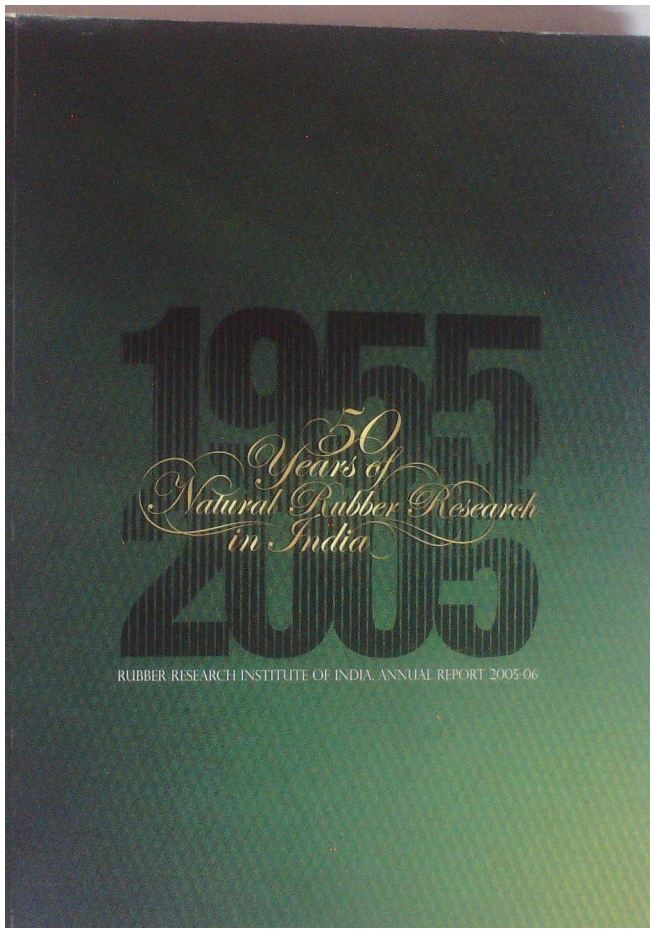

RUBBER RESEARCH INSTITUTE OF INDIA ANNUAL REPORT 2005-06

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

Location

The RRII is located on a hillock 8 km east of Kottayam town in Kerala State and is easily

accessible by road. Kottayam is connected to all major cities in the country by rail. There are two International airports, one at Thiruvananthapuram, 160 km south and another at Nedumbassery, 95 km north to RRII.

Functions

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

Organization

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

Research divisions and functions

The major research divisions are Agronomy/Soils; Biotechnology; Botany; Germplasm; Plant Pathology; Plant Physiology; Rubber Technology and Economics. Studies on Latex Exploitation, Clone Evaluation, Genome Analysis and DRIS Fertilization are dealt seperately.

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Years of
Natural Rubber
in India

ANNUAL REPORT
2005-2006

RUBBER RESEARCH INSTITUTE OF INDIA
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Contents

Torch bearers of Indian Rubber Research

The Rubber Research Institute of India (RRII) has completed its 50 years of fruitful existence in 2005. The history of RRII is incomplete without mentioning the valuable contributions of the former Directors of the Institute.

When RRII was formally established in 1955, Shri. K.N. Kaimal, the then Rubber Production Commissioner (RPC) of the Indian Rubber Board, was assigned with the additional charge of the Director of Research since the RPC has the additional responsibility of undertaking research on rubber as per Rubber Rules 1955. He is perhaps the most important scientist who had given leadership in organising the new Institute and initiating systematic research in natural rubber (NR) in India in Agronomy, Botany and Pathology. He was the Director of Rubber Research Institute of Malaya (now Malaysia) before he took over charge as RPC in the Indian Rubber Board. As an experienced Botanist with not less than 23 years research experience in Malaya it was under his guidance that the breeding/ selection work was taken up and a series of hand pollinations were carried out in different private estates which later led to the development of the RRII 100 and 200 series clones. He was able to bring 20 RRIM clones of 500 and 600 series from RRI of Malaya which helped India to raise both NR production and productivity. He could also develop in the minds of people the desire for scientific knowledge on the cultivation of rubber. He passed away while in service, after 10 years of service in Rubber Board.

After the demise of Shri. K.N. Kaimal, Shri. T.S. Ramakrishnan, Head of Pathology Division, officiated as Director of Research from 1960 till his retirement in 1964. He joined the RRII as Pathologist in 1955 and had started systematic research in NR diseases. His major contribution was the development of low volume spraying using copper oxychloride for the control of abnormal leaf fall disease. He passed away in 1971.

Dr. K.T. Jacob was appointed as the first full time Director of the RRII on 25 May 1964. He joined Rubber Board after 18 years of service in Bose Research Institute, Kolkata. It was Dr. Jacob who streamlined the structure and functioning of RRII by establishing well developed Divisions such as Agronomy and Soils, Botany and Anatomy, Plant Pathology and Mycology and Chemistry and Rubber Technology, with well equipped laboratories. Deputy Directors were appointed in charge of each Division. Another major contribution of Dr. Jacob was the establishment of the Central Experiment Station (CES) at Chethackal in 1966. It was Dr. Jacob who planted the first plant at CES. Dr. Jacob left RRII, consequent to his appointment as Chairman of Cardamom Board in 1968.

Shri. K.C. Ananth, Deputy Director (Agronomy) was appointed as officiating Director in 1968. It was during his term that the budded stumps of 10 clones of RRII 100 series including RRII 105 were made available to the rubber growers for small scale planting. This was the first time that the clones bred at RRII were made available to the Indian

rubber growers. India also became IRRDB member during his tenure as Director. He was appointed as RPC on 14 May 1970 and Shri. V.K. Bhaskaran Nair was put in full additional charge of the post of Director in addition to his duties as Deputy Director.

Shri. V.K.Bhaskaran Nair joined RRII in 1958 as Research Assistant after his service in RRI of Malaya as Assistant Botanist during 1952-57. He was involved in the selection and breeding of high yielding clones like RRII 105, RRII 118 and RRII 208. His additional charge as Director of Research ended in 1972 when Dr. C.K.N.Nair took over charge as Director of Research.

Dr. C.K.N. Nair who was the Senior Scientific Officer in the National Chemical Laboratory in Pune joined the RRII as Agronomist on 21st October 1955. As an agronomist, he formulated the first official fertiliser recommendations for NR in South India, on the basis of information on soils in NR growing tracts in South India and on data available from other major rubber growing countries. His fertiliser trials resulted in the recommendation of the most efficient and economic fertiliser usage for rubber in South India. He quit the RRII in 1959 and later became the Principal of the Agricultural College, Vellayani. He rejoined RRII in 1972 as Director and continued to head the Institute till retirement in 1978.

Shri. V.K.Bhaskaran Nair was appointed as full time Director of RRII in 1978 after the retirement of Dr. C.K.N. Nair. One of the most outstanding contribution during his tenure as full time Director was the release of the high yielding clone RRII 105 in 1980. The RRII celebrated its Silver Jubilee in 1980 and the "Handbook of Natural Rubber Production in India" which contains up to date scientific information on NR production and processing was published in commemoration of the Silver Jubilee celebrations. The foundation stone for the Silver Jubilee Block at RRII was laid by Sri. Pranab Kumar Mukherjee on the occasion of the celebrations. The commissioning of Mobile Soil Testing Laboratory in November 1979 was another remarkable contribution by him. RRII was able to benefit a lot by the first IRRDB expedition to Amazon Valley by introducing the 1981 IRRDB wild germplasm collection into India and establishing the accessions in different germplasm gardens. Mr. Bhaskaran Nair retired on 31st October 1981.

Dr. M.R. Sethuraj was appointed as Director of Research after Mr. V.K. Bhaskaran Nair and he assumed charge on 18 December 1981. He joined the Institute as Research Assistant in 1964 and was subsequently appointed as Plant Physiologist. Later he became the Deputy Director of Plant Physiology and Exploitation Division. Dr. Sethuraj steered the Institute through a period of significant developments and achievements and helped the country to achieve the world's highest productivity in NR. Molecular studies in RRII were started under his initiative. The publication of 'RRII Annual Report' and the 'Indian Journal of Natural Rubber Research' (now 'Natural Rubber Research') were started under his leadership. A dedicated scientist who has been awarded Ompraksh Bhasin Award for Agriculture in 1993 has been able to make significant contributions in improving rubber cultivation. He retired on 30.6.1997 after meritorious service as Director for more than 16 years.

Dr. N.M. Mathew who joined Rubber Board in 1972 assumed as Director on 24.7.1997 and he is the first rubber technologist to become the Director of RRII. Dr. Mathew co-ordinated the successful efforts of the Rubber Board to control Corynespora Leaf disease when the fungus attacked the plantations in North Kerala and Karnataka. He steered the Institute on the occasion of its Golden Jubilee Celebrations and the release of the premium productivity RRII 400 series clones as a Golden Jubilee gift by RRII to the growers was made during his tenure. He also took the initiative in establishing an Advanced Research Centre for Rubber Technology with modern laboratory complex at RRII. A joint recipient of the Dunlop Award 1983 and K.M. Philip Award 2000, he has over 100 research papers to his credit besides co-authoring and editing many books on rubber and related subjects. ■

Shri. K.N. Kaimal
(1955–60)
Specialisation: Botany
Assignment: RPC/Director

Shri. T.S. Ramakrishnan
(1960–64)
Specialisation: Plant Pathology
Assignment: Pathologist (In-charge)

Dr. K.T. Jacob
(1964–68)
Specialisation: Pathologist
Assignment: Full Time Director (In-charge)

Shri. K.C. Anand
(1968–70)
Specialisation: Agronomy
Assignment: DD Officiating

Shri. V.K. Bhaskaran Nair
(1970–72)
Specialisation: Botany
Assignment: DD Officiating

Dr. C.K.N. Nair
(1972–78)
Specialisation: Agronomy
Assignment: Full-time Director

Shri. V.K. Bhaskaran Nair
(1978–81)
Specialisation: Botany
Assignment: Full-time Director

Dr. M.R. Sethuraj
(1981–97)
Specialisation: Plant Physiology
Assignment: Full-time Director

Dr. N.M. Mathew
(1997 onwards)
Specialisation: Chemistry
Assignment: Full-time Director

Foreword

Rubber Research Institute of India (RRII) established in 1955 has played a vital role in developing the natural rubber plantation industry in the country. It is a matter of great pride that the foundation stone for the Institute was laid by President Dr. Rajendra Prasad in 1955 and its golden jubilee celebrations were inaugurated by President Dr. A.P.J. Abdul Kalam in 2005.

The primary objective of RRII is to provide research support for attaining self sufficiency in production of good quality rubber in the country. Although commercial cultivation of natural rubber started in India in the early 1900s, its productivity remained extremely poor for five decades. The advent of the Institute's flagship clone RRII 105 made it possible for the country to make great strides in increasing the productivity of natural rubber, thanks also to the excellent extension service of the Rubber Board and the whole hearted acceptance of the research findings by a million strong small growers. The latest clones evolved by RRII, namely RRII 414 and RRII 430 were formally launched in 2005 and they are expected to take productivity to even greater heights. The success of Indian natural rubber plantation industry is in no way less significant than the green revolution or the white revolution.

I am sure that the scientists of RRII are aware of the dangers of large-scale cultivation of one or a couple of clones, and therefore the need to release more clones. A new clone should have, in addition to good (rubber and timber) yields, excellent secondary attributes such as tolerance to climatic stresses, pests and diseases which are increasingly becoming serious concerns for rubber productivity. There is a felt need to evolve clones and farm technologies that are best suited to different agroclimatic conditions, especially in the non-traditional

rubber growing regions of the country, cost effective methods for crop management, effective and cheap plant protection techniques, efficient crop harvesting systems and latex processing techniques.

Being the golden jubilee year, RRII organized a series of programmes during 2005-06 and this annual report describes these activities. The major contributions made by RRII in the past 50 years are also documented in this report.

Doing research in a perennial tree species like natural rubber is a daunting task. I congratulate all the members of the RRII family, both present and past for the significant achievements they could ensure in natural rubber research. RRII has been instrumental in creating a revolution in the natural rubber plantation industry in the country and catapulting India to the first position in the world in terms of natural rubber productivity. While RRII can rightfully take pride in its achievements, it should be borne in mind that success should not make us complacent. I hope RRII will orient itself in the right trajectory to effectively address the challenges that the world natural rubber industry will have to face in the next 50 years and beyond.

Sajen Peter I.A.S.
Chairman, Rubber Board

Kottayam
01/03/2008

Director's Review

50 Years of Natural Rubber Research in India

The year 2005 marks the Golden Jubilee of the Rubber Research Institute of India (RRII) and it is pertinent to evaluate the contributions of the RRII to the rubber industry in general and to the smallholding sector in particular. The national policy on NR adopted since independence has been characterized by the emphasis on attaining self sufficiency. The two pronged strategy adopted by Rubber Board and the RRII for attaining this objective was improvements in production and productivity in the traditional belt and expansion of rubber cultivation to non-traditional areas. For achieving these goals, the role of R & D support was very significant and the infrastructure for systematic research on NR got established with the formation of RRII in 1955. For the development of the industry it is very essential to keep the R & D activities dynamic and the priorities reset from time to time to face the new challenges and in tune with the needs of the time.

RRII has redefined its research priorities.

Improvement in productivity has been attempted mainly through a well defined breeding programme. The most outstanding contribution of RRII towards enhanced rubber production and productivity is the development and popularization of the clone RRII 105, one of the best in the world in terms of potential and realised yield. Today almost all the clones, found in rubber plantations spread over the length and breadth of the country, were either developed by RRII or evaluated under Indian conditions. Now two new clones, RRII 414 and RRII 430, which were formally released for large scale cultivation by His Excellency the President of India, Dr. A.P.J. Abdul Kalam on 29th July 2005 were RRII's gifts to the nation on the occasion of its Golden Jubilee. Onfarm trials for evaluating the performance of RRII 400 series clones are in progress both in the traditional and nontraditional regions. 42 newly evolved hybrid clones superior to RRII 105 are under further evaluation.

The narrow genetic base of the existing rubber clones has been identified as a major constraint in varietal improvement. In order to address this issue, the Institute established a Germplasm Division in the year 1988 with a collection of nearly 5000 accessions, mostly wild, the genepool being maintained and evaluated by the Division is a great resource for the future crop improvement programme.

Research programmes in biotechnology include development of *in vitro* propagation methods, development of transgenic plants and development of modern tools such as haploid plants, triploid plants and *in vitro* fertilization techniques. Studies of molecular mechanism and characterization of genes with tolerance to abiotic stresses and study of laticifer cell specific gene expression and characterization of laticifer cell specific promoters are also progressing.

The RRII has consolidated and updated scientific practices in various aspects like planting materials, density of planting, soil conservation and irrigation, intercropping, fertilizer application and weed management. The discriminatory fertilizer recommendation (DFR) system evolved by the Institute ensured increased yield, fertilizer saving and reduced environmental pollution. Polybag plants are recognized as the ideal planting material to reduce vacancies and to ensure uniform stand. Density trials showed that lower densities will lead to lower yield per hectare but a higher yield per tree. A resource soil survey and mapping of rubber growing soils of Kerala and Tamil Nadu was completed.

In-depth studies were conducted on the physiological and molecular basis of growth and yield, environmental physiology, TPD syndrome etc. Research on the impact of rubber cultivation on the environment is also another key area. The carbon sequestration potential of rubber plantations has been worked out. In the field of exploitation technology, the most important contribution is the recommendation of low frequency tapping (LFT) without reduction in land yield. Contributions towards popularizing the long handled modified gouge knife for controlled upward tapping (CUT) is also well recognized. Base values of latex diagnosis parameters were developed for the clone RRII 105 for optimum production under 1/2S d/3 system of tapping.

Cost reduction, productivity enhancement and establishment of healthy farm environment by minimising pollution have been the main goals in crop protection research. India is the only country where a practically feasible crop protection technology including neces-

sary application equipment have been developed. RRII is the only Institute of its kind where considerable research on bee keeping has been conducted. The Institute has developed efficient effluent management system for the dominant smallholding sector.

The focus of economic research during the initial phase (1986-92) which coincided with the last leg of the protected policy regime pursued since 1947, had been on issues related to farm management, NR processing and primary marketing. The contributions during this phase were: (i) examining the status and implications of developments in various sub- sectors of India's rubber sector; (ii) efforts to build up a conceptual basis to define the basic issues confronting the rubber sector and (iii) attempts to build up reliable databases on various segments. The broad areas of research for the second phase beginning from 1993, which has been confronted with a host of R&D challenges emanating from the launching of liberalised economic policy in India, include farm management, primary processing and marketing of rubber, rubber products manufacturing industry, foreign trade, inter-crops and by-products.

Technologies have been evolved for improvements in the primary processing of NR. Alternative coagulants for latex were identified and cost effective drying systems developed. A semi-automatic cleaning machine was developed for upgradation of low quality sheet rubber. The RRII has evolved conditions under which sulphuric acid can safely be used for latex coagulation in sheet rubber production. Research focused also on various aspects of latex technology including development of prevulcanized latex, deproteinized latex and radiation grafted latex. Identification of major degrading agents of NR and the associated failure mechanism is another commendable contribution of the Institute. Pilot plant-scale production of epoxidised natural rubber (ENR) and other modified forms such as styrene grafted natural rubber (SGNR), liquid natural rubber, NR modified plastics and NR based thermoplastic elastomers were made as attempts to popularize them as substitutes for synthetic materials. Latex based nanocomposites with higher modulus and better barrier properties have been developed. Formulations and processes were evolved for different rubber products for the benefit of small-scale rubber product manufacturers.

As there is limited scope for expansion in the traditional rubber growing regions in India due to shortage of land, extension of rubber cultivation to different non-traditional zones became highly essential. Regional Research Stations were established in Agarthala (Tripura), Guwahati (Assam), Tura (Meghalaya) and Nagrakatta (West Bengal) all in North East India, Dapchari (Maharashtra) in Western India and Dhenkanal (Orissa) in Eastern India for evolving suitable clones and agrotechnology for these regions.

Valuable information have been generated on growth, nutrient and water requirements and yield when the crop is grown under stress conditions.

The high yielding clones for North East India include PB 235, RRIM 600, RRII 208, RRII 203, RRII 118 and RRII 105 for Tripura, RRIM 600, RRII 105, PB 235, RRII 208 and RRII 118 for Assam and RRIM 600, PB 311, RRII 208 and RRII 118 for Meghalaya. Chinese clones in general and RRIM 600, PB 311, PB 235 and RRII 208 gave promising performance in the Doars (Nagrakatta) region of West Bengal. In the drought prone North Konkan region of Western India RRII 208 recorded good girth and yield in the early mature phase. At Dhenkanal

in Orissa RRIM 600 and SCATC 88-13 are the high yielders. In all the Stations where evaluation was conducted, polyclonal population gave promising results indicating their usefulness in stress prone areas.

Over the past 50 years, RRII had contributed over 2300 research papers covering various disciplines of NR research of which 1171 are research articles, 784 are presentations in scientific seminars and 97 are theses/dissertations. The international journal, *Natural Rubber Research*, since its inception in 1988 has been effectively disseminating original research contributions in disciplines relevant to NR research from India and abroad. The Institute has published 20 books and 39 monographs and compiled 10 bibliographies. In addition to a series of training programmes, RRII organized 18 major conferences of which eight were international. The state-of-the-art website of Rubber Board also helps in the speedy dissemination of NR information. As part of the Golden Jubilee of the Institute a series of programmes were organized for projecting the contributions of the Institute before the scientific community and the public at large.

The development of the NR industry in India since the establishment of RRII has depended on well targeted R & D. Our R & D efforts in the past have been focusing on enhanced NR production through expansion of area under rubber and evolving improved planting materials and better agromanagement practices. The R&D efforts contributed well for the overall increase in the annual production of NR in the country from 23730 tonnes in 1955-56 to 802625 tonnes in 2005-06. More importantly the national average annual yield per hectare was raised from 353 kg to 1796 kg during the same period. But the situation has changed drastically with the integration of Indian NR industry with the international market and the consequent uncertainties in NR prices. As remunerative price being the most important component for ensuring sustainability of NR production, strategies to achieve the same are important. But there are serious limitations for improvements in competitiveness ensuring remunerative prices.

The new policies underlines the need for a relook into the self-sufficiency criteria irrespective of cost. Economic and environmental sustainability of rubber cultivation shall be given greater attention. Therefore our R & D in future shall be focused on increasing or maximizing income from unit area through integrated farm management approaches with minimum demand on the environment. As 89 per cent of area under rubber in India is under smallholdings with a mean holding size just about 0.5 ha, a more focused farm management strategy that ensures smallholding rubber cultivation sustainable and viable has become need of the time. Due emphasis shall be given to value added rubber products manufacturing sector too. Otherwise our R & D efforts and achievements in the farm management and processing front during the past five decades will get nullified. ■

Golden Jubilee Year of the Rubber Reserch Institute of India

The Rubber Research Institute of India (RRII) was established in 1955 as the Research Department of the Rubber Board under the Ministry of Commerce and Industry, Government of India. From a modest beginning with a small laboratory and three scientists, the Institute has emerged as one of the largest rubber research institutions in the world with eight major Divisions, a Central Experiment Station, 10 Regional Research Stations, 120 scientists and over 300 supporting staff.

A beginning was made in 1955 by establishing the Institute in Kottayam town in the Ancheril Buildings of the Rubber Board with a temporary laboratory. During the early days, the RRII had only Agronomy, Botany and Pathology Divisions with temporary laboratory facilities for agronomical and pathological research. In October 1955, after the acquisition of land at Kothapara, a hillock 8 km east of Kottayam town, field nurseries and experimental planting was started. The then President of India, Dr. Rajendra Prasad, laid the foundation stone of RRII building on 4th February 1956 and RRII and Rubber Board started functioning in it from 10th December 1962.

The Chemistry and Rubber Technology (C & RT) Division started functioning on 1st June 1963 which was renamed as Rubber Chemistry Physics and Technology (RCPT) Division in 1986. The Economic Research Unit, which started functioning in 1968, became the Economics Division of the RRII in September 1986. The full-fledged Plant Physiology and Exploitation Division has started functioning in 1979, Biotechnology Division in December 1985 and Germplasm Division in February 1989. During August 1997 a Genome Analysis Laboratory was established for undertaking various molecular genetic studies. When the World Bank scheme was implemented in 1994, the additional activities were taken up.

The Central Experiment Station (CES) at Chethackal, 50 km away from Kottayam, was established in 1966. To conduct location specific research, the Institute has established a research complex for the North East India with Regional Research Stations at Agartala in Tripura, Guwahati in Assam and Tura in Meghalaya. RRII has also set up Regional Research Stations at Dapchari (Maharashtra), Dhenkanal (Orissa), Nagarakatta (West Bengal), Paraliyar (Tamil Nadu), Padiyoor (Kerala) and Nettana (Karnataka). Presently RRII has eight regional soil testing laboratories. Mobile units for soil and leaf analysis are available at the Kozhikode,

Muvattupuzha and Adoor laboratories, besides the unit at the headquarters. The mobile unit attached to the RRS, Tripura caters to the needs of the growers of the entire NE region.

The present research supporting sections include Library and Documentation, Instrumentation and Statistics and Computer. There is also a small experimental farm of 33 ha at the headquarters of RRII.

The basic priorities of research of the Institute are (1) improvements in production and productivity of NR through evolving and introducing location specific high yielding clones and appropriate rubber based farming systems in different agroclimatic regions, (2) integrated approaches to reduce cost of production and improve quality competitiveness through efficient systems of field management, exploitation, plant protection, processing etc., (3) research support for extension of rubber cultivation to nontraditional areas by selection and breeding of location specific clones, perfecting nutrient management and exploitation schedules, designing rubber based systems integrating region specific agro-economic aspects, and (4) investigating all aspects of post harvest technology, product development and marketing.

The year 2005 marked the Golden Jubilee of the Rubber Research Institute of India. A series of programmes were organized during this memorable occasion for projecting the conspicuous contributions of the Institute before the scientific community and the public at large.

Inauguration of Golden Jubilee Celebrations - 29 July 2005 RRII, Kottayam

The year long Golden Jubilee celebrations of RRII was inaugurated by the President of India His Excellency Dr. A.P.J. Abdul Kalam at the headquarters of the Institute at Puthuppally, near Kottayam, Kerala, on Friday the 29th July 2005. It is a coincidence that 50 years ago the first President of India Dr. Rajendra Prasad had laid the foundation stone of the main laboratory complex of the Institute in February 1956. It is a matter of pride and great privilege for the Rubber Board and the RRII that the First Citizen of the country has inaugurated its Golden Jubilee celebrations.

The function was held in a beautiful makeshift auditorium constructed in the campus. The logos of Rubber Board and Golden Jubilee of RRII were elegantly printed on the backdrop and were displayed on the huge side screens. Closed circuit television was provided in the permanent Auditorium and Silver Jubilee Hall of the Institute for convenient viewing of the function by those who could not be accommodated in the main venue.

A 25 minute long documentary on RRII was screened before the audience before the arrival of the President. The film, which highlighted the history and major research contributions of the Institute during the past 50 years, was well appreciated by the elite audience assembled in the auditorium representing a cross section of rubber industry, media and the staff of RRII and the Rubber Board.

The meeting started at 1.50 pm as the President reached Kottayam town only about two hours late, owing to inclement weather conditions. A traditional Kerala style welcome with panchavadyam and thalappoli was offered to His Excellency and other dignitaries on their arrival on the dais.

The President, Dr. A.P.J. Abdul Kalam, in his inaugural address, said that

though there was a phenomenal increase in the area under rubber cultivation and per hectare production over the past 50 years, there still exists considerable scope for raising the production of natural rubber to meet the growing domestic and global demand. Hailing the RRII for conducting excellent work in the area of rubber research and providing inputs for making the rubber industry prosperous, Dr. Abdul Kalam also suggested a six-point mission for the Institute as follows:

(a) Increase the annual per hectare revenue of the rubber growers from the existing Rs. one lakh to Rs.2 lakh within the next three years by adopting results materialized from research.

(b) Produce additional one million tonnes of rubber within the next decade so that India can export part of the rubber produced in the country, which will result in additional earnings and increase the employment potential.

(c) Enable production of rubber in non-traditional areas with minimal inputs, by establishing technologies through research.

(d) Identify locations in which enterprises producing value added rubber could be established contiguous with the rubber farms for realizing the benefit of reduced logistic cost and processing cost.

(e) Develop a chemically modified form of natural rubber, which can replace synthetic rubber for special applications. This will reduce the atmospheric pollution created by synthetic rubber factories and also eliminate the need for importing some intermediate inputs.

(f) Organize an international conference of users of natural rubber, which will assist Kerala for evolving a ten-year mission of growing rubber plantation taking into account competitiveness.

The President urged the RRII scientists and staff of Rubber Board to play a key role in contributing to the "Bharath Nirman Programme" of the government by adopting 20 villages in Kottayam and establishing a model PURA having electronic and knowledge connectivity, lead-

ing to economic growth and prosperity of rural areas.

On the occasion, the President also dedicated to the nation, two new rubber clones, RRII 414 and RRII 430, developed by the Institute after extensive research spanning over two and a half decades. He presented the clones to the Chief Minister Mr. Oommen Chandy who hails from the village where RRII is located. Results of SST showed that the newly released clones yield significantly more than the current highest yielding clone RRII 105.

The Chief Minister of Kerala, Mr. Oommen Chandy remembered the day way back in 1956, when the first President of India, Dr. Rajendra Prasad laid the foundation stone of the Institute, in which he participated as a schoolboy. He participated in the inaugural function of the Golden Jubilee with great pride that the Institute has lived up to the expectations of the nation and has emerged as one of the best research institutions of its kind in the world with significant contributions. Mr. Oommen Chandy also expressed his happiness that the President of India is visiting the renowned institute situated in his home village. He heartfully wished that His Excellency's presence would boost the morale of all involved in the rubber sector. The RRII which is known to the people of Kerala for the exquisite clone, RRII 105 with its highest productivity on commercial plantations, has developed two new clones namely RRII 414 and RRII 430 which are claimed to be higher yielding. The Chief Minister congratulated the scientists and all those who have helped in evolving these high yielding clones for the benefit of the rubber farmers in Kerala. Mr. Oommen Chandy and RRII Director Dr. N.M. Mathew, during their speeches, paid homage to the late Dr. V.C. Markose and the late Dr. J. Licy, who have contributed among others in the development and evaluation of the newly released clones RRII 414 and RRII 430. Mr. Oommen Chandy also unveiled the foundation stone of the Golden Jubilee Laboratory Complex.

The Minister of State for Commerce and Industry, Mr. E.V.K.S. Elangovan inaugurated the planting in the proposed rubber clone museum which houses the cardinal rubber clones that had accelerated NR productivity in the last fifty years. The museum will also have models of scientific achievements in the area of NR cultivation and manufacturing technology. All arranged in the form of a theme park, the clone museum is designed and desired to be a place of learning and leisure. Giving due credit to the contributions of RRII in developing the clone RRII 105 which had become a legend in the history of plantation crop development in the country, the Union Minister stated that RRII has a significant role in meeting future technological needs. As the market integration through the implementation of WTO agreement and the consequent removal of quantitative restrictions have made re-orientation of marketing strategies imperative for survival in international rubber trade, the focus should be for increased support to processing, product manufacturing and marketing sectors. Making value-added products at lower cost, product diversification and non-conventional application for rubber could be the keys. Products with locational advantages may have to be identified and manufactured for the export market. On the rubber production front, the minister stressed the need for cost effectiveness. Breeding for higher yield and tolerance to biotic and abiotic stresses, reduction in the immaturity period, improvement in crop management and harvesting as well as additional income generation through by-products are the means. Development

of sustainable farming systems leading to community development and poverty alleviation of tribal populations should be aimed at in the non-traditional rubber growing regions.

Members of Parliament, Mr. Vayalar Ravi, Mr. Suresh Kurup, Mr. P.C. Thomas and Mr. A. Sengupta, Additional Secretary (Plantations), Department of Commerce were also present on the occasion. Rubber Board Chairman Mr. S. M Desalphine, IAS welcomed the gathering. Dr. N.M. Mathew, Director, RRII introduced the new clones, the Clone Museum and the Golden Jubilee Laboratory Complex. Dr. A.K Krishnakumar, Rubber Production Commissioner of Rubber Board proposed the vote of thanks.

National Workshop on CDM and the Indian Rubber Sector
12 August 2005, RRII, Kottayam

On 12 August 2005, RRII organized a National Workshop on Clean Development Mechanism (CDM) under the Kyoto Protocol with reference to the Indian rubber sector, at Kottayam. The Workshop focused on carbon trading and the potential financial benefits the various players in the rubber sector can gain through it. The Kyoto Protocol to the UN Framework Convention on Climate Change that entered into force on February 16, 2005 puts legally binding restrictions on the emission of greenhouse gases (GHGs) such as CO_2 by the rich industrialized countries. CDM is a market instrument of carbon trading instituted under the Kyoto Protocol aimed at helping the industrialized countries to meet their GHG emission reduction targets cost effectively. CDM which encourages investing in environment-friendly projects by the industrialized countries in developing countries, envisages technology transfer and financial flow from developed countries to developing countries for environment-friendly projects that are in tune with the sustainable developmental needs of the people in the developing countries in the tropics and subtropics. Such projects should result in a net reduction in the emission of greenhouse gases that are responsible for global warming and climate change.

There are several aspects of the Indian rubber plantation sector and rubber goods manufacturing industry that can qualify for CDM funds but so far no

CDM projects have been developed from the Indian rubber sector. Lack of proper information about the newly emerging CDM market and the absence of adequate capacity building are responsible for this. The national workshop on CDM and the Indian Rubber Sector addressed this deficiency and helped to identify suitable areas where CDM projects could be developed. The workshop felt that time is running out especially for the rubber sector to cash in on the legal compulsions of the industrialized nations to restrict the GHG emission by 2012.

In his inaugural address, Mr. Sajen Peter IAS, Chairman, Rubber Board, said that though the RRII is credited with excellent research work in the past 50 years, more concern should be there on ecological issues. Ms. Ulka Kelkar, Convener, Centre for Global Environment Research, New Delhi delivered the keynote address. She said that India is slowly emerging as the leading player in GHG emission reduction projects.

Dr. N.M. Mathew, Director, RRII presided over the function. Dr. A.K. Krishnakumar, RPC, Rubber Board, India, Mr. M.K. Balagopalan Nair, Director, Rubber Board and Dr. V. Murugappan, Director, Tamil Nadu Agricultural University felicitated.

The key speakers at the workshop included Dr. G. Ravishankar Reddy, Indian Council of Forestry Research and Education, Prof. N.H Ravindranath, Indian Institute of Science, Dr. S. Rajamony, Central Leather Research Institute, Mr. P.K. Mohammed, Appollo Tyres, Dr. S. Shankar, Kerala Forest Research Institute, and Dr. H.S. Sharma, former F A O consultant. A few scientists of RRII and officers of Rubber Board also presented papers. A couple of CDM project developers participated in the Workshop and shared their experience. About 150 participants representing various stakeholders including planters, industrialists, foresters, academicians and scientists attended the workshop.

The workshop enlightened the key players in the Indian rubber sector on the potential financial benefits their respective sectors can obtain from the CDM under the Kyoto Protocol and sensitized CDM project facilitators/developers/consultants and the likely buyers of Certified Emission Reduction (CER) units on the scope of CDM in the Indian rubber sector. The workshop also brought together all stakeholders from the Indian rubber sector, potential CDM project facilitators/developers/consultants and CER buyers to one platform.

International Natural Rubber Conference - 5-8 November 2005, Kochi

The International Natural Rubber Conference, INRC INDIA 2005, organized by the Institute was held at Cochin during 6-8 November 2005. The conference provided a forum for more than 400 researchers from all over the world to interact, evaluating the trends in natural rubber research during the last decade and to set an agenda for future research.

The Minister of State for Commerce and Industry, Mr. E.V.K.S. Elangovan inaugurated the conference on 6th November. Mr. Dominic Presentation, Minister for Fisheries and Sports, Govt. of Kerala, presided over the function. Rubber Board Chairman, Mr. Sajen Peter IAS welcomed the gathering. Mr. P.C. Thomas, M.P., Dr. Abdul Aziz, Secretary-General, International Rubber Research and Development Board (IRRDB), Mr. Phillip T. Pondikou, Secretary-General, Association of Natural Rubber Producing Countries (ANRPC), Mr. D. Raveendran, Secretary General, Automotive Tyre Manufacturers Association (ATMA) and Dr. A.K. Krishnakumar, RPC, Rubber

Board, India felicitated. Dr. N.M. Mathew, Director, RRII, proposed vote of thanks.

The inaugural session of the INRC was followed by the keynote address on the outlook for natural rubber and the need for partnership for policy formulation by Dr. Hidde P. Smit, Secretary-General of the International Rubber Study Group (IRSG). He pointed out that with the growth of the world economies there will be increased demand for rubber while the production is likely to grow at a slower pace, leading to deficit.

The technical sessions were held on the 7 and 8 November 2005. Research papers on various disciplines were presented in two parallel sessions followed by the plenary sessions on both the days. A poster session was also organized.

In the first plenary session, Dr. Abdul Aziz bin S.A. Kadir outlined the emerging trends in natural rubber research and pointed out that the rubber research institutes all over the world are trying to address the issues of coping up with the increase in demand for natural rubber. Prof. Fu Guohua, Dean of the Economics and Management School of the South China University of Tropical Agriculture, pointed out that there will be a demand-supply gap of one million tonnes of NR in China during 2005, which is expected to increase to 1.6 million tonnes by 2010. Dr. K.R. Vijayakumar, Director, Department of Training, Rubber Board, India, presented a database on the exploitation (harvesting) systems being followed in different rubber growing countries. Mr. Phillip T. Pondikou, Secretary-General, ANRPC, presided over the session.

In the session on Crop Improvement chaired by Dr. K.U.K Namboothiri, former Director, CPCRI, India and Dr. Ramli Othman, RRIM, Malaysia, 23 papers were presented of which 15 were oral. In the Crop Management Session, chaired by Dr. A.K. Krishnakumar, RPC, Rubber Board, India and Dr. Yin Song (Cambodia), eight papers were presented orally and six as posters. Dr. M.R. Sethuraj, former Director, RRII and Dr. Cavaloc (Brazil) presided over the Crop Physiology Session, where eight papers were presented. Three papers were presented in the Session on Extension chaired by Mr. P. Mukundan Menon, former RPC, Rubber

Board, India and Mr. Preecha Pechmala (Thailand). Five oral and four poster presentations were included in the Session on Crop Harvesting in which Dr. K.R. Vijayakumar, Director of Training, Rubber Board, India and Dr. Eric Gohet, CIRAD, France were the moderators.

In the second plenary session held on 8th November, Mr. Phillip T. Pondikou, Secretary-General, ANRPC pointed out that 85.9 per cent of the world's NR production is from the member countries of ANRPC. In the backdrop of the current trends in NR production, consumption and trade, the role of these countries in the industry was highlighted. The ANRPC tries to support the member countries in the development of their NR industry. In another talk, Dr. Thomas Wijaya analysed the role of smallholdings in the NR industry in Indonesia. Analysing the latex product manufacturing industry, Dr. R.K. Mathan, India pointed out that outsourcing is practised by the industry to cope up with global competition. Dr. Abdul Aziz, Secretary General, IRRDB presided over the session.

Fifteen papers were presented in the Crop Protection session chaired by Dr. Chen Qiubo, Chinese Academy of Tropical Agricultural Sciences, (CATAS), China and Dr. P.K. Koshy, former Joint Director, CPCRI, India. A total of six papers were presented in the session on Economics chaired by Prof. Alkala, (Phillipines) and Mr. Arumugham, ANRPC, Malaysia, of which four were presented orally. Dr. E.V. Thomas, former Director, Rubber Board and Dr. Lai Van Lam (Vietnam) presided over the Rubber Technology session, where 12 papers were presented of which 10 were oral. In the discussion it was pointed out that some of the findings reported have direct industrial applications and hence the technology may be transferred to the Industry.

The concluding session was held at 4.00 PM on 8th November in which the valedictory address was delivered by Dr. K.V. Peter, Vice-Chancellor, Kerala Agricultural University. Mr. Sajen Peter IAS, presided over the function. Dr. N.M. Mathew, Dr. Abdul Aziz and Dr. M.A. Nazeer, Joint Director, RRII, also spoke.

The response to INRC 2005 was good as most of the international agencies and major rubber producing countries participated. A number of delegates from ANRPC member countries and IRRDB member institutes participated in this conference, besides a number of Indian delegates representing various stakeholders.

International Workshop on Tapping Panel Dryness 10 November 2005, RRII, Kottayam

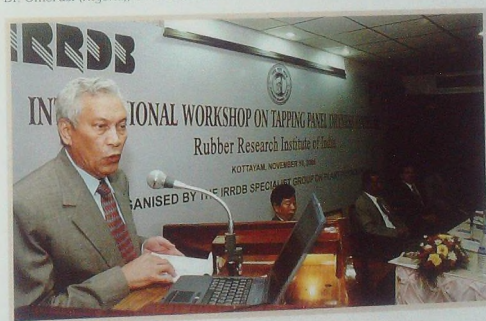
Rubber growers throughout the world are extremely concerned about tapping panel dryness (TPD) which is as old as the rubber plantation industry itself. Although this is not a new problem, its seriousness has increased manifold in recent times as more areas with high yielding clones have come into tapping. There are different schools of thought about the possible causes of TPD. But the exact cause is still unknown, in spite of a large volume of scientific literature available on this subject. The International Rubber Research and Development Board (IRRDB) through its Specialists Group on Physiology has been actively co-ordinating TPD research in various member countries and institutes. The RRII hosted the International Workshop on Tapping Panel Dryness (TPD) of rubber, organized by the International Rubber Research and Development Board (IRRDB) Expert Group on Physiology, at Kottayam on 10th November. The Workshop underscored the need to address the problem in a comprehensive and

holistic manner and to evolve research based strategies to contain it.

