded for every tap under each system of tapping. The systems of exploitation being advocated on the five clones, *viz.*, RRII 105, RRII 300, PB 235, PB 260 and PB 311.

The study revealed significant variation for yield among the clones tapping systems, months as well as interaction between these factors. RRII 105 recorded the highest yield of 83.73 g/t/t, while RRII 300 recorded the lowest (42.611 g/t/t). Similarly, under the different tapping systems, system 5 registered the highest yield of 106.97 g/t/t while 1/2S d/4 6d/7 with stimulation level 2 system of tapping recorded the lowest yield of 38.47 g/t/t. The peak yielding months were November (106.31 g/t/t) followed by December (94.99 g/t/t) and October (92.21 g/t/t).

2. Crop improvement

2.1 Evaluation of ortet clones

This trial constituted of three experiments laid out with the common control clones RRII 105, RRIM 600 and GT1. The first two experiments have 17 clones each and the third experiment had 14 clones. Among the control clones, RRIM 600 showed better

Table Kar. 1. **Growth performance of different clones in 1987 and 1988 experiments**

Clone	Mean girth (cm)	Percentage girth increment			
		April	July	October	January
1987 Experiment					
RRII 105	63.433	1.002	1.134	0.522	0.571
RRII 300	60.480	1.620	2.195	0.622	0.492
PB 235	74.730	1.806	2.293	0.632	0.345
PB 260	68.450	1.164	1.803	0.926	0.718
PB 311	65.553	1.070	1.424	0.934	0.631
Mean	66.529	1.332	1.770	0.727	0.551
1988 Experiment					
RRII 118	72.220	1.320	1.180	2.280	1.830
PR 255	52.830	1.450	1.260	1.510	0.980
PR 260	60.070	0.980	1.560	1.610	1.220
RRIC 36	56.940	1.490	1.470	1.500	1.250
RRIC 45	56.350	1.210	1.370	1.650	0.840
Mean	59.682	1.290	1.368	1.710	1.224

growth performance followed by GT 1 in terms of girth increment. Considering the relative performance, five clones (O 12, O 17, O 47, C 70 and T2) in experiment I recorded greater growth in terms of girth increment than all the control clones. Similarly, two clones in experiment II (O 53 and C9) and nine clones in experiment III (O 26, O 30, O 39A, O 49, O 55, O 56, O 64, C 32 and C 140) registered better growth over the three control clones.

2.2 Large scale clone trials

The first experiment for the evaluation of modern clones was planted in 1989 and consisted of 14 clones. The second experiment for the evaluation of second selections and a few modern clones was planted in 1990 and consisted of 15 clones.

In the 1989 experiment, RRII 203 registered better growth (70.44 cm) while Haiken 1 continued to show poor growth (46.49 cm). In the 1990 experiment, clone PB 235 registered better growth (58.35 cm) while Tjir 1 exhibited the lowest growth (48.38 cm) (Table Kar. 2).

2.3 Composite clone trials

This constitutes of three small - scale experiments planted in 1991. The first experiment consisted of 36 clones while the second and third experiments included 13 clones each with GT 1 as the common control. Besides, RRII 105 has been included in experiment 1 and 2 while RRIM 600 included in experiment 1 and 3. GT 1 recorded an average girth of 49.17, 49.26 and 46.51 cm in the three experiments respectively. In the experiment 1, clones *viz.*, PB 235, PB 260, PB 217, PB 310, PB 314 and RRIC 100 showed better growth performance. In the second experiment RRII 5, RRII 308 and Nab 17 recorded better growth performance.

Table Kar. 2 **Performance of clones in large-scale trials**

1989 Experiment		1990 Experiment	
Clone	Girth (cm)	Clone	Girth (cm)
RRII 105	59.19 bcd	RRII 105	54.00 a-e
RRII 203	70.44 a	HP 185	52.97 a-f
RRII 300	58.90 bcd	HP 187	50.65 c-f
RRII 308	60.83 bcd	HP 204	50.09 def
RRIM 600	55.78 de	HP 223	56.50 ab
PB 255	59.78 bcd	HP 372	56.46 ab
PR 255	50.10 fg	PB 217	53.70 a-f
PR 260	57.50 cd	PB 235	58.35 a
KRS 25	60.98 bcd	PB 260	58.20 a
KRS 128	64.02 b	PB 311	53.71 a-f
KRS 163	61.81 bc	Hil 28	52.67 b-f
SCATC 88 - 13	52.21 ef	MIL 3/2	54.37 a-d
SCATC 93 - 114	50.91 efg	GT 1	55.86 abc
Haiken 1	46.49 g	GI 1	48.83 ef
		Tjir 1	48.38 f

* Clones followed by same letters are not significantly different by DMRT at 0.05

2.4 Estimation of genetic parameters

This trial consisted of 12 clones and their respective half-sib progenies planted during 1990 with the objective of estimating the genetic parameters. Considering the growth of the clones, PB 235 registered the highest growth (80.97 cm) while Tjir 1 recorded the least (69.12 cm). Among the half-sibs, the progenies of clone PB 235 recorded the highest growth (66.00 cm) while the progenies of IAN 873 registered the least (43.67 cm).

2.5 Polycross garden

This trial consisted of nine pre-potent clones that were planted in a polycross fashion in order to evaluate their performance. Girth recording has been initiated in 3 selected plots of 9 x 9 dimension.

3. Crop protection

Survey on *Corynespora* leaf disease was conducted in major rubber growing areas of Mangalore, Kundapur (Karnataka) and Kanhangad (Kerala). In Coastal Karnataka, higher disease incidence was noticed in Subramanya where the CLF disease was first observed in damaging dimensions. Puttur, Sullia and Madikere, the adjoining areas of Subramanya, recorded moderate incidence. Kundapur and Belthangady registered fewer incidences. In North Malabar, Kanhangad recorded higher incidence followed by Hosdurg and Nileshwar (Table Kar. 3). Among the clones surveyed, the popular

Table Kar. 3. **Average incidence of *Corynespora* leaf fall disease in different locations during three survey seasons**

Location	Disease intensity (%)		
	1998	1999	2000
Kundapur	26.42 (30.00) bc	31.14 (33.30) b	17.45(23.96) d
Belthangady	24.85 (29.17) c	29.83 (32.51) c	15.82(22.98) d
Puttur	36.00 (36.26) bc	58.56 (50.32) a	32.87(34.07) abc
Sullia	40.46 (38.82) abc	58.96 (51.44) a	34.20(34.93) abc
Madikere	32.50 (33.94) bc	53.11 (47.04) ab	31.64(33.04) a-d
Subramanya	52.26 (46.57) a	66.00 (56.12) a	36.56(36.47) ab
Kanhangad	45.42 (42.12) ab	61.35 (52.13) a	38.80(37.76) a
Nileshwar	-	-	18.00(24.44) cd
Hosdurg	-	-	23.80(27.95) bcd
CV(%)	35.21	32.04	39.40

Figures in parentheses indicate arcsine transformed average values.
Location means having same letters under each season are not significantly different by L.S.D test at 5% level.

clone RRII 105 widely planted in these locations showed severe infection as compared to other clones (Table Kar. 4).

Experiment conducted to evaluate the water dispersible powder formulations of fungicides for the control of *Corynespora* leaf disease at Sampaje Estate, Sullia, Karanataka showed that Mancozeb and Carbendazim were superior to copper oxychloride (COC) and Bordeaux mixture (1%).

Experiments were conducted in rubber plantations owned by Karnataka Forest Development Corporation Ltd. (KFDC) with oil dispersible powder formulations of Mancozeb, COC and Mancozeb + COC (mixed) liquid formulation of Mancozeb. Results of the experiment indicated that Mancozeb both liquid and powder formulations were more effective and recorded less disease incidence. COC mixed with Mancozeb and COC alone were also found to be effective for disease control.

Experiment carried out at plantations of KFDC Subramanya division with Hexaconazole (2% dust), Carbendazim (1.5% dust) and Tridemorph (1.5% dust) indicated that Hexaconazole dust was more effective. However, Carbendazim and Tridemorph dust also recorded less disease incidence and were equally effective for the disease control.

