RUBBER RESEARCH INSTITUTE OF INDIA

ANNUAL REPORT
2007-2008

ISSN 0970-2490 . CODEN ARRIEU

Rubber Research Institute of India

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 RRII in its scientific worth and research contributions has won it the recognition as an International Centre of Excellence in 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. There are two major International Airports, one at Thiruvananthapuram, 160 km south and the other at Nedumbassery, 95 km north to 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
2007-2008

RUBBER RESEARCH INSTITUTE OF INDIA
KOTTAYAM-686 009, KERALA, INDIA
Email: rrii@rubberboard.org.in
Website: www.rubberboard.org.in

CONTENTS

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 and 1982. 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 Rubber Board. The Rubber Research Institute of India (RRII) works under the administrative control of the Board, the Director being the head of the institution. Besides RRII, there are eight departments under the Board *viz.* Administration, Rubber Production, Processing & Product Development, Finance & Accounts, Training, Licensing & Excise Duty, Statistics & Planning and Market Promotion.

Chairman
Mr. Sajen Peter IAS

Rubber Research Institute of India
Dr. James Jacob
Director

Rubber Production Department
Dr. A.K. Krishnakumar
(on deputation from February 2006)
Rubber Production Commissioner

Administration Department
Mr. Viju Chacko FCA
Secretary (in charge)

Processing & Product Development Department
Mr. M.K. Balagopalan Nair
Director

Finance & Accounts Department
Mr. Viju Chacko FCA
Director

Training Department
Dr. K.R. Vijayakumar
Director

Licensing & Excise Duty Department
Mr. T.V. Muthuswamy
Director

Statistics & Planning Department
Mr. G. Mohanachandran
Joint Director

Market Promotion Department
Deputy Director
Vacant

ADVISORY PANEL OF EXPERTS

CROP IMPROVEMENT

Dr. K.U.K. Nampoothiri
Project Director
M.S. Swaminathan Research Foundation
Community Agrobiodiversity Centre
MSSRF, Puthoorvayal P.O.
Kalpetta, Wayanad – 673 121

Dr. V.A. Parthasarathy
Director
Indian Institute of Spices Research
Marikunnu P.O., Kozhikode – 673 012

BIOTECHNOLOGY / GENOME ANALYSIS

Dr. George Thomas
Lab Chief
Interfield Laboratories
XIII/1208 Interprint House
Kochi – 682 005

Dr. K. Nataraja Karaba
Department of Crop Physiology
University of Agricultural Sciences
GKVK Campus
Bangalore – 560 065

CROP MANAGEMENT

Dr. V.K. Venugopal
(Retd. Professor & Head
Department of Soil Science
& Agricultural Chemistry
Kerala Agricultural University)
Madhavi Nivas
GRA – 231, Gowrisapattom P. O.
Thiruvananthapuram – 695 004

Dr. J. Thomas
Director of Research
Indian Cardamom Research Institute
Myladumpara, Kailasanadu P. O.
Idukki – 685 553

CROP PROTECTION

Dr. T. Marimuthu
Professor of Plant Pathology
Centre for Plant Protection Studies
Tamil Nadu Agricultural University
Coimbatore – 641 003

Dr. Jim Thomas
Associate Professor and Head
Department of Entomology
College of Horticulture
Vellanikkara, Thrissur – 680 656

Dr. C. Balagopalan
Dean, Biosciences
Mar Athanasios College for Applied
Science and Technology (MACFAST)
Thiruvalla, Pathanamthitta– 689 101

Dr. G.G.S.N. Rao
Project Co-ordinator
Central Research Institute for
Dry Land Agriculture
Santhosh Nagar, Hyderabad – 500 059

CROP PHYSIOLOGY/ EXPLOITATION TECHNOLOGY

Dr. Prabhat Kumar Sharma
Head, Dept. of Botany
University of Goa, Goa – 403 206

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 and 1982. 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 Rubber Board. The Rubber Research Institute of India (RRII) works under the administrative control of the Board, the Director being the head of the institution. Besides RRII, there are eight departments under the Board *viz.* Administration, Rubber Production, Processing & Product Development, Finance & Accounts, Training, Licensing & Excise Duty, Statistics & Planning and Market Promotion.

Chairman
Mr. Sajen Peter IAS

Rubber Research Institute of India
Dr. James Jacob
Director

Rubber Production Department
Dr. A.K. Krishnakumar
(on deputation from February 2006)
Rubber Production Commissioner

Administration Department
Mr. Viju Chacko FCA
Secretary (in charge)

Processing & Product Development Department
Mr. M.K. Balagopalan Nair
Director

Finance & Accounts Department
Mr. Viju Chacko FCA
Director

Training Department
Dr. K.R. Vijayakumar
Director

Licensing & Excise Duty Department
Mr. T.V. Muthuswamy
Director

Statistics & Planning Department
Mr. G. Mohanachandran
Joint Director

Market Promotion Department
Deputy Director
Vacant

ADVISORY PANEL OF EXPERTS

CROP IMPROVEMENT

Dr. K.U.K. Nampoothiri
Project Director
M.S. Swaminathan Research Foundation
Community Agrobiodiversity Centre
MSSRF, Puthoorvayal P.O.
Kalpetta, Wayanad – 673 121

Dr. V.A. Parthasarathy
Director
Indian Institute of Spices Research
Marikunnu P.O., Kozhikode – 673 012

BIOTECHNOLOGY / GENOME ANALYSIS

Dr. George Thomas
Lab Chief
Interfield Laboratories
XIII/1208 Interprint House
Kochi – 682 005

Dr. K. Nataraja Karaba
Department of Crop Physiology
University of Agricultural Sciences
GKVK Campus
Bangalore – 560 065

CROP MANAGEMENT

Dr. V.K. Venugopal
(Retd. Professor & Head
Department of Soil Science
& Agricultural Chemistry
Kerala Agricultural University)
Madhavi Nivas
GRA – 231, Gowrisapattom P. O.
Thiruvananthapuram – 695 004

Dr. J. Thomas
Director of Research
Indian Cardamom Research Institute
Myladumpara, Kailasanadu P. O.
Idukki – 685 553

CROP PROTECTION

Dr. T. Marimuthu
Professor of Plant Pathology
Centre for Plant Protection Studies
Tamil Nadu Agricultural University
Coimbatore – 641 003

Dr. Jim Thomas
Associate Professor and Head
Department of Entomology
College of Horticulture
Vellanikkara, Thrissur – 680 656

Dr. C. Balagopalan
Dean, Biosciences
Mar Athanasios College for Applied
Science and Technology (MACFAST)
Thiruvalla, Pathanamthitta– 689 101

Dr. G.G.S.N. Rao
Project Co-ordinator
Central Research Institute for
Dry Land Agriculture
Santhosh Nagar, Hyderabad – 500 059

CROP PHYSIOLOGY/ EXPLOITATION TECHNOLOGY

Dr. Prabhat Kumar Sharma
Head, Dept. of Botany
University of Goa, Goa – 403 206

Prof. A. Narayanan
Emeritus Scientist (ICAR)
Door No.19, Phase V
Maharani Avenue, Vadavalli
Coimbatore – 641 041

Prof. V.R. Sasidhar
Department of Crop Physiology
UAS, GKVK Campus
Bangalore – 560 065

ECONOMICS

Dr. D. Narayana
Associate Fellow
Centre for Development Studies
Medical College P.O.
Ulloor, Prasanth Nagar
Thiruvananthapuram – 695 011

Prof. K. Nagaraj
Madras Institute of Developmental Studies
79, Second Main Road
Gandhi Nagar, Adayar
Chennai – 600 020

RUBBER TECHNOLOGY/ TECHNICAL CONSULTANCY

Prof. Anil K. Bhowmick
Head, Rubber Technology Centre
Indian Institute of Technology
Kharagpur – 721 302

Prof. Rani Joseph
Head
Dept. of Polymer Science and Rubber Technology
Cochin University of Science and Technology, Kochi – 682 022

DIRECTOR'S REVIEW

Crop improvement research aimed at evolving high yielding clones for traditional and non-traditional areas through hybridisation and clonal selection, field evaluation of clones, breeding for specific objectives such as compact canopy and drought tolerance and participatory clone evaluation through multiclonal onfarm evaluation of promising pipeline clones in growers' field is under progress. Development of need-based propagation strategies and investigations on GxE interactions at four agroclimatically diverse locations including traditional and non-traditional regions are also in progress. As part of the morphological characterisation of popular clones, a taxonomic guide has been developed for the identification of RRII 400 series clones. The popularity of the newly released clones namely, RRII 414 and RRII 430 was reported to be on the increase at the field level.

A total of 3576 wild *Hevea* accessions is being conserved in the re-established source bush nurseries. Other available species of the genus *Hevea* and inter-specific hybrids are also being maintained in the arboretum. The wild accessions are under different stages of evaluation for better agronomic traits such as biotic and abiotic stress tolerance and superior quantitative and qualitative timber characteristics. A breeding garden was established at RRII comprising 30 potential wild accessions with promising rubber and timber yield and disease and drought resistance, along with 46 genetically divergent domesticated clones. Studies on the inclination and orientation of laticifers revealed that the primary clone, PB 86 had the laticifers inclined clockwise unlike the other clones studied. The angle of inclination ranged from 0.33^{0} – 13.39^{0} towards the left.

Molecular Biology and Biotechnology research at RRII deal with the development of *in vitro* propagation methods for elite *Hevea* clones, development of transgenic plants for better latex yield, disease tolerance and adaptation to environmental stress, development of *in vitro* fertilization techniques, molecular mechanisms and characterisation of genes controlling tolerance to diseases, abiotic stresses, tapping panel dryness (TPD), expression and characterisation of laticifer cell-specific genes and promoters. Field evaluation of the somatic plants raised from immature anther and immature inflorescence is being attempted.

Genes coding for superoxide dismutase, sorbitol-6-phosphate dehydrogenase, *cis*-prenyl transferase, hmgr 1, farnesyl diphosphate synthase and osmotin are being used for genetic transformation studies to develop transgenic plants for tolerance to TPD, abiotic stresses and high latex yield.

Genome analysis laboratory focused on the development of molecular tools for SSRs, SNPs and AFLPs and validated for the assessment of genetic diversity, clone

identification and genome mapping. It is also concentrating on the development of genetic markers for biotic and abiotic stress tolerance through transcriptome analysis, cloning and characterisation of agronomically important lignin genes (CAD) for wood quality studies.

The molecular biology team of RRII in association with the District Hospital, Kottayam, characterised the chikungunya virus from the blood samples of virus infected patients. They were sequenced and deposited in the NCBI gene bank.

The crop management group focused on the development of various agro-management techniques such as integrated nutrient management, soil and water conservation, planting density, intercropping, radio tracer studies on TPD, reduction of immature period of rubber and the development of rubber information system using remote sensing and GIS.

The crop physiology team continued the research activities in the major areas of environmental physiology, physiology of growth and yield, TPD, gene expression and ecological impact of NR cultivation. Under environmental physiology, studies are in progress on physiological adaptation to drought stress, molecular basis of drought tolerance, irrigation requirement in the North Konkan region, cultivation of elite rubber clones in high altitude region, screening of *Hevea* germplasm for intrinsic drought tolerance traits *etc*. Studies on the effect of stimulation on latex regeneration and relationship of ATP status with yield are in progress.

Studies on the impact of climate change on rubber sector are also progressing. Analysis of 53 years rainfall data (1957-2007) of rubber growing tract indicated a possible shift of the rainfall period away from the normal south west monsoon period. An annual increase in maximum temperature (0.05 °C/ year) and minimum temperature (0.03 °C/year) and a decrease of daily sunshine hours (0.02 h/year) were also noted in RRII.

Applied research on different aspects of latex harvesting was continued. Suitable stimulation schedule for clone GT 1 tapped under d/4 frequency in the agroclimatic conditions of South Kanara was identified. If the BO-1 panel of a tree is affected by TPD, there is no response to yield stimulation on its BO-2 panel. In the LFCUT trial, it was observed that, yield stimulant application at fortnightly interval is essential on the S/3 cut following groove application method to realise optimum yield. Periodic changing of panel (BO-1 to BO-2 and *vice versa*) during basal panel tapping did not increase yield under different tapping systems. Widespread occurrence of chikungunya in rubber tracts of the traditional region had a negative impact on production. This was apparently related to altered weather pattern.

Crop protection group observed high leaf retention in RRII 400 series clones in different locations in Kerala which is a promising indication of less incidence of abnormal leaf fall disease. Sixty isolates of *Corynespora* from different *Hevea* clones from Kerala and Karnataka showed high levels of genetic variations in their virulence. The studies on TPD revealed that about 70 per cent of the TPD-affected trees showed presence of LMW-RNA band in R-PAGE analysis. An extensive study conducted in five locations showed different symptoms of TPD and the data are being compiled. As part of the waste management studies in rubber

processing sector, an integrated effluent treatment system was installed and commissioned at Elavampadam Rubber Producers' Society, Palakkad. Second international training under the CFC- funded project on *Corynespora* leaf disease was organised at RRII during July, 2007.

Studies were initiated with the objective of forewarning major pests and diseases in rubber through agrometeorological researches. In the case of *Corynespora*, consecutive days with Humidity Thermal Index (HTI) remaining above 5.5 resulted in maximum number of spores after a period of six to eight days.

Studies conducted in Economics Division showed that the prevalence of a volatile price for longer period leads to changes in the hitherto followed tapping system which is indicative of the challenges to the adoption of the recommended practices for crop harvesting. The outbreak of chikungunya in central Kerala during 2007 severely affected tapping labourers and 57 per cent of the tapping days were lost during the month of June. The loss of tapping days was the highest in Ernakulam (91%) district followed by Pathanamthitta and Kottayam (86%) districts during the month of June. Analysis of technically-specified rubber processing industries in India identified the various factors affecting the capacity utilisation of the industry which included fluctuations in price and supply of raw materials, market uncertainty, lack of working capital and margins *etc.*

A new method for faster processing of skim latex was attempted by the Rubber Technology Division under the Advanced Centre for Rubber Technology (ACRT). This method involved deproteinisation using liquid papain followed by creaming. The creamed latex thus obtained can be coagulated easily to a consolidated mass. For the prediction of quality parameters like ZST, MST and viscosity of fresh centrifuged latex, an accelerated ageing test was standardised. PVC compatible/dispersible grade of NR was prepared by the latex stage incorporation of NR-g-PMMA co-polymer. This grade of NR could be mixed easily with PVC and used in areas where NBR/PVC are used. A tread compound was prepared using a new polymeric filler system and the properties of the same were comparable to that of a conventional tread compound. Preliminary evaluation of the suitability of the use of ENR 25 and ENR 50 in silica-filled tyre compositions was carried out in association with an industry partner. An Indian patent was granted for the invention titled "Rubber-silica composite with ENR as a reinforcement modifier" (Patent No.217042 dated 24/03/08).

Technical Consultancy Division under the ACRT prepared project reports for the establishment of three rubber-based industries and developed 12 rubber products as per requests from entrepreneurs. The division also gave support to various types of industries by testing the raw materials, rubber compounds, rubber products *etc.* and by advisory services through factory visits.

Studies were carried out at regional research stations to identify clones suited for different locations in the traditional and non-traditional regions with better rubber and timber yields, tolerance to drought/diseases *etc.* Plants raised in root trainers exhibited high percentage of budding success and better yield trend in early tapping stage. The various regional research stations in the non-traditional rubber growing areas were also involved in studies related with crop

improvement, management, protection and harvest technology. Adaptability of different clones to the agroclimatic conditions prevailing in this region, screening of clones for yield, tolerance to diseases, TPD, cold, drought, high wind speed *etc.*, identification of suitable planting materials and development of location-specific agro technology like irrigation systems, nutritional requirements *etc.* are the thrust areas of research in these stations. It was found that leaf N content has a major role in protecting the leaves from photoinhibitory damage under low temperature stress during winter season. The sprouting percentage of budded stumps in winter could be increased by keeping them in polyhouses. A socio-economic survey conducted on the impact of NR cultivation in the NE region indicated considerable increase in their income through rubber. Studies are also initiated to find out the technical feasibility of growing rubber on the abandoned tea growing areas of Dooars belt of North Bengal.

The well-established library of RRII added 245 books to the stock during the reporting year. Overall, the past year has been quite productive with several research groups in RRII reassessing their priorities and re-orienting their approaches with a clearer vision for the future.

AGRONOMY/SOILS DIVISION

The major research focus of the Division is to develop agromanagement techniques for improving the growth and yield of rubber, reducing cost of cultivation and sustaining soil health and productivity. Experiments on integrated nutrient management with organic and inorganic sources of nutrients, soil and water conservation, density of planting and intercropping are in progress. Radiotracer studies on tapping panel dryness using ^{32}P were conducted. Research programs with altered planting systems are also in progress. Experiment to develop agronomic package to reduce the gestation period of rubber is continued. Studies to assess and sustain the quality of rubber growing soils are also being continued. Development of rubber information system using remote sensing and GIS is in progress.

1. Nutrient management

The field experiment initiated at CES, Chethackal in 2001 to study the effect of long-term use of inorganic and organic nutrient sources on the growth and yield of rubber and soil physico-chemical properties was in progress. Significant improvement in plant girth was recorded with the application of 25 per cent chemical fertilizer and 75 per cent farm yard manure (FYM) compared to that of no - fertilizer, no - manure control plots (Table Ag. 1).

Table Ag. 1. **Effect of long-term use of inorganic and organic nutrient sources on growth of rubber**

Treatment	Girth (cm)
No fertilizer/no manure (Control)	38.52
FYM alone	42.90
Fertilizers (Standard recommendation)	42.28
25% Fertilizers + 75% FYM	44.42
50% Fertilizers + 50% FYM	42.67
75% Fertilizers + 25% FYM	41.35
SE	1.05
CD (P=0.05)	3.16

The field experiment to evaluate the effect of skipping of fertilizers on growth and yield of mature rubber was continued. The girth increment for the period 2002-2008 and yield for 2007-2008 indicated that

Table Ag. 2. **Effect of skipping of fertilizers on growth and yield of rubber**

Treatment	Girth increment (cm) (2002-2008)	Yield (g/t/t)
Standard practice	10.03	102.55
Application of full dose every year (Pre-monsoon)	11.47	120.03
Skipping pre-monsoon fertilizer application	11.28	97.03
Skipping post-monsoon fertilizer application	11.26	111.39
Skipping for one complete year	10.19	118.61
Skipping for two complete years	12.32	126.21
Continuous no manuring	11.91	118.66
SE	0.87	12.14
CD (P=0.05)	NS	NS

Table Ag. 3. **Effect of treatments on buddability and uptake of nutrients**

Treatments	Buddability* (%)	Uptake of nutrients (mg/plant)		
		N	P	K
T_1- NPK@ 6-6-2.4g/plant (N and P as urea and RP)	63.3	152.4	7.29	58.0
T_2- T_1 + Cow dung slurry	68.3	210.0	8.24	93.8
T_3- T_1 + Ground nut cake	60.0	220.2	8.06	85.3
T_4- Standard practice (N and P as ammophos)	80.0	185.8	8.20	79.0
T_5- T_4+ Cow dung slurry	78.3	329.8	12.25	132.0
T_6- T_5 +Ground nut cake	83.3	257.4	10.81	114.8
T_7- T_4 + Phytonol	73.3	228.2	8.40	72.5
T_8- 50% of T_4 +PGPR	98.3	212.2	10.63	103.5
SE	4.67	10.32	0.63	5.6
CD (P=0.05)	14.00	30.97	1.90	16.8

* in 10 months

the growth and yield were not significantly influenced by skipping of fertilizers up to a period of six years (Table Ag. 2). No significant difference was observed either in soil nutrient status or in leaf nutrient content.

Study on partial substitution of potassium (K) with sodium (Na) in mature rubber at Malankara estate, Thodupuzha was continued. Substitution of K with Na up to 50 per cent showed no difference in girth and girth increment. Partial substitution of K with Na did not affect yield of rubber adversely.

The nursery experiment to study the effect of addition of varying levels of sulphur (S) in elemental form to soil along with rock phosphate on growth of rubber seedlings indicated that 62 per cent of S-applied plants attained buddable diameter in 10 months time. For no-P treatments, addition of S @ 55 kg/ha increased buddability from 47 to 60 per cent. P availability increased with increasing levels of S application while uptake of other nutrients was not affected.

The nursery experiment to study the nitrogen-use efficiency of urea using labelled-urea indicated no significant difference between different levels of N and diameter or height of plants, three and six months after planting. Buddability and dry matter production were comparable between treatments.

In a polybag nursery experiment, the highest buddability percentage (Table Ag. 3) was attained by the application of plant growth promoting rhizobacteria (PGPR) along with 50 per cent of recommended level of N and P as ammophos (20-20).

Table Ag. 4. **Effect of organic manure application on the growth of seedlings in nursery**

Treatment	Diameter of seedlings (mm)					Buddability (%)
	January	February	March	April	May	May
Control	4.0	6.0	7.7	10.0	11.0	43
C-POM	3.9	6.0	7.7	10.2	11.5	35
FYM+C-POM	3.9	6.1	7.9	10.2	11.0	47
FYM	4.1	6.3	8.2	10.5	11.3	40
SE	0.21	0.15	0.17	0.40	0.42	3.8
CD (P=0.05)	NS	NS	NS	NS	NS	11.6

Table Ag. 5. Effect of organic manures on the growth of polybag plants

Treatment	Diameter of seedlings (mm)					
	January	February	March	April	May	June
Control	4.7	5.4	6.0	8.0	9.3	10.9
C-POM 1.0kg	4.5	5.2	5.8	8.0	9.4	11.0
C-POM 0.5 kg	4.6	5.5	6.3	10.0	10.2	11.0
C-POM 0.5 kg +FYM 0.5 kg	4.9	5.5	6.1	9.0	11.4	12.5
FYM 0.5 kg	4.8	5.5	6.1	9.0	11.3	13.0
FYM 1.0kg	4.4	5.6	5.6	8.0	9.8	12.0
SE	0.04	0.06	0.04	0.04	0.09	0.08
CD (P=0.05)	NS	NS	NS	NS	0.27	0.24

Quantity of manures is on per polybag basis

Nursery experiments were conducted to study the effect of coir pith organic manure (C-POM) on the growth of rubber in seedling nursery and polybag nursery. No significant difference was observed between treatments on diameter of seedlings while difference was significant in the case of number of buddable plants in the FYM plus C-POM treatment (Table Ag. 4).

No significant difference was recorded between treatments on shoot and root biomass of seedlings in nursery as well as soil properties while the difference was significant for polybag plants. Application of FYM alone or in combination with C-POM significantly improved the diameter of polybag plants (Table Ag . 5).

Another field experiment to study the effect of C-POM on early establishment and growth of rubber plants in sandy soil at Thanneermukkom, Cherthala was initiated.

2. Radio tracer studies on tapping panel dryness

An experiment was conducted to study the P movement and utilisation efficiency in normal and TPD-affected trees through radiotracer studies using ^{32}P. Radioactive phosphorus (^{32}P) was supplied to mature rubber through root feeding as well as soil injection. The three categories of trees *viz.* normal, partially dried and completely dried trees were compared for the ^{32}P activity in different plant parts and latex at periodic intervals. The completely dried trees were tapped on the opposite panel or on the upper side for latex sample collection. No significant difference was recorded in ^{32}P activity in leaves after 15th day of application among the three categories. However, accumulation of ^{32}P was noted in the partially dried and completely dried trees with advancement of time indicating non-translocation to the site of latex biosynthesis. In bark samples on the 30th and 45th days of sampling, no ^{32}P could be traced in the normal and partially dried trees while in the completely dried trees it was recorded indicating non-incorporation to the latex. In latex, ^{32}P activity was recorded on the 20th day after application in all the three categories of trees. But on the 30th and 45th days ^{32}P was recorded in completely dried trees, indicating non-utilization of phosphorus from applied source for latex biosynthesis and regeneration. The study indicated that in the TPD affected trees, the xylem and phloem transport mechanism is active up to the laticiferous system but the latex biosynthesis and regeneration is affected or impaired.

3. Intercropping and cropping systems

The experiment on intercropping coffee and cocoa in mature rubber was concluded. Growth and yield of rubber trees were not significantly influenced by growing coffee and cocoa as intercrops. Coffee established well, but the yield continued to be very low. Yield of cocoa was about 40 per cent of that of monoculture. There was no difference in yield of rubber with 100 or 50 per cent levels of standard doses of fertilizers.

Experiments to find out the feasibility of growing perennial intercrops in the rubber were continued. Perennial intercrops, coffee, vanilla, *Garcinia* and nutmeg are being evaluated in normal system and in paired-row system of planting in rubber. In normal planting system, availability of photosynthetically active radiation at the centre of inter-row area was 5 per cent of that of open area, where as in the paired-row system of planting, a strip of width 3.5 m was available at the centre of wide inter row area without shading. In both experiments significant differences were not observed between treatments with respect to girth of rubber plants. Yield of *Garcinia* and vanilla at the normal spacing experiment was higher compared to that in the paired-row experiment and monoculture indicating the beneficial effect of shade. Coffee yield was comparable in both experiments and also comparable to that of monoculture. Nutmeg has not started flowering in both the experiments.

Cropping system experiment at CES, Chethackal initiated in 1993 to develop a cropping system model for smallholdings with extended intercropping period and integrating diverse annual, short-term and perennial intercrops, was concluded. Growth and yield (g/t/t) of rubber continued to be higher in the inter-cropped area with altered spatial arrangement of planting (406 trees/ha) compared to monoculture under normal spacing (445 plants / ha). Yield of coffee has started to improve and 157 kg (dry weight) was harvested from one hectare of the cropping system.

Interaction between rubber and wild jack (*Artocarpus hirsuta*) in mixed stand indicated significantly low girth of rubber compared to rubber monoculture. Distance of wild jack from the rubber had significant effect on rubber growth and yield. Wild jack standing closer (1.5 m) to the rubber gave poor yield compared to rubber at a distance of 2.0 m.

Experiment of inter-planting of rubber with teak, wild jack and mahogany at CES, Chethackal was in progress. Girth and girth increment of rubber were not significantly affected by row spacing, type of timber and their interaction. Growth of rubber was significantly better in monoculture than intercropped rubber. Among the timber species, growth of wild jack was better followed by teak and mahogany.

Experiment on effect of density of timber inter-planting on growth of rubber was continued at CES, Chethackal. Girth of rubber did not vary significantly due to density of timber trees while growth of timber varied significantly with density. Girth of teak was significantly better at the highest density.

4. Reduction in gestation period

The experiment to develop an agronomic package to reduce the immaturity period of *Hevea brasiliensis* at Malankara estate, Thodupuzha was continued. The girth of plants under integrated management was significantly superior to all other treatments (Table Ag. 6)

Table Ag. 6. **Effect of agromanagement practices on growth of rubber**

Treatment	Girth (cm)
Standard practice	20.49
Selective manuring	24.02
Enhanced nutrient application	23.75
Conservation-oriented tillage	24.28
Irrigation	25.21
Irrigation+ enhanced nutrient application	25.56
Integrated management	27.98
SE	0.49
CD (P=0.01)	1.51

5. Planting systems

An experiment was initiated at B.C. Cheruvally estate, Erumely to study the effect of different planting geometrics on canopy development, growth and yield of rubber in RRII 105. The different planting geometrics are square (4.5 x 4.5 m), triangular (2 x 5.9 x 5.9 m), twin (1.2 x 5.75 x 5.75 m), four cluster (2.3 x 6.7 x 6.7 m) and paired row (2.5 x 4.0 x 12.0 m). The density is maintained at 500 per hectare in all the treatments.

Experiment on effect of density of planting on growth and yield of rubber at CES, Chethackal was continued. The trees in the lowest density of 420 trees/ha had significantly higher girth (Table Ag. 7).

Table Ag. 7. **Girth of rubber plants in different planting densities**

Treatment	Girth (cm)		
	M1	M2	Mean
D_1 – (420 trees/ha)	67.75	68.82	68.29
D_2 – (479 ")	62.56	61.26	61.91
D_3 – (549 ")	65.20	60.83	63.02
D_4 – (638 ")	58.92	61.37	60.15
D_5 – (749 ")	59.57	57.35	58.46
Mean	62.80	61.93	

Main plot treatment SE – 1.16
CD(P=0.05) – 2.53
Subplot treatment SE – 1.35
CD - NS
M1 - nutrients applied on area basis
M2 - nutrients applied on per plant basis

The experiment to study the effect of planting pits of various dimensions on the growth and yield of rubber at CES, Chethackal was continued. Girth of rubber plants was not significantly influenced by size of planting pits (Table Ag. 8).

Table Ag. 8. **Effect of pit size on growth of rubber**

Pit size (cm)	Girth of plants (cm)
No pitting and planting polybag plants in holes	38.90
45 x 45 x 45	38.12
60 x 60 x 60	39.66
75 x 75 x 75	39.74
90 x 90 x 90	38.08
60 x 60 x 60	37.70
90 x 90 x 60	36.83
SE	2.51
CD	NS

6. Soil and water conservation

The experiment to study the influence of silt pits on the growth and yield of mature rubber and to explore the possibility of applying fertilizer for rubber in silt pit was concluded. The growth and yield of rubber trees were significantly influenced by the presence of silt pits. Yield was enhanced by 15 per cent in plots where 250 pits/ha were practised. There was substantial increase in soil moisture storage also. Therefore, opening of pits is a viable soil conservation and water harvesting technology in rubber plantations.

7. Root studies

Root distribution pattern of mature rubber trees (Table Ag. 9) indicated that more than 50 per cent of fine roots were concentrated in the surface 10 cm layer of soil.

Table Ag. 9. **Vertical distribution of fine roots (g/plant)**

Soil depth (cm)	Age of trees		
	7 years	19 years	29 years
0 -10	360.45	1298.19	1986.35
10-30	200.25	769.58	1009.63
30-60	57.85	175.23	262.00
> 60	31.15	93.46	82.79
Total	649.70	2336.34	3340.78

8. Rubber growing soils

The study on comparison of soil ecosystems continued with the major objective of assessment of quality and health of different soil ecosystems with special reference to soil organic matter. Six soil ecosystems *viz*. mature rubber, rubber-*Mucuna* cover-cropped, rubber-pineapple-intercropped, cassava monocrop, teak-mature plantation and forest in Kottayam District (between 76° 52′ and 77° E longitude and 9° 25′ to 9° 30′ N latitude) were investigated. Soil samples were collected and analysed for chemical and biological parameters. The total nitrogen and organic carbon contents of different systems decreased in the order Forest > *Mucuna* > Teak = Pineapple = Rubber > Cassava. Available Ca and Mg are distinctly lower in rubber and *Mucuna* soils compared to other soils. NH_4-N in soils under different systems did not vary significantly. However, N mineralization in soils under different systems varied significantly. Mineralized NH_4-N was significantly higher in forest soil than all other soils. Between teak and mature rubber soils, mineralized NH_4-N was significantly higher in teak soils. In *Mucuna* and pineapple soils, initial and mineralized NH_4-N contents were quite similar. The studies on population of macro/mesofauna in different ecosystems indicated that forest soils were having significantly higher number of all the macro and mesofauna.

Experiment to study the changes in fertility status of soil upon continuous cultivation of rubber was in progress. After the first cycle of rubber cultivation, a reduction in organic carbon and available potassium was noticed while an increase was noted for available phosphorus. (Table Ag. 10).

9. Development of rubber information system through remote sensing and GIS

Development of rubber information system in traditional region using remote sensing and GIS technique was in progress.

Table Ag. 10. **Soil nutrient changes after first cycle of rubber cultivation**

Soil nutrients	0-30 cm			30-60 cm		
	Ayiranalloor	Kulathupuzha	Laha	Ayiranalloor	Kulathupuzha	Laha
	OC %			OC %		
Initial	2.17	2.15	1.56	1.48	1.54	1.13
After 30 years	1.40 **	1.30**	1.11*	1.20*	1.00*	0.85*
	Av.P (mg/100g)			Av.P (mg/100g)		
Initial	0.47	0.56	0.37	0.27	0.28	0.20
After 30 years	0.98	1.00*	0.60*	0.40	0.70**	0.50**
	Av.K (mg/100g)			Av.K (mg/100g)		
Initial	9.79	10.36	6.49	8.54	7.77	5.24
After 30 years	5.90**	5.60**	5.20	4.40**	5.00**	5.00
	pH			pH		
Initial	5.09	5.32	4.76	5.02	5.31	4.59
After 30 years	5.10	5.20	4.50	5.00	5.20	4.50

* Significant at P=0.05

** Significant at P=0.01

With the help of NBSS and LUP, Banglore soil series were regrouped into soil management units based on organic carbon, slope, depth and gravel content. Initiated work on geo referencing and extracting themes from toposheets and soil maps. Completed classification of IRS P6 satellite image for Kottayam district and post classification assessment carried out.

10. Fertilizer advisory group

The activities of the Fertilizer Advisory Group were to offer advisory services to rubber smallholdings through discriminatory fertilizer recommendation based on soil and leaf analysis and latex testing for DRC estimation. The Group coordinated the activities of the 8 regional and 2 mobile soil testing laboratories at Kozhikode and RRII. Apart from the above, investigations on problems reported from rubber estates/holdings were also undertaken.

A total of 4200 discriminatory fertilizer recommendations were offered to small holdings based on the analysis of 8210 soil and 370 leaf samples. Mobile soil testing laboratories attached to the RRII and Regional Lab, Kozhikode were utilized for offering on-the-spot fertilizer recommendation and arranged testing programmes at 96 locations. During the period under report 60430 latex samples were tested for DRC in eight regional laboratories.

BIOTECHNOLOGY DIVISION

Genetic improvement of *Hevea brasiliensis* using modern tools is the major goal of Biotechnology research at RRII. The major ongoing research programmes in the Division are i) development of *in vitro* propagation methods for elite *Hevea* clones ii) development of transgenic *Hevea* plants for better latex yield, disease tolerance, adaptation to environmental stress, recombinant protein production in the latex *etc.* iii) development of *in vitro* fertilization techniques and embryo rescue and development of triploid plants to compliment conventional breeding programmes iv) study of molecular mechanism and characterization of genes controlling tolerance to diseases, abiotic stress, tapping panel dryness and latex biosynthesis and v) study of laticifer cell-specific gene expression and characterization of laticifer cell - specific promoters.

1. Somatic embryogenesis

New leaf cultures were initiated from budded plants of clone RRII 105 grown in glasshouse for callus induction. Yellow friable calli obtained in proliferation medium were subcultured in modified MS medium containing B5 vitamins, increased sucrose (60 g/L) and phytohormones NAA, Kin, BA and GA_3 for embryogenic callus induction. The media also contained vitamins, amino acids, organic supplements such as coconut water, casein hydrolysate, sucrose and phytohormones. Experiments to enhance embryo induction were also carried out by changing the concentrations of media constituents such as major salts, amino acids, myoinositol (0-300 mg/L), adenine sulphate (0-100 mg/L) and phytohormones according to the texture of the callus to be subcultued. In earlier experiments, good embryo

Table Ag. 9. **Vertical distribution of fine roots (g/ plant)**

Soil depth (cm)	Age of trees		
	7 years	19 years	29 years
0 -10	360.45	1298.19	1986.35
10-30	200.25	769.58	1009.63
30-60	57.85	175.23	262.00
> 60	31.15	93.46	82.79
Total	649.70	2336.34	3340.78

8. Rubber growing soils

The study on comparison of soil ecosystems continued with the major objective of assessment of quality and health of different soil ecosystems with special reference to soil organic matter. Six soil ecosystems *viz*. mature rubber, rubber-*Mucuna* cover-cropped, rubber-pineapple-intercropped, cassava monocrop, teak-mature plantation and forest in Kottayam District (between 76° 52′ and 77° E longitude and 9° 25′ to 9° 30′ N latitude) were investigated. Soil samples were collected and analysed for chemical and biological parameters. The total nitrogen and organic carbon contents of different systems decreased in the order Forest > *Mucuna* > Teak = Pineapple = Rubber > Cassava. Available Ca and Mg are distinctly lower in rubber and *Mucuna* soils compared to other soils. NH_4-N in soils under different systems did not vary significantly. However, N mineralization in soils under different systems varied significantly. Mineralized NH_4-N was significantly higher in forest soil than all other soils. Between teak and mature rubber soils, mineralized NH_4-N was significantly higher in teak soils. In *Mucuna* and pineapple soils, initial and mineralized NH_4-N contents were quite similar. The studies on population of macro/mesofauna in different ecosystems indicated that forest soils were having significantly higher number of all the macro and mesofauna.

Experiment to study the changes in fertility status of soil upon continuous cultivation of rubber was in progress. After the first cycle of rubber cultivation, a reduction in organic carbon and available potassium was noticed while an increase was noted for available phosphorus. (Table Ag. 10).

9. Development of rubber information system through remote sensing and GIS

Development of rubber information system in traditional region using remote sensing and GIS technique was in progress.

Table Ag. 10. **Soil nutrient changes after first cycle of rubber cultivation**

Soil nutrients	0-30 cm			30-60 cm		
	Ayiranalloor	Kulathupuzha	Laha	Ayiranalloor	Kulathupuzha	Laha
	OC %			OC %		
Initial	2.17	2.15	1.56	1.48	1.54	1.13
After 30 years	1.40 **	1.30**	1.11*	1.20*	1.00*	0.85*
	Av.P (mg/100g)			Av.P (mg/100g)		
Initial	0.47	0.56	0.37	0.27	0.28	0.20
After 30 years	0.98	1.00*	0.60*	0.40	0.70**	0.50**
	Av.K (mg/100g)			Av.K (mg/100g)		
Initial	9.79	10.36	6.49	8.54	7.77	5.24
After 30 years	5.90**	5.60**	5.20	4.40**	5.00**	5.00
	pH			pH		
Initial	5.09	5.32	4.76	5.02	5.31	4.59
After 30 years	5.10	5.20	4.50	5.00	5.20	4.50

* Significant at P=0.05

** Significant at P=0.01

With the help of NBSS and LUP, Banglore soil series were regrouped into soil management units based on organic carbon, slope, depth and gravel content. Initiated work on geo referencing and extracting themes from toposheets and soil maps. Completed classification of IRS P6 satellite image for Kottayam district and post classification assessment carried out.

10. Fertilizer advisory group

The activities of the Fertilizer Advisory Group were to offer advisory services to rubber smallholdings through discriminatory fertilizer recommendation based on soil and leaf analysis and latex testing for DRC estimation. The Group coordinated the activities of the 8 regional and 2 mobile soil testing laboratories at Kozhikode and RRII. Apart from the above, investigations on problems reported from rubber estates/holdings were also undertaken.

A total of 4200 discriminatory fertilizer recommendations were offered to small holdings based on the analysis of 8210 soil and 370 leaf samples. Mobile soil testing laboratories attached to the RRII and Regional Lab, Kozhikode were utilized for offering on-the-spot fertilizer recommendation and arranged testing programmes at 96 locations. During the period under report 60430 latex samples were tested for DRC in eight regional laboratories.

BIOTECHNOLOGY DIVISION

Genetic improvement of *Hevea brasiliensis* using modern tools is the major goal of Biotechnology research at RRII. The major ongoing research programmes in the Division are i) development of *in vitro* propagation methods for elite *Hevea* clones ii) development of transgenic *Hevea* plants for better latex yield, disease tolerance, adaptation to environmental stress, recombinant protein production in the latex *etc.* iii) development of *in vitro* fertilization techniques and embryo rescue and development of triploid plants to compliment conventional breeding programmes iv) study of molecular mechanism and characterization of genes controlling tolerance to diseases, abiotic stress, tapping panel dryness and latex biosynthesis and v) study of laticifer cell-specific gene expression and characterization of laticifer cell - specific promoters.

1. Somatic embryogenesis

New leaf cultures were initiated from budded plants of clone RRII 105 grown in glasshouse for callus induction. Yellow friable calli obtained in proliferation medium were subcultured in modified MS medium containing B5 vitamins, increased sucrose (60 g/L) and phytohormones NAA, Kin, BA and GA_3 for embryogenic callus induction. The media also contained vitamins, amino acids, organic supplements such as coconut water, casein hydrolysate, sucrose and phytohormones. Experiments to enhance embryo induction were also carried out by changing the concentrations of media constituents such as major salts, amino acids, myoinositol (0-300 mg/L), adenine sulphate (0-100 mg/L) and phytohormones according to the texture of the callus to be subcultued. In earlier experiments, good embryo

induction with a frequency of above 60 per cent could be obtained, with normal embryos in a hormone combination of BA (0.3 mg/L), Kin (0.5 mg/L), GA_3 (0.8 mg/L) and NAA (0.1 mg/L). Simultaneous embryogenic callus formation and embryogenesis were also observed in this medium.