In his opening address Dr. Wan Abdul Rahaman, Chairman, IRRDB said that the Board has identified TPD as one of the most important problems to be addressed by scientists, since TPD results in heavy loss in production. The IRRDB has been organizing similar workshops since 1988 generating keen interest among researchers of different natural rubber producing countries. He also hailed the contributions of RRII in this regard. While reviewing the current status of research, he said, the focus should also be made on assessing the gravity of TPD incidence in various rubber growing countries.

Dr. N.M. Mathew, Director, RRII presided over the function. Dr. Abdul Aziz, Secretary General, IRRDB and Prof. Chen Qiubo, CATAS, China felicitated. Dr. Abdul Aziz released the CD containing the conference papers and the book, *Tapping Panel Dryness: An Annotated Bibliography*. There were 28 oral presentations and the key speakers included Dr. Omorusi (Nigeria), Dr. Pascal Montoro (France), Dr. Daniel Nandris, Eric Cavaloc, Dr. Panida, Dr. Unchera Sookmark (Thailand), Dr. Do Kim Thanh (Vietnam), Dr. Padma Ramachandran, IARI, New Delhi, Dr. M.R.Sethuraj, former Director, RRII, Dr. K. R. Vijayakumar, Director of Training, Rubber Board and Dr. James Jacob, Laison Officer, Expert Group on Physiology, IRRDB.

More than 150 scientists from about 10 different countries participated in this Workshop. About 30 papers were presented at the Workshop in areas such as, Prevalence of TPD, Physiology, Biochemistry and Molecular Biology of TPD, Pathology of TPD and Economics and Management of TPD. There was an active brain storming session at the end of the presentations. Although TPD is an old problem and a lot of scientific work has been done on this subject, a comprehensive book on TPD is not available at the moment. Therefore, RRII took the initiative to come out with a book entitled "Tapping Panel Dryness of Rubber Trees", which is an edited volume comprising all the papers presented at the Workshop as well as a few invited articles.



National Training Programme on Application of Molecular Markers 28 November – 14 December 2005, RRII, Kottayam

DNA based molecular marker techniques both on their own and in combination with conventional techniques has recently attained significant importance in the conservation and management of Plant Genetic Resources. The recent developments in molecular marker techniques have been realized as highly potential tools applicable to areas of direct relevance in the conservation, characterization and evaluation of germplasm resources. Knowledge on the identity of germplasm, the degree of differences or similarity among the germplasm accession in the collection, structure and amount of genetic variability present and finally locating desirable genes in accessions are some of the important applications of molecular markers in plant genetic resource (PGR) management. In this background, it was felt that the application of molecular marker techniques in the management of plant genetic resources in plantation crops like rubber, coffee, tea, spices etc in India has to be strengthened by imparting advanced training to scientists working in this field.

The 15 day national training programme on Application of Molecular Markers in Plant Genetic Resource Management in plantation crops like rubber, coffee, tea, spices etc was organized from 28 November – 14 December 2005 to train the scientists working on the management of plant genetic resources in these crops. The resource persons for this training programme included Dr. K.V. Bhat, National Bureau of Plant Genetic Resource (NBPGR), New Delhi, Dr. M. Maheswaran, Tamil Nadu Agricultural University, Coimbatore, Dr. H.E. Shasidhar, University of Agriculture Sciences, Bangalore and Dr. T. Mohapatra, IARI, New Delhi.

The training programme was inaugurated by Dr. K.V. Peter, Vice-Chancellor, Kerala Agricultural University. He said that molecular biology and PCR based molecular marker techniques were highly contextual after signing of the intellectual property rights (IPR) agreements. For conserving the biodiversity of crops, distinctiveness, uniformity and sustainability are vital where molecular marker techniques like RAPD, RFLP and Micro satellites are highly relevant, he said. In the

presidential address Mr. Sajen Peter IAS, Chairman Rubber Board stressed the relevance of molecular marker techniques which would contribute to productivity enhancement in the Indian agricultural sector especially rubber. Dr. A.K. Krishnakumar, RPC, Rubber Board, Dr. M.R. Sethuraj, former Director, RRII and Dr. K.V. Bhat, Senior Scientist, NBPGR felicitated. Dr. N.M. Mathew, Director, RRII welcomed the gathering and Dr. Y. Annamma Varghese, Dy. Director (Germplasm) proposed vote of thanks. The Rubber Board Chairman released the book entitled *Descriptors for Rubber* and the Laboratory Manual prepared for the training programme.

The programme provided training to the participants on a wide range of topics from DNA extraction to demonstrations in most recent topics like functional genomics, genome mapping, marker assisted selection etc. The laboratory practicals were endorsed by theory and demonstration sessions by the eminent resource persons covering a host of divergent topics of practical relevance. Fifteen scientists from various national institutes and universities participated in the training programme. The programme came to a close on 14 December 2005 with a concluding session chaired by Dr. N.M. Mathew, Director, RRII. Dr. T. Mohapatra, IARI New Delhi, offered the concluding remarks, highly appreciating the various components of the programme. Dr. Y. Annamma Varghese, Course Coordinator proposed the vote of thanks.

The national training programme on Application of Molecular Markers in Plant Genetic Resource Management in plantation crops, sponsored by the Department of Biotechnology, New Delhi was corroborated as a capacity building programme for the participating scientists working on molecular marker technologies in plantation crops in India. The programme offered an insight in to recent developments in the DNA marker technology for the better management and utilization of plant genetic resources for sustainable crop improvement in various plantation crops in India.

Farmer Scientist Interaction programmes - February – April 2006

As part of the Golden Jubilee Celebrations of RRII, the Institute has conducted farmer – scientist interaction programmes at seven different places in Kerala and one in the North-East. The purpose of the programme was to have a close interaction with innovative growers who have developed useful technologies/innovations in various areas like agromanagement practices, crop processing, crop harvesting, pollution control, development of good quality grade sheets, bee keeping etc.

The programme could be successfully conducted with the help of Rubber Production Department who identified innovative farmers from these regions. Scientists representing various disciplines of RRII, Senior Officers of the Rubber Production Department and extension officers of the region also participated in each programme.

Mr. Sajen Peter IAS, Chairman, Rubber Board formally inaugurated the series of state level Farmer-Scientist Interaction programme at Vayala East Model RPS on February 9, 2006. In his inaugural address the Chairman said that these programmes are organized to identify the real problems faced by the growers, to find scientific solution to these problems and to formulate future research strategies. Mr. Muraleedharan Thazhekkara, All India Radio, Trivandrum was the moderator. About 40 selected farmers coming under the purview of Regional Offices of Pala, Erattupetta and Thodupuzha participated in this prog-

ramme. In the second programme of the series held at Model RPS, Chirakkadavu on February 17, selected growers from Kottayam, Kanjirappally and Changanachery participated. Dr. N.M. Mathew, Director, RRII was the moderator during interaction. Selected farmers from Ernakulam, Kothamangalam and Muvattupuzha regions participated in the third interaction programme held at Mekkadampu Model RPS on February, 24. Mr. P. Mukundan Menon, former Rubber Production Commissioner, Rubber Board was the moderator.

The fourth one in the series was held at Nedumangad on March 1, 2006 in which selected farmers from Trivandrum and Nedumangad regions participated. Dr. Vikraman Nair, former Director of Research, Kerala Agricultural University was the moderator. Nilambur was the venue for the fifth Farmer-Scientist Interaction programme in which farmers under Trichur, Palghat, Mannarkkadu, Manjeri, Nilambur and Calicut Regional Officers actively took part. Dr. M.A. Nazeer, Joint Director, RRII was the moderator. The sixth programme in the series was held at Thadikkadavu RPS, Taliparamba and about 30 rubber growers coming under Kanhangad, Taliparamba, Sreekandapuram and Thalassery Regional Offices shared their practical experiences in rubber cultivation with the scientists. Dr. M.A. Nazeer, Joint Director, RRII was the moderator.

The last of the series in the traditional region was held at Central Experiment Station, Chethackal on March 16, 2006. Dr. N.M. Mathew, Director, RRII formally inaugurated the function. Dr. K.R. Vijayakumar, Director, Training Dept. who presided over the function formally released the annotated bibliography on farming system compiled by RRII Library. About 40 farmers coming under Kottarakkara, Adoor, Pathanamthitta and Punalur Regional Offices participated.

One programme was conducted at RRS, Guwahati jointly by the Regional Research Station, Guwahati, RRII and the Zonal office, Guwahati. Scientists from all the North Eastern Regional Research Stations, representative senior officer of RRII and planters from various states like Assam, Tripura, Meghalaya, Mizoram and Nagaland participated in the discussions. Many innovative ideas of farmers could be noted which will be studied in depth by the RRII.

Interactive Session on TSR Processing Industry
4 April 2006, RRII, Kottayam

The Rubber Research Institute of India had initiated a detailed investigation on the issues confronting the TSR sector and its prospects. Accordingly, an interactive session of the stakeholders of TSR processing industry was organized on 4 April, 2006 at RRII. In all, there were 104 participants including 23 representatives of the TSR processing industry.

The half day session was inaugurated by Mr. Sajen Peter IAS, Chairman, Rubber Board and was presided over by Dr. N.M. Mathew, Director of RRII. Apart from the brief presentation by Mr. S. Veeraputhran, Scientist, on the objectives of the study, a draft questionnaire was circulated among the participants for obtaining critical comments on the proposed study. There were two sessions: the first session focused on 'Issues, Challenges and Alternatives' and was chaired by Prof. K.K. Abraham, President, Pala Rubber Marketing Society and Chairman, Indian Block Rubber Association. The second session on 'Objectives of the Study' was chaired by Mr. M.K. Balagopalan Nair, Director, Processing & Product Development, Rubber Board.

The four major issues discussed at length in the first session were; pricing of TSR, availability and quality of the raw material, scale of production and Foreign Direct Investment (FDI) in the TSR sector. The discussion in this session justified the need for undertaking a techno-economic study on the TSR sector from a long-term perspective. The proposed objectives, scope and mode of investigation were approved by the participants. The representatives of the TSR processing sector offered their co-operation for the timely completion of the project.

The second session was exclusively meant for a detailed discussion on the questionnaire circulated among the participants for gathering the relevant information from the existing TSR processing units. Mr. M.K. Balagopalan Nair explained the objectives of the study and the relevance of the quality of data intended to be collected. Clarifications were made on different topics presented in the questionnaire. As suggested by the participants, the five year period of study was modified to include the year 2005-2006.

International Training on Strategies for Management of *Corynespora* Leaf Disease of *Hevea brasiliensis* 18–29 April 2006, RRII, Kottayam

The RRII was selected as the international training centre on "Strategies for the Management of *Corynespora* Leaf Disease" by the Common Fund for Commodities (CFC). This training forms a component of the R & D project on 'Improvement of Management Strategy in Combating *Corynespora* Rubber Leaf Fall Disease' funded by the CFC and carried out in four countries namely Indonesia, Malaysia, Sri Lanka and India under the technical supervision of the International Rubber Research and Development Board (IRRDB) and the International Rubber Study Group (IRSG). Twelve trainees from 10 IRRDB member countries namely Indonesia, Malaysia, Thailand, Philippines, Cambodia, China, Vietnam, Sri Lanka, Nigeria and India were selected for the training programme. The participants included both scientists and extension officers. These trainees are expected to lead the R & D activities against *Corynespora* leaf disease in their respective countries after their training at RRII. The training was organized from 18 – 29 April 2006.

The training was inaugurated by Dr. N.M. Mathew, Director, RRII. The programme consisted of classroom lectures, practicals and field demonstrations. The subjects covered in the classroom training included identification of the disease by symptoms and morphological characters of pathogen, variability of pathogen, environmental impact, host pathogen interaction, toxins and their role in varietal screening, clonal susceptibility, control of disease by cultural, chemical, biological, genetic and integrated disease management and a case study of successful disease management strategies adopted in Sri Lanka.

The practicals included morphological and molecular identification of the pathogen, isolation and detection of enzymes and PR proteins involved in host defense, pathogen toxin, its isolation, purification and use in screening for disease tolerance in cultivated clones and germplasm, disease intensity assessment methodology and chemical/ biological disease control techniques.

The severity of infection by *Corynespora* and the strategies adopted for its control were demonstrated to the trainees. The use of different equipments developed for spraying in different types of plantations in the disease affected areas was demonstrated in the Hevea Breeding Sub-station of RRII at Nettana, Karnataka. The field laboratory for plant pathological research at Kadaba was used for laboratory work on observation and study of the pathogen. The arrangements for recording meteorological parameters and for monitoring of spore load in the atmosphere using spore trap were also demonstrated. A seminar on future trends in Natural Rubber Research was also organized. The trainees prepared action plans for research and extension activities to be undertaken on return to their respective countries under the guidance of the expert faculty and presented them for discussion and modification. A post conference tour also was organized. The evaluations conducted before and after the course revealed a significant improvement in the knowledge of the participants on all aspects of *Corynespora* leaf disease and its management strategies.

Orientation programme on Identification of RRII 400 series clones 17-24 August 2006, RRII, Kottayam

An orientation programme on 'Identification of RRII 400 series clones was organized for the extension officers of Rubber Board, as a joint venture of the RRII and Rubber Production Department of the Rubber Board during 17 – 24 August 2006. The programme was formally inaugurated by Mr. Sajen Peter IAS, Chairman, Rubber Board at RRII on 17 August 2006. Dr. N.M. Mathew, Director, RRII presided. Lecture session and field demonstrations were conducted for three batches of 20 participants each, from all the Regional Offices of the traditional rubber growing region. The programme provided the participants a forum to identify the salient morphological feature of the RRII 400 series clones in order to facilitate easy identification of these clones from budwood and polybag nurseries as well as young plants in the field.

A reference manual on 'Identification of RRII 400 series clones of *Hevea* in the early growth phase' incorporating

the newly released clones RRII 414 and RRII 430 along with RRII 417, RRII 422 and RRII 429, was brought out in this connection. This manual will serve as a practical guide having essential technical details and key salient morphological features presented in a simple and systematic manner.

Despite the fact that the RRII 400 series clones are the progenies of the same parental combination, one can make out the unique diagnostic features of each one of them through close monitoring and experience. In the context of the overwhelming demand for these clones and the serious concerns of growers in ensuing the authenticity of planting materials procured, especially from private nurseries, the programme was organized to train the extension officers, so that they can disseminate the information among other target groups including growers and nursery owners.

Rubber Growers Conference - 24 October 2006, RRII, Kottayam

The Rubber Growers Conference, 2006 held at RRII, Kottayam on 24 October was the resultant programme of the series of farmer-scientists interaction conducted by the RRII. About 500 selected growers and representatives of Rubber Producers' Societies attended the conference. Mr. Sajen Peter IAS, Chairman, Rubber Board inaugurated the Conference which was presided over by Dr. N.M. Mathew, Director, RRII. In his inaugural address Mr. Sajen Peter IAS said that interaction between rubber growers and the scientists working in rubber sector is very essential and should be a regular exercise. Even though Kerala, which accounts for 90 per cent of rubber production in India, lies outside the ideal rubber belt, it has achieved a very high level of productivity and rubber cultivation has successfully been extended even to North Eastern areas which are far beyond the traditional rubber growing area. This is because of the strong research and developmental activities carried out in Indian rubber sector and the high level adoption of technologies by the rubber growers.

Mr. Sajen Peter also said that the series of grower- scientist interactions conducted earlier, throughout the traditional rubber growing area, were immensely successful and provided the scientists with numerous new ideas, indigenous knowledge and also results of several field level research activities conducted by the growers. Based on the success of these interactions, the Board moots an idea to make it a regular exercise.

About 50 innovative growers from different parts of the traditional rubber growing areas presented their observations and results of research activities and agromanagement practices conducted by them in their fields. These growers were selected from among hundreds of the growers who made presentations in the zonal farmer-scientist interactions conducted over the previous few months.

The book *Abhivrudhi Anubhavangaliloode*, a malayalam compilation of the papers presented in the Growers' Conference and a documentary film on the success story of the Rubber Board in the North East were released by Mr. Sajen Peter and the first copies were received by Dr. N.M. Mathew, Director and Mr. K.K. Raghavan, Jt. Rubber Production Commissioner. Another book, *Karshakarkku Snehapoorvam* (To Farmers with Love) written by Mr. Sajen Peter, was released by Dr. N.M. Mathew and the first copy was received by Mr. Augustine Mylackal, President, Aimcombu RPS.

Interactive Session on Non-tyre Rubber Products Manufacturers in Kerala 27 October 2006, RRII, Kottayam

Results of the preliminary investigations undertaken by the Economics Division of the RRII indicated that the worst-hit victims of the NR price uncertainty consequent to economic reforms launched in India since 1991 have been the small rubber growers and the small and medium scale rubber products units in the non-tyre sector. It is in this background an interactive session of non-tyre rubber products manufacturers in Kerala was organized by the RRII at Kottayam on 27 October, 2006. The session was attended by 67 representatives of the rubber products manufacturers, scientists and other officials of the Rubber Board.

The dignitaries who took part and deliberated in the interactive session included Chairman of the Rubber Board, Mr. Sajen Peter IAS, Dr. N.M. Mathew, Director of RRII, Shri. K.T. Thomas, President, All India Rubber Industries Association, Shri. N. Satyaraj, Director, Common Facility Centre, Changanacherry and Dr. D. Narayana, Fellow, Centre for Development Studies, Thiruvananthapuram.

The programme was formally inaugurated by Mr. Sajen Peter, IAS Chairman Rubber Board. The major observations based on the investigations carried out earlier in the Economics Division of the RRII were summarized by Dr. K. Tharian George, Joint Director, Economics Division in his welcome speech.

Dr. N.M. Mathew while presenting the issues confronted by these industries opined that the obsolete technology, micro characteristics of production facilities and unhealthy competition were the major issues demanding immediate attention and redressal. Mr. Sajen Peter assured that the Rubber Board and Rubber Research Institute of India would provide all possible technical support to the rubber goods manufacturers. Mr. K.T. Thomas who chaired the session stated that technological upgradation and cost minimization were the inevitable *'Mantras'* to survive in the globalised market.

Mr. N. Satyaraj observed that his efforts on evolving a Cluster Approach had been yielding promising results and the strategy was expected to provide the required stimuli for the sustainability of small scale units in Kerala.

Responding to the problems raised by latex based rubber goods manufacturers, Mr. Sajen Peter assured quality raw materials at notified price to the manufacturers on the condition that the purchase should always be made regularly from the NR trading companies promoted by the Rubber Board.

One of the important outcomes of the session was the relevance of a consortium approach to procure quality raw materials at competitive prices and also for common processing facilities to incorporate modern technology in the production process. The consortium could also be an effective tool to consolidate the markets for the small scale manufacturers.

Important issues raised in the session were consolidated and presented in the workshop by Dr. D. Narayana.

Golden Jubilee Publications

1. *Harmonised System Nomenclature: A Reference Manual on Rubber and Rubber Products* by Tharian George K. and Joby Joseph.

The Harmonised Commodity Description and Coding System, popularly known as the HS, is one of the central pillars of the WTO mandated international trading system. This multipurpose product nomenclature, developed by the Customs Co-operation Council, accounts for more than 98 per cent of merchandise in international trade. This reference manual contains salient features and usage of the HS with special reference to rubber and rubber products. The details contained in the four chapters of the manual are based on the latest version of the HS (2002).

2. *A Manual on Breeding of Hevea brasiliensis* by Kavitha K. Mydin and C.K. Saraswathyamma.

This book is a step-by-step guide on the techniques of rubber breeding for the benefit of young researchers, technical personnel from various disciplines involved in plant breeding experiments, students of perennial crop breeding and all individuals interested in the various facets and dimensions of crop improvement programmes. The book elaborates the time tested conventional breeding procedures in rubber with the aid of line drawings, flow charts and colour illustrations. Modern breeding techniques and intellectual property rights have been explained in a lucid manner along with support data and various formats neces-

sary for successful implementation of crop improvement programmes.

3. The Proceedings of the *International Workshop on Exploitation Technology* edited by K.R.Vijayakumar *et al.*

This include 21 presentations made in the workshop held during 15-18 December 2003. Fifteen papers are on exploitation technology and the remaining six on allied disciplines of plant breeding, socio-economics, tapping panel dryness and latex diagnosis. The workshop was conceived with the objective of bringing together scientists of member countries of the International Rubber Research and Development Board (IRRDB) to take stock of the science and technology of harvesting of *Hevea*. This book will be a good reference book for researchers as well as extension personnel.

4. *Descriptors for Rubber* by G. Prabhakara Rao *et al.*

The book was prepared for the first time in an internationally accepted format as per the norms set by the International Plant Genetic Resources Institute (IPGRI), Rome incorporating specific information pertaining to rubber. It is an authentic guide for the management of *Hevea* germplasm containing a comprehensive description of the different growth stages of various germplasm materials. This publication will be very useful to all those involved in rubber research especially those in the conservation, management and utilization of *Hevea* germplasm.

5. *Fifty Years of Natural Rubber Research in India: A Bibliography*, compiled by Accamma C. Korah and Mercy Jose.

This is a comprehensive list of about 2500 scientific and technical papers published by RRII/Rubber Board from 1955 to 2005. The compilation consists of four sections. In section 1, Bibliographic details of papers are arranged in chronological order under author's surname. Section 2 is the keyword index, comprising all the 'key words' indicating the subject coverage and Section 3 is the author index. The affiliation and addresses of authors are given in Section 4. This publication would be of great use not only to scientists but also to all those who are involved in the sector in exchanging and sharing information at the global level.

6. *Tapping Panel Dryness*, compiled by N. Latha and Mercy Jose.

The bibliography consists of literature on brown bast, bark dryness, stimulation methods, TPD control and related areas of tapping panel dryness. The compilation provides a reference list of TPD or brown bast research in India and abroad since 1917. The compilation consists of three sections. In the first section, the references are arranged in the chronological order under the surname of each author. The keyword index and author index are suffixed with their entry numbers

7. *Rubber Based Farming Systems* compiled by Sujatha *et al.*

This compilation lists bibliographic details of 256 research articles published all over the world from 1941 to 2005 on rubber based farming systems and relates aspects. This bibliographic tool provides the international trends on different aspects of intercropping in various rubber producing countries.

8. *Preprints of Papers: International Natural Rubber Conference 2005* edited by N. M. Mathew *et al.*

This compilation contains 111 papers presented in the conference held at Cochin, Kerala as part of the Golden Jubilee celebrations of the Institute. The papers are arranged under eight disciplines besides the key-note address and the eight papers presented in the two plenary sessions.

9. *Corynespora Leaf Disease of Hevea brasiliensis*, edited by C.K. Jacob.

This is a compilation of reviews on the current status of the management of one of the most serious leaf diseases of rubber. All aspects of the disease including its occurrence, symptoms, pathogen, toxin, clonal resistance and different control measures are covered in the 17 chapters of the book. The disease control measures in Sri Lanka since its initial detection in 1985 is also included and the detailed bibliography in the end facilitates further reference.

10. *RRII 400 Series Clones of Rubber* by C. K. Saraswathyamma *et al.*

This book gives a comprehensive account of yield and other secondary attributes of RRII 400 series clones and their parents RRII 105 and RRIC 100. The book, organized in eight chapters, covers history of evolution of the clones, characteristics of mature and five-year-old trees, as well as six-months-old plants, leaf characteristics, genetic variation of the clones etc.

11. *Training Programme on Application of Molecular Markers in Plant Genetic Resource Management in Plantation Crops* by S.T. Abraham *et al.*

This laboratory manual covered a wide range of topics from DNA extraction to functional genomics and genome mapping.

12. *International Training Programme on Management of Corynespora Leaf Fall Disease of Hevea* by C.K. Jacob *et al.*

This manual covered laboratory and field manual techniques on *Corynespora* leaf fall disease and its management ranging from morphological identifications to molecular plant pathology.

13. *Identification of RRII 400 series clones of Hevea in early growth phase* by V. Thomas *et al.*

This manual is a practical ready reference tool for the proper identification of RRII 400 series clones in budwood, polybag nurseries and immature stage in field. It provides the required technical details with key salient morphological features in a simple, systematic and lucid manner.

14. *Kyoto Protocol and the Rubber Industry* edited by James Jacob and N.M. Mathew.

This is the first book dealing with the implications of Kyoto Protocol on the rubber industry. Clean Development Mechanism (CDM) is one of the flexible market mechanisms established under the Kyoto Protocol with the objective of helping the industrialized countries to meet their greenhouse gas (GHS) emission reduction targets set under the protocol cost-effectively. This book will be highly useful as a beginner's guide for those interested in earning carbon revenue through CDM projects.

15. *Tapping Panel Dryness on Rubber Trees* edited by James Jacob, R. Krishnakumar and N.M. Mathew.

Organized in to 33 chapters, contributed by 83 scientists from eight different countries, the book, discusses topics such as the extent of prevalence of TPD, physiology, biochemistry and molecular biology of TPD, pathology of TPD and its economics and management. ■

Agronomy/Soils Division

Contributions since establishment

The Agronomy/Soils division is one of the major divisions of Rubber Research Institute of India since its establishment in 1955. Development of various agro management techniques that are economically viable and environmentally compatible were the major research activity of the Division. Accordingly the Division focused on various agro management aspects such as planting designs and density, nutrient management, soil/water conservation, weed management, inter cropping, physico-chemical soil characterization and soil/leaf analysis based fertilizer recommendation.

Fertilizer trials in rubber were initiated in India since 1955. Later clone cum fertilizer experiments conducted at different agro climatic zones led to general fertilizer recommendations in nursery, immature and mature stages of rubber cultivation. Nursery trials revealed that N,P,K mixture application have positively influenced the height and girth of seedlings which is necessary for the establishment of uniform growth. Nitrogen and phosphorus applications had improved the growth of seedlings in general, while beneficial effects of potassium and magnesium were seen only in highly impoverished soils. N, P, K, Mg application at

10:10:4:1.5 level was found effective in improving the growth of young rubber plants with leguminous cover crop.

Clone cum fertilizer experiments were conducted on mature trees of clones RRII 105 and PB 235 with different levels of NPK. In both the clones, NPK application at 30, 30, 25 kg/ha level had reflected positively and significantly on girth and girth increment. NPK at 60, 30 and 40 kg/ha/annum gave highest yield in early tapping phase.

Various trials had revealed that leguminous cover crops *Mucuna bracteata* and *Pueraria phsaeoiloides* had beneficial effects on growth of young rubber and later in the yield. Dry matter production was more in the second year of establishment in both the legume species and was more in the case of *Mucuna*. However, N and P turn over during the initial two years was more in case of *Pueraria* while turnover for K was more in *Mucuna*. Annual litter addition ranged from 6.8 to 7.8 tonnes/ha in mature rubber plantations and released 94 to 130 kg of N, 5 to 6 kg of P and 22 to 25 kg of K in case of RRIM 600. In a similar study, in clone RRII 105 litter addition was 4.8 tonnes/ha releasing 88 kg N, 2.4 kg P, 45 kg K, 60 kg Ca, 16 kg Mg, 1.5 kg Mn and 0.25 kg Zn.

Ecological desirability of rubber in terms of habitat diversity, soil physical properties and nutrient cycling was established through a comparative evaluation of rubber, teak and natural forest. Continuous cultivation of rubber was found to reduce the total N and K status of the soil and increase the P status, pointing to the necessity of application of higher dose of N and K fertilizer and reduction in P fertilizer.

Liming was found to improve the P and K availability in soil. Also it was effective in improving the dry matter production and nodulation of *Pueraria phaseoloides*. Bowl sludge, a waste product from latex centrifuge factory was found to be a good source of phosphorus for rubber. In another experiment on nutrient inflow through rainfall and leachability of nutrients from rubber canopy were estimated. Gross nutrient addition through rainfall was 45.2, 13.2, 23.8, 4.7, 0.6, 0.5 and 0.6 kg N, K, Ca, Mg, Fe, Cu and Zn per hectare respectively.

Discriminatory fertilizer usage (DF) was initiated in 1965 based on soil analysis and later modified with leaf analysis in 1970. At present the discriminatory fertilizer recommendation (DFR) is offered to estate and smallholding sectors. Diagnosis and Recommendation Integrated System (DRIS) norms for the nutrients N, P, K, Ca and Mg were formulated for rubber.

Among the different extractants evaluated for available P in soil, Bray II was found more suitable for rubber growing soils. Studies indicated that AER (Anion Exchange Resin) based extractant would provide a better picture of available P status of the soil, since such extractants make an assessment of the labile P pool also. For acidic rubber growing soils, neutral ammonium acetate and Morgan extractant had resulted in similar values for exchangeable K, Ca, and Mg. Suitability of 0.1 M $BaCl_2$ as an extractant for soil available nutrients was also established. Leaf sampling period for the purpose of fertilizer recommendation were standardized, and the period 220 and 310 days after leaf emergence was optimum for leaf sampling. However, the period can be widened to 200 and 320 days, if corrections for N content are applied.

A simple and rapid non-digestion method for the determination of K, Ca

and Mg in leaf samples and a rapid method for the determination of N, P and K in *Hevea* fresh leaf were evolved.

The soils under rubber were surveyed, characterized and mapped in traditional region including Kerala and Tamil Nadu in 1:50000 scale. A total of 62 soil series were identified and 411 soil units were mapped, which were combinations of these soil series. The rubber growing soils come under three soil orders i.e., Entisols, Inceptisols and Ultisols. Soils under rubber in both traditional and non-traditional regions were characterized for their physical, chemical and mineralogical properties. Moisture retentions curves were developed for few rubber growing soils of SW peninsula. It was noticed that adoption of proper agro management practices had resulted in organic matter enrichment which improved soil physical environment and moisture holding capacity. Influence of altitudinal differences on soil properties like morphology, physico-chemical and exchange characteristics was studied.

It was found that major portion of total K was in the lattice and organically bound form. Organic carbon had positive and significant correlation with all the forms of K while clay had positive and significant correlation with only total K. Significant correlations were observed between organic carbon and total available S. Micronutrients, i.e., Fe, Mn, Zn and Cu were different in soils of different regions and were positively correlated to organic carbon content.

A study on Quantity-Intensity parameters indicated that the soils of Kerala (CES) can supply K for longer time than soils of Tripura (RRS) because of its higher buffering capacity (PBC^K). Similarly, K fixation was found to be more in soils of CES, Kerala compared to RRS, Tripura. In general, soils under rubber in traditional region fix more P and is indicated by Fe bound P content, which is a dominant inorganic form of P. It was suggested that Al bound P and also total P could be considered as better indices of P availability because of their relationship with leaf P content. It was found that soils from CES tend to fix more P than soils of RRS, Tripura. Among rubber growing soils wide variations in available micronutrients such as Mn and Zn were recorded.

Intercropping with diverse annual and short term crops was introduced to generate income during the unproductive phase of the plantation cycle. Growing intercrops at 1.5 m away from the base of rubber with separate and adequate manuring for both rubber and intercrops will enhance growth of rubber. By altering the planting geometry of rubber, intercrops could be cultivated during the entire immaturity period of rubber. To generate additional income during mature phase, feasibility of cultivating perennial intercrops was explored and cocoa was found to be a promising intercrop with around 60 per cent yield compared to monoculture. Feasibility of growing other timber trees with rubber was studied. In situations of mixed planting of rubber with wild jack (*Artocarpus hirsutus*), upto 20 per cent of wild jack did not affect rubber growth.

The density of planting was found to have a direct bearing on per hectare and per tree yield. Per hectare yield was highest when the density of plantation was 549 trees/ha, and higher densities had declined the per hactare yield. Also, high density lead to high maintenance and tapping cost. High benefit cost ratio was recorded in 450-500 tree/ha.

Crop coefficients were worked out for immature rubber using lysimeter. The crop coefficient values increased from first year to the third year of planting.

Irrigation at 50 per cent depletion of available soil moisture was optimum for growth of seedlings in nursery. Basin and drip methods of irrigation for rubber were comparable and irrigation had resulted in reduction of the immaturity period by six months to one year. Irrigation at 50 per cent of the crop evapotranspiration was sufficient for improving the growth.

Soil and water conservation strategies were designed and developed for rubber plantations. The recommended practices on hilly and undulating lands for conserving moisture and preventing erosion include contour terracing, establishment and maintenance of legume ground cover, construction of stone pitched retaining walls (edakkayyalas), digging of silt pits, mulching and providing adequate drainage facilites. Experiments on effect of conservation pits in mature rubber revealed that 4-9 tonnes of soil was conserved and thus prevented from being eroded when the number of pits was increased from 100 to 250 /ha. Rubber yield was found to be increased by 15 – 25 per cent by taking pits @ 250/ha.

Physical, chemical and cultural measures were developed for controlling weeds during different stages of rubber growth. Scraping, uprooting and slashing are commonly resorted to in manual (physical) weeding. Scraping was found to significantly reduce the weed population, but the cost incurred was very high. It is estimated that weed control alone accounts for about 28 per cent of the total cost of cultivation which can be brought down considerably with the use of herbicides. Different combinations of herbicides were found to be more effective in controlling a mixed weed population rather than the use of a single herbicide. Establishment and maintenance of legume ground cover in the early phase can minimise the weed infestation in the interspaces to a great extent. An integrated approach involving a combination of manual, physical and chemical method was developed which was cost effective and eco-friendly. The method involves spraying glyphosate in the plant basin and slash weeding the remaining area along the planting strip and establishment of legume ground cover in the inter space. Application of pre-emergence herbicide, diuron @ 2 kg/ha was found effective in controlling weeds in seedling nursery. Mulching the nursery beds after fertilizer application reduces the weed population substantially. Use of recycled polythene material for mulching plant base was found to curtail weed growth. 2, 4 D (Fernoxone), paraqat (Gramaxone) and glyphosate (Roundup) are the recommended soil applied herbicides for controlling weeds in the planting strips. Recommended combinations and dose of each chemical were also developed. The effectiveness of herbicides like glyphosate can be enhanced by addition of kaolin and ammonium sulphate. Herbicide spraying is done using knapsack sprayers or controlled droplet applicators. Use of controlled droplet applicator results in considerable savings in the spray volume (15-30L per ha) and man days, thus making herbicide spraying easier and cheaper.

Remote sensing technique could be utilized in discriminating rubber from other vegetation and with the aid of Global Positioning System (GPS), even clonal differences could be made out.

Ongoing Research Programmes

Development of improved agro-management practices for profitable cultivation of natural rubber is the major research theme of the crop management unit. The thrust areas identified are nutrient management, inter cropping and cropping systems, soil and water conserva-

tion, density of planting, management of natural resources, etc.

1. Nutrient management

Nutrient requirement studies of clone RRII 105 initiated in 1989 showed that girth increment and yield were not significantly influenced by the different levels of NPK. Studies also indicated that skipping P fertilizer up to 8 years did not affect the growth and yield of rubber. An increase in dry matter production as well as N and P uptake in rubber seedlings were noted on application of rock phosphate at recommended level along with elemental sulphur. Adaptive mechanisms at the rhizhosphere involved in the acquisition of phosphorus and micronutrient by rubber was being studied. Length and area of rubber roots were monitored in two seasons in the low and high phosphorus soils and it was high in the former situation indicating the specific physical adaptation of increased root growth under low P availability to increase the absorbing surface. Per cent VAM infection in both the locations was low. Partial substitution of K with Na up to 50 per cent showed no difference in girth, dry rubber content, while treatment with 75 per cent K and 50 per cent Na gave higher yield than other treatments.

Effect of liming on the growth of immature rubber showed that in immature phase fertilizer and lime treatments alone or in combinations did not differ but were significantly superior to control. Highest girth was recorded by 100% (Line Requirement)+ NPK Mg treatment which was closely followed by the other lime + fertilizer treatments. In mature rubber, liming showed positive effect on growth. Highest girth increment (GI) was recorded by shell lime followed by dolomite. Fertilizer and lime combination also showed significant effect on rubber yield with NPK + Mg recorded highest yield followed by NPK + shell lime.

Experiment to study the effect of coir pith organic manure (CPOM) as pit manure as well as mulch material for immature rubber indicated significant difference in girth and GI for FYM and CPOM treatments over no pit manure control. No significant difference in girth was obtained between FYM and CPOM.

Experiment on fine root production of rubber in relation to precipitation was continued to find the optimum time for fertilizer application after onset of monsoon. Fine root production of rubber decreased with advancement of summer season, however at deeper layer the effect was not seen.

Experiment on integrated use of organic and inorganic manure for nutrient management in rubber initiated in 2001 is being continued. Leaf N and P were significantly higher in the FYM alone applied plots. No significant difference was observed between treatments with regard to girth and girth increment. However, the application of 25% fertilizer + 75% FYM gave numerically higher girth. In another experiment, application of fertilizer alone significantly increased exchangeable and total K while FYM alone or in combination with fertilizer numerically improved different forms of K in 0 – 15 cm layer of soil. Integrated use of organic and inorganic manure improved microbial population. Application of 25% fertilizer + 75% FYM showed highest microbial population.

Methods of fertilizer application significantly influenced available P and K status in mature rubber. Highest available P and K was noticed in pocket application around the plant basin. Ex-

periment in mature rubber indicated that yield and girth increment of rubber were not significantly influenced by fertilizer skipping treatments.

2. Physical and chemical properties of soil

Analysis of the NBSS & LUP soil survey data indicated that the soil depth and coarse fragments were important soil properties that classify the different soil series into three groups suggesting the importance of effective soil volume in response of rubber to quantity and split application of fertilizer. The experiment on change in physical and chemical properties of soil by planting different intercrops is being continued. A slight reduction in bulk density and increase in porosity was noted in tapioca intercropped area.

Experiments on soil characterization of rubber ecosystem showed that organic matter and humic acid were significantly higher in mature rubber plantations followed by immature rubber plantations with *Pueraria* and *Mucuna* as cover crop. In the case of fulvic acid no significant difference was found between the three different systems.

In the experiment on comparison of different soil ecosystems, organic fractions, organic carbon and total nitrogen were compared between rubber, teak, cassava and forest ecosystems. The results indicated that forest system was having more OM and OC in all size physical fractions compared to the cultivated systems. Among the cultivated systems cassava was having the least OM and OC. Total nitrogen showed an increasing trend till the third size fraction (250 – 53 um) in all the systems and then a declining trend as the size fraction decreased except in rubber. In rubber system total N steadily increased as the size decreased, however, not reflected on available N.

Differences in soil properties under five locations, distinctly different in agro-climatic conditions, indicated that soil needs to be regarded and included as a component of environment when G x E kind of studies are taken up.

3. Soil and water conservation

The experiment initiated in 1998 to study the influence of silt pits on growth and yield of mature rubber and to explore the possibility of applying fertilizer for rubber in silt pits is being continued. Making conservation pits @ 250 per ha showed significantly higher rubber yield and mean soil moisture (Table Ag. 1). Annual girth increment showed a positive trend with number of pits per ha.