Table Kar. 4. **Average disease incidence in different clones in nine locations**

Clone	KPR	BTD	PTR	SLA	SBM	MDK	KGD	NLS	HSD
RRII 105	2.81 a	2.30 a	3.20 a	3.15 a	3.37 a	3.06 a	3.29 a	2.50 a	2.80 a
PB 260	1.40 bc	1.22 b	1.80 b	1.68 b	2.20 b	2.17 b	2.21 b	1.85 b	1.90 b
GT 1	0.50 d	0.47 d	0.67 c	0.82 c	0.86 c	0.65 c	0.75 e	0.97 d	0.80 c
RRIM 600	0.80 cd	0.78 c	1.00 c	0.84 c	1.17 c	0.97 c	1.27 d	1.07 d	0.85 bc
PB 217	1.47 b	1.23 b	1.79 b	1.57 b	2.12 b	2.13 b	2.22 bc	1.57 c	-
PB 235	-	-	-	-	2.07 b	2.00 b	2.04 c	-	-

KPR : Kundapur, BTD : Belthangady, PTR : Puttur, SLA : Sullia, SBM : Subramanya, MDK : Madikere, KGD : Kanhangad, NLS : Nileshwar, HSD : Hosdurg
Clone means having same letters under each location are not significantly different by LSD test at 5% level.
Disease score: 0.00 : No disease; 0.01 – 1.00 : Very light; 1.01 - 2.00 : Light; 2.01 – 3.00 : Moderate; 3.01 – 4.00 : Severe; 4.01 – 5.00 : Very severe

HEVEA BREEDING SUB-STATION, PARALIYAR, TAMIL NADU

The research projects being pursued in this station are two onfarm trials at New Ambadi Estate, Maniankuzhy, three large-scale clone evaluation trials initiated as part of World Bank Assisted Project and one unit of the multilocational clone evaluation trial, undertaken by the Botany Division.

1. Evaluation of clones

With a view to generate new clones with

high yield and promising secondary characters, this project was initiated during 1987. Two breeding orchards were laid out in an area of five ha and a total of 51 parental clones were planted at wider spacing. By constant pruning and pollarding of branches, the canopy of the parental plants were maintained in such a way that hand pollination could be attempted conveniently from the ground itself. Hand pollination was attempted with different parental combinations. The hybrid plants obtained from hand pollination, carried out during 1997 and 1998, were raised in nursery for preliminary evaluation.

As part of ortet selection programme, 40 potent high yielders were selected and a budwood nursery was established.

2. Standardisation of root trainer nursery

A field trial was initiated to compare the performance of plants in root trainers and polybag, after transplanting to the field. Green budded stumps of RRII 105 and PB 235 were planted in root trainers and polybags and observations were recorded every month. Pattern of root development was observed by visual and destructive sampling. Initially growth was found better in polybags, but growth was found to be more vigorous in root trainers from second whorl onwards. Tap root reached bottom of polybags 6 to 8 weeks after planting and coiled inside. In root trainers, coiling was avoided completely. They were planted in field in RBD with four replications.

3. Polyclonal seed garden

A project was initiated to establish a series of polyclonal seed gardens in this region with modern high yielding clones as parents. A seed garden was initiated at New Ambadi Estate, Maniankuzhy. Planting was carried out as one-directional polycross design of nine clones. Sufficient polybag plants of the parental clones have been maintained for vacancy filling during the next planting season.

LIBRARY AND DOCUMENTATION CENTRE

The library continued its important role of communicating and disseminating information on natural rubber and allied subjects through its library collection, information services and publications. The library facilities were also extended to the manufacturers and others related to natural rubber industry. Research scholars and students from Universities and colleges were also allowed to utilize the library facilities.

1. Library resources development

During the year, 161 books were added to the stock of the library making a total collection of 22010. The library subscribed 81 foreign journals and 46 Indian journals. About 60 journals were also received as gift/exchange.

2. Documentation and Information services

Four issues of Documentation list, four numbers of Rubber alerts and two issues of new additions were compiled and distributed. 101 articles were sent to various libraries/institutes as per request and also procured 16 numbers of photocopies/reprints of articles by inter-library loan services.

3. Computerization activities

As part of the computerization activities in the RLIND and RLCAT Databases, articles from journals, seminar papers, conference proceedings *etc.* and details of books purchased were added and updated. Information on rubber and allied subjects were retrieved from the above databases.

4. Publications

The Institute has brought out a new book, 'Natural Rubber : Agromanagement and Crop Processing' as a revised and enlarged version of the 'Handbook of Natural Rubber Production in India' published during 1980. The book covers all aspects of natural rubber cultivation and primary processing of the crop. The centre also engaged in the sales promotion of RRII publications.

AGROMETEOROLOGY

Monthly rainfall data for 22 years since 1976, covering 12 districts of Kerala was collected from the Indian Meteorological Department (IMD). Rainfall data was also collected from the plantation tracts representing each district. Mann-Kendall rank statistic test at 95% level of confidence was used for finding the trends in rainfall, if any. No specific trend has been observed in any of these districts and the state as a whole (Table Agromet. 1). Plantation area showed an increasing trend in annual rainfall. Contribution of post monsoon rains to the annual rainfall is notable. However, more data are to be analysed to confirm the results. Disease initiation and progress at HBSS, Nettana and CES, Chethackal has been observed in the unsprayed areas to find out the environmental conditions congenial for the outbreak of the diseases. Weekly disease intensity has been calculated in the case of powdery mildew disease.

Table Agromet. 1. **Trend analysis of rainfall data**

District	No. of year	Mann-Kendall rank Correlation coefficient
Trivandrum	30	-0.03
Kollam	21	0.31
Alleppy	21	0.31
Idukki	21	0.05
Ernakulam	21	0.07
Thrissur	19	-0.12
Palghat	21	-0.06
Malappuram	19	0.03
Calicut	24	0.15
Wayanad	21	0.04
Kannur	16	0.13
Kasaragod	21	0.06

The meteorological data recorded from different stations are summarised in Table Agromet. 2.

Table Agromet. 2. **Meteorological data from different station**

Month	Max. Temp. (°C)	Min. Temp. (°C)	RH (%)		Wind speed (km/h)	Sunshine (h)	Evapo-ration (mm)	Rainfall (mm)
			AM	PM				
Kottayam								
January	33.0	21.5	84	49	1.4	7.8	4.1	000
February	34.6	23.3	88	51	1.6	8.5	4.6	041
March	35.3	24.6	90	57	1.9	8.4	4.8	013
April	32.4	24.5	87	69	1.7	4.8	3.1	204
May	30.6	23.7	93	78	1.3	4.5	2.7	565
June	30.3	23.3	95	80	1.3	5.6	2.8	612
July	29.4	22.9	97	86	1.6	3.2	2.5	474
August	30.3	23.4	96	84	1.7	5.6	3.2	215
September	32.0	23.4	95	80	1.6	7.2	4.0	061
October	30.4	22.9	87	74	1.4	4.5	2.3	796
November	32.6	23.0	93	64	1.0	4.5	2.3	209
December	33.3	22.4	90	56	1.0	7.6	3.7	007
CES, Chethackal								
January	34.3	19.8	85	62	1.5	5.2	-	008
February	35.4	20.0	89	45	1.5	8.1	-	126
March	35.9	22.3	91	48	1.0	9.1	-	49
April	32.5	22.9	91	70	1.1	5.3	-	432
May	31.0	23.1	92	78	0.7	3.9	-	541
June	30.5	22.6	93	73	1.3	5.8	-	536
July	29.3	22.4	94	82	1.8	3.3	-	580
August	30.3	22.4	91	71	1.4	5.2	-	244
September	31.8	22.3	92	64	1.2	7.0	-	119
October	30.7	22.4	92	70	0.7	4.3	-	961
November	32.9	21.6	91	61	0.6	6.9	-	97
December	34.0	20.9	88	54	1.1	4.5	-	011