After extensive optimizations, the phytohormone concentrations were further reduced to 0.2 mg/L BA, 0.1 mg/L Kin, 0.5 mg/L GA_3 and 0.1 mg/L NAA. Subculture of the embryogenic calli in hormone - free medium enhanced the rate of embryo induction by changing the texture and increasing the embryogenic capacity of the callus. The concentrations of proline (200 mg/L) and arginine (50 mg/L) were slightly increased to improve embryo induction. Cotyledonary embryos showing normal development could be obtained after three weeks culture in the fresh medium. Presence of thiamine (10 mg/L) favoured embryo development. Subculturing single embryos and maintaining in dark was found to be more effective for their enlargement and conversion to cotyledonary stage.

Secondary embryogenesis was initiated from the hypocotyl region of some of the regenerating plantlets as a very small lump which expanded within two weeks showing speedy growth, comprising several small embryos. The rate of embryo maturation and apex induction was only 40 per cent in these embryos. Plant regeneration (20%) from apex-induced mature embryos was obtained in ½ MS as well as WPM containing myoinositol (100 mg/L), coconut water (5%), sucrose (30 g/L) and phytohormones such as BA (0.3 mg/L), GA_3 (0.3 mg/L) and IBA (0.1 mg/L).

Somatic embryogenesis was also achieved from immature anther explants of clone RRII 105 and RRII 414 using the protocol developed earlier. Field performance of one batch of somatic plants raised using immature anther explants (clone RRII 105) was not uniform and the growth was comparatively low compared to the bud-grafted control plants. Somatic plants with maximum growth had vigorous tap root as well as lateral roots.

Plant regeneration via somatic embryogenesis from immature inflorescence of RRII 105 and 400 series clones was carried out employing the earlier standardized protocol. Multiplication of the induced embryos at the globular stage through secondary embryogenesis was also made use of for increasing the efficiency of the pathway. The regenerated plants were subject to hardening and the hardened plants were kept in polybags in the shade house.

Field evaluation of somatic plants raised from immature inflorescence was carried out. Girth of the somatic and control plants planted during 2000 was recorded. Alternate daily tapping of these plants was carried out for three months. Yield and other yield attributing parameters like initial flow rate, plugging index and drc were determined. The girth as well as girth increment was higher for somatic plants compared to the control bud-grafted plants. Somatic plants also had better yield and other yield attributes compared to the control. Average girth of the somatic plants planted during 2003 and 2006 was on par with that of the control bud-grafted plants.

A new experiment for inducing mutation in *Hevea* through irradiation of *in vitro* cultures using electromagnetic radiation was initiated. Embryogenic calli derived from immature inflorescence of clone RRII 105 was selected as the target tissue for irradiation. Equal quantities of these calli were exposed to different doses of gamma radiation ranging from 10 to 100

Gy at an increment of 10 Gy. The irradiated calli were transferred to fresh media of the same composition and kept in the dark. Proliferated calli were transferred to embryo induction media and subcultured periodically. Induced embryos after maturation were transferred to plant regeneration medium. Experiments were carried out for *in vitro* screening of the irradiated cultures for various traits like drought and cold tolerance through the incorporation of high levels of phytagel/PEG in the medium and by exposing the irradiated calli to lower temperatures.

For ovule culture, refinement experiments were carried out with the earlier developed protocol. Initially the unpollinated ovules were pre-cultured on N_6 medium with 30 per cent sucrose for five days at 4°C and transferred for callus induction. The callus induction medium was MS with nine per cent maltose and a growth regulator combination of 2,4-D (0.2 mg/L), NAA (0.4 mg/L) and Kin (0.3 mg/L). Callus formation was observed within 15 days of culture and they were proliferated in the same medium with reduced concentration of hormones. Embryogenic callus formation was observed in N_6 medium supplemented with organic supplements *viz.* malt extract (500 mg/L), banana powder (200 mg/L) and yeast extract (100 mg/L) along with amino acids like glutamate (1g/L), glycine (100 mg/L), proline (200 mg/L), phenyl alanine (100 mg/L) and arginine (200 mg/L). Subculture of the embryogenic calli to MS basal medium with NAA (0.4 mg/L), Kin (1.0 mg/L) and BA (0.5 mg/L) resulted in embryo induction. The embryo induction frequency was increased to 80 per cent. The embryo clumps obtained were separated and kept in the same medium for enlargement.

For triploid plant production through endosperm culture, factorial experiments were performed with different combinations of NAA & Kin, IBA & Kin and 2, 4-D & Kin. A high concentration of sucrose (50 g/L) and phytagel (0.5%) was also used. Endosperms from open-pollinated mature seeds were cut into small pieces and inoculated in various media. Attempts were also made to culture the immature endosperm from the rescued embryos. Immature endosperm was separated from the rescued embryos and inoculated in MS medium supplemented with 2 mg/L 2, 4-D and 3 mg/L Kin. Callus induction was obtained from all the three experiments. However, the highest frequency of callus induction (99%) was obtained with the 2,4-D and Kin combinations ranging from 2,4-D (1-5 mg/L) and Kin (1-5 mg/L). Callus proliferation was higher in the combination of 2, 4-D (2.0 mg/L) and Kin (3.0 mg/L). Calli were induced from the mature endosperm and proliferated. Callus induction was also observed from immature endosperm, in medium supplemented with 2, 4-D (2.0 mg/L) and Kin (3.0 mg/L) with a low frequency. Compared to mature endosperm, callus proliferation was found to be low and the calli turned into pro-embryonic mass.

2. *In vitro* fertilization and embryo rescue in *Hevea brasiliensis*

For *in vitro* fertilization, flowers were collected and sterilized using 0.1 per cent $HgCl_2$ and blotted dry on a sterile filter paper. Ovules were isolated from female flowers and inoculated in the nutrient medium. Sterilized $CaCl_2$ solution was poured over the ovules and kept for 24 hours. These ovules were then pollinated with freshly isolated anthers from sterilized male flowers. Embryos were obtained and kept for germination. They were very small

compared to *in vivo* embryos and failed to germinate.

Embryo rescue experiments were continued to optimize the pathway for the rescue of embryos from immature fruits derived from hand-pollinated flowers. Open - pollinated fruits of different maturity were collected (1 week to 8 weeks) and inoculated in different combinations of nutrient medium for the recovery of plantlets. Different sterilization techniques were also tried. Along with Nitsch basal medium, different concentrations of zeatin (1-5 mg/L), Kin (1-5 mg/L) and combinations of zeatin, Kin and GA_3 were tried. Effect of incubation conditions (dark/light) were also studied. Among the different stages of fruits cultured, embryo recovery could be possible from two - week old fruits onwards. The lowest recovery was from two-week-old fruits (6%) and the highest from eight-week-old fruits (60%) respectively. It was observed that light incubation inhibited embryo development and no embryos could be recovered. Among the different growth regulators tried, GA_3 (1.0 mg/L) was found to be essential for the early stages of embryo development. Endosperm development did not occur in all the embryos. Zeatin (2.0 mg/L), was found to be ideal for embryo as well as endosperm development. Kin (3.0 mg/L) also promoted embryo development, but showed no positive influence on the endosperm development. The plants obtained through embryo rescue during the previous year were hardened and field planted. Attempts were also made to induce polyembryony in cultured ovules. Polyembryony could successfully be induced in few of the fertilized ovules cultured. The number of embryos from a single ovule varied from 2-12. The embryos were germinated and four plants could be hardened and field-planted.

3. Genetic transformation

Genetic transformation experiments were continued to develop transgenic plants with increased tolerance to tapping panel dryness, abiotic stresses and higher latex yield. The genes coding for superoxide dismutase under the control of CaMV 35S and FMV 34S promoters separately, sorbitol-6-phosphate dehydrogenase, *cis*-prenyl transferase, hmgr 1, farnesyl diphosphate synthase and osmotin were used in these studies.

New *Agrobacterium* infections were carried out for generating more transgenic lines of the SOD gene with CaMV 35S and FMV 34S promoters. Different target tissues such as two-month-old anther callus, embryogenic callus, leaf discs, fresh callus derived from leaves and embryogenic leaf calli were used. Several sets of infections were carried out with each type of target tissue. Routine subculture of infected tissues was carried out into fresh plates containing selection antibiotics every three weeks. After antibiotic selection over paramomycin, nine putatively transformed cell lines were obtained with FMV 34S promoter and the GUS positive cell lines were proliferated in callus induction medium containing 300 mg/L paramomycin. The proliferated callus was transferred to modified MS and WP basal media fortified with hormones. WP medium was modified by reducing the concentration of potassium sulphate to 450 mg/L, calcium nitrate to 200 mg/L and incorporating 800 mg/L potassium nitrate and B5 vitamin. Modification was made in MS basal medium by reducing major nutrient to half strength and addition of 200 mg/L calcium nitrate as well as B5 vitamins. The growth regulators used for getting friable callus were 2,4-D (1 mg/L), BA (0.5 mg/L) and NAA (0.2 mg/L).

Effect of growth regulators on embryo induction was assessed by supplementing hormones 2,4-D (0.2 – 1 mg/L), NAA, BA and Kin (0.2 – 0.5 mg/L). Embryos were obtained from one line. The embryos were cultured for maturation and further development.

PCR confirmation of the *uid*A, *npt*II and the SOD gene integration was carried out with the five transgenic lines obtained earlier with MnSOD gene under the control of CaMV 35S promoter. Good amplification was observed with all the primers. Embryo induction was noticed in two different lines. These embryos were separated and cultured for maturation. Sodium chloride stress was given to these transgenic lines with NaCl ranging from 100 - 300 mM. Two transgenic lines showed tolerance up to 200 mM NaCl. Selected transgenic lines were also utilized for stress studies using different concentrations of PEG (6-12%) and phytagel (0.6 %). Transgenic lines which were showing tolerance to these treatments were subcultured for embryo induction.

Four sets of transformations were carried out with the *Agrobacterium* strain EHA 105 and LBA 4404 harbouring hmgr 1 gene using embryogenic callus and two -month- old anther callus as the target tissue. The transformation efficiency was clearly different for the two strains and greater for LBA 4404 when the embryogenic callus was used for tissue infection. Twenty four transgenic lines were obtained with the strain LBA 4404 and four lines with the strain EHA 105. The transgenic lines obtained were proliferated and PCR confirmation was carried out for five lines using *npt*II gene-specific and promoter-specific primers. Good amplification was obtained with the *npt*II specific primer, hmgr 1 and promoter-specific primers. For further confirmation, the PCR product was cloned into a cloning vector and sequenced. The sequence showed 100 per cent homology with the sequence of *npt*II gene.

New *Agrobacterium*-mediated genetic transformations were also carried out with the genes coding for sorbitol-6-phosphate dehydrogenase, osmotin, *cis*-prenyl transferase and farnesyl diphosphate synthase. The transgenic lines obtained with sorbitol-6-phosphate dehydrogenase and farnesyl diphospahte synthase genes were proliferated and transferred to embryo induction medium.

4. Molecular studies

4.1. Molecular mechanism of disease tolerance

The inverse PCR experiments were repeated to amplify upstream elements further to the earlier amplified region of â-1,3-glucanase gene. The genomic DNA of clone RRII 105 was digested with six nucleotide blunt end cutting enzyme *Ssp* 1. After circularizing the digested product and linearising with *Bgl* enzyme, extensive optimization of PCR conditions was made to amplify larger fragments. As a result, in addition to the three bands amplified earlier, a fourth band of 1.2 kb has been amplified which was larger than the earlier amplified three bands. The amplified band was cloned and sequenced. The sequence revealed 910 bp and on comparison of the coding region with other forms, it was confirmed that the newly amplified fragment is the promoter of another novel genomic form of â-1, 3-glucanase gene. Thus a total of four promoter forms have been identified. Sequencing has been done twice in order to confirm the results obtained. Out of the four forms, the smallest fragment with 198 bp showed exact alignment with the earlier reported sequence. The other three fragments showed similarity to a considerable length from the

translation initiation codon and beyond that more variations were observed. The four forms also showed variations in the position of consensus sequences like "TATA" and "CAAT" boxes. Though "TATA" box was observed in all the forms "CAAT" box was found to be absent in the expected region of 910 and 550 bp fragments. The promoter region also showed other common elements like GAAT, E-box , WRKY *etc.*

4.2. Tissue-specific gene expression and characterization of promoters

Attempts were continued to characterize the major genes involved in the rubber biosynthetic pathway. In the earlier studies, the existence of intron-less genomic forms of hevein gene was observed. Attempts were made to identify similar forms for *hmgr* 1, REF and *cis*-preny 1 transferase genes. The earlier reported genomic form of FDP gene was with out introns. Therefore, attempts were also made to identify FDP gene with introns.

A PCR strategy was developed based on exon-exon junction-based reverse primer and forward primer. This was found successful for the specific amplification of intron-less genomic form of hevein. Oligonucleotide primer complimentary to the above sequence was synthesized. A single band was amplified when PCR was carried out at an annealing temperature of 60 °C using 0.6 U *Taq* DNA polymerase and 20 ng of genomic DNA as template. In order to confirm the authenticity of the experiment, the recombinant TOPO TA cloning vectors containing hevein gene sequence with and without intron as inserts were used as control templates during PCR. No amplification was observed with negative control (plasmid containing hevein gene with intron as insert). Amplified DNA fragment was cloned, sequenced and the sequence data confirmed the specific amplification of intron-less hevein gene. Using this exon-exon junction based primer strategy, intron-less genomic sequences were identified for REF and *cis*-prenyltransferase genes also. However, no intron-less genomic form could be identified for hmgr 1 gene.

To check whether the intron-less genes observed are processed pseudo genes, an attempt has been made to find whether these DNA fragments contain poly (A) tail at 3′ end. A set of PCRs using gene-based forward primer and four different variant oligo dT primers were carried out for the amplification of intron-less genomic forms of hevein, REF, FDP and *cis*-preny 1 transferase with poly (A) tail if present. Even after repeated PCR trials with varying parameters no amplification corresponding to the above mentioned genomic forms with poly A tail was observed.

The earlier reported 1.13 kb genomic sequence coding for farnesyl diphosphate synthase gene was single exonic. In the present study a 4.7 kb amplicon was obtained instead of the expected ~1.13 kb DNA fragment. The PCR was carried out with the gene-specific forward (5′ GAATCCATGCGGATCTGAAGTCA3′) and reverse - (5′TCTGTCTCTTGTAAATTTTTGGCC3′) primers using genomic DNA as template. Specific amplifications were obtained at optimum PCR conditions. The PCR profile include an initial denaturation for 4 min at 94° C followed by 36 cycles of denaturation at 94° C for 1 min, annealing at 60° C for 1 min and extension at 72° C for 2 min and a final extension for 10 min at 72° C. The amplified fragment was cloned and sequenced. Sequence data revealed that the isolated fragment contain 4,699 bp. Sequence data when aligned with earlier reported FDP genomic sequence (AY349419) significant

homology was observed, which indicates that the isolated sequence belongs to the FDP gene family. On alignment with the earlier reported single exonic genomic and cDNA sequences (AY349419 & AY135188) it was found that the reading frame in the isolated FDP gene was interrupted by 11 introns, shuffling the coding sequence into 12 exons. Extensive variations in number of nucleotides were observed in different introns and exons. The first intron was the biggest and contained 1,475 bp with a dinucleotide repeat $(CT)_{10}$ at its 5′ region. The fifth intron was the smallest one with 82 bp. All the 11 introns began with the conserved splice donor GT and ended with AG, the splice acceptor. All the introns were AT rich and the first intron contained 65% A+T. The exons were seen highly scattered among the introns. Exons included a micro exon of 25 bp, and the rests were between 45 bp to 129 bp. The sequence contained translation initiation codon (ATG) at 7th position and termination codon (TAA) at 4697th position. The sequence has been registered at NCBI GenBank database under the Accession number EF 593108.

Several FDP gene homologs were observed when the sequence was submitted for BLAST analysis. Significant hits were observed with various FDP gene sequences reported from other plant species. On alignment through clustalW, considerable homology was observed among the heterologous FDP gene sequences reported from different species. A valid phylogenetic tree has been constructed using the nucleotide sequence data of FDP mRNA reported from 9 different plant species belonging to phylum Magnoliophyta. Similar gene structure was observed with the FDP gene reported from *Arabidopsis thaliana* (L46367) and *Humulus lupulus* (AB053486), both contain 11 introns and 12 exons like *Hevea* FDP gene.

Evolutionary distances of FDP gene sequences of different genus were calculated using PHLYLIP software package version 3.2. Phylogenetic tree was generated using Neighbour Joining Method. Phylogenetic tree indicated genetic relationship among

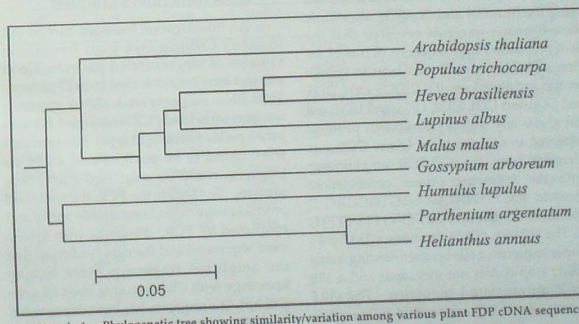

Fig. Biotech. 1. **Phylogenetic tree showing similarity/variation among various plant FDP cDNA sequences**

different plant species studied (Fig. Biotech. 1). *Hevea brasiliensis* FDP gene sequence showed maximum similarity with *P. trichocarpa*, and these two species together in the tree formed a separate clade, indicating probable evolutionary similarity. Two other latex producing species *Parthenium argentatum* and *Helianthus annus* having nucleotide sequence homology (92%) formed separate clade indicating high degree of evolutionary similarity between them.

5. Isolation and characterization of TPD-induced / regulated cDNAs by subtractive hybridization and mRNA differential display

Differential dispaly-PCR analysis was carried out between healthy and TPD affected trees and differentially expressed cDNAs were identified. A total of 10 cDNA fragments (6 down-regulated and 4 up-regulated cDNAs in TPD tree) was successfully isolated from the sequencing gel, re-amplified and cloned into T-vector. Cloned cDNAs were sequence-characterized and were compared with the GenBank database using the BLASTX and BLASTN algorithms. Bioinformatic analysis revealed that the deduced amino acid sequence of one of the clones (DD1) showed similarity to known protein and nine clones (DD2, DD3, DD4, DD5, and DD6 and UD1, UD2, UD3, and UD4) did not show any identity to known proteins reported in the database. Clone DD1 was identified from the DD-PCR amplification with the following primer combination: forward 5′ CTTGTACGCGTGTGCGAC 3′ and reverse 5′ CGGATCCTTTTTTTTTTTTG 3′. The 1024 bp cDNA contains a 239 bp 5′-leader sequence, a 606 bp open reading frame (ORF; stop codon not included) and a 176 bp 3′-untranslated sequence. The ORF encodes for a 202 amino acid polypeptide with a predicted molecular mass of 23.5 kDa and the calculated pI value was 9.5. A database search identified this cDNA as encoding a putative translocase of outer mitochondrial membrane (*TOM*) protein, designated as *HbTOM20*. The multiple amino acid sequence alignment of *HbTOM20* with other known plant *TOM20* genes revealed that the *HbTOM20* exhibits 27 per cent similarity with *Solanum tuberosum TOM20* (X92491), 26 per cent with *Arabidopsis thaliana TOM20* (AJ296024) and 17 per cent with *Oryza sativa TOM20* (NM001051764). The predicted protein contained the conserved domain, a *TOM20* motif in the N-terminal half, whereas a region close to the C-terminus was variable and rich in Gly residues. The phylogenetic tree showed that the *TOM20* of *Hevea* formed a cluster with *TOM20* of *Arabidopsis*, *Solanum*, and *Oryza* homologues. Hydropathy analysis of the deduced amino acid sequence indicated that *HbTOM20* was strongly hydrophobic.

6. Characterization of Chikungunya virus from blood samples

An investigation has been carried out to detect Chikungunya virus from blood samples of virus infected patients. Blood samples have been collected from 23 patients. Total RNA was prepared, cDNA synthesis was performed and PCR was carried out with gene-specific primers (E1 type). Nine samples were found to be positive and a 205 bp fragment could be amplified from these samples. To validate the PCR, the amplified products were cloned into shuttle vector and confirmed by PCR. Plasmids with inserts were sequenced and the data confirmed that the amplified fragments were having homology with Chikungunya virus E1 gene (203 bp). The sequence has been deposited in the NCBI GenBank.

BOTANY DIVISION

Crop improvement being the thrust area of research of the Division, evaluation of clones for latex and timber yield and drought and disease tolerance was continued. Need-based investigations on propagation strategies and anatomical aspects of bark and wood were also carried out. Histochemical studies in relation to tapping panel dryness were continued. A project on participatory plant breeding through multi-locational on-farm evaluation of the next series of promising pipeline clones was initiated with the multiplication of two batches of clones.

1. Evolving high yielding clones for the traditional area

1.1. Hybridization and clonal selection

Evaluation of the promising clones generated through the 1986 hybridization programme was continued in 14 small-scale trials (SST) at Central Experiment Station (CES), Chethackal, to assess their long-term yield performance. Among the 43 hybrid clones under evaluation in four SST planted in 1989, 28 clones maintained higher yield than RRII 105 during the 10th year of tapping (Table Bot.1).

Among the 37 promising clones under evaluation in eight SST planted in 1990, 21 clones continued to maintain higher annual mean yield compared to RRII 105 in the ninth year of tapping in the respective trials. Among the 24 clones tested in two SST planted in 1992, four clones continued to be superior to RRII 105 with respect to mean yield during the eighth year of tapping (Table Bot. 2).

Out of the 26 hybrid clones and their parents under evaluation in the two small-

Table Bot. 1. **Yield of selected rubber clones in four SST in the 10th year of tapping**

Trial A		Trial B		Trial C		Trial D	
Clone	Yield (g/t/t)	Clone	Yield (g/t/t)	Clone	Yield (g/t/t)	Clone	Yield (g/t/t)
86/23	98.57	86/122	192.25	86/428	137.19	86/597	115.97
86/157	98.27	86/111	158.13	86/650	91.10	86/99	100.07
86/244	94.15	86/64	115.25	86/424	82.38	86/674	79.35
86/613	87.18	86/117	101.79	86/778	67.80	86/98	69.04
86/602	81.32	86/32	80.93	86/966	60.70	86/188	67.86
86/60	80.85	86/174	80.72	86/908	53.47	86/400	63.55
86/902	80.41	86/651	78.17	86/968	52.50	86/599	58.27
86/304	79.50	86/44	62.94	RRII 105	50.56	86/68	52.02
86/120	77.85	86/79	55.55			86/191	45.00
86/660	71.75	86/306	48.90			86/70	41.77
86/607	69.54	RRII 105	59.18			RRII 105	76.71
86/5	66.18						
86/110	64.99						
86/59	64.90						
86/34	63.92						
86/957	63.10						
RRII 105	70.92						

Table Bot. 2. **Yield of the promising hybrid clones in the 1992 SST in the eighth year of tapping**

Trial A		Trial B	
Clone	Yield (g/t/t)	Clone	Yield (g/t/t)
92/772	74.35	92/575	73.75
92/380	70.92	92/756	60.06
92/948	52.05	92/368	48.82
92/356	50.09	RRII 105	41.09
92/450	49.96		
92/424	35.75		
RRII 105	59.51		

scale trials planted in 1998, performance of 13 clones was on par with RRII 105 in terms of yield. In trial A, two clones, *viz.* 93/37 and 93/45, progenies of RRIM 600 x RRII 118, were found to be superior to RRII 105, in the third year of tapping.

Forty clones were evaluated for yield in the second year of tapping in two small-scale trials planted in 1999. There was significant clonal variation in yield. Thirteen hybrids recorded higher yield than RRII 105 in the respective trials. Clone 95/510, resultant of the cross RRII 105 x RRII 118, was significantly superior yielding (61.43 g/t/t). Based on summer yield in the two trials, 10 hybrid clones were found superior to RRII 105.

Table Bot. 3. **Girth and yield of promising clones**

Clone	Girth (cm)	Mean yield (g/t/t)	
		5th year	Over 5 years
95/7	70.96	75.21	60.89
95/27	77.94	67.43	48.88
95/64	72.88	64.23	57.25
95/79	64.86	59.69	54.60
95/95	68.28	71.36	61.99
95/102	65.04	53.04	47.68
95/124	65.58	50.70	48.54
95/243	58.46	45.56	42.80
95/308	63.88	62.16	54.54
95/309	65.29	77.93	54.21
95/349	67.13	60.68	43.65
95/356	70.33	52.09	49.78
RRII 105	53.46	40.00	40.00

Among the 34 hybrid clones under evaluation in the SST planted in 1995, 12 clones recorded better yield than RRII 105 in the fifth year of tapping. Data on yield and girth of promising clones are given in Table Bot. 3.

Among the 26 hybrid (WxA) clones under evaluation in SST planted in 1995, 10 clones showed higher yield than the control clone RRII 105 in the fifth year of tapping. Data on yield and girth of promising clones are given in Table Bot. 4.

Among 36 hybrid (WxA) clones under evaluation in a clonal nursery at CES, 10 clones showed higher yield than the control clone RRII 105. The girth and yield of promising clones are given in Table Bot. 5.

Bot. 4. **Girth and yield of promising clones**

Clone	Girth (cm)	Mean yield (g/t/t)	
		5th year	Over 5 years
95/10	76.28	62.02	52.99
95/21	71.89	43.38	32.04
95/25	60.39	42.37	39.31
95/29	82.75	47.52	36.46
95/34	67.58	57.36	41.60
95/170	66.42	46.34	34.72
95/171	75.83	40.89	26.04
95/241	70.00	43.31	33.87
95/271	74.08	53.80	37.51
95/340	58.38	51.71	33.81
RRII 105	52.44	36.56	35.22

Table Bot. 5. **Girth and test tap yield of promising selections in the clonal nursery**

Clone	Girth (cm)	Yield (g/t/10 taps)
97/4	20.92	35.68
97/10	20.31	32.00
97/47	20.13	35.20
97/182	20.33	44.51
97/196	18.58	34.54
97/219	20.83	30.67
97/213	21.17	87.38
97/225	16.67	34.80
97/245	20.17	33.63
97/300	25.25	79.52
RRII 105	12.03	23.91

Hybrids generated from the 2002 hand pollination programme and half-sib seedlings were planted in a clonal nursery at CES for evaluation. Total number of entries in the trial was 25, including four parent clones as check, in an RCBD lay out with three replications. Hybrids of 2005 hand pollination programme numbering 231 were maintained in the nursery for observations and phenotypic selection.

1.2. Ortet selection

In the SST of 25 ortets, selected from Plantation Corporation of Kerala Ltd. (Kodumon estate), OKn 39 was the best yielding clone over 5 years of tapping with 59.21 g/t/t. The control clone RRII 105 yielded 47.74 g/t/t over the same period. In the above trial in the fifth year of tapping, the highest yield was recorded by OKn 49 (54.45 g/t/t) followed by OKn 36 (51.93 g/t/t), whereas the control clone RRII 105 recorded 48.75 g/t/t. In the SST of ortets selected from various smallholdings and CES, O 73, a selection from Kanjirappally, and O 72 (selfed progeny of RRII 105) were found to be potential latex-timber clones with a mean yield (g/t/t) of 94.18 and girth (cm) of 77.06 and 80.26 and 76.45 respectively, in the fourth year of tapping (Table Bot. 6). In the above trial, yield and girth of control clone RRII 105 was 40.70 g/t/t and 61.73 cm respectively.

In the SST of 12 ortets selected from Kaliyar estate, Thodupuzha, OKr 48 continued to be the highest yielder followed by OKr 75. In another SST, three ortet clones showed higher yield than RRII 105 in the third year of tapping (Table Bot. 7).

Table Bot. 6. **Yield and girth of the ortets in the fourth year of tapping**

Clone	Yield (g/t/t)	Girth (cm)
O 73 (Kanjirappally)	94.18	77.06
O 72 (selfed progeny of RRII 105)	80.26	76.45
O 66 (PCK Ltd., Kodumon)	31.10	52.22
O 49 (PCK Ltd., Kodumon)	30.57	71.75
O 36 (Kothamangalam)	28.44	71.83
O 81 (CES, Chethackal)	27.89	80.87
O 74 (Kanjirappally)	27.58	74.26
O 77 (Erumely – EB1)	25.25	44.01
O 80 (CES, Chethackal)	25.02	56.53
O 75 (Kanjirappally)	20.95	70.20
O 79 (CES, Chethackal)	20.25	56.17
O 78 (CES, Chethackal)	19.57	65.86
O 76 (Kanjirappally	14.89	61.25
RRII 105	40.70	61.73
CD (P=0. 05)	27.04	14.68

Table Bot. 7. **Girth and yield of ortets on three years of tapping**

Clone	Girth (cm)	Mean yield (g/t/t)	
		3rd year	Over 3 years
O 32/6	56.55	37.56	32.50
RRIM 600	52.54	44.42	34.93
RRIC 110	63.12	55.61	50.27
O 12	67.07	72.20	54.02
PR 261	53.55	47.55	41.45
O 4	65.30	42.78	34.78
BPM 24	54.59	52.09	39.92
O 33/8	70.72	78.26	68.49
O 35	61.64	70.90	61.63
RRII 105	61.71	56.33	48.30

2. Evaluation of clones

2.1. Large-scale evaluation

The long-term performance of the clones in the large-scale trial (LST) planted in 1989 at CES, Chethackal, was assessed in terms of yield over 10 years and girth over 17 years. The results were included in a technical report for the upgradation of clones PB 312, PB 314 and PB 280 from Category 3 to Category 2 of the planting recommendations. The above three Prang Besar (PB) clones were significantly superior in yield and girth compared to RRII 105. Yield data for the 10th year and mean yield over 10 years of tapping, along with girth in the 17th year after planting have been summarized in Table Bot. 8.

Table Bot. 8. **Yield and girth of PB clones**

Clone	Mean yield (g/t/t)		Girth (cm)
	10th year	Over 10 years	at 17th year
PB 235	67.86	56.81	86.51
PB 311	78.41	65.51	87.06
PB 280	96.67	70.66	83.13
PB 314	83.35	68.82	86.53
PB 312	94.92	71.00	83.23
PB 217	77.97	54.71	81.41
PB 260	84.80	63.47	81.88
PB 255	73.99	52.54	75.14
RRII 105	67.38	58.83	74.23
GM	80.59	62.48	82.13
C.D. (P=0.05)	-	7.09	5.83

The mean yield of selected exotic clones during their ninth year of tapping in the LST planted at RRII farm in 1989 showed that in Trial I, RRII 5 and RRII 118 were the highest yielders, which performed better than RRII 105. In Trial II, the yield of introduced PB clones *viz.* PB 235, PB 255, PB 280, PB 312 and PB 314 was significantly superior to that of RRII 105.

In another large-scale evaluation of exotic and indigenous clones at CES, clones HP 44, RRIM 712 and HP 120 were found to be superior to RRII 105 in terms of yield registering 67.17, 59.87 and 54.68 g/t/t respectively over six years of tapping. Clone HP 44 continued to be the highest yielding clone with 75 per cent tappable trees. Another clone HP 120 was also performing well with the highest percentage of tappable trees (88. 63%) and better summer yield (38.31 g/t/t).

Regarding RRII 400 series clones which were in the seventh year of tapping (Table Bot. 9) in the LST at CES (1993), in Trial I, the clones RRII 414, RRII 417, RRII 429, RRII 403 and RRII 402 were superior to RRII 105. In Trial II, RRII 430, 422 and PB 330 performed better than RRII 105.

Table Bot. 9. **Yield of clones in large-scale trial in the seventh year of tapping**

Trial I		Trial II	
Clone	Yield (g/t/t)	Clone	Yield (g/t/t)
RRII 446	34.34	RRII 52	68.62
RRII 55	64.23	RRII 53	19.75
RRII 54	21.28	RRII 410	65.56
RRII 417	102.4	RRII 422	76.51
RRII 407	55.74	RRII 427	59.98
RRII 403	79.54	RRII 430	87.64
RRII 449	37.52	RRII 434	32.40
RRII 429	75.74	RRII 454	33.88
RRII 402	81.20	PB 330	91.05
RRII 453	34.90	RRII 105	63.33
RRII 414	72.16		
RRII 105	70.65		
GM	60.81	GM	59.87
CD (P=0.05)	12.70	CD (P=0.05)	14.32

Two LST of potential hybrid clones comprising of 13 clones each, located at RRS, Padiyoor were opened for regular yield recording. Two LST of ortets comprising of 22 promising selections based on the data from SST at Koney, Mundakayam and Cheruvally estates, were periodically monitored.

2.2. On-farm evaluation

In the on-farm trials (OFT) at Sasthamkotta, nine clones, including two indigenous and seven introduced clones were evaluated. Mean yield in the fifth year

Table Bot. 10. **Girth and yield of clones at Sasthamkotta**

Clone	Girth (cm)	Mean yield (kg/ha/year)	
		5th year	Over 5 years
GT 1	55.67	2015	1376
RRII 203	61.64	2133	1459
PB 217	60.54	1974	1494
PB 255	65.70	2572	1878
PB 260	56.10	2059	1676
PB 311	57.42	2246	1831
PB 314	57.95	2460	2030
PR 255	61.06	1830	1830
RRII 105	56.49	2775	2094

of tapping and mean yield over five years are given in Table Bot. 10. RRII 105 was the highest yielder followed by PB 314.

OFTs of RRII 400 series clones at four locations *viz.* Aimcombu, Cheruvally, Kaliyar and Koney, are under tapping. All the RRII 400 series clones maintained superior yield and growth compared to RRII 105 in all the locations. All the RRII 400 series clones except RRII 429 were superior to RRII 105 in terms of growth and tappability. In terms of yield over five years of tapping, all the five clones were superior compared to RRII 105. RRII 430 showed the highest yield followed by RRII 414, RRII 429, RRII 417 and RRII 422.

Early growth data of RRII 400 series clones in the OFT at Kanjirapally, Punalur and Kulathupuzha showed that all five clones registered better growth than the check clone RRII 105.

Girth and disease incidence in RRII 400 series clones were recorded from the fields of 22 small growers. The trees attained tappable girth in four locations. Feed back on the performance of the clones was collected from 100 smallholdings using a questionnaire. About 94 per cent of the farmers opined that these clones are good in terms of growth and 89 per cent of the farmers observed better disease tolerance in RRII 400 series clones.

2.3. Investigations on GxE interactions

Annual growth and yield recording were continued in the experiments to study the genotype and environment interactions at four locations. Mean yield during fifth year of tapping was recorded from three trial locations *viz.* Kanyakumari, Agartala and Nagrakata. RRII 105 was the highest yielder in Kanyakumari region (63.30 g/t/t) followed by RRII 430 (58.19), RRII 422 (50.68) and RRII 203 (49.10). Clones RRII 417 and RRII 414 recorded relatively less yield. At RRS Agartala, RRII 422 showed significantly superior yield (44.82 g/t/t) than RRIM 600 (34.91). The yield of RRII 429 (41.13 g/t/t), RRII 417 (40.18) and RRII 430 (37.11) was also better than the check RRIM 600. At RES Nagrakata, RRII 429, the consistent high yielder (56.93 g/t/t) followed by RRII 417 and RRII 422 recorded significantly superior yield than the check clones *viz.* RRIM 600 and RRII 105. The performance of clone RRII 414 was poor in both Agartala and Nagrakata.

At Regional Research Station (RRS) Padiyoor, RRII 430 (55.21 g/t/t) recorded significantly superior yield than RRII 105 (43.31) in the second year of tapping. RRII 417 (48.92 g/t/t), RRII 414 (48.54) and RRII 422 (46.66) also recorded higher yield than RRII 105. Tapping was initiated at Institute of Minerals and Materials Technology (IMMT), Bhubaneswar. Overall growth performance of the clones indicated that four clones *viz.* RRII 203, RRII 430, RRIC 100 and RRII 417 were found to be significantly superior to the check RRIM 600. Girth of clones RRII 414, RRII 422 and RRII 429 were on par.

3. Participatory evaluation of rubber clones

Twenty pipeline clones and three high yielding check clones, *viz.* RRII 105, RRII 414 and RRII 430 were multiplied and maintained in polybag nurseries in 12 private estates and CES, Chethackal. Site selection was completed for laying out 14 field trials at various locations.

4. Breeding for other specific objectives

4.1. Compact canopy

Evaluation of recombinants from crosses between compact canopy clone and

high yielding clones such as RRII 105, RRIM 600 and RRII 118 as female parents was continued. Among the hybrid progenies, three clones recorded compactness and growth in the sixth year. Two clones (genetic variant x RRII 118 and RRIM 600 x genetic variant) showed normal growth with compact canopy.

Among the half-sibs from compact canopy type, normal morphotypes and intermediate compact types recorded only comparable rubber yield with that of RRII 105. The intermediate type could be used as a potential candidate in breeding for further yield improvement.

4.2. Drought tolerance

Five hybrid clones, earlier subjected to screening for drought tolerance on the basis of physiological and anatomical features, are under small-scale evaluation for *in situ* screening for drought tolerance, along with some wild germplasm accessions in the drought-prone area of RRS, Dapchari. One year after planting, clones 93/270 and RRII 430 recorded maximum girth.

The annual mean yield and summer yield of the 24 hybrid clones and seven parents in two SST planted in 1998 in the third year of tapping showed that five of the hybrid clones had significantly superior yield than RRII 105. In the 1998 SST, all the ortet clones from Dapchari recorded a drop in yield in the summer months lower than that of RRII 105 in the third year of tapping. Two clones, D 111 and D 37 were significantly superior to RRII 105.

Data from trials planted in 1999 revealed significant clonal variation. Among the 70 clones under evaluation, 31 clones showed higher yield than the check clone RRII 105. Fourteen clones were significantly superior in terms of annual mean yield in the second year of tapping. Yield of the clones ranged from 19.20 to 54.93 g/t/t. The above clones also showed 20.31 to 72.06 per cent drop during summer months. Thirteen clones exhibited higher yield coupled with a drop in yield in the summer months which was lower compared to that of RRII 105. Heritability was estimated as 70 per cent for annual mean yield and 62 per cent for summer yield.

4.3. Polycross progeny evaluation

There was significant variation among progenies in the two field trials with respect to yield during the seventh year of tapping. The mean yield of the progenies ranged from 29.07 to 64.88 g/t/t. In Trial I, progeny of PB 215 gave the highest mean yield, followed by progenies of RRII 105 and PB 217. In Trial II, the highest mean yield and recovery of high yielding clones were recorded in the progeny of PB 252, followed by progeny of PB 28/83 and Ch 26. Thirteen clones in Trial I and 19 clones in Trial II with mean yield ranging from 55.99 to 127.89 g/t/t performed better than RRII 105.

In the clonal nursery evaluations, growth of the 56 clones planted in two locations was monitored. The clones were test-tapped two years after planting. In general, the growth and yield of clones were better at CES, Chethackal, compared to that of the drought-prone location of RRS, Padiyoor. The clones showed an average juvenile yield of 5.39 g/10 tappings at RRS Padiyoor and 15.98 g /10 tappings at CES. The clone 263 (progeny of clone PB 255) showed the highest test tap yield at both locations.

5. Anatomical investigations

Studies on anatomy and histochemistry of cambium in TPD-affected trees of *Hevea brasiliensis* revealed permanent alterations in

the cambium of affected trees which were expressed in the form of shortening of fusiform initials, increase in the number of rays, terminal cell of the ray and width of rays. In the TPD-affected area, many of the fusiform initials underwent transformative divisions and produced ray and parenchyma cells. Ethephon stimulation in affected bark resulted in triggering of structural aberrations in the cambium.

6. Studies on propagation

To study the effect of indole butyric acid (IBA) on growth and survival of green-budded stumps, a polybag nursery experiment was conducted for two consecutive years. Results showed pre-treatment of taproot with 500 ppm as the best treatment for better survival and growth of green-budded stumps. Treatment of dipping taproot of green-budded stumps in water before planting to avoid desiccation was promising in relation to viability and growth of the plants.

Girth of the plants evolved from different types of planting materials was recorded in the sixth year after planting. Significant difference for girth between field budded plants and other forms of planting materials was noted. In another experiment, during third year, growth of the plants raised from leaf axil buds, scale buds, light green buds and unhealthy buds was found to be non-significant. Plants raised from light green buds recorded the highest variance in the population (Table Bot. 11).