4. Density of planting

Experiment was initiated to study the effect of density of planting on growth and yield of rubber as plant density and sub plot treatments showed that plants in lowest density of 420/ha had significantly higher girth and girth increment compared to all other treatments. Per tree yield decreased significantly with increase in density where as annual yield (kg/ha/year) increased with increase in density up to 549 trees/ha and beyond that significant increase was not observed (Table Ag. 2).

5. Intercropping and cropping system

In the cropping system experiment started in 1993 at CES, growth and yield of rubber were higher in the cropping system compared to monoculture. Growth and yield of rubber were not influenced by growing coffee and cocoa in the later phase of immaturity. Coffee yield continued to be poor, but cocoa performed comparatively better. The population of microorganisms was found to be higher under intercrops compared

to rubber monoculture or rubber in intercropped fields.

In two on farm trials having one block of rubber (RRII 105) with excess number of naturally sprouted wild jack (*Artocarpus hirsute*) trees, the interaction between them was studied. Girth of rubber with wild jack up to 2 m from rubber was significantly low compared to rubber without wild jack. Girth of rubber showed a declining trend with increase in wild jack density. In both experiments tapping of rubber has been started and yield is being monitored.

Two experiments on inter planting rubber with timber trees were being continued. First experiment was with rubber spacing, 6.7 x 3.7 m and 10 x 2.4 m, as main plot and timber species, wild jack, teak and mahogany as sub plot. Girth and girth increment of rubber was not significantly influenced by row spacing, type of timber inter crop and their interaction. Among the timber species, growth performance of wild jack was better followed by teak and mahogany. Second experiment was to study the effect of different density of teak and mahogany on growth of rubber. Teak and mahogany were inter-planted at 8, 22 and 31 per cent of total of 445 rubber plants in the system with proportionate reduction in the rubber plants. Inter planting of timber intercrop on replacement basis did not affect the girth and height of rubber compared to respective monoculture rubber.

Experiments were initiated in 2001 to study the feasibility of inter cropping perennial crops like nutmeg, coffee, garcinia, and vanilla along with rubber

Table Ag.1. Effect of conservation pits on growth and yield of rubber

No. of pits / ha	Girth increment (cm) 2001- 06	Yield (g/t/t)
150 (S)	7.43	54.40
150 (P)	6.74	55.80
250 (S)	7.66	59.34
250 (P)	8.06	61.19
No pit & standard practice	6.68	50.16
No pit & no fertilizer	6.27	52.11
SE	0.66	2.28
CD	NS	6.74

Table Ag. 2. Mean rubber yield under different planting density

Treatment (tree/ha)	Yield (g/t/t)	Yield (kg/ha/yr)
420	65.6	1745.4
479	50.6	1825.4
549	51.7	2119.3
638	46.7	2198.6
749	43.3	2145.6
Main plot	3.48	137.60
SE	7.58	299.83
CD		
Sub plot	3.14	117.08
SE	NS	NS
CD		

Table Ag. 3. Regression models for through fall stem flow and interception

Parameter	Equation	R^2	SE
Through fall	-0.69 + 0.84 x RF	0.99	1.6
Stem flow	-0.37 + 0.10 x RF	0.84	0.8
Interception	1.10 + 0.06 x RF	0.40	1.6

during immaturity phase. Girth increment during summer season was significantly higher in the treatments with intercrops compared to rubber alone. PAR availability, in the inter row area in experiment I with normal spacing (6.7 x 3.4 m) was 53 per cent of open while in the middle of wide inter row area (12m) was 100 per cent of open. By intercropping coffee and cocoa the growth and yield of mature rubber was not significantly affected. The performance of coffee was not satisfactory. The monthly average yield of cocoa was 6.8 pods.

6. Rainfall interception

Rubber canopy intercepted 11.8 per cent of total rainfall. Mean percent of interception during the period was 15.5 per cent. Interception was lower than evaporation in most of the period. Regression model was developed for through fall, stem flow and interception using rainfall as an independent factor (Table Ag. 3).

Maximum interception capacity of fifteen year old rubber canopy was around 3.5 mm and total annual litter interception was 15.0 mm. Nutrient flux through rainfall process has been observed. Annual nutrient transfer to soil in rubber plantation through rainfall process was 27.36 kg N, 9.64 kg K, 9.5 kg Ca, 2.0 kg Mg, 0.18 kg Fe, 0.20 kg Cu and 0.05 kg Zn. Unlike other nutrients, nitrogen content of through fall and stem flow was lower than rainfall indicating absorption of readily available forms of N present in the rain water by the rubber leaves.

7. Others

Effort to develop a rubber information system in traditional region using remote sensing and GIS technique and application of remote sensing technique to identify powdery mildew disease of rubber is being continued.

Two field experiments were initiated in 2000, one each in immature and mature rubber with the objective to document the variations in the experimental unit and to identify the most appropriate plot size and shape for field experimentation in rubber. Experiment in mature rubber has been concluded. In immature rubber results have indicated that the optimum plot size is 6-7 trees per plot.

On the basis of 700 soil and 550 leaf analysis, 645 individual fertilizer recommendations were offered to 25 large estates. ■

DRIS Unit

Contributions since establishment

The activities of the DRIS Unit included offering advisory services to rubber smallholdings through discriminatory fertilizer recommendation(DFR) based on soil and leaf analysis and latex testing for dry rubber content (DRC) and volatile fatty acid (VFA) estimation. Studies on nutrient management and methods of fertilizer application were continued. Investigations on special problems in rubber estates/holdings and feasibility studies for rubber cultivation were carried out. The Unit also coordinated the activities of the eight regional and four mobile soil testing laboratories.

Soil testing service for rubber cultivation was initiated in RRII in 1964. Initially, estate sector was the main beneficiary of this service and only a limited number of smallholders availed this facility. Soil samples are tested for soil reaction, organic carbon, available phosphorus, potassium, calcium and magnesium. With a view to popularize the discriminatory fertilizer usage in smallholdings, the Agronomy/Soils Division of RRII has introduced a mobile soil testing laboratory (MSTL) in 1979. The MSTL visited major rubber growing areas in Kerala, Kanyakumari District (Tamil Nadu) and South Kannada District (Karnataka State) and offered on-the-spot fertilizer recommendation. Considering the increased demand from the planting community, three regional laboratories with MSTL were set up at Nagercoil (shifted to Nedumangadu in 1998), Thodupuzha (shifted to Muvattupuzha in 1989) and Kozhikode in 1986. During 1990-91, five satellite laboratories were set up at Punalur (shifted to Adoor in 1995), Pala, Thrissur, Taliparamba and Mangalore (Karnataka) to provide advisory services to rubber growers. In 1996, a laboratory was set up in Kanjirappally.

During 1986 to 2006 a total of 2,15,000 soil and 18,610 leaf samples were collected from smallholdings located in the traditional rubber growing areas of Kerala, Karnataka and Tamil Nadu and 1,08,700 discriminatory fertilizer recommendations were offered to rubber growers. Soil testing programmes were also arranged through four mobile labs mainly in areas where small growers are concentrated. More than 1600 mobile soil testing programmes were arranged at various rubber growing regions during the period 1979-2006 and offered on-the-spot fertilizer recommendation.

In addition to the soil and leaf testing services, latex testing was started in regional labs in 1997. During the period 1997-2006, a total of 2,15,500

latex samples were tested for DRC and 1850 samples for VFA.

Fertility status of the rubber growing soils was worked out for 11 districts in Kerala. The data were summarized district-wise and nutrient indices for individual districts were worked out. Data indicated that organic carbon content in soils of five districts (Kottayam, Idukki, Kozhikode, Kannur and Kasargod) is high and medium in other districts (Trivandrum, Kollam, Ernakulam, Thrissur, Palakkad and Malappuram). Available P status in all the districts is low. Available K status is medium in Thrissur and low in other districts. Available Mg is high in Kasargod, Kannur, Kozhikode, Malappuram, Palakkad and Thrissur districts and medium in other districts.

Similar study conducted in the rubber growing areas in Kanyakumari District of Tamil Nadu indicated that organic carbon is medium, available P and K are low and available Mg is high.

An impact analysis to evaluate the benefit to smallholders both in terms of savings in fertilizer and yield increase was undertaken through a sample survey, which revealed that an average annual saving of Rs.397/- per ha in fertilizer cost and yield increase of 132 kg/ha were obtained due to the adoption of DFR.

Problems reported from estates and smallholdings were attended and appropriate recommendations offered through regional labs. Advanced training on soil, plant, fertilizer and latex analysis and fertilizer recommendation was imparted to trainees deputed from various organizations.

Ongoing Research Programmes

The DRIS unit was engaged in studies related to phosphorus fixation, nutrient cycling, rooting pattern of *Hevea* in relation to different soil conditions, advisory service to smallholdings by providing DFR and mobile soil testing programmes for giving on the spot fertilizer recommendation.

Soil and nutrient studies

Phosphorus fixation study was extended to four soil series *viz.*, Vijayapuram, Manjalloor, Kaipuzha and Panachikkad. The available P was highest in Panachikkad series in comparison with Manjalloor and Kaipuzha. Clay content was highest in Kaipuzha and lowest in Vijayapuram. Study on seasonal variation of nutrient content in soil under rubber and forest was continued. Soil pH, organic carbon and available K were higher in October and December and lowest in February. Soil available P decreased in October and an increase was noted in April.

Preliminary results of the experiment on effect of relief on yield indicated that slope is one of the factors influencing the soil properties. Slope causes spatial variability in soil properties and thus the growth and yield of rubber. Eighteen year old rubber tree was uprooted and root biomass estimated at different depths. Out of the total tree biomass, root biomass accounted for 10.86 per cent. Coarse and fine roots are concentrated within 30 cm depth and woody roots upto 90 cm depth.

Experiment on effect of split application of fertilizer for rubber showed no significant difference in girth and height of plants between two and four split applications. Comparative evaluation of household compost and chemical fertilizers indicated no significant difference between treatments with regard to growth of rubber. ■

Botany Division

Contributions since establishment

Crop improvement research was initiated by the Botany Division from the very inception of RRII, the most important milestone being the release of the high yielding hybrid clone RRII 105, which took rubber production in India to unprecedented levels. Genetic improvement programmes are pursued mainly through conventional methods like introduction, half-sib program analysis like ortet selection and polycross breeding, hybridization and clonal selection, induction of mutations and polyploidy. Molecular approaches have been incorporated wherever necessary. Breeding programmes are oriented towards achieving specific objectives suitable for rubber cultivation in the traditional and non traditional areas. The prolonged gestation period of this perennial species being a hindrance to the quick release of clones, methods to shorten the breeding and selection cycle and early evaluation techniques have been subjected to in depth studies.

The major objectives of *Hevea* breeding in India are to develop clones with high production potential in terms of rubber and timber combined with desirable secondary characters like high vigour, smooth and thick bark with high

number of latex vessel rows, good bark renewal, high growth rate, tolerance to diseases and environmental stresses like cold, drought, wind etc. Priority is also being given to evolve clones having low occurrence of tapping panel dryness and good response to stimulation.

Introduction of over 127 exotic clones was effected in the early years, coupled with bilateral exchange of clones with Cote'd Ivoire, Thailand, China, Malaysia, Indonesia and Sri Lanka. These clones have been evaluated over the years in various locations across the country. The superior performance of clones like PB 260, PB 280, PB 312 and PB 314 in the traditional belt, RRIM 600, RRII 208 and PB 311 in the drought prone tracts of the non-traditional areas and RRIM 600 PB 235 and RRIM 703 in the North eastern states is noteworthy.

The most important method of developing clones of desirable genetic constitution is the controlled hybridization between selected parent clones, evaluation of F1 hybrids and selection of promising recombinants and their further evaluation. During the initial years, primary clones were used as parents for hybridization, which resulted in RRII 100, 200 and 300 series of clones. Among the clones of RRII 100 series, RRII 105 is an outstanding high yielder which enjoys maximum popularity in the planting sector. The best selections from RRII 200 series are RRII 203 and RRII 208 and that from RRII 300 series are RRII 300 and RRII 308.

In the early hybridization programmes spanning 25 years from 1954, 133 cross combinations of selected clones were attempted. The post 1980 hybridization programmes involved crosses among more modern clones which were selected on the basis of yield, secondary attributes and yield components. The choice of parents for crossing programmes from 1992 onwards was based on genetic divergence studies and general combining ability/prepotency, in addition to specific stress tolerance traits, both from Wickham clones and the wild germplasm. Breeding for specific objectives like drought tolerance, disease tolerance, timber yield and compact canopy for high density planting and introgression of genes from the wild Amazonian germplasm was given special emphasis from 1990 onwards.

Conventional breeding takes over three decades from the time of generating hybrid seedlings to the release of clones. Evaluation of clones comprises four phases *viz.*, nursery evaluation, small scale trials (SST), large scale trials (LST) and on farm trials (OFT). Over the years, crop improvement efforts in the RRII have been geared towards shortening the breeding and selection cycle in a phased manner. Initial efforts consisted of conducting large scale and onfarm trials simultaneously. Clonal nursery evaluation successfully helped in identifying precocious high yielders at an early stage with a high correlation with yield in the small scale trial. This opened up the possibility of replacing SSTs with clonal nurseries, thus reducing the time span of the breeding procedure by five years. The crop improvement group has evolved a modified breeding scheme which enables the release of clones within a period of 23 years, thus shortening the breeding cycle by several years.

Breeding for biotic and abiotic stresses have been effected in a multidisciplinary manner. Parent clones have been characterized for physiological and anatomical parameters of drought tolerance, biochemical parameters of disease tolerance and also anatomical, physiological and biochemical attributes related to latex and timber yield. This has rendered possible, a proper choice of specific parent clones for various breeding programmes.

The RRII 400 series clones comprise the latest series of hybrids evolved in the Institute. These are resultant of hybridization conducted in 1982 between the high yielding clone RRII 105 as female parent and RRIC 100, a vigorous and disease tolerant clone of Sri Lankan origin, as male parent. The five top ranking selections with respect to the yield in this series *viz.*, RRII 414, RRII 417, RRII 422, RRII 429 and RRII 430 exhibit desirable secondary characters and better tolerance to diseases than RRII 105. Clones RRII 414 and RRII 430 performed consistently well in the various stages of evaluation and were upgraded to Category I of the planting recommendations in 2005 and released for large scale cultivation.

Ortet selection was initiated in India in 1950. In the early years, approximately 1,00,000 mature trees in seedling stands in certain large estates and smallholdings were screened to select elite trees. The early ortet selection programmes led to the release of the RRII 1-10 series of clones, of which RRII 5 is an outstanding clone suitable for both latex and timber purposes. Among the later selections, RRII 33 was found to be resistant to *Phytophthora*. In the second phase of the ortet selection programme which was initiated in 1981, systematic screening of smallholdings and large estates was undertaken. Smallholdings with prospective seedling areas suitable for screening were evaluated and over 112 ortet clones were selected from smallholdings, which are presently under small scale evaluation in 7 field trials at two locations. Screening of over 636.60 ha of seedling populations comprising 1,66,052 trees in large estates and subsequent small scale evaluation of 135 selected ortet clones has helped to identify 31 clones superior in latex yield, timber yield and response to ethrel stimulation when compared with popular Class I clones of India.

The polycross breeding approach aims at evolving superior seed material for planting and also for generating superior base populations of seedlings for the selection and cloning of elite individuals for development of improved primary clones. In the present day, ortet selection method offers only a remote possibility as clonal plantations have almost entirely replaced mature seedling stands. In view of the dangers of monoculture in rubber, revival of polycross breeding has become a necessity. Prepotency, which is the ability of a parent clone to produce superior progeny even under open pollination, is a prerequisite for the polycross breeding approach.

Seedling progeny analysis of 32 popular clones at RRII has led to the identification of 13 parents as likely prepotents. These clones have been utilized as components of newer polyclonal seed gardens laid out with the purpose of generating good quality polyclonal seeds of improved parentage. The prepotent parents have also been utilized in biparental crossing programmes at RRII. Clonal selection from among progenies of prepotent clones has shown scope for a high recovery of superior clones with improvement in yield and number of latex vessel rows over the high yielding check RRII 105. Twenty two clones exhibited higher yield than the check over five years of tapping while 56 clones possessed higher number of latex vessel rows than RRII 105.

Cytogenetic investigation resulted in synthesizing tetraploids and triploids in rubber, for the first time. The first report on a natural triploid in rubber also exists to the credit of the RRII. Tetraploid cytotypes of three clones *viz.*, RRII 105, RRII 116 and PR 107 having chromosome number 2n=4x=72 have been generated. The induced triploid (2n=3x=54) was produced by crossing the diploid with the induced tetraploid.

The tetraploids were found to produce more rubber yield than the triploids. Two clones, RRII 50 and RRII 51, produced by induced mutagenesis were found to be high yielders under large scale evaluation.

Research on various aspects such as the anatomy of bark and wood, propagation methods, morphology, cytology and palynology lend support to crop improvement programmes in rubber. Clones Ch 2, RRII 35, GT1 and SCATC 93-114 have been identified as male sterile or often male sterile. Investigations on low temperature storage of *Hevea* pollen have indicated the scope for successful utilization of stored pollen in crossing programmes, thus overcoming problems associated with non- synchronous flowering among parent clones.

A system of clone identification based on over 225 morphological markers was developed and is being widely utilized. Over 37 popular clones have been thus characterized both in the immature and mature stages. A morphological variant having compact canopy was confirmed to be a genetic variant and is being utilized in hybridization programmes aimed at developing high yielding clones with compact canopy for high density planting.

Propagation studies have led to the standardization of the bench-grafting technique for rubber. Other important investigations include the feasibility study on young budding technique and studies on seed storage which proved that immersion of rubber seeds in water prolong its viability.

Anatomical investigations have led to the first report on the occurrence of intraxylary phloem in rubber and its relation with drought tolerance. The association of various anatomical parameters with yield, drought and disease tolerance have been subjected to in depth analysis and some of the important findings include the relationship of the density of petiolar stomata with susceptibility of clones to *Phytophthora* infection and the direct positive effect of laticifer area index on yield. Investigations on rubber wood relating to ethrel application in mature trees have revealed that the physical and mechanical properties and green weight of logs were not adversely affected by stimulation.

Fifty years of *Hevea* breeding efforts in India have resulted in the release of over 15 clones of Indian origin and a number of parental clone combinations for improved polyclonal seed gardens. Presently over 140 superior hybrids and primary clones are in the pipeline in various stages of evaluation in the traditional and non-traditional regions of India.

The Botany Division has to its credit, over 232 research papers, 75 popular articles, 13 book chapters and 6 books covering information on various rubber clones recommended for planting, newly evolved clones and their identifying features, descriptors for the morphological identification of clones and methods of *Hevea* breeding. These books have proved to be valuable reference manuals of benefit to rubber growers, extension personnel, research workers and students of Botany.

Ongoing Research Programmes

Emphasis during the golden jubilee year of the RRII was on the release of new hybrid clones. The RRII 400 series after evaluation in the small-scale trial was undergoing large-scale evaluation in six locations across the country and on-farm evaluation in various regions of Kerala. Clones RRII 414 and RRII 430 were upgraded to category I and released to the nation by His Excellency, the President of India, Dr. A. P. J. Abdul Kalam on 29th July 2005.

A new batch of clones comprising hybrids, ortets and selections from polycross progenies was identified as

pipeline clones for the future.Studies on anatomical aspects of bark and wood with emphasis on wood quality parameters following ethephon stimulation were continued.

1. Evolving high yielding clones for the traditional area

Among the progeny from the 1983 hybridization programme (HP) 111 clones were under evaluation in the 1988 SST at KAU Campus, Trichur. Eleven clones *viz.*, 83/24, 83/35, 83/29, 83/102, 83/173, 83/181, 83/372, 83/191, 83/17, 83/224 and 83/234 exhibited higher yield compared to RRII 105 in the fourth year of tapping with yield ranging from 48.79 to 68.72 g/t/t. In the four small scale trials (1989 SSTs) planted with progenies of the 1986 HP, twenty six hybrid clones established superiority over RRII 105 in terms of yield in the fifth year of tapping (Table Bot.1).

Among the hybrid clones under evaluation in eight small-scale trials planted in 1990, 29 clones registered significant improvement in yield over RRII 105. A source bush nursery of the promising yielders of the 1989 and 1990 SSTs was established to generate material for large scale and on farm evaluation. In the sixth year of tapping in the 1992 SSTs, four clones *viz.*, 772 (98.73 g/t/t), 380 (66.06 g/t/t), 575 (74.93 g/t/t) and 756 (54.03 g/t/t) recorded higher yield than RRII 105.

Among the 76 hybrid clones inclusive of those from W x A crosses under evaluation in three small-scale trials planted in 1995, 15 clones recorded better yield than RRII 105 in the third year of tapping. Yield and related attributes of some of the promising clones from W x A crosses are given in Table Bot. 2.

Tapping was initiated in the 1998 and 1999 SSTs at CES, Chethackal. Six clones were on par with RRII 105 in the 1998 SSTs in terms of yield in the first year of tapping.

Hybrids and half-sib seedlings resultant of hand pollination programme 2002 were test tapped employing a new method of yield collection wherein dry rubber content (DRC) determination and collection of test tap yield as latex was tried. The details of growth and rubber yield of seedlings in the 3rd year are given in Table Bot. 3.

Hybrid seedlings of 2005 hand pollination programme were established and

Table Bot. 1. Rubber and timber yield of hybrid clones

Clone	Yield (g/t/t)	Clear bole volume (m^3)	Clone	Yield (g/t/t)	Clear bole volume (m^3)
86/23	54.87	0.13	86/122	75.30	0.12
86/34	48.11	0.13	86/174	66.48	0.15
86/59	57.87	0.37	86/306	57.59	0.18
86/60	50.45	0.15	86/651	66.15	0.09
86/157	54.05	0.11	86/428	89.68	0.24
86/304	69.81	0.14	86/68	48.35	0.13
86/602	51.43	0.17	86/70	48.35	0.12
86/607	48.34	0.17	86/98	44.02	0.18
86/613	51.73	0.12	86/99	47.43	0.23
86/64	60.37	0.32	86/188	47.51	0.16
86/79	58.87	0.26	86/597	67.23	0.27
86/111	101.90	0.20	86/599	47.37	0.21
86/117	60.97	0.16	86/674	49.52	0.18

Table Bot. 2. Yield, girth and structural attributes of some selections from W x A crosses

Clone	Girth (cm)	Yield (g/t/t)	BT (mm)	LVR
10	71.28	49.69	6.42	8.94
25	56.64	37.30	7.79	18.28
29	75.50	33.69	7.08	10.61
34	61.85	36.32	6.75	8.22
170	62.83	29.31	6.36	8.39
193	59.25	24.18	6.56	12.61
265	58.27	22.18	7.04	12.39
271	69.13	33.17	6.26	10.16
340	56.87	35.63	5.95	9.28
274	67.00	48.26	6.73	14.95
55	66.59	24.85	6.27	10.73
102	54.17	33.18	6.52	5.78
109	64.00	30.66	6.68	11.67
129	65.14	22.27	6.06	9.61
130	66.46	16.57	7.01	9.94
132	60.25	21.47	5.72	9.50
88	32.72	6.07	5.47	12.33
RRII 105	47.85	39.34	7.07	14.06

Table Bot. 3. Family wise latex and dry rubber yield of hybrids and half-sibs

Family	Progeny size	Seedlings selected	Girth (cm)		Latex yield* (ml/t/t)		Rubber yield (g/t/10t)		CV % range
			Min	Max	Min	Max	Min	Max	
Hybrids									
RRII 414 x PB 330	21	5	5.2	24.3	0.5	5.6	1.5	15.5	26.3-50.4
RRII 429 x PB 330	6	2	6.0	17.0	1.0	4.6	3.0	8.7	26.3-42.9
RRII 414 x MT 2226	39	2	4.5	21.5	0.7	5.8	2.1	11.8	19.6-40.9
PB 330 x RRII 429	52	8	5.0	21.5	1.1	5.8	2.7	13.5	33.3-68.7
PB 330 x RRII 414	132	22	4.5	34.2	0.5	19.6	1.5	41.4	33.0-66.9
Half-sibs									
RRII 105	269	9	4.3	28.3	1.0	5.8	3.0	15.3	24.3-57.0
RRII 414	142	17	3.9	23.4	0.8	9.0	2.4	20.6	12.2-55.0
RRII 429	126	11	5.0	26.0	0.5	11.4	1.5	22.8	32.7-53.3
PB 330	151	14	5.6	25.0	0.8	6.6	2.0	16.0	28.8-58.0

* Means of 35 tappings

maintained in the nursery for further studies and subsequent selection. A total of 233 recombinants are maintained in the observation nursery.

Two large scale trials with 19 potential latex and timber yielding ortets along with control RRII 105 were laid out at CES, Chethackal. Fortnightly yield recording and annual girth recording were done from the ortets selected from PCK Estate, Kodumon in the 5th year of tapping in the small scale trial. Among the 16 ortet clones O 39 recorded 59.21 g/t/t over five years of tapping with a mean girth of 74.63 cm whereas RRII 105 re-

Table Bot. 4. Yield of clones in the multidisciplinary trials

Clone	Yield 7th year (g/t/t)	Clone	Yield 7th year (g/t/t)
RRII 5	89.31	PB 217	49.03
RRII 118	66.44	PB 235	80.64
RRII 208	52.59	PB 255	81.81
RRII 300	38.51	PB 260	74.45
RRII 308	46.33	PB 280	76.28
RRIM 600	36.67	PB 310	63.93
RRIM 703	44.94	PB 311	63.92
PR 255	40.90	PB 312	81.99
PR 261	36.25	PB 314	81.63
SCATC 88/13	45.26	KRS 25	46.82
SCATC 93/114	19.67	KRS 128	45.31
Haiken 1	24.86	KRS 163	78.51
RRII 105	46.53	RRII 105	56.49
GM	45.25	GM	67.75

corded an yield of 47.74 g/t/t and girth of only 61.8 cm during the period. Another set of 25 ortets selected from PCK Estate, Kodumon are in the 3rd year of tapping in SST. Yield over three years of tapping showed that out of the 25 ortet clones selected, mean yield of O 36 (46.70 g/t/t) was superior to RRII 105 (40.85 g/t/t). O 38 and O 41 maintained very good girth on tapping with 76.80 cm and 76.55 cm respectively with moderate yield. The girth of RRII 105 was 56.45 cm.

In the evaluation of ortets selected from various smallholdings and CES, Chethackal, yield over two years showed that O 21, a selection from a smallholding at Erattayar and O 72, one selection from the selfed progeny of RRII 105 recorded superior yield to RRII 105. Good growth with moderate yield was shown by two clones O 73 and O 81.

2. Evaluation of clones

The performance of indigenous and exotic clones in the multidisciplinary evaluation trials in the seventh year of tapping is shown in Table Bot. 4. Clones RRII 5, RRII 118, PB 314, PB 312, PB 255 and PB 235 were superior in yield. The yield in the 6th year of tapping along with incidence of diseases in the 16 introduced clones under evaluation in the LSTs planted in 1989 are shown in Table Bot. 5.

The RRII 400 series clones under large-scale evaluation in two trials were studied for yield in the fifth year of tapping. Clones RRII 417, RRII 422, RRII 430, RRII 429, RRII 414, RRII 402 and RRII 403 were superior to RRII 105 in terms of annual mean yield and clones RRII 52, RRII 403, RRII 422 and RRII 414 in terms of summer yield (Table Bot. 6).

In the large scale evaluation of exotic and indigenous clones, yield over three years showed that HP 44 (PB 252 x RRII 105) recorded 35% improvement over RRII 105 with 68.11 g/t/t, highest number of latex vessel rows and better bark thickness. Yield of the introduced Malaysian clone RRIM 722 was superior to RRII 105, recording 59.64 g/t/t. Trees were opened for regular yield recording in the large-scale evaluation of 26 potential hybrid clones planted at RRS Padiyoor. Out of 13 clones planted, hybrid 61 recorded highest mean girth (58.08 cm) followed by hybrid 428 (53.09 cm).

Table Bot. 5. Performance of clones in large scale trial

Clone	6th year yield (g/t/t)	Incidence of pink (%)	Incidence of brown bast (%)
PB 235	59.37	19.30	27.08
PB 311	73.79	8.33	14.28
PB 280	66.66	1.72	10.52
PB 314	73.23	2.04	20.00
PB 312	61.10	3.39	18.64
PB 217	54.03	11.32	20.00
PB 260	71.20	4.84	15.52
PB 255	46.48	11.54	20.41
KRS 163	46.48	23.33	17.30
RRIM 600	57.38	15.94	12.50
Haiken 1	45.87	8.82	25.40
SCATC 88/13	76.37	17.30	4.90
KRS 128	45.67	22.03	9.62
SCATC 93/114	30.66	4.55	3.17
KRS 25	39.08	26.67	6.67
RRII 105	67.93	31.36	17.86

Table Bot. 6. Yield of the RRII 400 series clones in large-scale trial

Clone	Trial I		Clone	Trial II	
	Yield (g/t/t)			Yield (g/t/t)	
	Annual mean	Summer		Annual mean	Summer
RRII 446	29.62	12.66	RRII 454	37.00	20.99
RRII 55	61.36	33.99	RRII 430	79.08	31.29
RRII 54	21.45	13.46	RRII 434	29.77	17.21
RRII 417	84.23	33.06	RRII 427	74.98	31.76
RRII 407	66.10	34.24	RRII 53	21.78	10.35
RRII 403	71.78	40.56	RRII 422	86.39	39.90
RRII 449	28.03	15.97	PB 330	70.73	29.57
RRII 429	79.06	34.62	RRII 410	52.36	22.27
RRII 402	72.98	34.94	RRII 52	57.53	45.87
RRII 453	27.91	11.09	RRII 105	61.54	25.29
RRII 414	75.93	37.40			
RRII 105	61.01	31.14			
GM	56.62	27.75	GM	57.12	27.45
VR	49.19**	22.52**	VR	20.30**	18.80**
CD (P=0.05)	9.13	6.41	CD (P=0.05)	14.39	7.23

The onfarm evaluation trials at Sasthamkotta and Chemoni were in the third and eighth years of tapping respectively. Clones RRII 105 (1850 kg/ha/yr), PB 314 (1827 kg/ha/yr) and PB 255 (1810 kg/ha/yr) performed better in Sasthamkotta and clones PB 260 (1996 kg/ha/yr) and RRII 105 (1685 kg/ha/yr) were found promising in Chemoni. On farm trials of the RRII 400 series clones

in seven locations are under various stages of growth. Trials in three locations *viz.*, Aiymcombu, Cheruvally and Koney are under tapping. The RRII 400 series clones maintained superior yield and growth compared to RRII 105 in all the three locations.

In the evaluation of clones for genotype x environment interactions, in general, the yield performance of all the five RRII 400 series clones in the third year of tapping was superior to or comparable with that of RRII 105 in three locations *viz.*, Kanyakumari, Agartala, and Nagrakatta. In Kanyakumari, RRII 203 recorded the highest yield of 71.60 g/t/t followed by RRII 422 (66.94 g/t/t) and RRII 105 (66.11 g/t/t). Both RRII 414 and RRII 430 recorded 58 g/t/t. In Agartala RRII 422 was the highest yielder (46.31 g/t/t) followed by RRII 429 (44.56 g/t/t). RRII 429 showed significantly superior yield performance (49.00 g/t/t) in Nagrakatta over the other clones followed by RRII 417 (36.64 g/t/t) The control clone RRII 105 recorded 37.35 g/t/t in Agartala whereas it was 24.51 g/t/t in Nagrakatta.

3. Breeding for other specific objectives

In the evaluation trial of recombinants of the cross between a genetic variant (GV) and high yielding and vigorous clones such as RRII 105, RRIM 600 and RRII 118 as female parents, high variability exists with respect to height and canopy diameter of the trees. Three clones from progenies of the crosses GVx RRII 118, RRIM 600 x GV and GVx RRII 118 showed normal growth with compact canopy in the fifth year after planting.

Fifteen drought tolerant ortets selected from the drought prone North Konkan region of Maharashtra are under evaluation for their yield potential in Kerala. In the first year of tapping, four ortet clones gave higher yield than RRII 105, of which one clone D 111 was significantly superior with a mean yield of 96.53 g/t/t.

Among the hybrid clones developed by crossing parents with high yield and various drought tolerance attributes, 15 clones were evaluated for leaf epicuticular wax, intraxylary phloem, stomatal density, membrane stability, extent of lipid peroxidation and photosynthetic rate under drought stress. Five selected clones based on yield potential, physiological and anatomical parameters were established in polybag nurseries in the drought prone North Konkan region of Maharashtra for further field testing.

The 150 clones comprising polycross progenies of 10 parent clones were evaluated in two trials for girth, dry rubber yield, volume of latex and dry rubber content on a seasonal basis in the fifth year of tapping. In trial 1, 13 clones with yield ranging from 55.58 to 72.87 g/t/t were better than RRII 105 which gave 55.48 g/t/t. Progeny of RRII 105 recorded the highest mean yield followed by that of PB 28/83. Mean girth was highest in the progeny of PB 215 and PB 217 followed by PB 242, PB 252, PB 28/83 and Ch 26. Progeny of AVT 73 recorded the highest volume of latex in the peak season while mean DRC was highest in the progeny of PB 242 followed by PB 252. In trial 2, 16 selections were identified to be better than RRII 105 with yield ranging from 59.13 to 97.05 g/t/t while progeny of PB 252 was the most vigorous followed by that of RRII 105 and PB 28/83. The mean DRC was high in progenies of PB 28/83, PB 252 and PB 215.

Another study was initiated with 48 clones selected from half-sib progenies of eight clones *viz.*, PB 260, GT 1, RRII 203, PB 255, PB 217, RRII 105, PB 28/83 and RRIM 600 based on juvenile yield.

These clones were planted along with their parents and check clones in clonal nurseries at 1.5 m x 1.5 m spacing in two locations *viz.*, CES, Chethackal where optimum conditions for rubber cultivation exists and RRS, Padiyoor in North Kerala characterized by severe summer heat and moisture stress. The clones in both the locations were evaluated for sprouting and early growth attributes. The drought tolerant check clone RRIM 600 along with 11 test clones showed superior growth in Padiyoor while nine test clones were found to be superior at Chethackal. Three clones showed superior growth in both the locations. The yield of 11 full sib progenies and their parents over three years of tapping was evaluated. Progeny of the cross RRIM 600 x RRII 203 showed the highest mean yield (48.43 g/t/t) followed by that of RRII 105 x RRII 118 (47.50 g/t/t).

4. Cytogenetics and floral biology

Scanning Electron Microscopic studies of the pollen grains of RRII 400 series clones *viz.*, RRII 414, RRII 417, RRII 422, RRII 429 and RRII 430 and their parental clones RRII 105 and RRIC 100 were carried out. The aperture and exine ornamentation showed variation among the clones. Pollen grains were basically 3-zonocolporate. The exine ornamentation of RRIC 100 was very predominant and pronounced. The pattern of exine ornamentation of RRII 429 and RRII 430 showed resemblance to RRIC 100 while RRII 414, RRII 417 and RRII 422 showed similarity to RRII 105. The pollen size was comparatively smaller for RRII 417 and medium for RRII 422 and RRII 429. Clones RRII 105, RRII 414 and RRII 430 showed larger pollen grains.

5. Anatomical investigations

Bark samples were collected from three year old seedlings (full sib and half-sib progenies of 2002 HP) and recorded bark thickness (BT) and number of latex vessel rows (LVR). In the WA progenies BT (4.3 mm) and LVR (7) were recorded for the progenies of the cross RRII 414 x MT 2226. WW progeny of the cross PB 330 x RRII 414 recorded maximum BT (5.5 mm) and LVR (8). Among the clonal half sibs, maximum BT (4.5 mm) was recorded for half sibs of PB 330.

The dry bark from TPD affected trees of RRII 105 was removed by successive tappings leaving the cambium undisturbed. Three year old regenerated bark was tapped and found to be productive whereas the affected bark on rest did not show a continuous flow of latex. Anatomical studies revealed that there is considerable difference in the bark thickness, number of latex vessel rows, number of cells constituting the cambial zone and mineral status in the unaffected area, TPD affected area on rest and regenerated bark from the affected area after debarking of the same tree.

Anatomy of the fine roots in *Hevea* was studied. Fine root in the surface 0 - 7.5 cm soil layer showed remarkable increase after the receipt of rains. The hairs were unicellular, un-branched and found to be epidermal in origin.

Effect of ethephon stimulation on rubber wood quality with respect to mechanical properties was studied. Among the major properties tested, bending tests, in general, showed no significant variation among the stimulated and control trees. RRII 105 recorded an average modulus of rupture (MOR) value of 703.7 kg/cm^2 and the corresponding value for RRIM 600 was 782.2 kg/cm^2. The values from stimulated trees were comparable with their respective controls. With respect to modulus of elasticity (MOE), there was a significant difference between clones, with RRII 105 showing 66,140 kg/cm^2 and RRIM 600

recording 85,845 kg/cm^2. The stimulated trees in both the clones recorded slightly lower MOE values than the controls, but the differences were not significant. Compressive (crushing) strength tests were performed by applying the load in two directions i.e., along the grain (parallel) and across the grain (perpendicular). Either way there was no variation in these properties as a result of stimulation. RRII 105 showed no significant difference in the major mechanical properties from stimulated and unstimulated trees. Barring a few exceptions the

Table Bot. 7. **Mechanical properties of rubber wood in stimulated and unstimulated trees**

Properties		RRII 105		RRIM 600	
		Control	Stimulated	Control	Stimulated
Static bending kg/cm^2					
Fibre stress at limit of proportionality		348.0	327.5	415.5	406.4
Modulus of rupture (MOR)		703.7	636.4	782.2	783.7
Modulus of elasticity (MOE)		66140	62900	85845	80670
Compressive strength (kg/cm^2)					
Parallel to grain	Compression at limit of proportionality	243.60	242.20	296.20	280.60
	Compression at maximum load	353.00	361.20	410.90	380.40
	Modulus of elasticity	32890	35341	38770	38608
Perpendicular to grain	Compression at limit of proportionality	76.90	79.00	81.20	79.20
	At compression 2.5mm	141.9	141.2	148.1	144.6
Tensile-parallel to grain (kg/cm^2)					
Tensile strength at proportional limit		238.40	256.00	325.70	259.10
Tensile strength at maximum load		701.00	752.60	870.40	849.30
Maximum shear stress – parallel to grain (kg/cm^2)					
Radial		101.90	104.30	116.70	105.50*
Tangential		97.50	98.90	107.80	98.60
Hardness (load to penetrate a depth of 0.64 cm in kg)					
Radial		481.30	436.20	481.80	453.50
Tangential		491.50	480.30	490.00	477.00
End		590.90	550.70	592.90	562.70
Cleavage (kg/cm^2)					
Radial		55.30	61.80	52.40	59.00
Tangential		64.00	64.20	68.60	66.60
Nail holding power (kg)					
Radial		151.3	135.4	150.8	149.4
Tangential		141.4	128.5	150.4	140.9
End		109	118.9	141.7	113**
Screw holding power (kg)					
Radial		310.8	283.3	352.7	308.7**
Tangential		322.2	352.4	362.3	348.3
End		218.49	216.5	230.58	229.74

* Significant at 0.05%, ** Significant at 0.1%

Table Bot. 8. Growth of plants five years after planting in the field

Type of planting material	Girth (cm)	Girth increment (cm)
Brown budded stumps	32.76	8.74
Field budded plants	26.90	9.69
Green budded plants	38.00	8.79
Brown budded plants	36.54	9.72
Young budded plants – stock seedlings - 42 days old	36.13	8.30
Young budded plants – stock seedlings - 49 days old	34.47	9.10
Young budded plants – stock seedlings - 56 days old	34.57	9.05

properties of stimulated trees of RRIM 600 were also comparable with their control suggesting that they were not affected by stimulation in the mature trees (Table Bot. 7).