Table Agromet. 2. **Meteorological data from different station** *(continued)*

Month	Max. Temp. (°C)	Min. Temp. (°C)	RH (%) AM	RH (%) PM	Wind speed (km/h)	Sunshine (h)	Evapo-ration (mm)	Rainfall (mm)
Guwahati								
January	24.8	11.5	87	56	2.9	7.4	1.3	000
February	29.5	14.8	81	52	2.5	6.6	1.9	000
March	32.6	14.6	74	37	3.2	7.5	2.4	000
April	33.5	19.1	85	59	2.6	7.1	2.4	017
May	31.4	20.6	92	79	1.8	4.5	1.1	158
June	33.2	24.2	94	77	1.4	4.1	1.5	220
July	31.9	24.3	94	83	1.1	2.7	0.9	240
August	31.8	24.7	94	81	1.4	3.9	1.0	311
September	32.1	24.0	94	80	1.1	4.7	1.7	135
October	30.0	22.4	90	77	1.5	5.4	2.0	136
November	29.1	18.2	88	68	2.3	7.6	1.6	002
December	25.9	12.9	84	62	1.9	7.5	1.5	013
Agartala								
January	27.0	11.1	93	39	1.3	7.9	1.4	000
February	28.3	10.7	91	42	1.1	9.2	2.5	000
March	33.5	19.1	93	46	4.2	8.0	3.8	117
April	34.5	25.5	88	48	6.0	8.4	4.5	008
May	32.9	24.9	87	67	6.0	5.6	3.5	216
June	31.7	25.6	86	77	5.9	5.3	2.6	270
July	31.1	25.3	94	78	4.2	3.8	3.0	470
August	30.7	25.7	90	80	4.3	3.3	3.4	338
September	31.4	24.7	92	77	3.1	4.1	2.6	164
October	30.7	24.1	92	74	1.7	3.0	2.0	273
November	30.4	19.8	92	62	0.8	8.4	2.1	001
December	27.9	12.4	92	50	0.8	6.8	1.9	002
Tura								
January	25.5	7.7	80	56	–	7.1	2.4	000
February	28.3	10.6	75	41	–	8.4	2.7	000
March	31.2	12.8	66	39	2.4	8.1	--	014
April	31.1	19.0	86	62	2.7	6.4	3.5	285
May	30.5	20.1	87	75	2.2	4.5	3.0	289
June	30.4	22.5	92	80	1.8	3.5	2.6	438
July	30.2	21.8	92	80	1.3	3.5	2.8	171
August	28.3	22.3	94	86	1.2	2.2	2.5	515
September	29.6	20.5	92	82	0.6	3.9	2.3	034
October	29.5	19.5	88	78	1.3	5.0	2.8	112
November	27.6	15.6	81	61	0.9	7.6	3.1	000
December	25.8	10.9	79	54	0.7	7.9	2.3	000
Kolasib								
January	28.6	11.7	90	81	6.5	6.5	2.0	000
February	33.1	12.6	93	82	7.1	7.1	2.5	000
March	35.1	15.3	91	74	7.2	7.2	2.7	129
April	36.1	21.1	91	66	7.5	7.5	3.1	045
May	34.3	21.4	90	77	4.0	4.0	2.0	405
June	34.3	22.4	98	76	2.3	2.3	1.4	210
July	34.1	22.8	90	81	3.2	3.2	1	343
August	33.6	22.9	90	79	2.4	2.4	0.9	281
September	33.8	22.6	90	76	4.8	4.8	0.9	302
October	33.3	22.7	91	81	2.5	2.5	1.8	199
November	31.7	17.4	90	73	5.9	5.9	2.3	017
December	29.5	13.3	90	71	5.9	5.9	2.1	001

Table Agromet. 2. **Meteorological data from different station** *(continued)*

Month	Max. Temp. (°C)	Min. Temp. (°C)	RH (%) AM	RH (%) PM	Wind speed (km/h)	Sunshine (h)	Evapo-ration (mm)	Rainfall (mm)
Nagrakatta								
January	26.8	5.5	94	47	0	7.9	2.3	000
February	29.3	10.5	93	42	0	7.8	2.1	000
March	30.6	12.5	87	41	0.6	8.4	3.2	016
April	32.0	21.8	84	57	0.8	5.9	3.5	203
May	31.1	24.7	94	70	0.1	4.9	4.6	313
June	31.5	24.7	96	75	0	3.9	2.9	487
July	31.7	25.7	96	84	0.1	3.0	2.6	1158
August	30.7	24.9	92	82	1.6	2.4	3.1	852
September	31.3	25.1	90	78	1.6	4.7	3.1	524
October	30.8	22.2	90	67	1.1	5.9	2.6	143
November	29.7	16.0	90	54	1.0	8.3	1.9	082
December	26.8	10.8	95	55	1.0	7.8	1.9	000
Dapchari								
January	30.4	13.1	95	81	0.5	9.0	-	000
February	34.0	17.1	92	69	0.7	8.9	-	000
March	36.1	18.6	85	65	1.5	9.8	-	000
April	36.6	22.7	-	-	2.0	10.1	-	000
May	35.0	25.7	-	-	3.1	8.8	-	008
June	31.9	25.6	89	72	2.3	4.4	-	568
July	29.1	25.1	93	88	2.4	1.6	-	640
August	29.1	25.1	93	88	1.3	1.6	-	640
September	30.7	24.0	95	76	0.7	5.6	-	315
October	33.2	21.8	90	67	0.6	8.0	-	207
November	33.6	17.0	84	49	0.8	8.9	-	000
December	32.6	14.1	83	45	0.8	8.8	-	000
Dhenkanal								
January	27.5	8.9	87	44	-	8.3	3.3	000
February	31.7	14.9	93	42	-	9.0	4.5	000
March	38.1	19.1	84	35	-	9.2	6.3	000
April	41.3	24.2	91	86	-	9.5	7.9	014
May	36.8	23.2	84	77	4.6	7.8	5.8	116
June	33.2	23.6	89	83	-	5.8	3.4	194
July	31.6	23.8	90	76	-	3.3	3.4	253
August	31.6	22.9	91	80	-	4.5	2.3	410
September	31.0	23.0	92	81	-	3.9	2.5	193
October	29.8	21.0	93	82	-	7.2	3.2	583
November	27.2	14.2	94	76	-	7.8	2.4	000
December	26.3	12.1	89	75	-	8	2.8	000
Nettana								
January	34.0	15.4	88	44	-	8.4	-	000
February	36.7	17.7	89	36	-	9.1	-	000
March	37.0	22.0	87	40	-	8.2	-	000
April	35.3	22.7	87	49	-	7.4	-	036
May	31.5	22.9	91	72	-	4.2	-	398
June	29.8	22.3	92	76	-	4.2	-	825
July	27.4	22.2	93	88	-	1.8	-	1718
August	29.0	22.7	92	81	-	3.7	-	836
September	31.5	22.2	91	70	-	5.6	-	320
October	31.5	22.6	92	84	-	4.9	-	760
November	33.5	20.1	87	68	-	7.5	-	009
December	33.5	17.3	85	55	-	8.4	-	002

Table Agromet. 2. **Meteorological data from different station *(continued)***

Month	Max. Temp. (°C)	Min. Temp. (°C)	RH (%) AM	RH (%) PM	Wind speed (km/h)	Sunshine (h)	Evapo-ration (mm)	Rainfall (mm)
Paraliyar								
January	32.0	21.0	93	52	-	7.5	-	006
February	33.6	22.5	93	52	-	7.9	-	074
March	35.4	22.8	89	49	-	8.1	-	067
April	32.5	24.2	91	69	-	5.5	-	156
May	30.8	24.2	93	73	-	5.3	-	285
June	30.2	23.5	93	73	-	6.2	-	353
July	29.7	24.3	83	72	-	4.9	-	161
August	31.2	23.9	91	68	-	6.8	-	036
September	33.0	22.9	92	61	-	7.1	-	090
October	29.7	23.0	97	83	-	3.5	-	404
November	31.6	22.8	95	68	-	6.0	-	099
December	31.8	21.6	89	57	-	6.9	-	007

ANNUAL EXPENDITURE

Expenditure at a glance 1999-2000

Head of Account	Expenditure (Rs. in lakhs)
Non-plan	
General charges	416.33
Schemes	19.67
Projects (CES)	114.53
Total	**550.53**
Plan	
General charges	110.99
Schemes	174.47
NERDS Research Component	136.36
Total	**421.82**
World Bank Project	**170.59**
Grand Total	**1142.94**

PUBLICTIONS

RESEARCH ARTICLES

Abraham, J., Nair, R.B., Punnoose, K.I., Philip, M.E. and Mathew, M. (1997*). Leaf age and nutrient status of *Hevea brasiliensis*. *Indian Journal of Natural Rubber Research*, **10**(1&2) : 66-74.

Chandrashekar, T.R., Mydin, K.K., Alice, J., Varghese, Y.A. and Saraswathyamma, C.K. (1997). Intraclonal variability for yield in rubber (*Hevea brasiliensis*). *Indian Journal of Natural Rubber Research*, **10**(1&2) : 43-47.