In the second year, growth of the plants raised from fresh seed stocks was significantly better compared to the stored seed stocks. No significant girth difference was noted in the plants raised from 4-year and 20-year- old bud wood stocks.

Table Bot. 11. **Girth of plants after third year of field planting**

Treatment	Girth (cm)	Variance
Budded plants- mature brown buds	17.19	0.55
Budded plants – semi-green	16.52	0.73
Budded plants -scale buds	17.27	0.73
Budded plants -whorl buds	16.56	0.86
Budded plants – light-green buds	15.68	2.44
Budded plants -unhealthy buds	15.10	1.95
CD (P=0.05)	NS	

7. Morphological characterisation of popular clones

A taxonomic key was developed for identification of RRII 400 series clones based on morphological traits in the juvenile phase. A book on identification of RRII 400 series clones was published in Malayalam for use to local farmers. To disseminate information on the identification of the RRII 400 series clones, field visits and out-station training programmes were conducted.

GERMPLASM DIVISION

The major activities of the Division include conservation of the domesticated gene pool, introduction and conservation of remaining *Hevea* species, conservation of the wild germplasm, its agronomic evaluation, screening for diseases, drought and cold stress resistance, timber-latex traits and molecular characterisation.

1. Introduction, conservation and documentation

1.1 Domesticated gene pool (Wickham collection) from secondary centers

The domesticated gene pool comprising 183 Wickham clones are being conserved in field gene banks, one source bush nursery (Clone Museum) at RRII and two Germplasm Gardens at CES.

The performance of the five IRCA clones in Garden IV is given in Table Ger.1. IRCA 130 and IRCA 111 continued to show superiority over RRII 105 for girth, while they were on par for yield.

Table Ger. 1. **Girth and dry rubber yield of IRCA clones at the age of 15 years**

Clones	Girth in the16th year of planting (cm)**	Dry rubber yield (5th year of tapping) (g/t/t)**
IRCA 130	70.57	72.94
IRCA 109	61.57	45.60
IRCA 111	70.25	66.19
IRCA 18	64.79	38.45
IRCA 230	62.78	41.52
RRII 105	64.74	67.37
CD (P=0.05)	5.69	15.76

** Clonal differences significant at P = 0.01

In Germplasm garden V, RRIC 100 maintained its superiority among the 20 clones in terms of yield (67.9 g/t/t) and girth (84.9 cm). The values for the control clone RRII 105 were 36.5 g/t/t and 65.2 cm respectively (Table Ger. 2).

Table Ger. 2. **Performance of 20 Wickham clones in the fourth year of tapping**

Clone	Yield** (g/t/t)	Girth** (cm)
RRIC 100	67.9	84.9
RRII 23	59.9	78.9
SCATC 93-114	48.5	61.2
RRIM 609	47.7	75.2
RRII 178	41.7	80.1
RRIC 148	41.0	76.3
RRIC 102	39.8	72.6
RRIC 36	36.8	63.1
RRII 105	36.5	65.2
PR 255	35.1	52.8
RRII 15	30.0	66.9
RRII 27	29.4	51.0
RRII 108	27.7	67.0
RRII 22	26.7	54.2
Haiken 1	24.6	68.0
SCATC 88-13	19.6	65.7
RRII 20	19.2	64.1
PB 255	15.9	79.1
RRII 12	12.8	66.5
RRIM 618	12.4	50.3
CD(P=0.05)	17.14	10.23

** Clonal differences significant at P = 0.01

1.2. IRRDB (1981) wild gene pool

Field conservation of a total of 3576 wild accessions was continued in conservation nurseries. Morphological characterisation, preliminary evaluation, test tapping *etc.* are being carried out in the accessions maintained in the reestablished source bush nurseries. Morphological characterisation of accessions indicated significantly superior height for RO 3153, AC 1952, 24/449, OR 1180 and RO 750 whereas MT 908, RO 394 and RO 2328 exhibited better girth in one set of wild accessions.

1.3. Other *Hevea* species

The arboretum at CES comprising all the species and inter-specific hybrids of *Hevea*, is being maintained.

2. Characterisation and preliminary evaluation

Growth and yield were monitored in the eight Preliminary Evaluation Trials (PET) planted up to 2002. In PET 94A, accession AC 757 (70.69 cm) was superior to RRII 105 for girth, followed by RO 895 (55.18 cm) and MT 940 (54.27 cm). In PET 94B, the highest yielder AC 962 had only half the yield of RRII 105, while AC 643 and AC 748 were statistically superior to RRII 105 for girth. In PET 94C, accession RO 893 (64.07 cm) and AC 465 (63.44 cm) recorded superior girth to RRII 105. All the wild accessions had very low yield in the three trials. In the ortet trial PET 94D, none of the wild accessions was better than the control RRII 105 for girth or yield. However, OR 1181 was found to have a high number of latex vessel rows, on par with that of the control. Since this is a wild accession, it is likely to have new alleles for this trait, and hence can be used for crop improvement.

Among the wild accessions in PET(Ortets) 99, OR 1182 and OM 1107 had the highest girth (61.8 and 59.6 cm respectively) while that of the three controls were 65.7 cm (RRII 105), 62.4 cm (PB 260) and 58.7 cm (RRIM 600). Processing of immature bark samples collected in the fifth year of growth showed that OA 1092 and OR 1064 recorded high number of latex vessel rows compared to the control clone RRII 105.

Annual girth recorded in PET 2000A was the maximum in accession AC 3609 (42.80 cm), followed by AC 2537 (41.63 cm) and RO 4363 (40 cm), while the control clones RRII 105, RRII 208 and RRIM 600 recorded 26.26, 31.20 and 27.71 cm respectively. In PET 2000 B at RRS, Padiyoor with 166 wild accessions, compared to three control clones RRII 105, RRII 208 and RRIM 600, 15 accessions showed high girth and 16 accessions showed good summer period girth increment. Thirteen accessions expressed branching at higher level indicating timber potential.

In PET 2002, accessions AC 567 (26 cm), AC 1964 (24 cm) and MT 724 (23 cm) recorded higher girth than the control clones RRII 105 (22.45 cm), RRII 208 (18.35 cm) and RRIM 600 (26.79 cm). Test tapping was also conducted to assess juvenile yield performance of the accessions.

3. Further evaluation and selection

The annual girth at the age of 12 years and rubber yield (4th year of tapping) were recorded and analysed in the FET 95. The annual girth was maximum for the accession MT 1032 (72.04 cm) and minimum for MT 188 (34.91 cm). The mean girth of RRII 105 was 56.88 cm. Six accessions (MT 1032, MT 941, MT 1630, MT 1674, MT 999 and MT 1640) showed the annual girth significantly higher than the control, RRII 105. Seventy three accessions were statistically on par with the control clone for girth.

Among the wild accessions, 14 accessions had the mean dry rubber yield for the summer and peak season statistically on par with that of RRII 105, whereas, the annual total yield of 10 accessions was statistically on par with RRII 105. One wild accession, AC 166 showed consistent performance for summer, peak and annual yield during fourth year of tapping.

In the FET 2003, the highest girth was recorded for RO 2629 (36.50 cm) followed by AC 4149 (35.09 cm) and MT 2233 (30.75 cm), while the control clones RRII 105, RRII 208 and RRIM 600 recorded 29.31, 27.81 and 28.38 cm respectively. Test tapping was conducted to assess juvenile yield performance of the accessions.

Clonal differences for girth and height in the second year of growth were highly

significant among the 22 wild accessions planted for further evaluation in FET 2005 with three controls. MT 185 followed by MT 4788, RO 1570 and RO 2255 had the highest girth, on par with the best control PB 260. MT 185 and RO 2255 were also significantly superior to the control RRII 105 for height, and were on par with PB 260.

Thirty two promising selections from SBN 2001 and SBN 2003 along with two controls were multiplied for further evaluation.

4. Screening for stress tolerance

4.1. Biotic stress resistance

Screening of the wild accessions for resistance to *Phytophthora, Corynespora* and *Colletotrichum* was continued in collaboration with Plant Pathology Division. *In vitro* screening for resistance to *Phytophthora* was completed and 86 wild accessions were reported to be highly tolerant. Laboratory screening for *Corynespora* resistance and field screening for *Colletotrichum* resistance are in progress.

4.2. Abiotic stress resistance

4.2.1. Drought tolerance

In the field screening trial planted in 2003 at RRS, Dapchari with 130 wild accessions, RO 1769 and RO 2976, were identified with test tap yield greater than the control clones RRII 105 and RRIM 600. In 12 accessions, annual girth increment was higher than the three control clones. During summer, 13 accessions recorded better growth than the drought tolerant clone RRIM 600.

A further field evaluation of selected *Hevea* clones RRII 430, RRII 414, RRII 105, RRIM 600, RRII 208 and Tjir 1 was initiated at RRS, Dapchari comprising 23 wild accessions, five HP clones and six check clones in collaboration with Botany Division. The growth of plants was assessed during the first summer period and visual scoring on drought-related growth parameters was undertaken.

In another study, nine sets of clones from polyclonal seed garden at HBSS, Nettana were evaluated with one set of assorted origin in a pot culture experiment. During the first summer season, family of clone AVT 73 showed good growth characters but percentage of yellow leaves was less in the clone PB 28/83 whereas it was more in PB 242. Clone AVT 73 continued its superiority in growth after one year and was having the highest girth in second year also. Throughout the period, the performance of the family of assorted seeds was inferior to all the nine families of clones both in terms of growth and percentage of yellow leaves. Another experiment initiated was the evaluation of drought tolerance potential of half-sib progenies raised in a seedling nursery, using the seeds from prepotent *Hevea* clones of polyclonal seed garden at HBSS, Nettana (collaborative study with Botany Division). Conducted test tapping during both peak and summer seasons and assessed the familywise performance of clones. Summer season test tap yield was the highest in the family of the clone PB 28/83.

In the collaborative project on rapid screening of *Hevea* germplasm lines for intrinsic drought tolerance traits, a preliminary field-level scoring for drought tolerance was conducted in 550 wild accessions during the summer months, based on drought-related morphological parameters and 31 potential accessions were identified for further evaluation. Initiated laboratory screening of selected top, medium and bottom ranking accessions based on field screening in SBNs 2003, 2004, 2005 and SBN 2006. In the drought evaluation trial 1996 at

Rubber Demonstration Centre, Sukma with 36 genotypes, annual girth was recorded. Clone RRII 208 recorded the highest girth of 76.87 cm followed by RO 2635 (72.4 cm), RO 5430 (74.62 cm) and RRII 118 (73.50 cm).

4.2.2. Cold tolerance

In two trials, 64 wild accessions were screened for cold resistance at Regional Experiment Station, Nagrakata. Girth of the eight-year-old plants recorded during pre - and post - winter period, showed significant variation. Higher annual girth was observed in AC 3353 (58.64 cm), RO 2902 (58.26 cm), and RO 3204 (58.03 cm) compared to clone SCATC 93-114 (50.98 cm) and RRIM 600 (51 cm) in trial 1. In trial 2, clone RO 2727 recorded the highest girth of 60.38 cm followed by MT 915 (60.36 cm) and MT 900 (57.27 cm), while the control clones RRIM 600 and Haiken 1 recorded 49.79 and 55.08 cm respectively.

5. Screening for timber characteristics

5.1. Field screening

The field screening of *Hevea* germplasm for desirable quantitative timber traits, annual girth and bole height were recorded and estimated the bole volume at the age of seven years. The mean girth of wild accessions ranged from 24.30 – 40.77 cm. The maximum girth was recorded by MT 999 and minimum for AC 651. Among the six Wickham clones, RRI1 33 (48.22 cm) showed the highest girth followed by RRII 118 (46.21 cm), PB 260 (45.73 cm), PB 235 (45.34 cm) and RRII 105 (38.56 cm) and the lowest in RRIM 600 (36.24 cm). Three accessions (MT 999, MT 941 and MT 915) had the girth, statistically on par with PB 260. Eleven accessions showed the girth on par with RRII 105 and 14 accessions had girth statistically on par with RRIM 600. The bole volume in the wild accessions and Wickham clones ranged from 0.014 – 0.036 m^3 and the variation was not significant.

5.2. Screening for timber quality traits through lignin biosynthesis studies

Estimation of lignin and cell wall phenolics was carried out in four wild accessions and two control clones from the source bush nursery. The presence of lignin was higher in three wild accessions, ranging from 25.39 – 29.36 per cent than the control clones (22.83 -23.18 %). However, cell wall phenolics was more or less same in wild accessions and control clones (0.198 – 0.238 µ OD / mg/dry wt. of EXR).

5.3. Studies on variability in structure and properties of wood of *Hevea* clones

The major mechanical properties of wood such as static bending, compressive strength, shearing strength, tensile strength and wood hardness were tested in all the 10 clones and compared with that of teak wood.

5.3.1. Static bending

The modulus of rupture (MOR) of the wood of clone RRII 105 was significantly superior to PB 260, PB 311, PR 255, RRIM 600, RRII 44 and RRII 45 and was on par with PB 235 and PB 310 (Table Ger.3). The MOR of RRII 105 was comparable to that of teak wood (959.00 kg/cm^2). The modulus of elasticity (MOE) of wood from clone PB 235 was significantly higher than the other eight clones and did not differ significantly with that of RRII 105 wood. The clone RRII 105 showed significant superiority in terms of bending strength over all the other clones studied. The MOR and MOE values of all the 10 clones were lower than that of teak wood, whereas the parameters such as horizontal shear stress at LP and horizontal shear stress at maximum load of all the 10 clones were superior to that of teak wood.

Table Ger. 3. **Static bending properties of wood of *Hevea* clones**

Clone	MOR (kg/cm^2)	Max. load (kg)	FS at LP (kg/cm^2)	HS at LP (kg/cm^2)	HS at ML (kg/cm^2)	MOE (kg/cm^2) x 1000
PB 235	916.15	175.65	588.66	20.98	33.08	97.41
PB 260	712.42	137.35	426.59	15.21	25.86	62.23
PB 310	847.70	162.27	520.52	18.66	29.94	81.40
PB 311	707.93	134.73	480.28	17.15	25.27	71.03
PR 255	662.55	123.43	333.65	13.59	23.47	60.58
PR 261	629.45	118.77	400.18	14.24	22.40	53.10
RRIM 600	731.70	138.91	451.03	16.08	26.09	74.44
RRII 45	629.74	119.09	409.06	14.44	22.81	56.40
RRII 44	650.36	125.96	411.08	14.66	23.64	51.19
RRII 105	953.46	181.33	634.86	22.66	34.04	87.59
CD (P = 0.05)	124.25	24.65	112.90	4.02	4.63	13.03
*Teak wood**	959.00	-	651.00	10.40	14.90	119.60

* Shukla and Lal, 1985

(FS at LP: Fiber stress at limit of proportionality, HS at LP: Horizontal shear stress at limit of proportionality, HS at ML: Horizontal shear stress at maximum load)

5.3.2. Tensile strength

The tensile strength properties such as maximum load, tensile stress at limit of proportionality (TS at LP) and tensile stress at maximum load were determined from the wood samples of 10 clones. Results indicated that all the parameters under tensile strength did not differ significantly. In comparison with teak wood, none of the clones was superior with regard to TS at LP whereas the clone PB 260 had better tensile strength at maximum load than that of teak wood.

5.3.3. Compressive strength

The maximum compressive load bearing capacity parallel to grain was noticed in RRII 105 (1807.61 kg) which was significantly higher than PR 261 (1566.92 kg), PR 255 (1457.86 kg), RRII 44 (1465.77 kg) and RRII 45 (1473.19 kg) whereas PB 235, PB 310, PB 311, PB 260 and RRIM 600 were on par with RRII 105. The wood of RRII 105 showed superiority over the other clones for all other parameters related to compressive strength. None of the *Hevea* clones showed superiority over teak for compressive strength.

5.3.4. Shearing strength

The parameters under radial and tangential shearing strength were not statistically significant. However, the wood of all the 10 clones showed higher values with respect to maximum radial shear stress than that of teak wood. In the case of maximum tangential shear stress, except two clones PB 235 and PR 261, all the other eight clones had comparable values with teak.

5.3.5. Hardness

Hardness represents the ability of the timber surface to withstand hard and tough loads both parallel and perpendicular to grain. It also reflects the abrasion and wear and tear properties, especially for applications like flooring, sports goods, furniture, joinery, carving, tool handle *etc.* The results of the hardness test at timber surfaces (radial, tangential, end and side) of 10 clones indicated significant variation in the parameters in hardness test. Hardness at radial (492.86 kg) and end surfaces (645.43 kg) was maximum for PB 310 whereas RRII 105 (549.81 kg) had shown the highest tangential hardness. The

clone RRII 105 was superior to PB 260 and RRII 45 for radial hardness, superior to PB 235, PB 260, PR 261 and RRII 45 for tangential hardness and superior to PB 260 for end hardness. Side hardness is the average of radial and tangential hardness values. In comparison with teak wood, three clones PB 310, RRII 105 and RRII 44 had comparable tangential hardness whereas all the 10 clones showed higher values for end hardness than that of teak wood.

6. Utilisation of *Hevea* germplasm

6.1. W X A open pollination garden 2005

The open-pollination garden at RRS, Padiyoor planted in 2005, comprising 24 Amazonian and 11 Wickham clones, was maintained.

6.2. Breeding garden at RRII

A breeding garden was established in 2007 at RRII campus in an area of 2 ha Comprising potential domesticated (Wickham) clones and selected accessions of wild germplasm. Thirteen wild accessions were selected based on rubber yield, timber yield, rubber and timber yield together, disease resistance (for *Oidium*), drought resistance, number of latex vessel rows *etc.* along with 46 genetically divergent domesticated clones from Category I, II and III and are planted in the garden during 2007.

7. Other studies

7.1. Feasibility of ratooning in *Hevea*

Girth was recorded in the eighth year of growth in both sets of plants, which included 51 different clones. The ratoons continued to be superior to their corresponding polybag-grown plants (Table Ger. 4). Thirty two more ratoons were brought under tapping, bringing the total to 120, while only six (3%) polybag grown plants could be opened for tapping this year.

Table Ger. 4. **Growth of ratoon plants**

	Ratoons	Polybag plants
No. of plants	150	201
Min. girth (cm)	31.0	12.5
Max. girth (cm)	84.0	56.5
Mean girth (cm)	58.2	32.4
No. of plants with > 50 cm girth	120 (80.5%)	6 (3.0%)

7.2. Effect of stimulation in the laticiferous tissues of *H. brasiliensis*

Bark samples were collected from the trees of RRII 105 under regular tapping (S/2 d3 BI-1 Panel) and newly opened trees (S/2 d3; BO-1 Panel) before and after stimulation and recorded the number of functional and disorganised laticifer rows.The result indicated that the disorganisation of laticifers in the bark of BI-1 panel showed an increasing trend after stimulating with 5 per cent ethephon (bark application) for a period of one year (3 stimulations at 4-month interval) in comparison with the unstimulated controls.

7.3. Studies on the inclination of laticifers and clonal variability in *H. brasiliensis*

Studies on the inclination of laticifers are being continued with the objective of categorisation of *Hevea* clones based on laticifer inclination and also to develop clone-specific tapping systems based on laticifer inclination. Bark samples were collected from 14 mature trees of the clone PB 86 from the 1990 Genetic Evaluation Trial at HBSS, Nettana. The samples were processed and reconfirmed the inclination pattern of laticifers. All the experimental trees showed the leftward inclination of laticifers with the inclination angle ranging from 0.33 ° to 13.39 °.

8. Participatory clone evaluation

8.1. On-farm evaluation of pipeline clones-Phase I

Planting materials required for 15 clones were raised in polybag nurseries for planting the field during ensuing planting season, at four estates: Shaliacary Estate, Punalur, Mooply Estate, Thrissur, TR&T Estate, Mundakayam and Calicut Estate, Kozhikode.

PLANT PATHOLOGY DIVISION

The Division is primarily concentrating on studies on the economic and ecofriendly management of diseases and pests. Attempts were made to control pathogens and pests using chemical and biological agents. Evaluation of sprayers and spray oils, assessment of yield loss due to diseases, evaluation of newly evolved clones for disease resistance, maintenance of culture bank of pathogens, studies on tapping panel dryness, bee keeping in rubber plantations, use of beneficial microorganisms for plant growth, treatment of sheet processing effluents *etc.* were the other areas of research.

1. Leaf diseases

1.1. Abnormal leaf fall disease

Field trial carried out at Kulathupuzha Estate, Punalur, Chimoni Estate and Pudukad Estate, Trichur to evaluate the usefulness of indigenously fabricated Aspee atomiser supplied by M/s Aspee Co. Ltd. showed comparable performance to that of imported Micronair, AU 8120 (Table Path. 1).

Preliminary block trial carried out at Kulathupuzha Estate, Punalur and Pudukad Estate, Thrissur in clone RRIM 600 indicated that the performance of biodegradable oil supplied by M/s. Indian Oil Corporation was comparable to IOC conventional spray oil (Table Path. 2).

Table Path. 2. **Percentage leaf retention (RRIM 600)**

Treatment	Leaf retention (%)	
	Pudukad, Trichur	Kulathupuzha, Punalur
Biodegradable oil	39.4	37.1
IOC Spray oil	46.3	43.3
Control	15.0	4.4
CD (P=0.05)	11.7	14.2

The experiment on the efficacy of spray oil emulsion from M/s Indian Oil Corporation, Kozhikode in combination with water-based COC was carried out at Kulathupuzha Estate, Punalur and Pudukad Estate, Thrissur. Water-based COC at the rate of 8 kg/ha was tested with higher doses of IOC emulsion *i.e.* 6, 8 and 10 per cent. Results indicated that addition

Table Path. 1. **Percentage leaf retention in plots sprayed using different atomisers**

Treatment	Pudukad, Trichur (RRIM 600)	Chimoni, Trichur (RRII 105)	Kulathupuzha, Punalur (RRIM 600)
Micronair (AU 8120)	46.3	-	43.3
Aspee atomiser	31.9	56.1	44.3
Normal atomiser	20.0	43.6	26.0
CD (P=0.05)	18.9		14.5

of higher dose of IOC emulsion with water-based COC was not effective for abnormal leaf fall (ALF) control.

Field screening of HP clones in the 1993 large-scale trials (Trial I and II) for ALF disease at CES, Chethackal under sprayed conditions was continued. The highest leaf retention was recorded in RRII 414, RRII 417, RRII 453 and RRII 105 in Trial 1 and RRII 430, RRII 410 and RRII 105 in Trial II.

Recording of ALF disease severity in RRII 400 series clones in Clone Trial (1998) at Cheruvally Estate, Erumely and Clone Trial (1999) at Kaliyar Estate, Thodupuzha was also continued. Higher leaf retention was recorded in the clones RRII 410, RRII 430 and RRII 429 at Cheruvally Estate and the clones RRII 410, RRII 430 and RRII 417 at Kaliyar Estate.

The ALF disease was very severe during 2007. The leaf retention was higher in 400 series clones compared to RRII 105 both in sprayed and unsprayed areas in different locations in Kerala (Table Path. 3).

The study on survival of *Phytophthora* spp. causing ALF disease in rubber revealed that they survive mostly in soil and litter during unfavourable environmental conditions. Initial rain water and streams near to rubber plantations also showed the presence of *Phytophthora* spores. DNA fingerprinting detected *Phytophthora* from the infected materials even at low concentrations. PCRs using *Phytophthora*-

Table Path. 3. **Percentage leaf retention in different smallholdings and estate sector (2007)**

	Unsprayed					Sprayed				
Place/ Age of plants	RRII 414	RRII 430	RRII 417	RRII 422	RRII 105	RRII 414	RRII 430	RRII 417	RRII 422	RRII 105
Malayattoor (6 years)	90	90	90	65	60					
Kottarakkara (6 years)	85	85	70	80	60					
Vadakkancherry (5/6 years)	90			40	15					
RRII Kottayam (22 years)	65	75	60	55	67					
Oonnukal (4 years)						90	90	90	85	75
Erattupetta (5 years)									90	75
Chettuthodu (5 years)						90			80	
Vannappuram (7 years)						70				50
Konni (7 years)				60		90	90	90	90	50
Thrissur (6 years)						70				50
Chittar (5 years)						90			90	75

specific primers identified three species of *Phytophthora, viz. P. meadii, P. colocassiae* and *P. citrophthora* from soil and litter. *In vitro* studies revealed that *Phytophthora* survived at a pH of 4.5 to 6.0. Maximum growth of *Phytophthora* was at a pH of 5 to 6 and survival was reduced at a pH above 8.5.

Mature leaves of F_2 population of RRII 105 were inoculated with virulent strains of *Phytophthora* and selected the tolerant lines. DNA from tolerant lines and parental clones amplified with 40 random primers and two RAPD primers showed polymorphic banding pattern with susceptible parent Tjir 1.

1.2. Powdery mildew disease

The trial at New Ambadi Estate, Kanyakumari to evaluate crop loss due to powdery mildew disease in clone RRII 105 was continued and pre-treatment application of sulphur was undertaken at recommended dose using paired plot design. Intensity of the disease and monthly block yields were recorded. Moderate disease was observed in both the plots.

A field trial was initiated at RRS Padiyoor during 2008 to evaluate the yield loss due to powdery mildew disease in clones RRII 105, RRIM 600, PB 235 and PB 5/51 and pre-treatment application of sulphur dusting was undertaken at recommended dose at an interval of 10 days.

Evaluation of water-based fungicides, *viz.* wettable sulphur, carbendazim (Bavistin), hexaconazole (Contaf) and sulphur carried out at New Ambadi Estate, Kanyakumari using micron sprayer was not effective in checking powdery mildew disease in mature rubber plantation.

1.3. Corynespora leaf disease

Thirty isolates of endophytic bacteria from different plant parts *viz.* leaves, flowers, tender stems and roots of the clones GT 1 and RRII 105 were tested for their detoxification of phytotoxin from *Corynespora cassiicola*. Two isolates, E-85 and 3Pd were effective in detoxification. Among the eight phenolic acids *viz.* chlorogenic acid, ferulic acid, cinnamic acid, protocatechuic acid, p-coumaric acid, vanillic acid, caffeic acid and salicylic acid tested for detoxification of *Corynespora* toxin, chlorogenic acid, ferulic acid and caffeic acid reduced the activity of toxin. The reduction in lesion size was found to be 59, 50 and 52 per cent respectively.

Sixty isolates of *C. cassiicola* from different clones of *H. brasiliensis* from Kerala and Karnataka during 2000 to 2007 showed high levels of genetic variation and variation in their virulence.

Tolerant (GT 1) and susceptible (RRII 105) clones were induced with *C. cassiicola* ($7x10^4$ spores/ml) and salicylic acid (0.01%). Chitinase assay was carried out with the leaf samples collected from 24 to 192 h after inoculation. A marked rise in chitinase activity was observed in salicylic acid-treated plants in initial hours while a rise in enzyme activity was observed from 96 h up to 144 h in *C. cassiicola* induced plants. The decline of enzyme activity was at 168 h in tolerant clone (GT 1) in both cases. The chitinase cDNA from both salicylic acid and pathogen-treated plants on sequenced analysis showed uniform homology with other chitinase gene.

Field evaluation of bacterial antagonists against *C. cassiicola* was carried out at Kothamangalam (Kerala) and Eswaramangalam (Karnataka). The results showed that foliar spraying of antagonists was comparable to carbendazim (Table Path. 4).

Table Path. 4. **Effect of endophyte application on *Corynespora* leaf fall disease**

Treatment	Per cent disease index
Endophyte foliar spray ($1x10^6$ cfu/ml)	5.54
Endophyte root application ($1x10^6$cfu/ml)	10.08
Fungicide (carbendazim 1g/L)	6.78
Control (without any treatment)	13.85
CD (P= 0.01)	1.91

2. Brown root disease

In the brown root disease control experiment at Babu Land Estate, Kanyakumari, the fungicide drenching was undertaken for the third year with tridemorph (Calixin 0.5%), propiconazole (Tilt 0.2%), hexaconazole (Contaf 0.04%) and thiram (Thiride 1.5%). The field observations revealed that the spread of the disease was not occurred in any of the fungicide treatments. In the evaluation of biocontrol agents against brown root disease at Eachipara Division of Chimoni Estate, Trichur, the plants treated were monitored and disease incidence was observed only in very few plots.

3. Maintenance of pathogens

Two phytopathogenic fungi, *C. cassiicola* and *P. meadii* were preserved with five different storage methods *viz.* continuous growth method, immersion in sterile distilled water, desiccation (storage of fungi in sterile filter paperdiscs and storage of fungal spores in sterile soil), cryopreservation (colonised agar plugs placed in glycerol solution at -80° C) and lyophilisation. Viability was evaluated at 1, 3, 6, 9, 12, 18, 24 and 36 months. Immersion in sterile distilled water was the best method with a revival rate of 71 and 62 per cent for *C. cassiicola* and *P. meadii*, respectively. *P. meadii* could not survive well in any other methods, however, *C. cassiicola* survived in cryopreservation and desiccation treatments. The virulence of the pathogen *C. cassiicola* could be maintained in all preservation methods. However, immersion in sterile distilled water was the only method which could preserve the virulence of *P. meadii*.

4. Tapping panel dryness (TPD)

Total RNA from leaf, bark and root samples of TPD affected trees showed the presence of LMW-RNA having electrophoretic mobility similar to viroid in R-PAGE. RT-PCR with new viroid-specific primers designed from conserved region of viroids yielded product in the range of viroid only in affected plants. The direct sequencing of the PCR product was performed and a part of the sequence showed homology to Citrus Bent Leaf viroid on BLAST analysis. Indicator plants showed epinasty when inoculated with total RNA isolated from affected trees (Fig.Path.1). Transmission of LMW-RNA was noticed in plants bud-grafted with LMW-RNA +ve scion and -ve stock and *vice versa* and the plants are under test tapping for the expression of symptoms. Grafts from +ve stock and +ve scion showed presence of LMW-RNA bands in 100 per cent of test samples (Table Path. 5). Of a number of trees

Inoculated with RNA of TPD trees | Inoculated with RNA of healthy tomato plant

Fig. Path. 1. **Epinasty symptoms on the indicator tomato plants**

Table Path. 5. **Results of R-PAGE test on seedlings under transmission study through budding**

Stock	Scion	Total plants studied	R-PAGE result	
			+	-
+	+	11	11	0
+	-	16	8	8
-	+	10	7	3
-	-	16	5	11

tested randomly, 70 per cent of the TPD affected trees showed presence of LMW-RNA band in R-PAGE analysis. Some of the apparently healthy trees also showed presence of LMW- RNA band in R-PAGE which turned to TPD later indicating that such trees might remain symptomless carriers. A large- scale study was conducted in rubber plantations in five locations by collecting data from 1.5 lakh trees to study the different symptoms and to estimate the intensity of TPD. Different symptoms were identified and documented. Number of TPD trees increased from 8 in BO-1 panel to 27 per cent in BI-2 panel. Incidence of TPD in clusters was found to be more compared to single trees indicating the chance of spread of disease.

5. Pests of rubber

Considerable reduction in the population of the bark feeding caterpillar, *Aetherastis circulata* Meyer by entomopathogen *Beauveria bassiana* was observed under natural condition. A field trial was carried out at Kodumon Estate, Pathanamthitta to compare the efficacy of insecticides and an entomopathogenic nematode (EPN). Chemical control of the caterpillar was tried with high volume spraying. The results indicated 53 per cent control with fenvalarate (0.02%) and 40 per cent with imidacloprid (0.005%) EPN was not effective (Table Path. 6). A stem remedy formulation (SRF) by Kerala Agricultural

Table Path. 6. **Effect of treatments against *A. circulata* on rubber stem**

Treatment	Mean per cent reduction of caterpillar	
	After one week	After three weeks
Imidacloprid 0.005% + SRF	28.99	40.84
Imidacloprid 0.005%	32.70	40.35
Fenvalarate 0.02% +SRF	41.35	54.28
Fenvalarate 0.02%	45.57	53.43
EPN @ 2 lakhs/tree	19.31	26.25
Control	14.63	23.31
CD (P= 0.05)	4.16	8.39

University was also tried as an additive in the insecticide. However, there was no synergistic or antagonistic effect or systemic translocation in the mode of action of the insecticides.

Survey on the natural occurrence of EPN in rubber growing soils was completed. Isolation and mass culturing of EPN in laboratory condition were carried out and their *in vitro* pathogenecity against the pests of rubber was studied.

A field study on control of mooply beetles using deltamethrin and ecofriendly agents such as *B. bassiana* and EPN was conducted. Deltamethrin showed 90 per cent mortality followed by *B. bassiana* and EPN. The effect of EPN on the larvae of mooply beetle, *Luprops curticollis* was studied. Sixty per cent mortality was recorded under the laboratory condition.

Other pest infestation in rubber recorded during the year includes rubber tree borer : *Raphipodus subopacus* family : Cerambicidae, order : Coleoptera. The borers were observed on PB 5/51 clone in February – April 2008 at Kulathupuzha Estate, Punalur.

6. Bee keeping in rubber plantations

Different types of honey were collected from market and moisture percentage,

specific gravity, sugar percentage and minerals were assessed.

The results indicated that *Apis mellifera* honey had lower moisture than other honey. Glucose content was higher *i.e.* 37.54 per cent in rubber honey of *A. cerana indica.* The honey from dammar bee is considered to be superior as it is gathered mostly from medicinal plants. It showed lower moisture (21.20%) and sucrose contents (1.23%), which are the good quality factors of honey (Table Path. 7).

7. Microorganisms for improving growth of rubber and cover crops

Intrinsic antibiotic resistance (IAR) pattern of 10 isolates of root nodule forming bacteria of *Mucuna* collected from north eastern states of India was studied along with *Mucuna* and *Pueraria* isolates from RRII, to evaluate their competitive ability with the natural strains in colonizing nodules of *M. bracteata.* Six antibiotics were studied at concentrations ranging from 25 to 175 ppm. The isolates showed different response to the antibiotics and IAR markers for each isolate was identified.

A polybag experiment to evaluate the effect of different doses of *Azospirillum* cultures on rubber seedlings was carried out. One ml (10^8 cfu) bacterial application did not show any improvement in girth and height of plants compared to control in six-month growth period. However, applications of the culture (10^8 cfu/ml) for six times with five ml and one time with 10 ml showed more growth of the plants. Girth and height of plants inoculated with *Azospirillum* at 50 per cent nitrogen was comparable with full nitrogen applied plants in polybag studies. Effect of phosphofungi inoculation at lower levels of phosphorus application on rubber seedlings showed the survival of the inoculated fungi in soil. Plants applied with 50 per cent P and phosphofungi showed better growth of plants during the six-month period.

A total of 149 isolates of endophytic and root colonizing bacteria were screened for growth promotion of rubber seedlings. Fifty isolates were selected based on their effect on shoot and root growth parameters for further screening.

Root colonizing endophytes and rhizosphere bacteria isolated from RRII 414, RRII 417, RRII 429, RRII 422, RRII 430 and RRII 105 were assessed for various properties that support plant growth and disease control. Out of the 115 isolates, 44 showed solubilisation of phosphates in apatite agar medium. Ten selected phosphobacteria were also capable of solubilising ferric phosphate,

Table Path. 7. **Comparison of honey from different bee sources**

Bee species	Nectar source	Moisture (%)	Ash (%)	Specific gravity	Total reducing sugar (%)	Fructose (%)	Glucose (%)	F/G	Sucrose (%)	Acidity
A. cerana indica	Rubber	21.58	0.152	1.39	73	38.33	37.54	1.02	2.12	0.128
A. cerana indica	Weeds (Non-rubber)	22.2	0.21	1.3	71.82	37.61	37.02	1.01	2.03	0.208
A. mellifera	Rubber	19.73	0.123	1.41	72.84	37	38.61	0.958	2.15	0.115
A. dorsata	Forest	23.2	0.267	1.36	69.73	36.05	36.38	0.99	2.2	0.188
Dammar bee – *Trigona* sp.	Many herbs	21.2	0.119	1.4	70.70	36.52	36.91	0.99	1.23	0.204

aluminium phosphate and tricalcium phosphate in Pikovaskay's medium. Among the 115 isolates, 32 showed antagonism against *Phytophthora meadii* and 25 against *Phellinus noxius*, the soil-borne pathogens of natural rubber. Twenty one antagonists showed siderophore production and the selected isolates also produced antipathogenic volatile compounds. Out of 115 isolates, 65 showed improvement in various growth parameters of rubber seedlings raised in small cups compared to uninoculated control. Many of the isolates belonged to *Pseudomonas* and *Bacillus* groups.

A polybag study using the mixed inoculum of beneficial bacteria on rubber seedlings showed that 10 ml of culture inoculation for three months gave better growth of plants. The inoculated cultures survived in the soil and the count was more with more number and dose of inoculation.

8. Waste management in rubber processing

The high rate reactor was evaluated for treating waste water from rubber processing (collaborative research project with TNAU, Coimbatore) for one year. The effluents from two sources *viz*. sheet serum and floor wash (after removal of rubber content by coagulation) were passed through a filter bed and pumped into an overhead tank, then to vertically erected cylindrical anaerobic high rate reactor through its bottom. The biogas generated was collected in a gas holder. The treated water removed from the top of the reactor was oxygenated in an aeration system to remove the remaining pollutants by aerobic microbial degradation and was directed to sedimentation tank, where the sludge was separated. The overflow from the sedimentation tank was passed through a filter bed. The clear water was collected for reuse in sheet processing.

The average volume of sheet serum generated in the RSS processing was 4 L/kg DRC. This comprised of the water content in the latex, water added for the dilution of latex during coagulation and the diluted formic acid used for coagulation. Floor wash generated while processing was on an average 8 L/ kg dry rubber.

An integrated effluent treatment system consisting of two stage filtration, high rate anaerobic diffused aeration, sedimentation and filtration was installed and commissioned at Elavampadom RPS, Palakkad.

The coagulation of the floor wash resulted in the recovery of 800 g of dry rubber per 1000 L of effluent collected daily.

The extent of reduction in pollution parameters of effluent at each stage of treatment was estimated and compared with the safe limit. There was an increase in the pH from 5.5 from the initial to 7.7 at the final stage. The total solid content was reduced from 14280 mg/L to 420 mg/L. The reduction of total solids in this treatment system was 97 per cent indicating oxidation of the organic constituents in the waste water by the action of microorganisms. The COD was reduced from 11944 mg/L to 182 mg/L in the final discharge (98.4% reduction). BOD also was reduced to 48 mg/L from 4065 mg/L (98.8% reduction). The significant reduction in both COD and BOD is due to the biological oxidation of the organic matter in the processing effluent. Since the final discharge was within the safe limit, the treated water was found suitable for reuse in processing. All the sheets made using the treated water were graded consistently as RSS 1.

The maximum biogas production of 3210 L/day was obtained during November

Table Path. 8. **Characteristics of effluent after integrated treatment**

Source	Effluent parameter (mg/L)			
	pH	TS	COD	BOD
Raw effluent	5.5	14280	11944	4065
After biomethenation	6.5	1756 (-87.7)	912 (-92.3)	204.4 (-94.9)
After aeration and settling	7.7	880 (-93.8)	240 (-97.9)	67 (-98.3)
Final discharge	7.7	420 (-97)	182 (-98.4)	48 (-98.8)
Safe limit	6-8	2100	250	100

Per cent reduction in parentheses

which may be due to the generation of large volume of waste water during the period. The biogas was found to contain up to 67 per cent methane. The gas was burned in a smoke house (250 kg capacity) for five hours using biogas stove. The maximum temperature build up in the smoke house was 52°C. The comparative study on the use of firewood alone and in combination with biogas revealed that the heat generated by burning 100 kg of firewood could be attained by initial burning of biogas for five hours followed by use of 70 kg firewood, a saving of 30 per cent firewood.

The new system thus saves energy and water input for sheet processing in group processing centres.

8.1. Development of antimicrobial agent for NR latex processing

The microbial count of latex could be reduced by treating the tapping panel, spout, cup, knife and hands of tapper with antimicrobial agents. Dettol was found to be the most effective. Since increase in microbial population led to enhanced VFA in the latex it could be arrested by treating with disinfectants, avoiding pre-coagulation. Cold storage of latex also showed a reduction in microbial population.

PLANT PHYSIOLOGY DIVISION

The major research areas of the Division include environmental physiology, physiology of growth and yield, stock-scion interaction, tapping panel dryness, gene expression studies, secondary metabolites and ecological impact of NR cultivation.