6. Studies on propagation

The study on the performance of certain modern clones with different combinations of root systems was continued. Highest yield (59.1 g/t/t) and highest girth (88 cm) were recorded by RRII 203 scion on RRII 203 stock and other combinations were on par.

Comparative growth performance of different forms of planting materials (Table Bot. 8) showed that green budded plants recorded the highest mean girth of 38.00 cm followed by brown budded plants (36.54 cm) after five years of field planting. Field budded plants recorded significant reduction in growth.

In order to test the influence of age of bud wood stock on growth and yield of plants, bud wood from 4 and 20 year old bud wood stock was collected from different sources and brown budding was carried out on one year old stock seedlings and the trial is under observation.

In the experiment on controlling die back of green budded plants in the polybags, treatment of taproot with Indole Butyric Acid (IBA) in higher concentration (2000 ppm) was tried. Results showed toxic effect on budded stumps with reduction in viability. Hence, another polybag nursery experiment was laid out with green budded stumps by adopting lower concentration of IBA.

7. Morphological characterization of popular clones

A new study was initiated for developing morphological keys for the identification of RRII 400 series clones of *Hevea* in the early growth phase. Morphological traits such as leaf characters, including shape of the leaf storey, leaf scar, leaf shape, petiole and petiolule and their orientation etc. were documented. ■

Germplasm Division

Contributions since establishment

Right from its inception in December 1989, the Germplasm Division has been responsible for the management of the three genepools: the domesticated or 'Wickham' collection, the 1981 IRRDB wild *Hevea* germplasm collection and the collection of other species of *Hevea*.

The domesticated genepool comprising the older obsolete clones as well as the present day cultivars, both exotic and indigenous, are mostly derived from the original seed collection made by Sir Henry Wickham in 1876. Newer clones are added to it from time to time, and the collection now reached 183 genotypes. These are being conserved in field gene banks as conservation nurseries as well as arboreta and serve as a source of material (budwood, shoot tips, leaves, pollen seed etc.) of a wide range of clones for various projects of the Institute. Bilateral clone exchange programme was made with Institute de Recherches sur le Caoutchoue (IRCA), Cote de Ivorie to procure five IRCA clones, and in reciprocation five RRII clones were sent to them.

A total of 4548 wild *Hevea* germplasm accessions were introduced by the Division during the period from 1984 to 1990 from the Malaysian center, as a share of 1981 IRRDB expedition. Most of the wild accessions established in the North East at Agartala and Guwahati have also been brought to the tradi-

tional region to be established in insurance nurseries. In addition to this, 24 wild accessions selected on the basis of performance reports in other countries, were also imported from the base collection in Malaysia recently. All the wild germplasm accessions are being conserved in budwood nurseries ensuring proper identity. Reestablishment of the conservation nurseries is also taken care by the Division in a phased manner. The Division also maintains a herbarium collection with specimens of 413 wild accessions. National Accession Register for all the accessions introduced is being maintained and the basic data in this register has been computerised. Developed a user-friendly software for documentation of the detailed database of *Hevea* germplasm for storage and easy retrieval as and when necessary.

A rough evaluation of these wild accessions is done in Preliminary Evaluation Trials (PETs) and superior accessions identified are advanced to Further Evaluation Trials (FETs). 1262 accessions were already evaluated in 16 PETs at five locations and 123 accessions are under evaluation. A wide range of variability for morphological and anatomical traits has been observed in the wild germplasm collection. As a first step, a core set of 27 accessions was identified from a total of 81, using Principal Compound Analysis (PCA) based on 12 quantitative morphological traits, and validated using Shannon Weaver Diversity Indices (SDI) values from 18 qualitative traits.

Accessions showing superiority for individual traits like girth, leaf size, bark thickness, number of latex vessel rows etc. has been identified. In general, accessions from Mato Grosso provenance were superior to the Acre and Rondonia provenance for yield, vigour and *Phytophthora* tolerance, while Acre accessions had superior timber qualities. Five floral variants suspected to be interspecific hybrids, were discovered in this collection. A standard descriptor format has been designed for the management of *Hevea* germplasm and a book "Descriptors for Rubber" was published for the first time. So far, 1534 accessions were characterized in the juvenile stage using 22 morphological traits. Wide variability observed, as indicated by the SDI values.

A full-fledged disease screening laboratory was established at CES, Chethackal. Routine screening of germplasm accessions against diseases caused by *Phytophthora, Oidium* and *Corynespora* was done in collaboration with the Pathology Division. Three accessions with high levels of tolerance to *Oidium,* could be identified from the entire collection of wild germplasm and these accessions have been included in hybridization programmes. 82 tolerant accessions against *Corynespora* were also identified.

Field trials were taken up by the Division in hot spot areas for screening the wild germplasm accessions for drought and cold tolerance. 235 wild accessions were screened in the drought prone area at RRS, Dapchari and 24 potential accessions could be identified. In general Mato Grosso and Rondonian accessions proved their superiority for drought tolerance. Collaborative project on screening for intrinsic drought tolerance of wild accessions was started with Plant Physiology Division and four potential accessions were identified from a set of 200 accessions. Another set of 36 accessions is being screened at RDC, Sukma from which RO 5363 has recorded good girth and yield. Similarly 64 wild accessions are being screened for cold resistance at cold prone areas of RES, Nagrakata, of which 12 have shown potential for cold tolerance.

Screening of *Hevea* germplasm for qualitative and quantitative timber traits is in progress. A pioneering study was

made to understand the lignification pattern in developing stems of *Hevea brasiliensis* through lignin biosynthesis studies. Studies on variability in structure and properties of wood of *Hevea* clones were also carried out. The results indicated that though the timber yield of the popular clone RRII 105 is low, the quality of wood is superior for its high basic density, low volumetric shrinkage, high values in mechanical properties and less incidence of tension wood and high lignin content in comparison with other clones.

A well-equipped laboratory was set up in the Division for the molecular characterization of wild germplasm. A miniprep protocol for extraction of genomic DNA could be standardized. In the experiment on RAPD profiling and evaluation of genetic diversity in wild *Hevea* accessions in collaboration with Genome Analysis laboratory, 110 wild accessions were grouped into eight clusters using 16 primers based on geographic distribution indicating geographical distinction between the three provenances of Acre, Rondonia and Mato Grosso. Mato Grosso genotypes showed maximum genetic divergence compared to other provenances. RAPD reactions in 35 accessions from cold screening trial at RRS, Nagrakata, using 20 primers were completed and DNA profiles were scored for further analysis.

Four accessions of three species (*viz.*, *H. pauciflora* and *H. nitida* from Sri Lanka, and *H. pauciflora* and *H. camargoana* from Indonesia) were successfully introduced from Malaysian Rubber Board. These are included along with other morphological variants in the wild germplasm and Wickham clones for characterisation, evaluation, and assessment of the extent of genetic diversity both at the morphological and molecular levels. *H. camargoana* has shown precocious flowering at the age of three months itself.

Utilization of the wild germplasm for crop improvement in *Hevea* was initiated a decade ago in India. Though it was believed that direct selection from wild germplasm would not be possible, around 46 accessions so far have shown promising yield in the conservation nurseries on par with the popular controls. The yield potential of these accessions are being confirmed in FETs.

Four HP programmes of hybridization of cultivars with selected wild accessions have resulted in few promising recombinants which are under field evaluation.

A detailed investigation on the structure of bark of *Hevea brasiliensis* with special reference to the inclination of laticifers and clonal variability was carried out in ten clones and clonal variability was observed. The laticifers are inclined towards right, left and even towards both direction within the clones. Inclination of phloic rays has been identified as the most influential positive factor on laticifer inclination.

Studies on the feasibility of ratooning in rubber are in progress. The ratoons were found to be superior to their corresponding polybag grown counterparts in a preliminary study. Interdivisional collaborative studies such as characterization of TPD on the basis of bark symptoms and the effect of stimulation in the laticiferous tissues of *Hevea* are in progress in collaboration with Plant Pathology and Plant Physiology Divisions.

National Workshop on "Application of Molecular Markers in Plant Genetic Resource Management in Plantation Crops" was organized by the Division from 28 November to 14 December 2005.

Ongoing Research Programmes

The major activities of the Division include maintenance of the domesticated genepool collection, 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 characterization.

1. Introduction, conservation and documentation

Seven Wickham clones are under multiplication for inclusion in the clone museum at RRII Farm, Kottayam. Identification and standardization of suitable molecular markers for the genetic authentication of the identity of all the accessions in the Clone Museum has been initiated using molecular markers.

Data recording from Garden III was completed and the experiment wound up. Annual girth and monthly cup lump yield was recorded from Gardens IV and V. Among the five IRCA clones, IRCA 130 and IRCA 111 continued to show superiority over RRII 105 in terms of girth, dry rubber yield and timber volume (Table Ger. 1).

Table Ger. 1. Performance of IRCA clones in the fourteenth year of growth

Clone	Girth (cm)	Dry rubber yield (g/t/t)	Timber volume(m^3)
IRCA 111	67.1	53.0	0.117
IRCA 130	65.7	67.8	0.150
IRCA 109	59.7	37.3	0.098
IRCA 230	57.7	32.4	0.091
IRCA 18	55.4	34.1	0.085
RRII 105	59.1	49.1	0.076
CD(P=0.05)	6.54	12.29	0.024

In Germplasm Garden V, RRIC 100 maintained its superiority among the 20 clones in terms of girth (80.27 cm) and yield (68.95 g/t/t). Other clones showing high girth were RRII 178 (74.97 cm), RRIC 102 (70.06 cm) and PB 255 (71.27 cm), while the control clone RRII 105 had a girth of 58.27 cm. RRIM 609 (55.84 g/t/t), RRII 23 (48.71 g/t/t) and PR 255 (44.29 g/t/t) also showed relatively high yield.

Re-establishment of the conservation nurseries is in progress. The third set of 701 accessions was planted in conservation nursery 2005 in an augmented RBD with three controls. Multiplication of the next set of 1000 wild accessions was carried out for planting in the next phase of the reestablished conservation nursery proposed for 2006.

H. benthamiana, *H. spruceana*, an interspecific hybrid FX 516, five floral variants discovered earlier in the 1981 wild germplasm, and two *H. brasiliensis* clones along with the imported accessions *H. pauciflora*, *H. nitida* and *H. camargoana* were planted in an arboretum at CES, for characterization, evaluation, and assessment of the extent of genetic diversity both at the morphological and molecular levels.

2. Characterization and preliminary evaluation

In Preliminary Evaluation Trial (PET) 1994A, one accession, AC 757 (63.46 cm), was superior to RRII 105 for girth, while RO 895 and MT 940 were on par with the control. RO 262, MT 1012 and MT 930 had the highest yield among the wild accessions, though they were far below that of the control. In PET 1994 B, 1994 C and 1994 D nine accessions exhibited superior/on par girth to RRII 105. In PET (Ortets) 1999, the girth of the wild accessions ranged from 14 cm (OR 1145) to 47.3 cm (OM 1107), while that of the controls was 47.4 cm (PB 260), 47.9 (RRIM 600) and 49.4 cm (RRII 105). Annual girth recorded in PET 2000 A was the maximum in AC 3406 (34.78 cm), followed by RO 4363 (32.02 cm) and AC 3609 (31.68 cm). In PET 2000 B with 166 wild accessions, annual girth and crotch height were recorded and timber potential was worked out. There

were five accessions with greater bark thickness and more number of latex vessel rows than the control clones.

In PET 2002, AC 567 (17.50 cm) recorded the highest girth followed by AC 824 (17 cm) and MT 624(15.40 cm), while the control clones RRII 105, RRII 208 and RRIM 600 recorded a girth of 13.13 cm, 14.10 cm and 15.16 cm respectively.

3. Further evaluation and selection

The annual girth, bark anatomical traits such as number of laticifer rows, density of latex vessels per row per unit distance, diameter of latex vessels, volumetric timber (bole) yield and dry rubber yield at fortnightly intervals were recorded and analysed at the age of 13 years.

The annual girth was maximum for the accession MT 1674 (58.7 cm) and minimum for RO 2908 (32.5 cm). The mean girth of RRII 105 was 48.9 cm. Five accessions (MT- 4, RO-1) showed significantly higher girth than the control RRII 105 and 60 accessions (AC-14, RO-14 and MT-32) showed the annual girth statistically on par with the control.

Number of laticifer rows was maximum for AC 635 (9.75) and minimum for two accessions *viz.*, MT 191 and MT 197 (4.00). Two Acre accessions (AC 635 and AC 166) had significantly higher latex vessel rows than RRII 105 (7.00). The density of latex vessels per row per mm distance was the minimum for AC 675 (22.67) and maximum for RO 368 (34.67). 11 accessions showed the density on par with RRII 105 (32.27). The diameter of latex vessels was highest in MT 919 (26.28 μm) and lowest in MT 199 (17.71 μm). 33 accessions (AC-10, RO-8 and MT-15) were on par with RRII 105 (25.78 μm).

The mean dry rubber yield (average of ten tappings) was maximum for MT 1020 (21.01g/t/t) and minimum for AC 661 (2.00 g/t/t) whereas the mean yield of RRII 105 was 29.95 g/t/t. None of the wild accessions showed a higher dry rubber yield than the control clone RRII 105. However, 10 accessions (AC – 3, RO – 2 and MT – 5) showed 50 - 70 per cent and another 10 accessions showed 40 – 49 per cent of the yield of RRII 105.

The timber (bole) volume was maximum for MT 941 (0.072 m^3) and minimum for RO 1739 (0.020 m^3). Five Mato Grosso accessions had significantly higher bole volume than RRII 105 (0.044 m^3). Altogether 70 accessions (Acre – 20, Rondonia - 15 and Mato Grosso - 35) were on par with RRII 105 for bole volume.

In the Further Evaluation Trial (FET 2003), highest girth was recorded for RO 2629 (14.84 cm) followed by AC 4149 (12.66 cm) and MT 2233 (12.44 cm). The control clones RRIM 600, RRII 105 and RRII 208 recorded a girth of 11.59 cm,11.28 cm and 10.78 cm respectively. A new FET was planted using 22 selections and three control clones in a simple lattice design.

4. Screening for stress resistance

Three accessions have been short listed after screening the wild germplasm nurseries for resistance to *Oidium* for confirmation in statistically laid out trials in collaboration with Plant Pathology Division. Laboratory screening for *Corynespora* resistance so far has shown that 29 out of 112 accessions were tolerant.

From the 2001 and 2002 screening trials for drought tolerance at RRS, Dapchari with 63 and 42 wild accessions, 25 accessions identified as drought tolerant were selected and DNA extracted for RAPD analysis. In the field trial planted in 2003 at RRS, Dapchari with 130 wild accessions, monthly girth was recorded. Annual and summer girth increment were worked out to assess

the drought tolerance potential of these accessions. The accessions from Rondonia provenances showed their superiority during the second year of growth, indicating the potential of these accessions in the drought prone area.

Among the 37 wild *Hevea* germplasm accessions screened for their drought tolerance potential, the total chlorophyll content varied from 2.4–4.6 mg cm^{-2} with a mean chlorophyll content of 3.3 mg cm^{-2} and the clonal differences were highly significant. Chlorophyll reduction percentage varied from 2.7 – 26.8 per cent with a mean percentage reduction of 12.8 percent. The lowest chlorophyll reduction was noticed in the wild accession MT 5156 (2.7%) followed by MT 5098 (3.2%) whereas the highest reduction was in the accession RO 5047 (26.8%). The total wax content among the accessions showed a wide range from 37.5–183.6 µg cm^{-2} and mean ECW content recorded was 105.9 µg cm^{-2} and the difference was highly significant. Significant range of variation was observed among the 37 wild accessions for all the parameters studied. The accessions were classified into low, medium and high performers for drought tolerance with reference to each of the parameters studied using mean and SD values. Twelve accessions were selected for studying their cell membrane injury.

The extent of variability for cellular membrane stability (CMS) varied from 18 – 67 per cent with a mean of 38 per cent. The accessions MT 4694, MT 5125 and MT 5093 showed highest tolerance to water and temperature stress and stability on par with RRIM 600 as indicated by low relative injury. The accessions MT 5156, RO 5023 and AC 4833 indicated their drought susceptibility by recording the maximum injury to cell membrane.

A provenance wise comparison was also made for each of the parameters to assess the variability among the accessions between the provenances. Nine accessions were identified as superior for more than one of the drought related biochemical parameters studied.

A preliminary field scoring for drought tolerance was conducted in another set of 700 wild accessions during the summer months, based on drought related morphological parameters. Potential accessions were selected for detailed laboratory study. In the drought evaluation trial 1996 at RDC, Sukma with 36 genotypes, annual girth and yield were recorded. RRII 208 recorded the highest girth followed by RO 2635, RO 5430 and RRII 118. Mean yield (g/t/t) over two seasons was highest in RRII 118 (27.86) followed by RRII 208 (26.04), RO 5363 (15.82), GT 1 (15.05). The popular clone RRII 105 recorded an yield of 13.99g/t/t.

The two ongoing trials at RES, Nagrakatta continued with almost the same trend during last year in the pre and post winter period.

Response in growth to cold stress was assessed using girth increment values over stress period in the two trials. In trial I, RO 2976 had the highest girth increment of 2.35 cm. Those five accessions, which showed highest annual girth values had only medium rate of growth during the stress period. In trial II, maximum girth increment over the stress period was in RO 2727 (2.41 cm). Four accessions with highest girth recorded in the pre winter phase also had high girth increment during the stress period.

5. Screening for timber characteristics

Annual girth, bole height, bole volume and percentage of wood lignin were recorded at the age of 5½ years from the field trial planted in 2000 at RRS, Padiyoor. The mean girth of the wild accessions ranged from 21.45 – 31.94 cm.

Wide variability was noticed in bole height in the wild accessions and Wickham clones. Among the wild accessions, the bole height was maximum for MT 915 (3.08 m) and minimum for AC 637 (2.42m). In Wickham clones RRII 118 (3.52m) had the highest bole height. The bole volume (m^3) in the wild accessions was within the range of 0.008 – 0.024 with the maximum value in AC 655 (0.024) and minimum in the two accessions AC 651 and MT 937 (0.008). Among the Wickham clones, the highest bole volume was observed in RRII 118 (0.018) and the lowest in RRIM 600 and RRII 105 (0.008).

Identification and localization of Cinnamyl Alcohol Dehydrogenase (CAD) enzyme activity to understand the lignification pattern of 19 wild accessions and six Wickham clones revealed that CAD activity is involved in the lignification process in *Hevea* stem and its activity is restricted in the mature xylem.

The percentage of insoluble lignin (% weight of EXR) was estimated in the timber screening trial at RRS, Padiyoor. Lignin content ranged from 19.28 - 24.75 per cent among the wild accessions whereas in Wickham clones, the range was 20.08 - 23.36 per cent.

The major mechanical properties of wood such as static bending, compression stress and hardness were tested in ten clones and analysed.

The MOR was highest in RRII 105 followed by PB 235 and the lowest in PR 261. The maximum MOE was recorded by PB 235 and minimum by RRII 44 (Table Ger. 2).

The maximum load and compressive stress at maximum load were the highest in RRII 105 followed by PB 235 and the lowest in PR 255.

The hardness at different surfaces (radial, tangential and end surfaces) were higher in PB 310 and RRII 105 and minimum for PB 260.

Though the timber yield of the popular clone RRII 105 is low, the quality of wood is superior for its high basic density, low volumetric shrinkage, high values in mechanical properties and less incidence of tension wood in comparison with other clones.

6. Molecular characterization

In the experiment on RAPD profiling and evaluation of genetic diversity in wild *Hevea* accessions, in collaboration with Genome Analysis laboratory, RAPD reactions using 20 primers in 35 accessions from two cold screening trials at RES, Nagrakatta was completed and DNA profiles were scored. RAPD reactions in another set of 70 wild accessions in source bush nursery (SBN) 2000 using 20 informative primers was completed and compared with 40 Wickham clones for the extent of genetic variability. Genetic divergence studies in another set of 44 wild accessions of rubber using RAPD markers was completed.

7. Utilisation of *Hevea* germplasm

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

8. Other studies

In the experiment on the feasibility of ratooning in rubber at CES, girth was recorded in both ratoon and polybag plants in their fourth year of growth. The ratoons continued to be superior to their corresponding polybag-grown counterparts. In the observation plot in a planter's field at Aluva, the girth of the two-year-old plants of uncertain pedigree ranged from 8 cm to 31.3 cm with an average of 18.23 cm.

Anatomical investigations on bark samples collected from trees with bark

Table Ger. 2. **Static bending properties**

Clone	MOR (kg/cm²)	Max load (kg)	FS at LP (kg/cm²)	HSS at LP (kg/cm²)	HSS at ML (kg/cm²)	MOE (kg/cm²)
PB 235	916.15	175.65	588.66	20.98	33.08	97413.24
PB 260	712.42	137.35	426.59	15.21	25.86	62226.60
PB 310	847.70	162.27	520.52	18.66	29.94	81397.28
PB 311	707.93	134.73	480.28	17.15	25.27	71031.67
PR 255	662.55	123.43	333.65	13.59	23.47	60582.25
PR 261	629.45	118.77	400.18	14.24	22.40	53101.63
RRIM 600	731.70	138.91	451.03	16.08	26.09	74436.02
RRII 45	629.74	119.09	409.06	14.44	22.81	56404.99
RRII 44	650.36	125.96	411.08	14.66	23.64	51199.74
RRII 105	953.46	181.33	634.86	22.66	34.04	87590.13
CD (P=0.05)	124.25**	24.62**	112.90**	4.02**	4.63**	13033.64**

** MOR: Modulus of Rupture; MOE: Modulus of elasticity; FS at LP: Fiber stress at limit of proportionality; HSS at LP: Horizontal shear stress at limit of proportionality; HSS at ML: Horizontal shear stress at maximum load

scaling, trees with normal TPD, trees next to bark scaled trees, trees next to normal TPD and healthy trees were subjected to anatomical investigations in collaboration with Plant Pathology Division. The intensity of sclerification and stone cell formation varied considerably among the bark samples. The proportion of soft bark gradually reduced in bark scaled trees due to the high intensity of stone cell formation, whereas in normal TPD trees the soft bark region was almost fully occupied by stone cells except for the zone contiguous to cambium.

An experiment on grafting of bark from trees affected by TPD to healthy trees and vice versa was carried out in two locations at CES, Chethackal. Strips of virgin bark of size 20 x 7.5 cm with intact cambium from 25 healthy mature trees and 25 TPD trees (trees with partial TPD and full TPD) were taken from the basal panel. Grafting success was observed in a total of 16 trees.

An experiment on the effect of stimulation in the laticiferous tissues of *Hevea* was initiated in collaboration with Plant Physiology Division. Bark samples were collected from the tapping panel of 10 trees of the clone RRII 105 under regular tapping at the age of 24 years.

A detailed investigation on the structure of bark of *Hevea brasiliensis* with special reference to alignment of phloic elements and clonal variability was carried out in ten clones in the mature phase and in seedlings of two Wickham x Amazon hybrid progenies (RRII 105 x MT 1005 and RRIM 600 x AC 495) and budded plants of RRII 105 and RRIM 600. In six clones *viz.*, RRIM 703, GT 1, RRII 300, Tjir1, PB 235 and Gl 1 the laticifers were inclined towards the right. In PB 86 the laticifers were inclined towards the left and in three clones *viz.*, RRII 105, PB 28/59 and RRIM 600 the inclination of laticifers was towards both left and right. Phloic rays and laticifers showed uniform pattern of inclination and alignment irrespective of bark zone. ■

Biotechnology Division

Contributions since establishment

Biotechnology research for the genetic improvement of *Hevea* was initiated at RRII during 1986. The major research programmes include development of *in vitro* propagation techniques, genetic transformation with agronomically important genes, development of modern tools to compliment conventional breeding programmes, gene characterization and expression studies. Initial focus was to develop micropropagation protocols for the elite *Hevea* clones. A method for the production of self rooted tissue culture plants through shoot tip culture was developed. Field evaluation of these plants is going on at RRII and the preliminary yield data shows an increase in yield in the clones RRII 105, RRIM 600 and PB 311.

Attempts were also made simultaneously for the micropropagation of *Hevea* through somatic embryogenesis which is an essential pre-requisite for employing any transgenic approach for crop improvement. Methods were perfected to produce tissue culture plants using immature anthers as well as immature inflorescence of *Hevea* clone RRII 105 as initial explants. The preliminary molecular studies revealed genetic uniformity. Recently, a method has been perfected to regenerate plantlets through somatic embryogenesis using leaf explants which are available

through out the year. The technology developed in Biotechnology Division is the best one available so far for the *in vitro* production of *Hevea* plants through somatic embryogenesis. First set of field trial with somatic plants derived from immature inflorescence was initiated at RRII in the year 2000. Subsequent field trials have been initiated at Central Experiment Station, Chethackal, with somatic embryogenesis derived plants from immature anther and inflorescence explants of clone RRII 105 in three consecutive years since 2001.

The main objectives of genetic transformation at RRII are improvement of agronomic traits of high yielding clones and recombinant protein production. Initial focus was to develop transgenic plants of clone RRII 105 tolerant to abiotic stress and tapping panel dryness (TPD). With these objectives four genes coding for sorbitiol-6-phosphate dehydrogenase, isopentenyl transferase, superoxide dismutase and antisense ACC synthase were identified for developing transgenic plants. Biotechnology Division has developed a very high frequency (more than 60%) *Agrobacterium* mediated genetic transformation system for the development of transgenic *Hevea* plants. Transgenic plants integrated with the gene coding for superoxide dismutase were developed, hardened and maintained in the containment facility for further evaluation. Preliminary biochemical studies revealed over expression of SOD in transformed callus when subjected to water stress. This is the first report from India about the development of a transgenic tree species. The stable integration of the introduced gene was confirmed through molecular methods. Transgenic tissues incorporated with the other three genes are under different developmental stages.

In order to enhance the rubber biosynthesis, attempts were initiated to develop transgenic plants integrated with the gene coding for important enzymes in the pathway such as HMGR1, farnesyl-diphosphate synthase (FDP), rubber elongation factor (REF) and cis-prenyl transferase. The above genes were successfully cloned into binary vectors and genetic transformation experiments initiated.

Transgenic experiments were also initiated with genes to develop *Hevea* plants with disease and stress tolerance, and for the production of recombinant proteins in the latex. The genes selected are 1) osmotin gene conferring tolerance to fungal diseases as well as abiotic stresses, 2) Myb1 transcription factor gene for conferring tolerance to abiotic stresses and TPD, and genes coding for aprotinin and TB antigen for the production of recombinant proteins. Transgenic *Hevea* tissues were developed with TB antigon gene, PCR analysis was carried out with the transgenic tissues and presence of transgene was confirmed.

A protocol has been perfected for plant regeneration from protoplasts of *Hevea* with the help of a nurse culture. Embryogenic cell suspension of *Hevea* clone RRII 105 was used as the explant source for protoplast isolation. Methods were standardized for *in vitro* fertilization in *Hevea* and the embryos could be grown up to the cotyledonary stage. Protocol has also been developed to produce plantlets from 2 - 3 month old fruits. Developed a method for triploid plant production through somatic embryogenesis following endosperm culture. Few plantlets were developed and confirmed to be triploid with 2n = 3x=54. A method for the induction of haploid callus from isolated microspores of *Hevea* has been developed.

Perfected a number of most modern molecular biology techniques for *Hevea* such as gene amplification by polymerase chain reaction, cloning of genes,

development of genomic and cDNA libraries, isolation and characterization of genes from genomic and cDNA libraries through PCR, isolation and characterization of gene promoters, isolation and characterization of differentially expressed genes through differential display analysis as well as suppression subtractive hybridization and development of gene constructs (binary vectors) for genetic transformation. Now the RRII Biotechnology laboratory is one of the world leading laboratories for *Hevea* molecular biology, tissue culture and genetic transformation studies.

By comparing the protein profiles of tolerant and susceptible clones of *Hevea* to abnormal leaf fall disease, protein markers were identified. The Division had identified three DNA markers for abnormal leaf fall disease tolerance, identified and characterized two DNA markers for tolerance to tapping panel dryness by comparison of the RAPD profiles of tolerant and susceptible clones, and also identified and characterized DNA markers/genes controlling dwarf trait in *Hevea brasiliensis*. Analyzed DNA polymorphism between 37 clones representing variability for several morphological, physiological and other characters. Results revealed that most of the primary clones were clustered together and the genetic relationship among some of the clones is closer, although they are developed from different breeding programmes. Genomic and cDNA libraries of *Hevea* clone RRII 105 were developed and this is being used for the isolation and characterization of genes controlling important agronomic traits. Identified 28 new genes from *Hevea*, which are not reported earlier from any source.

The mechanism controlling abnormal leaf fall disease tolerance at the molecular level was studied. It was identified that, β-1,3-glucanase gene could control the incidence of abnormal leaf fall disease and the gene for tolerance is present both in tolerant and susceptible clones. The different isoforms of the gene coding for β-1,3-glucanase involved in *Phytophthora* tolerance were isolated and characterized. In the tolerant clones there is a continuous expression of the gene which prevented the proliferation of the pathogen. The β-1,3-glucanase protein is over expressed in bacteria by incorporating the isolated gene into an expression vector and purified. Characterized the structure of β-1,3-glucanase and hevein genes of important *Hevea* clones, with different level of tolerance to abnormal leaf fall disease.

Attempts were made to identify the differentially expressed genes in the TPD affected and healthy trees. Two cDNA libraries (expressed genes) of TPD affected and healthy tissues were developed. A total of 145 unique genes were identified. Expression of two genes coding for a Translationally Controlled Tumour Protein and Myb-1 transcription factor gene having important role in TPD development were studied. It was found that the expression of these two genes was down regulated in the tapping panel dryness affected tissues. An mRNA differential display analysis between TPD affected tissues and healthy tissues were carried out and five markers specific for healthy tissues and one marker specific for TPD affected tissues were identified.

The rubber biosynthetic genes as well as genes used for the production of recombinant proteins require laticifer specific promoters for their over expression, specifically in the latex vessels. Identified genes with laticiferous specific over expression (β-1, 3-glucanase isoform, rubber elongation factor, Hevein, HMG Co-A reductase). Promoters of a laticifer specific β-1,3-glucanase isoform (198 bp), rubber elongation factor (378 bp), hevein

(1865) and HMG Co-A reductase (294) genes which are over expressed in the latex vessels were amplified through Random amplified genomic DNA ends (RAGE), isolated, cloned and the sequences were characterized.

Ongoing Research Programmes

The major ongoing research programmes in the Division are 1) development of *in vitro* propagation methods for elite *Hevea* clones, 2) development of superior transgenic *Hevea* plants for better latex yield, disease tolerance, adaptation to environmental stresses, recombinant protein production in the latex etc., 3) development of modern tools to compliment conventional breeding programmes, 4) study of molecular mechanism and characterization of genes controlling tolerance to diseases, abiotic stresses, tapping panel dryness and latex biosynthesis, and 5) study of laticifer cell specific gene expression and characterization of laticifer cell specific promoters.

1. Micropropagation

The biochemical and molecular mechanism of root induction in shoot tip cultures was studied. Polyacrylamide gel electrophoresis was done with immature shoots of seed propagated and clonal plants collected from glasshouse and *in vitro* cultures. Several bands found in fresh clonal shoots were absent in clonal shoots after *in vitro* growth for about one month while most of the seedling shoots were found to retain all of them. An additional protein band was found specifically expressed in shoots of both seedlings and clones after one month *in vitro* culture.

2. Somatic embryogenesis

Calli produced from immature anthers of clone RRII 105 were subcultured and transferred to embryo induction medium. Embryogenic calli were differentiated into globular embryiods and the embryos are at different stages of development. Similarly callus induced from 400 series clones were proliferated and transferred for embryo induction. Embryoids which appeared on the surface of calli were further subcultured for development.

Plant regeneration through somatic embryogenesis from immature inflorescence of clone RRII 105 was continued using secondary embryogenesis system. Embryogenic calli as well as the globular stage embryos were cultured over embryo induction medium fortified with 1.0 µM NAA. In the case of embryogenic calli, faster proliferation could be achieved. For globular stage embryos, development of numerous secondary embryos has been made possible by serial subculture of these embryos at three weeks interval. Embryo maturation and plant regeneration could be obtained.

Actively growing root tips of somatic plants were also utilized as the initial explant for embryo induction and plant regeneration. Induction of embryos from root derived embryogenic calli could be achieved successfully. Also multiplication of the embryogenic calli at a hormone combination of 1.0 µM 2,4 – D and 1.5 µM NAA could be achieved.

Attempts have also been initiated to develop plant regeneration pathways for important RRII 400 series clones using immature inflorescence as explants. Callus induction occurred within 3-4 weeks for all the clones in media containing 2,4-D (3.2 µM), NAA (1.6 µM) and kinetin (1.0 µM) with varied frequency. Proliferation of these calli was brought about by subculturing over modified callus induction medium containing half strength basal medium along with auxin levels reduced to one fourth of the original concentration.

For the small-scale field trial commenced in 2000, recording of girth and

test tapping were conducted. For 2003 planting, the girth of the somatic plants were on par with control budgrafted plants and the seedlings. In general, the somatic plants showed better values for yield and other yield attributes.

Callus induction was observed within 4 weeks of incubation in new cultures raised from leaf explants of clones RRII 105 and 400 series clones. Proliferation of calli formed earlier and embryo induction occurred in the dark. Cultures when kept in the dark, the embryos enlarged and apex induction occurred. Good plant development occurred in the light when subcultured in ½ MS media devoid of hormones and containing organic supplements such as coconut water (10%) and malt extract (100 mg/l) and sucrose (30 g/l). Fully developed plantlets obtained after 3-4 weeks of culture were transferred to sterile potting mixture for hardening and initially maintained in a growth chamber. Plantlets after leaf maturation were transferred to glasshouse and hardened.

Anatomical studies on root morphogenesis were carried out with plants derived from shoot tip culture, embryo culture and somatic embryogenesis which revealed basic difference in the root initiation and structure.

Experiments were continued for the leaf expansion of the germinating plantlets obtained from ovule culture. Embryo induction percentage was highly improved by changing the basal medium from WPM to N_6. Growth regulators like kin (3.0 mg/l), NAA (1.0 mg/l) and ABA (0.5 mg/l) favored embryo induction and frequency was increased to 85 percent. Embryo maturation and germination was achieved in the N_6 medium with BA (0.5 mg/l) and IBA (0.3 mg/l) supplemented with 0.4 percent charcoal.

The experiment with colchicine was repeated in microspore culture to confirm the growth promoting effect of this anti-mitotic chemical at different concentrations (0.1 -1%) and for different durations (24, 48, 72, 96 hrs). The effect of different genotypes (RRIM 600, RRII 430, RRII. 429, and RRII 105) on microspore division and subsequent callus induction was assessed. 100 mg/l colchicine for 96 hrs and 400 mg/l for 24 hrs positively influenced the callus growth. The microspore division was observed in all the clones. The microspore division and callus induction was faster for the clone RRIM 600 compared to RRII 105. The callus obtained from anthers was sub-cultured to the proliferation medium.

Embryo induction and maturation was obtained from proliferated endosperm callus in medium supplemented with the growth regulators GA_3 (0.5 mg/l), ABA (0.3 mg/l) along with 5 per cent sucrose and 0.5 per cent phytagel. Germination of the embryos was tried in media supplemented with different growth regulators *viz*., GA_3, BA and IBA at varying concentrations. A callus induction frequency of 14 per cent, embryo induction frequency of 50 per cent and a maturation frequency of 24 per cent were achieved. The germination frequency could be enhanced from 8 to 15 per cent in a growth regulator combination of BA and GA_3. Addition of activated charcoal (0.2%) also favored germination. For getting organogenesis from *Hevea* endosperm, immature endosperm from 4-5 month old fruits was used with different combination of growth regulators. Three factorial experiments were performed with different auxin cytokinin combinations. Direct embryogenesis was observed in few cultures.

3. Genetic transformation

Attempts were continued to develop transgenic plants with increased tolerance to tapping panel dryness, drought and environmental stresses and to enhance the rubber yield. The genes coding for superoxide dismutase under the

control of CaMV 35S and FMV 34S promoters separately, sorbitol-6-phosphate dehydrogenase with separate signal peptides for targeting to the cytoplasm and chloroplast, HMGR1, farnesyl diphosphate synthase and rubber elongation factor were used. In addition, the gene coding for osmotin for enhanced disease and abiotic stress tolerance, Myb1 transcription factor gene to enhance TPD and abiotic stress tolerance, and aprotinin and TB antigen genes for recombinant protein production were also initiated.

The transgenic plants incorporated with SOD gene were multiplied through bud grafting to raise material for molecular and biochemical evaluation of the efficiency of the transgene and also for field evaluation. To confirm the stability of the SOD gene integration in *Hevea*, plantlets were regenerated from the root explants of SOD-transgenic plants through somatic embryogenesis. Histochemical staining of the callus and embryos in this experiment showed they were GUS positive. PCR amplification was observed with *npt* II primers in the transgenic tissues. The 702 bp sequences corresponding to the SOD cDNA were amplified in all the transgenic tissues tested which further confirmed the stability of the gene.

To enhance the *Agrobacterium* mediated genetic transformation frequency in *Hevea brasiliensis*, different explants *viz.*, intact immature anther and ovule, newly developed as well as embryogenic callus derived from immature anther, ovule and leaf explants were tried as target tissue for *Agrobacterium* infection. Different *Agrobacterium* strains, binary plasmid vectors, various acetosyringone concentrations (10-100 mg/l) and duration (10-30 min) of *Agrobacterium* infection were tried. The result indicated that the explants have significant role in transformation efficiency. The intact anther and ovule had no positive response on transformation efficiency. Putatively transgenic lines obtained showing resistance to kanamycin were GUS positive.

A transformation frequency of 4 – 7 per cent was observed with two month old calli derived from anther, ovule and leaf. A much higher frequency was obtained for embryogenic calli derived from immature anther, ovule and leaves. The highest transformation frequency of 62 per cent was obtained for anther derived embryogenic calli.

PCR analysis was carried out with 10 GUS positive lines integrated with SOD gene under the control of CaMV 35S promoter and all the lines were found to be PCR positive with *npt* II specific primers. Embryogenesis was obtained from two lines. With the SOD gene under the control of FMV 34S promoter, 11 transgenic lines were obtained and they were proliferated in the proliferation medium and embryogenic calli were obtained. Embryo induction could be obtained from the transgenic cell lines integrated with Sorbitol-6-phosphate dehydrogenase gene for drought tolerance.

In the transformation experiments with rubber biosynthetic genes, embryogenic callus was obtained with the gene coding for rubber elongation factor. For the gene coding for HMGR1, the newly emerged transgenic cell lines were subjected to PCR analysis and the presence of transgene is confirmed. Experiment was also initiated with the gene coding for cis-prenyl transferase under the control of CaMV 35S promoter and fresh *Agrobacterium* infection was carried out to raise transgenic cell lines. With the TB antigen gene for recombinant protein production, transgenic embryos were developed. Presence of *npt* II gene was confirmed by amplification of 0.8 Kb single products in all the transgenic cell lines and embryos.