Choudhury, M., Raj, S., Eappen, T., Varghese, M., Sarma, A.C. and Dey, S.K. (1999). Effect of different levels of inorganic nutrients on growth and yield of rubber. *National Seminar on Development in Soil Scientist*, 26-30 November 1999, Tamil Nadu Agricultural University, Coimbatore, India.

Claramma, N.M., Varghese, L., Thomas, K.T. and Mathew, N.M. (2000). Radiation induced graft copolymerisation of styrene onto natural rubber. *Eighteenth Rubber Conference*, 20-21 January 2000, Mumbai, India.

Dey, S.K. and Mathew, N.M. (1999). Rubber for development of North East. *North Eastern Regional Seminar on Science and Self-reliance : Development of North Eastern Region*, 2-4 June 2000, Agartala, India.

Edathil, T.T., Jacob, C.K. and Joseph, A. (2000). Leaf diseases. In : *Natural Rubber : Agromanagement and Crop Processing* (Eds. P.J. George and C. Kuruvilla Jacob). Rubber Research Institute of India, Kottayam, pp. 273-296.

George, B., Alex, R. and Mathew, N.M. (2000). In : *Natural Rubber : Agromanagement and Crop Processing* (Eds. P.J. George and C. Kuruvilla Jacob). Rubber Research Institute of India, Kottayam, pp. 453-470.

George, E.S., Sudhakumari, B., Bindhumol, G.P. and Punnoose, K.I. (1997*). Response of *Pueraria phaseoloides* to direct and residual phosphorus from different sources. *Indian Journal of Natural Rubber Research*, **10**(1&2) : 113-115.

George, K.T. (1999). Resource base and industrialization : The case of rubber based industrial sector in Kerala. *International Seminar on Resource Based Industries in Kerala*, 8 December 1999, Cochin University of Science and Technology, Cochin, India, 21 p.

George, K.T. (1999). The natural rubber sector : Emerging issues in the 1990s. In : *Kerala's Economic Development : Issues and Problems* (Ed. B.A. Prakash). Sage Publications, New Delhi, pp. 186-199.

George, K.T., Reghu, C.P. and Nehru, C.R. (2000). By-products and ancillary source of income. In : *Natural Rubber : Agromanagement and Crop Processing* (Eds. P.J. George and C. Kuruvilla Jacob). Rubber Research Institute of India, Kottayam, pp. 507-520.

George, P.J. (2000). Germplasm resources. In : *Natural Rubber : Agromanagement and Crop Processing* (Eds. P.J. George and C. Kuruvilla Jacob). Rubber Research Institute of India, Kottayam, pp. 47-58.

George, P.J. and Panikkar, A.O.N. (2000). Rubber yielding plants. In : *Natural Rubber : Agromanagement and Crop Processing* (Eds. P.J. George and C. Kuruvilla Jacob). Rubber Research Institute of India, Kottayam, pp. 20-28.

George, S., Punnoose, K.I., Mathew, M., Pothen, J., Mani, J., George, E.S. and Jessy, M.D. (1997*). Response of two high yielding *Hevea* clones to applied fertilizer during immature phase. *Indian Journal of Natural Rubber Research*, **10**(1&2) : 80-85.

Idicula, S.P. and Jose, V.T. (2000). Plant protection equipment and chemicals. In : *Natural Rubber : Agromanagement and Crop Processing* (Eds. P.J. George and C. Kuruvilla Jacob). Rubber Research Institute of India, Kottayam, pp. 347-368.

Jacob, C.K. and Idicula, S. P. (1997*). Effect of fungicide spraying on pink disease incidence in *Hevea brasiliensis*. *Indian Journal of Natural Rubber Research*, **10**(1&2) : 48-52.

Jacob, G. and Chandy, B. (2000). Marketing. In : *Natural Rubber : Agromanagement and Crop Processing* (Eds. P.J. George and C. Kuruvilla Jacob). Rubber Research Institute of India, Kottayam, pp. 493-506.

Jacob, J. (2000). Rubber tree, man and environment. In : *Natural Rubber : Agromanagement and Crop Processing* (Eds. P.J. George and C. Kuruvilla Jacob). Rubber Research Institute of India, Kottayam, pp. 599-610.

Jayasree, P.K., Asokan, M.P., Sobha, S., Sankariammal, L., Rekha, K., Kala, R.G., Jayasree, R. and Thulaseedharan, A. (1999). Somatic embryogenesis and plant regeneration from immature anthers of *Hevea brasiliensis* (Muell.) Arg. *Current Science*, **76** : 1242-1245.

Jayasree, P.K., Kala, R.G. and Thulaseedharan, A. (2000). High frequency somatic plant regeneration in *Hevea brasiliensis via*. somatic embryogenesis. *National Seminar on Recent Advances in Plant Biology*, 2000, Kasaragod, India, pp. 57-58.

Joseph, K., Vimalakumari, T.G., Mathew, J. and Kothandaraman, R. (1997*). Effect of *Azotobacter* inoculation on rubber seedlings. *Indian Journal of Natural Rubber Research*, **10**(1&2) : 34-38.

Joseph, M., Philip, A., Nair, R.B., Antony, P.A. and Punnoose, K.I. (1997*). Leaf nutrient concentration of different clones of rubber. *Indian Journal of Natural Rubber Research*, **10**(1&2) : 61-65.

Joseph, T., Chandy, B., Lekshmi, S. and Viswanathan, P.K. (1997*). A comparative analysis of commercial yield performance of *Hevea* clones in India. *Indian Journal of Natural Rubber Research*, **10**(1&2) : 6-14.

Joseph, T., Chandy, B., Viswanathan, P.K. and Lekshmi, S. (1999). Commercial yield performance of *Hevea* clones in India : A comparative analysis. Rubber Research Institute of India, Kottayam, India, 66 p. (Monograph)

Joseph, T., George, K.T. and Chandy, B. (1999). An evaluation of the insurance scheme for rubber plantations in the context of natural damage. *The Indian Economic Journal*, **47**(2) : 97-103.

Karthikakuttyamma, M., Joseph, M. and Nair, A.N.S. (2000). Soils and nutrition. In : *Natural Rubber : Agromanagement and Crop Processing* (Eds. P.J. George and C. Kuruvilla Jacob). Rubber Research Institute of India, Kottayam, pp. 170-198.

Kothandaraman, R. and Idicula, S.P. (2000). Stem diseases. In : *Natural Rubber : Agromanagement and Crop Processing* (Eds. P.J. George and C. Kuruvilla Jacob). Rubber Research Institute of India, Kottayam, pp. 297-308.

Krishnakumar, A.K. and Meenattoor, J.R. (2000). Cultivation in non-traditional areas. In: *Natural Rubber : Agromanagement and Crop Processing* (Eds. P.J. George and C. Kuruvilla Jacob). Rubber Research Institute of India, Kottayam, pp. 555-568.

Krishnakumar, R., Sasidhar, V.R. and Sethuraj, M.R. (1997). Influence of TPD on cytokinin level in *Hevea* bark. *Indian Journal of Natural Rubber Research*, **10**(1&2) : 107-109.

Kuriakose, B. and George, M. (2000). Crepe rubbers. In : *Natural Rubber : Agromanagement and Crop Processing* (Eds. P.J. George and C. Kuruvilla Jacob). Rubber Research Institute of India, Kottayam, pp. 399-413.

Kuriakose, B. and Thomas, K.T. (2000). Ribbed sheets. In : *Natural Rubber : Agromanagement and Crop Processing* (Eds. P.J. George and C. Kuruvilla Jacob). Rubber Research Institute of India, Kottayam, pp. 386-398.

Licy, J., Dickinson, M., Bligh, F.J., Power, J.B., Saraswathyamma, C.K. and Davey, M.R. (1999). Approaches to identify disease resistance gene analogues in *Hevea*. *IRRDB Rubber Conference*, 17-22 October 1999, Haikou, Peoples Republic of China.

Madhavan, J, Abraham, S.T., Reghu, C.P. and George, P.J. (1997*). A preliminary report on two floral variants in the 1981 wild *Hevea* germplasm collection. *Indian Journal of Natural Rubber Research*, **10**(1&2) : 1-5.

Mandal, D., Singh, R.P., Sarma, A.C. and Chaudhuri, D. (2000). Influence of rubber plantation on physico-chemical properties of soil : A case study. *Proceedings of the National Seminar on Recent Advances in Plant Biology*, 3-5 February 2000, Central Plantation Crops Research Institute, Kasaragod, India.