1. Environmental physiology

1.1. Physiological adaptation to high light and drought stress

One-year-old polybag plants of *Hevea brasiliensis* (clones RRII 105, RRIM 600 and RRII 208) were subjected to drought stress by withholding irrigation for three weeks during summer season. Drought stress concomitant with high solar light intensity reduced the chlorophyll and carotenoid contents in leaf. The rate of photosynthetic oxygen evolution and effective quantum yield of PSII (Ó PSII) were drastically inhibited in drought affected plants. On the contrary, dark respiration rate of leaf increased during early drought (Table Phy.1).

A consistently over-expressing 23 k Da chloroplast small heat shock protein (sHSP) was observed in drought and high-light stressed plants. Under drought condition, the level of expression of the sHSP was higher in RRIM 600 than other clones. The expression of the sHSP in the chloroplast appears to have a role in abiotic stress tolerance in rubber plants.

Table Phy. 1. **Effect of drought stress on the photosynthetic pigments and photosynthetic and respiratory activities**

Clone	Total chlorophyll (mg/g fresh weight)		Carotenoids (mg/g fresh weight)		Dark respiration O_2 (μ Mol/m^2/S)		Photosynthetic oxygen evolution (μ Mol/m^2/S)		Quantum yield (Ó PSII)	
	Control	Drought	Control	Drought	Control	Drought	Control	Drought	Control	Drought
RRII	4.2 ±	1.8±	1.7±	0.7±	1.4±	2.4±	9.0±	3.1±	0.46±	0.24±
105	0.7	0.5	0.3	0.09	0.08	0.1	0.7	0.4	0.06	0.04
RRIM	3.4±	2.3±	1.3±	0.92±	1.3±	3.1±	9.8±	4.5±	0.43±	0.32±
600	0.4	0.5	0.4	0.15	0.04	0.09	1	0.3	0.08	0.03
RRII 208	3.7±	2.5±	1.5±	0.95±	1.7±	3.4±	10.4±	3.9±	0.41±	0.28±
	0.5	0.3	0.5	0.2	0.06	0.07	1.2	0.4	0.08	0.04

1.2. Identification of molecular basis for drought tolerance

A few differentially expressed gene transcripts were identified under drought stress in *Hevea* by differential display RT-PCR method. Gene transcripts which were similar to NAC 1 protein, RNA binding protein, nucleotide exchange factor, cation channel protein and reductase 1 were found to be up-regulated under drought stress in *Hevea* while gene transcripts which were similar to histidine kinase, MAC/perforin domain containing protein and general secretory pathway protein were found to be down-regulated due to drought stress.

1.3. Xylem sapflow measurements in mature rubber plants

The average water mining of a 18 years old rubber tree is around 25 L/day. The seasonal variation in xylem sapflow rate was analysed in two clones (RRII 5 and PR 255). Summer months (March-April) recorded a decline in flow rate. During heavy rainy days also the sapflow rate was less and it was attributed to the low transpirational pull due to stomatal closure. During wintering the flow rate declined in clone RRII 5 and started increasing slowly during refoliation period. The sap-flow rate had a direct positive relationship with the daily sunlight load at canopy level. The latex yield did not have any relation with the xylem flow.

1.3.1. Irrigation requirement of mature rubber in North Konkan region

The present study was aimed at examining whether irrigation could be reduced from the maximum level (1 ETc) to 0.2 ETc in a mature yielding plantation with no adverse effect on its physiology. Irrigation was provided during January-May in 2007 and 2008. During summer 2008, irrigation was provided in plot B (0.2 ETc level, deep soil) and plot C (1.0 ETc level, shallow soil) and plot A was left as rainfed (unirrigated). The rubber yield was recorded for the summer months and compared with previous year yield (Table Phy. 2).

The rubber yield in rainfed-control was significantly lesser than the irrigated plants. In shallow soil, 1 ETc irrigation (plot C) during 2008 did not give any yield improvement over the partially irrigated (deep soil area) plot B. The deep soil area recorded significantly higher yield than shallow soil area. It was reconfirmed that partial irrigation (0.2 -0.25 ETc level) is enough for deep soil area in a mature stand.

Table Phy. 2. **Yield of clone RRIM 600 under different levels of irrigation in Dapchari**

Irrigation level	Projected yield (kg/ha) (Jan–May)		Yield (g/t/t)	
	2007	2008	2007	2008
Unirrigated- Plot A	546	368	35^{a}±3.7	21^{b}±4
0.2 ETc-Plot B (deep soil)	826	985	53^{a}±5.4	54.7^{a}± 4.4
1.0 ETc- Plot C (shallow soil)	624	721	40^{ab}±4.3	40^{ab}± 5.2

* values followed by same alphabets are not critically different from each other

1.4. Measurement of flux in CO_2 and water vapour in rubber canopy

Eddy covariance system was installed in RRII campus during April 2007 to monitor the ecosystem level carbon dioxide and water flux and canopy level photosynthesis in rubber. The eddy covariance system was installed initially at agrometeorological observatory of RRII to standardize various flux parameters.

1.5. Cultivation of elite rubber clones in high altitude location in Kerala

An experiment was initiated at Haileyburiya Tea Estate Ltd., Elappara to evaluate the performance of various modern clones in a high elevation situation in the traditional belt. In addition to 2.0 ha planting with five clones in July 2006, an area of 0.3 ha was brought under cultivation during July, 2007 with 10 modern clones. Evaluation of growth performance of rubber plants at high altitude showed that clone RRIM 600 performed better in terms of plant height in trial 2006 (Table Phy. 3). GT 1, PB 235 and PB 260 showed almost comparable growth whereas clone PR 261 had poor growth. In trial 2007, the clone PB 311 recorded better growth followed by clones PB 235, RRIM 600 and the clone RRII 105 was the lowest in terms of plant height.

Table Phy. 3. **Growth of plant at Elappara**

Clone	Plant height(cm)
PB 260	258.8±5.64
RRIM 600	268.4±5.48
PB 235	260.4±6.29
GT 1	261.6±3.51
PR 261	228.2±6.53

1.6. Rapid screening of germplasm for intrinsic drought tolerance traits

1.6.1. Field evaluation of germplasm accessions for drought tolerance

Visual scoring of 3073 wild genotypes for drought tolerance was recorded in germplasm source bush nurseries (SBN) raised during 2003, 2004, 2005 and 2006. Clones RRIM 600, RRII 105 and PB 235 were included as control plants. Genotypes that were exhibiting low senescence and yellowing in field under drought conditions were ranked as tolerant ones. Similarly genotypes exhibiting high senescence and yellowing were ranked as susceptible ones. Based on this scoring, five genotypes each were selected as top, middle and bottom ranking accessions from SBN- 2003, SBN-2004, SBN- 2005 and SBN- 2006. The clones RRIM 600, PB 235 and RRII 105 were ranked as top, middle and bottom drought tolerant clones, respectively.

1.6.2. Laboratory screening of germplasm accessions

The tolerant accessions MT 5100, MT 5078, MT 4788, MT 4856 and the susceptible genotypes MT 4694 and RO 4615 were evaluated for drought tolerance traits at nursery stage. Chlorophyll fluorescence

measurements were carried out in leaves from fully-irrigated and drought-imposed plants. Analysis of data showed that the genotype MT 4788 exhibited higher photochemical efficiency under drought than other genotypes.

1.7. Physiological, biochemical and molecular basis for the adaptation of photosynthetic apparatus under drought stress

Physiological studies were conducted in drought-stressed polybag plants of clones RRII 105, RRIM 600, RRII 208 and PR 261. The intensity of drought status was assessed by measuring the leaf water potential. The light harvesting efficiency of these plants was studied by measuring the activity of PSII using Li-6400, PAM 2100 and IMAGE PAM. Results showed that the PSII Quantum Yield was decreased to varying extent in different clones. The light response curves of net photosynthetic rate (A) showed that the 'A' was unable to increase with the increasing light intensity in the drought-stressed plants. However, when the light response curve was made for a drought-stressed plant under increased ambient CO_2 levels, it was found that the photosynthetic rate was increasing with the increased light intensity. This might be an indication that the low rate of photosynthesis under drought stress was caused by limited CO_2 availability probably caused by closure of stomata to prevent water loss. The light absorption efficiency in leaves adapted to a high light intensity and shade was measured using IMAGE PAM and it was found that the PAR absorption capacity was significantly higher in leaves adapted to low light intensity. The PSI activity was not significantly inhibited under drought stress when compared with the PSII activity.

The changes in chlorophyll a/b ratio were studied under drought-stressed conditions. The observed difference in chlorophyll a/b ratio under drought stress might probably be an attempt to adapt to the drought stress and accompanying high light load. The activity of peroxidase and SOD and the content of MDA were also analysed under drought stress.

2. Physiology of growth and yield

2.1. Yield and yield components

Sixteen year yield data from twelve clones planted in 1982 at CES, Chethackal exhibited wide variations in the yield trend. Based on per tree yield, the clones were broadly categorised as high yielders (above 40g/t/t) including RRII 105, PB 235, RRIM 600, low yielders below 30 g/t/t including PR 107, RRIM 612 and medium yielders 30-40 g/t/t including RRII 118, RRII 300, RRIM 703, RRIM 501, GT 1, Gl 1 and Tjir 1. The mean yield per tree was high in clone RRII 105 for the first 10 years of tapping and thereafter the clone PB 235 recorded higher yield.

A reduction in yield was observed in clones RRIM 703, RRII 300, RRIM 600, RRIM 612, RRIM 501, RRII 105 and GT 1 at 16th year of tapping. The period of peak yield varied in clones between 2nd - 15th year of tapping (Table Phy. 4). The peak yielding period in *Hevea* differs with clones and is vital for the estimation of yield and yield component parameters. Clones PB 235, RRII 118, RRIM 600, GT 1 and Gl 1 maintained a long period of higher yield output compared to all other clones.

The mean of 16 years was taken as an indicator of good yield output for the clones and reduction in subsequent years from the mean yield was considered as the yield declining phase of a clone. At sixteenth year

Table Phy. 4. **Yielding pattern of *Hevea* clones with respect to age of the trees**

Clone	Tapping period (years)	Peak yielding period (years)	Peak yielding phase (year)	Yield declining phase (year)	Peak yielding span of tree (age)
RRII 300	16	8	3rd -10th	11th	19
PB 235	16	11	5th -15th	16th	24
RRII 105	16	9	3rd -11th	12th	20
RRIM 600	16	11	4th -14th	15th	23
GT 1	16	10	5th -14th	15th	23
PR 107	16	9	5th -13th	14th	22
Gl 1	16	10	5th -14th	15th	23
RRIM 501	16	8	5th -12th	13th	21
RRII 118	16	11	4th -14th	15th	23
RRIM 703	16	10	2nd -11th	12th	20
Tjir 1	16	7	4th -10th	11th	19
RRIM 612	16	10	4th -13th	14th	22
Mean	16	9.5 (≈10)	4 - 13	14	21.6 (≈22)

of tapping the highest decline in yield was noticed in clone RRIM 703 followed by clones RRIM 501, RRII 300 and RRIM 600. Clone RRII 105 recorded 20 per cent decline from the mean yield. It was almost negligible in clones RRII 118 and Gl 1. About 30 per cent reduction from peak yield was observed in clones RRII 105, RRIM 600, GT 1 and RRIM 612.

To overcome the declining trend in yield, controlled upward tapping (CUT) was initiated in all clones (S/3 d2 6d/7 ET 5% 6/ Y). Yield was recorded daily and mean yield per tree was calculated. Increase in yield was observed in all clones under CUT (Table Phy. 5). A two-three-fold increase in yield was observed under CUT. Yield was enhanced more than three-fold in clones PB 235, RRII 118 and GT 1. However, in clones RRII 105, Tjir 1, RRIM 703 and Gl 1 the yield increased by two-fold.

2.2. Tapping induced loss of biomass

To understand the mechanism of missing biomass in tapped trees, a project was started with five clones in a 1987 plantation at HBSS, Nettana, Karnataka. The trees were opened for tapping during July 1997 and the untapped trees were maintained as control.

The annual biomass increment of tapped trees was smaller than untapped control trees of clones RRII 105 and PB 260. In PB 235 there was no difference in annual biomass increment between untapped and tapped trees. At the end of 10 years of

Table Phy. 5. **Mean yield after 16 years of normal tapping (NT) and controlled upward tapping (CUT)**

Clone	Mean yield (g/t/t)		
	1991-2007 NT (S/2 d2)	2006-2007 NT (S/2 d2)	2007-2008 CUT (S/3 d2)
RRII 300	36.0±1.71	26.7±1.35	93.6±8.10
PB 235	53.8±2.53	47.5±3.60	187.2±17.90
RRII 105	52.5±2.50	43.2±2.80	97.5±10.26
RRIM 600	40.6±1.91	29.9±2.81	90.8±7.34
GT 1	38.3±2.20	29.8±1.16	132.3±10.73
PR 107	25.2±1.13	24.0±1.44	62.5±4.21
Gl 1	32.8±1.57	32.6±1.40	71.0±3.55
RRIM 501	31.5±1.75	21.7±1.72	67.0±6.27
RRII 118	36.7±1.71	38.2±2.16	136.6±8.20
RRIM 703	37.6±2.52	25.7±2.81	67.5±5.95
Tjir 1	34.9±1.70	34.5±2.30	74.0±8.71
RRIM 612	22.7±1.64	18.2±1.81	55.3±6.11

tapping, RRII 105 lost maximum biomass (32%) in S/2 d2 6d/7 system of tapping. The standing biomass in S/2 d3 6d/7 tapped tree was higher than S/2 d2 6d/7 in RRII 105, RRII 300 and PB 235, indicating intensive tapping had a bearing on shoot biomass.

The biochemical composition of bark tissue from tapped and untapped trees showed that tapped trees recorded significantly more carbohydrates and proteins than untapped trees probably due to increased metabolic activities in the tapping panel. The ATP content of latex was analysed during summer season of 2007. The trees tapped on d3 system in PB 235 recorded significantly higher ATP than d2 trees and in the case of RRII 105 there was no significant difference between d2 and d3.

2.3. On-farm trial for the selection of latex-timber clones

With an aim of selecting latex-timber clones, four clones from Malankara estate which were already undergoing tapping were selected to find out the existence of any relationship between yield and annual girth increment. The annual girth increment and annual yield data were recorded. The relationship between the annual biomass increment and yield has been established.

Table Phy. 6. **Latex ATP content in young plants from 10 clones with different yield potentials**

Clone	Latex ATP (µM)
RRII 105	369.2
RRIM 600	306.0
PB 235	323.3
PB 217	240.4
PB 260	317.8
PB 5/51	221.0
Tjir 1	289.3
GT 1	319.9
RRII 33	215.6
RRII 38	180.6
CD (P = 0.05)	37.1

2.4. Relationship of ATP status of latex, lutoid membrane composition and ATPase activity with rubber yield

The measurement of latex ATP in three-year-old young plants was continued (monthly) in clones with different yield potentials to confirm the correlation between latex ATP and yield at an early stage (Table Phy. 6).

The results showed a higher latex ATP in high yielding clones (RRII 105, RRIM 600, PB 235, PB 260 and GT 1) than the other medium and low yielders.

2.5. Clonal variation and effect of stimulation on latex regeneration mechanism

Standardised a method for measuring protein biosynthetic capacity of C-serum using a mixture of ^{14}C labelled amino acids. Measurements of protein biosynthesis in different clones are in progress.

2.6. Oxidative stress preceding senescence/ leaf fall

In continuation of the experiment to assess the relationship between oxidative stress and leaf senescence, ascorbate (one of the important components of antioxidant mechanism) was measured in senescent leaves (50 and 75% yellowing) and non-senescent mature green leaves. Ascorbate content was found decreased in senescent leaves compared to non-senescent leaves.

3. Stock-scion interaction

3.1. A study on scion to scion communication

Wintering nature of double bud-grafted plants was monitored. The leaf shedding time was prolonged for one week in clone RRIM 600 when it was grafted with RRII 105. It indicated that the RRIM 600 did not winter

completely. The trait of the partial wintering nature of clone RRII 105 may have influenced the wintering pattern of clone RRIM 600.

3.2. Stock-influenced differential expression of genes in the scion of *Hevea*

DD RT-PCR was done to find out the gene profile of various field-grown bud-grafted plants. Remarkable variation in the gene expression pattern was observed in the latex collected from both stock and scion of the bud-grafted plants.

4. Tapping panel dryness

4.1. Relationship of biochemical and latex ionic composition with yield and TPD

The biochemical and ionic composition of latex were correlated with flow characteristics, yield and incidence of TPD in seven *Hevea* clones. Thiols in the latex showed significant positive correlation with total latex volume and significant negative correlation with plugging index. Sucrose content in the latex showed significant positive correlation with initial flow rate, total volume and yield. Among the latex ionic components, Pi showed significant positive correlation with initial flow rate, total volume and yield, while Ca showed significant negative correlation with total volume and yield. The biochemical or ionic components in the latex of different clones did not show significant correlation with TPD incidence.

4.2. Molecular basis of TPD

4.2.1. Cloning and characterization of TPD responsive genes by differential display analysis

Twenty differentially expressed transcripts which were cloned into PCR-TRAP vector were sequenced. Only nine transcripts showed similarity with reported genes and the other transcripts did not match with any reported genes possibly specific to *Hevea*. The nucleotide sequence information of all transcripts has been submitted in the GenBank database.

The transcripts which were up-regulated are HbTPD16 (Prefoldin, a protein kinase), HbTPD17 (gibberellin regulated protein, snakin2), HbTPD21 (no match), HbTPD28 (expressed protein), HbTPD31 (Villin head piece), HbTPD32 (no match) and HbTPD33 (no match). The transcripts which were down-regulated were HbTPD19 (ABC transport membrane protein), HbTPD20 (no match), HbTPD22 (Antiporter, drug transporter), HbTPD23 (no match), HbTPD24 (NAC1 protein), HbTPD25 (proline-rich cell wall protein), HbTPD26 (no match), HbTPD27 (no match), HbTPD30 (maturase), HbTPD34 (no match) and HbTPD35 (no match). The DNA sequence details are submitted in the Gen Bank database (Gen Bank No. EG030748 to EG030780).

4.2.2. Cloning and characterisation of TPD responsive genes by subtractive hybridization

mRNA isolation was standardized using an efficient protocol using magnetic beads. Subtractive hybridization was performed with the mRNA isolated from latex and bark using the commercial PCR-Select Subtraction Kit of 'Clontech'. One subtraction was done with mRNA isolated from latex samples of healthy as well as trees with 50 per cent TPD intensity. mRNA isolated from latex samples of five trees in each group was pooled together and the subtractive hybridization reaction was performed in both forward and reverse reactions. The transcripts obtained by these reactions were cloned into pGEM-

T Easy Vector of Promega and transformed into GenHunter competent cells. The transformed colonies were selected by colony PCR method and the selected clones were later sequenced by M/s. Macrogen, Korea.

Another round of subtraction was carried out using the bark samples from wet and dry portions of the same tree with 50 per cent TPD. Subtraction was done in both forward and reverse directions and about 750 clones were obtained out of which about 550 clones were short-listed for DNA sequencing. The short-listed clones were sequenced and found that few genes are specific to TPD.

4.3. Ethylene in rubber biosynthesis and TPD

In order to develop antiserum for proteins involved in rubber biosynthesis, an attempt was made to PCR amplify the coding sequence of ACC synthase and ACC oxidase from *Hevea*. cDNA was synthesized and the coding sequences of ACC oxidase and β-cyanoalanine synthase were PCR-amplified and cloned into pGEM-T Easy vector. Identity of these clones was confirmed after DNA sequencing and BLAST analysis. Further, to facilitate cloning these cDNAs into the pET 20b expression vector specific primers were synthesized with flanking restriction sites. PCR amplification with the modified primers was performed and the amplicons were cloned into pGEM-T Easy Vector. Restriction digestion analysis is being performed with the isolated plasmid DNA to facilitate cloning into the specific restriction sites of pET expression vector.

4.3.1. Ethylene receptors and signal transduction mechanism

The work was carried out as a collaborative project at Department of Biological Sciences, Dartmouth College, USA to study the molecular mechanism by which ethylene is perceived, signal transduced and resulting in increased latex production. mRNA was isolated from bark samples of control and ethylene-stimulated trees of clone RRII 105. Relative RT-PCR of the known ethylene receptor (ETR-1) was carried out and compared with the internal control gene ubiquitin and found that the gene ETR-1 was induced after ethylene treatment.

In order to identify other ethylene receptors in *Hevea*, the nucleotide sequence data of known ethylene receptors of different species were aligned and degenerate primers were designed. Degenerate PCR, cloning and sequencing of the amplified products led to the identification of a new ethylene receptor in addition to the database sequence. Both these genes appeared to be of subfamily-1 members due to the sequence similarity and both are transcriptionally up- regulated by ethylene.

5. Gene expression studies

5.1. Construction of expression vector for *Bacillus subtilis* and over-expression of chitinase in endophytes

An expression vector pHCMC05 for transforming *Bacillus subtilis* was obtained from BGSC, Ohio and was used for the over-expression of chitinase gene. mRNA was isolated from the leaves of *H. brasiliensis* and coding sequence of chitinase gene was PCR amplified after cDNA synthesis. The primers were flanked with specific restriction sites. PCR amplified chitinase fragment was cloned into the corresponding sites of the pHCMC05 vector. Transformation protocol for *B. subtilis* was standardized and the pHCMC vector with the chitinase gene was

transformed into *B. subtilis*. Transformed *Bacillus* colonies were identified using PCR and expression of chitinase protein was monitored in selected colonies using standard protocols.

6. Secondary metabolites

6.1. Quantification and identification of inositols

The protocol developed was adopted for the isolation of L-quebrachitol from the latex samples of RRII 105, RRIM 600, RRII 414 and RRII 430. The isolates obtained from these clones were analysed by HPLC. Purity and identity of the isolates were tested by standard techniques. It was confirmed that the isolates were pure L-quebrachitol. It was evident that the protocol developed was suitable for all types of latex sera. The extraction percentage was found high in RRII 400 series sera than other clones studied. Seasonally there was no significant difference in the content of quebrachitol from latex of the clones studied.

6.2. Water relations of latex with reference to the contents of inositols and sugars in the latex during drought

Latex samples were collected from various clones during different seasons. The C- sera were used for the estimation of osmotic concentration and activity of the enzyme myo-inositol-1-phosphate synthase. From the trichloroacetic acid extract of latex, cations such as Ca, Mg, and K were estimated and their contribution to water relation was worked out. It was found that osmotic concentration was high in all clones during the stress season than the peak yielding season. The clonal and seasonal variations for the latex Ca content were found significant but there was no clone to season interaction. Clonal and seasonal variations and clone to season interactions were observed to be significant in the case of latex K content whereas Mg showed significant clonal and clone to season interaction. Contribution of K to osmolarity and osmotic concentration showed significant clonal variation and clone to season interaction. Significant clonal variations were observed for the activity of the enzyme myo-inositol-1-phospahte synthase.

7. Ecological impact of rubber cultivation

7.1. Impact of climate change on Indian plantation sectors

An investigation was initiated to find out the possible long-term changes in the NR plantation sector in Kerala region due to climate change. The temperature and rainfall data were collected from the India Meteorological Department (IMD), Pune. A comparison of the long-term trends in the rainfall of the rubber growing regions in Kerala, Konkan and Goa and North-east regions was also carried out. For this, 100 years rainfall data were collected from IMD which contained the rainfall data of almost 50 rainguage stations spread across Kerala subdivision. These data would help to simulate different climatic scenarios and models to understand how they will influence the natural rubber productivity regionally in the country.

RUBBER TECHNOLOGY DIVISION

The major research priorities of the division during the period were quality improvement through improved processing technique, non-conventional energy for rubber processing, rubber nanocomposites, reinforcement of natural rubber, rubber plastics blends and modification of natural rubber.

1. Primary Processing

Pilot plant-scale trials on low temperature storage of natural rubber latex were continued during different seasons. Technically Specified Rubber (TSR) conforming to the requirements specified for ISNR 3L could be prepared from the stored latex.

To find out a new preservation system for NR latex, few chemicals were screened for replacing TMTD in the LATZ system and one chemical which showed encouraging results for field latex preservation was selected for further trials.

A protocol was evolved for faster processing of skim latex and quality improvement of skim rubber using surfactant and alkali. Since processing of skim latex using this method is costlier than the conventional method, another method involving deprotenization using liquid papain followed by creaming was attempted for faster processing. The creamed latex could be coagulated easily to a consolidated mass. For the treatment of latex serum from the centrifuging unit an up-flow anaerobic reactor was fabricated and its performance was studied. Process variables such as loading time, pH, BOD, COD, nitrogen content, suspended solids and dissolved solids were evaluated.

Existing solar drier was modified using water heater panels and heat exchanger. Preliminary trials conducted using crumb rubber and cup lumps revealed that faster drying could be achieved using radio frequency drier. Designed and fabricated a drier for drying cup lumps for RRS Padiyoor and put into operation.

2. Latex technology

Trials were conducted to reduce the percentage error in quick determination of dry rubber content (DRC) and to extend the method to ammonia-preserved latex. It was observed that, for fresh NR latex, the error could not be reduced to less than 0.5 per cent by using quick coagulation and quick drying steps. For ammonia preserved latex and fresh NR latex, drying in microwave oven followed by air oven was attempted. In this case, the error could be reduced to less than +0.1 per cent. Standardized an accelerated ageing test for the prediction of quality parameters like ZST, MST and viscosity of

Table Chem. 1. **Formulation of carbon black-filled mixes and cure characteristics at 150° C**

Ingredient	NR obtained by soap sensitized coagulation	NR obtained by conventional method
Natural rubber	100.00	100.00
ZnO	5.00	5.00
Stearic acid	2.00	2.00
Antioxidant TDQ [1]	1.00	1.00
HAF black	40.00	40.00
Aromatic oil	4.00	4.00
CBS [2]	0.75	0.75
Sulphur	2.50	2.50
Parameters	Cure characteristics at 150°C	
Maximum Torque, dNm	14.93	10.15
Minimum Torque, dNm	0.57	0.62
Optimum cure time, min	13.05	9.01
Scorch time, t_s, min	2.46	2.34

[1] 2, 2, 4-trimethyl 1, 2, dihydroquinoline

[2] N-cyclohexyl -2 benzothiazole sulphenamide

fresh centrifuged latex. In connection with studies on fatty acid-sensitized coagulation of NR latex, effect of *in situ* formed fatty acid as plasticizer for filler was evaluated in carbon black-filled vulcanizate. As in the case of gum mix, the carbon black-filled mix also showed higher level of vulcanization (Table Chem. 1) and better mechanical properties (Table Chem. 2).

Table Chem. 2. **Mechanical properties of carbon black filled vulcanizates from NR obtained through conventional and fatty acid sensitized coagulation**

Parameter	NR obtained by soap sensitized coagulation	NR obtained by conventional method
Modulus 100%, MPa	3.60	2.50
Modulus 200%, MPa	9.40	6.80
Modulus 300%, MPa	16.70	13.10
Tensile strength, MPa	28.40	27.40
Elongation at break, %	440.00	420.00
Hardness, Shore A	66.00	58.00
Resilience, %	58.00	58.00
Compression set, 22h/70° C, %	21.00	20.00
Heat build-up, ΔT, °C	21.00	20.00

The conditions for the production of natural rubber – silica composite by *in situ* precipitation were modified and the composite was prepared on pilot plant-scale. Better mechanical properties were observed for the same compared to conventional NR-silica mix. Standardized the dosage of a solid peptizer for preparing stabilized low Mooney viscosity rubber. Raw rubber properties of the rubber and HAF-filled mix were compared with those of ISNR 5. It was observed that the technological properties were not affected by the incorporation of the peptizer. (Table Chem. 3).

A method was standardized for the production of deproteinized natural rubber (DPNR) from fresh NR latex using stabilized liquid papain.

Table Chem. 3. **Technological properties of low Mooney viscosity rubber**

Property	ISNR 5	Low viscosity rubber
Tensile strength, MPa	26.4	26.2
300% Modulus, MPa	5.5	6.0
Elongation at break, %	966.0	967.0
Tear strength, N/mm	93.8	93.0
Hardness, Shore A	54.0	50.0
Abrasion loss, mm^3	92.0	92.0
Compression set, %	30.0	33.0
Heat build up, ΔT° C	21.0	20.0
Resilience, %	55.0	57.0
Demattia flexing		
Crack initiation, KCy	57.0	57.0
Failure, KCy	89.0	92.0

3. Blends

Laboratory-scale trials were initiated for preparing PVC compatible/dispersible grade of NR using latex stage blending and coagulation of NR and NR-g-PMMA co polymer. The blend was then mixed with plasticized PVC at an NR/PVC ratio of 70:30 and the vulcanizate properties were determined.

It was observed that addition of small quantities of polymeric to NR improved the mechanical properties and this was confirmed by conducting a comparative evaluation in different testing laboratories. A tread compound was prepared using the new polymeric filler system and the properties were compared with a conventional tread compound. Heat build-up was very low for the compound containing the new polymeric filler and other technological properties were comparable. DMA studies showed that tan ð at 60° C was lower than that of the conventional system, thus leading to reduced rolling resistance (Table Chem. 4).

4. Nanocomposites

Stabilized dispersions of modified and unmodified nanoclays were prepared and

Table Chem. 4. DMA data of conventional and polymeric-filled tread compounds

Mixes	Tan δ at 0°C	Tan δ at 60° C	Reduction in rolling resistance (%)
Conventional tread (NR/carbon black)	0.0959	0.1544	-
NR/polymeric filler	0.0959	0.1026	33.6

Table Chem. 5. Technological properties of nanocomposites

Property	NR/PP	NR/PP nanocomposite	NR/HDPE	NR/HDPE nanocomposite
Tensile strength, MPa	33.2	34.4	32.3	33.1
Modulus 300%, MPa	12.3	15.3	5.1	8.5
Tear strength, N/mm	68.4	76.5	60.5	68.0
Hardness, Shore A	60.0	66.0	50.0	56.0
DIN abrasion loss, mm^3	88.0	78.0	57.0	50.0
Heat build-up, ΔT, °C	7.0	9.0	6.0	8.0

formulations for specific end use applications were designed. Catheters as per IS specifications (IS 7523) were fabricated using latex nanocomposites. The grade of nanoclay suitable for NR melt mixing has been identified based on the results of permeability, swelling, DMA, TGA, XRD and TEM analysis data. Technological properties of NR/PP and NR/HDPE nanocomposites containing 10 phr of organoclay were studied. Addition of organoclays to the blends improved the mechanical properties of the composites (Table Chem. 5).

Initiated a work on rubber-silver nanocomposites and nano-silver was prepared both by thermal reduction of silver salts using higher alcohols and radiolytic reduction of silver salts using gamma rays. The nano-silver obtained was characterized and antimicrobial property was assessed.

5. Epoxidised natural rubber (ENR)

Initiated a work on the effect of reaction conditions on initial Mooney viscosity and storage hardening behaviour of ENR. Preliminary evaluation of the suitability of the use of ENR 25 and ENR 50 in silica-filled tyre compositions was carried out in association with an industry.

6. Evaluation of rubber from different clones

Evaluation of sheet rubber from Agartala for clonal/seasonal variation was completed.

7. Collaborative project

The project for the development of rubber compounds suitable for footwear soles for leprosy and diabetic patients in collaboration with M/s. Schiefflin Leprosy Research and Training Centre (SLR and TC), Karigiri, Tamil Nadu was continued. A few compounds were screened and the selected compound was scaled up and microcellular sheets were prepared at SLRTC.

TECHNICAL CONSULTANCY DIVISION

The activities of the Division were focused mainly on establishment of rubber-based industries, product development, quality control, advisory services, training programmes and schemes on diversified uses of natural rubber (NR).

1. Establishment of rubber-based industries

Project reports were prepared for the following industries.

Product	Firm
i Technically specified rubber	M/s. Tripura Forest Development and Plantations Corporation Limited (TFDPC)
ii Technically specified rubber	M/s. Palazhi Rubbers, Pala (updation of project report)
iii Moulded goods black	M/s. Trideep Narayan Deb, Guwahati

2. Product development

The following products were developed as per request from the entrepreneurs:

i. Rice polisher
ii. Fender compound
iii. Auto components and bellows
iv. Tyre flaps from EPDM and butyl rubbers
v. Hard rubber
vi. NBR sponge
vii. Horn compound and balloon
viii. Floor wipers (Squeeze lip)
ix. Hammer mill pad
x. Industrial gloves
xi. Transparent rubber band
xii. Latex adhesive

3. Quality control

Support was provided to various spectra of industries by testing the raw materials, rubber compounds, rubber products *etc.* The Division received 1350 samples for testing and 5835 parameters were tested. Evaluation of 30 rubber chemicals *viz.* accelerators, stabilizers, reclaimed rubber, plasticizers *etc.* was also made.

4. Advisory services

Advisory services through factory visits were offered to six firms. Technical advice was given for the queries received from 510 firms. The Division had also associated with rubber parks at Kochi, Tripura and Nagercoil at various levels of establishment.

Rubber Park, Kochi

Provided technical assistance for completion of the project.

Rubber Park project, Tripura

Master plan design of the Rubber Park was entrusted with M/s. IL & FS, New Delhi and they have started design of Rubber Park.

Rubber Park project, Nagercoil

Total planning and preparation of tender documents of the park were completed. The site clearing and development works have been commenced.

5. Scheme on diversified uses of natural rubber

i. Rubberization of road (Collaborative project with Central Road Research Institute, New Delhi) : Final report on performance evaluation on NRMB roads was completed.

ii. Second phase of the study of NRMB roads of Kerala in association with National Transportation Planning and Research Centre (NATPAC), Trivandrum, was completed.

The Division had collected a total amount of Rs.5,99,472/- towards testing, development and consultancy.

ECONOMICS DIVISION

The Division continued its research activities confining to the five thrust areas, *viz.* (i) farm management; (ii) primary processing and marketing of NR; (iii) rubber products manufacturing industry and foreign trade; (iv) intercrops and by-products and (v) inter-divisional collaborative projects. Four projects were completed and reported during the period under review.

1. Farm price volatility and its impact on rural labour market under neo-liberal regime: a study of rubber tapping labourers in Kerala

Economic liberalisation coupled with de-protection policies in the domestic market transformed the stable and remunerative domestic market for NR into a volatile one characterised by wild and frequent price fluctuations. Persistence of a volatile price for a longer period leaves its devastating consequences in respective labour markets too.

The study analysed the impact of neo-liberal economic policies on the labour market for rubber tapping labourers in Kerala since the second half of the 1990s. The study found that on an average, a tapping labourer expends 17 months under apprenticeship and the duration varied from 11 to 30 months in different regions depending on the availability of non-farm employment. The Tables Eco. 1 and 2 show age-specific distribution of tapping labourers and composition of the time spent by the tappers for tapping, latex collection and processing.

Table Eco. 1. **Age of the tapper and tapping performance**

Age group (year)	Percentage of tappers	Number of trees tapped daily (no.)
20-30	16	319
30-40	24	325
40-50	34	339
50-60	18	303
60-70	8	283

The age-specific distribution of tapping labourers found that 60 per cent of them belonged to 40 to 50 years and above age-group. It also indicated that an important individual characteristic influencing tapping task is the age of the tapper.

The relationship between age of the tapper and the tapping efficiency showed that tappers in the age group of 40-50 years performed better than other age groups. It was found that 85 per cent of the tapping

Table Eco. 2. **Time spent by a tapper on different activities of tapping 100 trees**

Activities	Age group of tappers (years)					Average time spent
	20-30	30-40	40-50	50-60	60-70	(min)
Tapping	53	55	54	68	71	57.42
Latex collection and processing	54	50	46	66	69	52.18
Total	107	105	100	134	140	109.60

labourers hailed from agricultural labour households. Regular employment was reported to be the primary reason to choose tapping work over general agricultural operations. The NR sector could attract labourers because of regular employment, piece-wage system and pecuniary benefits offered to labourers including interest-free wage advances. Tapping labour market was found to have the prevalence of an informal tie-up between credit and labour markets. Two factors influencing the informal tie-up between credit and labour markets are: size of holdings of natural rubber and duration of service under a single grower.

The declining price of NR since 1997 had impacted on the average annual days of tapping. During the period between 1997 and 2000 the average loss of tapping days across the five regions, *viz.* Changanacherry, Kottayam, Pala, Kanjirappally and Thodupuzha was around 10 per cent. However, the average piece-wage rate for tapping 100 trees increased to the extent of 25 per cent in all the five sample regions. But the wage rate for tapping labourers failed to keep pace with the wage rate for general agricultural labourers in four out of the five sample regions. Further, decline in net income of farmers forced them to stop interest-free wage advances and other pecuniary benefits to the tapping labourers. Consequent upon those changes in the sector, the withdrawal of the main tapper from the labour market was followed by the retreat of tapping assistants as well. The observations of the study indicate that the volatile price scenario for NR, if persists for a long period, will certainly lead to important changes in the hitherto followed tapping system. The cumulative effect of these trends is indicative of the challenges to the adoption of the recommended practices for crop harvesting.

2. Rubber smallholder systems in north-eastern states

The study was the first attempt to understand the status of NR cultivation under the smallholdings not covered under the Block Planting Scheme (BPS) and its potential. The field survey covered 309 sample households from Tripura, Assam and Meghalaya. The following were the major observations: (i) the average size of holdings varied from 2.29 (Assam) to 2.67 ha (Tripura); (ii) rubber cultivation had been superimposed in a pre-existing integrated farming system and therefore, the share of area under rubber varied from 63 (Meghalaya) to 67 per cent (Tripura); (iii) family labour participation (67 in Tripura to 76% in Meghalaya) and female labour participation (25 in Tripura to 38% in Meghalaya) were higher than traditional regions; (iv) tapping wages were paid on a monthly basis and it varied from Rs. 1200 - 1800; (v) total operational cost varied from Rs 11,012/- (Meghalaya) to Rs. 16,082/- per ha (Assam); (vi) the relative share of tapping costs was more than 65 per cent in the total operational cost, and (vii) the average yield of rubber varied from 1043 (Meghalaya) to 1238 kg/ha (Tripura) and the net income varied from Rs. 44,427 (Assam) to Rs. 54,292/ha (Tripura) during the year 2005.

3. Economic impact of viral fever in the NR production sector in Kerala

The study was undertaken in the context of the outbreak of Chikungunya fever in Central Kerala during the year 2007. The incidence of this viral fever was widespread in Pathanamthitta and Kottayam districts. More than 90 per cent of the tapping labourers were infected with Chikungunya in these two districts. In other districts, the level of incidence of the disease varied between 8 (Kannur district) and 80 per cent (Ernakulam district). The severity of the incidence was relatively less in northern part of Kerala. On an average, 53 per cent of tapping labourers in the State were infected with Chikungunya and a tapping labourer was incapacitated for about 18 days during the study period from May 1st to July 15th. The percentage of tapping days lost due to viral fever was the highest (57%) during June. The loss of tapping days during June was the highest in Ernakulam district (91%) followed by Pathanamthitta and Kottayam (86%) districts.

The study estimated that 58677 t of NR was lost due to viral fever during the study period (Table Eco. 3) and in monetary terms the loss amounted to Rs. 4694.1 million. For the tapping labourers, 365.1 million man-days were lost and it amounted to a wage loss of Rs. 492.9 million. The estimated net loss to farmers was Rs. 4201.1 million.

4. Analysis of Technically Specified Rubber (TSR) processing industry in India

The study covered all the functional units during the period under review. The major observations of the study are: (i) the industry is confronted with supply constraints in terms of both quantity and quality of raw material; (ii) rigidities in the raw material and TSR markets; (iii) lower scale of operations; (iv) uneconomic levels of capacity utilisation, and (v) uncertain margins and external competition. The estimated annual average capacity utilisation of the industry was 54 per cent with sector-specific variations. The private sector recorded higher utilisation, with 56.30 per cent followed by public (53.15%) and, co-

Table Eco. 3. **Districtwise production and wage losses due to viral fever**

District	Total man-days lost (lakhs)	Wage loss (Rs. in lakhs)	Loss of NR due to VF (t)	Financial loss due to VF (Rs. in lakhs)
Trivandrum	0.84	113	1346	1077
Kollam	2.05	277	3296	2637
Pathanamthitta	6.75	911	10842	8673
Kottayam	18.05	2438	29025	23220
Ernakulam	4.84	237	3300	2640
Idukki	2.05	653	7776	6220
Thrissur	0.30	40	475	380
Palakkad	0	0	0	0
Kozhikode	0.44	59	1585	1268
Malappuram	0.99	133	701	561
Kannur	0.08	10	123	98
Kasaragode	0.13	17	208	166
Kerala	36.51	4929	58677	46941

operative (52.30%) sectors. The unit cost of the industry had been Rs.5.52 per kg, and only the private sector exhibited a notable economic efficiency throughout the period under review and its average unit cost had been Rs.4.24 per kg. The lower unit cost with higher capacity utilisation in the private sector was achieved by minimising the administrative, establishment and other costs. In all other sectors, these costs accounted for a higher share in their total costs. However, the theoretically perceived inverse relationship between capacity utilisation and cost was not observed in the industry. Frequent and wider fluctuations in prices of output and raw materials, processing based on advance sales order, market uncertainty, lack of working capital and margins *etc.* are the factors affecting the capacity utilisation of the industry.