4. Molecular studies

Work has been initiated to characterize

the sequences coding for β-1,3-glucanase from different clones with different levels of tolerance to abnormal leaf fall disease. The genomic sequences coding for β-1,3 glucanase was PCR amplified from 5 clones relatively tolerant to abnormal leaf fall disease (FX 516, RRII 105, GT 1, RRII 33, GL 1) and four susceptible clones (PR 107, PB 86, RRIM 600, RRII 414, RRIM 701). The sequence analysis of all the clones revealed the presence of a single intronic sequence at +103 position starting from the translation initiation codon (TIC). The intron sequences of all the clones studied were found to have 'CT' repeats which varied from clone to clone.

Experiments were carried out to amplify the full length laticifer specific promoters of hevein, HMGR1 and farnesyl diphosphate synthase genes through 5' RAGE analysis. Through extensive PCR trials with the adapter ligated, restriction enzyme digested DNA fragments using the adapter specific forward and gene specific reverse primers, promoter fragments of 0.5 Kb with hevein gene, 0.3 Kb with HMGR1, 0.2 Kb with FDP were amplified upstream to the transcription initiation site. Under optimum PCR condition a 1934 bp fragment was obtained. Excluding the adapter sequence from the 5' end and gene sequence from the 3' end a promoter sequence of 1865 bps was obtained upstream to the translation initiation codon. From the comparison of the promoter region of the plant genes so far characterized a number of consensus motifs *viz.*, GATA box, I box, MYB core elements, MYBST1, MAR box, WRKY elements, and AMY Box were reported as cis-acting elements.

1865 bp hevein gene promoter isolated in the present study from the clone RRII 105 was compared with an earlier reported 1830 bp promoter sequence. In the present study 48 more nucleotides were observed upstream to the earlier reported sequence. On comparison with the earlier reported sequence, one major deletion of 23 nucleotides "CATATTA-TATATGAATAATATTT" at –1117, 6 nucleotide sequence deletion "CAAGGA" at –513 and additions of 9 nucleotide sequence each at –1276 "TTGCCTCTG" and –1286 "AAAAATATT" positions from the TIC were found.

Remarkable variation in the number and sequence of nucleotides were observed among the selected clones and of 32 nucleotides between –200 and –232 positions relative to the TIC was observed. This deletion is 6 nucleotides upstream to the CAAT motif. This was observed with three *Hevea* clones RRII 430, RRII 38 and PB 86. In this region a nucleotide repeat of (ATTCCA) was observed with a nucleotide sequence of 24 in between. This flanking sequence and upstream ATTCCA were absent in the above mentioned three clones with nucleotide deletion.

A 0.3 Kb 5' upstream sequence of HMGR1 was amplified through RAGE from the *Dra* I digested DNA fragment. Nucleotide sequence data revealed the presence of 294 nucleotides upstream to the translation initiation codon (TIC). TATA motif was observed at -88 position relative to the TIC. Sequence data was deposited under the accession No.DQ649474. 0.2 Kb 5' upstream region of FDP gene was amplified through RAGE from the *Ssp* I digested DNA fragment. Amplified fragment contains 132 bps promoter sequences. A putative TATA box is found at -30 relative to the TIC.

5. Isolation and characterization of wound/stress inducible cDNAs

The DNA sequence of all the cDNA clones obtained earlier in the suppression subtraction cDNA library between the TPD tolerant and susceptible trees were characterized. 145 DNA sequences were registered in the NCBI database.

Genome Analysis Laboratory

Contributions since establishment

The Genome Analysis laboratory was established as a central facility for molecular characterization of *Hevea* genome under the World Bank scheme and started functioning since August 1997. The research activities of the laboratory are focused on four major areas *viz.*, 1) development, optimization and validation of molecular tools for the assessment of genetic diversity in rubber, clone identification and genome mapping; 2) genetic markers for biotic and abiotic stress tolerance; 3) cloning and characterization of agronomically important genes and 4) molecular characterization of fungal pathogens of rubber.

In total, 76 *Hevea* genomic sequences having long microsatellites were identified, characterized and registered with the NCBI GenBank, USA (accession numbers: AY439286 to AY439314 and AY962189 to AY962235).

A combination of four microsatellite markers was successfully used to discriminate uniquely 27 cultivated *Hevea* clones. Cross-species amplification of the markers developed in *H. brasiliensis* had also been demonstrated with two other *Hevea* species, *H. benthamiana*

and *H. spruceana* indicating high degree of sequence homology at the flanking regions.

Repeat sequences were detected at 3'UTR of 3-hydroxy-3-methylglutaryl-CoA reductase (*HMGR*) gene encoding HMG-CoA reductase in *Hevea brasiliensis*. Existence of two microsatellite alleles and their repeat compositions was demonstrated in cultivated rubber clones. In wild populations of rubber, nine microsatellite alleles ('A' to 'I') were identified at the same locus (*HMGR*) revealing a wide allelic diversity compared to cultivated clones. In total, 15 allelic combinations were noticed for *HMGR* among wild accessions and four of them were unique. This work is a significant step towards understanding the functional variability of *HMGR* for latex production in *Hevea brasiliensis*.

Genetic relationship among the wild *Hevea* germplasm had been assessed using RAPD markers and a set of universal chloroplast microsatellite markers for getting an insight of the chloroplast genome differentiation among them. Genetic diversity studies in wild *Hevea* accessions belonging to three different provinces, *i.e.*, Acre, Rondonia and Mato-Grosso of Brazil clearly showed the presence of three distinct gene pools for wild rubber.

Single nucleotide polymorphism (SNP) studies were undertaken in rubber to identify polymorphism which could be used to get an insight of the complex biochemical traits that regulate some important phenomena in *Hevea*, such as tapping panel dryness, ethylene induced latex production *etc.* Surveyed the frequency of SNPs on 12 genes (cDNA) encoding important enzymes catalyzing several biochemical reactions in 16 cultivated rubber genotypes/clones. SNPs were detected only in 7 out of 12 loci sequenced from all the 16 genotypes. These 7 loci are: 1) Geranyl-geranyl diphosphate synthase with 5 SNPs, 2) Ubiquitin precursor with 6 SNPs and a large insertion deletion polymorphisms (indel) of 45 bases in length, 3) Latex patatin homolog with 6 SNPs, 4) Latex abundant protein with 1 SNP, 5) Farnesyl diphosphate synthase with 6 SNPs, 6) Latex plastidic aldolase with 1 SNP and 7) Mevalonate kinase with 3 SNPs and 3 indels. A total of 31 SNPs (28 substitution and 3 insertion/deletion polymorphisms) were detected.

Retrotransposons are dispersed as interspersed repetitive sequences throughout the host genome and exploited as genetic tools for plant genome analysis. Confirmed the abundance of retrotransposons in *Hevea* genome through (i) Southern analysis of genomic DNA of *Hevea brasiliensis* with partial coding sequence of reverse transcriptase (RT) gene and (ii) genomic library screening. Both LTR (long terminal repeat) and non-LTR retrotransposons were identified in rubber genome.

Resistant gene analogue (RGA) approach was adopted to identify disease resistant gene in *Hevea*. Nucleotide sequences of 15 putative RGA clones isolated from rubber were found to have encoded characteristic aminoacid motifs of NBS regions, namely, P-loop, kinase-2 and GLPL when the translated sequences were searched for similarity against protein database at the NCBI GenBank. Amino acid alignment showed that *Hevea* RGAs share homology with well characterized R-genes from other plants, for example, *Ipomoea*, *Arabidopsis*, *Citrus*, *Oryza*, *Populas*, Coffee etc. All these 15 sequences were unique as revealed through multiple sequence alignment and formed five major clusters.

Transcript profiling in response to cold stress was carried out to understand stress adaptation processes in rubber to develop markers for cold tolerance. Cold-stressed *Hevea* leaf samples of three genotypes: RRII 208, PB 260 and PR 261 from Munnar and control leaf samples from RRII, were used for differential gene expression studies. Totally 180 differentially expressed major bands (down or up-regulated) were excised out of the dried gel and 144 band were successfully reamplified. Twenty-one fragments comprising 12 down-regulated and nine up-regulated transcripts of the clone RRII 208 under stress conditions were cloned. Sequencing was done for all 21 clones. Out of 21, only four sequences revealed homology with four known gene sequences i.e., catalase, phosphatidyl-inositol/ phosphatidyl-choline transfer protein, NADH dehydrogenase and chloroplast FtsH protease respectively.

As rubber wood is having low level of lignification, cloning of cinnamyl alcohol dehydrogenase (CAD) gene, involved in the lignin biosynthesis pathway has been attempted for quantitative improvement of lignin in wood fibers through genetic manipulation. A partial coding sequence of CAD gene has already been cloned.

A partial protein coding sequence of 'Flowering Locus T' gene has been identified in rubber, which controls flowering through activation of flowering pathways in plants. FT and TFL1 (Terminal Flower 1) are homologous to phosphatidyl ethanolamine binding proteins (PEBPs), a wider group of proteins that have diverse roles in animals, yeast, and bacteria. The predicted amino acid sequence of the cloned fragments from rubber containing 91 amino acids showed maximum homology with flowering locus T like protein of *Populus nigra* (E value = 1e-24) when subjected to BLAST search.

Association of *Colletotrichum acutatum* with *Hevea* was reported for the first time in India from our laboratory, which is now believed to be the major pathogen of Colletotrichum leaf disease of *Hevea* besides *C. gloeosporioides*. Subsequently two SCAR (sequence characterized amplified region) markers were developed for easy PCR-based identification of *Colletotrichum* at the species level. These markers (SCARs): OPB-$17_{(874)}$ for *Glomerella cingulata* (anamorph: *Colletotrichum gloeosporioides*) and OPI-$06_{(788)}$ for *Glomerella acutata* (*Colletotrichum acutatum*), had been registered with the NCBI GenBank. Genetic structuring of *Corynespora* isolates collected from different rubber growing regions revealed existence of ten different pathotypes/races of which one appeared to be the most virulent pathotype based on DNA profiling that correlated with the severity of disease incidence.

From the Genome Analysis laboratory 110 sequences were registered with the GenBank at National Centre for Biotechnology Information (NCBI), USA. These sequences were fungal genomic sequences, *Hevea* genomic sequences containing microsatellite repeats and resistance gene analogues in rubber.

Ongoing Research Programmes

The Genome analysis laboratory continued its research activities in three major areas (a) development, optimization and validation of molecular tools for the assessment of genetic diversity in rubber, clonal identification and genome mapping, (b) genetic markers linked to biotic and abiotic stress tolerance and (c) cloning and characterization of agronomically important genes.

1. Molecular tools for the assessment of genetic diversity in rubber, clonal identification and genome mapping

Development of microsatellite markers was continued with the isolation and characterization of *Hevea* genomic clones containing microsatellite/ simple sequence repeats (SSRs). SSR-mining was also carried out using NCBI genbank sequence data on rubber and identified repeat sequences at 3' untranslated region (3'UTR)/5'UTR of *Hevea* gene sequences. SSR polymorphisms were detected in *HMGR* gene encoding HMG-CoA reductase in *Hevea* germplasm, an important enzyme involved in rubber biosynthesis. Nine alleles were identified based on the variation in the repeat motif of microsatellites in the 3'UTR of the coding sequences among wild accessions.

Single Nucleotide Polymorphism (SNPs) studies were continued to identify polymorphism, which could be used to get an insight of the complex biochemical traits that regulate some important phenomena in *Hevea*. SNPs identified in the sequences are being validated using 'Tetra primer ARMS-PCR' method.

A *Hevea* genomic library was constructed to clone a full-length retroelements. Out of the 23 positive clones identified through blot hybridization, 10 were sequenced from both directions and analyzed. Two clones RT-3 and RT-15 showed homology with putative non-LTR retroelement reverse transcriptase of *Oryza sativa* (japonica cultivar-group), clone RT-13 showed homology with putative 22 kDa kafirin cluster of Ty3-Gypsy type retroelements from *Oryza sativa* (japonica cultivar-group) and also with polyprotein of *Ananas comosus*, and clone RT-20 showing homology with gag/Pol polyprotein of *Pisum sativum*.

A data set was prepared based on the segregating bands/loci generated by RAPD and AFLP studies of the progenies including parents for their further use in linkage analysis.

2. Genetic markers for biotic and abiotic stress tolerance

Resistant gene analogue (RGA) approach was adopted to identify disease resistant gene in *Hevea*. Nucleotide sequences of 32 putative RGA clones isolated from rubber were analyzed. Out of 32 sequences, 15 were found to have encoded characteristic aminoacid motifs of NBS regions, namely, P-loop, kinase-2 and GLPL when the translated sequences were searched for similarity against protein database at the NCBI Genbank. Amino acid alignment showed that *Hevea* RGAs share homology with well-characterized R-genes from other plants, for example, *Ipomoea, Arabidopsis, Citrus, Oryza, Populas*, Coffee etc. All these 15 sequences were unique as revealed through multiple sequence alignment and formed five major clusters. However, translated sequences (encoded aminoacid sequences) were grouped into six clusters showing more variation at the protein level.

Transcript profiling for functional genomic studies in relation to cold stress was continued. Cold-stressed leaf samples of three genotypes: RRII 208, PB 260 and PR 261 from Munnar and control leaf samples of the same from RRII, Kottayam, were used for differential gene expression studies. Totally 96 differentially expressed major bands (down or up-regulated) were excised out of the dried gel and successfully reamplified. Reamplified products were cloned in pGEM-T vector and processed for sequencing to determine identity of

the candidate cDNA. Twenty-one fragments comprising 12 down-regulated and 9 up-regulated transcripts of the clone RRII 208 under stress conditions were successfully cloned. Sequencing was done for all 21 clones. Out of 21, only four sequences revealed partial match with four known gene sequences i.e., catalase, phosphatidylinositol/ phosphatidylcholine transfer protein NADH dehydrogenase and chloroplast FtsH protease existing in the NCBI GenBank.

3. Cloning and characterization of agronomically important genes

Efforts were made to isolate full-length gene from *Hevea* that encodes CAD (cinnamyl alcohol dehydrogenase), a key enzyme for lignin biosynthesis and R gene(s) conferring disease resistance in rubber. A *Hevea* genomic library was screened with a heterologous CAD (cloned from jute) and resistant gene analogue (isolated from *Hevea*) respectively to identify positive clones bearing the above gene(s) of interests. However, most of the positive clones were found to be retroelements through sequence homology. Therefore an RT-PCR techinque was adopted to amplify CAD cDNA from bark RNA avoiding the interference of retro sequence in *Hevea* genome. Consequently, we could successfully clone a partial CAD cDNA from rubber. ■

Plant Pathology Division

Contributions since establishment

The Plant Pathology Division, one of the earliest research disciplines established under the RRII has made significant contributions in developing appropriate strategies for disease management.

Among the major diseases of rubber, abnormal leaf fall disease (ALF) is considered as the most severe one in India since 1908, when it was first reported from Palappally in Trichur District. Although spraying of Bordeaux mixture was recommended from the early days, large plantations could hardly be protected by prophylactic spraying due to the time consuming and labour intensive nature of high volume spraying. Since the establishment, the Division concentrated its research on improvements in spraying technology and developed the micron spraying system for control of ALF in rubber plantations. Appropriate low volume sprayers for use in different growth stages of rubber trees were designed and developed in collaboration with the industry.

Another area of research was the improvements in fungicide carriers. Copper oxychloride dispersed in agricultural spray oil was recommended and this

could protect the crop with a single annual prophylactic spraying. Partial replacement of spray oil with rubber seed oil has also been successful. Besides, oil based mancozeb also was found to be effective and could be used instead of copper oxychloride.

RRII conducted experiments on fungicide dosage and spray volume for aerial spraying, control over coverage and use of alternate fungicide formulations and spray oils. However, paucity of helicopters are now posing serious problems in aerials praying.

As the smallholders resort to high volume spraying of Bordeaux mixture using family labour, attempts were made to improve the high volume spraying technology and reduce the cost. Motorized high volume spraying has been observed to reduce cost by improving the coverage by three to four times. Zinc sulphate can replace copper sulphate in Bordeaux mixture by 50 per cent and consequently reduce the cost, retaining the efficacy.

Efforts were also made in improving the spraying technology for powdery mildew disease. Micron dusters carried by four workers for use in mature rubber areas and smaller ones carried by two workers for young plantations have been developed. Use of systemic dust fungicides was attempted for control of powdery mildew disease and integrated schedules were developed.

Corynespora leaf disease appeared as epidemic in mature plantations in South Karnataka and North Kerala during 1996. A crop protection schedule was developed by 1998 and the entire rubber growing areas in the region was protected in a World Bank assisted crop protection campaign during 1999. The inoculum of the fungus could be brought to manageable levels by this concerted effort. Subsequent regular surveys on the disease show no resurgence of the inoculum and this remain as a very successful crop protection effort in which the timely intervention of RRII along with the extension officers of Rubber Board and the co-operation of the rubber growers could effectively control an epidemic plant disease. The competence of RRII in the development of effective disease control strategy has now gained international recognition and Common Fund for Commodities (UK) has identified RRII as the international training center for the Corynespora disease management project.

Disease management strategies have been developed for other leaf diseases also. The identity of the fungus causing severe form of gloeosporium leaf disease has recently been confirmed as *Colletotrichum acutatum* using molecular fingerprinting technique.

Stem diseases like pink disease, patch canker and dry rot could be controlled by evolving effective disease control strategies. Improvements were made in the tenacity of Bordeaux paste used for pink disease control by incorporating additives like neem oil and rubber seed oil. Use of thiride incorporated in rubber coat was recommended as an alternative to Bordeaux paste for application in wet weather. Carriers using china clay and polyvinyl acetate were also developed for preparing fungicide paints using systemic fungicides to prevent rain-wash. Prophylatic painting of Bordeaux paste or spraying of Bordeaux mixture also were found effective in reducing disease incidence. New systemic and non-systemic fungicides were identified for the control of pink, patch canker and dry rot diseases.

RRII had earlier recommended mercurial fungicides for protecting the tapping panel from black stripe disease.

Later, when the potential hazard of mercurial fungicides to human beings became evident it was withdrawn from recommendation. Mancozeb was identified as an effective alternative and its dosage and application techniques were standardized.

Tapping panel dryness (TPD) has remained a disorder with unknown etiology. A recent development is the observation that a low molecular weight RNA is associated with TPD.

Disease control strategies have been evolved for root diseases as well. Agromet observations have been set up at all rubber growing and prospective areas and regular monitoring of weather is being undertaken. Attempts are also being made to develop disease prediction models based on weather parameters. Rubber being a tree with laticiferous tissue is not a preferred host for most insect pests. Effective control measures have been developed for all pests attacking rubber trees. Biological control for root grubs and bark feeding caterpillars have been evolved. Simple techniques for control of snails and crickets damaging rainguards were developed. Attempts are being made to control termites using botanical pesticides.

In the context of eco-friendly agriculture, conventional crop protection techniques may have to be replaced with sustainable techniques demanding low input costs. One of the significant studies in this direction made by RRII was the development of the abnormal leaf fall disease tolerant clone RRII 105 which does not suffer overall crop loss in a planting cycle while clones like RRIM 600 loses more than 30 per cent crop. However, under situations of very high humidity and inoculum load, RRII 105 also needs prophylatic protection.

The efforts on developing new clones with disease resistance and high yield is one of the focus areas of research. The new clones evolved by RRII are under close observation and evaluation in different locations. The Institute has a large collection of germplasm from Brazil, which are systematically screened for disease resistance characters so that these will serve as sources of resistance genes in future breeding programmes.

Another approach is genetic engineering for disease tolerance. Genes conferring resistance to plants like β-1,3 glucanase and chitinase are being identified for development of transgenic plants. Induction of systemic resistance and use of endophytic microorganisms to protect the plants from diseases are other areas of active research.

Research programmes to identify and utilize beneficial microorganisms for improving plant growth and environmental health were also undertaken. The evaluation of *Mucuna bracteata* introduced to Southern India from Tripura for use as cover crop in rubber plantations was undertaken. *M. bracteata* was observed to be beneficial due to its fast coverage with more litter and deep root penetration. As it was preventing weed growth and soil erosion and supporting growth of rubber, its use was recommended. An effective rhizobial strain for improving growth of *Pueraria phaseoloides* was isolated, multiplied and distributed.

Organisms effective in pollution control have been utilized for treatment of rubber sheet processing effluent and generation of biogas to partially meet the energy requirements of smoke houses. A high rate reactor developed recently is efficient in reducing the HRT to 24 hours. This in combination with an aerobic treatment is successful in over-

coming the pollution due to processing effluent besides generating bioenergy in the group rubber sheet processing centre where it is installed.

Rubber tree is a rich source of nectar. It was found that the extrafloral nectary glands are present at the end of the petiole where the leaflets join. About 15 beehives can be placed in a hectare of rubber plantation. The yield is nearly 10 kg of honey/hive/year. This can serve as an additional income for rubber growers. Rubberwood saw dust, a solid waste from rubberwood processing industry was identified as a substrate for edible mushroom culture. This is also an additional income for rubber growers besides disposing solid waste.

Ongoing Research Programmes

Chemical and biological control of diseases and pests of rubber, vigilance on occurrence of new diseases and strains of pathogens, management of effluent from rubber processing for pollution abatement and biomethanation, post harvest storage of sheets, bee keeping etc. were the thrust areas of research of the division.

1. Leaf diseases

The experiment to evaluate the possibility of partial substitution of neem seed oil (NSO) and rubber seed oil (RSO) for ALF control showed that NSO was comparable to RSO but was costlier. Micron spraying of akomin and salicylic acid against ALF disease was not effective compared to high volume spraying of Bordeaux mixture (1%).

Experiment to evaluate the efficacy of water-based COC (Fytolan) when sprayed using IOC emulsion oil in clone PB 260 showed that 4 and 6% IOC emulsions were comparable to spraying of oil dispersable COC at the rate of 8 kg/ha in 40L (Table Path.1).

Eight F2 progenies out of 29 obtained by selfing RRII 105 showed the same level of tolerance to *Phytophthora* as the parent under *in vitro* screening. RAPD analysis of the isolated DNA of RRII 105 and the tolerant progenies along with susceptible and tolerant parents of RRII 105 with 60 random primers were carried out. Four primers, (OPF 10, OP A2, OPA 10 and OPF 13) produced polymorphic banding pattern with the susceptible parent.

rDNA from *Phytophthora* isolates were cloned, sequenced and analysed to confirm *P. citrophthora* as one of the species causing ALF disease in *Hevea* in India. The identification report from International Mycological Institute (IMI), UK indicated homology with *P. citrophthora* and *P. colocassia*.

The field tolerance of the germplasm accessions selected for *Phytophthora* resistance through laboratory screening, was confirmed (leaf retention 50-95%). Field screening of HP clones for ALF disease in LST at CES, Chethackal was carried out under sprayed conditions. In Trial 1, RRII 55 recorded highest leaf retention (91%) followed by RRII 429 and RRII 105 (82%). In Trial II, RRII 430 and RRII 422 (90%) recorded high leaf retention.

Among the RRII 400 series clones, RRII 430, RRII 417 and RRII 422 recorded high leaf retention (90%) at Cheruvally Estate, Erumely (1998 trial). At Kaliyar Estate, Thodupuzha (1999 trial) also RRII 430 and RRII 417 recorded high (95%) leaf retention. When 12 clones in G X E trial were evaluated for ALF disease at Padiyoor, maximum leaf retention was noticed for RRII 414 (79.58%) and minimum for RRIM 600 (33.33%). The progenies of the families in prepotent trial were screened for ALF disease at CES. Maximum leaf retention was for PB 215 (59.78%).

Table Path. 1. Percent leaf retention in water based spraying of fytolan with different doses of IOC emulsion

Treatment	Leaf retention (%)
Fytolan + IOC emulsion oil (3%) + water	65.73
Fytolan + IOC emulsion oil (4%) + water	72.80
Fytolan + IOC emulsion oil (6%) + water	71.80
Chlorocop + IOC oil (1: 5)	70.86
Unsprayed control	37.61

In the evaluation of crop loss due to powdery mildew disease in clones RRII 105 and PB 28/59 at Maruthi Estate, Kanyakumari, the pre-treatment application of sulphur was continued.

The experiment on control of Colletotrichum leaf disease at Malankara Estate, Thodupuzha on first year plants of clone RRII 105 showed minimum disease intensity in azoxystrobin application followed by difenconazole.

No genetic variation was observed in both the highly virulent and less virulent isolates of *Corynespora* when subjected to different concentrations of carbendazim(Bavistin) and hexaconazole (Contaf) even after passing through five generations, showing low chance of resistance development to these fungicides on repeated spraying in the field. The resistant clone GT1 and the susceptible clone RRII 105 showed marked difference in symptom expression from 96 h after artificial inoculation with *C. cassiicola*. Leaf samples collected at different intervals after inoculation revealed a marked rise in the chitinase activity for the inoculated plants of GT 1 while the enzyme activity was only slightly higher and was constant in the inocluated plants of RRII 105 compared to uninoculated control (Table Path. 2). Leaves of GT1 also showed a marked rise in chitinase activity in the initial hours of salicylic acid treatment (24-72 hrs) and became steady thereafter.

Among the 85 endophytic bacteria from *H. brasiliensis*, 45 showed *in vitro* antagonism against *C. cassiicola*. One isolate showed an inhibition zone of 4.5 cm and two others of 4 cm each. 39 produced siderophore and 42 produced salicylic acid. Two isolates were effective in detoxifying the phyto toxin from *C. cassiicola*.

The 2,4-diacetylphloroglucinol (2,4 DAPG) gene was detected in five antagonistic bacteria. Sporulation of *C.cassiicola* was inhibited in the media containing 5000 ppm 2, 4 DAPG.

Table Path. 2. Chitinase activity (units) of *Hevea* clones inoculated with *C.cassiicola*

Clone	24 h after inoculation		48 h after inoculation		72 h after inoculation		96 h after inoculation		120 h after inoculation	
	Control	Inoculated	Control	Inoculated	Control	Inoculated	Control	Inoculated	Control	Inoculated
GT 1	20	30	20	34	20	40	20	72	20	96
RRII 105	10	16	10	16	10	16	10	16	10	16

A consortium of three efficient antagonistic endophytes showing induced systemic resistance to *C. cassiicola* (*Bacillus subtilis, B.atrophaeus, Penibacillus macerans*) was evaluated by application to four year old RRII 105 plants in Nettana Farm, Karnataka. The treated plants showed a reduction in disease incidence. The bacteria could be reisolated from the hypersensitive areas of leaves and was confirmed by ERIC-PCR.

Out of 112 short listed germplasm accessions 29 were confirmed to show tolerance against *C. cassiicola in vitro*.

Molecular studies revealed the association of *Alternaria* in causing a leaf blight disease, which resembled with the Corynespora leaf spot disease in rubber. The identification of the pathogen as *A. alternata* was confirmed by IMI, UK. Koch's postulates were satisfied to confirm the infection of *A. alternate* on *H. brasiliensis*. Alternaria leaf blight on *Hevea* caused by *A. alternata* is reported for the first time in India.

Cylindrocladium disease incidence in different clones at Kaliyar Estate was recorded. The clone RRII 410 was most susceptible followed by RRII 407 and RRII 414. The disease incidence was mild for all other clones. Among the six fungicides screened *in vitro* against *Cylindrocladium*, Carbendazim was most effective with complete inhibition at 500ppm.

2 Stem diseases

Diffenconazole completely arrest the growth of the pink disease pathogen even at 50ppm. In the screening of clones at Cheruvally Estate (1998 trial) RRII 429 recorded highest pink disease incidence (30.77%) followed by RRII 414 (7.69%) and RRII 422 (6.15%). Lowest disease incidence was in RRII 430. At Kaliyar Estate (1991 trial) also RRII 429 recorded the highest (30.76%) disease incidence followed by RRII 414 (10.76 %). RRII 422 showed the lowest disease incidence (3.84 %). The survey on pink disease revealed that Marthandom, Kanjirapally and Kanhangad regions had higher pink disease incidence among Southern, Central and Northern regions of the traditional rubber growing area. In the non-traditional regions Meghalaya state recorded higher disease incidence followed by Goa while in other states the disease incidence was low or even absent.

The field trial on patch canker disease control at Lahai Estate on clone PB 28/59 showed maximum recovery in the cymoxanil treatment closely followed by mancozeb.

A new panel protectant from M/S Southern Tar Products, Chennai was found effective for bark rot disease. *In vitro* studies showed that propiconazole and hexaconazole were highly effective fungicides for arresting the growth of the dry rot pathogen (even at 50ppm). Thiram was effective only at 100ppm.

3. Root diseases

A brown root disease control experiment was initiated at Babuland Estate, Kanyakumari to evaluate the fungicides tridemorph (0.5 %), propiconazole (0.2 %), hexaconazole (0.04 %) and thiram (1.5 %). An experiment on biological control of brown root disease was started at Chemoni Estate, Trichur where the previous planting was severely affected by the disease, using the bio-agents *Trichoderma* sp. and *Pseudomonas* sp.

4. Maintenance of fungal pathogens

Storage under water and cryopreservation were found to be efficient upto 18 months for long-term preservation of fungal pathogens of rubber. The other

techniques *viz.*, encapsulation, lyophilisation and desiccation were found good for short periods of storage.

A database containing all the details of the fungi was prepared to retrieve information about the fungal pathogens of rubber. At present, the culture bank has more than 300 isolates.

5. Tapping panel dryness (TPD)

To study the transmission of LMW-RNA and expression of TPD symptoms, grafting of bark was carried out on healthy trees from 28 completely/partially-dried trees and *vice versa* in clones RRII 208 and RRII 105 and are being monitored.

Out of 100 trees in each group the rootstocks of 85 healthy trees, 25 partially dried trees and 13 fully dried trees showed normal flow of latex. In 59 fully dried trees and 21 partially dried trees the rootstock was also fully dry. In most of the partially affected trees, drying is confined only to the roots below the dried portion of the scion.

A study was conducted in Nagercoil region of Tamil Nadu, India, to estimate the incidence of TPD in estate sector. The clones selected were RRII 105, RRIM 600, PB 28/59 and GT 1. The number of trees in the category of very high TPD intensity (>75%) showed an increasing trend from BO 1 to BI 2 panel in all the clones

Incidence of TPD in estate sector of Southern and Central Kerala were estimated in randomly selected large estates for two clones, RRII 105 and GT 1 comprising of 24,000 trees. The incidence of TPD showed an increasing trend as the years under tapping progressed.

The TPD incidence in the upward system of tapping using gouge knife showed that for RRII 118 and GT 1, 57 per cent of the trees with TPD in the basal panel showed TPD in the upper panel also and it was 52.5 per cent for RRIM 600. In RRII 118, 34 per cent of the trees in which the basal panel was healthy showed TPD in the upward system of tapping and it was 32 and 47 in GT 1 and RRIM 600 respectively.

cDNA synthesized from the LMW RNA was amplified with viroid specific primers. Cloning and sequencing of the amplified PCR product is being attempted.

6. Pests of rubber

The comparative efficacy of Spray oil 6% (IOC – Servo Agro spray), Meothrin 30 EC 3 per cent, *Beauveria* sp. (3.25 x 10^4 cfu) against mooply beetle (*Luprops curticollis*), was evaluated. Application of Meothrin 30 EC resulted in mortality of 96 and 99 per cent after one and three days respectively. Spray oil and *Beauveria* showed 25 – 30 per cent mortality after three days of treatment. An *in vitro* study conducted on the effect of *B. bassiana* against *L. curticollis* showed that the treatment affected the longevity of the infected adult beetles.

Drenching arrowroot (*Curcuma zedoria*) extract at 8 and 10 per cent gave 77.25 and 99.50 per cent control of termites respectively for three months. The bark feeding caterpillar, *Aetherastis circulata* Meyer, on rubber could be controlled by spraying of Dipel (*Bacillus thuringensis* var *kirstaki*) at 0.20 and 0.25 per cent concentrations giving 73.50 and 85.75 per cent control respectively. Spraying and dusting of the entomopathogenic fungus *B. bassiana* were not effective. Spraying insecticides such as Deltamethrin (Decis) 0.0056 per cent and fenpropathrin (Meothrin) 0.06 per cent gave 93.67 and 90.33 per cent control of the caterpillars. Application of carbaryl 0.50 % + lamdacyhalothrin 0.02 % two times at

an interval of one week was very effective and gave 96.75 per cent control of borers on standing rubber trees.

In a survey on entomopathogenic nematodes 15 per cent of the soil samples from different rubber plantations showed their presence. Roots of 22 healthy and 14 TPD affected trees were evaluated for the incidence of plant parasitic nematodes. The population of nematode varied in different stock scion combination. The healthy plants of RRII 208/ RRII 208 combination showed maximum incidence (370/g root) followed by assorted/RRII 105 (305/g. root). In TPD affected plants nematode population was comparatively higher. Maximum population was recorded in GT 1/GT 1 combination (900/g.root).

7. Beekeeping

A field study was conducted for the management of TSBV disease in *Apis cerana indica* with turmeric and vitamin C. The net income from beekeeping with *A. cerana indica* and *A. mellifera* was Rs. 98/- only and Rs.1,459 per hive and by utilizing family labour the income could be raised to Rs. 350 and Rs. 1,850 respectively. The average honey yield was 7 kg/hive for *A. cerana indica* and 26 kg/hive for *A. mellifera*. The total honey production during 2005-06 was 1950 tonnes. The honey yield was higher in the 6-frame hive (8.67 kg/hive) when compared with the ISI 8-frame hive (6.50 kg/hive) colonies. Sugar syrup was used for artificial feeding to bee colonies during dearth period of June to September and also colony bifurcation period of October and November. An average of 7.1 kg sugar per hive was used for *A. cerana indica* and 28.05 kg per hive for *A. mellifera*.

The population dynamics and foraging activity of *A. cerana indica* in the RRII campus was studied. The brood development was at its peak during May and October with a decline during June to August. The population of bees in the hive showed a rising trend during April to June and September onwards, while it declined during June to August. The pollen and nectar gathering were maximum during forenoon period *i.e.,* 6.00 – 11.00 h with a peak between 6.00 – 8.00 h. The overall foraging activity was higher during March.

8. Microorganisms for improving growth of rubber and cover crops

Ten *Azospirillum* isolates collected from different rubber growing areas were evaluated for plant growth promotion of rubber seedlings in polybags and the efficient strains selected. Out of the nine phosphofungi collected from rubber growing soils six improved growth of the inoculated rubber seedlings. Out of 55 isolates of rhizobacteria tested for their ability to solubilize insoluble phosphates, seven solubilised aluminium phosphate and tricalcium phosphate, but only two solubilised ferric phosphate. A reduction in pH of the media was also noticed. Seventy seven rhizosphere colonising bacteria as well as 150 endophytic root colonising bacteria collected from the rubber clones RRII 105 and GT 1 from Kottayam, Konni and Nettana regions were evaluated for their efficiency to promote initial root development of rubber seedlings and 50 isolates were selected.

A consortium of bacterial cultures were made consisting of two nitrogen fixing *Azotobacter* isolates, three phosphate solubilising bacteria and four rhizobacteria (*Pseudomonas*). The efficiency of these isolates to promote plant growth was reconfirmed by inoculating them to rubber seedlings in small cups. A field trial was started at three locations in Central Kerala using the consortium in combination with different levels of fertilizer application.

Rubber seedlings inoculated with a combination of *G. fasciculatum* and *G.mosseae* showed higher rate of growth followed by those inoculated individually with G. *fasciculatum, G. mosseae* and *G. margarita* in the descending order.

9. Waste management in rubber processing

The pilot high rate reactor installed at Elavampadom model RPS, Palakkad showed a COD removal efficiency of 67.8 to 80.4 per cent and BOD reduction of 72.1 to 81.8 per cent. The gas production ranged from 25 to 120 l/h with maximum during March. The gas flow was more in the afternoon and evening. The gas contained 34 to 36% CO_2 and 60 to 66% methane. The population of total anaerobes (13×10^5 cfu) and methanogens (7×10^3 cfu) in the treated effluent indicate high activity of anaerobes in the reactor.

A study was undertaken to investigate the characteristics of the combined effluent from ribbed smoked sheet (RSS) and estate brown crepe (EBC) units, and to design an efficient treatment system. The COD and BOD removal efficiency were studied using a laboratory model aeration tank. The efficiency was maximum at a flow rate of 20 l/h and it decreased with increase in flow rate.

A case study of effluent management in the RPS at Elavampadom which processes an average of 500 kg of rubber per day generating about 5000 litres of wastewater was undertaken. About 7-8 litre of biogas was generated per litre of wastewater. It could replace firewood for sheet drying by 32.4%, cooking food for workers by 100% and electricity for processing and pumping operations by 80%. The fuel requirement for honey processing (10 tonnes) in the RPS is met using biogas alone.

Effluent samples were collected from different stages of processing from Pilot Crumb Rubber Factory of RRII at fortnightly interval. Various parameters like COD, BOD, TS, TDS, sulphides, total bacteria, coliforms and *E. coli* were very high in the milling and scrap effluents but was lower in composite tank because of dilution. Thereafter, a drastic reduction in these parameters were observed in aerated tank, sedimentation tank, and filtered as well as treated water. Formalin treatment of field coagulum did not cause any change in the total bacterial count of the effluent. Bacteria like coliforms and *E. coli* were present in the effluent.

10. Post harvest storage of sheet rubber

Seventy bacterial isolates from cup lumps, scrap rubber, dried sheet rubber and from latex were studied for their antagonism against the three major storage contaminant moulds of sheet rubber, namely *Pencillium* sp., *Aspergillus sp.*, *Trichoderma sp.* Two isolates SC-8 and SC-1 showed complete inhibition of these contaminants. A talc based bioformulation prepared with these two isolates was applied on stored sheets at six warehouses. No mould growth was observed on stored sheets in all the locations even eight months after treatment. ■

Agrometeorology

Contributions since establishment

Agroclimate being an inseparable part of rubber research, all research stations under the RRII are equipped with well laid out manually recording agrometeorological observatories. Readings are taken daily at 0700 and 1400 hrs IST. The agrometeorological station at RRII Headquarters also caters to synoptic readings for the India Meteorological Department (IMD) for which the station has been classified as Class II B. Observations are also made in collaboration with large rubber plantations in major rubber growing areas.

Climatic water balance, water relations in the plant-soil-atmosphere system, soil moisture status during dry and wet periods, soil temperature, radiation interception at different canopy levels, diffusion resistance, leaf water potentials and effect of wet and dry seasons on latex yield are some significant aspects studied in relation to weather. Differences in climatic water balance for rubber growing regions were identified. Patterns of annual water deficit and its correlation with yield were worked out for rubber. The results in Kerala indicated that the total rainfall, moisture deficiency and water surplus increased by two or three times from south to north along the Western Ghats. Thermal and moisture indices were developed and integrated into a hydro-thermal index and six hydro-thermal zones were identified which are congenial to latex production under rainfed cultivation. Areas marginally or conditionally suitable for rubber cultivation in different parts of India with irrigation and soil conservation were identified. Phytoclimate studies in rubber with hourly data between the canopy and outside along with prediction of dry and wet weeks in RRII by utilizing the Markov Chain method was made. On a long-term perspective, the variability of monsoon over different physiographical divisions of Kerala comprising the rubber growing tracts were also studied.