Marattukalam, J.G. and Mercykutty, V.C. (2000). Propagation techniques. In : *Natural Rubber : Agromanagement and Crop Processing* (Eds. P.J. George and C. Kuruvilla Jacob). Rubber Research Institute of India, Kottayam, pp. 75-96.

Mathew, J., Kumaran, M.G., Joseph, K. and George, E.S. (2000). Waste management. In : *Natural Rubber : Agromanagement and Crop Processing* (Eds. P.J. George and C. Kuruvilla Jacob). Rubber Research Institute of India, Kottayam, pp. 479-492.

Mathew, N.M. and Claramma, N.M. (2000). Latex preservation and concentration. In : *Natural Rubber : Agromanagement and Crop Processing* (Eds. P.J. George and C. Kuruvilla Jacob). Rubber Research Institute of India, Kottayam, pp. 414-433.

Mercy, M.A., Babu, L.C., George, P.J. and Nair, R.B. (2000). Preliminary screening of wild *Hevea* germplasm for drought resistance based on cellular membrane stability. *National Seminar Recent Advances in Plant Biology*, 2000, Kasaragod, India.

Mandal, D., Singh, R.P, Mondal, G.C., Gohain, T., Chaudhuri, D. and Varghese, Y.A. (1999). Impact of agroclimate on growth and establishment of *Hevea* clones during immature phase. *Proceedings of the National Symposium on Plant Physiology and Biochemistry in Relation to Agriculture and Environment*, 15-17 February 1999, Indore, India.

Mohanakumar, S. and George, K.T. (1999). Indian rubber products manufacturing industry : Evolutionary dynamics and structural dimensions. Rubber Research Institute of India, Kottayam, India (Monograph), 38 p.

Mydin, K.K., John, A., Marattukalam, J.G., Saraswathyamma, C.K. and Saraswathy, P. (1999). Variability and distribution of tapping panel dryness in *Hevea brasiliensis*. *IRRDB Rubber Conference*, 17-22 October 1999, Haikou, Peoples Republic of China.

Nair, N.U. (2000). Biochemistry and physiology of latex production. In : *Natural Rubber: Agromanagement and Crop Processing* (Eds. P.J. George and C. Kuruvilla Jacob). Rubber Research Institute of India, Kottayam, pp. 249-260.

Nehru, C.R. and Thankamony, S. (2000). Pests in rubber plantations. In : *Natural Rubber : Agromanagement and Crop Processing* (Eds. P.J. George and C. Kuruvilla Jacob). Rubber Research Institute of India, Kottayam, pp. 337-346.

Pothen, J., Joseph, T. and George, K.T. (2000). Plantation management. In : *Natural Rubber : Agromanagement and Crop Processing* (Eds. P.J. George and C. Kuruvilla Jacob). Rubber Research Institute of India, Kottayam, pp. 521-538.

Premakumari, D. and Saraswathyamma, C.K. (2000). The Para rubber tree. In : *Natural Rubber : Agromanagement and Crop Processing* (Eds. P.J. George and C. Kuruvilla Jacob). Rubber Research Institute of India, Kottayam, pp. 29-35.

Premakumari, D., Panikkar, A.O.N., Sethuraj, M.R. and Marattukalam, J.G. (1997*). Associations of structural traits : Yield, girth and occurrence of tapping panel dryness in *Hevea brasiliensis*. *Indian Journal of Natural Rubber Research*, **10**(1&2) : 27-33.

Punnoose, K.I. and Lakshmanan, R. (2000). Nursery and field establishment. In: *Natural Rubber : Agromanagement and Crop Processing* (Eds. P.J. George and C. Kuruvilla Jacob). Rubber Research Institute of India, Kottayam, pp. 129-148.

Punnoose, K.I., Kothandaraman, R., Philip, V., and Jessy, M.D. (2000). Field upkeep and intercropping. In : *Natural Rubber : Agromanagement and Crop Processing* (Eds. P.J. George and C. Kuruvilla Jacob). Rubber Research Institute of India, Kottayam, pp. 149-169.

Rajalakshmy, V.K. and Jayarathnam, K. (2000). Root diseases and non-microbial maladies. In : *Natural Rubber : Agromanagement and Crop Processing* (Eds. P.J. George and C. Kuruvilla Jacob). Rubber Research Institute of India, Kottayam, pp. 309-324.

Rajalakshmy, V.K., Joseph, A., Varghese, Y.A. and Kothandaraman, R. (1997*). Evaluation of *Hevea* clones against powdery mildew caused by *Oidium heveae* Steinm. *Indian Journal of Natural Rubber Research*, **10**(1&2) : 110-112.

Rajasekharan, P. and Krishnamoorthy, S. (1999). Technical efficacy of natural rubber production in Kerala : A panel data analysis. *Indian Journal of Agricultural Economics*, **54**(4) : 545-553.

Rao, D.V.K.N. and Punnoose, K.I.(2000). Identification of rubber vegetation using satellite data. *Presented in the National Symposium on Remote Sensing Application for Natural Resources*, 22-24 March, 2000, Bhubaneswar, India.

Rao, G.P. and Reghu, C.P. (2000). Variability and character associations in wild *Hevea* germplasm. *International Conference on Managing Natural Resources for Sustainable Agricultural Production in the 21st Century*, February 2000, New Delhi, India.

Roy, S., Raj, S., Dey, S.K., Choudhury, M., Deka, H.K., Alam, B., Sudhasoumyalatha, M.K., Das, G., Varghese, Y.A. and Nazeer, M.A. (1999). Rubber based farming system : A preliminary report. *National Seminar on Strategies for Agricultural Research in the North East*, 10-12 November 1997, Shillong, India.

Sailajadevi, T., Rao, A.V.R.K., Kothandaraman, R. and Sethuraj, M.R. (1997*). Markov chain model for planning agricultural operations in rubber : A case study. *Indian Journal of Natural Rubber Research*, **10**(1&2) : 75-79.

Saraswathyamma, C.K., Licy, J. and Marattukalam, J.G. (2000). Planting materials. In : *Natural Rubber : Agromanagement and Crop Processing* (Eds. P.J. George and C. Kuruvilla Jacob). Rubber Research Institute of India, Kottayam, pp. 59-74.

Satisha, G.C., Dey, S.K. and Varghese, Y.A. (1999). Assessment of soil site characteristics for suitability for rubber cultivation in Kolasib District of Mizoram, North East India. *National Seminar on Development in Soil Science*, 26-30 November 1999, Tamil Nadu Agricultural University, Coimbatore, India, p. 209.

Singh, R.P., Mandal, D. and Choudhuri, D. (1999). Effect of agroclimate on early establishment of *Hevea* in nursery. *National Seminar on Strategies for Agricultural Research in the North East*, 10-12 November 1999, ICAR Research Complex for N.E. Hill Region, Shillong, India, p. 25.

Sobhana, P., Rajagopal, R., Vijayakumar, K.R., Jacob, J. and Sethuraj, M.R. (2000). Effect of growth hormones on rooting in air-layers of *Hevea brasiliensis*. *National Seminar on Plant Physiological Paradigm of Fostering Agro and Biotechnology and Augmenting Environmental Productivity in Millennium*, 7-9 November 2000. Indian Institute of Sugarcane Research, Lucknow.

Sobhana, P., Rajagopal, R., Vijayakumar, K.R., Jacob, J. and Sethuraj, M.R. (2000). Variability in rooting response of air-layers in twelve clones of *Hevea brasiliensis*. *Journal of Plantation Crops*, **28**(3) : 191-195.

Sudhasoumyalatha, M.K., Priyadarshan, P.M., Dey, S.K. and Varghese, Y.A. (1997*). Low fruit set in *Hevea brasiliensis* in Tripura : Implications of floral attributes. *Indian Journal of Natural Rubber Research*, **10**(1&2) : 15-26.

Sulochanamma, S. and Thomas, K.U. (2000). Yield stimulation. In : *Natural Rubber : Agromanagement and Crop Processing* (Eds. P.J. George and C. Kuruvilla Jacob). Rubber Research Institute of India, Kottayam, pp. 239-248.

Sushamakumari, S., Jayasree, R. and Asokan, M.P. (1999). Evaluation of parameters affecting the isolation and culture of protoplasts of *Hevea brasiliensis* (Muell.) Arg. *Current Science*, **77** : 1580-1581.