EXPLOITATION TECHNOLOGY DIVISION

Exploitation Technology Division continued applied research work on different aspects of latex harvesting. All the ongoing experiments, on-farm trials and lab to land programmes progressed well during the period under report. More growers have adopted low frequency tapping (LFT) during the period. Other areas of study were evaluation of mini and reduced spiral tapping cuts, long-term evaluation of rain guarding and crop loss due to rain, panel change and low frequency controlled upward tapping (LFCUT). Advisory on various aspects of latex harvest technology and testing of various samples of rainguard adhesive and ethephon were continued. The widespread occurrence of Chikungunya disease had influenced the production during the year mainly due to absenteeism of tappers.

1. Low frequency tapping systems

Experiment on the yield performance of LFT with different levels of stimulation in clone RRII 105 (from BO-I panel) was continued. Yield under d4 and d6 frequencies of tapping was comparable to that of d2 frequency. Yield under d3 frequency with various levels of stimulation was significantly higher than d2, d4 and d6 frequencies of tapping which is due to panel change effect (BI-1 first year during 2007-08). In another experiment comparing d6 and d10 frequency, yield performance was similar to 06-07.

The on-farm experiment on S/2 d4 6d/7 system of tapping at Apella Estate (13 commercial tapping blocks each under conventional and modified stimulation) to identify location-specific stimulation schedule for clone GT 1 in South Kanara region was concluded during 2007-08. Yield obtained during 2003-08 under modified stimulation schedule was significantly higher (Table Exp. 1). Cumulative TPD incidence as on August 2007 was 5.7 per cent.

The LFT trials with rainguard in Kanthimathy Estate (d7) and in Hariharaputhra Estate (d4) in Kulasekharam region (Tamil Nadu) were continued. At Kanthimathy Estate, dry rubber yield of 2613 kg/400 trees could be obtained under d7

3. Economic impact of viral fever in the NR production sector in Kerala

The study was undertaken in the context of the outbreak of Chikungunya fever in Central Kerala during the year 2007. The incidence of this viral fever was widespread in Pathanamthitta and Kottayam districts. More than 90 per cent of the tapping labourers were infected with Chikungunya in these two districts. In other districts, the level of incidence of the disease varied between 8 (Kannur district) and 80 per cent (Ernakulam district). The severity of the incidence was relatively less in northern part of Kerala. On an average, 53 per cent of tapping labourers in the State were infected with Chikungunya and a tapping labourer was incapacitated for about 18 days during the study period from May 1st to July 15th. The percentage of tapping days lost due to viral fever was the highest (57%) during June. The loss of tapping days during June was the highest in Ernakulam district (91%) followed by Pathanamthitta and Kottayam (86%) districts.

The study estimated that 58677 t of NR was lost due to viral fever during the study period (Table Eco. 3) and in monetary terms the loss amounted to Rs. 4694.1 million. For the tapping labourers, 365.1 million man-days were lost and it amounted to a wage loss of Rs. 492.9 million. The estimated net loss to farmers was Rs. 4201.1 million.

4. Analysis of Technically Specified Rubber (TSR) processing industry in India

The study covered all the functional units during the period under review. The major observations of the study are: (i) the industry is confronted with supply constraints in terms of both quantity and quality of raw material; (ii) rigidities in the raw material and TSR markets; (iii) lower scale of operations; (iv) uneconomic levels of capacity utilisation, and (v) uncertain margins and external competition. The estimated annual average capacity utilisation of the industry was 54 per cent with sector-specific variations. The private sector recorded higher utilisation, with 56.30 per cent followed by public (53.15%) and, co-

Table Eco. 3. Districtwise production and wage losses due to viral fever

District	Total man-days lost (lakhs)	Wage loss (Rs. in lakhs)	Loss of NR due to VF (t)	Financial loss due to VF (Rs. in lakhs)
Trivandrum	0.84	113	1346	1077
Kollam	2.05	277	3296	2637
Pathanamthitta	6.75	911	10842	8673
Kottayam	18.05	2438	29025	23220
Ernakulam	4.84	237	3300	2640
Idukki	2.05	653	7776	6220
Thrissur	0.30	40	475	380
Palakkad	0	0	0	0
Kozhikode	0.44	59	1585	1268
Malappuram	0.99	133	701	561
Kannur	0.08	10	123	98
Kasaragode	0.13	17	208	166
Kerala	36.51	4929	58677	46941

operative (52.30%) sectors. The unit cost of the industry had been Rs.5.52 per kg, and only the private sector exhibited a notable economic efficiency throughout the period under review and its average unit cost had been Rs.4.24 per kg. The lower unit cost with higher capacity utilisation in the private sector was achieved by minimising the administrative, establishment and other costs. In all other sectors, these costs accounted for a higher share in their total costs. However, the theoretically perceived inverse relationship between capacity utilisation and cost was not observed in the industry. Frequent and wider fluctuations in prices of output and raw materials, processing based on advance sales order, market uncertainty, lack of working capital and margins *etc.* are the factors affecting the capacity utilisation of the industry.

EXPLOITATION TECHNOLOGY DIVISION

Exploitation Technology Division continued applied research work on different aspects of latex harvesting. All the ongoing experiments, on-farm trials and lab to land programmes progressed well during the period under report. More growers have adopted low frequency tapping (LFT) during the period. Other areas of study were evaluation of mini and reduced spiral tapping cuts, long-term evaluation of rain guarding and crop loss due to rain, panel change and low frequency controlled upward tapping (LFCUT). Advisory on various aspects of latex harvest technology and testing of various samples of rainguard adhesive and ethephon were continued. The widespread occurrence of Chikungunya disease had influenced the production during the year mainly due to absenteeism of tappers.

1. Low frequency tapping systems

Experiment on the yield performance of LFT with different levels of stimulation in clone RRII 105 (from BO-I panel) was continued. Yield under d4 and d6 frequencies of tapping was comparable to that of d2 frequency. Yield under d3 frequency with various levels of stimulation was significantly higher than d2, d4 and d6 frequencies of tapping which is due to panel change effect (BI-1 first year during 2007-08). In another experiment comparing d6 and d10 frequency, yield performance was similar to 06-07.

The on-farm experiment on S/2 d4 6d/7 system of tapping at Apella Estate (13 commercial tapping blocks each under conventional and modified stimulation) to identify location-specific stimulation schedule for clone GT 1 in South Kanara region was concluded during 2007-08. Yield obtained during 2003-08 under modified stimulation schedule was significantly higher (Table Exp. 1). Cumulative TPD incidence as on August 2007 was 5.7 per cent.

The LFT trials with rainguard in Kanthimathy Estate (d7) and in Hariharaputhra Estate (d4) in Kulasekharam region (Tamil Nadu) were continued. At Kanthimathy Estate, dry rubber yield of 2613 kg/400 trees could be obtained under d7

Table Exp. 1. **Yield (kg/400 trees) performance of clone GT 1 to S/2 d4 frequency of tapping**

Year	Conventional stimulation schedule	Modified* stimulation schedule
2003-04	1577	1588
2004-05	1692	1698
2005-06	1627	1757
2006-07	1603	1805
2007-08	1728	1938
Mean	1645	1757
95 per cent confidence interval	1553-1737	1705-1809

* April, June, July, Oct., Nov., Dec. & Jan.

system of tapping during 2007-08 in clone RRII 105 with the highest per tap yield of 85 kg in the month of November. The annual average per tap yield was 51.5 kg. However, under d4 frequency of tapping at Hariharaputra Estate, the highest per tap yield of 45 kg was observed. Dry rubber yield of 1788 kg/400 trees was obtained under d/4 system of tapping over a period of 10 months during 2007-08.

On farm trial on weekly tapping initiated during 2002-03 at five locations in Kerala in clone RRII 105 was concluded during 2007 (Table Exp. 2). Due to labour strike in some locations, lower yield was obtained during 04-05 and 06-07. However, collection of yield data and other information from two locations *viz.* Manickal Estate, Mundakkayam and Tropical Plantations, Adivaram, Calicut was continued to monitor the long-term performance. Dry rubber yield of 1976 kg and 1733 kg was obtained from Tropical Plantations and Manickal Estate, respectively, during 2007-08.

In the demonstration plot at CES, promising yield of 2277 kg/400 trees was obtained under weekly tapping with monthly stimulation during 2007-08. Yield of 5.7 kg/tree and mean annual per tap yield of 43.7 kg was obtained during 2007-08. Incidence of tapping panel dryness was low (2.7%). In the exploratory trial on d10 frequency, dry rubber yield of 2162 kg/400 trees was obtained. The highest per tap yield of 105.8 kg was obtained during September 2007 and the TPD incidence was very low (1.4%).

The experiment on response of TPD-affected trees (basal panel) to stimulation was carried out in the Experimental Farm Unit of RRII. Two sets of trees of clone RRII 105 with complete TPD incidence in panel BO-1 were selected. All the trees were under S/2 d4 6d/7 system of tapping on panel BO-2. One set of 26 trees was subjected to the recommended frequency of stimulation per year. The other set of 26 trees was maintained without stimulation. Twenty

Table Exp. 2. **Dry rubber yield (kg/400 trees) under weekly tapping (d6) in clone RRII 105**

Location	2002-03	2003-04	2004-05	2005-06	2006-07	Cumulative TPD (2007)
Manickal Estate, Mundakkayam	1454	1782	1946	1789	1591 *	6.5
Vijayadri Estate, Kottayam	1471	2651	1758	1582 **	1792	5
Balanoor Estate, Perinthalmanna	1600	2154	1553 *	1830	1683 *	4
Kulappadam, Mannarkkad	1896	1972	1212 *	1693	1876	5
Tropical Plantations, Calicut	1733	1934	2565	2002	1867	4.8

* Labour strike **10 months tapping

nine trees in the adjoining plot (same clone of the same age and the same panel status *i.e.* BO-2 first year) under S/2 d3 6d/7 system with three annual stimulations was used to compare the yield.

Table Exp. 3. **Yield (kg/400 trees) of BO-1 panel TPD affected trees when tapped on BO-2 panel with stimulation**

Year	d4 + 6 stim	d4 + no stim	d3 + 3 stim
2004-2005	2117 (8/26)	2417 (4/26)	5438 (1/29)
2005-2006	1280 (15/26)	1865 (8/26)	5830 (1/29)
2006-2007	844 (15/26)	1600 (9/26)	4279 (2/29)

NB: Numerator values within parentheses are TPD trees.

Good response to stimulation as evidenced by good yield was obtained in BO-2 panel when the trees were not affected by TPD in BO-1 panel. But, there was no response to stimulation in BO -2 panel when the trees were affected by TPD in BO-1 panel (Table Exp.3). If the BO-1 panel TPD affected trees are stimulated on BO-2 panel, incidence of TPD will be higher.

2. Low Frequency Controlled Upward Tapping (LFCUT)

An experiment on LFCUT was carried out in clone RRII 105 during 2002-2007 at EFU, RIT. Good and comparable yield was obtained in LFCUT under d3, d4 and d6 frequency (Table Exp. 4). Yield of reduced spiral cuts could be increased by more frequent application of 5 per cent ethephon. Under weekly tapping (S/3 d6) fortnightly stimulation would be ideal for obtaining good yield.

In another LFCUT experiment (CRD) with periodic panel change carried out during 2004 to 2007 at EFU, RIT, CUT of even S/4 d6 frequency of tapping with fortnightly stimulation gave good response (Table Exp. 5). CUT with periodic panel change gave sustainable high yield.

Another experiment on LFCUT was carried out in clone RRIM 600 at CES. The trees were rainguarded with wider polythene (36" width) and tapped throughout the year. Yield under fourth daily and weekly frequencies of tapping was comparable with third daily tapping (Table Exp.6). Sustainable yield was obtained under low frequency tapping. Under S/4 d3 and S/3 d4 frequencies of CUT, lace method of stimulation gave better response. However, groove method is essential under weekly frequency of tapping. If yield is very

Table Exp. 4. **Yield response (kg/400 trees) under LFCUT with rainguard in clone RRII 105**

Treatment	Total*	Mean*	kg/tree
S/4U d3 6d/7 ET5.0% La.12/y (m)	19339	3868	9.7
S/3U d4 6d/7 ET5.0% La (3w)	17854	3571	8.9
S/3U d4 6d/7 ET5.0% La.12/y (m)	18147	3629	9.1
S/3U d6 6d/7 ET5.0% Ga. (2w)	15282	3056	7.6
S/3U d6 6d/7 ET5.0% Ga. 36/y	17796	3559	8.9
S/2U d4 6d/7 ET5.0% La.8/y	18133	3627	9.1
S/2U d4 6d/7 ET5.0% La.6/y	19862	3972	9.9
S/2U d6 6d/7 ET5.0% Ga. (2w)	15132	.3026	7.6
S/2U d6 6d/7 ET5.0% Ga (3w)	16548	3310	8.3
CD (P=0.05)	NS	NS	NS

*Cumulative of five years * Mean of five years

Table Exp. 5. **Yield response (kg/400 trees) to LFCUT with periodic panel change in clone RRII 105**

Treatment	2004-05*	2005-06**	2006-07**	Mean (kg/tree)
S/4U d3 6d/7 ET5%La (m); S/2 d3 6d/7 ET2.5% Pa 2/y	3639	3573 abcd	3526 a	8.9
S/3U d4 6d/7 ET5% La(2w); S/2 d4 6d/7 ET2.5%Pa 3/y	3900	3908 abc	2970 abc	8.9
S/3U d4 6d/7 ET5% La(3w); S/2 d4 6d/7 ET2.5%Pa 3/y	2995	2684 cd	1774 d	6.2
S/3U d4 6d/7 ET5% La(m); S/2 d4 6d/7 ET2.5%Pa 3/y	3260	3551 abcd	3113 ab	8.3
S/4U d4 6d/7 ET5% La(2w); S/2 d4 6d/7 ET2.5%Pa 3/y	3878	4815 a	3845 a	10.4
S/4U d4 6d/7 ET5% La(3w); S/2 d4 6d/7 ET2.5%Pa 3/y	2920	2837 cd	2046 cd	6.5
S/4U d4 6d/7 ET5% La(m); S/2 d4 6d/7 ET2.5%Pa 3/y	2580	2767 cd	2353 bcd	6.4
S/3U d6 6d/7 ET5% Ga(10d); S/2 d6 6d/7 ET2.5%Pa (m)	3842	3324 bcd	2696 abcd	8.2
S/3U d6 6d/7 ET5% Ga(2w); S/2 d6 6d/7 ET2.5%Pa (m)	2996	3803 abcd	2360 bcd	7.6
S/3U d6 6d/7 ET5% Ga(3w); S/2 d6 6d/7 ET2.5%Pa (m)	2516	2562 d	1778 d	5.7
S/4U d6 6d/7 ET5%Ga(10d);S/2 d6 6d/7 ET2.5%Pa (m)	2746	2804 cd	1972 d	6.3
S/4U d6 6d/7 ET5%Ga(2w); S/2 d6 6d/7 ET2.5%Pa (m)	2961	4425 ab	2399 bcd	8.1
S/4U d6 6d/7 ET5%Ga(3w); S/2 d6 6d/7 ET2.5%Pa (m)	2571	2705 cd	2109 bcd	6.1

* NS **Values followed by same letter/s are not critically different from each other

poor in the renewed panel due to high TPD, poor bark quality due to injurious tapping etc., continuous CUT with rainguarding is the only way for getting sustainable yield for long term.

3. Other experiments

The experiment on long-term evaluation of rainguard was continued at RIT. Comparable yield could be obtained in non-rainguarded trees with stimulation under d2 or d3 frequencies of tapping. Higher per tap yield and per tree yield were observed in trees without rainguarding under d/3 frequency of tapping (Table Exp. 7). Per tap yield of more than 40 kg/400 trees could be obtained under d/3 frequency of tapping without rainguarding.

The experiment to evaluate long-term effect of panel change on yield performance

Table Exp. 6. **Yield response of LFT for CUT with rainguard in clone RRIM 600 at CES, Chethackal**

Treatment	Total	Mean	kg/tree
S/4U d3 6d/7 ET5% La. (3w)	17031	3406	8.5
S/4U d3 6d/7 ET5% Ga. (3w)	15012	3002	7.5
S/3U d4 6d/7 ET5% La. (3w)	16790	3358	8.4
S/3U d4 6d/7 ET5% Ga. (3w)	14650	2930	7.3
S/3U d6 6d/7 ET5% La. (3w)*	11721	2344	5.9
S/3U d6 6d/7 ET5% Ga. (3w)*	13478	2696	6.7
S/2U d/6 6d/7 ET5% La. (3w)	15124	3025	7.6
S/2U d/6 6d/7 ET5% Ga. (3w)	16159	3232	8.1
CD (P=0.05)	NS	NS	NS

* Frequency of stimulation changed to fortnightly from June 2003

Table Exp. 7. **Effect of stimulation under d2 and d3 frequencies of tapping in clone RRII 105 with and without rainguarding on recovery of yield**

Treatment	Yield* (kg/400 trees)	kg/tap/400* trees	kg/tree*	DRC* (%)	Tapping days
S/2 d2 6d/7 with RG	1895 ab	18.2 c	4.7 ab	39.5 ab	104
S/2 d2 6d/7 without RG	1727 ab	24.3 bc	4.3 ab	40.3 a	71
S/2 d2 6d/7 ET2.5% Pa 3/y (without RG)	1714 ab	24.3 bc	4.3 ab	38.3 b	71
S/2 d2 6d/7 ET2.5% Pa 5/y (without RG)	1522 b	21.4 c	3.8 b	39.4 ab	71
S/2 d3 6d/7 ET2.5% Pa 3/y (with RG)	2118 ab	25.8 bc	5.3 ab	40.0 a	86
S/2 d3 6d/7 ET2.5% Pa 3/y (without RG)	1909 ab	35.7 ab	4.8 ab	40.4 a	53
S/2 d3 6d/7 ET2.5% Pa 5/y (without RG)	1760 ab	33.4 b	4.4 ab	40.7 a	52
S/2 d3 6d/7 ET2.5% Pa 7/y (without RG)	2379 a	45.3 a	5.9 a	40.7 a	53
CD (P=0.05)	691.70	11.82	1.73	1.50	-

* Values followed by same letter/s are not critically different from each other

Table Lht. 8 : **Effect of panel change on dry rubber yield of clone RRII 105 under different frequencies of tapping**

Treatment	Panel	Yield* (kg/ha)
S/2 d2 6d/7 (without PC)	BI-1 - 3rd year	1917 ab
S/2 d2 6d/7 (with PC)	BO-2 - 4th year	1697 b
S/2 d3 6d/7 ET2.5% Pa 4/y (without PC)	BI-1 - 1st year	2321 a
S/2 d3 6d/7. ET2.5% Pa 4/y (with PC)	BI-1 - 1st year	1893 ab
S/2 d4 6d/7. ET2.5% Pa 7/y (without PC)	BO-2 – 5th year	1817 ab
S/2 d4 6d/7. ET2.5% Pa 7/y (with PC)	BO-2 – 5th year	1846 ab
S/2 d4 6d/7. ET2.5% Pa 9/y (without PC)	BO-2 – 5th year	2195 ab
S/2 d4 6d/7. ET2.5% Pa 9/y (with PC)	BO-2– 5th year	1999 ab
CD (P=0.05)	-	539.5

* Values followed by same letter/s are not critically different from each other

in clone RRII 105 was continued. Panel change did not result in increased yield under different systems of tapping. The lowest yield was observed under d2 frequency of tapping with panel change and the highest yield was obtained under d3 system of tapping without panel change (Table Exp. 8).

The experiment on evaluation of mini and reduced spiral (S/R) tapping cuts at EFU, RIT was continued. The performance of S/4 d3 and S/R 10 d3 was continued to be better.

imentonevaluationofmini

GENOME ANALYSIS LABORATORY

Research activities of the Genome Analysis Laboratory are focused on three major areas which include (i) the development, optimisation and validation of molecular tools for the assessment of genetic diversity in rubber, clonal identification and genome mapping (ii) development of genetic markers for biotic and abiotic stress tolerance and understanding the stress adaptation processes through transcriptome analysis and (iii) cloning and characterisation of agronomically important genes.

1. Development, optimisation and validation of molecular tools for the assessment of genetic diversity in rubber, clonal identification and genome mapping

1.1. Microsatellite markers for characterisation of germplasm

Development of microsatellite markers in *Hevea brasiliensis* was continued with the isolation and characterisation of *Hevea* genomic clones containing microsatellite/ simple sequence repeats (SSR). Eight polymorphic microsatellites (hmac13, hmac14, hmac17, hmct1, hmct11, hmct16, hmct19 and hmct48) were used for diversity analysis in cultivated rubber clones including RRII 400 series.

Construction of an SSR-enriched genomic DNA library for trinucleotide repeats was reported last year. All the primary positive clones were subjected to second round of screening prior to sequencing of individual clones. So far 104 positive clones have been sequenced and 38 of them are having the following trinucleotide motifs: AAG/CTT, GGT/ACC, GTG/CAC. Primers were synthesised based on the flanking sequences of the repeats to develop markers.

1.2. Single nucleotide polymorphisms (SNPs)

Characterisation of nucleotide substitutions (SNPs) in four genes: geranyl geranyl diphosphate synthase, farnesyl diphosphate synthase, mevalonate kinase and HMG-CoA synthase involved in rubber biosynthetic pathway was carried out in high yielding RRII 400 series rubber clones. Mainly untranslated regions were preferentially amplified for SNP detection. Specific amplification of the desired gene fragments was obtained. All the four genes except geranyl geranyl diphosphate synthase possess introns resulting in bigger amplicon size than the expected ones. PCR products were sequenced directly and the chromatograms were analysed. Only the PCR products derived from parental clones (RRII 105 and RRIC 100) were cloned and sequenced for haplotype detection. A total of 20 SNPs were identified in the four genes. Four SNPs were detected in geranyl geranyl diphosphate synthase coding region, six intronic SNPs both in farnesyl diphosphate synthase and HMG-CoA synthase genes and four SNPs (one coding along with three intronic SNPs) in mevalonate kinase. Frequency of SNPs in each gene was calculated using the SNP data.

1.3. Genetic linkage map in rubber

Construction of a genetic linkage map in *Hevea* was continued with the screening of 32 AFLP primer combinations for polymorphisms between parental clones; RRII 105 and RRII 118. Out of 32 primer combinations, 17 primer combinations were selected for progeny analysis. Four polymorphic microsatellite markers (Hev-

glu, hmac14, hmct1 and hmct19) were also used for segregation analysis among the progenies.

2. Development of genetic markers for biotic and abiotic stress tolerance and understanding the stress adaptation process through transcriptome analysis

2.1. Development of molecular marker(s) linked to the locus conferring resistance to fungal diseases

2.1.1. *Resistance gene analogue (RGA) in rubber*

RGA approach was adopted to identify disease resistant genes in *H. brasiliensis*. Isolation and characterisation of genomic RGAs in rubber were reported. An attempt was also made to identify the functionally active RGAs from *Corynespora* - challenged leaf samples of RRII 105 through RT-PCR using degenerated primer-pairs specific to NBS conserved motifs. So far 35 clones (RT-RGA clones) were sequenced and analysed for characteristic motifs existing in resistance genes.

2.1.2. *Genes involved in host resistance to Corynespora leaf disease*

Gene expression profiles of *Corynespora*-challenged leaf samples and uninfected control of RRII 105 were studied using DD-PCR technique. Initially 17 differentially expressed (only up-regulated) major bands were excised out of the dried gel and successfully re-amplified. These were cloned in pGEM-T vector and processed for sequencing to determine identity of the candidate cDNA. Two clones DDCT7 and DDCT12 showed significant homology with anthocyanidin 3-O-glucosyltransferase (E value: 4e-48) and GRAS transcription factor (E value: 1e-15) respectively. These two genes can be considered as markers for disease tolerance.

2.2. Characterisation of stress-tolerant clones of *H. brasiliensis* using molecular markers and gene regulation under abiotic stresses

2.2.1. *Cold tolerance in rubber*

Transcript profiling for functional genomic studies in relation to cold stress was continued. Several over-expressed cDNA fragments under cold stress were reamplified, cloned and sequenced. Sequence annotation is in progress.

2.2.2. *Rubber EST Project and gene discovery*

High quality sequences of 156 subtracted cDNA clones (ScDNA) derived from the cold stressed leaf samples were subjected to 'contig analysis' to assemble similar sequences in groups. Thirty one contigs containing 90 clones (2 to 8 clones per contig) and 66 singletons (single sequences) were identified. All sequences were subjected to BLASTX search to know about the homology with the gene sequences existing in GenBank from rubber or other plant species. Transcripts/clones were assigned to the category based on the shared structural elements and (or) inferred functions. All these ESTs, except few with unknown functions, are relevant to cold responsiveness and are mainly grouped in to the following categories for which interesting functions with relevance to stress response could be inferred. These groups are (i) osmoprotection /detoxification, (ii) oxidoreductases, (iii) cell wall and polysaccharide metabolism, (iv) protein / amino acid metabolism (v) transport and secretion and (vi) transcription factors.

2.3. DNA methylation in rubber genome

In rubber, methylation status of the genomic DNA under stress condition was studied. Genomic DNA was isolated from three clones planted at Elappara estate to study their genomic methylation status

GENOME ANALYSIS LABORATORY

Research activities of the Genome Analysis Laboratory are focused on three major areas which include (i) the development, optimisation and validation of molecular tools for the assessment of genetic diversity in rubber, clonal identification and genome mapping (ii) development of genetic markers for biotic and abiotic stress tolerance and understanding the stress adaptation processes through transcriptome analysis and (iii) cloning and characterisation of agronomically important genes.

1. Development, optimisation and validation of molecular tools for the assessment of genetic diversity in rubber, clonal identification and genome mapping

1.1. Microsatellite markers for characterisation of germplasm

Development of microsatellite markers in *Hevea brasiliensis* was continued with the isolation and characterisation of *Hevea* genomic clones containing microsatellite/ simple sequence repeats (SSR). Eight polymorphic microsatellites (hmac13, hmac14, hmac17, hmct1, hmct11, hmct16, hmct19 and hmct48) were used for diversity analysis in cultivated rubber clones including RRII 400 series.

Construction of an SSR-enriched genomic DNA library for trinucleotide repeats was reported last year. All the primary positive clones were subjected to second round of screening prior to sequencing of individual clones. So far 104 positive clones have been sequenced and 38 of them are having the following trinucleotide motifs: AAG/CTT, GGT/ACC, GTG/CAC. Primers were synthesised based on the flanking sequences of the repeats to develop markers.

1.2. Single nucleotide polymorphisms (SNPs)

Characterisation of nucleotide substitutions (SNPs) in four genes: geranyl geranyl diphosphate synthase, farnesyl diphosphate synthase, mevalonate kinase and HMG-CoA synthase involved in rubber biosynthetic pathway was carried out in high yielding RRII 400 series rubber clones. Mainly untranslated regions were preferentially amplified for SNP detection. Specific amplification of the desired gene fragments was obtained. All the four genes except geranyl geranyl diphosphate synthase possess introns resulting in bigger amplicon size than the expected ones. PCR products were sequenced directly and the chromatograms were analysed. Only the PCR products derived from parental clones (RRII 105 and RRIC 100) were cloned and sequenced for haplotype detection. A total of 20 SNPs were identified in the four genes. Four SNPs were detected in geranyl geranyl diphosphate synthase coding region, six intronic SNPs both in farnesyl diphosphate synthase and HMG-CoA synthase genes and four SNPs (one coding along with three intronic SNPs) in mevalonate kinase. Frequency of SNPs in each gene was calculated using the SNP data.

1.3. Genetic linkage map in rubber

Construction of a genetic linkage map in *Hevea* was continued with the screening of 32 AFLP primer combinations for polymorphisms between parental clones; RRII 105 and RRII 118. Out of 32 primer combinations, 17 primer combinations were selected for progeny analysis. Four polymorphic microsatellite markers (Hev-

glu, hmac14, hmct1 and hmct19) were also used for segregation analysis among the progenies.

2. Development of genetic markers for biotic and abiotic stress tolerance and understanding the stress adaptation process through transcriptome analysis

2.1. Development of molecular marker(s) linked to the locus conferring resistance to fungal diseases

2.1.1. *Resistance gene analogue (RGA) in rubber*

RGA approach was adopted to identify disease resistant genes in *H. brasiliensis*. Isolation and characterisation of genomic RGAs in rubber were reported. An attempt was also made to identify the functionally active RGAs from *Corynespora* - challenged leaf samples of RRII 105 through RT-PCR using degenerated primer-pairs specific to NBS conserved motifs. So far 35 clones (RT-RGA clones) were sequenced and analysed for characteristic motifs existing in resistance genes.

2.1.2. *Genes involved in host resistance to Corynespora leaf disease*

Gene expression profiles of *Corynespora*-challenged leaf samples and uninfected control of RRII 105 were studied using DD-PCR technique. Initially 17 differentially expressed (only up-regulated) major bands were excised out of the dried gel and successfully re-amplified. These were cloned in pGEM-T vector and processed for sequencing to determine identity of the candidate cDNA. Two clones DDCT7 and DDCT12 showed significant homology with anthocyanidin 3-O-glucosyltransferase (E value: 4e-48) and GRAS transcription factor (E value: 1e-15) respectively. These two genes can be considered as markers for disease tolerance.

2.2. Characterisation of stress-tolerant clones of *H. brasiliensis* using molecular markers and gene regulation under abiotic stresses

2.2.1. *Cold tolerance in rubber*

Transcript profiling for functional genomic studies in relation to cold stress was continued. Several over-expressed cDNA fragments under cold stress were reamplified, cloned and sequenced. Sequence annotation is in progress.

2.2.2. *Rubber EST Project and gene discovery*

High quality sequences of 156 subtracted cDNA clones (ScDNA) derived from the cold stressed leaf samples were subjected to 'contig analysis' to assemble similar sequences in groups. Thirty one contigs containing 90 clones (2 to 8 clones per contig) and 66 singletons (single sequences) were identified. All sequences were subjected to BLASTX search to know about the homology with the gene sequences existing in GenBank from rubber or other plant species. Transcripts/clones were assigned to the category based on the shared structural elements and (or) inferred functions. All these ESTs, except few with unknown functions, are relevant to cold responsiveness and are mainly grouped in to the following categories for which interesting functions with relevance to stress response could be inferred. These groups are (i) osmoprotection /detoxification, (ii) oxidoreductases, (iii) cell wall and polysaccharide metabolism, (iv) protein / amino acid metabolism (v) transport and secretion and (vi) transcription factors.

2.3. DNA methylation in rubber genome

In rubber, methylation status of the genomic DNA under stress condition was studied. Genomic DNA was isolated from three clones planted at Elappara estate to study their genomic methylation status

under cold environment with that of plants grown in RRII farm. Clones selected are RRII 105, RRIM 600 and PB 260.The following methylation sensitive restriction endonucleases and their non-sensitive isoschizomers *Hpa*II/ *Msp*I, *Ava*I/ *Bso*BI and *Psp*GI/ *Bst*NI were used for digestion of genomic DNA. *Ava*I/ *Bso*BI combination showed variation in the digestion pattern when DNA of the same plant was digested. This may be due to the presence of methylation in rubber genome at a significant level. When *Psp*GI/*Bst*NI was used, poor digestion was observed for the methylation sensitive *Psp*GI while *Bst*NI showed a clear digestion pattern. This may be due to higher methylation in their binding sites. More samples should be analysed to confirm the results.

2.3.1. Bisulphite sequencing of promoter regions

Promoter regions of the following genes from *H. brasiliensis* were selected for bisulphite sequencing to analyze the methylation pattern in them. They were (i) rubber elongation factor (REF) gene, (ii) 3-hydroxy-3-methyl-glutaryl CoA reductase 1 (hmgr 1) gene, (iii) coronatine-insensitive 1 (COI1) gene and (iv) farnesyl diphosphate synthase (FDP) gene. PCR primers were designed for amplification of CpG - rich regions of these promoters. Simultaneously nine pairs of bisulphite sequencing primers were also designed. Genomic DNA of clones RRII 105, RRIM 600 and PB 260 were treated with bisulphite to convert the unmethylated cytosine to uracil. Standardisation of PCR amplify the bisulphite treated DNA is in progress.

3. Cloning and characterisation of agronomically important genes

3.1. Cloning and characterisation of lignin biosynthesis gene(s)

Wood quality relies on secondary xylem formation and more particularly on lignin deposition in secondary cell walls. Therefore, a substantial effort has been put on the functional characterisation of genes involved in lignin production.

3.1.1. Cinnamyl alcohol dehydrogenase

Cloning and characterisation of the full-length cinnamyl alcohol dehydrogenase (CAD) cDNA from bark RNA was reported. The full-length gene (CAD) cDNA was of 1413 bp in size including both the 5′ and 3′ UTRs. Subsequently a long PCR was attempted to amplify the genomic sequence of CAD gene from RRII 105 as well as GT 1 using the same primer-pair designed to amplify the full-length cDNA fragment. The amplified genomic fragment was around 2000 bp in both the cases indicating the presence of 600 bp intron/s (approx.) in the CAD gene sequences.

Bacterial expression cassette for the CAD gene controlling lignin biosynthesis in rubber was constructed. The CAD cDNA fragment was sub-cloned into an expression vector (pRSET) to generate recombinant protein in *E. coli* under the control of a T7 promoter. Sequencing of the construct was carried out to confirm the gene in frame and proper orientation. Recombinant pRSET plasmid was transformed into BL21(DE3)pLysS cells to express the recombinant protein from the expression vector containing the CAD gene.

CENTRAL EXPERIMENT STATION, CHETHACKAL, KERALA

The Central Experiment Station, Chethackal, caters to the needs of the scientists of various disciplines of Crop Improvement, Crop Management, Crop Protection, Crop Physiology and Latex Harvest Technology. The Station works under A and B Divisions of almost equal area. Apart from clone trials and maintenance of budwood nursery of pipeline clones, trials on low frequency tapping, CUT, Germplasm accessions and fertilizer dosages make up bulk of the experimental areas. Specialized trials like gas - based tapping (G-Flex), intercropping and immaturity period reduction also make part of the experimental area.

The Station is situated near Ranni at a distance of about 56 km from Kottayam. The station was established during 1966 to cater the research needs of different divisions of RRII. The Station has a total land area of 254.8 ha. which is planted for different research projects. During the reporting period the total crop realized was 157581 kg. A total of 299 tapping days was possible in the year and 54 tappers were engaged for tapping. The total mandays engaged were 47772.5. The CES Dispensary caters to the medical needs of the workers and the total patients attended to during the period under report were 6376.

REGIONAL RESEARCH STATION, GUWAHATI, ASSAM

The priority areas of research of the station included crop improvement, crop management, crop protection and latex harvest technology.

1. Crop improvement

1.1. Evaluation of Clones

The 1985 clone trial with 10 clones (Table Ghy. 1) showed the highest mean girth in RRII 118 (84.7 cm) over 22 years of planting closely followed by RRII 203 (84 cm), RRIM 600 (81.8 cm) and the lowest in PB 5/51 (56.2 cm). Clone RRII 118 also showed the highest girth increment (2.71 cm) followed by PB 235 (2.44 cm), RRII 203 (2.27 cm), RRIM 600 (2.01 cm) while PB 5/51 recorded the lowest (0.86 cm). The annual mean yield (g/t/t) was maximum in RRII 203 (48.9g) followed by RRIM 600 (44.2 g), GT 1 (43.5g), PB 235 (42.2 g) and minimum in PB 5/51 (22.6 g) in 14th year under the normal system of tapping (S/2 d2 with tapping rest). In case of continuous tapped trees (S/2 d2 without rest), the highest annual mean yield was recorded in RRII 118 (44.3 g) followed by RRII 203 (39.8 g), GT 1 (37.9 g), RRIM 600 (36.8 g) and the lowest was in Gl 1 (24.9 g)

In 1986 clone trial with 10 clones (Table Ghy. 2), the highest mean girth over 21 years was noticed in RRIC 102 (86.5 cm) followed by RRII 118 (84.5 cm), PB 310 (79.8 cm) and the lowest was in RRII 105 (68.4 cm). The clone RRII 118 showed the highest girth increment (3.45 cm) followed by RRII 5 (2.5 cm), RRIC 102 (2.23 cm), PB 310 (2.23 cm) and the lowest in PB 260 (1.24 cm). The annual mean yield (g/t/t) recorded in 13th year was the highest in PR 255 (50.9 g) followed by RRII 208 (45.3 g), PB 310 (38.5 g) and the lowest in PB 260 (24.4 g) under normal system of tapping.

Table Ghy. 1. **Growth and yield performance of 10 clones in 1985 clone trial**

Clone	Growth (cm)		Annual mean yield (g/t/t)		Projected yield (kg/ha/year)*	
	Girth	Girth increment	NT	CT	NT	CT
RRII 105	67.7	1.34	37.5	31.4	1635.0	1884.0
RRII 118	84.7	2.71	39.6	44.3	1726.0	2658.0
RRII 203	84.0	2.27	48.9	39.8	2132.0	2388.0
RRIM 600	81.8	2.01	44.2	36.8	1927.0	2208.0
RRIM 605	73.7	1.77	39.1	27.2	1704.0	1632.0
PB 86	76.7	1.30	37.2	31.9	1621.0	1914.0
PB 235	77.0	2.44	42.2	29.7	1839.0	1778.0
PB 5/51	56.2	0.86	22.6	32.0	985.0	1920.0
GT 1	77.4	1.76	43.5	37.9	1896.0	2274.0
GI 1	62.7	0.90	25.5	24.9	1111.0	1494.0

NT- Normal Tapping, CT - Continuous Tapping

* Yield based on 400 trees from 150 tapping days/ha/year (CT) and 109 tapping days/ha/year (NT)

Table Ghy. 2. **Growth and yield performance of 10 clones in 1986 clone trial**

Clone	Growth (cm)		Annual mean yield (g/t/t)		Projected yield (kg/ha/year)*	
	Girth	Girth increment	NT	CT	NT	CT
RRIC 102	86.5	2.23	35.9	30.3	1565.0	1818.0
RRIC 105	73.7	1.26	32.9	26.4	1434.0	1584.0
RRII 5	70.2	2.5	35.1	31.0	1530.0	1860.0
RRII 105	68.4	2.2	36.5	30.6	1591.0	1836.0
RRII 118	84.5	3.45	35.2	29.0	1534.0	1740.0
RRII 208	74.0	1.7	45.3	41.0	1975.0	2460.0
PB 260	70.5	1.24	24.4	31.9	1063.0	1914.0
PB 310	79.8	2.23	38.5	41.0	1678.0	2460.0
PB 311	73.7	1.36	26.2	41.0	1142.0	2460.0
PR 255	78.2	2.05	50.9	25.0	2219.0	1500.0

NT- Normal Tapping, CT - Continuous Tapping

* Yield based on 400 trees from 150 tapping days/ha/year (CT) and 109 tapping days/ha/year (NT)

1.1. Evaluation of polyclonal population

Evaluation of polyclonal population in terms of growth and yield was continued and the results are shown in Table Ghy. 3. Amongst the 10 promising polyclonal seedling trees, the highest girth over 20 years of planting was observed in selection S2 (126.9 cm) followed by S10 (121.8 cm) and the lowest in S8 (89 cm). The selection S10 showed the highest girth increment (5.5 cm) followed by S6 (4.3 cm), S2 (4.2 cm) while S4 recorded the lowest (1.4 cm). The highest annual mean yield (g/t/t) in 13th year of tapping was observed in selection S2 (204 g) followed by S8 (101 g), S1 (92.9 g) and the lowest in selection S5 (40 g). Out of 10 promising polyclonal selections, the selection S2 ranked first (112.4 g) in terms of annual mean yield (g/t/t) over the first 13 years of tapping followed by the selection S1 (94 g), S9 (70.4 g), S10 (65.7 g) and the lowest in S5 (50.3 g).