Agrometeorological observations in rubber research were first initiated in the North-eastern regions in Agartala, Tripura since 1979. In order to understand the prevailing crop-weather relations in this non-traditional area, studies were mainly concentrated on growth

and yield. Climatic water balance studies in Agartala indicated that the maximum water deficit is seen during March-April period. The study on the effect of *Aspect* on soil temperature and growth of rubber trees on a gently undulating terrain of North East India confirmed that tree growth was better in the south-facing slope because soil temperatures were significantly higher compared to north-facing slopes.

By raising rubber plantation, it was observed that deleterious effects of shifting cultivation practiced in Tripura could be moderated through improvement in available water storage capacity of the soils. The study on relationship of environmental parameters with latex yield showed that varied responses of yield in relation to environmental factors depend on clonal character. Soil moisture storage values one day and three days prior to tapping were found to be the primary parameters affecting yield for the non-winter tapping and winter tapping periods respectively. It was observed that the clone RRII 105, with a comparatively lower yield to that of RRIM 600, was more susceptible to daily water deficit conditions during the non-winter season. Homogeneous rainfall areas conducive for rubber cultivation in Northeast India have been classified within the seven north-eastern states. The study utilized 139 raingauge stations spread uniformly across the entire region. Annual and monthly Precipitation Concentration Indices (PCI) were studied utilizing mean values, inter-annual variability and diversification. The regions classified as optimal, sub-optimal, moderate and marginal comprises of 14.5, 26.9, 46.4 and 12.2 per cent of the total area in the Northeast. Consecutive wet and dry spells (weeks) of different length periods were analyzed for rainfall data sets ranging from 30 to 54 years. Probability rainfall estimates have also been studied in the context of seasonal variations. The assured rainfall at 50 and 75 per cent probabilities were analyzed for ten rubber growing stations in the Northeast. It was found that some stations received little chances of rainfall from October to March in the region.

Studies on the disease-weather relationships of abnormal leaf fall and powdery mildew diseases of rubber have identified the optimum range of weather conditions predisposing the onset of the disease. Studies conducted in both the traditional and non-traditional regions showed that forecasts could be refined in future adoption of prophylactic measures to control these diseases.

Ongoing Research Programmes

1. Rainfall climatology of the rubber growing areas

During the reporting year summer rains were more during 18 to 24 h. South-west monsoon rains were more during 24 to 6 h followed by 6 to 12 h. During NE monsoon more rainfall was received during 18-24 h. A total of 85 h of rain and 52 h of trace during 6 -12 hours (tapping and collection hours) followed by 120 h of rain and 60 h of trace during 24 -6 h were recorded during the year. High intensity rains were received on 18 days during June followed by July (12 days). The rainfall per hour was high during summer followed by NE monsoon with the highest (120 mm/h) at 15-16 hours during April.

2. Forewarning on pests and diseases of rubber

Disease intensity in the plantations at Padiyoor and Kulasekharam was re-

corded periodically during 2004 to 2006 to formulate a disease prediction model for powdery mildew disease. Maximum disease severity was recorded during 2005 at both the locations. The general environmental conditions conducive for severity of the disease were a maximum temperature of 34–39 °C, a minimum temperature of < 22 °C with relative humidity above 90 and 60% respectively during morning and evening hours with an average of more than 80%. Occurrence of at least one cloudy day resulted in disease occurrence after a lag period of 7 days.

3. Crop growth stimulation model of rubber

An experiment was initiated at CES and RRII Farm to study the influence of meteorological parameters on the yield of RRII 105 at 1/2S d/2 tapping frequency. The daily yield of RRII 105 was collected for the period April 2004 to March 2006. Inter-year variation of daily yield in four seasons (April-May, June-September, October-December, January - March) were studied in relation to the variation in weather. From the daily trend of yield it could be inferred that yield is directly related to duration of sunshine and quantity and distribution of rainfall.

4. Agroclimate in the NE region

Preliminary study on the variability of leaf fall due to *Oidium* attack with meteorological factors for the clones RRIM 600 and RRII 105 found the frequency of occurrence in Nagrakatta to be higher than that of Agartala. It has been identified that the antecedent conditions of sunshine hours and afternoon relative humidity are the two most important parameters in determining the onset of the disease. Intense leaf fall is observed after ten days of such manifestation of conidial spores on the surface in the case of RRIM 600 and a day or two less for RRII 105 (Table Agromet. 1 and 2). During the period the average sunshine duration varied with a mean of 5.8 h/day and a mean relative humidity of 57 per cent. This disease occurrence is also noted during the onset of wintering when partial leaf fall occurs mainly in RRII 105 and sometimes in RRIM 600. Time of wintering has considerable influence on the intensity of powdery mildew and early wintering trees generally escape severe disease incidence and sometimes even infection. The clone RRII 105 is fast wintering and starts to shed leaves earlier compared to other clones and begin to reflush immediately after completion of leaf shedding.

A clear cut relation of the meteorological factors which are conducive to the occurrence and spread of this disease in a location can impart prior knowledge as to how preventive measures can be adopted for a plantation.

Table Agromet. 1. Instances of lag period influence of the afternoon relative humidity and bright sunshine hours 8 to 12 days prior to intense (peak) leaf fall in Agartala

Instances	Afternoon relative humidity				Bright sunshine hours				RRIM 600		RRII 105	
	Low		High		High		Low		Leaf amount	Date	Leaf amount	Date
	%	Date	%	Date	Hours	Date	Hours	Date				
1	51	15.03.03	62	16.03.03	5.7	15.03.03	4.0	16.03.03	-	-	17	27.03.03
2	53	18.03.03	62	19.03.03	3.6	18.03.03	3.4	19.03.03	18	28.03.03	-	-
3	52	21.03.03	59	22.03.03	9.6	21.03.03	5.6	22.03.03	27	01.04.03	13	31.03.03
4	38	25.03.03	57	26.03.03	9.6	25.03.03	8.0	26.03.03	11	03.04.03	-	-
5*	58	29.03.03	100	30.03.03	7.7	30.03.03	3.5	31.03.03	17	12.04.03	9	11.04.03
6	38	28.03.04	53	29.03.04	8.9	29.03.04	5.4	30.03.04	12	10.03.04	-	-
7	27	02.03.04	30	03.03.04	9.2	03.03.04	8.2	04.03.04	10	12.03.04	13	12.03.04
8*	35	06.03.04	91	07.03.04	8.7	07.03.04	0.0	08.03.04	-	-	81	17.03.04
9	38	08.03.04	52	09.03.04	6.9	09.03.04	4.2	10.03.04	29	19.03.04	-	-
10	52	09.03.04	94	10.03.04	4.2	10.03.04	0.7	11.03.04	21	21.03.04	-	-
11*	60	19.03.05	59	20.03.05	6.4	20.03.05	4.8	21.03.05	14	01.03.05	14	03.03.05
12	39	21.03.05	52	22.03.05	8.6	22.03.05	6.1	23.03.05	16	05.03.05	-	-
13	25	28.02.05	36	01.03.05	9.6	01.03.05	6.0	02.03.05	113	12.03.05	7	10.03.05
14	30	02.03.05	31	03.03.05	9.2	03.03.05	8.7	04.03.05	26	15.03.05	-	-
15	50	06.03.06	61	07.03.06	8.8	05.03.06	5.1	06.03.06	8	15.03.06	-	-

* Rainy day/days

Table Agromet. 2. Instances of lag period influence of the afternoon relative humidity and bright sunshine hours 8 to 12 days prior to intense (peak) leaf fall in Nagrakatta

Instances	Afternoon relative humidity				Bright sunshine hours				RRIM 600		RRII 105	
	Low		High		High		Low		Leaf amount	Date	Leaf amount	Date
	%	Date	%	Date	Hours	Date	Hours	Date				
1	45	24.02.02	57	25.02.02	9.0	25.02.02	2.6	26.02.02	58	07.03.02	67	07.03.02
2	36	26.02.02	53	27.02.02	3.7	28.02.02	2.7	01.02.02	116	11.03.02	134	11.03.02
3	40	05.03.02	60	06.03.02	7.2	06.03.02	4.5	07.03.02	161	15.03.02	198	15.03.02
4	40	08.03.02	40	09.03.02	9.5	09.03.02	8.4	10.03.02	331	18.03.02	303	18.03.02
5	41	13.03.02	49	14.03.02	8.0	13.03.02	6.3	14.03.02	100	24.03.02	83	24.03.02
6	56	27.02.04	63	28.02.04	8.2	27.02.04	4.7	28.02.04	81	08.02.03	91	08.02.03
7*	71	10.03.04	87	11.03.04	9.7	10.03.04	0.0	11.03.04	30	19.03.04	27	19.03.04
8	82	20.03.04	87	21.03.04	0.0	21.03.04	0.0	22.03.04	21	01.04.04	12	01.04.04
9	48	23.02.05	57	24.02.05	9.3	22.02.05	3.4	23.02.05	-	-	33	03.03.05
10	65	26.02.05	72	27.02.05	9.2	25.02.05	6.0	26.02.05	-	-	76	06.03.05
11	58	02.03.05	65	03.03.05	4.7	03.03.05	3.3	04.03.05	-	-	58	13.03.05
12	61	10.03.05	69	11.03.05	6.9	11.03.05	2.6	12.03.05	-	-	59	21.03.05
13	56	13.04.06	59	14.04.06	9.8	13.04.06	8.2	14.04.06	-	-	75	07.03.06
14	51	04.05.06	65	05.05.06	8.1	04.05.06	2.2	05.05.06	-	-	128	13.03.06
15	52	08.03.06	63	09.03.06	8.9	08.03.06	9.6	09.03.06	27	15.03.06	84	15.03.06

* Rainy day(s)

Table Agromet. 3. Agrometeorological data of different research stations for the year 2005

Location & Month	Temperature (°C)		Relative humidity (%)	Wind speed (km/hr)	Sunshine (hrs/day)	Rainfall (mm)	Evaporation (mm/day)
	Maximum	Minimum					
RRII, KOTTAYAM, KERALA							
January	33.7	20.9	57	2.1	7.2	0005.4	4.6
February	34.8	20.3	63	2.3	8.7	0000.0	5.3
March	35.5	22.5	68	2.4	7.9	0030.6	5.4
April	33.4	23.4	78	2.0	6.5	0245.8	4.2
May	33.2	23.8	78	1.9	6.4	0190.0	4.5
June	29.9	22.6	88	1.5	3.5	0602.0	1.8
July	29.1	22.2	88	2.6	3.3	0666.1	2.6
August	30.5	22.2	81	2.7	6	0212.2	3.3
September	29.6	22.1	85	2.2	4.9	0426.8	2.9
October	31.2	22.1	81	1.8	4.8	0319.8	3.0
November	30.9	21.4	82	1.5	4	0332.2	2.3
December	30.9	21.3	75	1.6	6.6	0055.8	2.9
CES, CHETHACKAL, KERALA							
January	34.1	20.2	65	2.2	8.1	0100.2	5.2
February	35.8	20.0	63	1.6	9.2	0024.7	5.2
March	36.0	22.2	66	1.9	7.5	0070.3	5.1
April	33.1	22.5	76	1.1	4.4	0385.6	2.7
May	32.9	23.0	76	1.2	4.6	0144.5	3.4
June	29.7	22.4	88	1.1	1.6	0593.2	1.8
July	28.8	21.9	—	1.8	1.6	0782.7	1.9
August	30.5	21.7	—	2.2	4.5	0258.1	3.3
September	29.8	21.7	—	1.7	5.6	0570.3	-
October	31.3	21.3	—	1	4.5	0258.9	3.4
November	30.9	21.4	—	0.7	4.3	0375.0	2.2
December	31.5	19.9	—	1.2	7.9	0025.6	3.7
RRS, PADIYOOR, KERALA							
January	34.1	19.4	85	2.5	7.8	0005.0	3.5
February	35.6	19.7	81	3.1	9.5	0000.0	4.7
March	36.5	21.8	77	3.5	8.7	0000.0	5.2
April	35.9	23.4	72	3.3	7.4	0071.6	4.4
May	35.7	23.9	72	3.3	7.3	0047.8	4.6
June	30.7	22.7	87	2.4	2.7	1008.8	2.0
July	28.7	22.4	89	3.0	1.0	1138.0	1.3
August	29.9	22.1	85	3.0	3.0	0468.6	2.2
September	29.8	22.0	85	2.6	3.9	0424.4	2.3
October	31.4	22.3	85	1.8	4.4	0163.8	2.2
November	32.5	21.0	74	1.6	5.3	0138.2	2.6
December	33.2	19.5	68	1.8	7.7	0027.2	3.1

Location & Month	Temperature (°C)		Relative humidity (%)	Wind speed (km/hr)	Sunshine (hrs/day)	Rainfall (mm)	Evaporation (mm/day)
	Maximum	Minimum					
HBSS, PARALIAR, TAMILNADU							
January	33.7	20.5	68	-	6.6	0043.0	4.5
February	35.1	21.8	69	-	8.1	0070.0	4.8
March	35.7	22.7	72	-	7.0	0078.4	4.1
April	33.4	23.6	83	-	5.0	0273.8	3.5
May	34.3	24.0	82	-	6.2	0222.5	4.4
June	31.3	24.8	74	-	4.4	0212.5	2.7
July	30.5	24.2	87	-	3.8	0421.0	2.7
August	32.6	24.0	79	-	6.8	0127.3	4.4
September	31.0	23.5	84	-	6.0	0189.8	3.2
October	30.3	23.0	89	-	4.3	0269.8	3.2
November	30.1	23.1	90	-	3.6	0268.9	2.5
December	31.2	21.9	82	-	6.4	0160.0	3.7
HBSS, NETTANA, KARNATAKA							
January	34.3	15.7	64	5.4	7.5	0000.0	3.5
February	36.2	16.0	60	5.7	8.6	0000.0	4.9
March	37.0	19.1	60	8.0	5.4	0000.0	5.4
April	35.4	20.7	68	7.5	7.4	0214.9	4.0
May	35.0	21.6	71	-	7.2	0089.0	4.6
June	29.4	20.6	87	-	2.4	0913.0	1.6
July	28.0	20.2	89	-	1.2	1675.7	1.7
August	28.9	20.0	86	-	2.5	1329.6	1.5
September	26.2	20.2	83	-	3.5	0647.9	2.3
October	31.4	19.9	81	-	4.7	5326.2	2.2
November	32.8	17.2	68	-	5.7	0071.6	3.3
December	33.9	15.5	67	-	7.5	0000.0	3.2
RRS, DAPCHARI, MAHARASHTRA							
January	32.4	12.1	57	0.5	8.4	0000.0	3.9
February	33.4	14.2	54	2.2	9.5	0000.0	4.0
March	37.1	18.4	54	1.9	9.3	0000.0	5.5
April	40.2	21.6	58	2.2	8.6	0000.0	6.3
May	38.1	24.0	64	3.0	10.5	0000.0	6.2
June	35.6	25.5	80	4.8	8.1	1048.0	4.7
July	31.2	25.6	87	4.8	1.1	0912.2	2.6
August	30.0	24.4	87	3.4	2.5	0066.1	2.9
September	34.0	24.2	88	3.0	3.4	0718.8	3.2
October	33.4	20.5	65	1.4	7.7	0054.8	3.7
November	33.8	15.8	57	1.4	8.7	0000.0	3.4
December	31.6	13.7	59	1.3	7.8	0000.0	2.8

Location & Month	Temperature (°C)		Relative humidity (%)	Wind speed (km/hr)	Sunshine (hrs/day)	Rainfall (mm)	Evaporation (mm/day)
	Maximum	Minimum					
RRS, AGARTALA, TRIPURA							
January	25.0	11.0	71	1.2	06.3	002.5	1.7
February	29.3	15.1	64	2.5	08.1	025.8	2.6
March	31.9	21.0	71	3.8	07.1	129.4	2.4
April	33.1	22.4	74	3.0	08.0	133.8	2.3
May	32.1	22.3	78	3.5	07.0	434.6	2.2
June	33.7	26.0	81	3.6	04.0	108.7	2.7
July	31.6	25.6	84	3.3	03.8	285.4	1.8
August	31.5	25.7	85	4.0	03.9	220.0	1.6
September	32.4	25.2	83	1.7	04.7	278.5	2.5
October	31.1	23.7	85	1.5	05.6	177.4	1.6
November	29.4	16.9	76	0.8	08.0	000.0	2.2
December	28.1	12.5	74	0.8	08.0	000.0	1.7
RRS, GUWAHATI, ASSAM							
January	24.0	11.6	72	3.3	05.7	010.0	1.1
February	27.8	14.3	61	4.7	07.2	000.0	1.9
March	29.5	17.2	70	2.7	05.9	146.2	1.7
April	30.2	19.2	74	2.4	07.3	053.0	1.5
May	30.5	21.3	80	1.7	05.9	122.0	1.3
June	33.7	24.5	83	1.4	05.2	104.8	2.0
July	32.9	25.2	86	1.2	04.3	269.2	1.3
August	33.2	25.4	87	1.0	04.1	227.2	1.6
September	34.8	24.7	81	0.3	06.0	133.6	1.8
October	30.1	21.5	88	0.3	04.7	143.8	1.5
November	29.5	17.3	77	0.2	06.6	005.2	1.7
December	27.5	12.8	72	0.1	06.6	000.0	1.6
RRS, TURA, MEGHALAYA							
January	23.5	7.4	68	1.9	06.0	000.0	1.5
February	27.1	10.6	65	4.1	07.8	000.0	3.1
March	30.7	14.8	70	3.0	07.0	194.0	3.0
April	31.7	16.4	74	2.7	08.5	300.0	3.0
May	32.9	17.9	81	2.1	06.2	821.0	2.9
June	33.2	21.5	85	1.2	02.7	623.0	3.0
July	32.1	22.2	86	1.1	03.3	759.0	2.8
August	31.2	22.7	85	0.8	03.0	344.0	3.5
September	32.5	21.6	85	0.9	03.6	299.0	3.2
October	31.3	18.4	81	1.3	03.6	687.0	2.5
November	28.1	13.8	72	1.1	04.8	020.0	2.5
December	26.3	10.8	68	1.2	06.4	000.0	1.9

Location & Month	Temperature (°C)		Relative humidity (%)	Wind speed (km/hr)	Sunshine (hrs/day)	Rainfall (mm)	Evaporation (mm/day)
	Maximum	Minimum					
RES, NAGRAKATTA, WEST BENGAL							
January	24.0	08.0	82	0.4	06.0	014.8	1.3
February	26.6	12.1	79	1.3	06.4	009.8	2.1
March	29.3	16.4	81	0.9	05.8	281.0	2.6
April	30.3	18.4	82	0.7	07.0	205.9	2.7
May	30.9	21.3	83	0.6	05.4	675.1	2.6
June	32.7	24.4	85	0.6	04.2	498.2	2.7
July	31.6	24.7	89	0.3	02.9	1092.3	1.9
August	32.1	25.1	88	0.2	03.1	701.1	1.7
September	33.7	24.1	83	0.1	05.9	491.7	2.2
October	30.0	19.6	86	0.1	05.4	307.5	1.5
November	28.8	13.4	79	0.1	07.5	007.4	1.6
December	26.7	08.8	77	0.2	07.3	000.0	1.5
RRS, DHENKANAL, ORISSA							
January	28.2	15.1	60	1.6	06.7	036.4	2.2
February	32.8	16.9	61	1.8	10.1	002.2	3.4
March	37.6	21.1	66	2.7	08.1	031.7	4.8
April	39.5	23.8	61	3.3	08.5	023.4	5.7
May	41.0	26.1	61	3.6	09.6	066.1	6.5
June	40.7	27.7	63	0.9	05.4	158.6	5.2
July	32.7	25.1	82	2.0	03.5	612.9	1.3
August	32.9	25.3	83	1.2	03.5	122.5	1.7
September	32.6	24.9	85	2.8	04.9	249.8	1.2
October	31.4	23.6	87	2.0	05.0	154.0	1.3
November	29.8	15.2	71	1.0	07.7	000.0	1.9
December	27.7	11.7	69	0.9	06.9	000.0	1.6

Plant Physiology Division

Contributions since establishment

In the nearly three decades of its existence since 1978, the Division of Plant Physiology and Exploitation has come of age and established itself as an important research group whose research findings have very significant and direct practical relevance to the rubber plantation sector. The major emphasis during the early days has been on exploitation studies, yield component analysis, biochemistry of latex flow and regeneration, latex stability and stock-scion interaction. Subsequently, environmental physiology and water relations also became important research areas. Considering its importance, the Exploitation Unit under the Physiology Division has been given special and independent status under the World Bank project since 1995.

A systematic analysis of the various yield components and subcomponents in *Hevea* and their relationship to dry rubber yield has been one of the earliest important contributions of the Physiology group. Some of these findings have already been successfully used as inputs in the breeding programmes.

The need to extend rubber cultivation to the non-traditional areas that are agro-climatically less favorable led to the establishment of the Environmental Physiology Unit in the Physiology Division during the 1980s. Importance of environmental stress is reflected in the fact that majority of the field trials being carried out at RRS, Dapchari, a highly drought-prone location in the North Konkan. Considerable amount of knowledge on how to cultivate rubber under conditions of limited water supply is now available with RRII. The technical feasibility of growing a number of shade loving medicinal plants in mature rubber plantation was established in the early 1990s.

Earlier studies under production physiology include yield and yield component analysis, physiological and biochemical subcomponents of latex, rubber biosynthetic enzymes, lipid metabolism, isozyme analysis and lutoid membrane protein variability in different clones of rubber. Studies on tapping induced loss of biomass, physiological and biochemical changes during growth and development, energy metabolism and characterization of clones based on general metabolism were then initiated. The results established that respiratory rates of the bark and latex ATP content are good indicators of yield potential of a clone.

The molecular mechanism of biomass loss upon tapping (other than through rubber yield) has been elucidated and this holds the key to develop latex timber clones. Physiological and biochemical characterization of a large number of clones and HP lines have been achieved. Several useful physiological traits associated with growth, yield and secondary traits have been characterized and clones with these traits were identified which could form potential parents.

Drought and cold stress are important factors that limit the expansion of rubber cultivation to newer areas in India. Studies have established the molecular, biochemical and physiological mechanisms of tolerance to these environmental stresses and relatively stress tolerant clones have been identified. Quick and efficient laboratory screening protocols for intrinsic environmental stress tolerance traits have been developed and employed in screening wild germplasm lines for drought tolerance. A viable technology for cultivating rubber with minimum "life-saving" irrigation in extremely drought-prone regions have been developed.

Studies have shown that excess light aggravates the harmful effects of environmental stress such as drought and temperature through over-production of energy-rich electrons in the photosynthetic apparatus. The fundamental molecular events leading to this high light syndrome have been worked out. Leaves of young rubber plants experiencing drought and high light stress concomitantly have a novel protein present in their photosynthetic apparatus. High light should be used as an additional selection pressure while screening for drought tolerance. Thus shading for drought stress management in young rubber plants during severe drought and winter would help the young rubber plants to tide over drought and winter events. In rubber nurseries, shade may be conveniently given by shade nets and in the field, suitable live shade like banana could be grown that may provide some economic return also. The molecular response of rubber plants to environmental stresses, TPD, ageing and senescence have been elucidated. About 100 genes have been cloned, sequenced, identified and registered with the gene data bank. Many of them were novel genes. No country

has done this work in rubber in response to drought and senescence.

Natural or induced, ageing and senescence of leaves is related to production of reactive oxygen species at levels much higher than what can be scavenged and the resultant oxidative damage. Mechanism of the ubiquitous nature of oxidative stress which leads to aging and senescence, be it induced by the environment, TPD or normal biological process was studied. Therefore, managing oxidative stress is important to any effort aimed at delaying ageing, senescence or TPD.

The genetic heterogeneity of the rootstocks has been known to be a source of large phenotypic variations between the trees despite the genetic homogeneity of the scion. It is suspected that tree-to-tree variations in growth and yield, incidence of TPD etc. are related to the rootstock genetics. The genetic distance between the stock and scion was not markedly different in the high biomass or low biomass trees of a given clone. However, the genetic distance between the stock and scion appeared to be greater in TPD affected trees than in healthy trees.

Systematic analysis of various physiological and biochemical components in the TPD affected tissues and the relationship with the occurrence of TPD has been one of the earliest contributions. It is also confirmed that over exploitation leads to internal stress and thus some trees succumb to TPD. This is not due to decrease in carbohydrate level but because of the impaired biochemical machinery responsible for the conversion of sugar into isoprene. Earlier studies also confirm that tapping rest will not be a permanent solution for TPD. Endogenous ethylene production, oxidative stress, cyanide metabolism and its implications on TPD are also being investigated. The bark tissues from TPD affected trees (not stimulated) were hypersensitive to *in vivo* ethylene production. Even in healthy trees, a single dose of ethrel application led to severe stress responsive reactions. Therefore, maximum care should be given to avoid TPD in the first phase, especially in young trees, because they have high stakes. Thus, a comprehensive set of recommendations were proposed to manage TPD in rubber plantations based on the principle "translocated type of root-shoot incompatibility".

An international workshop on TPD was organized at RRII during November 2005 under the auspices of the IRRDB Specialist Group on Plant Physiology. While there is still no conclusive evidence on a biotic cause for this syndrome, there is consensus that increased exploitation load, especially increased use of ethrel is a sure cause for large number of trees going dry in a field.

Our studies have established the presence of inositol, a high value secondary metabolite in latex and a technique has been perfected to extract it from the latex.

Our studies show that water consumption by rubber trees is rather conservative. They have high water use efficiency. Long-term cultivation of natural rubber has led to considerable improvements to the physical, chemical and biological properties of the soil. Natural rubber is an ideal candidate for afforestation of degraded landscapes and their eco-restoration.

Carbon dioxide sequestration potential of rubber plantations was estimated. Conducted elaborate studies on the implications of the Kyoto Protocol to the rubber industry. Several areas of potential CDM activities were identified from the rubber sector for carbon trad-

ing under Kyoto Protocol. Two CDM projects were developed with the help of TERI, New Delhi.

A national workshop on CDM and the Indian rubber sector was held at RRII during August 2005 and a Task Force has been constituted to look into this matter. Our analysis show that there are several aspects of the natural rubber cultivation that may qualify for CDM which include carbon sequestration, biomethenation of sheet processing effluents, improving energy efficiency in the product manufacturing sector, use of renewable energy for drying rubber, partial substitution of synthetic rubbers with natural rubber etc.

Two books entitled "Kyoto Protocol and the Rubber Industry" and "Tapping Panel Dryness" have also been released by the Division.

Ongoing Research Programmes

1. Environmental physiology

Screening for intrinsic drought tolerant traits in wild germplasm accessions (182 nos.) was carried out in the laboratory. Four accessions (MT 5100, MT 5078, MT 4788, MT 4856) were selected as most tolerant and two accessions (MT 4694 and RO 4615) as most susceptible to drought stress. Two HP lines (HP 105 and HP 92) were also identified as most intrinsic tolerant ones for drought stress and PR 261 and RRIM 600 as intrinsically tolerant to low temperature stress.

Wild germplasm accessions from the source bush nursery, CES, Chethackal, were visually scored in the field for intrinsic drought tolerance traits during summer. Among the 700 wild accessions 39 accessions were identified as superior to the drought tolerant clone, RRIM 600 and three accessions (MT 2210, RO 1367 and RO 2634) scored maximum values.

From the preliminary screening data the top ten HP clones were screened for intrinsic drought tolerance characters after subjecting the leaf to osmotic and oxidative stresses. HP 92 and HP 105 were the top stress tolerant clones.

In another study a 23 kDa stress protein was consistently over-expressed in high light and drought affected plants. The protein was a small chloroplast heat shock protein (sHSP) which play an important role in tolerance to a variety of abiotic stresses.

Differential expression of genes in leaves of two clones (RRII 105 and RRIM 600) under drought conditions was studied using differential display RT PCR. A total of 77 and 109 transcripts were identified as differentially expressed transcripts from clones RRII 105 and RRIM 600 respectively. Out of this, 18 transcripts were cloned into PCR-TRAP cloning vector and were designated as *Hevea brasiliensis* drought responsive transcripts (HbDRT; 1, 3, 5a, 6, 8, 21b, 25, 26, 28, 29, 68, 69, 73, 74, 75, 110, 113 and 119). A second set of 46 differentially expressed transcripts were cloned into PCR-TRAP cloning vector and plasmid DNA was purified.

Studies conducted at high altitude location, (Munnar, Idukki Dist.) showed that the clones PR 261 and RRIM 600 were tolerant to cold stress. Based on these results, an experiment was initiated at Chinnar tea estate, Elappara, Idukki Dist (750 M msl) to explore the possibility of cultivating rubber plants in high altitudes.

2. Physiology of growth and yield

The *Hevea* clone PB 235 continued to be the high yielder with high biomass and tree girth. All the 20 year old *Hevea* trees exhibited significantly high variations in biomass production ranging from 429 kg/tree for clone RRIM 501 to 1184 kg/tree for clone PB 235. The clone RRII 118, a medium yielder, was a

prominent latex timber clone having a biomass production next to PB 235. Very low rubber yield was recorded in clones RRIM 612, RRIM 703 and PR 107.

The trees that were left untapped always maintained higher biomass. The differences in biomass revealed that the clone that had lost more biomass due to tapping gained higher biomass production when they were left untapped. Maximum variation in biomass accumulation was noticed in clone RRII 43 (53% gain) followed by PB 311 (45% gain) over the tapped trees of respective clones.

The experiment initiated at HBSS, Nettana, to study the missing biomass in tapped trees showed that the clone RRII 105 lost the maximum biomass (31.5 %) in d/2 tapping system at the end of eighth year of tapping. The biomass loss in d/3 was smaller than d/2 system indicating that the lower the frequency of tapping, the smaller will be the missing biomass. Compared to untapped trees, the tapped trees consistently recorded higher rates of Cyt-c as well as alternative respiration (AOX). The tapping sensitive clone RRII 105 recorded increased AOX activity than PB 235 (a relatively small biomass loser). The unaccountable missing biomass in tapped trees can partially be explained by increased rate of non-phosphorylating AOX respiration. Results showed that d/3 trees recorded more ATP than d/2 trees and d/2 trees of RRII 105 drained significantly higher sugars and soluble protein in latex than other clones.

Experiments conducted at RRII showed that the shoot biomass accumulation of untapped trees of RRII 105 was significantly higher than tapped trees. After seven years of tapping, the trees lost around 34 per cent of shoot biomass as compared to untapped trees.

Tapping resulted in an enhanced respiratory activity both in intact soft bark tissue and in isolated mitochondria. The NADH dependant total respiration rate in isolated mitochondria was significantly higher in tapped trees. The AOX mediated oxygen uptake rate and ATP content in the latex were higher in tapped trees than in untapped trees. Respiration rate increased with an increase in latex volume indicating the requirement of increased metabolic activities for latex biosynthesis.

Tapped trees had significantly higher total sugars, starch, protein and MDA in the bark tissues than untapped trees. An enhanced level of 70-72 kDa protein, higher expression of a 82 k Da protein in the soluble protein fraction as well as in the total protein profile were recorded in tapped trees compared to untapped trees.

The latex ATP content of two-year old plants of 10 clones with different yield potentials were analyzed. Clones RRII 105, RRIM 600, PB 235, PB 260, Tjir 1 and GT 1 showed a higher ATP content in latex. A significant positive correlation was observed between latex ATP in young plants and their mature yield in field trials.

The HMGR protein antibody was used for studying the cross-reactivity of the specific antigen and was found positive. The enzyme antigen isolated from the soft bark tissue and C-serum of the latex of *Hevea* also showed cross-reactivity with the HMGR antibody developed. The investigations are in progress to study the HMGR enzyme protein content in the bark tissues of different *Hevea* clones in relation to yield and TPD.

RuT enzyme analysis carried out in the latex samples of two high yielding (RRII 105 and RRIM 600) and two low yielding clones (RRII 33 and RRII 38) of *Hevea* showed that RuT activity was high in high yielding clones, especially in RRII 105.

Differential display experiment was carried out in green and 50 per cent yellowing leaves of RRII 105. A total of nine transcripts were successfully identified.

Differential display experiments was done in latex to study the stock influenced expression of genes in the scion of two budgrafted and two tissue culture plants of RRII 105. No differentially expressed genes were obtained in the latex of these samples.

3. Stock-scion interaction

In *Hevea*, the intraclonal variations shown in growth and yield are suspected due to root stock effect. There was considerable intraclonal variation with respect to yield and girth in several *Hevea* clones studied (Table Phy. 1).

The experiment at CES indicated that upward tapping reduced the incidence of TPD. Moreover, by upward tapping fairly good number of TPD affected trees became normal.

Tapping experiments, normal and upward tapping at different heights from the bud union, were carried out in two estates *viz.*, Kodumon estate of Plantation Corporation of Kerala Ltd. and CES, Chethackal. The data showed the efficiency of upward tapping in managing TPD incidence (Table Phy. 2).

Phenol concentrations were analysed in bark samples collected from different heights from the bud-union of high and low girth trees, TPD affected and normal healthy trees, own-rooted (air-layered) plants, budded plants and tissue

Table Phy. 1. Yield and girth of 13 *Hevea* clones

Clones	Yield (g/t/t)		Girth (cm)	
	Mean	CV	Mean	CV
GT 1	46.3	44.6	74.4	11.8
Tjir 1	18.7	66.1	71.5	19.5
RRIM 600	26.9	66.5	64.7	11.7
Gl 1	23.2	60.4	63.5	9.0
RRII 105	66.4	43.6	75.4	14.9
RRII 38	49.6	77.1	80.4	13.9
RRII 308	59.8	43.3	86.9	14.3
RRII 43	30.7	61.3	67.3	12.6
RRIM 623	26.3	46.6	66.1	13.1
RRII 118	64.5	42.0	98.2	10.3
RRII 300	25.1	60.7	75.4	15.9
PB 311	65.8	56.4	83.5	16.4
HP 20	44.7	70.9	77.4	21.5

Table Phy. 2. Incidence of TPD in normal and upward tapping at Kodumon estate (Clone RRII 105)

Treatments	Total no. of trees	Incidence of TPD (%)
Normal tapping	298	8.1
Downward tapping(50cm)	92	7.6
Upward tapping (50cm)	180	2.8

culture trees. Normal healthy, own-rooted and tissue culture plants have significantly low phenol concentration as the panel goes upwards. Such a gradient in the phenol concentration was absent in low girth plants and TPD affected trees. Phenol concentration was low at all heights in own-rooted plants compared to budgrafted plants.

4. Tapping panel dryness

The bark tissues of TPD trees contain more ROS such as H_2O_2 and peroxidase compared to normal trees. Studies on wound induced ethylene production and cyanide content of the soft bark tissues of mature *Hevea* trees showed that both the components were high in low yielding clone RRII 38 compared to high yielding clone RRII 105 during the drought season (March/April) and minimum during the monsoon season (June/July).

An experiment was initiated to study the involvement of β-cyanoalanine synthase activity, ACC-oxidase and ACC-synthase in the bark tissues in relation to TPD.

The trees from 12 clones were monitored for the occurrence of TPD, and concentrations of ions in the latex was analyzed. Out of the 12 trees in each clone, one tree each of clones GT 1, RRIM 600, two trees each of clones Gl 1, Tjir 1, three trees each of clones RRII 105 and RRII 308 showed TPD syndrome.

The genes that are differentially expressed were identified in the bark tissues of trees with TPD syndrome. Among a total of 62 differentially expressed bands obtained, 15 were cloned and sequenced. When analyzed using BLAST tool, the sequences of nine transcripts showed homology to known genes and other six did not show any homology. The DD RT PCR study showed that some kinase genes were up-regulated, some others down-regulated and some transcripts did not show any homology during TPD. It appears that genes involved in apoptosis and senescence are triggered and the genes involved in metabolic activities are down-regulated under TPD conditions.

5. Secondary metabolites

Characterization and confirmation of molecular identity of the isolated compound from latex after alcohol extraction and column chromatography was done by LC/MS, FTIR and NMR analysis. It was confirmed that the isolated compound is quebrachitol.

Studies on water relations of latex with reference to the contents of inositols and sugars in the latex during drought showed that during the peak yielding season, osmotic potential of relatively drought tolerant clones were higher than susceptible clones. Total lipid content of bottom fraction was high in drought tolerant clones where as that in the rubber fraction was high in susceptible ones.

6. Ecological impact of NR cultivation

A National Workshop on CDM and the Indian Rubber Sector was held at RRII on 12 August 2005 which was well received by the stakeholders. Initiated action to develop two CDM projects. They are biomethenation of RSS processing effluents and biomass gasification for drying TSR. The Energy and Resources Institute (TERI), New Delhi has been hired as a consultant for this work. ■

Exploitation Technology

Contributions since establishment

Research works on tapping systems were commenced in India only during 1960s. The Malaysian system of tapping was in use in India before 1960.

Research on region-wise variation in rainfall and necessity of rainguarding were carried out initially. India is the first country to adopt rainguarding commercially and contributions made by RRII and rubber companies in this field is commendable. Economic aspects of rainguarding and associated aspects such as occurrence of panel diseases, prevention and cure of such panel diseases were the various research activities in the early days, and suitable recommendations were brought out. India could succeed in low frequency tapping systems like once in four days tapping (3 taps/fortnight) and weekly tapping (one tap /week) because of the practice of rainguarding in plantations of India. Research findings indicated that in case of trees tapped under d/2 frequency, it is not possible to compensate yield loss in non rainguarded trees by stimulation. However, it is possible to partly compensate yield loss by stimulation under d/3 system of tapping. Studies showed that, even in areas with low rainfall like Kulasekharam region of Tamil Nadu, rainguarding is essential to ensure regu-

lar tapping and to maintain the productivity level under once in four days tapping and weekly tapping.

Research work on various methods of application of ethephon on renewed bark (third and fourth panel) in medium yielding clones were carried out. Bark application of 5 per cent stimulant (ethephon) was found to be effective and was recommended. Similarly multiple band application on upper bark was recommended for slaughter tapping. Lace application of ethephon was recommended for renewed bark (BI-1 and BI-2). Later many experiments were conducted on various methods of ethephon application on the virgin panels. Application of ethephon just above the tapping cut, i.e., on fresh tissue on the panel, was found to be the most effective at low concentration of 2.5 per cent and less labour intensive (1000 trees/worker/day). Diluting ethephon with palm oil or coconut oil was found to be more effective than with water. Panel application of ethephon at 2.5 per cent concentration on virgin panel was recommended in 2001.

When coconut shells became insufficient for collection of latex from high yielding clones like RRII 105, plastic cups were manufactured and introduced to rubber plantation industry. Use of plastic cups was found to reduce scrap percentage. Replacement of coconut shells with plastic cups and its popularity was an important mile stone in Indian rubber plantation industry.

Recommendations were made on controlled upward tapping (CUT) and low frequency tapping (LFT). Controlled Upward Tapping and long handle modified gouge knife were modified to suite the agro-climatic conditions in India, evaluated, recommended and popularized. The best system suitable for our agro-climatic condition is periodic panel change. In this system, during the rainy season (June-November), normal downward tapping on the basal panel is carried out and during the non-rainy period (December – May) CUT on the high panel can be practiced. Irrespective of the girth of trees, 1/4S upward cut is ideal. Ethephon (5%) is applied on the lace and the application frequency varies with tapping frequency. It is compulsory to use modified gouge knife for high panel tapping in CUT to get sustainable yield for longer duration.