Thankamony, S., Jose, V.T. and Kothandaraman, R. (1997*). Evaluation of pesticides for control of root-knot nematode infestation of rubber (*Hevea brasiliensis*) seedlings. *Indian Journal of Natural Rubber Research*, **10**(1&2) : 97-101.

Thomas, K.K. and Panikkar, A.O.N. (2000). Indian rubber plantation industry : Genesis and development. In : *Natural Rubber : Agromanagement and Crop Processing* (Eds. P.J. George and C. Kuruvilla Jacob). Rubber Research Institute of India, Kottayam, pp. 1-17.

Thomas, K.T., Madhusoodanan, K.N. and Mathew, N.M. (1999). Natural rubber modified bitumen : A review of the past and present experience. *Technical Seminar, Indian Oil Corporation*, 2 November 1999, Cochin, India.

Thomas, K.T., Mathew, N.M. and Jacob, J. (1997*). Variability in quality and molecular breakdown behaviour of skim rubber. *Indian Journal of Natural Rubber Research*, **10**(1&2) : 53-60.

Udayakumar, M., Bhojaraja, R., Sheshayce, M.S., Gopalakrishnan, R. and Jacob, J. (1999). How do plants cope with excess light ? The role of ferritin. *Journal of Plant Biology*, **26** : 135-142.

Varghese, L., Nair, N.R. and Kumaran, M.G. (2000). Crop collection and pre-processing. In : *Natural Rubber : Agromanagement and Crop Processing* (Eds. P.J. George and C. Kuruvilla Jacob). Rubber Research Institute of India, Kottayam, pp. 377-385.

Varghese, S., Kuriakose, B. and Joseph, R. (1997*). Preparation and evaluation of natural rubber coated prilled urea. *Indian Journal of Natural Rubber Research*, **10**(1&2) : 39-42.

Varghese, Y.A. and Mydin, K.K. (2000). Genetic improvement. In : *Natural Rubber : Agromanagement and Crop Processing* (Eds. P.J. George and C. Kuruvilla Jacob). Rubber Research Institute of India, Kottayam, pp. 36-46.

Varghese, Y.A., Thulaseedharan, A. and Jayasree, P.K. (2000). Rubber biotechnology. In : *Biotechnology of Horticultural Crops*, Volume I. (Eds. V.A. Parthasarathy, P.C. Deka, P. Das, S.K. Mitra and S. Mohan Das). Naya Prokash, Calcutta, pp. 630-660.

Varghese, Y.A., Abraham, S.T. (1999). Germplasm conservation, utilization and evaluation in rubber. In : *Crop Improvement in Plantation Crops* (Eds. M.J. Ratnambal, P.M. Kumaran, K. Muraleedharan, V. Niral and V. Arunachalam). Central Plantation Crops Research Institute, Kasaragod, pp. 124-133.

Venkatachalam, P.V., Thanseem, I. and Thulaseedharan, A. (1999). A rapid and efficient method for isolation of RNA from bark tissues of *Hevea brasiliensis*. *Current Science*, **77**(5) : 101-103.

Vijayakumar, K.R., Chandrashekar, T.R. and Philip, V. (2000). Agroclimate. In : *Natural Rubber : Agromanagement and Crop Processing* (Eds. P.J. George and C. Kuruvilla Jacob). Rubber Research Institute of India, Kottayam, pp. 97-116.

Vijayakumar, K.R., Thomas, K.U. and Rajagopal, R. (2000). Tapping. In : *Natural Rubber : Agromanagement and Crop Processing* (Eds. P.J. George and C. Kuruvilla Jacob). Rubber Research Institute of India, Kottayam, pp. 215-238.

* *Published during 1999-2000.*

POPULAR ARTICLES

Chakraborty, S.K. and Dey, S.K. (1999). Latex to rubber : Coagulation and preservation Part I & II. *The Dainik Sambad*, 31 July 1999; 25 December 1999; 8 January 2000 (Bengali).

George, K.T. (1999). Elastomer industry : Challenges in the new millennium. *The Hindu*, 3 November.

Jessy, M.D. and Punnoose, K.I. (1999). *Rubber*, **400** : 8-10 (Malayalam).

Jose, V.T. (1999). Mooply beetles in rubber plantations. *Rubber*, **397** : 27-28 (Malayalam).

Jose, V.T. (2000). Bark feeding caterpillar. *Rubber*, **406** : 7-8 (Malayalam).

Jose, V.T. (2000). Bee-keeper brothers of Chettuthodu village. *Rubber*, **407** : 17-18 (Malayalam).

Jose, V.T. and Joseph T. (2000). Bee keeping in rubber plantations : A profile. *Rubber Mithram*, **2**(6) : 11-16 (Malayalam).

Joseph, J., Pal, T.K. and Dey, S.K. (2000). Biogas from rubber.technology. *Jnan Bichitra*, **24**(8) : 17-19 (Bengali).

Joseph, K. (1999). Mushroom cultivation using rubber wood saw dust. *Rubber Mithram*, **1**(3) : 50-52 (Malayalam).

Joseph, M. (1999). Balanced fertilizer usage for sustainable agriculture. *Rubber*, **405** : 1-7 (Malayalam).

Joseph, M. (1999). Soil and plant nuitrients. *Rubber*, **403** : 21-21 (Malayalam).

Joseph, T., Chandy, B., Lekshmi, S., Viswanathan, P.K. (1999). Productivity of different planting materials. *Rubber*, **407** : 11-12 (Malayalam).

Marattukalam, J.G. and Varghese, Y.A. Bench grafting. *Rubber*, **405** : 11-13 (Malayalam).

Mercykutty, V.C., Marattukalam, J.G. and Thomas, V. (1999). Wind damage and its control measures. *Rubber*, **400** : 6-7; **401** : 5-6; **402** : 6-7; **403** : 3-4 (Malayalam).

Mohanakumar, S. (1999). Crisis in the rubber sector : A review. *Rubber Mitliram*, **1**(7) : (Malayalam).

Mohanakumar, S. (1999). Indian tyre industry after economic liberalization. *Desabhimani*, June 23 & 24 (Malayalam).

Mohanakumar, S. and Viswanathan, P.K. (1999). Foodgrain price rise and rubber growers. *Rubber Mithram*, **1**(1) : 52-55, 62-63 (Malayalam).

Nair, N.R. (1999). Use of solar energy in readymade smoke houses. *Rubber*, **398** : 13 (Malayalam).

Saraswathyamma, C.K. and George, P.J. (1999). RRII 105 : An evaluation of its merits and demerits. *Rubber*, **402** : 10-11 (Malayalam).

Singh, R.P. (1999). Importance and levels of sulphur and zinc for rubber. *Rubber Samachar*, **37** : 7-9; **38** : 6-7; **39** : 9-11 (Hindi).

Singh, R.P. and Chakraborty, S.K. (1999). Physico-chemical properties of soils of RRS, Ganolgere farm, Tura, Meghalaya and ICAR Regional Research Centre Gauri Farm Bazar, Arunachal Pradesh. *Rubber Samachar*, **40** : 12-14 (Hindi).

Thomas, K.T. (1999). The meaning of rubber. *Rubber*, **400** : 29 (Malayalam).

Thomas, V. (1999). Latex vessels in the bark of *Hevea*. *Rubber*, **398** : 11-12 (Malayalam).

Thomas, V. and Mercykutty, V.C. (1999). Uses of rubber seed. *Rubber Mithram*, 44-47 (Malayalam).

Varghese, S. (1999). Sheet washing machine. *Rubber*, **402** : 5 (Malayalam).

Viswanathan, P.K. and Joseph, T. (1999). Commercial importance and market potential of rubber wood. *Rubber Mithram*, **1**(2) : 6-11 (Malayalam).

Viswanathan, P.K. and Joseph, T. (1999). Rubber wood processing and product development. *Rubber Mithram*, **1**(2) : 12-15 (Malayalam).