2. Crop management

2.1. Development of an Integrated Nutrient Management system for young rubber

An experiment for development of an Integrated Nutrient Management system for

Table Ghy. 3. **Performance of 10 seedlings selections vis-à-vis polyclonal seedlings**

Selection	Girth (cm)	Annual girth increment (cm)	Annual mean yield (g/t/t)	Mean yield over 13 years (g/t/t)
S1	92.0	3.8	92.9	94.0
S2	126.9	4.2	204.0	112.4
S3	109.2	2.2	52.9	59.0
S4	94.7	1.4	67.5	61.5
S5	105.3	1.9	40.0	50.3
S6	92.9	4.3	72.0	60.7
S7	114.4	3.4	78.5	62.7
S8	89.0	1.5	101.0	57.4
S9	100.8	3.1	76.5	70.4
S10	121.8	5.5	75.8	65.7
Mean	104.7	3.1	86.1	69.4

young rubber with cover crop was initiated at RRTC Hahara during 2008. The clone planted is RRIM 600 with seven treatments laid in RBD including control. The treatments involved combination of different doses of inorganic fertilizers with and without biofertilizers and a biofertilizer alone treatment. The biofertilizers applied are *Azotobactor, Pseudomonas, Phosphobacteria* and AM fungi.

3. Crop protection

3.1. Survey of diseases and pests

Survey on pests and diseases of rubber was carried out in 35 locations covering 17 different rubber growing tracts in Assam, Meghalaya, Tripura and northern part of West Bengal. Severity of powdery mildew disease was confined only to the lower branches of the affected trees. Clones *viz*. PB 235, PB 5/51, RRII 300, RRII 308, RRII 430, Gl 1, and RRII 51 are susceptible and PB 86, SCATC 88-13, RRII 208, RRII 203, RRII 429, GT 1 and RRIM 600 are tolerant to powdery mildew disease. Minor incidence of pink disease (below 2%) was noticed on RRII 105 in smallholdings plantation at Mahadev in Meghalaya. Minor incidence of brown root, *Periconia* leaf blight and secondary leaf fall diseases was also noticed in some pockets of this region. Mild infestation of stem borer on banana crop in intercrop trial at RRTC, Hahara was noticed. Minor infestation of scale insect, termites and slugs was also noticed. Minor incidence of TPD (below 10 %) was

Table Ghy. 4. **TPD incidence under different panels of exploitation (fully dried panel) in Assam region**

Location	Exploited Panel	TPD incidence (%)			
		Summer (Apr-May)	Rain (Jul-Aug)	Pre -winter (Oct-Nov)	Winter (Dec-Jan)
Kamrup	BO-1 (1st year)	0.2	0.2	0.2	0.2
Kamrup	BO-1 (2nd year)	0.7	0.7	0.7	0.7
Bongaigaon	BO-1(3rd year)	0.6	0.6	0.6	0.6
Kamrup	BO-1(4th year)	-	-	0.3	1
Bongaigaon	BO-1 (5th year)	0.6	0.6	0.6	0.6
Kamrup	BO-2 (1st year)	-	0.3	1	1
Bongaigaon	BO-2 (2nd year)	6	6	6	6
Kamrup	BI-1 (2nd year)	4.7	4.7	10	10
Kokrajar	BI-2 (4th year)	-	-	20.7	20.7

observed on RRII 105 in mature plants of different smallholdings in Assam, Meghalaya and Tripura.

3.2. Isolation and identification of fungal pathogens of rubber

Routine isolation and microscopic observation of diseased samples of rubber were carried out at laboratory for identification of fungal pathogens. The cultures of *Periconia heveae* causing leaf blight disease of *H. brasiliensis* were also examined for regional strain differentiation.

3.3. Evaluation of wild germplasm for tolerance to powdery mildew disease

Severity of powdery mildew disease was assessed and found that 17 out of 540 and 21 out of 246 wild accessions of *Hevea* germplasm conserved at Sarutari farm under RRS, Guwahati and Taranagar farm under RRS, Agartala respectively were tolerant to powdery mildew disease.

3.4. Study on the incidence and intensity of Tapping Panel Dryness (TPD) in Assam

An investigation on the occurrence and intensity of Tapping Panel Dryness has been conducted in the states of Assam and Tripura. Trees under different age groups and progressive years of exploitation have been taken into account. The maximum TPD incidence (fully dried panel) have been recorded in BI-2 (4th year) panel (20.7%) whereas noted BI-1 (2nd year) panel 10.0%. The trees under A panel of exploitation recorded less TPD incidence (Table Ghy. 4).

An assessment of microbial population showed that rhizosphere soils of healthy trees harboured more number as compared to TPD affected trees (Table Ghy. 5). Not much difference was observed in the fungal species composition and only a few fungal species was found to be quite dominant. Similarly the mycorrizhal spore population was also more in the rhizosphere of healthy trees (Table Ghy. 6).

Table Ghy. 5. **Total fungal and bacterial population of TPD and healthy trees**

Location	Fungi ($x10^3$)		Bacteria ($x10^5$)	
	TPD	Healthy	TPD	Healthy
Naikgaon	34.7	37.6	21.6	26.5
Khogorpur	23.8	30.6	18.2	18.5
Tulungia	24.0	24.8	20.8	25.6
Amtola	30.1	34.3	25.6	26.8
Barnihat	29.4	33.8	18.2	25.1

Table Ghy. 6. **Mycorrizhal spore population (per 10 g soil) of rhizosphere soil of TPD affected and healthy trees**

Location	TPD trees	Healthy trees
Bongaigaon	35.0	44.0
Kamrup	21.6	29.0
Kokrajar	19.6	25.7

3.5. Improvement of P uptake of rubber through AM fungi (AMF) inoculation

A few dominant AMF spores (*viz. Glomus fasciculatum, G. mosseae* and *G. margarita.)* were isolated and identified and mass multiplied by inoculating single spore in *Sorghum bicolor* as the host plant. It has been observed that the dual inoculation of

Table Ghy. 7. **Effect of AMF on growth of 5 month-old-seedlings**

Treatment	Growth parameters			
	Girth	Height	Leaf No.	Whorl No.
G .fasciculatum	4.51	41.67	12.5	1
G. mosseae	4.44	39.50	13.7	1
G. margarita	4.35	39.27	11.8	1
G. fasciculatum+G. mosseae	4.75	46.12	13.0	1
G. fasciculatum+G. margarita	4.56	44.60	13.0	1
Uninoculated control	3.44	29.95	10.8	1

Table Ghy. 8. **Effect of some beneficial microorganisms on growth of 5 months-old-seedlings**

Treatment	Growth parameters			
	Girth	Height	Leaf no.	Whorl no.
AMF	4.63	43.47	14.17	1
PSM	4.58	41.95	11.55	1
Azotobacter	4.27	36.58	11.40	1
AMF + *Azotobacter*	4.69	44.18	14.82	1
AMF + *PSM*	4.96	46.08	15.88	1
Uninoculated control	3.44	29.95	10.80	1

Table Ghy. 9. **Variation in growth and yield of rubber under different exploitation systems (clone RRIM 600)**

Treatment	Av. girth (cm)	Annual girth increment (cm)	DRC (%)	Yield (g/t/t)	No. of tapping days	Yield (kg/ tree/ yr)
S/2 d2 6d/7 - regular tapping	73.35	1.75	30.85	36.72	143	5.25
S/2 d2 6d/7 - one month rest (Feb)	65.15	1.15	30.25	33.85	131	4.43
S/2 d2 6d/7 - two months rest (Feb & March)	67.50	1.09	29.68	32.35	120	3.88
S/2 d2 6d/7 - three months rest (Jan-March)	69.95	1.19	32.80	41.10	107	4.40
S/2 d3 6d/7 - ET 2.5% Pa 5/4 continuous tapping	70.60	1.22	29.96	47.68	95	4.53
S/2 d3 6d/7 - ET 2.5% Pa 5/4 one month rest – (Feb)	73.20	1.18	32.25	50.70	88	4.46
S/2 d3 6d/7 - ET 2.5% Pa 5/4 two months rest – (Feb-March)	76.00	1.60	31.85	71.80	81	5.82
S/2 d3 6d/7 - ET 2.5% Pa 5/4 three months rest – (Jan-March)	72.20	1.16	31.70	59.68	72	4.30
S/2 d4 6d/7 - ET 2.5% Pa 7/Y continuous tapping	72.85	1.20	31.75	63.15	73	4.60
S/2 d4 6d/7 - ET 2.5% Pa 7/Y one month rest – (Feb)	73.86	1.22	31.55	64.35	67	4.31
S/2 d4 6d/7 - ET 2.5% Pa 7/Y two months rest (Feb-March)	70.72	1.46	34.10	65.66	61	4.07
S/2 d4 6d/7 - ET 2.5% Pa 7/Y three months rest – (Jan-March)	78.40	1.90	34.25	77.98	55	4.29
CD(P=0.05)	NS		2.56	18.94		

AMF (*G. fasciculatum* and *G. mosseae*) led to better growth performances in all aspects as compared to singly inoculated plants. The singly inoculated plants with *G. fasciculatum* showed the highest growth rate followed by *G. mosseae* and *G. margarita* respectively. In the nursery, seedlings treated with *G. fasciculatum* and phosphate solubilizing bacteria (PSM) were found to be superior in enhancing the growth rate followed by combined inoculation of *G. fasciculatum* and *Azotobacter* treated seedlings. In single inoculation, seedlings treated with *G. fasciculatum* showed better performance followed by PSM and *Azotobacter* inoculation (Tables Ghy. 7 & 8).

4. Latex harvest technology

An experiment on tapping rest and frequency interaction studies in *Hevea* was started in 1999 with the clone RRIM 600. Normal tapping (S/2 d2 6d/7) with and without rest was compared with other tapping systems *viz.* S/2 d3 6d/7 and S/2 d4 6d/7 where stimulation had been imposed. The data revealed that treatments were not significant with respect to girth and girth increment. Maximum girth (78.4 cm) was recorded in S/2 d4 6d/7 with seven rounds of stimulation and three months rest followed by S/2 d3 6d/7 with five stimulations and two months rest and minimum in S/2 d2 6d/7.The yield and DRC were influenced by the treatments (Table Ghy. 9). The experiment had been concluded.

REGIONAL RESEARCH STATION, AGARTALA, TRIPURA

The Station continued its research activities mainly on nutritional requirement, intercropping, clone evaluation and exploitation techniques. The other aspects of investigations included germplasm evaluation, diseases and latex technological property. A socio-economic survey was initiated to study the impact of rubber cultivation in this region. Advisory services and training to the growers of this region were also undertaken on a priority basis.

1. Crop improvement

1.1. Evaluation of clones

In the clone evaluation trial of 1995 involving 10 clones, PB 235 (50.6), SCATC 88-13 (49.9 g/t/t), RRIM 600 (47.8) and PB 260 (47.0 g/t/t) were the high yielders. In genotype x environment interaction study, clone RRII 422 recorded the highest yield (47.2 g/t/t) followed by clones RRII 429 (43.6) and RRII 417 (42.4). In the clonal block trial of eight clones, PB 235 showed the highest girth (48.8 cm) followed by RRII 203 (43.5), RRIM 600 (42.9) and RRII 208 (40.9). In another on-farm trial involving seven clones, RRII 429 (13.2 cm) recorded the highest girth followed by RRII 430 (12.8) compared to other 400 series clones in the second year after planting.

In ortet evaluation, selections 315 (50.1 cm) and 365 (49.3 cm) exhibited higher girth than RRIM 600 (44.5 cm).

1.2. Conservation and evaluation of germplasm

In the evaluation trial of Amazonian germplasm accessions, it was observed that accession MT 4906 (75.6 cm) and RO 5449 (66.9 cm) were comparable in girth with popular clone RRIM 600 (68.9 cm). All germplasm accessions showed lower yield compared to RRIM 600.

2. Crop management

In tea intercropping trial, annual green tea leaf yield was 910 kg/ha. and the average rubber yield in the third year of tapping was 1612 kg/ha. In organic and inorganic trial, maximum girth continued to be noticed on application of recommended dose of fertilizer with 20 kg of FYM/plant/year.

Clone RRII 429 showed higher girth (27.2 cm) in the fourth year compared to other clones *viz.* RRII 417, RRII 430 and RRIM 600 in response to high dose of fertilizer. In another experiment, no difference was observed in the fifth year of growth of RRIM 600 in response to different levels and time of fertilizer application. However, it was observed that the highest growth was recorded on application of recommended dose of fertilizer in two equal splits compared to single application during pre-monsoon or two-third during pre-monsoon and one- third during post-monsoon period.

3. Crop physiology

In continuation of the experiment on role of leaf nitrogen content on low temperature stress-induced photoinhibitory damage in *H. brasiliensis*, it was observed that the potential quantum efficiency of PSII (dark adapted Fv/Fm), when measured during the peak winter period (January), recorded a reduction by 67, 22 and 17 per cent in the leaves of LN (Low Nitrogen), MN (Medium Nitrogen) and HN (High Nitrogen) types of seedlings. Similarly, the efficiency of PSII photochemistry (ϕ PSII) was found to be reduced by 65, 30 and 25 per cent in these three kinds of seedlings respectively.

The results of this experiment suggest that leaf nitrogen content plays a major role in protecting the leaf from photoinhibitory damage under low temperature stress during winter season.

In another experiment, low temperature-induced photoinhibition was observed in 400 series clones (RRII 414, RRII 422, RRII 429 and RRII 430). Photosynthetic rate at saturating PFD (P_{sat}) computed from P_N/PPFD response curves ranged from 3.1 µmol $CO_2/m^2/s$ (RRII 414) to 7.6 µmol $CO_2/m^2/s$ (RRII 429). The maximum apparent quantum yield for CO_2 fixation was recorded in RRII 429 and the minimum in RRII 414. Significant difference in compensation irradiance (Ci) was also recorded and ranging from 35 µmol m^2/s in (RRII 429) to 134 µmol m^2/s in (RRII 414). Significant differences were also found in the response of P_N to Ci. Among these clones, RRII 429 maintained maximum P_N of 6.9 when measured at Ca (350 ppm). The *in vivo* carboxylation efficiency (CE) calculated from P_N/Ci response curves was the highest in RRII 430 and the lowest in RRII 414.

Low sprouting percentage of bud graft is a problem during winter period in this region. In this context, an experiment was conducted to increase the sprouting of budded stumps keeping inside polyhouse during winter period. It was observed that average sprouting percentage was higher (80.6%) inside polyhouse compared to outside (33%). Average maximum temperature was higher (38.0° C) inside polyhouse compared to outside (26° C).

Study on rubber seed availability was continued in agroclimatic condition of Tripura for the second year. It was observed that an average 384 kg/ha of seeds were obtained in 25-year-old plantation of clone RRIM 600 with an average 372 seeds per tree. Maximum seed fall was observed during first fortnight of August. It was also observed that maximum seed germination (92%) was recorded during the month of July.

3.1. Latex harvest technology

In latex harvesting study, RRII 105 continued to give high yield in S/2 d2 frequency of tapping system without stimulation. Yield under S/4 d2 and S/3 d2 system of tapping with application of five and three stimulations respectively was comparable with S/2 d2 system without stimulation. In different systems of tapping experiment in clone PB 235, the highest yield was recorded in S/2 d3 system of tapping compared to S/2 d4 and S/2 d6 system of tapping. In another experiment, S/3 double cut alternated panel tapping system (DCA) with six stimulation (3+3) showed higher yield in RRIM 600, PB 235 and GT 1 compared to S/2 d2 system of tapping.

4. Crop protection

Powdery mildew, *Colletotrichum* leaf disease, *Periconia* leaf spot and brown root disease of rubber were observed in Tripura. Severe incidence of powdery mildew disease was observed in young rubber plants. However, intensity of disease was moderate in mature plants. Promising clones *viz.* RRIM 600 and RRII 105 recorded 68 and 75 per cent disease index of powdery mildew respectively. Severity of other leaf diseases casued by *Colletotrichum* and *Periconia* was observed to be moderate to severe in this locality. Three to four per cent sporadic incidence of brown root disease was observed in South Tripura district.

5. Rubber technology

Latex parameters of seven clones *viz.* RRII 414, RRII 417, RRII 422, RRII 429, RRII 430, RRII 105 and RRIM 600 were studied for 10 months. Annual clonal variation of dry

Table Agr. 1. **Annual latex parameters in different clones**

Clone	TSC (%)	DRC (%)	NRC (%)	Ash (%)	Nitrogen (%)	Magnesium (ppm)
RRII 414	42.76	39.08	3.68	0.52	0.48	117
RRII 417	42.40	38.90	3.50	0.52	0.50	132
RRII 422	41.20	37.47	3.73	0.50	0.48	132
RRII 429	40.81	37.43	3.38	0.51	0.48	128
RRII 430	41.21	37.24	3.97	0.49	0.49	120
RRII 105	39.26	35.38	3.88	0.49	0.47	143
RRIM 600	40.22	36.59	3.63	0.48	0.46	137

rubber content (DRC), total solid content (TSC) and magnesium content was observed. Total solid content per cent ranged from 39.26 to 42.76, dry rubber content from 35.38 to 39.08 per cent and magnesium from 117 ppm to 143 ppm (Table Agr. 1). However, variation of non-rubber content (NRC), ash and nitrogen was not observed.

Dry rubber analytical values (Table Agr. 2) did not show any change with seasons except the gel content which showed a decreasing trend from summer (April-May) to winter (December-January).

To study the effect of storage on properties of rubber sheets, the sheets were stored at three locations in Tripura and one set was stored in controlled condition of temperature and humidity (air-conditioned room). It was observed that the sheets were affected with mould after five months of storage. However, sheets stored in controlled conditions of temperature and humidity did not show any mould growth.

The adoption of technology transfer in group processing centers of Tripura was evaluated. Deviation from the recommended practices was noticed in dilution and sieving of the latex, dosage and mixing of acid used, thickness of the sheets, temperature of the smoke house *etc.*

6. Economics

A project titled "NR cultivation in the North Eastern Region under the Block Planting Scheme: A socio-economic assessment of its impact on the beneficiaries in Tripura" was initiated. The study focuses on the targeted communities and a sample survey covering about 480 beneficiaries is in progress. The preliminary survey results of 99 households indicated considerable increase in income in the case of beneficiaries and for majority of them rubber is the major source of income.

7. Advisory work

Discriminatory fertilizer recommendation based on soil and leaf analyses was offered to 273 rubber growers. A total of 546 soil and 24 latex samples were analysed for the benefit of growers and processors.

Table Agr. 2. **Seasonal average values of different dry rubber parameters**

Season	P_o	PRI	Ash (%)	ASHT	MV	Gel (%)	N (%)
April-May	42	75	0.58	5	80	24.37	0.48
Aug-Sept	43	76	0.35	5	80	7.36	0.40
Dec-Jan	44	76	0.37	8	76	16.70	0.41

REGIONAL RESEARCH STATION, TURA, MEGHALAYA

The Regional Research Station, Tura continued the research activities on evaluation of clones, polyclonal population, evolving suitable exploitation system and crop management.

1. Crop improvement

Yield data were recorded from 1985 and 1986 clone trials. In 1985 trial, yield in various clones: RRIM 600 (45.3 g/t/t), RRII 105 (46.9 g/t/t), RRII 203 (44.6 g/t/t), PB 235 (42.1 g/t/t), RRII 118 (35.2 g/t/t), PB 86 (36.7 g/t/t), GT 1 (38.1 g/t/t), PB 5/51 (35.8 g/t/t), Gl 1 (33.7 g/t/t) and RRIM 605 (32.8 g/t/t). In 1986 trial, yield of the clones was; PB 311 (48.3 g/t/t), RRII 105 (45.6 g/t/t), PB 310 (41.6 g/t/t), RRII 208 (42.8 g/t/t), RRII 118 (36.5 g/t/t), PB 260 (41.0 g/t/t), RRII 5 (35.6 g/t/t), RRIC 102 (34.4 g/t/t), PR 255 (36.5 g/t/t) and RRIC 105 (32 g/t/t). Selected trees from the polyclonal population have been multiplied during the year.

2. Crop physiology and latex harvesting technology

In Garo hills of Meghalaya, low temperature during winter season is one of the stress factors which adversely affected the growth, yield, DRC and early defoliation. The contribution of yield during winter period was 24.78 per cent while 30.11 per cent contribution was observed in post – monsoon season. During winter period DRC range was 26 to 29 per cent.

The different tapping systems in combination with tapping rest especially during winter season was studied. Yield and TPD were recorded in S/2 d2 and S/2 d3 tapping systems in different temperature regime i.e. Control, 10-10° C, 15-15° C and 20-20° C. Results indicated that under S/2 d2 tapping system, maximum yield (kg/ha/year) was recorded in control treatment (1633) followed by 10-10° C temperature regime (1268), 15-15° C (922.64) and 20-20° C (756.65). In S/2 d3 tapping system, maximum yield (kg/ha/year) was recorded in control treatment (1495) followed by 10-10° C temperature regime (852), 15-15° C (848) and 20-20° C (774). S/2 d3 tapping system showed higher yield than S/2 d2 tapping systems under Garo Hills condition. In the month of Nov/Dec, TPD incidence was recorded and results indicated that maximum incidence was in S/2 d2 than S/2 d3 tapping system. In both tapping systems, maximum TPD incidence was recorded in continuous tapping system.

3. Crop management

3.1. Nutritional studies (On-farm trial at Borgang, Assam)

Soil and leaf samples from different treatments of nutritional trial were collected and analyzed for available nutrient contents. Cup lump yield (g/t/t), DRC (%) and total volume (ml/t/t) were also recorded on a monthly basis. Recording of girth was done quarterly. Results indicated that $N_{60}P_{30}K_{45}$ recorded the highest girth (78.63 cm), girth increment (3.12 cm), yield (8.02 kg/tree/year), DRC (36.73 %) and total volume of latex (22.78 L/t/year) followed by $N_{60}P_{30}K_{30}$. Application of NPK fertilizers, significantly increased the O.C. content, available P and K. A building-up of soil available P and K was also observed.

3.2. Leaf nutrient concentration in different clones of *Hevea* growing in the West Garo hills of Meghalaya

For providing clone-specific fertiliser recommendation, leaf samples were collected and analyzed for N, P and K in leaf

from different clones in the West Garo hills of Meghalaya. The results showed that the N concentration in leaf is in medium range irrespective of clones. The P and K contents in leaf were low to medium.

3.3. Moisture retention characteristics of soil in the rubber growing area of Meghalaya

Soil samples were collected (0-15, 15-30 and 30- 60 cm) from RRS Ganolgre farm during the stress period and moisture content was determined. It was found that soil moisture increased with increasing depth of soil and ranged between field capacity and permanent wilting point *i.e.* 19.64 % to 22.58 %.

3.4. Analytical/Advisory work for fertilizer recommendation

Collected 136 soil samples from 68 rubber growing areas of Meghalaya and analyzed the available nutrients. Fertilizer recommendations were given to the growers. Soil fertility evaluation indicated that organic carbon status was the highest in West Garo hills and lowest in South Garo Hills, with 9.47 per cent samples showing low, 79.40 per cent medium and 11.10 per cent high level of organic carbon content in entire state of Meghalaya. Fertility rating for available P content was low and available K content was medium for the entire state of Meghalaya. The soil pH was very strongly acidic (3.97) to moderately acidic (5.41) in nature in all the locations.

Thirty soil samples were collected from the shifting cultivation sites in West and South Garo Hills of Meghalaya to compare the physico - chemical properties of soils of rubber growing areas and shifting cultivation sites. In general both the soil sites of shifting cultivation are clay loam in texture. Decline of nutrients was observed with increase in cultivation period. Base saturation showed an increasing trend from 26.5 to 28.4 per cent and 18.4 to 23.6 per cent in soil samples of West and South Garo Hills respectively.

REGIONAL EXPERIMENT STATION NAGRAKATA, WEST BENGAL

1. Crop improvement

1.1. Evaluation of clones

The four field experiments laid out to screen clones for yield and tolerance to high-speed wind, cold and high-sunshine intensity for this agroclimatic condition were maintained. The result showed that (Table Nag.1) in Trial I, the girth in Haiken 1 was significantly higher followed by SCATC 93-114 and RRIM 703. Similarly, RRIM 612 and PB 86 showed higher girth in Trial II. In Trial III, PB 235 recorded better growth. Haiken 1 showed higher girth followed by PB 280 and SCATC 93-114 in Trial IV.

In terms of average yield (Table Nag. 2), the SCATC 88-13 was the best yielder followed by PB 235 in Trial I. In Trial II, RRII 208 recorded the highest yield followed by RRIM 605. PB 235 gave the highest yield in Trial III followed by RRII 208 and RRIM 600. The Haiken 1, RRII 105 and RRIM 600 ranked high in Trial IV.

Table Nag.1. **Growth of performance of different clones**

Trial I Clone	Girth (cm)	Trial II Clone	Girth (cm)	Trial III Clone	Girth (cm)	Trial IV Clone	Girth (cm)
PB 5/51	60.03	Gl 1	62.3	PR 107	60.33	RRIC 104	55.20
PB 311	63.83	PR 107	64.0	PB 310	61.66	RRII 308	56.90
GT 1	66.03	RRII 105	69.0	RRII 208	62.87	RRII 105	59.13
SCATC 88-13	66.47	RRII 208	69.0	PB 86	63.17	PR 261	59.67
RRII 300	66.47	RRIM 605	69.0	PB 260	63.90	RRII 208	60.70
PB 235	68.17	PB 86	71.3	RRIM 600	64.53	RRII 300	61.23
RRII 203	69.70	RRIM 612	71.8	RRIC 102	65.57	RRIM 600	61.84
RRII 118	69.70			RRIM 612	66.53	PB 235	62.53
RRIM 703	72.00			SCATC 93-114	66.63	SCATC 93-114	62.54
SCATC 93-114	72.60			Haiken 1	66.73	PB 280	65.17
Haiken 1	73.07			PB 235	71.47	Haiken 1	66.37
CD (P=0.05)	2.32	CD (P=0.05)	2.53	CD (P=0.05)	2.83	CD (P=0.05)	2.93

Table Nag. 2. **Yield in different clones**

Trial I	Yield (g/t/t)	Trial II	Yield (g/t/t)	Trial III	Yield (g/t/t)	Trial IV	Yield (g/t/t)
Haiken 1	32.01	Gl 1	29.93	PR 107	23.83	SCATC 93-114	21.95
PB 5/51	32.68	PR 107	35.93	SCATC 93-114	28.32	RRIC 104	28.26
RRII 300	39.07	RRIM 612	41.83	RRIM 612	29.64	RRII 300	33.94
RRII 203	40.72	RRII 105	47.34	PB 86	34.26	PB 235	35.17
RRIM 703	41.21	PB 86	49.85	RRIC 102	37.02	RRII 308	37.56
PB 311	41.60	RRIM 605	56.91	PB 260	39.58	PR 261	38.68
RRII 118	42.25	RRII 208	66.17	PB 310	44.40	PB 280	42.67
SCATC 93-114	44.36			Haiken 1	46.86	RRII 208	42.87
GT 1	45.91			RRIM 600	51.52	RRIM 600	44.27
PB 235	48.75			RRII 208	53.72	RRII 105	44.82
SCATC 88-13	56.83			PB 235	60.21	Haiken 1	45.69
CD (P=0.05)	3.50	CD (P=0.05)	7.88	CD (P=0.05)	5.47	CD (P=0.05)	3.74

1.2. Evaluation of germplasm

The experiment to study the adaptability of 21 different genotypes compared to few standard check clones in the climatic condition of North Bengal and also to conserve selected germplasm for this region, showed maximum girth in RO 2890 followed by RO 3172 and RO 5557. Among the Wickham clones maximum girth was noticed in PB 260 (Table Nag. 3).

During the first year of tapping, RO 5363 registered the highest yield followed by AC 1950. The clone RRII 105 showed the highest yield among the four Wickham collections.

1.3. Performance of polyclonal seedlings

In the experiment to evaluate the polyclonal seedlings, initiated in 1990, tappable girth was achieved after eight years of growth. Average girth of the block was 61 cm with an average block yield of 34.6 g/t/t.

1.4. Availability of local seeds and their viability

A small-scale experiment on assessing the availability of seeds locally and their viability was initiated last year in order to overcome the problem of non-viability / or late availability of rubber seeds transported from Kanyakumari to NE region. The

Table Nag. 3. **Growth and yield in different accessions**

Accession	Girth (cm)	Yield (g/t/t)
AC 1950	54.6	30.1
AC 607	29.4	1.6
AC 619	50.7	2.2
AC 623	42.5	0.0
AC 68	54.9	5.0
AC 763	46.7	11.0
MT 196	48.1	12.9
MT 2229	53.8	7.8
MT 2594	43.5	6.0
MT 44	46.0	7.2
RO 2629	50.6	5.2
RO 2635	55.8	2.2
RO 2890	62.3	3.5
RO 3172	60.6	1.0
RO 5329	50.5	11.0
RO 5348	55.4	0.0
RO 5363	57.6	61.2
RO 5408	48.0	4.4
RO 5430	57.5	7.7
RO 5557	59.4	1.6
RO 6139	46.1	3.3
GI 1	50.1	26.6
GT 1	52.9	27.0
PB 260	56.2	20.1
RRII 105	52.9	44.1
CD (P=0.05)	2.93	4.86

average germination percentage of these seeds was 50. Maximum seeds were collected from RRIM 600 followed by RRII 300 and RRII 105.

2. Crop management

2.1. Nutritional trials

The 3^3 NPK factorial trial initiated in 1989 was continued. The girth and yield were recorded and the highest girth of 73 cm and yield of 63.3 g/t/t were noticed in the treatment $N_{45} P_{40} K_0$.

2.2. Intercropping trials

The experiment on intercropping tea in rubber was continued. Girth and yield of rubber and tea plants were recorded. No significant difference was observed among the different treatments.

3. Latex harvest technology

3.1. Tapping system vs. tapping rest

The split-plot design experiment laid out in RRS, Nagrakata to formulate appropriate tapping system for Dooars region of West Bengal was continued. The main treatment comprised of tapping systems and sub-treatments involving varying winter temperature rest regimes. Results showed that, there is no significant difference between the main treatments. However, significant difference was noticed among the sub-treatments. Significantly lower yield compared to control was noticed at < 15° C and < 18° C rest regimes. Rubber yield at < 12°C was noted to be at par with the control (Table Nag. 4). The data shows that, S/2 d2 system with minimum duration of rest at < 12°C would be ideal for this region.

Table Nag.4. **Dry rubber yield (g/t/t) under two tapping systems with winter tapping rest**

System of tapping	Temperature regimes (°C)			
	Control	< 12° C	< 15° C	< 18° C
S/2 d2	37.9	39.2	33.5	30.0
S/2 d3	35.8	34.2	29.8	25.7
CD (P=0.05)	3.47			

4. Performance of rubber clones in abandoned tea growing areas of Dooars belt of North Bengal

There are areas lying vacant inside the large tea estates (nearly 20% area estimating approximately 16000 ha) where the soil is either sodic or stony or the land low lying. However, rubber having a wide range of

adaptability could be introduced in these areas without conflicting with tea. The large tea growers are also interested in cultivating rubber in tea gardens for additional income generation. Keeping this in view, it is felt worth studying the technical feasibility of growing rubber in these vacant lands on a priority basis. Three areas, having pH of 5.8, 6.5 and 8.1 are chosen to see performance of five clones (RRIM 600, RRII 208, RRII 105, RRII 429 and GT 1). The soil is sandy loam to sandy in nature and having calcium deposit. The land clearing is over and pitting has been started. Polybag planting material is ready and planting will be done by the end of August, 2008.

REGIONAL RESEARCH STATION DAPCHARI, MAHARASHTRA

Thrust areas of the Station are identification of suitable planting materials and development of location-specific agrotechnology for drought-prone region. Experiments to evaluate low frequency tapping systems, irrigation requirement and screening of wild germplasm for drought tolerance are also being carried out. The research projects undertaken can be classified broadly into two categories, namely, environmental physiology and crop improvement.

1. Environmental physiology

The research programmes were prioritised 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 experiments with ETc-based basin (1.00 ETc, 0.75 ETc and 0.50 ETc) and drip (0.75ETc, 0.50 ETc 0.25 ETc) irrigation treatments in clone RRII 105 were continued. The objective was to standardize and evaluate the advantages, if any, in terms of water saving and total economy. From February 2000, the 0.75 ETc basin and 0.50 ETc drip were reduced to 0.25 ETc (basin and drip) to test whether irrigation requirement can further be reduced. The trees from all level of basin irrigation showed higher girth compared to drip irrigation system. The basin-irrigated trees recorded higher yield in comparison to drip and control (Table Dap.1). Reducing the irrigation to lower level did not affect the growth and yield of rubber.

In another trial, the effect of different levels of irrigation (1.00 ETc, 0.75 changed

Table Dap. 1. **Effect of irrigation on growth and yield**

Treatment	Girth (cm)*	Yield (g/t/t)
Control (No irrigation)	61.9	48.9
1.00 ETc basin	71.9	59.5
0.25 ETc basin *(Earlier 0.75 ETc)	69.0	60.8
0.50 ETc basin	67.7	62.4
0.75 ETc drip	67.2	57.3
0.25 ETc drip * (Earlier 0.50 ETc)	67.0	53.4
0.25 ETc drip	63.7	51.0
SE +	1.08	6.08
CD (P=0.05)	2.22	NS

* As on March 2008. Changed from 0.75 ETc to 0.25 ETc from February 2000

Table Dap. 2. **Effect of irrigation on growth and yield**

Treatment	Girth (cm)*		Yield (g/t/t)	
	RRII 105	RRII 118	RRII 105	RRII 118
Control (No irrigation)	63.7	77.1	54.5	56.4
1.00 ETc	70.6	88.7	62.7	62.0
0.25 ETc *	69.5	89.1	69.1	59.3
0.50 ETc	67.3	83.7	62.0	49.3
For irrigation treatments				
SE +	2.25		6.73	
CD (P=0.05)	4.91		NS	
For Clones				
SE +	1.21		2.29	
CD (P=0.05)	5.23		NS	

* as on March 2008. Changed from 0.75 ETc to 0.25 ETc from February 2000

to 0.25 ETc from February 2000 and 0.50 ETc) on yield and yield components of two clones *viz.*, RRII 105 and RRII 118 was monitored. Results indicated that RRII 118 performed better in terms of growth while clone RRII 105 recorded better yield in response to different levels of irrigation treatments (Table Dap. 2).

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. Irrigated trees were categorized into two with respect to soil depth, one being maintained under reduced irrigation of 1/5 ETc (deep soil) and the other with 1.0 ETc (shallow soil). The irrigation level was reduced to further minimum level from 1/4 to 1/5 ETc in good soil depth area and the effect is being studied.

2. Crop improvement

2.1. Clone evaluation

The clone evaluation trial to evaluate growth, drought tolerance and yield of 15 modern clones indicated that the clone RRII 208 continued to perform better in terms of growth and yield (Table Dap. 3).

Table Dap.3. **Growth and yield of *Hevea* clones**

Clone	Girth (cm)*	Yield (g/t/t)
RRII 5	61.3	34.7
RRII 6	62.1	29.4
RRII 105	58.2	37.3
RRII 208	66.5	35.2
RRII 308	58.8	17.1
RRIM 605	58.4	19.7
PB 260	62.5	27.2
PB 310	65.0	30.0
PB 311	60.9	32.9
RRIC 52	66.7	16.2
RRIC 100	60.3	32.3
RRIC 102	60.5	23.0
RRIC 105	58.6	19.2
PR 255	60.3	33.3
PR 261	58.6	21.0
SE (+)	2.56	6.14
CD (P=0.05)	5.26	12.58

*as on March 2008

3. Germplasm

3.1. Screening of germplasm for drought tolerance

A field trial for screening of wild germplasm for drought tolerance studies under Dapchari condition was laid out in July 2003 using 130 wild accessions along with three selected clones *viz.*, RRII 105, RRIM 600, Tjir 1 as check clones in an Augmented Block Design. The observation

on growth, pre and post-drought and relative water content per cent were recorded. The observations showed a wide variability for all characters studied. In general, Mato Grosso accessions were superior for all the growth characters studied than those from Rondonia and Acre provenances. Among the control clones, RRIM 600 and RRII 208 were superior to RRII 105. Twenty-five accessions were identified as drought tolerant based on 3-4 years field performance and detailed studies are in progress.

3.2. Further evaluation of germplasm and clones for drought tolerance

Another field evaluation for drought tolerance using 25 identified drought tolerant germplasm accessions, along with five HP clones and RRII 105, RRIM 600, Tjir 1, RRII 430 and RRII 208 as check clones in a rectangular lattice design was initiated in 2007. The observation on growth was recorded. The accessions showed a wide variability for all characters studied.

REGIONAL RESEARCH STATION DHENKANAL, ORISSA

The Regional Research Station in Dhenkanal representing dry sub-humid climate, continued its research activities on crop improvement, management and crop protection, with specific objective of identifying clones suited to the prevailing drought- prone conditions of the region.

1. Crop improvement

Under the projects on evaluation of clones and polyclonal population, there are five clone evaluation trials. The trials were laid out to screen the most adapted and high yielding clones under the dry sub-humid climate.

1.1. Clone evaluation

In the 1987 trial, GT 1 (74.0 cm) and RRIM 600 (69.8 cm) recorded significantly higher mean girth over RRII 105 (65.3 cm). RRIM 600 recorded the highest mean yield of 30.0 g/t/t. GT 1 recorded the lowest yield (24.1 g/t/t). The clone RRIM 600 was found to be superior in terms of both growth and yield.

In the second clone trial (1990), clones *viz.* SCATC 93-114 (79.6 cm), RRIM 600 (75.9 cm) and RRII 208 (73.9 cm) showed superior growth. RRII 208 (38.1 g/t/t) followed by SCATC 88-113 (34.8 g/t/t) showed overall superior performance with maximum yield compared to SCATC 93-114 , RRIM 700 and RRII 300.

In the third trial (1991), the performance of *Hevea* clones and polyclonal seedlings was compared. Clones GT 1 (79.9 cm), RRII 208 (77.6 cm) and RRIC 102 (75.7 cm) showed superior growth. However, polyclonal seedlings with a mean girth of 90.1 cm exhibited better growth and adaptability compared to the above clones. Among the clones, RRII 208 recorded maximum mean yield (38.7 g/t/t) followed by RRII 105 (34.0 g/t/t). RRII 208 exhibited better growth, yield and adaptability in the region.

In the fourth trial on G x E (1996), located at the Institute of Minerals and Materials Technology, Bhubaneswar, clones *viz.* RRII 430 (58.20 cm), RRII 414 (55.31 cm) and RRIC 100 (57.2 cm) exhibited better

performance in terms of girth. In general, RRII 400 series clones exhibited good adaptability and growth in the region.

In the fifth clone trial (1999-00), the highest mean girth was recorded in IRCA 111 (42.85 cm) followed by RRII 208 (41.10 cm) and RRII 600 (41.0 cm) along with RRII 300 and RRII 352. RRII 51 (32.47 cm) recorded minimum girth.

1.2. Polyclonal trial

To evaluate the growth and yield performance and adaptability of polyclonal seedlings, a trial was laid out in 1989. In the trial, maximum mean girth was recorded in tree no. 11 (127.0 cm), followed by tree no. 471 (120.0 cm). Maximum annual mean yield was recorded in tree no 452 (65.4 g/t/t). From the clone trials, 10 elite trees have been selected and multiplied for further field evaluation.

2. Crop protection

Survey was carried out on powdery mildew disease in rubber plantations. So far, powdery mildew disease was not noticed in this region. High temperature prevailing during the summer months might be the reason for absence of the disease.

REGIONAL RESEARCH STATION, PADIYOOR, KERALA

The long-term research programmes initiated with the objective of identifying clones suited to the region and evaluation of clonal tolerance to drought/disease were continued. The field trials laid out include evaluation of germplasm screening of clones for timber-latex traits, investigations on Genotype x Environment interaction, large-scale testing of potential hybrid clones, water requirement studies, disease evaluation of clones and study of cropping systems.