CUT was popularized and successfully implemented in a large number of estates and medium holdings under the direct supervision of scientists and staff of the Division. Long term experience from the growers' field indicate that, CUT if implemented properly is very efficient in managing TPD, in addition to ensuring sustainable high yield for a long term. Introduction of CUT was instrumental in the complete replacement of 'V' cut tapping and ladder tapping.

Extensive experiments were conducted simultaneously on various frequencies of tapping in the research farms as well as in large estates on all the popular clones (RRII 105, RRIM 600, GT 1, PB 217 etc.) Promising experimental results were further evaluated in on farm trials and participatory research programmes were conducted in large number of tapping blocks. All these conclusively proved that, when trees are tapped under d/3 frequency with 3-4 rounds of ethephon application at 2.5 per cent following panel application method, sustainable yield increase upto 30 per cent could be achieved compared to unstimulated control. Similar yield can be achieved under d/4 frequency of tapping with 5-7 rounds of ethephon application. Similarly 12 rounds (monthly interval) of ethephon application will result in same crop under weekly frequency tapping. A set of recommendations comprising once in 3

days tapping (100 taps/year), once in 4 days tapping (75 taps/year) and once in a week tapping (50 taps/year) with 3-4, 5-7 and 12 rounds of ethephon application per year respectively at 2.5% concentration were issued to the growers in 2001.

Application of LFT with good quality rainguarding by plantations could ensure uninterrupted regular tapping and thus achieve same crop as that of stimulated d/3 tapping from the first year of tapping onwards. By the adoption of LFT, cost of production will be considerably reduced. Also per tapper yield will be much higher and hence the tapper gets the advantage of over poundage.

In the weekly tapping trees, during the first two years of opening, ethephon has to be applied at fortnightly interval to achieve same crop. From the third year onwards, it could be reduced to monthly interval. Moreover, in case of trees under weekly tapping, time of tapping after stimulation (within 48-72 hours) is also important. Long term information from various fields under LFT with recommended level of stimulation indicate that TPD is well below 5 per cent in all cases compared to very high incidence under high frequency tapping like d/2.

After the success of LFT on basal panel, CUT trials were also successfully carried out under d/4 and d/7 frequency. Moreover, difficulty in rainguarded tapping of CUT is also solved by the use of a simple extra cup hanger. Long term experiment on reduced spiral cut and extension trial in farmers field indicated that 1/4S cut tapping can be adopted for early opening of trees i.e., one year prior to normal opening (girth above 43cm). It ensures reasonable crop of over 2.5 kg/tree/year, in addition to normal growth. After one year, the trees attain 50 cm or more growth, then the cut length can be extended to 1/2S.

There are many growers who want to continue high frequency tapping like d/2 due to socio-economic reasons. Results from long term experiments with 1/3S cut indicated that such growers can adopt it. This ensures reasonable crop of around 5 kg/tree/year, in addition to longer economic life due to the availability of a third virgin panel. TPD is also lower.

All the achievements of the exploitation scientists in past, especially during the past twenty years placed RRII much ahead of other Rubber Research Institutes. In recognition of this, the IRRDB has constituted an expert group on Exploitation Studies and the liaison ship is awarded to India. An international workshop on exploitation technology was also organized at RRII in December 2003.

Latex Diagnosis(LD) is a technique used for assessing the exploitation status of rubber trees. The LD parameters tested are sucrose, thiols, inorganic phosphorus (Pi) and dry rubber content.

For the development of LD as a tool for optimizing exploitation in rubber plantations, critical limits for LD parameters were developed under 1/2S d/3, the recommended tapping system for clone RRII 105 and validated in smallholdings in three agro-climatic zones of the traditional rubber growing regions. The levels of Pi and thiols relative to critical limits were identified as indicators of the exploitation status of smallholdings. The holdings whose Pi and thiol levels were within the critical limits were assessed as well exploited with optimum productivity whereas the holdings whose Pi levels were above/below the critical limits were assessed as over/under exploited with lower productivity. The holdings

whose thiol levels were below the critical limits could be classed as holdings under stress. An optimum exploitation system was evolved for clone RRII 105 based on clonal typology.

The production metabolism and production potential of RRII 105 was characterized and found that the production metabolism of RRII 105 is active and the production potential of RRII 105 with an active metabolism and a low sugar reserve i.e., the ability of the clone to respond hormonal stimulation is low. Latex Diagnosis studies conducted in RRII 105 under different exploitation systems revealed 1/2S d/3 with three stimulations a year as the optimum tapping system for this clone and that an increase in yield is not obtained beyond five stimulations a year under d/3 or d/4 tapping systems. Threshold levels of LD parameters developed could be used for fixing optimum limit of achievable yield through stimulation maintaining the physiological balance of the trees. The genetic potential of the newly released RRII 400 series clones were confirmed through Latex Diagnosis.

Ongoing Research Programmes

Various exploitation experiments, trials on LFT and onfarm trials on LFT progressed well during the period under report. During the current year LFT was started in many medium plantations under the advice of the Division.

1. Low Frequency Tapping (LFT) systems

The experiment to evaluate the response of RRII 105 to LFT with different levels of stimulation (from panel BO1) was continued. Yield was higher under d/2 (3289 kg/ha) and d/6 (2873-3171 kg/ha) frequencies of tapping. On farm experiment on LFT (1/2S d/4 6d/7) in twenty four tapping blocks in clone GT 1 at Appela Estate, South Karnataka showed mean per tree yield in the range of 4.41 to 5.13 kg/tree. The on farm experiment on weekly tapping with different levels of stimulation was continued in the third year in 24 tapping blocks of clone GT 1 at Neria Estate, South Karnataka. Variation in yield was noticed among the treatments.

The trial to compare and evaluate long term impact of stimulation under d/3 and d/4 systems of tapping in clone RRII 105 continued in the tenth year at Vijayadri plantation. Dry rubber yield (more than two tones) and related parameters were continued to be very good. This field was under yield stimulation during all these ten years as per recommended schedule. Cumulative TPD was 6 per cent under d/4 and 5.7 per cent under d/3 frequencies of tapping.

The trials on LFT (d/7) with rainguard in Kanthimathy Estate and d/4 with rainguard in Hariharaputra Estate, Kulasekharam region, Tamil Nadu were continued in the third year also. Dry rubber yield of more than 2300 kg/400 trees was obtained in clone RRII 105 in both the estates (Table Exp. 1). Mean annual dry rubber content under weekly tapping was 37.5 and 34.8 per cent under d/4 in Kanthimathy and Hariharaputhra Estates respectively.

In the demonstration plot on weekly tapping at CES, Chethackal, dry rubber yield was 1997 kg/400 trees during 2005-06. In the plot under d/10 frequency of tapping, dry rubber yield was 1971 kg/400 trees.

The evaluation of stimulation recommendation in on farm trials on LFT were continued in various locations. To overcome the tapper shortage experienced at Thrithala, Palakkad, from April 2005, tapping frequency was reduced to d/6 from d/3. The trees were on continuous

Table Exp. 1. Dry rubber yield under LFT in Kulasekharam region

Month	Kanthimathy (d/7)		Hariharaputra (d/4)	
	kg/400 trees	kg/tap	kg/400 trees	kg/tap
April-05	72	27.2	117	22.6
May	165	38.7	209	32.2
June	199	51.3	180	28.7
July	289	65.8	270	42.0
August	256	57.2	234	34.6
September	251	58.8	232	37.3
October	308	69.3	211	33.4
November	315	73.6	308	49.2
December	296	67.0	257	39.7
January 06	249	56.4	226	34.5
February	121	30.2	91	15.9
March	75	17.0	-	-
Total	2596	-	2337	
Mean	216	51.0	212	33.6

stimulation (3/year) for six years under d/3. Dry rubber yield under stimulation (12/year) was 2806 kg/ha more than that under d/3. The on farm trials on 1/2S d/3 system of tapping in clone RRII 105 at Neria Estate in South Karnataka was continued. Annual yield (kg/400 trees) was 2388 under stimulation compared to 2149 in the control.

On farm trials on d/6 frequency of tapping in clone RRII 105 progressed well in all five locations *viz.*, Tropical plantation, Adivaram; Balanoor Estate, Perinthalmanna; Kulappadam Estate, Mannarkad; Vijayadri Estate, Kottayam and Manikal Estate, Mundakkayam. Good yield was obtained in all locations. Clones like PB 260, PB 311 and PB 235 also showed good performance under weekly tapping.

In the current year more medium plantations in Kerala, Tamil Nadu and Karnataka started LFT under our advice. Moreover, those who have few years experience in LFT, extended it to more fields.

2. Low Frequency Controlled Upward Tapping (LFCUT)

LFCUT experiment in clones RRII 105 and RRIM 600 with rainguarding initiated during 2003-04 at CES was continued. Yield under LFCUT (d/4 and d/6) were comparable with d/3 frequency tapping. 1/4S d/4 continued to give highest per tree yield of 20 kg/tree/year in RRII 105. In another experiment on LFCUT in clone RRII 118, 1/4S d/4 and 1/3S d/6 with once in three weeks stimulation gave good yield. Experiments on LFCUT in RRII 105 with periodic panel change at EFU, RIT were also continued. Yield under 1/3S d/6 + ET 5% Ga at 10 days interval was 2716 kg/400 trees and 1/3 S d/4 + ET 5% La at monthly interval was 2354 kg/400 trees. The field under LFT at EFU, Pampady was converted to LFCUT during 2005 showing good yield under all systems of tapping (Table Exp. 2).

3. Other experiments

In the experiment at EFU, Pampady, higher yield was observed in treatments with panel change (Table Exp. 3).

Experiment on crop loss recovery under d/2 and d/3 frequencies of tapping in RRII 105 without rainguarding, and with yield stimulation was continued at EFU, Pampady. Yield loss under d/2 frequency in the absence of rainguard could not be recovered by stimulation. Dry rubber yield was 3566 kg/ 400 trees

Table Exp.2. Yield under LFCUT with rainguard in RRII 105 at EFU, Pampady

Treatment	Tapping system	Yield* (kg/400 trees)
T1	1/2S ↓ d/3 + 2stim; 1/4S ↑ d/3 + monthly stim.	3939 a
T2	1/2S ↓ d/4 + 4stim; 1/4S ↑ d/4 + once in 21 days	3606 abc
T3	1/4S ↑ d/4 + once in 3 weeks stim.	4204 a
T4	1/4S ↑ d/4 + Once in 21 days	3822 ab
T5	1/4S ↑ d/4 + Once in 21 days	3973 a
T6	1/2S ↓ d/6 + monthly; 1/4S ↑ d/6 + fortnightly	2467 d
T7	1/4S ↑ d/6 + once in 15 days	3687 abc
T8	1/4S ↑ d/6 + once in 15 days	3371 abc
T9	1/4S ↑ d/6 + once in 15 days	2942 bcd
T10	1/2S ↓ d/6 + monthly ; 1/3S ↑ d/6 + once in 3 weeks	2285 d
T11	1/3S ↑ d/6 + once in 21 days	3424 abc
T12	1/3S ↑ d/6 + once in 21 days	2800 cd
T13	1/3S ↑ d/6 + once in 21 days	3017 bcd

*Values followed by same letter/s are not critically different from each other
CD (P=0.05) = 272

Table Exp. 3. Performance of LFT with panel change in clone RRII 105 at EFU, Pampady

Treatment	Yield			DRC (%)
	(kg/ha)	kg/tap	kg/tree	
1/2S d/2 6d/7 (without PC)	3892 ab	26.25 ab	9.7 ab	39.5 abcd
1/2S d/2 6d/7 (with PC)	4249 a	29.04 ab	10.6 a	39.1 cd
1/2S d/3 6d/7. ET 2.5%. Pa.4/y (without PC)	2350 c	23.16 b	5.9 cd	39.1 bcd
1/2S d/3 6d/7. ET 2.5%. Pa.4/y (with PC)	3552 abc	35.40 ab	8.9 abc	38.5 d
1/2S d/4 6d/7. ET 2.5%. Pa.7/y (without PC)	2265 c	29.58 ab	5.7 d	40.4 ab
1/2S d/4 6d/7. ET 2.5%. Pa.7/y (with PC)	2905 abc	37.33 a	7.3 bcd	40.6 a
1/2S d/4 6d/7. ET 2.5%. Pa.9/y (without PC)	2734 bc	36.05 a	6.8 bcd	39.9 abc
1/2S d/4 6d/7. ET 2.5%. Pa.9/y (with PC)	2372 c	31.07 ab	5.9 cd	39.3 bcd
LSD(0.05)	1241	12.42	3.10	1.172

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

under d/2 frequency with rainguard whereas without rainguard and with stimulation, it was 2858 kg. However, dry rubber yield was 2712 kg/ 400 trees under d/3 frequency with rainguard whereas without rainguard and with stimulation, it was 3188 kg. Hence, under d/3 system, crop loss can be fully recovered by stimulation.

In the stimulation trial on TPD affected trees on clone RRII 105, during the second year also, no stimulation response could be obtained in BO- 2 panel of trees affected by TPD in its BO-1 panel. The trial to evaluate the performance of mini and reduced spiral tapping cuts, it is found that even on second panel also, 1/4S d/3 tapping with monthly stimulation, yield was highest among other systems.

4. Latex Diagnosis Studies in smallholders' plots

LD has been developed as a crop harvest management technology for assessing the exploitation status as well, over/ under exploitation of smallholdings based on the levels of inorganic phosphorus (Pi) and thiols (RSH) relative to the critical limits. The exploitation status of holdings whose Pi and thiol levels were within the critical limits were assessed as well-exploited with high productivity levels and comparatively less incidence of Tapping Panel Dryness (TPD). The holdings whose Pi levels were above the critical limits were classed as over exploited with low productivity levels and higher TPD percentage. The holdings whose Pi levels were below the critical limits were classed as under exploited. The holdings in which thiol levels below critical limits could be classed as holdings under stress. This technology would enable the 10.5 lakh smallholdings to detect over exploitation and optimize exploitation to achieve sustainable productivity.

5. Latex Diagnosis for optimizing exploitation in stimulation trials

Field experiments were continued for optimizing stimulation schedules using latex diagnosis in popular clones RRII 105 and PB 260 under d/3 and d/4 frequencies of tapping at Vaikundom Estate, Kulasekharam in the South (Table Exp. 4) and Cheruvally Estate, Erumeli in the Central Zone (Table Exp.5). Preliminary results indicate d/3

Table Exp. 4. Productivity status and LD parameters under d/3 tapping systems with different levels of stimulation in clone RRII 105 (First year of opening in Vaikundam Estate)

Treatment	Thiol (mM)	Pi (mM)	Sucrose (mM)	DRC (%)	Productivity (g/t/t)	kg/t/y
T_0 (Control) (d/3 without stimulation)	0.34	17.13	15.88	41.85	82.32	7.90
T_1(d/3 with 1 stimulations)	0.39	19.45	11.94	39.39	89.21	8.56
T_2(d/3 with 2 stimulations)	0.33	18.24	12.14	41.95	107.69	10.33
T_3(d/3 with 3 stimulations)	0.42	22.20	14.91	36.95	120.42	11.56
T_4(d/3 with 4 stimulations)	0.42	22.57	12.91	37.69	124.84	11.98
CD	0.04	2.75	2.61	2.12	8.81	
No. of tapping days	d/3 - 96					

with 3 stimulations to be optimum treatment in terms of productivity and dry rubber yield. Results of Table Exp.5 indicate that d/3 and d/4 systems were comparable in terms of productivity (g/t/t) and levels of LD Parameters. However, the dry rubber yield (kg/t/y) was higher under d/3 system.

6. Clone characterization studies

During the reporting year LD studies were continued in newly released 400 series clones and popular clones for evaluating the production potential of clones for evolving clone specific exploitation systems (Table Exp. 6 and 7). RRII 403 and RRII 427 which are having significantly higher thiol levels than RRII 105 showed lower TPD incidence in the fourth year of tapping when compared to RRII 105. PB clones 235, 255, 260, 280 and 311 showed significantly high Pi levels and productivity (g/t/t) as compared to RRII 105.

Table Exp. 5. Productivity status and LD parameters under d/3 and d/4 tapping systems with different levels of stimulation in clone PB 260 (II^{nd} year of opening in Cheruvally Estate)

Treatment	Thiol (mM)	Pi (mM)	Sucrose (mM)	DRC (%)	Productivity (g/t/t)	kg/t/y
T_0 (Control) (d/3 without stimulation)	0.77	16.98	4.07	43.57	56.92	5.35
T_1(d/3 with 3 stimulations)	0.77	17.47	3.64	44.98	55.30	5.19
T_2(d/4 with 3 stimulations)	0.76	18.35	3.43	42.15	57.45	4.07
T_3(d/4 with 5 stimulations)	0.77	20.08	3.40	42.68	57.35	4.07
T_4(d/4 with 7 stimulations)	0.67	18.82	2.69	43.74	57.37	4.07
CD	NS	NS	NS	NS		
No. of tapping days	d/4-71				d/3 -99	

Table Exp. 6. LD Parameters and TPD (%) of RRII 400 series - 4^{th} year (2005)

Clone	Thiol (mM)	Pi (mM)	Sucrose (mM)	DRC (%)	% FBB*	Yield (*g/t/t)
RRII 403	0.57	17.92	17.46	46.80	3	71.78
RRII 407	0.38	19.76	8.11	32.69	3	66.10
RRII 414	0.40	10.46	12.37	39.26	5	75.93
RRII 417	0.53	24.96	7.76	39.94	8	84.23
RRII 429	0.43	21.58	9.59	43.59	11	79.06
RRII 410	0.45	25.34	7.72	43.07	0	52.36
RRII 422	0.46	23.27	11.08	42.44	13	86.39
RRII 427	0.57	14.81	10.34	40.13	0	74.98
RRII 430	0.33	9.57	8.50	43.89	10	79.08
RRII 105	0.35	16.44	9.78	42.28	3	61.54
CD	0.20	NS	3.76	5.72		

Table Exp. 7. LD Parameters of Popular clones planted at RRII farm, (2005-06)

Trial I

Clone	Thiol (mM)	Pi (mM)	Sucrose (mM)	DRC (%)	Yield (*g/t/t)
RRII 5	0.408	9.97	9.36	44.38	74.71
RRII 118	0.428	5.62	8.82	47.29	62.87
RRII 208	0.377	21.38	15.66	49.57	49.80
RRII 300	0.480	12.80	11.26	44.83	40.40
RRII 308	0.520	5.94	13.48	47.87	44.30
RRIM 600	0.365	8.80	11.83	41.10	36.37
RRIM 703	0.477	15.20	10.77	33.73	37.91
RRII 105	0.429	12.59	14.22	48.49	51.00
CD	0.08	5.53	4.25	4.39	6.03

* Fully Brown Bast

Trial II

Clone	Thiol (mM)	Pi (mM)	Sucrose (mM)	DRC (%)	Yield (*g/t/t)
RRII 105	0.429	12.59	14.22	48.49	51.00
PB 217	0.530	24.71	26.82	41.15	43.25
PB 235	0.354	27.17	6.66	48.49	76.79
PB 255	0.468	32.44	8.66	48.35	80.26
PB 260	0.553	31.84	4.66	44.12	73.66
PB 280	0.548	27.62	8.64	49.71	79.08
PB 310	0.442	14.79	9.35	42.59	56.29
PB 311	0.396	30.83	6.62	37.91	69.79
CD	0.08	5.53	4.25	4.39	6.03

Rubber Technology Division

Contributions since establishment

Since its establishment in 1963, the Division has been undertaking research and development programmes on processing of natural rubber (NR) with a view to reduce the cost and to improve the quality. Also the Division looked into chemical and technological aspects of natural rubber. Technical support in terms of consultancy/testing was imparted to the manufacturing units especially in the non-tyre sector. A number of rubber products were developed and the technologies were transferred to the clientile on request.

In the rubber processing front the Division was instrumental in improving the methods of processing, especially of the sheet rubber in smallholder sector. New coagulants were suggested/standardized in the context of shortage of formic acid. Modifications were suggested for the conventional smoke houses for drying sheet rubber. A trolley has been fabricated in this connection by which 40 to 55 per cent saving on cost of firewood can be achieved. A sheet cleaning machine was developed which can clean 750-800 kg sheets per hour whereby quality of sheets could be upgraded, fetching higher price to the grower. Both of the above inventions have been patented.

The Pilot Crumb Rubber Factory established in 1976 was initially attached to

the Rubber Technology Division. It functioned as a centre dissipating basic information on the technical and economic aspects of block rubber processing. Protocols to improve the quality of field coagulum and thereby the grades of ISNR were also formulated. Studies on factors influencing the storage of marketable forms of NR were carried out and guidelines could be evolved on storage conditions. Useful data on comparative evaluation of sheet and ISNR grades being produced in Kerala were generated. A survey on quality of RSS 4 grade sheets in the conventional rubber growing regions has shown that much inconsistency does not exist for the sheets.

The Division has developed/refined technology for physical/chemical modification of NR to make it suitable for broader applications and the know-how has been transferred. Oil extended natural rubber (OENR), carbon black master batches, thermoplastic natural rubber (TPNR), superior processing (SP) rubber, liquid natural rubber (LNR), deproteinised natural rubber (DPNR), chlorinated rubber, epoxidised natural rubber (ENR), constant viscosity (CV) rubber, grafted natural rubber, *etc.* are such modified forms. Pilot plant level facilities are available in the Division for production of epoxidised natural rubber having better air impermeability and oil resistance than natural rubber.

Studies on prevulcanized latex has been carried out and the effect of storage on properties of the same has been explored in detail. The radiation vulcanization plant for NR latex attached to Division is being rated as the biggest in Asia. The proteins in the NR latex is reported to cause allergic problems for certain individuals and hence pose threat to the latex industry. The Division has developed a technique for deproteinization of latex using enzymes.

Short fibre rubber composites for specific applications have been developed by the Division. Blends of natural and synthetic rubber have been optimized, targeting specific applications. Epoxidised natural rubber, identified as a reinforcement modifier in rubber silica compounds, leads to a possible substitution of costly silane coupling agents partially or fully. The concept has been patented. Also initiated work on nanofiller- rubber composites. In collaboration with Cochin Refineries and Highway Research Station, Chennai, substantial data could be generated endorsing the advantage of rubber modified bitumen for pavement application. This has led to the installation of a pilot plant at Cochin Refineries for production of modified bitumen.

The Division has offered R & D support to many public/private sector undertakings in developing rubber products with critical specification. The Division developed a special type of rubber casings for sensitive electronic equipment to be installed under sea for the Defense Research and Development Organisation (DRDO) and a flex seal compound was developed for the GSLV project with funding from Vikram Sarabhai Space Centre (VSSC). Rubber packer elements for drilling applications for Oil and Natural Gas Commission (ONGC), rubber connectors for medical applications, rubber diaphrams for special pumps, cushion gum for precured retreads, self-vulcanizing compounds etc. are few other products developed by the Division and the technology was transferred to the concerned. In collaboration with the Malaysian Rubber Producers Research Association (MRPRA), the Division has carried out a UNIDO funded project to evaluate the performance of bias/belted and radial passenger tyres on Indian road conditions.

The Division keeps close association with academic institutions offering

courses in Rubber Technology. Since its inception in 1973, the Department of Polymer Science & Rubber Technology, Cochin University had close interaction with the Division in formulating the curriculum and conducting the course. The Division offers facilities for research in the discipline of rubber technology. Strong R & D links exist between the Division and Rubber Technology Centre, IIT Kharagpur, Madras Institute of Technology (Anna University), School of Chemical Sciences, MG University, Sree Chithira Tirunal Institute of Medical Science, Trivandrum and Bhabha Atomic Research Centre, Mumbai.

Ongoing Research Programmes

Factory evaluation of deproteinized NR latex prepared using liquid papain, process for production of natural rubber silica composite by *in situ* precipitation of silica and process for the production of high quality skim rubber by enzyme treatment were the significant contributions of the Division during the reporting period. Reduction in storage period of centrifuged latex, blends of SBR/ENR, EPDM/ENR, NR/NBR, trials on new preservation system for NR latex, microwave drying for quick determination of DRC and evaluation of rubber from different clones were the other areas of research.

1. Primary processing

A method was standardized for easy processing of skim latex and reduction of its nitrogen content by using two commercially available deproteinising enzymes. Quality survey of sheet rubber collected from different locations in Kerala revealed that the quality of RSS 4 was consistent in the entire area.

To study the differences in properties of latex and rubber from normal and TPD affected trees, latex samples were collected, CV and non CV rubbers were prepared and analyzed for raw rubber characteristics. The results indicated that latex from TPD affected trees showed comparable properties with that from normal trees. Evaluation of solar dryer using water as a heat transfer medium was attempted. Further trials on quality upgradation of field coagulum based TSR indicated that formalin was superior to other bactericides in preserving the quality of field coagulum.

2. Blends

Blending of EPDM with ENR 50 showed that the blends had a substantial reduction in air permeability without adverse effect on ageing properties (Fig. Chem. 1 and 2).

3. Latex technology

Factory production of deproteinised NR latex concentrate using papain in liquid

Fig. Chem.1. Air permeability of EPDM/ENR 50 gum blends

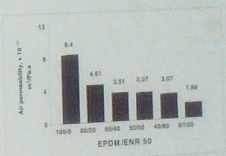


Fig. Chem. 2. Variation in physical properties of peroxide cured EPDM/ENR gum blends

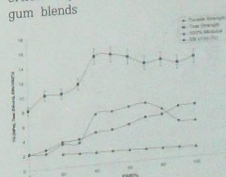


Table Chem. 1. Protein content of surgical gloves

Treatment	Extractable protein content ($\mu g/dm^2$)			
	1	2	3	4
Without leach	100	110	298	43
One wet gel leach	87	95	268	37
One wet gel leach and one post-cure leach	50	65	208	32
One wet gel leach and two post-cure leaches	45	52	173	30
One wet gel leach and three post-cure leaches	43	48	146	22

form and its evaluation for the manufacture of gloves was carried out. Results showed that use of this low protein latex in the production of surgical gloves reduced EP content to less than 50 $\mu g/dm^2$ (Table Chem. 1).

Natural rubber silica composite was prepared by *in situ* precipitation of silica from sodium silicate in field latex. Compared to the conventional silica filled NR vulcanizates the *in situ* formed silica filled NR vulcanizate showed improvement in properties such as tear strength and abrasion resistance (Table Chem. 2).

In an attempt to reduce storage period of concentrated latex, experiments were done by heating field latex at a temperature of 50-60°C prior to centrifugation. It was found that latex concentrate prepared from fresh field latex subjected to accelerated ageing had a comparatively high initial MST and lower KOH number than that prepared from fresh NR latex. Studies to find out new preservation systems for NR latex using nonionic biodegradable surfactant along with low concentration of ammonia was initiated. Laboratory trials indicated that quick coagulation of field latex using surfactant and alkali followed by microwave drying could substantially reduce the time required for the determination of DRC of fresh NR latex.

4. Nanocomposites

A simple procedure was standardized for production of NR/NBR blend nanocomposites from skim latex without any creaming process. Mechanical properties of NR/NBR blends were compared with those of NR and NBR (Table Chem. 3). The results indicated that NR/NBR 25/75 blend nanocomposite had

Table Chem. 2. Technological properties

Properties	*In situ* silica	Conventional silica
Tensile strength, MPa	34.66	33.00
Elongation at break, %	698.00	660.00
Modulus at 100% elongation, MPa	1.32	1.44
Modulus at 300% elongation, MPa	3.35	4.27
Tear strength, N/mm	50.00	38.00
Abrasion loss, mm^3	106.00	120.00
Hardness, Shore A	50.00	49.00
Compression set, %	34.24	33.69
Heat build-up, DT°C	7.00	8.00
Resilience, %	73.00	73.00

Table Chem. 3. Mechanical properties of NR/NBR blends

Parameter	NR	*NBR 75	**NBR 75/5	NBR
Modulus 30%, MPa	1.99	2.04	3.16	3.71
Tensile strength, MPa	22.00	18.20	20.80	4.10
Hardness, Shore A	50.00	47.00	52.00	50.00
Compression set, %	18.00	26.70	27.40	35.00
Heat build up, °C	14.00	24.00	26.00	28.00

* NR/NBR – 25/75
** NR/NBR – 25/75 blend containing 5 phr organoclay

good mechanical properties and ageing characteristics. Life time of these vulcanizates predicted using Arrhenius model was evaluated.

Natural rubber latex nanocomposites, prepared from sodium fluorohectorite and sodium bentonite, were analyzed for air permeability. Results indicated that 5 phr fluorohectorite loaded NR nanocomposites showed four times reduction in air permeability compared to the gum sample, whereas six fold reduction was registered with 10 phr nanocomposites. Similarly 5 phr bentonite nanocomposites showed four fold decrease in air permeability. Nanocomposites based on epoxidised natural rubber were produced by melt mixing of ENR with organically modified silicates. The dispersion was studied by X-ray diffraction (XRD) and transmission electron microscopy (TEM). These composites exhibited faster curing and improved mechanical properties.

Efficiency of nano zinc oxide in NR latex vulcanizate was evaluated in comparison with ordinary ZnO. It was found that small amount of nano ZnO (1/10 of normal) will give identical latex vulcanizates.

5. Evaluation of rubber from different clones

A study was initiated to find out the seasonal/clonal variation in the quality of rubber from different clones grown in North Eastern region.

Table Chem. 1. Protein content of surgical gloves

Treatment	Extractable protein content ($\mu g/dm^2$)			
	1	2	3	4
Without leach	100	110	298	43
One wet gel leach	87	95	268	37
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Technical Consultancy Division

Contributions since establishment

Technical Consultancy Division (TC) was set up at RRII in the year 1986, with a view to cater to the rubber based industrial growth of our country. The activities of the Division are designed in such a way that the rubber based units of our country amounting to over 6000 in number will be able to tap the benefits of applied research and developments being conducted in its laboratory.

The main activities of the Division include preparation of project profiles on various rubber products, technical bulletin on rubber products which cover details of raw material, formulation, manufacturing techniques, quality control and testing methods, probable defects and remedies and project reports on request. They provide the techno-economical viability of each project and help in getting financial assistance from various financial institutions. The Division also provides market survey reports on different rubber products, various trade directories, testing and certification of different grades of rubber, rubber compounds, rubber products and rubber chemicals.

Table Tech. Con. 1. List of products and consumers.

Packer rubber Element (for ONGC) (import substitution)	M/s. KDM Institute of Petroleum, Dehradun.
Rubber Lid (490mm x390mm) (import substitution)	M/s. Bharath electronics Ltd., Bangalore
Sonobuoy NR chords (import substitution)	i) M/s. Keltron, Thiruvanthapuram ii) M/s. Tat Electronics, Bangalore
Sealing Rings for Galvanised Steel Pipes	M/s. Jindal Aluminium Ltd., Bangalore
NR Latex Compound for Spray Coating on Bandages	M/s. Dynamic Orthopaedics, Alwaye
Heat Resistant Rubber Liner	M/s. Artificial Insemination Project (Indo-Swiss) Mattupetti
White NR Diaphgrams of various sizes of Silicon Rubber (import substitution)	M/s. Instrumentation Ltd., Palakkad.
NR Insole for Anatomic Shoes (Import substitution)	M/s. Lily White Leathers, Bangalore
Nitrile Rubber Tubings (import substitution)	M/s. Triton Valves, Bangalore
Transducer Cover and Nose cone compounds, NR & Silicon rubber cords	M/s. Navel Physical & Oceanographic Laboratory, Cochin
TV Camers Lens, Diaphragm and Support Tubes	M/s. Bharath Electronics Limited, Bangalore
Sponge Rubber Compounds Laboratory, Hyderabad	M/s. Defence Research Development
Printing Rollers	M/s. Hindustan Machines Tools, Kalamessery
Bridge Bearing Pads Institute, Ranchi.	M/s. Structural Engineering Research
Uridrain Condoms (import substitution)	M/s. Sevena Medicals, Kizhakkambalam, Kerala
Fluorocarbon Rubber Gasket (import substitution)	M/s. The Fertilizers & Chemicals Travancore Limited, Udyogamandal
Automobile Rubber components	M/s. Penta Tech Rubbers (P) Ltd., Kuravilangadu
PU Gaskets (import substitution)	M/s. Tata Keltron, Palghat
Stator for Monopump	M/s. Foam Mattings India Ltd., Alleppey
Heat Sealing Compound (Back up Rubber)	M/s. Milma

cont'd...

Oxygen Cylinder Cap	M/s. Lama Industries, Kochi.
Dock Fender	M/s. Hevea Rubber Technologies, Kottayam
Rubber Component for Springler System	M/s. Micro Rubbers, Jalgaon
Surgical Valve (import substitution)	M/s. Tata Memorial Hospital, Bombay
Railway Grooved Pad	M/s. Kerala Rubber
Rubber Mats for LPG Carriers Pathanamthitta and more.	M/s. Tensile Polymers,
Viton gaskets	M/s. FACT Udyogamandal
NR Diaphragms (replacing silicon diaphragms)	M/s. Instrumentation Ltd., Palakkad
Rubber components for floor cleaning machines	M/s. Roots Multiclean (P) Ltd, Coimbatore
Automobile and industrial rubber products	M/s. Matson Rubbers, Alwaye
Automobile bellows	M/s. Topmost General Trading, UAE
Diaphragms for diesel automobile engines	Mr. Mani of Ayarkunnam, Kerala

The Division is committed to the manufacturers' requirements of product development as per various specifications to suit individual end use. This facility helps the manufacturer to produce and successfully market rubber products meeting stringent specifications prescribed by the customers and Govt. and Public Institutions, Railways, Defense establishments etc.

Few technologies successfully developed and transferred to various institutions are given in Table Tech. Con. 1.

The Division has also been instrumental in promoting the non conventional uses of natural rubber like road rubberization, irrigation canal lining, development of seismic bearings etc. The Division also has been actively participating in the development of rubber industrial parks at Cochin in Kerala, Nagercoil in Tamilnadu and Agartala in Tripura.

In addition, various training courses are offered for the benefit of the rubber product manufacturers and entrepreneurs. The Division is also capable of remedying technical problems faced by the units, by visiting and solving these problems *in situ*. The Division also extends facilities for project work of Polymer Chemistry and Rubber Technology students of various Universities in our country.

Ongoing Research Programmes

The Technical Consultancy Division provides technical assistance to promote rubber goods manufacturing industry in the country. The major activities of the Division include technical assistance to rubber based industries, solving production problems of existing units, quality

control, testing of rubber, chemicals, compounds and products, product development, advisory services and training programmes.

The Division prepared 15 project reports/schemes/profiles for the setting up of rubber based industries and provided advisory services to M/s. Hindustan Latex Ltd., Trivandrum on 'Capacity assessment and consumption norms review' for their condom units at Peroorkada and Belgaum.

1. Product development

On demand from existing entrepreneurs, the Division developed 25 products including latex adhesive, latex carpet backings, pre-vulcanized latex, latex compound for trials in cement blocks, NR based floor mats for export, rubber pad for ultrasonic application, industrial and automobile rubber components, anti-vibration mounts, NR based pharmaceutical closures, MC sheets, rubber moulds for making designer tiles, damper pulley compound and solution adhesives.

2. Rubber industrial parks

The Division continued to provide technical assistance to the setting up of Rubber Park at Kochi and entrusted the preparation of master plan and design of the rubber park with Infrastructure Leasing and Financial Services Ltd. (IL&FS), Delhi. The total planning and preparation of tender documents of the rubber park in Tripura is completed.

3. Schemes on diversified uses of NR

The study on performance evaluation of Natural Rubber Modified Bitumen (NRMB) roads by CRRI, Delhi was completed. Another study of NRMB roads in Kerala was signed with National Transportation Planning and Research Centre (NATPAC), Trivandrum. In collaboration with Structural Engineering Research Centre (SERC), Chennai, the Division completed the first phase of the project on indigenous design and development of NR based seismic bearing. The collaborative project on canal lining with Kerala Engineering Research Institute (KERI), Peechi is in progress. ■

Economics Division

Contributions since establishment

The Economics Division was formally established as a constituent part of the Rubber Research Institute of India in 1986. The research priorities and contributions of the Division since its establishment can be chronologically assessed in two phases. The first phase (1986-92) coincided with the last leg of protected policy regime pursued since 1947. Conversely, the second phase beginning from 1993-04 has been confronted with a host of research and development (R&D) challenges emanating from the formal launching of liberalised economic policy package in India. This chronological classification of the contributions of the Division assume importance for a critical assessment of the compatibility between the research priorities and the contextually specific issues.

In the first phase, the focus of the nascent Division had been on issues related to farm management, NR processing and primary marketing. This phase was also marked by studies on rubber based manufacturing sector and ancillary products of rubber plantations. The highlights in the farm management studies included, building up of a comprehensive time series database on com-

mercial yield of selected planting materials, evaluation of the planting policy in the estate sector, adoption of planting materials in the estate and smallholdings sectors, pattern of resource use in the smallholdings sector, economics of intercropping, cover cropping and rainguarding in the smallholdings sector and the pivotal role of institutional interventions in the expansion of rubber cultivation in India. The two critical evaluations on the efficacy of input subsidy schemes routed through the Rubber Producers' Societies were earnest attempts to assess the usefulness of the new mode of institutional interventions to ensure sustainability of the dominant smallholdings sector. The pioneering studies undertaken on block rubber processing industry and farm gate price of natural rubber in India had laid down the conceptual basis for subsequent research programmes and policy initiatives in these areas. Another important landmark during this phase was the systematic exposition of the limits in the linkages between resource endowments/ locational advantages and resource based industrialisation, as observed in the tardy progress of rubber based industrialisation in the state of Kerala. This phase was also notable for the beginning of building up time series databases on ancillary products and external trade in rubber products.

In sum, the research priorities and contributions of the Division during the initial phase were centered around short-term preparatory work for the formulation and sequencing of studies in various sub- sectors of India's rubber sector from a long term perspective. The perceived objective was to build up a conceptual basis to define the basic issues confronting the rubber sector under the protected policy regime based on reliable databases on various segments of the rubber sector. The policy inputs derived from the studies have been immensely useful in redefining the R & D priorities during the second phase coinciding with the changes in the macro economic policies of the country.

In response to the drastic changes in the macro economic policies of the country, especially with regard to external trade, the research priorities of the Division had been restructured into five broad areas, *viz.*, (i) farm management; (ii) primary processing and marketing of rubber; (iii) rubber products manufacturing industry and foreign trade; (iv) inter-crops and by-products; and (v) inter-divisional collaborative projects. The major observations derived from the studies in the farm management sector are: (i) vulnerability of the production sector to NR market uncertainty with long-term implications on yield and production potential; (ii) growing trend towards adverse age profile; (iii) questions on the sustainability of NR cultivation in the agro-climatically marginal lands and the need for reliable baseline data; (iv) relevance of agro-climatic zoning with region-specific R&D interventions; (v) policy questions on maximising NR output versus maximisation of net income per unit area; and (vi) factors hindering the compatibility of prevailing institutional support mechanisms with the emerging issues. Another major contribution in the farm management sector has been detailed analyses on the dynamics of tapping labour market and factors contributing to labour shortages in the smallholdings sector.