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James Jacob, M.Sc.(Ag.), Ph.D., DIC, Ph.D.	Deputy Director
*N. Usha Nair, M.Sc.(Ag.), Ph.D.	Senior Scientist (BC)
P. Sobhana, M.Sc.	Plant Physiologist
Molly Thomas, M.Sc., Ph.D.	Scientist S3
**K.U. Thomas, M.Sc., Ph.D.	Scientist S3
R. Krishnakumar, M.Sc., Ph.D.	Scientist S3
**R. Rajagopal, M.Sc., M.Phil., Ph.D, Dip. Stat.	Plant Physiologist
K. Annamalainathan, M.Sc., M.Phil, Ph.D.	Plant Physiologist
D. Bhuvanendran Nair, M.Sc., Ph.D.	Scientist S3
S. Sreelatha, M.Sc.	Scientist S3
Badre Alam, M.Sc., M.Tech., Ph.D.	Environmental Physiologist
K. Karunaichamy, M.Sc., Ph.D.	Scientist (ES)
M.B. Mohammed Sathik, M.Sc., M.Phil.	Scientist S2
**Jayasree Gopalakrishnan, M.Sc., M.Phil.	Scientist S2
N. Geetha, M.Sc., Ph.D.	Junior Scientist
S. Visalakshy Ammal, B.Sc.	Assistant Technical Officer
C.C. Joseph	Assistant Farm Superintendent
*C.G. Varghese	Assistant Farm Superintendent

Rubber Chemistry, Physics and Technology Division

Baby Kuriakose, M.Sc., LPRI, Ph.D., PGDPM	Joint Director (Rubber Technology)
K.T. Thomas, M.Sc., LPRI, M.Tech., Ph.D.	Deputy Director
N.M. Claramma, M.Sc.	Rubber Chemist
Mariamma George, M.Sc. Ph.D.	Scientist S3
N. Radhakrishnan Nair, M.Sc., M.Tech., PGDHRM, Ph.D.	Scientist S3
Jacob K. Varkey, M.Sc., M.Tech.	Scientist S3
Leelamma Varghese, M.Sc., PGDHRM	Scientist S3
Rosamma Alex, M.Sc., LPRI, M.Tech, Ph.D.	Rubber Technologist
*Siby Varghese, M.Sc., Ph.D.	Scientist (Rubber Technology)
K.N. Madhusoodanan, M.Sc.	Rubber Chemist
Benny George, M.Sc.	Scientist S2
C.K. Premalatha, B.Sc., LPRI, Dip. NRP	Assistant Technical Officer
C. Madheswaran, B.A.	Technical Assistant (Glass Blowing)

Agricultural Economics Division

K. Tharian George, M.A., Ph.D.	Deputy Director
P. Rajasekharan, M.Sc.(Ag.), Ph.D.	Economist
Toms Joseph, M.A.	Economist
Binni Chandy, M.A., B.Ed.	Scientist S2
S. Mohanakumar, M.A., M.Phil.	Junior Scientist
S. Veeraputhran, M.A., M. Phil.	Junior Scientist
P.K. Viswanathan, M.A.	Junior Scientist
S. Lekshmi, M.Sc.(Ag.)	Junior Scientist

World Bank Scheme

*M.A. Nazeer, M.Sc., Ph.D.	Joint Director (PM)

Regional Research Stations	
Thomson T. Edathil, M.Sc., Ph.D.	Deputy Director
Statistics Section	
*P.V. Mathew, M.C.A., M.C.S.E.	Programme Analyst
Ramesh B. Nair, M.Sc.(Ag. St.)	Assistant Statistician
*B. Biju, M.Sc., PGDCA	Computer Assistant
Library and Documentation Centre	
Mercy Jose, B.Sc., M.L.I.Sc.	Documentation Officer
Accamma C. Korah, B.Sc., M.L.I.Sc.	Senior Librarian
Kurian K. Thomas, B.Sc., M.L.I.Sc.	Junior Publication Officer
A.S. Ajitha, M.A., B.L.I.Sc.	Librarian (Documentation)
Instrumentation Section	
S. Najmul Hussain, M.Tech., AMIETE	Instrumentation Engineer
Thomas Baby, M.Sc., M.Phil, Ph.D.	Instrumentation Officer
R. Rejikumar, M.Sc., M.Tech	Assistant Instrumentation Officer
Art/Photography Section	
K.P. Sreeranganathan	Senior Artist/Photographer
Maintenance Wing	
E.R. Subramanian	Assistant Estate Officer
Administration Section	
T.R. Mohankumar	Deputy Secretary (up to 14.12.1999)
P.C. Joseph	Assistant Secretary
T.M. George	Administrative Officer
Annamma Joseph	Assistant Section Officer
K.P. Chandrasekharan Nair	Assistant Section Officer
Accounts Section	
*G. Rajasekharan Nair	Dy. Director (Finance)
P.J. Franklin Raphy	Assistant Director (Finance)
R. Muraleedharan Pillai	Assistant Accounts Officer
J. Anandavally Amma	Assistant Section Officer
Experiment Station at RRII	
S. George	Assistant Farm Superintendent
Security Wing	
C.K. Abraham, B.A., B.Ed.	Assistant Security Officer
Central Experiment Station, Chethackal, Kerala	
Jacob Pothen, M.Sc.(Ag.)	Deputy Director
Jacob Abraham, B.Sc., M.B.B.S.	Medical Officer
Zacharia Kurian, M.Com., A.C.A.	Accounts Officer
Mary Varghese, M.Sc.(Ag.)	Junior Scientist
N. Bhargavan	Farm Superintendent
M.D. Isaac	Assistant Estate Superintendent
K.S. Thomas	Assistant Section Officer
Annamma Andrews, H.S.C.	Nurse (HG)
T.T. Varghese	Assistant Farm Superintendent
M.T. Varghese	Assistant Security Officer
T.R. Divakaran	Assistant Farm Superintendent

Regional Research Station, Padiyoor, Kerala

Radha Lakshmanan, M.Sc.(Ag.), Ph.D.	Agronomist
P.M. Narayanan	Assistant Farm Superintendent

Regional Research Station, Guwahati, Assam

Dhurjati Chaudhuri, M.Sc.(Ag.)	Deputy Director
Gopal Chandra Mondal, M.Sc., Ph.D.	Plant Pathologist
Ram Phool Singh, M.Sc.(Ag.), Ph.D.	Scientist S2
Debashis Mandal, M.Sc.	Scientist S2
Tankeswar Gohain, M.Sc.(Ag.)	Junior Scientist (up to 19.11.1999)
A.K. Hazarika, M.Com.	Assistant Accounts Officer

Regional Research Station, Agartala, Tripura

Sushil Kumar Dey, M.Sc., Ph.D.	Deputy Director
P. M. Priyadarshan, M.Sc., Ph.D.	Plant Breeder
*M.K. Sudhasoumyalatha, M.Sc., Ph.D.	Scientist (CE) (resigned on 12.05.1999)
Gitali Das, M.Sc, Ph.D.	Plant Physiologist
Shammi Raj, M.Sc., Ph.D.	Agrometeorologist
Krishna Das, M.Sc., Ph.D.	Scientist S2
S. Sasikumar, M.Sc.	Junior Scientist
*Santhanu Roy, M.Sc.(Ag.)	Junior Scientist
Mrinal Chaudhuri, M.Sc.(Ag.)	Junior Scientist
Joy Joseph, M.Sc.	Assistant Rubber Processing Technologist
Jiban Chakraborty, B.Com.	Accounts Officer
*K.K. Kunjachan	Assistant Farm Superintendent
N.K. Balasubramaniyam	Assistant Section Officer

Regional Research Station, Kolasīb, Mizoram

G.C. Satisha, M.Sc.(Ag.)	Soil Chemist (on study leave)

Regional Research Station, Tura, Meghalaya

A.P. Thapliyal, M.Sc., Ph.D.	Deputy Director
H.K. Deka, M.Sc., Ph.D.	Scientist S2
M.J. Reju, M.Sc.	Junior Scientist
K. Arunkumar, M.Sc., M.Phil.	Junior Scientist

Regional Research Station, Nagrakatta, West Bengal

Haradhan Bhowmik	Assistant Farm Superintendent

Regional Research Station, Dapchari, Maharashtra

Meena Singh, M.Sc.(Ag.), Ph.D.	Plant Physiologist (from 24.05.1999)
Gawai Prakash Pandharinath, M.Sc.(Ag.)	Scientist S2
K.N. Vijayachandran Nair	Assistant Section Officer
V.J. George	Assistant Farm Superintendent

Regional Research Station, Dhenkanal, Orissa

Chandra Gupta, M.Sc.(Ag.), Ph.D.	Agronomist
T.S. Sukumaran Nair	Assistant Section Officer
P.J. George	Assistant Farm Superintendent