1. Crop management

1.1. Physico-chemical characterisation of soil

Study of the morphological and physico-chemical characteristics of the soils

Table Pad.1. **Slope, altitude and physical properties expressed on First Layer Actual Soil Volume (FLASV)**

Slope class	Pit	Slope (‰)	Alt	FLT	FLCF	FLASV	Sand	Silt	Clay
				(m)		(m^3)		(t/m^3)	
1	1	9.8	95	0.13	0.64	2.48	1.14	0.13	0.52
1	2	7.5	74	0.13	0.71	2.41	0.79	0.30	0.51
1	3	8.1	87	0.10	0.63	1.77	1.15	0.17	0.42
1	4	5.6	85	0.12	0.65	2.23	0.80	0.17	0.59
2	5	11.8	86	0.14	0.76	2.60	0.70	0.09	0.96
2	7	11.7	105	0.13	0.74	2.38	0.66	0.12	1.08
3	6	16.0	88	0.14	0.96	2.41	0.62	0.13	0.75
3	8	15.8	140	0.12	0.85	2.03	0.64	0.07	1.16
3	9	17.7	99	0.13	1.24	1.88	0.61	0.11	1.00
3	10	19.5	95	0.13	0.74	2.38	0.49	0.21	1.08
4	11	25.4	103	0.17	1.44	2.64	0.51	0.27	1.18

along with the site characteristics was completed. Slope class significantly influenced first layer thickness (FLT) and first layer coarse fragments (FLCF). Slope was classified into four classes with slope class 1 having 5-10 per cent slope; slope class 2 with 10-15 per cent slope and slope class 3 having 15-25 per cent slope and slope class 4 with 25-33 per cent slope.

1.2. Water requirement studies

The experiment initiated in immature rubber with irrigation levels at IW/CPE ratios of 0.3, 0.6, 0.9, 1.2 and an unirrigated control was continued. Irrigation was given during the peak summer months.

Growth observations recorded at periodic intervals indicated that irrigated treatments maintained significantly higher girth of plants though the seasonal differences in girth were non-significant (Table Pad. 2).

Table Pad. 2. **Effect of irrigation on growth**

Treatment (IW/CPE)	Girth* (cm)	Girth increment (cm)	
		Dry months (Dec.-May)	Wet months (June-Nov.)
1.2	50.1	1.08	3.28
0.9	49.2	1.00	3.41
0.6	51.1	1.38	3.24
0.3	46.9	1.22	3.93
Unirrigated	43.8	1.4	3.53
CD (P=0.05)	4.31	NS	NS

* Eighth year

1.3. Response to applied fertilizers in high yielding clones

The experiment laid out in June 2002 was continued. The treatments comprised of three clones (RRII 105, RRII 414 and RRII 429) with four fertilizer levels (30:30:20, 60:30:20, 90:60:40 and 120:60:40 kg/ha. of N, P_2O_5 and K_2O). The organic carbon content of the soil was high with medium levels of available phosphorus and potassium. Higher doses of applied fertilizer did not affect the girth of the plants significantly (Table Pad. 3).

Table Pad. 3. **Effect of fertilizer on growth**

Treatment	Girth (cm)		
	RRII 105	RRII 429	RRII414
30:30:20	29.63	26.35	29.49
60:30:20	27.13	27.27	29.00
90:60:40	26.43	24.54	29.63
120:60:40	28.69	27.51	29.14
CD (P=0.05)	NS		

2. Crop improvement

2.1. Large-scale evaluation of clones

In the clone trial (1996 planting) with 11 clones, girth difference among the clones was not significant. The average annual yield of IRCA 130 (49.06g/t/t) was significantly superior to that of RRII 105 (33.63 g/t/t). The summer yield also showed a similar trend (Table Pad. 4).

Table Pad. 4. **Growth performance of modern *Hevea* clones**

Clone	Girth (cm)	Yield (g/t/t)	Summer yield (g/t/t)
RRII 105	54.99	33.63	20.54
PB 314	56.68	38.81	25.92
IRCA 130	58.95	49.06	33.48
PB 28/59	54.37	34.17	20.26
IRCA 109	54.96	34.08	23.73
PB 330	56.26	17.66	11.41
IRCA 18	57.32	28.92	15.36
RRIM 703	47.64	23.79	13.79
IRCA 111	54.39	31.45	20.57
PB 255	54.65	47.01	32.75
IRCA 230	55.56	32.31	19.79
CD (P=0.05)	4.31	13.37	12.58

2.2. Evaluation of rubber clones /selections at high altitude situations

The trial with 10 selections (9 from Panamaram in Wayanad and 1 from Iritty)

Table Pad. 5. **Growth of rubber in high altitude area**

Clone	Girth (cm)
RRII 105	42.0
RRII 203	57.7
RRIC 100	60.8
RRIC 102	53.0
PB 86	59.6
P 296	54.6
P 90	53.7
P 270	62.3
P 280	51.3
P 2	49.6
P 121	39.7
P 213	62.6
P 1	59.6
P 155	48.1
Iritty 1	56.4
CD (P = 0.05)	8.9

along with 5 clones (RRII 105, RRII 203, RRIC 100, RRIC 102 and PB 86) field-planted in 1996 under high altitude (974 m MSL) is being monitored for growth and disease incidence.

RRII 105 recorded the lowest value of girth over other popular clones/selections tested. By the 12th year, the girth of RRII 105 was only 42 cm while among the ortets, P 270 and P 213 recorded the highest girth values of 62.3 cm and 62.6 cm respectively. Among popular clones RRIC 100 recorded a mean girth of 60.8 cm (Table Pad. 5).

The ortet selection Iritty 1 showed the highest degree of disease tolerance to powdery mildew.

HEVEA BREEDING SUB-STATION, NETTANA, KARNATAKA

Identification of clones suited to the Karnataka region with tolerance against prevailing biotic and abiotic stresses is the major thrust area of research. Experiments on latex harvest technology and disease management are also being undertaken.

1. Crop improvement

1.1. Small-scale clone trials

Six small-scale clone trials are in progress, out of which three trials (1988A, 1988B and 1988C) planted in 1988 are small-scale evaluation of selected ortets. Remaining three trials (1991A, 1991B and 1991C) planted in 1991 are small-scale evaluation of indigenous and exotic clones.

In the trial 1988 A, four clones *viz.* T 2, GT 1, O 17 and O 15 recorded better yield than control clones (Table Kar.1). In the second trial (1988B), better yielding clones were T 1 and GT 1 closely followed by O 40 and O 53. Clones GT 1, C 140 and RRII 105 were on par in the third trial (1988 C).

In the 1991A trial, four-year yield data revealed better performance in three Prang Besar clones *viz.* PB 314, PB 235, PB 280 and RRII 300. In 1991B trial, two clones *viz.* RRII 5 and RRII 3 were found to be better. In the third trial (1991C), HP 83/224 and PB 28/59 were found to be high yielding than the control clones (Table Kar.2).

1.2. Large-scale clone trials

Among the clones in the 1989 large-scale clone trial, clone RRII 203 showed better yield performance (67.9 g/t/t) followed by KRS 25 (59.1 g/t/t). Clone SCATC 93-114 was the lowest yielder (11.5 g/t/t) (Table Kar.3). In the 1990 trial, clone PB 260 (58.9 g/t/t) followed by PB 235 (54.6 g/t/t) were the best

Table Kar.1. **Performance of top yielding ortets from the ortet trials**

Ortet trial	Clone	Girth* (cm)	Mean yield during 2007 (g/t/t)	Overall mean yield** (g/t/t)
1988A	T 2	103.90	91.20	69.00
	GT 1	79.60	84.20	65.20
	O 17	97.70	85.40	63.60
	O 15	84.20	91.90	63.30
1988B	T 1	104.70	66.80	68.50
	GT 1	88.30	54.80	67.80
	O 40	83.50	41.70	56.50
	O 53	84.70	47.20	56.10
1988C	GT 1	89.20	140.30	79.50
	C 140	92.70	93.30	76.30
	RRII 105	72.30	83.10	72.60
	O 49	83.00	142.70	63.90
	O 55	113.50	122.20	59.00
Control clones[z]	RRII 105	72.00	48.90	59.60
	GT 1	85.70	93.10	70.80
	RRIM 600	71.10	33.90	44.50

* Girth recorded in 20-year-old trees during December 2007
**Mean over six years; [z]Mean of data from three trials

Table Kar.2. **Performance of top yielding clones in the 1991 small-scale trials**

Trials	Clone	Girth * (cm)	Mean yield during 2007 (g/t/t)	Overall mean yield** (g/t/t)
1991A	PB 314	66.50	66.70	89.20
	PB 235	83.30	63.50	85.80
	PB 280	69.20	62.00	79.50
	RRII 300	81.70	60.90	57.40
	PB 217	78.20	61.50	57.00
1991B	RRII 5	74.60	84.10	69.90
	RRII 3	68.70	76.90	56.00
	Nab 17	75.30	50.20	49.10
	RRII 308	69.80	40.30	41.20
1991C	HP 83/224	81.70	77.10	62.90
	PB 28/59	79.40	78.90	50.00
	GT 1	74.40	57.10	43.00
	PR 261	70.90	46.60	43.00
Control clones[z]	RRII 105	58.90	39.20	49.80
	GT 1	71.10	48.60	40.40
	RRIM 600	57.80	28.10	33.30

*Girth recorded in 17-year-old trees during Dec 2007;
**Mean over four years; [z]Mean of data from three trials

Table Kar 3. **Growth and yield performance of clones in the large-scale clone trial (1989)**

Clone	Girth* (cm)	Mean yield during 2007 (g/t/t)	Overall mean yield** (g/t/t)
RRII 203	92.10	74.30	67.90
KRS 25	84.50	64.00	59.10
PB 255	75.20	59.50	52.90
KRS 163	80.70	40.40	52.60
KRS 128	80.30	50.80	52.30
RRII 105	72.60	37.90	49.70
RRII 308	82.10	47.50	44.50
SCATC 88-13	65.30	34.90	42.60
PR 255	64.40	33.40	38.10
Haiken 1	59.70	26.40	35.20
PR 261	71.10	22.10	33.80
RRIM 600	71.40	16.90	31.30
RRII 300	73.50	27.00	29.60
SCATC 93-114	67.80	10.90	11.50
SE (±)	2.40	7.60	5.10
CD (P=0.05)	6.90	22.00	14.90

*Girth recorded in 19-year-old trees during December 2007

**Mean over six years

performers in terms of yield (Table Kar. 4). In the large-scale clone trial started in 2000, RRII 414 recorded highest girth (56.3 cm), followed by RRII 430 (55.4 cm). RRII 422 recorded minimum girth (Table Kar. 5).

Table Kar. 5. **Growth performance of clones in the large-scale clone trial 2000**

Clone	Girth* (cm)
RRII 414	56.30
RRII 430	55.40
RRIC 100	48.20
RRII 429	46.60
RRII 407	42.60
RRII 105	41.60
RRII 403	38.90
RRII 422	38.30
SE (±)	1.20
CD (P=0.05)	3.70

*Data collected during December 2007

Table Kar. 4. **Growth and yield performance of clones in the large-scale clone trial (1990)**

Clone	Girth* (cm)	Mean yield during 2007 (g/t/t)	Overall mean yield** (g/t/t)
PB 260	81.00	58.30	58.90
PB 235	84.80	60.10	54.60
PB 311	72.90	58.50	51.00
RRII 105	71.60	48.10	50.00
HP 372	85.80	57.70	47.20
PB 217	75.90	60.50	47.10
GT 1	76.20	59.00	45.00
HP 223	83.10	49.50	43.90
GI 1	65.10	27.70	30.80
HP 187	70.20	36.80	27.70
HP 185	72.00	28.50	25.50
Hil 28	69.90	31.50	25.40
Mil 3/2	76.70	32.00	24.70
HP 204	65.20	18.90	20.20
Tjir 1	62.10	19.10	19.50
SE (±)	2.10	4.80	2.10
CD (P=0.05)	6.10	13.80	6.20

*Girth recorded in 18-year-old trees during December 2007

**Mean over five years

Table Kar. 6. **Growth and yield performance of parent clones in the 1990 trial**

Parent Clone	Girth* (cm)	Mean yield during 2007 (g/t/t)	Overall mean yield** (g/t/t)
PB 235	89.60	75.20	73.00
RRII 105	71.30	45.50	53.00
RRII 203	110.60	58.60	51.60
PB 5/51	70.90	43.80	40.40
GT 1	77.20	39.80	39.90
PB 242	72.40	36.20	39.40
PB 213	69.20	38.20	38.40
PB 252	76.80	30.40	35.80
RRIM 600	60.00	34.80	35.20
IAN 45/873	55.30	29.40	29.40
PB 86	59.70	21.50	29.00
Tjir 1	66.70	22.20	27.20
SE(±)	7.70	4.00	2.10
CD (P=0.05)	22.6	11.7	6.1

*Girth recorded in 18-year-old trees during Decemcer 2007

**Mean over five years

1.3. Trial on estimation of genetic parameters

Twelve clones and their half-sib progenies are under evaluation in the trial planted in 1990. Among the parent clones, clone PB 235 recorded the highest average yield (73 g/t/t) over the rest of the parents, followed by RRII 105 (53 g/t/t). The performance of the parent clone Tjir 1 (27.2 g/t/t) was poor (Table Kar.6). Progenies of parent clone RRII 203 recorded the highest average yield (45.9 g/t/t) and the lowest (22.4 g/t/t) in progenies of parent clone Tjir 1 (Table Kar. 7).

Table Kar.7. **Growth and yield performance of half-sib progenies in the 1990 trial**

Family	Girth* (cm)	Mean yield during 2007 (g/t/t)	Overall mean yield** (g/t/t)
RRII 203	93.20	47.80	45.90
GT 1	95.10	46.40	43.20
PB 235	98.50	41.80	43.10
PB 5/51	90.50	40.30	38.50
PB 242	94.70	31.50	37.90
IAN 45/873	89.10	31.50	35.10
PB 252	86.50	24.60	34.70
RRIM 600	82.10	41.20	34.60
RRII 105	88.00	34.40	33.70
PB 86	80.90	29.80	31.90
PB 213	100.60	21.50	25.20
Tjir 1-HS9	84.70	15.70	22.40
SE(±)	3.60	5.30	3.50
CD (P=0.05)	10.40	15.40	10.40

*Girth recorded in 18-year-old trees during December 2007
**Mean over five years

2. Latex harvest technology

Performance of different clones under different tapping systems was assessed in the 1987 experiment consisting of clones *viz.* RRII 105, RRII 300, PB 235, PB 260 and PB 311. All the clones, except PB 235 and PB 311 recorded higher yield under d4 system with stimulation. However, clones PB 235 and PB 311 recorded higher yield under d3 system.

HEVEA BREEDING SUB-STATION PARALIAR, TAMIL NADU

The major crop improvement activities of the Station during 2007-08 could be categorised under four heads namely, evaluation of the performance of selected clones in this region, evolving new clones by hybridization and polycross approach, standardisation of young budding in root trainers and studies on the influence of harmful solar radiations on the incidence of tapping panel dryness (TPD).

1. Clone evaluation

Tapping on panel BO-1 was completed in the large-scale trial (LST) 1994, at Keeriparai and the yield data were analysed. Out of 11 clones under evaluation, PB 255 (76.95 g/t/t) was the best yielder, followed by IRCA 109 (74.65 g/t/t). Two more exotic clones *viz.* PB 314 (72.56 g/t/t) and IRCA 111 (71.65 g/t/t) also exhibited better yield (Table Par. 1) than the control clone RRII 105 (54.26 g/t/t).

Tapping was completed in panel BO-1 in the block evaluation experiment (1994) at Keeriparai. Among the 13 modern popular clones evaluated in the trial, PB 311 (57.86 g/t/t) showed better yield than RRII 105 (54.98 g/t/t). The increasing yield exhibited by RRII 105 from the fourth year of tapping indicated its superiority over the others (Table Par. 2).

Table Par. 1. **Yield in the LST at Keeriparai (1994)**

Clone	Mean yield (g/t/t)	
	2007-08	Pooled data in BO-1
IRCA 18	64.54	57.82
IRCA 109	70.36	74.65
IRCA 111	71.98	71.65
IRCA 130	56.40	64.61
IRCA 230	75.59	54.52
PB 255	85.41	76.95
PB 314	72.07	72.56
PB 330	60.93	53.04
PB 28/59	53.45	53.48
RRIM 703	59.54	62.09
RRII 105	78.45	54.26
Mean	68.06	63.24
CD (P=0.05)	5.11	5.94

Table Par. 2. **Yield in the block trial at Keeriparai (1994)**

Clone	Mean yield (g/t/t)	
	2007-08	Pooled data in BO-1
RRII 5	42.65	42.71
RRII 50	59.63	43.48
RRII 51	35.92	34.81
RRII 176	40.35	40.66
RRIC 102	65.86	47.35
PB 217	54.29	49.02
PB 235	55.12	53.84
PB 260	51.32	47.97
PB 311	49.08	57.86
PB 28/59	68.04	54.78
PR 255	53.42	50.05
PR 261	52.49	47.06
RRII 105	73.33	54.98
Mean	53.96	48.04
SE	3.31	2.82

The trial on clonal composites (1994) with eight treatments formed by combination of clones belonging to different categories under various proportions, with RRII 105 as control. On completion of tapping in BO-1 panel, all the treatments showed a yield trend on par with RRII 105

Table Par. 3. **Yield in the trial on evaluation of clonal composites**

Composition of clones			Mean yield (g/t/t)	
15%	35%	50%	2007-08	Poled data in BO-1
PR 255	PB 28/59	RRII 105	64.11	53.11
PR 255	PB 235	RRII 105	47.52	52.01
RRII 5	PB 28/59	RRII 105	58.99	57.13
RRII 5	PB 235	RRII 105	54.94	58.31
PR 261	PB 28/59	RRII 105	50.06	49.52
PR 261	PB 235	RRII 105	47.26	52.54
PB 311	PB 28/59	RRII 105	54.40	51.81
PB 311	PB 235	RRII 105	58.23	50.64
RRII 105	(100%)		73.33	54.98
Mean			55.42	53.31
SE			3.94	4.86

(Table Par.3). Based on the above study, it could be inferred that various advantages of mixed planting of clones could be derived without compromising yield, provided the component clones are selected judiciously.

In the multi-locational clone trial (1996) to assess genotype x environment interaction, RRII 203 (57.18 g/t/t) yielded better than RRII 105 (55.12 g/t/t). In this trial, RRII 105 exhibited an increasing yield trend from third year. Among the hybrid clones belonging to the 400 series, the yield of RRII 430 (53.99 g/t/t), RRII 422 (51.16 g/t/t) and RRII 417 (48.03 g/t/t) was on par with RRII 105. At Vaikundam Estate, however, all the five clones belonging to 400 series showed an initial yield trend better than RRII 105. The yield of these clones exhibited wide variations compared to that in Kerala and the two nearby estates. In order to study further on the variation in the performance of these clones in this region, five block evaluation experiments were initiated representing five different micro-climates and observations on initial establishment, juvenile growth, occurrence of diseases *etc.* are being monitored at regular intervals.

2. Breeding orchards

The breeding orchards are being maintained and hand pollinations were attempted using different parental combinations during the flowering season in 2007. The hybrids obtained through hand pollinations during 2006 were test-tapped for preliminary selection and the hybrids of 2007 HP were raised in a nursery. The parent trees in the orchard were pollarded regularly and their canopies were maintained at a low profile to facilitate hand pollination.

3. New generation polyclonal seed garden

The polyclonal seed garden established at New Ambadi Estate (2000) was maintained and polycross seeds were collected and raised in a nursery for progeny analysis. A field experiment on improvement of polycross planting materials was initiated at Paraliar during 2008.

4. Root trainer planting technique

The planting materials raised through root trainer technology planted in a holding at Churlacode were opened for regular tapping during May 2007 and monthly yield is being recorded. Root trainer plants exhibited better yield trend compared to polybag plants. The experiment initiated during 2007 at HBSS, Paraliar, to study the suitability of different potting media was repeated during 2008.

Another experiment on young budding in root trainers, which was initiated at Cheerakuzhy Nursery, Mannarcad, was repeated during 2008. Budding on young plants raised in root trainers exhibited high percentage of budding success (94.0%) and these plants were found to have several advantages over those generated through conventional method. Since bud grafting was done on one-month-old seedlings raised in small root trainers, the cost of production could be reduced significantly. The root system was not disturbed and air pruning of roots supported vigorous growth of plants on transplantation to the field. Various advantages of bench grafting could be derived without uprooting the plants. Since bud wood is harvested every month, source bushes could be utilised more economically. The technique also prevents root coiling and favours development of more lateral roots which are oriented properly within the container.

5. Analysis of the effect of harmful radiations on the incidence of TPD

In order to study the possible association of sunscorch with incidence of TPD, one large-scale trial was initiated at Ponmanai and a block trial was initiated at Bethany Estate, Mukampalai during 2008. Vacancies were filled and treatments for protection against sunscorch were imparted repeatedly. Observations on sunscorch damage and initial establishment success were done at regular intervals. Sufficient plants were raised at HBSS, Paraliar for destructive sampling at the age of three years.

LIBRARY AND DOCUMENTATION CENTRE

During the year, 245 books were added to the stock of the library. The library subscribed 61 foreign journals and 86 Indian journals. About 30 other journals were also received as gift/exchange. Literature searches from AGRIS and RAPRA CDs were carried out.

Two issues of *Documentation List*, one issue of *Rubber Alerts* and one issue of *New Additions List* were compiled and distributed. The *List of Publications 2002-07: 10th Five Year Plan Period* of all Divisions of RRII was compiled. The database was updated by adding 318 articles. The binding of 3065 back volumes of journals for the period 2001-2007 was organised. A total 675 numbers of press clippings, 60 numbers of other SDI bulletins, 164 no. of back volumes and Vol.19 (1&2) 2006 of the journal *Natural Rubber Research* were distributed. A total of 112 RRII publications were sold and 116 numbers of *IRRDB Coffee Table Book* were distributed to officials of Rubber Board and others concerned in the rubber industry.

AGROMETEOROLOGY

1. Climate resource characteristics of rubber growing tracts

The data on rainfall, maximum temperature, minimum temperature and sunshine hours for Kottayam were analyzed for long-term trends of 53 years (1957 to 2007) in order to detect any significant change in the trend patterns observed. The total number of rainy days and rainfall amount were analyzed for weekly, monthly and seasonal trends. All the variables were subjected to trend analysis and the significance tested with the help of the standard Mann-Kendall statistics for significance.

1.1. Rainfall amount and total number of rainy days

There were no significant trends noted in the total annual rainfall amount on an annual and seasonal basis. For individual months, only the month of October showed an increasing trend (2.7 mm/year) in rainfall amount (Fig. Agromet. 1). There was a significant decrease in rainfall during the first week of March and it was estimated to be at 13.2 mm per 100 years. Decreasing trend was observed during the third week of August at 82.5 mm per 100 years. There was a significant decrease in total annual rainy days at 20.6 days per 100 years (Fig.

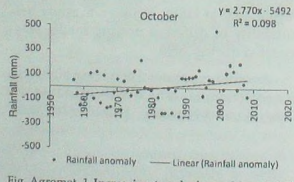

Fig. Agromet. 1. **Increasing trend of monthly rainfall amount in October for RRII, Kottayam**

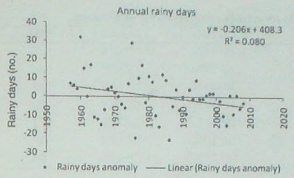

Fig. Agromet. 2. **Decreasing trend in annual rainy days**

Agromet. 2). The decrease was mainly contributed by the monsoon season (12.6 days in 100 years). No significant trends in rainy days were noted on a monthly and weekly basis. The above analysis indicates that there is a possible shift of the rainfall period away from the normal southwest monsoon period.

1.2. Temperature

Maximum temperature trends were significantly positive (99% significance level) over all the periods of weeks, months, seasons and year. However, week number 24 (second week of June) showed no trend at all. Positive trends in minimum temperature were highly significant when considered over an annual and seasonal basis. However, trends were only moderately significant (at 90%) during the months of December to February as also revealed by the individual weekly trends. The annual increase in maximum temperature was found to be 0.05° C per year and 0.03° C per year for the minimum temperature. These were in agreement with the general pattern reported earlier by Inter-governmental Panel for Climate Change (IPCC). For both the maximum and minimum temperatures, the rate of increase over the month of May was the highest during the summer season at 0.06°C per year and 0.04° C per year respectively. This is unlike the reported warming trend seen in both global daily maximum and minimum temperatures, with minimum temperatures increasing at a faster rate than maximum temperatures (IPCC, 2007). Week-wise analysis of both these parameters indicated that the 21st Standard Meteorological Week (SMW) i.e. third week of May showed the highest rate in temperature increase of 0.06° C per year and 0.039° C per year respectively.

1.3. Sunshine hours

Annual mean daily Bright Sunshine Hours (BSSH) showed a very high significant negative trend over the years (Fig. Agromet. 3). A decrease of 0.02 per year has been noted annually. Decline in sunshine hours was found to be highly significant during the winter and post-monsoon seasons. Consecutive weeks during these periods also showed a significant decline. The cooler month of January experienced the highest decline at 6 h/100 years with all the weeks having values above 5.8 h/100 years. The highest decline was noted during the fifth SMW, the last week of January.

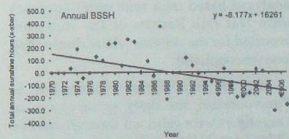

Fig. Agromet. 3. **Decreasing trend in annual bright sunshine hours at RRII, Kottayam**

2. Forewarning of pests and diseases

Experiments were initiated to study the major rubber diseases *viz.* abnormal leaf fall (ALF), powdery mildew and *Corynespora* leaf fall (CLF) in the traditional

Table Agromet. 1. **Experimental locations for studies on forewarning of diseases**

Locations	Latitude	Longitude	MSL
Jadkal, Kundapura, Dakshin Karnataka	13° 48'N	74° 47'E	35
Guthigar, Sullia, Dakshin Karnataka	12° 38'N	75°32'E	162
Adhur, Kasargode District, Kerala	10° 40'N	76° 08'E	30
RRS, Padiyoor, Kannur District, Kerala	11° 58'N	75° 36'E	20
RRII, Kottayam District, Kerala	09° 32'N	76° 36'E	73
Chemoni Estate, Trissur District, Kerala	10° 27'N	76° 24'E	45
Vaikundam Estate, Kanyakumari District, Tamil Nadu	08° 17'N	77° 43'E	40

regions. The stations were assessed for susceptibility to repeated attacks of the diseases and the daily leaf fall was recorded. A Stevenson Screen with maximum, minimum, dry bulb and wet bulb thermometers were used in the field. The disease intensity was assessed with the help of standard leaf baskets.

The field-based meteorological parameters recorded once - daily were maximum temperature, minimum temperature and rainfall and twice - daily recordings were of dry bulb and wet bulb temperatures installed in North Kerala and Karnataka (Table Agromet. 1). The morning and afternoon relative humidity and vapour pressure deficits were computed and analyzed based on a time series approach with leaf fall. Results of the study are reported for the stations where disease had been encountered.

In an experiment conducted at Pinavoorkudi, the daily spore counts of *Corynespora* were collected through exposed slides kept at four different heights of 1m interval within the canopy of mature trees of clone RRII 105. The twice daily based meteorological parameters were recorded from the field agrometeorological unit. Disease scorings were obtained from a 4-point scale every fortnight. The Humidity Thermal Index (HTI) which influences plant diseases had also been worked out. During

Table Agromet. 2. **Time series observation of spore count and HTI at four canopy height levels**

Date	Spore count at different height levels				HTI
	I	II	III	IV	
20-Jan-08	0.0	0.0	0.0	0.0	5.6
21-Jan-08	0.0	0.0	0.0	0.0	4.2
22-Jan-08	0.0	0.0	0.0	0.0	4.2
23-Jan-08	0.0	0.0	0.0	0.0	5.9
24-Jan-08	0.0	0.0	0.0	0.0	5.7
25-Jan-08	0.0	0.0	0.0	0.0	5.1
26-Jan-08	0.0	0.0	0.0	0.0	5.3
27-Jan-08	0.0	0.0	0.0	0.0	6.3
28-Jan-08	0.0	0.0	0.0	0.0	6.3
29-Jan-08	0.0	0.0	0.0	0.0	5.3
30-Jan-08	0.0	0.0	0.0	0.0	5.3
31-Jan-08	0.0	0.0	0.0	0.0	3.8
1-Feb-08	13.0	15.0	35.0	3.0	5.0
2-Feb-08	9.0	10.0	65.0	11.0	4.8
3-Feb-08	6.0	7.0	16.0	3.0	5.0
4-Feb-08	340.0	285.0	3487.5	200.6	4.8
5-Feb-08	131.3	24.4	150.0	50.6	5.3
6-Feb-08	519.4	99.4	56.3	56.3	4.7
7-Feb-08	474.4	106.9	24.4	99.4	4.9
8-Feb-08	131.3	112.5	125.6	155.6	4.3
9-Feb-08	43.1	5.6	31.9	37.5	4.3

the transition from tender light green stage to the mature green stage of the leaves, the spore count was found to be the maximum on certain days (Table Agromet. 2). These days coincided with the initial onset of the disease. Attempts at scoring the disease proved futile because of the simultaneous onset of severe *Oidium* disease. However, it was found that consecutive days with > 5.5

HTI did show the maximum number of spores after a period of six to eight days.

The maximum spore concentration was noted at 1m below the top of the canopy and the correlation worked out was at 0.85. The weather conditions noted at maximum spore counts are at maximum temperature 32.0 to 35.5° C, minimum temperature 9.0 to 23.0° C, RH (morning) >95 per cent and RH (afternoon) 46 to 73 per cent.

3. Agromet database management

New instruments were installed at CES Chethackal, RRS Dapchari and HBSS Nettana. Validation of meteorological data is being made for all stations. All research centres, private estates and several field stations are being monitored for accumulating data for various disease studies. Computer programs were designed for the data verification and processing.

ANNUAL EXPENDITURE

Expenditure at a glance (2007-08)

Head of Account	Expenditure (Rs. lakhs)
Non-Plan	
General charges	408.88
Projects (CES)	211.84
Total	620.72
Plan	
General charges	1196.88
NERDS Research Component	231.32
Total	1428.20
Grand total	**2048.92**

PUBLICATIONS

RESEARCH ARTICLES

Abraham, J. and Chudek, J.A. (2008). Studies on litter characterization using C^{13} NMR and assessment of microbial activity in natural forest and plantation crops (teak and rubber) soil ecosystems of Kerala, India. *Plant and Soil*, **303**: 265-273.

Chandrashekar,T.R. and Gireesh, T. (2008). Latex as yield may be better than rubber yield in juvenile screening for selection in rubber (*Hevea brasiliensis* Muell. Arg.). *Journal of Rubber Research*, **11** (1): 52-58.

Das, G., Chaudhuri, D. and Nazeer, M.A. (2008). Feasibility of tea-rubber interplanting in Dooars area of West Bengal. *Journal of Plantation Crops*, **36** (3): 368-371.

George, B., Maiti, S.N. and Varma, I.K. (2007). Impact modification of SAN using NR-g-SAN copolymers. *Journal of Material Science*, **42**: 8262-8270.

George, K.M., Rajammal, G., Geethakumariamma, M.L. and Mathew, N.M. (2007). Preparation and properties of low protein NR latex using stabilised liquid papain. *Journal of Rubber Research*, **10** (3):171-182.

George, K. M., Sebastian, T., Joseph, R. and Thomas, K.T. (2007). Breakdown behaviour and technological properties of natural rubber from selected *Hevea brasiliensis* clones. *Natural Rubber Research*, **20** (1-2): 15-22.

George, S., John, J., Joseph, P., Philip, A. and Punnoose, K. I. (2007). Impact of conservation pits on growth and yield of mature rubber. *Journal of Rubber Research*, **10** (1): 44-53.

Jacob, C.K., Srinivas, P., Prem, E.E., Manju, M.J., Mushrif, S.K. and Idicula, S.P. (2007). Rubber seed oil for partial substitution of mineral oil used as carrier for copper fungicide in the management of abnormal leaf fall disease of rubber. *Journal of Rubber Research*, **10** (1): 54-61.

Jacob, J. (2007). The kyoto protocol and the Indian natural rubber sector. *Planters' Chronicle*, **103** (6): 7-12.

Jayashree, R., Rekha, K., Jayasree, P.K., Sanju, R. and Thulaseedharan, A. (2007). Effect of colchicine on callus induction from isolated microspores in *Hevea brasiliensis*. *Plant Cell Biotechnology and Molecular Biology*, **8** (1-2): 89-92.

Jessy, M.D., Meera Bai, M., Nair, A.N.S. and Meti, S. (2007). Adaptability to low soil phosphorus in rubber trees (*Hevea brasiliensis*): Role of roots and arbuscular mycorrhizal fungi. *Journal of Plantation Crops*, **35** (3): 133-138.

Joseph, M., Sudhakumari, B., Punnoose, K.I. and Karthikakuttyamma, M. (2007). Response of rubber seedlings in the nursery to application of zinc. *Natural Rubber Research*, **20** (1-2):61-65.

Krishnan, B., Rao, K.N. and Nazeer, M.A. (2007). Growth performance of *Hevea brasiliensis* in a dry sub humid climate of Bastar region in central-eastern India. *Natural Rubber Research*, **20** (1-2):56-60.

Lakshmanan, R., Edathil, T.T., Chandrashekar, T.R. and Reghu, C.P. (2007). Effect of irrigation on growth and establishment of young rubber plants in a humid tropical region of India. *Natural Rubber Research*, **20** (1-2):23-31.

Mathew, F. and Reghu, C.P. (2007). Relationship of the angle of lean of trunk and growth eccentricity with tension wood formation in four clones of *Hevea brasiliensis*. *Natural Rubber Research*, **20** (1-2): 82-86.

Mathew, S. and Varghese, S, Rajammal, G and Thomas, P.C. (2007). Dipping characteristics of natural rubber layered silicate nanocompoistes. *Journal of Applied Polymer Science*, **104**(1):58-65.

Mohanakumar, S. (2008). Sources of instability in natural rubber price: An analysis in the post-reform phase. *Journal of Plantation Crops*, **36** (3): 517-523.

Mondal, G.C., Deka, H.K. and Chaudhuri, D. (2007). Reaction of *Hevea brasiliensis* clones against powdery mildew disease in north-eastern region of India. *Natural Rubber Research*, **20** (1-2):90-93.

Mondal, G.C., Singh, R.P., Mandal, D., Gohain, T., Chaudhuri, D., Nazeer, M.A. and Nair, R.B. (2007). Evaluation of yield potential of *Hevea brasiliensis* clones over ten years of tapping in Assam. *Natural Rubber Research*, **20** (1-2): 32-38.

Mydin, K.K. and Mercykutty, V.C. (2007). High yield and precocity in the RRII 400 series hybrid clones of rubber. *Natural Rubber Research*, **20** (1-2): 39-49.

Priya, P., Venkatachalam, P. and Thulaseedharan, A. (2007). Differential expression pattern of rubber elongation factor (REF) mRNA transcripts from high and low yielding clones of rubber tree (*Hevea brasiliensis* Muell. Arg). *Plant Cell Reports*, **26**: 1833-1838.

Priya, P., Venkatachalam, P. and Thulaseedharan, A. (2007). Molecular cloning of rubber elongation factor protein cDNA from *Hevea brasiliensis* Muell. Arg. and its heterologous expression in *Escherichia coli* and *Nicotiana tabacum*. *Current Science*, **93** (8):1077-1079.

Reghu, C.P., George, B.P. and Varghese, Y.A. (2007). Screening of *Hevea brasiliensis* germplasm for wood quality using Cinnamyl Alcohol Dehydrogenase (CAD) activity and lignification pattern. *Natural Rubber Research*, **20** (1-2):1-8.

Rejikumar, R., Hussain, N.S. and Philip, J. (2007). Measurement of dry rubber content of natural rubber latex with a capacitive transducer. *Journal of Rubber Research*, **10** (1):17-25.

Reju, M.J., Thapliyal, A.P., Singh, R.P., Soman, T.A., Nazeer, M.A. and Varghese, Y.A. (2007). Promising *Hevea brasiliensis* clones for the sub-tropical climate of Meghalaya. *Natural Rubber Research*, 20 (1-2):50-55.

Saha, T., Roy, C.B., Ravindran, M., Bini, K. and Nazeer, M.A. (2007). Allelic diversity revealed through SSR polymorphisms at the locus encoding HMG-CoA reductase in rubber (*Hevea brasiliensis*). *Silvae Genetica*, 56 (2): 58-65.

Singh, R.P., Deka, H.K. and Chaudhuri, D. (2007). Comparative efficiency of two cover crops on soil enrichment, accumulation of nutrients, microbial population and growth of *Hevea brasiliensis* in Meghalaya. *Natural Rubber Research*, 20 (1-2): 66-73.

Sobhana, P., Jacob, J. and Sethuraj, M.R. (2007). Rootstock -scion relationships in budgrafted plants with special reference to *Hevea brasiliensis*. *Natural Rubber Research*, 20 (1-2): 94-107.

Sreelatha, S., Simon, S.P., Kurup, G.M. and Vijayakumar, K.R. (2007). Biochemical mechanisms associated with low yield during stress in *Hevea* clone RRII 105. *Journal of Rubber Research*, 10 (2): 107-115.

Stephen, R., Raju, K.V.S.N., Varghese, S., Joseph, K., Oommen, Z. and Thomas, S. (2007). Dynamic mechanical and dielectric properties of nanocomposites of natural rubber and carboxylated styrene-butadiene rubber (XSBR) latices and their blends. *Rubber Chemistry and Technology*, 80(4): 672-689.

Varghese, L., Thomas, K.T. and Mathew, N.M. (2007). Formaldehyde treatment of field coagulum for quality improvement of technically specified rubber. *Natural Rubber Research*, 20 (1-2): 77-81.

Venkatachalam P., Jayasree, P.K., Sushamakumari, S., Jayashree, R., Rekha, K., Sobha, S., Priya, P., Kala, R.G. and Thulaseedharan, A. (2007). Current perspectives on application of biotechnology to assist the genetic improvement of rubber tree (*Hevea brasiliensis* Muell.Arg.): An overview. *Functional Plant Science and Biotechnology*. 1: 1-17.

Venkatachalam, P., Thulaseedharan, A. and Reghothama, K. (2007). Identification of expression profiles of tapping panel dryness (TPD) associated genes from the latex of rubber tree (*Hevea brasiliensis* Muell. Arg.) *Planta*, 226: 499-515.

CONFERENCE/SYMPOSIA PAPERS

Alex, R., Cherian., T., Varghese, L., Joseph, S., Vidya, G. and Thomas, K.T. (2007). Mechanical properties of rubber obtained through fatty acid sensitized coagulation of fresh natural rubber latex. *International Rubber Conference and Expo: Recent Advances in Rubber Science and Allied Material Technology*, 1-3 November 2007, Udaipur, India.

Alex, R., Kuriakose, B., Claramma, N. M. and Thomas, K.T. (2008). Plasticity and cure behaviour of skim rubber obtained by a creaming process. *International Conference on Rubber and Rubber like Materials*, 8-10 January 2008, Kharagpur, India.

Bini, K., Ravindran, M. and Saha, T. (2008). Development of trinucleotide microsatellite markers from an enriched genomic library of rubber (*Hevea brasiliensis*). *National Symposium on From Chromosomes to Genomes: Challenges and Prospects*, 26-28 March 2008, University of Kerala, Thiruvananthapuram, India.

Geetha, N., Sobhana, P., Thomas, M., Sathik, M.B.M., Mani, R.M. and Jacob, J. (2007). Root stock influences gene expression in budgrafted *Hevea brasiliensis*. *International Conference on New Horizons in Biotechnology (NHBT, 2007)*, 26-29 November 2007, Thiruvananthapuram, India.

George, K.M., Alex, R., Joseph, S. and Thomas, K.T. (2008). Deproteinization and easy coagulation of skim latex. *International Conference on Rubber and Rubber like Materials*, 8-10 January 2008, Kharagpur, India.

George, K.M., Rajammal, G., Joseph, S. Varghese, T.C., and Mathew, N.M. (2007). Deproteinized natural rubber latex and its use in the manufacture of medical gloves. *Seminar on Frontiers in Latex Technology*, 14 July 2007, Thiruvananthapuram, India,

George, K.M., Varkey, J.K., Joseph, S. and Thomas, K.T. (2007). Studies on carbon black filled blends of acrylonitrile butadiene rubber and epoxidised natural rubber. *International Rubber Conference and Expo: Recent Advances in Rubber Science and Allied Material Technology*, 1-3 November 2007, Udaipur, India.

George, S., John, J., Philip, A., and Nair, N.U. (2008). Runoff management technique for soil conservation and water harvesting in rubber plantations. *International conference on conservation farming systems and watershed management in Rainfed Areas for Rural Employment and Poverty Eradication*, 12-16 February 2008, NASC Complex, New Delhi, India.