Regional Research Station, Sukma, Madhya Pradesh	
*Bal Krishnan, M.Sc., Ph.D.	Scientist (Germplasm Evaluation)
K. Nageswara Rao, M.Sc.(Ag.)	Junior Scientist
***Hevea* Breeding Sub-station, Nettana, Karnataka**	
K.K. Vinod, M.Sc.(Ag.)	Plant Breeder
M.J. Manju, M.Sc (Ag)	Junior Scientist
M. Sasikumar, M.Sc (Ag)	Junior Scientist
C.K. Thomas	Assistant Farm Superintendent
***Hevea* Breeding Sub-station, Paraliar, Tamil Nadu**	
T.A. Soman, M.Sc., M.Phil., Ph.D.	Scientist S3
V. Vijayan	Assistant Farm Superintendent
Regional Soil Testing Laboratory, Adoor, Kerala	
Thomas Eappen, M.Sc.	Junior Scientist
Regional Soil Testing Laboratory, Muvattupuzha, Kerala	
C.P. Mary, M.Sc.	Assistant Technical Officer
Regional Soil Testing Laboratory, Calicut, Kerala	
Joyce Cyriac, M.Sc.	Junior Scientist
P.K. Madhusooddhanan, B.Sc.	Senior Scientific Assistant

* *Under World Bank Scheme*

** *Under World Bank Scheme on working arrangement*

RESEARCH ESTABLISHMENTS

RUBBER RESEARCH INSTITUTE OF INDIA

Rubber Board, Kottayam – 686 009, Kerala, India
Phone : 353311-20 (10 lines) Fax : 91 481 353327
Website : www.rubberboard.com E-mail : rrii@vsnl.com

REGIONAL RESEARCH STATIONS

Central Experiment Station
RRII, Rubber Board, Chethackal
Thompikandom P.O.
Ranni, Pathanamthitta - 689 676.
Kerala.
Phone : 91 473 526130 / 561176

Regional Research Station
RRII, Rubber Board, Bhalukia Tilla
Kunjaban P.O.
Agartala – 799 006
Tripura.
Phone : 91 381 225287
Fax : 91 381 323149
Email : agtrrs@dte.vsnl.net.in

Regional Research Station
RRII, Rubber Board
Padiyoor P.O.
Kannur – 670 703
Phone : 91 498 273003

Regional Research Station
RRII, Rubber Board
Central Block II (1st floor)
Housefed Complex
Beltola Basista Road
Dispur, Guwahati – 781 006.
Phone : 91 361 228220 / 228245
Email : dydirect1@sancharnet.in

Regional Research Station
RRII, Rubber Board
Dapchari – 401 610
Thane District
Maharashtra.
Phone : 91 2521 20071

Hevea Breeding Sub-station
RRII, Rubber Board
College Road, Kadaba – 574 221
D.K. District, Karnataka
Phone : 91 8251 60336

Hevea Breeding Sub-station
RRII, Rubber Board
Thadikarankonam P.O.
Kanyakumari – 629 851, Tamil Nadu.
Phone : 91 4652 289119

Regional Research Station
RRII, Rubber Board
Dhenkanal – 759 001, Orissa.
Phone : 91 6762 34946

Regional Research Station
RRII, Rubber Board, Sukma – 494 111
Bastar, Chattisgarh.
Phone : 91 778284 2301

Regional Research Station
RRII, Rubber Board, Tura – 794 001
Meghalaya.
Phone : 91 3651 23965

Regional Research Station
RRII. Rubber Board
Grassmore, Nagrakatta
Jalpaiguri – 735 225, West Bengal.
Phone : 91 3563 72316

Regional Research Station
RRII, Rubber Board, Kolasib – 796 081
Mizoram.
Phone : 91 3837 20357

REGIONAL SOIL TESTING LABORATORIES

Regional Soil Testing Laboratory
Hevea Breeding Sub-station
RRII, Rubber Board
College Road, Kadaba – 574 221
D.K. District, Karnataka
Phone : 91 8251 60336

Regional Soil Testing Laboratory
Rubber Board Regional Office
Taliparamba – 670 141
Kerala.

Regional Soil Testing Laboratory
Rubber Board, East Nadakkavu
Kozhikode – 673 011.
Kerala.

Regional Soil Testing Laboratory
Rubber Board, Peramangalam
Manappady, Trichur – 680 545, Kerala.

Regional Soil Testing Laboratory
Rubber Board, P.O. Junction
Moovattupuzha – 686 661
Kerala.

Regional Soil Testing Laboratory
Rubber Board, T.B. Road
Pala – 686 575
Kerala.

Regional Soil Testing Laboratory
Rubber Board, Ann's Buildings
Old Church Junction
Kanjirappally – 686 507
Kerala.

Regional Soil Testing Laboratory
Rubber Board,
Parvathy Mandiram
K.P. Road,
Adoor – 691 523
Kerala.

Regional Soil Testing Laboratory
Rubber Board
East Benglow
Nedumangad – 695 541
Kerala.

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Research divisions and functions

The major research divisions are Agronomy and Soils; Biotechnology; Botany; Germplasm; Mycology and Plant Pathology; Plant Physiology and Exploitation; Rubber Chemistry, Physics and Technology and Agricultural Economics.

The thrust areas of research of the Agronomy and Soils Division are investigations on the nutritional requirements of rubber, soil and water conservation, intercropping, weed management and the study of the rubber growing soils. Development of tissue culture and anther culture systems for propagation and crop improvement of *Hevea* are the important areas in which the Biotechnology Division is engaged. The important fields of research of the Botany Division are breeding, evaluation and selection of new clones, propagation techniques, planting methods, anatomical studies and cytogenetic investigations. The Germplasm Division is concentrating on the introduction, conservation and evaluation of *Hevea* germplasm. The Mycology and Plant Pathology Division is engaged in investigations on the diseases and pests of rubber and associated cover crops and their control. The Plant Physiology and Exploitation Division conducts studies on identification of characteristics related to yield, physiology of latex flow and yield stimulation. The Rubber Chemistry, Physics and Technology Division concentrates on improvement in primary processing of rubber, its chemical modification, rubber product manufacture and quality control of processed rubber. The Agricultural Economics Division undertakes studies on economic aspects related to rubber plantations.

The research supporting sections include Library and Documentation, Instrumentation, Statistics, Computer and Art/Photography. There is also a small experimental farm of 33 ha at the headquarters of the RRII.

Central Experiment Station

The 255 ha Central Experiment Station at Chethackal (Ranni), 50 km away from Kottayam, was started in 1966. Field trials laid out by the research divisions cover almost the entire area.

Regional Research Stations

The RRII has established a North-Eastern Research Complex with headquarters at Agartala, having regional research stations at Agartala in Tripura, Guwahati in Assam, Tura in Meghalaya and Kolasib in Mizoram. The RRII has also set up regional research establishments at Dapchari (Maharashtra), Dhenkanal (Orissa), Nagrakatta (West Bengal), Sukma (Chattisgarh), Paraliyar (Tamil Nadu), Nettana (Karnataka) and Padiyoor (Kerala).

Regional soil testing laboratories have been established at Mangalore, Thaliparambu, Kozhikode, Thrissur, Muvattupuzha, Pala, Kanjirappally, Adoor and Nedumangadu. Mobile units for soil and leaf analysis are available at the Kozhikode, Muvattupuzha and Adoor laboratories, apart from that at the headquarters.

National / International collaboration

The RRII is a member of the International Rubber Research and Development Board (IRRDB), an association of national organizations devoted to research and development on natural rubber. The Rubber Board is a member of the Association of Natural Rubber Producing Countries (ANRPC).

The RRII has research/academic linkages with the Banaras Hindu University (Varanasi), Kerala Agricultural University (Thrissur), Kerala University (Trivandrum), Mahatma Gandhi University (Kottayam), Cochin University of Science and Technology (Kochi), Indian Agricultural Research Institute (New Delhi), Indian Institute of Sciences (Bangalore), Indian Institute of Technology (Kharagpur), National Chemical Laboratory (Pune), University of Agricultural Sciences (Bangalore) and University of Goa (Goa).

Publications

Books

Natural Rubber : Agromanagement and Crop Processing
Rubber Wood : Production and Utilization
Plant and Soil Analysis

Serials

Indian Journal of Natural Rubber Research
RRII Annual Report

Correspondence

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