Gopalakrishnan, J., Thomas, M. and Jacob, J. (2007). Inositols: A potential secondary metabolite in natural rubber latex. *XVII Swadeshi Science Congress*, 6-8 November 2007, The Zamorins Guruvayurappan College, Kozhikode, India.

Jessy, M.D., Meti, S. and Nair, N.U. (2008). Crop diversification for early income better growth and yield of rubber trees (*Hevea brasiliensis*). *International*

Conference on Conservation Farming Systems and Watershed Management in Rainfed Areas for Rural Employment and Poverty Eradication. 12-16 February 2008, NASC Complex, New Delhi, India.

Joseph, J. and Dey, S. K. (2008). Primary processing of natural rubber. *Golden Jubilee Celebrations of Rubber Plantation Extension*, 18 March 2008, NRETC, Agartala, India.

Joseph, J., Thomas, M., Geetha, N. and Jacob, J. (2007). Differential expression of transcripts in *Hevea* clones under water stress. *International Conference on New Horizons in Biotechnology (NHBT, 2007)*, 26-29 November 2007, Thiruvananthapuram, India.

Mandal, D., Dey, S. K. and Baruah, T.C. (2007). Form of potassium and their distribution in rubber growing soils of Tripura. *National Seminar on Developments in Soil Science*, 2-5 November 2007, Birsa Agricultural University, Ranchi, India.

Philip, S., Joseph, K., Kareem, A.V.K., Sneha, P., Abraham, A., Elias, R.S., Joseph, A. and Jacob, C.K. (2007). Antifungal activity of endophytic bacteria against major leaf diseases of *Hevea brasiliensis*. *Microbes: Biofactories of the Future: Abstracts. 48th Annual Conference, Association of Microbiologists of India*, 18-21 December 2007, Indian Institute of Technology, Chennai, India.

Ray, D., Dey., S.K. and Jacob, J. (2007). Leaf nitrogen content is an indication of predisposition to photo inhibitory damage in *Hevea brasiliensis* seedlings under low temperature stress. *National Seminar on Plant Physiology (Physiological and Molecular Approaches for Increasing Yield and Quality of Agricultural, Horticultural and Molecular Plants Under Changing Environment)*, 29 November-1 December 2007, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, India.

Sathik, M.B.M., Philip, S., Musthapha, P.M., Jose, R.M., Joseph, K., Elias, R.S., Jacob, C.K. and Jacob, J. (2007). Engineering transient expression of chitinase in endosymbionts: An approach to control *Corynespora* leaf disease in *Hevea brasiliensis*. *International Conference on New Horizons in Biotechnology (NHBT, 2007)*, 26-29 November 2007, Thiruvananthapuram, India.

Sathik, M.B.M., Jose, R. M., Joseph, K., Kochunni, D.T., Thomas, M. and Jacob, J. (2007). Transcriptome analysis of healthy and trees affected with Tapping Panel Dryness in *Hevea brasiliensis*. *International Conference on New Horizons in Biotechnology (NHBT, 2007)*, 26-29 November 2007, Thiruvananthapuram, India.

Singh, R.P. (2007). Fertility status of soil of shifting cultivation sites in Garo hills of Meghalaya- A case study. *National Seminar on Development of Soil Scientce-2007: 72nd Annual Convention of Indian Society of Soil Science*, 2-5 November 2007, Birsa Agricultural University, Ranchi, India.

Singh, R.P. and Joseph, M. (2008). Soil fertility evaluation of the rubber growing rainfed areas of Meghalaya.*International Conference on Conservation Farming Systems and Watershed Management in Rainfed Areas for Rural Employment and Poverty Eradication*, 12-16 February 2008, Soil Conservation Society of India, National Agricultural Science Centre Complex, New Delhi, India.

Thomas, M., Scheffner, A.R., Birgit, G., Saha, T., Sathik, M.B.M., Joseph, J., Geetha, N. and Jacob, J. (2007). Detection of drought responsive genes in *Hevea brasiliensis* using micro array hybridization technique. *International Conference on New Horizons in Biotechnology (NHBT, 2007)*, 26-29 November 2007, NIIST, Thiruvananthapuram, India.

Thomas, V. (2007). Performance of RRII 400 series clones in the small grower's field: An Overview. *Rubber Growers Conference*, 25 October 2007, Rubber Research Institute of India, Kottayam, India.

Varghese, L., Nair, M.K.B., Thomas, K.T. and George, V. (2007). Studies on low temperature preservation of field latex. *International Rubber Conference and Expo: Recent Advances in Rubber Science and Allied Material Technology*, 1-3 November 2007, Udaipur, India.

Varghese, S. (2007). Preparation, structure-property relationship and applications of layered silicate rubber nanocomposites. *International Conference on Natural Polymers, Biopolymers, Biomaterials, their Composites, Blends, IPNs and Gels: Macro and Nano Scales*, 19-21 November 2007, Kottayam, India.

Varghese, S. and Mathew, S. (2007). Rheology and shapability of natural rubber latex layered silicate nanocomposites. *International Conference on Latex and Latex Based Products*, 23-24 January 2008, Madrid, Spain.

Varghese, S. and Thomas, K.T. (2007). Effect of clay type on the mechanical and barrier properties of natural rubber layered silicate nanocomposites. *International Seminar on Elastomers*, 23-27 September 2007, Freiburg, Germany.

Venkatachalam, P., Priya, P., Jayashree, R., Rekha, K. and Thulaseedharan, A. (2007). Molecular cloning and characterization of a 3-hydroxy-3-methylglutaryl-coenzyme a reductase 1 (hmgr 1) gene from rubber tree (*Hevea brasiliensis* Muell.Arg.): A key enzyme involved in isoprenoid biosynthesis, *International Conference on New Horizons in Biotechnology (NHBT, 2007)*, 26-29 November 2007, NIIST, Thiruvananthapuram, India.

Venkatachalam, P., Priya, P. and Thulaseedharan, A. (2007). Molecular cloning and characterization of a farnesyl diphosphate synthase I (fdpl) gene from rubber tree (*Hevea brasiliensis* Muell.Arg.): *International Conference on New Horizons in Biotechnology (NHBT, 2007)*, 26-29 November 2007, NIIST, Thiruvananthapuram, India.

BOOK CHAPTERS

Annamalainathan, K. and Jacob, J. (2007). Possible role of alternative respiration in plants. In: *Plant Physiology: Current Trends* (Ed. P.C. Trivedi). Pointer Publications, Jaipur, pp. 135-152.

Clement, D. A., Priyadarshan, P.M., Hoa, Tran Thi Thuy. and Venkatachalam, P. (2007). *Hevea* rubber breeding and genetics In: *Plant Breedings Reviews*. V. 29 (Ed. Jules Janick). John Wiley & Sons, New Jersey, pp. 177-283.

Jayashree, R., Rekha, K., Sushamakumari, S. and Thulaseedharan, A. (2007). Establishment of callus cultures from isolated microspores of *Hevea brasiliensis* from leaf explants. In: *Recent trends in Horticultural Biotechnology* (Eds. R. Keshavachandran, P.A. Nazeem, D. Girija, P.S. John and K.V. Peter). New India Publishing Agency, New Delhi, pp.385-390.

Kala, R.G., Jayasree, P.K, Sushamakumari, S., Sobha, S., Rekha, K. and Thulaseedharan. A (2007). *In vitro* regeneration of *Hevea brasiliensis* from leaf explants. In: *Recent trends in Horticultural Biotechnology* (Eds. R. Keshavachandran, P.A. Nazeem, D. Girija, P.S. John and K.V. Peter). New India Publishing Agency, New Delhi, pp.223-228.

Karunaichamy, K., Vijayakumar, K.R., Thomas, K.U. and Rajagopal, R. (2008). Approaches towards low cost harvesting technologies in rubber (*Hevea brasiliensis*). In: *Forest Biodiversity:* Vol.1 (Eds. K. Muthuchelian, S. Kannaiyan and A. Gopalan). Associated Publishing Company, New Delhi, pp.64-74.

Rekha, K., Jayashree, R., Sushamakumari, S., Sankariammal, L. and Thulaseedharan, A. (2007). Endosperm culture in *Hevea brasiliensis*. In: *Recent trends in Horticultural Biotechnology* (Eds. R. Keshavachandran, P.A. Nazeem, D. Girija, P.S. John and K.V. Peter). New India Publishing Agency, New Delhi, pp.111-116.

Varghese, Y.A. and Abraham, S.T. (2007). Rubber (*Hevea brasiliensis*). In: *Biodiversity in Horticultural Crops*. Vol. 1. (Eds. K.V. Peter and Z. Abraham). Daya Publishing House, New Delhi, pp. 340-364.

BOOKS

Jojomon, M. (2007). Rubberkrishiyum paripalanavum (Malayalam). Rubber Research Institute of India, Kottayam, India, 99 p.

Thomas, V., Meenakumari, T., Gireesh, T. and Varghese, Y. A. (2007). RRII 400 parambara rubber inangal: roopaparamaya saviseshathakalum thirichariyalum. (Malayalam). P&PR Division, Rubber Board, Kottayam, India, 46 p.

PATENTS

Varghese, S., Kuriakose, B., and Mathew, N.M. (2007). Trolley for sunlight-cum-smoke drying of natural rubber sheets. *Indian Patent No.* 212512 dated 31.12.2007.

Patent No: 217042 dated 24-03-2008 "Rubber – silica composite with ENR as a reinforcement modifier." Inventers: Jacob K. Varkey, Susamma Joseph and Mariamma George K. (Indian Patent No. 217042 dated 24/03/08)

POPULAR ARTICLES

Alex, R. (2007). Rubber paalile DRC kandupidikkan noothana margam. *Rubber*, **493**: 13-14 (Malayalam).

Chandy, B. (2007). Pookkalaayi viriyunna rubberilakal. *Rubber*, **500**: 28-29 (Malayalam).

George, K.M., Rajammal, G., Joseph, S., Varghese, T.C. and Mathew, N.M. (2007). Stabilised liquid papain can deproteinize NR latex. *Rubber Asia*, **21** (5): 81-84.

Jacob, C.K. (2008). SALB: Rubberinte janmanattile shathru. *Rubber*, **503**: 29-31 (Malayalam).

Jose, V.T. (2007). Rubber thottangalum kothuku niyanthranavum. *Rubber*, **496**: 14-17 (Malayalam).

Joseph, A. (2007). Rubberinu podikkumil rogam. *Rubber*, **501**: 12-13 (Malayalam).

Joseph. J. (2008). MFN tariff and value of imports of rubber and rubber products under the WTO regime. *Rubber*, **502**:37. (Malayalam).

Meenakumari, T., Thomas,V., Thomas, J., Reghu, C.P. and Saraswathyamma, C.K. (2007). Uthejakavushadhavum rubber thadiyum. *Rubber*, **493**: 19-21 (Malayalam).

Meenakumari, T., Thomas, V., Reghu, C.P. and Varghese, Y.A. (2007). Latex-timber clonukal: Thadiyude prasakthi. *Rubber*, **495**: 8-10 (Malayalam).

Meenakumari, T., Mydin, K.K. and Varghese,Y.A. (2008). RRII 400 parampara clonukal: Cherukida gaveshana phalangal. *Rubber*, **504**: 15-16 (Malayalam).

Mercykutty, V.C. (2007). Rubber nursery thudangumpol. 4. Thaithavarana. II. *Rubber*, **493**: 41 (Malayalam).

Mercykutty, V.C. (2007). Rubber nursery thudangumpol. 5. Budding reethikal- Green budding. *Rubber*, **494**: 15-18 (Malayalam).

Mercykutty, V.C. (2007). Rubber nursery thudangumpol. 6. Brown budding. *Rubber*, **495**: 24-26 (Malayalam).

Mercykutty, V.C. (2007). Rubber nursery thudangumpol. 7. Ottuthaikuttikalum koodathaikalum. *Rubber*, **497**: 16-18 (Malayalam).

Mercykutty, V.C. (2007). Rubber krishi: Chila samsayangalum marupadikalum. *Rubber*, **499**: 25-26 (Malayalam).

Mohanakumar, S. (2007). Dollarinte moolyasoshanavum rubber kayattumathiyum. *Rubber*, **496**: 20-21 (Malayalam).

Mohanan, K.G. and Nair, R. B. (2008). Cherukida rubber thottangalile pradesika vyathyasamanusarichulla aadaya vyathyasavum athinulla kaaranavum: Oru pradhamika padanam. *Rubber Mithram*, **10**: 56-58 (Malayalam).

Nair, A.N.S. (2007). Tap cheyyunna rubberinu vala prayogam. *Rubber*, **500**: 31-33 (Malayalam).

Pillai, V. and Sasidharan, K.K. (2007). Foam methakalude nirmanam. *Rubber*, **499**: 13-14 (Malayalam).

Rajammal, G. (2007). Vipaniyil labhyamaya vividhatharam rubber paal. *Rubber*, **495**: 15-17 (Malayalam).

Ray, D. (2007). Ensure quality planting materials for better productivity of NR in future: An opinion. *Rubber Samachar*; October-December: 5-6. (Bengali).

Reghu, C.P. and Thomas, J. (2007). Rubber thadi. 1. Rubber clonukalum thadi uthpadanavum. *Rubber*, **501**: 16-17 (Malayalam).

Reghu, C.P. and Thomas, J. (2008). Rubber thadi. 2. Rubberinangalum tahdiyude bhowthika swabhavangalum. *Rubber*, **502**: 17-18 (Malayalam).

Reghu, C.P. and Thomas, J. (2008). Rubber thadi. 3. Rubberinangalum thadiyude sankocha vikasa swabhavavum. *Rubber*, **504**: 17-19 (Malayalam).

Sasidharan, K.K. (2007). Nippilum kalippattangalum. *Rubber*, **494**: 19. (Malayalam).

Sasidharan, K.K. (2007). Rubber samskaranam: Rasavasthukkalum aarogya prasnavum. *Rubber*, **496**: 24-25 (Malayalam).

Sasidharan, K.K. (2007). Rubberum medical uthpannangalum. *Rubber*, **500**: 24-25 (Malayalam).

Sasidharan,K.K. (2007). Rubberuthpanna nirmanavum dipping mechinukalum. *Rubber*, **498**: 15 (Malayalam).

Sasidharan, K.K. (2007). Quality enhancement through nanotechnology. *Rubber Asia*, **22** (1): 47-48.

Sebastian, S., George, V. and Thomas, E.V. (2007). Application of low protein latex for laboratory scale production of examination gloves. *Rubber India*, **LIX** (3): 23-27.

Singh, R.P. (2007). A golden chance for needs of dry land farmers through bio-fuel plantation. *Rubber Samachar*, **84-85**: 5-7. (Hindi).

Soman, T. A. and Varghese, Y.A. (2007). Kappu thaikal: Rubberinoru naveena nadeel reethi. *Rubber*, **493**: 9-11 (Malayalam).

Soman, T.A. and Varghese, Y.A. (2008). Root trainer thaikal. *Rubber*, **503**: 16-18. (Malayalam).

Thomas, K.U. (2007). IUT: Prayogikamo ?. *Rubber*, **496**: 11-13 (Malayalam).

Thomas, K.U. (2008). Venalkkalathu tapping thudaramo?. *Rubber*, **503**: 6-7 (Malayalam).

Thomas, V. (2007). Vietnam Visesham. 3. Yudham thalarthiya Vietnam. *Rubber*, **493**: 22-23 (Malayalam).

Thomas, V. (2007). Eerandan thaikal? *Rubber*, **495**: 14 (Malayalam).

Thomas, V. (2007).The changing face of Vietnam rubber. *Rubber Asia*, , **21** (3); 158-162.

Thomas, V. (2007). Vietnam Visesham. 4. Vietnamile rubber krishi. Rubber, **495**: 32-33 (Malayalam).

Thomas, V. (2007). Rubber thaikal pidichukettanam. *Rubber*, **497**: 19 (Malayalam).

Thomas, V. (2007). Gunanilavaaramulla nadeel vasthukkal upayogikkuka. *Rubber*, **498**: 6 (Malayalam).

Thomas, V. and Varghese, Y.A. (2007). RRII 400 parampara: Rubber karshakarude saakshyam. Rubber, **496**: 9-10 (Malayalam).

Thomas, V. and Thomas, R.M. (2007). Baisan vaaliyil faciation. *Rubber*, **500**: 39 (Malayalam).

Thomas, V., Ramachandran, P.K. and Satheeshchandran, R. (2007). Manal parambile pareekshanam. *Rubber*, **501**: 21 (Malayalam).

Thomas, V. (2008). Amusing fasciation noticed in Kerala's rubber plantations. *Rubber Asia*, **22** (1): 83.

Thomas, V., Rajeev, K.P. and Sunilkumar, P.G. (2008). Veendum chila sayamees rubber marangal. *Rubber*, **504**: 29 (Malayalam).

Varghese, L. (2007). Ottupaalinte gunamenmayum block rubber uthpadanavum. *Rubber*, **497**: 6-7 (Malayalam).

Varghese, L. (2008). Rubber paal sheettakkumpol sradhikkenda karyangal. *Rubber*, **504**: 23-24 (Malayalam).

Varghese, L., Geethakumariamma, M.L., Thomas, K.T. and Mathew, N.M. (2007). Effect of storage on properties of marketable forms of natural rubber: Influence of humidity and temperature. *Rubber South News*, **3** (3): 7-10.

Varghese, L., Geethakumariamma, M.L., Thomas, K.T. and Mathew, N.M. (2008). Effect of storage on properties of marketable forms of natural rubber: Influence of humidity and temperature. *Rubber India*, **LX**; 3: 39-46.

Varghese, Y.A. (2007). Valaratte pala clonukal oru rubber thottathil. *Karshakan*, **15(4)**: 66 (Malayalam).

Varghese, Y.A. and Jacob, C.K. (2007). Puthiya rubberinangal bhaviyude vagdaanam. *Rubber*, **496**: 6-8 (Malayalam)

Varghese, Y.A. and Mydin, K.K. (2008). Nannooru paramparayinangalum uthpadanakshamathayum. *Rubber*, **503**: 11-13 (Malayalam).

GENBANK SUBMISSION

Saha, T., Roy, C.B. and Ravindran, M. (2007). Cloning and characterization of resistance gene analogs from *Hevea* species: 22 NBS resistance protein gene. Partial cds Accession Nos. EF 494705- EF 494726

SCIENTIFIC AND SENIOR SUPPORTING PERSONNEL

Director of Research
James Jacob, M.Sc., Ph.D., DIC, Ph.D.

Agronomy / Soils Division	
N. Usha Nair, M.Sc. (Ag.), Ph.D.	Joint Director
Mercykutty Joseph, M.Sc. (Ag.), Ph.D.	Senior Scientist
Elsie S. George, M.Sc.	Scientist C
D.V.K. Nageswara Rao, M.Sc. (Ag.), Ph.D.	Scientist C (resigned w.e.f. 13.07.07)
Sherin George, M.Sc. (Ag.), Ph.D.	Scientist C
M.D. Jessy, M.Sc. (Ag), Ph.D.	Scientist C
V.K. Syamala, M.Sc.	Scientist S3
Joshua Abraham, M.Sc., Ph.D.	Scientist S3
Annie Philip, M.Sc.	Scientist S3
P. Prasannakumari, M.Sc., Ph.D.	Scientist S3
Shankar Meti, M.Sc. (Ag.)	Scientist S3
Phebe Joseph, M.Sc. (Ag.)	Junior Scientist (EOL up to 24.05.08)
Aleyamma Augusthy, B.Sc., Dip.N.R.P.	Technical Officer
M.J. Thomas, B.Sc.	Assistant Technical Officer
Molly Pothen, B.Sc.	Assistant Technical Officer
K.S. Krishnakumari, B.Sc.	Assistant Technical Officer
P.A. Joykutty	Assistant Farm Superintendent
Antony P. Antony	Senior Scientific Assistant
B. Sudhakumari	Senior Scientific Assistant
Fertilizer Advisory Group	
A.N. Sasidharan Nair, M.Sc.	Scientist D
P.M. Mathews, M.Sc. (Ag.), Ph.D.	Scientist B
A. Ulaganathan, M.Sc.	Scientist S3
K.K. Ambily, M.Sc.	Scientist S2
C.K. Chacko, B.Sc.	Technical Officer
Botany Division	
Kavitha K. Mydin, M.Sc. (Ag.), Ph.D.	Senior Scientist
J. Rajeswari Meenattoor, M.Sc. (Ag.)	Scientist C (EOL w.e.f. 3.4.06)
V.C. Mercykutty, M.Sc., Ph.D.	Scientist C
L. Sankariammal, M.Sc., Ph.D.	Scientist C
Vinoth Thomas, M.Sc., Ph.D.	Scientist C
T. Meenakumari, M.Sc., Ph.D.	Scientist S2
T. Gireesh, M.Sc., Ph.D.	Scientist S2
Sobhana Sankar, M.Sc., B.Ed.	Assistant Technical Officer
K.K. Kunjachan	Assistant Farm Superintendent
T.G. Sasi	Assistant Farm Superintendent
P.C. Santhamma, M.Sc., B.Ed.	Senior Scientific Assistant
Germplasm Division	
Y. Annamma Varghese, M.Sc., Dr. Sc. (Ag.), Ph.D.	Joint Director
C.P. Reghu, M.Sc., Ph.D.	Senior Scientist
G. Prabhakara Rao, M.Sc. (Ag.)	Botanist (HG)
Saji T. Abraham, M.Sc. (Ag.), Ph.D.	Scientist S3 (EOL up to 16.4.08)
Jayashree Madhavan, M.Sc. (Ag.), Ph.D.	Scientist C
M.A. Mercy, M.Sc. (Ag.), Ph.D.	Scientist S3
Biotechnology Division	
A. Thulaseedharan, M.Sc., Ph.D.	Deputy Director

S. Sushamakumari, M.Sc., Ph.D.	Senior Scientist
P. Kumari Jayasree, M.Sc.	Scientist C
R.G. Kala, M.Sc.	Scientist C
P. Venkatachalam, M.Sc., Ph.D.	Scientist S3
R. Jayashree, M.Sc.	Scientist S3
K. Rekha, M.Sc. (Ag.)	Scientist S2
S. Sobha, M.Sc., L.L.B.	Scientist S2

Genome Analysis Laboratory

Thakurdas Saha, M.Sc., Ph.D.	Senior Scientist
K.U. Thomas, M.Sc.	Scientist A

Plant Pathology Division

C. Kuruvilla Jacob, M.Sc. (Ag.), Ph.D.	Joint Director
Jacob Mathew, M.Sc., Ph.D.	Senior Scientist
Annakutty Joseph, M.Sc., Ph.D.	Senior Scientist
S. Thankamony, M.Sc., Ph.D.	Entomologist
V.T. Jose, M.Sc. (Ag.), Ph.D.	Scientist C
Kochuthresiamma Joseph, M.Sc., Ph.D.	Scientist C
Shammi Raj, M.Sc., Ph.D.	Agrometeorologist (Scientist C)
Shaji Philip, M.Sc, Ph.D.	Scientist C
E. Edwin Prem, M.Sc. (Ag.)	Scientist S2
C. Bindu Roy, M.Sc., Ph.D.	Assistant Mycologist
Sadanand K. Mushrif, M.Sc. (Ag.)	Scientist S2 (study leave from 20.03.07)
P.M. Levy Joseph, B.Sc., Dip.NRP.	Technical Officer (retired w.e.f. 31.10.07)
T.V. Thomas	Assistant Farm Superintendent

Plant Physiology Division

R. Krishnakumar, M.Sc., Ph.D.	Senior Scientist
P. Sobhana, M.Sc., Ph.D.	Scientist C
Molly Thomas, M.Sc., Ph.D.	Scientist C
K. Annamalainathan, M.Sc., M.Phil, Ph.D.	Scientist C
D. Bhuvanendran Nair, M.Sc., Ph.D.	Scientist C
S. Sreelatha, M.Sc., Ph.D.	Scientist C
M.B. Mohammed Sathik, M.Sc., M.Phil, Ph.D.	Scientist S3
Jayasree Gopalakrishnan, M.Sc., M.Phil.	Scientist S3
N. Geetha, M.Sc., Ph.D.	Scientist S2
S. Visalakshy Ammal, B.Sc.	Technical Officer
T.V. Somaraj	Asst. Farm Superintendent
A.K. Peeusmon	Asst. Farm Superintendent
M. Jojomon	Asst. Farm Superintendent

Exploitation Technology Division

K.U. Thomas, M.Sc., Ph.D.	Senior Scientist
R. Rajagopal, M.Sc., M.Phil., Ph.D., Dip. Stat.	Scientist C
K. Karunaichamy, M.Sc., Ph.D.	Scientist C
P. Ajithkumar	Asst. Farm Superintendent

Rubber Technology Division

K.T. Thomas, M.Sc., LPRI, M.Tech., Ph.D.	Deputy Director
N.M. Claramma, M.Sc., Ph.D.	Senior Scientist
Rosamma Alex, M.Sc., LPRI, M.Tech, Ph.D.	Senior Scientist
K. Mariamma George, M.Sc.	Scientist C
N. Radhakrishnan Nair, M.Sc., M.Tech., MBA, Ph.D.	Scientist C
Jacob K. Varkey, M.Sc., M.Tech., Ph.D	Scientist C
Siby Varghese, M.Sc., Ph.D.	Scientist C
K.N. Madhusoodanan, M.Sc.	Scientist C
Leelamma Varghese, M.Sc., PGDHRM	Scientist C
Benny George, M.Sc., Ph.D.	Scientist C
Manoj Kurian Jacob, M.Sc.	Scientist A

Valsa George, M.Sc.	Assistant Technical Officer
Treasa Cherian, M.Sc.	Senior Scientific Assistant
Soosamma Joseph, M.Sc.	Senior Scientific Assistant
M.L. Geethakumariamma, M.Sc., Ph.D.	Senior Scientific Assistant
C. Madheswaran, B.A.	Technical Assistant (Glass Blowing)

Technical Consultancy Division

P. Viswanathan Pillai, M.Sc.	Deputy Director
G. Rajammal, M.Sc., M. Tech., LPRI, PGDBA	Rubber Technologist
K.C. Mary, B.Sc.	Assistant Technical Officer
P. Nishiath Rahman, M.Tech.	Assistant Rubber Technologist
K.S. Mohandas, M.Sc., M.Tech.	Assistant Rubber Technologist
Sheela Joseph, M.Sc., B.Ed., M. Tech.	Senior Scientific Assistant
K.I. Elizabeth, M.Sc., M.Tech., Ph.D.	Senior Scientific Assistant

PCRF

P.S. Sadeesh Babu, B. Tech., PGDBA	Rubber Chemist
I. John Britto	Radiation Safety Officer

Economics Division

K. Tharian George, M.A., Ph.D.	Joint Director
Toms Joseph, M.A.	Scientist C (working arrangement at H.O. w.e.f. 17.08.07)
Binni Chandy, M.A.	Scientist S3
S. Mohanakumar, M.A., M.Phil.	Scientist S3
S. Veeraputhran, M.A., M. Phil.	Scientist S3 (on deputation w.e.f. 01.08.07)
S. Lakshmi, M.Sc. (Ag.), Ph.D.	Scientist S2 (resigned w.e.f. 21.12.07)
K. Sreelakshmi, M.Sc. (Ag.), Ph.D.	Junior Scientist (resigned w.e.f. 25.05.07)

Project Monitoring

M.A. Nazeer, M.Sc., Ph.D.	Joint Director

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 (resigned w.e.f 19.07.07)
A.S. Ajitha, M.A., M.L.I.Sc.	Librarian (Documentation)
V.R. Sujatha, B.Sc., M.L.I.Sc.	Technical Assistant (HG)

Statistics and Computer

Ramesh B. Nair, M.Sc. (Ag. Stat.)	Assistant Director
B. Biju, M.Sc., M.C.A.	Assistant Director (Systems)
Suma George, P.G.D.C.A., M.C.A., B.Ed.	Computer Assistant
P. Aneesh, M.Sc., P.G.D.C.A.	Statistical Inspector

Instrumentation

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
M.R. Anilkumar, Dip. in Inst. Tech.	Assistant Instrumentation Officer

Administration

V. Ramakrishnan	Dy. Secretary (Admn.)
K.K. Saramma	Assistant Secretary
R. Babu	Assistant Secretary
P.N. Devarajan	Section Officer

Accounts

P.V. George, M.Com., M.B.A.	Joint Director (Finance)
K. Vijayamma, B.Com., P.G. Dip. in FM.	Assistant Director (Finance)

Benoy Varghese, B.Sc., P.G.D.C.A., A.I.C.W.A.	Accounts Officer
V.V. Suresh Kumar	Assistant Accounts Officer
P. Seetha Lakshmi	Section Officer

Maintenance

K.P. Sajeev, B.E.	Estate Officer
T. Manoj, B.E.	Assistant Engineer (Civil)

Experiment Station at RRII

P.M. Narayanan	Assistant Estate Superintendent
Mary Mathew	Senior Pharmacist

Security Wing

M.T. Varghese, M.A.	Assistant Security Officer

Central Experiment Station, Chethackal, Kerala

Sabu P. Idicula, M.Sc.(Ag.)	Deputy Director
Jacob Abraham, B.Sc., M.B.B.S.	Medical Officer
Zacharia Kurian, M.Com., A.C.A.	Assistant Director (Finance)
Mary Verghese, M. Sc. (Ag.)	Junior Scientist
V.S. Govindankutty	Farm Superintendent
T.R. Divakaran	Assistant Estate Superintendent
P.J. George	Assistant Estate Superintendent
O.S. Sathikumary	Section Officer
Annamma Andrews, H.S.C.	Nurse (HG)
K.G. Vijayan	Assistant Farm Superintendent
C.C. Joseph	Assistant Farm Superintendent
K.G. Jayan	Assistant Farm Superintendent
P. Babuji	Assistant Farm Superintendent

Regional Research Station, Padiyoor, Kerala

Radha Lakshmanan, M.Sc. (Ag.), Ph.D.	Senior Scientist
K.J. Joseph	Assistant Farm Superintendent

Regional Research Station, Guwahati, Assam

D. Chaudhuri, M.Sc.(Ag.), Ph.D.	Deputy Director
G.C. Mondal, M.Sc., Ph.D.	Plant Pathologist
H.K. Deka, M.Sc., Ph.D.	Scientist C
M. Choudhury, M.Sc. (Ag.)	Scientist B
Ashith Raj, M.Sc. (Ag.)	Scientist A (w.e.f. 05.03.08)

Regional Research Station, Agartala, Tripura

Sushil Kumar Dey, M.Sc., Ph.D.	Deputy Director
P. M. Priyadarshan, M.Sc., Ph.D.	Plant Breeder
T. Sailajadevi, M.Sc.	Agrometeorologist (Scientist C)
Krishna Das, M.Sc., Ph.D.	Scientist S3
Debasis Mandal, M.Sc.	Scientist S3
Joy Joseph, M.Sc.	Scientist S3
Debabrata Ray, M.Sc. (Ag.)	Scientist S2
Joby Joseph, M.A.	Scientist A
N.K. Gogoi, M.Sc. (Ag.)	Scientist A
P. Deepthi Antony, M.Sc. (Ag.)	Scientist A
Bhaskar Datta, M.Sc. (Ag.)	Scientist A
Jiban Chakraborty, B.Com.	Assistant Director (Finance)
Amal Chandra Sarma, B.Sc., ALC, LLB, PGDBM	Senior Scientific Assistant
Tapan Kumar Pal, M.Sc.	Senior Scientific Assistant
S. Dinesh, B.Com.	Section Officer

Rajan Mathew, B.Com.	Assistant Estate Superintendent
Haradhan Bhowmik, B.A.	Assistant Farm Superintendent
Regional Research Station, Tura, Meghalaya	
A.P. Thapliyal, M.Sc., Ph.D.	Deputy Director
R.P. Singh, M.Sc. (Ag.), Ph.D.	Scientist S3
M.J. Reju, M.Sc.	Scientist B
Pramesh Khoyumthem, M.Sc., Ph.D.	Scientist A
Regional Experiment Station, Nagrakata, West Bengal	
Gitali Das, M.Sc., Ph.D.	Senior Scientist
K. Satheesan, B.Sc.	Assistant Farm Superintendent
Regional Research Station, Dapchari, Maharashtra	
Meena Singh, M.Sc. (Ag. Bot.), Ph.D.	Plant Physiologist
K. Gopi, B.Sc.	Section Officer
P.G. Sasikumar, B.A., MET	Assistant Farm Superintendent
Regional Research Station, Dhenkanal, Orissa	
Bal Krishan, M.Sc., Ph.D.	Scientist C
S. Ravichandran	Scientist A
S.C. Mallik	Section Officer
C. Krishnan	Assistant Farm Superintendent
Hevea Breeding Sub-station, Nettana, Karnataka	
T.R. Chandrashekar, M.Sc., M.Tech. Ph.D.	Senior Scientist
K.K. Vinod, M.Sc. (Ag.)	Plant Breeder
M.J. Manju, M.Sc. (Ag.)	Scientist S3
K.V. Sumesh, M.Sc., Ph.D.	Scientist A
V.J. George	Assistant Estate Superintendent
Hevea Breeding Sub-station, Paraliar, Tamil Nadu	
T.A. Soman, M.Sc., M.Phil., Ph.D.	Scientist S3
M. Suryakumar, M.Sc.	Scientist S2
Regional Soil Testing Laboratory, Adoor, Kerala	
Thomas Eappen, M.Sc., B.Ed.	Scientist S3
K.C. Jayasree, B.Sc.	Assistant Technical Officer
Regional Soil Testing Laboratory, Muvattupuzha, Kerala	
C.P. Mary, M.Sc.	Technical Officer
Valsamma Mathew, M.Sc.	Senior Scientific Assistant
Regional Soil Testing Laboratory, Kozhikode, Kerala	
Joyce Cyriac, M.Sc.	Scientist B
P.K. Madhusooddhanan, B.Sc.	Assistant Technical Officer
K. Jayasree, M.Sc.	Senior Scientific Assistant
Regional Soil Testing Laboratory, Nedumangad, Kerala	
S. Sheela, M.Sc.	Assistant Technical Officer
Regional Soil Testing Laboratory, Thrissur, Kerala	
C. Viswambharan, B.Sc.	Senior Scientific Assistant
Regional Soil Testing Laboratory, Taliparamba, Kerala	
Suresh Babu Ayyappanchalil, M.Sc.	Senior Scientific Assistant

RESEARCH ESTABLISHMENTS

RUBBER RESEARCH INSTITUTE OF INDIA

Rubber Board, Kottayam- 686 009, Kerala, India
Phone- 91 481 2353311-20, 2352770-71, 2352773-79 (20 lines) Fax: 91 481 2353327
Email: rrii@rubberboard.org.in Website: www. rubberboard.org.in

REGIONAL RESEARCH STATIONS

Central Experiment Station
Rubber Board
Chethackal, Thompikandom P.O.
Ranni- 689 676, Kerala
Phone: 91 4735 261500, 261176

Regional Research Station
Rubber Board, Padiyoor P.O.
Kannur- 670 703, Kerala
Phone: 91 4982 273003

Regional Research Station
Rubber Board
Dapchari- 401 610
Thane, Maharashtra
Phone: 91 2528 202042

Regional Research Station
Rubber Board, PWD Road
Near District Employment Exchange
Dhenkanal- 759 001, Orissa
Phone: 91 6762 224946

Hevea Breeding Sub-Station
Rubber Board, College Road,
J.C. Complex, Kadaba- 574 221
D.K. Dt., Karnataka
Phone: 91 8251 260336

Regional Research Station
Rubber Board, Grassmore
Nagrakata, Jalpaiguri- 735 225
West Bengal
Phone: 91 3565 270016

Research Complex (N.E. Region)
Rubber Board
Beltola – Basista Road, Housefed Complex
Dispur, Guwahati- 781 006, Assam
Phone: 91 3612 228220

Regional Research Station
Rubber Board, Baluakiattila
Kunjaban- 799 006, Agartala, Tripura
Phone: 91 381 2355143

Regional Research Station
Rubber Board, Near AIR Quarters
Dakobgre, PB No. 26, Tura- 794 001
West Garo Hills, Meghalaya
Phone: 91 3651 232413

Hevea Breeding Sub-Station
Rubber Board, Thadikarankonam P.O.
Kanyakumari- 629 851
Tamil Nadu
Phone: 91 4652 289119

REGIONAL SOIL TESTING LABORATORIES IN KERALA

Regional Laboratory
Rubber Board Regional Office
Taliparamba- 670 141

Regional Laboratory
Rubber Board, East Nadakkavu
Kozhikode- 673 011

Regional Laboratory
Rubber Board, Peramangalam P.O.
Thrissur- 680 545

Regional Laboratory
Mary Matha Square
Arakuzha Road
Moovattupuzha- 686 661

Regional Laboratory
Rubber Board, T.B. Road
Pala- 686 575

Regional Laboratory
Rubber Board, Ann's Bldg.
Old Church Junction
Kanjirappally- 686 507

Regional Laboratory
Rubber Board, Parvathy Mandiram
K.P. Road, Adoor- 691 523

Regional Laboratory
Rubber Board, East Bungalow
Nedumangadu- 695 541

Rubber Research Institute of India
Annual Report 2007-2008
ISSN 0970 2490 CODEN ARRIEU

Cover Photo
High yielding ortet at high altitude station, RARS Ambalavayal (*Top*)
Newly constructed RRII Golden Jubilee Main Gate & RRII Building (*Bottom*)

Cover Design
Mr. K.N. Madhusoodanan

Printed at
Alois Graphics, Kottayam- 686 001

Continued from inside front cover

Research divisions and functions

The major research divisions are Agronomy/ Soils, Biotechnology, Botany, Germplasm, Plant Pathology, Plant Physiology, Exploitation Technology, Rubber Technology, Technical Consultancy and Economics.

The thrust areas of research of Agronomy/ Soils Division are investigations on the nutritional requirements of rubber, irrigation, intercropping, cover crop management, weed control and the study of the rubber growing soils. Development of tissue culture and genetic transformation 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 Plant Pathology Division is engaged in investigations on the diseases and pests of rubber and associated cover crops and their control. The Plant Physiology Division conducts studies on both fundamental and applied aspects of *Hevea* tree physiology. The Exploitation Technology Division is concentrating on all applied aspects of crop harvesting in rubber. The Rubber Technology Division concentrates on improvement in primary processing of rubber, its chemical modification, rubber product manufacture and quality control of processed rubber. The Technical Consultancy Division gives support to various types of industries through testing of raw materials, compounds and products and advisory services. The Economics Division undertakes studies on economic aspects related to rubber plantations.

The research supporting sections include Library and Documentation, Instrumentation, Statistics, Computer and Maintenance Wing. There is also a small experimental farm of 33 ha. at the headquarters of 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

RRII has established a North-Eastern Research Complex with headquarters at Agartala having regional research stations at Agartala (Tripura), Guwahati in Assam and Tura in Meghalaya. RRII has also set up regional research establishments at Dapchari (Maharashtra), Dhenkanal (Orissa), Nagrakata (West Bengal), Pasalur (Tamil Nadu), Nettana (Karnataka) and Padiyoor (Kerala).

Regional soil testing laboratories have been established at Taliparamba, Kozhikode, Thrissur, Nedumangad, Pala, Kanjirappally, Adoor and Nedumangad. These units for soil and leaf analysis are attached to the main laboratory, apart from that at the headquarters.

National/International collaboration

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. Rubber Board is a member of the Association of Natural Rubber Producing Countries (ANRPC) and International Rubber Study Group (IRSG).

The RRII has research/ academic linkages with the Banaras Hindu University (Varanasi), Kerala Agricultural University (Thrissur), Kerala University (Thiruvananthapuram), Mahatma Gandhi University (Kottayam), Cochin University of Science and Technology (Kochi), Indian Agricultural Research Institute (New Delhi), Indian Institute of Science (Bangalore), Indian Institute of Technology (Kharagpur), National Chemical Laboratory (Pune), Sree Chitra Tirunal Institute of Medical Sciences and Technology (Thiruvananthapuram), Tamil Nadu Agricultural University (Coimbatore), University of Agricultural Sciences (Bangalore) and University of Goa (Goa).

Correspondence

The Director of Research
Rubber Research Institute of India
Kottayam - 686 009, Kerala, India
Phone 91 481 2353311-20
91 481 2302776-78
91 481 2302779-80 (D/ Line)
Fax 91 481 2353327
Email rrii@rubberboard.org.in
Website www.rubberboard.org.in