In the fields of NR processing and primary marketing, the contributory factors behind the historical predominance of sheet rubber *viz-a-viz* TSR in India has been justified in the context of the growing process of corporatisation of NR processing and region-specific factors. The impediments to the desired rates of growth in TSR have been subjected

to detailed analysis. The conceptual constructs evolved on the changing dimensions of primary marketing of NR in India have been immensely useful in addressing issues emanating from growing volatility of NR prices in India. The notable shifts of price determinants from endogenous to exogenous factors and gradual replacement of the conventional system of marketing arrangements with its concomitant quest for protecting respective marketing margins by various participants, called for a paradigm shift in institutional interventions in primary marketing of NR.

The research priorities in the rubber products manufacturing sector were conceived to capture the challenges and responses of the tyre and non-tyre segments to the economic reforms from a policy angle. The results of the investigations highlighted limitations in sustaining the tempo of domestic demand driven growth in the context of growing competition from multilateral and regional trade agreement routes. The observations were subsequently underscored by a time series analysis on India's external trade in rubber and rubber products. Hence, a comprehensive strategy to exploit India's unique locational advantages in both rubber products manufacturing and external trade were suggested for appropriate policy interventions. The pioneering comprehensive study on WTO agreement and NR sector in India (contained in two volumes) not only assessed the evolutionary dynamics of GATT and the consequent policy measures initiated by Government of India from 1995-96 to 2001-02, but also spelled out specific policy inputs relevant to the NR sector in India. The suggested policy inputs included modification of bound rates, extent of possible ad valorem subsidisation, WTO compatible domestic support measures related to new planting, replanting and input subsidy schemes. As a follow up action, the Division has prepared 94 policy documents on behalf of the Rubber Board for appropriate policy initiatives by the Ministry of Commerce, Government of India. The first comprehensive documentation of Harmonised System (HS) nomenclature on rubber products has been supplementary to the efforts in comprehending the WTO related trade policy issues.

The studies on by-products of rubber plantations, *viz.*, rubber wood, honey and rubber seed have been primarily targeted to build up reliable databases and to assess the commercial potential in the emerging context. The results of the studies have highlighted inherent constraints in exploiting commercial potential and provided a road map for compatible interventions from a long-term policy perspective so as to maximise net income per unit area.

In the realm of inter-divisional collaborative projects, four multi-disciplinary research projects were completed and the analytical inputs provided by the Division have illustrated the comparative feasibility of net income maximising or cost saving mechanisms contained in the approaches. The observed results have both R&D and policy implications for utilising waste from rubber processing, development of planting materials, plant protection measures and NR processing. The preliminary results of a multi-disciplinary approach on the environmental impact of NR processing highlighted potential adverse effects of the prevailing systems of effluent treatment and the need for detailed investigations to ensure compatibility between short-term benefits and sustainability. In sum, the results of these research programmes highlighted the need for multidisciplinary approaches rather than compartmentalised visions on issues

entangling India's rubber sector from a global perspective.

In conclusion, it is necessary to underline that compared to the initial phase, the research priorities of the Division since 1993 have been geared to address issues from the angle of a liberalised policy framework and to provide policy inputs to ensure competitiveness of India's rubber sector. In this endeavour, the observations and results derived from the studies during the initial phase had provided the critical inputs and platform for introspection in retrospect and prospect.

Completed Research Projects

During the reporting period the Division has completed seven research projects including a short research note on Tapping Panel Dryness syndrome.

1. Harmonised System Nomenclature- A Reference Manual

A thorough understanding of the Harmonised System (HS) nomenclature is an essential pre-requisite as more than 98 per cent of world merchandise is classified under the same. This book is the outcome of a pioneering effort to explore the salient features and usage of the HS with special reference to rubber and rubber products. This includes the structure and usage of the HS, its evolution, major amendments and current composition from a historical perspective. The illustrative tables dealing with rubber and rubber products and its amendments, analysis on India's tariff policy and external trade are expected to be a useful reference to the stakeholders, academia and the policy makers.

2. Trade policy reforms and the plantation sector

This study is an exploratory analysis on the critical issues confronting India's plantation sector in order to identify the proximate causes and basic issues and to assess the compatibility between popular policy perceptions and issues. At the farm management level, detailed investigations on agro-climatic zoning and age profile of area under the crops are essential prerequisites in order to maintain the tempo in growth in yield. In the marketing front, the interventions shall be focused on the promotion of producers' consortiums so as to enhance the share of the production sector in the value chain. The external trade policy reforms have to consider the need for modifying the norms of value addition, sources of value added exports and issues arising from Regional Trade Agreements (RTAs) from a long term policy perspective.

3. Trends in India's external trade in rubber and rubber products

This study analyzed the trends in India's external trade in rubber and rubber products covering 17 year period from 1987- 88 to 2003-04, which was divided into the pre-reforms and post-reforms phases. Though the rubber products sub-sector exhibited a favourable balance of trade during the entire period under review, the long-run sustenance of the same is questionable based on the observed trends in external trade. The sharp increase in the value of imports and the steep fall in exports during the post-reforms phase suggest the need for product group-wise analysis. Product group-wise performance indicated declining shares and growth rates of the traditional sources of exports. Product groups which had shown higher growth rates accounted for only insignificant shares in the total value of exports. Conversely, the growth rate in imports of all the four major rubber products increased during the post-reforms phase. Extension of the analysis to the rubber and rubber prod-

ucts sector did not seriously alter the observations except for the major changes in the composition of the imports dominated by synthetic rubber and allied products (4002) and natural rubber and related products (4001). There was remarkable growth in the relative share of other articles of vulcanised rubber other than hard rubber (4016) but performance of this product group in imports had been better than exports during the post-reforms phase.

Though the historically inherited structure of the domestic rubber sector and its external trade appendages had been so far able to withstand the challenges arising from trade policy reforms from the multilateral trade route, India's RTAs have the potential to tilt the balance. In this process, the product groups in the non-tyre sector appear to be more vulnerable to imports than the automotive tyre sector. Even the dominant automotive tyre sector is also confronting serious challenges in the context of regional integration of the markets and this dominant segment has been restructuring the organisational arrangements related to production and marketing.

4. NR market and non-tyre sector during the post reforms phase

During the post reforms period gradual withdrawal of market regulating operations contributed to significant changes in the trading system and the structure of the market. The major observed consequences are; (a) intensification of upgrading and downgrading of rubber; (b) appropriation of higher margin by intermediaries by making standardized grades irrelevant and (c) weakening status of rubber marketing co-operatives. The non-tyre sector was forced to follow a backward system of marketing and to evolve a marketing structure questioning its competitiveness. The major factors strengthening these phenomena are unawareness of manufacturers about the actual grades of NR and their inaccessibility to terminal markets. The dominance of trading capital over the industrial capital in the non-tyre sector and its backward marketing system strengthened the bargaining and market controlling power of the tyre sector. These developments pose questions on the potential farm gate price as well as the sustainability of small and medium scale manufacturing units in the country.

5. TPD conundrum : Two methodological issues in estimating the economic loss

The research agenda on TPD has been dominated by biological investigations related to characterisation of the problem and evolving procedures to assess the extent of morbidity and mortality rates. From the stakeholders' angle, it is imperative to evolve consensual methods to estimate the economic loss for two important reasons: (i) the commercial implications of the incidence of TPD may vary across agro-climatic regions, clones and yielding phases; and (ii) more than the scientific curiosity, the validity of the research agenda ultimately depends on the extent of estimated economic loss in a perennial crop like natural rubber. However, the two methodological issues highlighted in the paper underline the need for data on life cycle yield profile of major clones to estimate the economic loss. This proposition is underscored by the point that potential economic loss will be more if the TPD incidence is more in the early phases than in the final yielding phase.

6. Supply determinants of tapping labourers

The study was undertaken with the major objective of understanding the dynamics of tapping labour market in

the context of market uncertainty. The sample survey was carried out among 127 small rubber growers and 130 tapping labourers located in Kottayam and Idukki districts of Kerala during the years 2001 and 2005. The major factors which sustained the supply of tapping labour in the smallholding sector were: (i) relative regularity of employment; (ii) permanent employer; (iii) wage advances; and (iv) chances of part-time work after normal working hours. A tapper attains the peak of his productivity in the age between 40-50. It was found that 60 per cent of tappers employ tapping assistants and 98 per cent of the tapping assistants expend as much time as that of the main tapper.

7. Environmental impact of NR processing industry in Kerala

The research programme initiated in 2004, is an effort to understand the environmental impacts of the primary rubber processing industry through integration of principles of sustainable management in the sector. The primary processing of rubber in the form of cenex, crepe, crumb and RSS generates huge untreated/partially treated effluent load ensuing in point source/diffuse pollution. Considering the potential threats, the Kerala State Pollution Control Board has classified the processing units *viz*., cenex and crumb rubber factories under the category red and orange, respectively indicating high pollution levels. The project initiated in 2004 attempt to envisage a multidisciplinary approach employing state of the art technologies from physical and social sciences. The study operates in a GIS and remote sensing framework, targeting the watersheds in a region. The major output of this research programme would be an eco friendly industry based location specific guideline, which would act as a reference point for future entrepreneurs.

As part of the initial phase of the study, the entire primary processing units in Kottayam District was mapped into a GIS framework by visiting the individual units, during 2005. The buffer distance of the units and the water bodies revealed that all the units lie in a 300 m radial distance of a water body out of which nearly 50 per cent lie in the concentric ring of 100 m. Several units were positioned in a radial distance of 50 m or even below indicating a high probability of the effluents reaching the water bodies. Work on assessment of slope and other topographical data along with identification and delineation of micro watersheds are in progress. ■

Central Experiment Station, Chethackal, Kerala

Contributions since establishment

The Central Experiment Station (CES) was established in 1966 by the Rubber Research Institute of India with the objective to conduct various field experiments in different disciplines so as to formulate appropriate scientific technology for rubber cultivation. The land extending 255 ha was acquired for the Station by Rubber Board on a lease agreement with the Kerala State Forest Department and subsequently the clearing of virgin forest was undertaken in a phased manner.

The first experimental planting was undertaken in 1966 itself for Botany Division to evaluate the new clones developed by RRII and this trial later generated the wonder clone, RRII 105 which contributed for the highest productivity of rubber in India. The other trials laid out subsequently were aimed at identification of clones suitable for traditional region and development of best agromanagement technology for cultivation. Later, large number of trials on breeding and evaluation, establishment of *Hevea* germplasm and characterization, nursery establishment, field upkeep including intercropping of annual and timber species and medicinal plants, exploitation techniques, disease management etc. were undertaken, the results of which formed part of Rubber Board's recommendations to growers. All basic informations on Golden Jubilee clones, RRII 414 and RRII 430 and

other RRII 400 series clones were generated from the small and large scale trials conducted at this Station.

Ongoing Activities

The priority areas of experimentation at present are breeding for high yield and other beneficial secondary characters with special emphasis on disease and drought tolerance, evaluation of clones developed conventionally and biotechnologically, intercropping systems, reduction in cost of cultivation, low frequency tapping systems etc.

The Station having 209 permanent and 100 casual workers is managed by Deputy Director (Regional Station) with 41 staff for office administration, farm management, dispensary, security and canteen. The dispensary with full-time and part time doctors provides medical care to the workers and the total number of cases attended to during the period under report were 6001.

Farm-statistics

During the reporting period the total crop realized was 140934.95 kg. Total of 305 tapping days was possible during the year and 59 tappers were engaged for tapping. Total man-days engaged were 55326. ■

Regional Research Station, Guwahati, Assam

Contributions since establishment

The Station was established in 1985 after opening a research farm at Sorutari in Kamrup District of Assam. Another farm was also opened in 2004 at Rubber Research & Training Centre (RRTC), Hahara, Guwahati. The thrust areas of research of the Station are the development of location specific agro-technology, evaluation of clones under different biotic and abiotic stress factors, identification of clones suitable for commercial cultivation and development of appropriate exploitation and crop protection methods for the region.

The commercial yield (kg/ha/year) over the first ten years of tapping in different *Hevea* clones indicated that RRIM 600 ranked first (2034) followed by PB 311 (1864), PB 235 (1745), PB 310 (1726), GT 1 (1715) and RRII 105 (1680). Higher yield and better growth of the clones suggest that these are potential clones for future planting under the agro-climatic conditions of Assam. However, planting of these clones in different locations with varying ecological conditions on commercial scale needs to be assessed before making a final recommendation. Ten promising selections from polyclonal seedlings exhibited early attainment of tappability, higher girth and girth increment on tapping and higher DRC in comparison to the popular clone RRIM 600. Yield evaluation over the first

eleven years of tapping revealed that two selections, S2 and S1 recorded two times higher yield than that of RRIM 600. They were free from TPD and wind damage and moderately tolerant to powdery mildew disease.

The survey on pests and diseases of rubber in Assam, Meghalaya, Arunachal Pradesh, Mizoram, Tripura and northern part of West Bengal indicated severe incidence of leaf diseases *viz.*, powdery mildew (*Oidium heveae*), periconia leaf blight (*Periconia heveae*), bird's eye spot (*Bipolaris heveae*), leaf spot (*Corynespora cassiicola*), secondary leaf fall (*Colletotrichum gloeosporioides*) and thread blight (*Pellicularia filamentosa*) in these areas. The incidence of pink disease (*Corticium salmonicolor*), pod rot (*Phytophthora botryosa*), brown root (*Phellinus noxius*) and purple root disease (*Helicobasidium compactum*) were also noticed.

High severity of powdery mildew disease resulting in an annual crop loss of 28.52 per cent was reported in Nagrakatta, West Bengal. Clones and accessions tolerant to powdery mildew disease were identified in this region. The incidence and severity of Periconia leaf blight disease was higher in Assam, Meghalaya and Arunachal Pradesh compared to other states of North East and northern part of West Bengal and the disease was controlled effectively by spraying of carbendazim (1 g/litre of water). The occurrence of Periconia leaf blight disease was confined only in North East India and northern part of West Bengal during December to March. The incidence of purple root disease noticed in Assam and Meghalaya was controlled effectively by spraying of calixin 80 EC (2 ml/litre of water). The high incidence of brown root disease noticed on rubber plants at the age of 4 to 6 years in South Tripura was controlled effectively by application of calixin 80 EC (5 ml/litre of water). Application of chelated zinc (5 ml/litre of water) could be a viable alternative approach for the management of powdery mildew disease and consequently healthy growth of rubber seedlings.

Different pests infestation *viz.*, scale insect (*Saissatia nigra*), weevil (*Hypomeces squamosus*), mealy bug, termites, slugs and snails on *Hevea* crop were also noticed in this region. The intensity of scale insect, termites and slugs infestation was high and caused a considerable damage to the crop. Weevil infestation on mature leaves of *Hevea* rubber was noticed only in Assam and was controlled effectively by spraying of Malathion 50 EC (2 ml/litre of water). The infestation of scale insect was controlled naturally by an entomogenous fungus *Hypocrella reineckiana*.

It was observed that continuous tapping under $^1/_2$S d/2 frequency in clone RRIM 600 resulted in high yield. However, tapping under $^1/_2$S d/3 frequency as well as $^1/_2$S d/4 with stimulation were comparable with the yield under d/2 system. $^1/_2$S d/3 frequency of tapping with five stimulations and two months rest (February and March) was found to be optimum for north east region.

Ongoing Research Programmes

The thrust areas of research of the Station are crop improvement, management, protection and exploitation technology.

1. Crop improvement

The girth (cm), girth increment (cm) and mean yield (g/t/t) in 1985 and 1986 clone trials show some deviations from the last year (Table Ghy.1).

2. Crop management

Results from the experiment on the effect of NPK fertilizer on growth and yield of rubber with clone RRII 105 at Nayekgaon, Kokrajhar also have shown

Table Ghy. 1. Girth, girth increment and mean yield of 1985 and 1986 trials

	Girth (cm)		Girth increment (cm)			Annual yield (g/t/t)					
						1/2 S with rest			1/2 S without rest		
Year	No. of clones	Highest	Lowest	Highest	Lowest	Max.	Min.	DRC range(%)	Max.	Min.	DRC range(%)
1985	10	RRII 203 (79.2)	PB 5/51 (54.9)	RRIM 600 (2.44)	PB 5/51 (0.66)	RRIM 600 (51.4)	PB 5/51 (27.4)	34.8 – 36.6	GT 1 (40.6)	GI 1 (25.5)	33.4 – 34.9
1986	10	RRIC 102 (81.8)	RRII 105 (66.3)	RRIC 102 (1.84)	RRII 5 (0.85)	PR 255 (56.7)	RRIC 105 (25.4)	32.6 – 36.6	PB 310 (36.0)	RRIC 105 (21.5)	32.3 – 34.4

significant increase in girth and yield with the application of 40:40:40 kg/ha compared to 20:20:20 kg/ha and control. However, highest dose of 60:60:60kg/ha resulted in highest yield and girth though it was only numerically superior compared to 40:40:40 kg/ha. The experiments on interaction between K and Mg have shown that potassium @ 40 kg/ha resulted in significantly higher yield (57.92 g/t/t for Sorutari and 56.38 g/t/t for Nayekgaon) and magnesium @ 15 kg/ha resulted in significantly higher yield (59.32 g/t/t for Sorutari and 57.92 g/t/t for Nayekgaon) compared to other treatments. However, their effects on girth and annual girth increment of rubber were not significant at Sorutari farm as well as at Nayekgaon, Kokrajhar.

The experiments at Sorutari farm and Nayekgaon, Kokrajhar to study the efficiency of phosphatic fertilizers with varying solubility and amounts have shown that 35 kg/ha of rock phosphate resulted higher yield (56.32 g/t/t) compared to the same amount single super phosphate at Sorutari farm and was significantly higher over control. Similar trend was also observed at Nayekgaon. No significant difference in mean girth among the treated plants was observed in both the trials.

Preliminary results have shown that the growth of rubber as monocrop as well as intercrop with pineapple is on par and is slightly lower when intercropped with banana. Banana as intercrop has attained fruiting stage six months after planting.

3. Crop protection

Survey on diseases and pests was continued in 44 locations covering 23 different rubber growing tracts in Assam, Meghalaya, Tripura and northern part of West Bengal. Incidence and severity of various pests and diseases were assessed and susceptible pockets were identified. Out of 21 wild accessions of *Hevea* germplasm, six showed stable tolerance to powdery mildew disease over years under the agro-climatic conditions in northern part of West Bengal. Only one accession (MT 44) out of the six showed very high degree of stable tolerance. 64 wild accessions out of 540 and 25 out of 246 conserved at Sorutari and Taranagar farms respectively showed high degree of tolerance. Out of these, three accessions (AC 462, MT 1021 and RO 2375) have shown very high degree of tolerance to powdery mildew disease over 5 years and these may be selected for *Hevea* breeding programme. Incidence of purple root disease was controlled in experimental plots at DDC, Jenggitchakgre in Meghalaya on treatment with Tilt, Calixin and Bioflora natural and also by 2 years of fallow bed.

4. Exploitation technology

The experiment on tapping rest and frequency interaction studies started during 1999 with the clone RRIM 600 was continued with the same trend as the previous year. ■

Regional Research Station, Agartala, Tripura

Contributions since establishment

The Station was established in 1979 for identification of appropriate agro-technologies suited for this region. Study on tolerance to prolonged winter experienced in this region is also given special emphasis. The impact of rubber cultivation on the eco-system is also under study.

Fertilizer management studies had shown that broadcasting of fertilizer in the inter row spaces of *Hevea* from the fifth year onward (when the canopy closes) resulted in better growth with minimised cost of cultural operations than pocket application. Application of water soluble phosphorus for first two years and subsequent application of water insoluble phosphate had influenced rubber growth positively. Graded level of NPK fertilizer (60:60:60) has increased the yield over the 30:30:30 kg/ha.

Annual litter fall in a mature rubber plantation ranged from 6.8- 7.8 t/ha which added 94-130 kg N, 5-6 kg P and 22-25 kg K to soil resulting in great enrichment of soil fertility. Intercropping of banana, pineapple, ginger, turmeric, pigeon pea, *Sesamum* and groundnut was found to be economically feasible in immature rubber plantations.

Table Ghy. 1. Girth, girth increment and mean yield of 1985 and 1986 trials

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Annual litter fall in a mature rubber plantation ranged from 6.8- 7.8 t/ha which added 94-130 kg N, 5-6 kg P and 22-25 kg K to soil resulting in great enrichment of soil fertility. Intercropping of banana, pineapple, ginger, turmeric, pigeon pea, *Sesamum* and groundnut was found to be economically feasible in immature rubber plantations.

Maintaining a tree density of 606/ha appears to give reasonable number of tappable trees in subsequent years in spite of loss due to wind damage. The build up of biomass, microflora and understorey vegetation in rubber plantation is comparable to that of other plantations and rubber could be planted for restoration of soil health and in recuperating the existing fragile eco-system in Tripura.

Based on the performance of clones in Tripura and on the basis of data collected from other Stations of northeast, 19 high yielding clones have been selected under three categories for cultivation in this region. Clone RRIM 600 was included in category I and RRII 105, GT 1, PB 235, RRII 203 and RRII 208 in category II. Other clones like RRII 5, RRII 118, RRII 417, RRII 422, RRII 429, RRII 430, PB 260, PB 310, PB 311, RRIM 703, SCATC 88/13, SCATC 93/114 and Haiken I were included in category III. Embryo culture and leaf mesophyll protoplast culture protocols were developed to supplement conventional crop improvement programme.

Continuous tapping under $^{1}/_{2}$S d/2 frequency resulted in high annual average yield (1488 kg/ha) in clone RRII 105 and was comparable to tapping under $^{1}/_{2}$S d/3 frequency with stimulation. Dry rubber content (drc) was high and percentage of tapping panel dryness (TPD) was less in $^{3}/_{4}$S d/3 system compared to $^{1}/_{2}$S d/2 system of tapping. However, $^{1}/_{2}$S d/3 frequency of tapping with five stimulation and two months rest during February and March appears to be reasonable for this region.

Yield is generally low during summer months and high during pre-winter months. October and November were the peak yielding period. The 10 °C minimum temperature is the critical point of low temperature stress, whereas 18 °C is the point of peak yielding stage.

It was observed that clone RRIM 600 showed least reduction in yield during low temperature stress period among the five clones studied (GT 1, RRII 105, RRII 118, PB 235 and RRIM 600). Tapping panel dryness and late dripping of latex has been observed during this period. However, tapping rest during severe winter could reduce the intensity of TPD. Biochemical study revealed that progression of TPD is associated with increase in free radical level with simultaneous depletion of its scavenging system.

Low temperature in the presence of high light intensity induces photoinhibition in *Hevea*. There was about 50% reduction in net photosynthetic rate in winter compared to the pre-winter and post-winter periods in young *Hevea* plants in field condition. Such photoinhibitory effect on *Hevea* plants could be reduced by partial shading. Techniques for making seedling nursery and good quality budded plants in tune with the climatic conditions of Tripura have been developed and successfully extended into growers' fields. Sufficient number of viable seeds are now produced in Tripura to meet the planting material requirement of the region.

The region experiences various biotic stresses due to the prevalence of certain diseases. High incidence of Powdery mildew disease caused by *Oidium heveae* was observed in the North East region. Other diseases like leaf blight (*Periconia heveae*) and brown root disease (*Phellinus noxius*) were also reported in different locations.

Homogeneous rainfall areas conducive for rubber cultivation in Northeast India have been classified within the seven states. Annual and monthly Precipitation Concentration Indices (PCI) were studied utilizing mean values, inter-annual variability and diversification.

The optimal, Sub-optimal, moderate and Marginal regions identified comprises of 14.5, 26.9, 46.4 and 12.2 per cent of the total area in the Northeast. Rainfall probability studies showed different dry spells at different places in the north-east. Studies on climatic water balance showed water deficit during March-April period. The relationship of prevailing antecedent environmental parameters with latex yield was established with five popular clones of *Hevea* in Agartala. Soil moisture storage values, one day and three days prior to tapping were found to be the primary parameters affecting yield for the non-winter tapping and winter tapping periods respectively. The clone RRII 105 was more susceptible to daily water deficit conditions during the non-winter season compared to RRIM 600. Both these high yielding clones were also found to be fairly dependent on the average temperature of the day prior to tapping. The study also confirmed the varied response of yield with the environmental factors.

Nutrient management recommendation practices for rubber were followed based on the soil and leaf analysis results. The Mobile Soil and Tissue Testing laboratory attached to this Station caters to the needs of the growers of the region. Soil and leaf samples were collected from the region and analysed and discriminatory fertilizer recommendations were given to the growers. Advisory service in latex processing is also given to the growers of this region for making good quality rubber sheet.

Ongoing Research Programmes

The Station continued its research activities in crop management, crop improvement and crop processing. The Station also continued its advisory services and training to the growers of this region.

1. Crop improvement

In a clone evaluation trial with 12 clones, RRII 208 had the highest 7 year mean yield (1528 kg/ha) followed by RRIM 600 (1318 kg/ha). The trial has been discontinued. In another clone trial with 10 clones, REYAN 93/114(33.5g/t/t) and RRII 105 (32.5 g/t/t) showed higher yield. In clonal demonstration trial involving four clones, GT 1 (20.9 g/t/t) showed the highest yield followed by RRIM 600 (18.9 g/t/t), RRII 105 (17.4 gt/t) and PB 235 (14.6 g/t/t). Girth data from the on farm trial at Killamura involving six high yielding clones selected on the basis of their performance in large scale clone trials conducted at Taranagar farm showed that RRII 203 (56.3 cm) had the highest girth followed by PB 260 (53.7 cm) and PB 235 (53.6 cm). In the clonal block trial at Bagafa involving eight clones, RRII 118 (32.9 cm) exhibited highest girth followed by PB 235 (32.2 cm) and PB 260 (31.8 cm). An on farm trial of five RRII 400 series clones *viz*., RRII 414, RRII 417, RRII 422, RRII 429, RRII 430 with RRII 105 and RRIM 600 as controls was initiated at the TRPC plantation, Pathalia (300 plants/block).

In the recombination breeding programme, the yield data collected from 75 trees of 1998 population, three probable high yielders *viz*., RRIM 600 x RO/PB/2 (RO 4616), RRII 105 x RRII 208 and RRII 105 x Haiken 1 (one each) were delineated. In the 1999 population, with 670 trees, 11 trees *viz*., RRIM 600 x RRII 208 (six recombinants), GT 1 x RRII 429 (two recombinants), RRIM 600 x PB 235, RRIM 600 x PB5/51 and RRIM 600 x MT/C/1 (MT 4888) (one each) exhibited more than 45 cm girth. These trees are being evaluated against RRIM 600 as reference clone. Eleven ortets selected polyclonal seedlings population are being evaluated with RRIM 600 as reference clone. Five

Table Net. 1. Pollen viability, germination and length of pollen tube in 400 series clones at Nagrakatta and Agartala

Clone	Viability (%)		Germination (%)		Length (mm)	
	Nagrakatta	Agartala	Nagrakatta	Agartala	Nagrakatta	Agartala
RRII 414	23.0	24.6	90.9	85.7	85.6	81.5
RRII 417	23.8	29.0	92.8	80.9	102.1	102.2
RRII 422	21.4	25.1	89.9	84.3	81.4	91.6
RRII 429	15.6	20.8	90.5	84.8	96.0	92.9
RRII 105	15.2	20.2	90.8	89.3	99.1	94.8
RRIM 600	27.5	24.2	85.4	86.8	102.4	89.3

selections were seen to be with better girth compared to RRIM 600 (29.7 cm). Pollen viability of RRII 400 series clones were studied at Agartala and Nagrakatta agroclimatic conditions and around 15 to 29% pollen were found viable. (Table Net. 1).

Conservation and evaluation of Brazilian germplasm accessions were continued. Acre (AC) accessions showed highest girth compared to Rondonia (RO) and Mato grosso (MT) in Trials I and II. Dry rubber yield (g/t/t) were 26.4 for MT, 23.1 for RO and 21.4 for AC in Trial I and 23.9 for MT, 26.2 for RO and 24.3 for AC in Trial II. However, control clone RRIM 600 was superior to all the accessions in terms of yield. Selection of germplasm accessions for photo oxidative stress is also in progress.

2. Crop management

The density trial with combination of different doses of fertilizer was continued with two popular clones *viz.*, RRII 105 and RRII 118. The density was 420, 606 and 824 trees per hectare. Results showed high growth of plant and high yield per tree, but relatively low yield per hectare in low density. Percentage of wind damage was low in high density. Response to high dose of fertilizer was not evident. In tea intercropping trial, annual green tea leaf yield was 1076 kg/ha. Average annual rubber yield was 1010 kg/ha. In organic and inorganic trial, immature girth continued to be maximum on application of recommended dose of fertilizer with 20 kg of FYM/plant/year.

No difference was observed in growth of RRII 400 series clones in the third year in response to high dose of fertilizer. Similar result was also observed in response to different levels and time.

In potassium dynamics study in the rubber growing soils of Tripura, surface soils from three geographical locations

Table Net.2. Percentage of K fixed in soils of Tripura

Geographical location	K-added / K-fixed (ppm/g)						
	10	20	40	60	80	100	Mean
Hills	41.2	35.5	29.5	27.5	26.1	23.8	30.6
Upland	59.4	51.3	44.5	42.3	41.3	39.8	46.4
Lowland	78.2	74.2	46.5	36.2	35.2	34.8	50.8
Mean	59.6	53.6	40.1	35.3	34.2	32.8	

viz., hills, upland and lowland were collected. Physico-chemical properties of these soils were determined. Data on fixation of potassium (Table Net. 2) in these soils showed that higher amount of potassium was fixed in lowland soils compared to upland and hill soils. Fixation of potassium is negatively correlated with sand (r = -0.48) but positively correlated with silt (r = 0.64) and clay (r = 0.73*) of soil.

Under low temperature stress, polythene overhead cover has increased the soil temperature by 1.92°C without any mulching and 1.74°C with FYM + straw mulching alone. Plants under polythene overhead cover had advantage during winter. However, with the increase in temperature during March-May, seedlings under both FYM + paddy straw mulching and polythene overhead with FYM + straw mulching attained more or less similar girth at the age of 6 months. A minimum of 46% seedlings attained required stem girth under FYM+ paddy straw mulching and 44% under polythene overhead with FYM + straw mulching whereas only 22% seedlings attained similar girth for budding during the same period.

3. Crop physiology

Continuous tapping under $^1/_2$S d/2 frequency resulted high annual average yield. However, tapping under $^1/_2$S d/3 frequency with stimulation was comparable with $^1/_2$S d/2 system. Dry rubber content was high in $^1/_2$S d/3 system than in $^1/_2$S d/2 system of tapping. Higher percentage of tapping panel dryness was observed in continuous $^1/_2$S d/2 system of tapping compared to $^1/_2$S d/3 system. However, yield of $^1/_2$S d/3 frequency of tapping with five stimulation and two month rest during February and March was comparable with $^1/_2$S d/2 system of tapping. In another study, tapping under $^1/_2$S d/2 frequency resulted in high annual average yield in clone RRII 105. It was also observed that comparable yield could be realized from the $^1/_2$Sd and $^1/_2$S d/2 system of tapping with application of five and three stimulation respectively.

Quantum yield, irradiance saturation and carboxylation efficiency of two popular clones *viz.*, RRII 105 and RRIM 600 showed low range of photosynthetic rate on a diurnal basis during winter period. During a day, RRIM 600 recorded maximum 4.6 µmoles $CO_2m^{-2}s^{-1}$ at around 12.30 pm and RRII 105 recorded 3.6 µmoles $CO_2m^{-2}s^{-1}$ at around 11.30 am. A low quantum yield (QY) recorded for both clones indicated the severity of the cold stress. However, irradiance saturation point was observed to be at 1500 µmoles $m^{-2}s^{-1}$ in case of RRIM 600 and 1475 µmoles $m^{-2}s^{-1}$ in case of RRII 105.

Table Net. 3. Latex and rubber properties of 400 series clones at Agartala

Clone	August				December			
	TSC (%)	DRC (%)	P_0	MV	TSC (%)	DRC (%)	P_0	MV
RRII 414	40.8	36.8	41	75	25.0	21.0	35	51
RRII 417	39.1	35.6	52	87	24.1	20.1	37	69
RRII 422	40.0	36.6	30	58	25.0	21.9	31	49
RRII 429	40.1	36.8	42	81	28.0	23.8	38	62
RRII 430	41.1	37.0	33	62	30.0	25.9	29	47
RRII 105	40.6	36.9	47	78	29.6	25.2	30	53
RRIM 600	40.9	36.9	40	70	26.8	23.0	36	58

Under saturated light condition, the carboxylation efficiency of RRIM 600 and RRII 105 were estimated to be 0.62 and 0.56 respectively.

4. Latex technology

The study on the seasonal variation of properties of rubber in 400 series clones with RRII 105 and RRIM 600 was continued. The DRC and TSC are very low in winter season while non-rubber content, ash and nitrogen did not show considerable difference with seasons (Table Net. 3). Dry rubber analytical values showed that P_0 and Mooney viscosity marginally decreased during winter season.

5. Advisory work

As a part of Discriminatory Fertilizer Recommendation (DFR) to the growers, 22 programmes were conducted during the reporting period and 456 recommendations were offered. Inspection of 72 MT of sheet rubber was done for quality for export from Tripura. Quality sheet making and DRC measurement were demonstrated at different RPSs and to the trainees.

■

Regional Research Station, Tura, Meghalaya

Contributions since establishment

The Regional Research Station, Tura (Meghalaya) was established in 1985. Under this Research Station there are two high altitude experimental farms, one at Ganolgre (600 m.) and the other at Darechikgre (1080 m.). The climate of this region is sub-tropical. Due to unfavorable climatic condition, the activities have been stopped at Darechkgre farm since 1991. The other Station is currently concentrating on various research projects in relation to evaluation of high yielding clones, identification of cold tolerant clones, suitable exploitation systems, control measures for pests and diseases of rubber and nutrient management under the agro climatic conditions of Garo Hills.

Among two clone evaluation trials established in 1985 and 1986, RRIM 600 (55.1 g/t/t) and PB 311 (50.4 g/t/t) are observed to be the top yielders. Among the population, highest yield was 52.3 g/t/t. Experiment in Garo hills indicated that July to September months are suitable for bud grafting in the region.

Since 1986, experiments on physiological aspect have been carried out under the agroclimatic condition of Garo hills and results indicated that during winter period (Dec- Feb) average minimum

air temperature is below 10°C in the region which adversely affected the growth of all *Hevea* clones. Rubber cultivation above 600 msl is not advisable in Garo hills. Poly bag plants inside poly house reduced the immaturity period. Seeds collected from the Garo hills showed 80-90 per cent viability. During winter period suitable tapping time is between 8 am to 10 am. A local made bamboo/mud type smoke house is useful/ eco-friendly to the growers of the region because of its low cost (Rs. 1000/- per unit with a capacity of 300 sheets) and good quality of sheets.

Performance of RRIM 600 clone was evaluated in West South West (WSW) and North North East (NNE) aspect of slopes. At WSW slopes RRIM 600 showed higher girth (81.1 cm), lower yield and lower volume of latex (154 ml/t/t) and early defoliation while in NNE slope the clone showed lower girth (77.7 cm), higher yield and higher volume of latex (171.6 ml/t/t) and late defoliation.

The different tapping systems in combination with tapping rest especially during winter season was studied. In 1/2S d/2 tapping system maximum yield was observed in 10°-10° C temperature regime (60.3 g/t/ t) followed by control (58.9 g/t/t), while in 1/2S d/3 tapping system maximum yield was under 15°-15° C temperature regime (54.0 g/t/t) and 10°-10° C temperature regime (52.1g/t/t). In 1/2S d/2 tapping system TPD incidence was 5 per cent while in 1/2S d/3 tapping system it was 3 per cent. Maximum TPD was recorded in RRII 203 (21.5 %) and minimum in RRII 118 (1.39 %) from 1985 trial. In 1986 trial maximum TPD was recorded in PB 260 (7.7 %) and minimum in RRIC 102 (2.9%). An assessment of TPD incidence carried out in different states of NE India observed that in RRII 105 the incidence was high in Assam (31.4 %) followed by Meghalaya (18.8 %). It was also noted that TPD incidence was high in plants having the girth range 51-70 cm.

The performance of rubber (RRIM 600) and tea at high altitude (600 m) was assessed. In Garo hills rubber cultivation is more profitable than tea.

An experiment was initiated to study the effect of different mulch materials on the growth of *Hevea* seedlings. Results indicated a significant increase in growth and height of plants as compared to unmulched plants.

To find out the optimum requirements of N, P and K fertilizers for the growth and yield of *Hevea* under the agro climatic condition of Assam and Meghalaya, three experiments were carried out in the growers' field. The data on immature phase showed that the optimum levels of $N_{40}P_{20}K_{20}$ kg /ha was suitable for proper establishment of *Hevea* in Lower Brahmaputra Valley Zone (LBVZ) of Assam and $N_{60}P_{30}K_{20}$ kg /ha was suitable for the East Garo hills of Meghalaya. For mature phase, a combination of $N_{60}P_{40}K_{40}$ kg/ha was suitable for proper establishment of *Hevea* in Assam. Improvement of fertility status of soil and leaf nutrient contents with application of NPK fertilizers, significantly increased the organic carbon content, available P and K and highest was recorded with the combination of $N_{60}P_{30}K_{45}$ kg /ha and minimum was in control plot ($N_0P_0K_0$).

Response of rubber seedlings towards NPK fertilizers in Assam condition has been studied. A combination of 333 kg of N, 250 kg of P_2O_5 and 62.5 kg of K_2O/ ha was found beneficial for optimum growth of *Hevea* seedlings.

Two field experiments were laid out during 1987 to find out the influence of K and Mg and their interaction on growth, yield, nutrient contents and soil proper-

ties of *Hevea* under the agro climatic condition of Assam. A combination of $K_{40}Mg_{75}$ kg/ha/yr was found suitable for immature phase and K_{40} Mg_{15} kg/ha/yr influence the growth and yield of *Hevea* significantly during mature phase.

Comparison on the efficiency of the two cover crops *viz., Pueraria phaseoloides* and *Mucuna bracteata* on soil nutrient profile and growth of young plants showed highest soil nutrient enhancement and other properties in fields with *Mucuna bracteata* planted in 1 m^2 patches followed by *P. phaseoloides* planted in 1 m^2 patches and minimum was in natural cover (control). Study on the altitudinal effect on the establishment of cover crops observed that *P. phaseoloides* showed similar growth performance at both 600 m and 1100 m above msl.

A study on leaf nutrient concentration in different clones of *Hevea* under Garo hills of Meghalaya has been initiated and results showed maximum N content in clone RRIM 600 (3.41 %) followed by PB 311, RRIM 605 and minimum was in clone Gl 1 (3.02 %). Maximum P content was noticed in the clone RRIM 600 (0.32 %) followed by PB 310, PB 311 and GT 1 and minimum was in clone Gl 1 (0.26 %). Maximum K content was noticed in clone RRIM 600 (1.60 %) followed by RRIM 605, PB 310 and PB 311 and minimum was in clone PR 255 (1.23 %).

A study on soil moisture retention characteristic of rubber growing soil under the agro-climatic condition of Meghalaya indicated that organic carbon was in medium to high range (0.90- 1.55 %), available phosphorus was very low (0.04 -0.69 mg/100 g soil) and available potassium was in low to medium range (3.8 to 6.5 mg/100g soil). Soil was acidic in nature in all the locations.

Since 1985, a periodical disease survey was conducted in Garo hills on rubber seedling nursery, immature and mature phases which indicated that no serious out break of disease was recorded in the rubber plantation. But the survey found mild incidence of powdery mildew, pink disease and leaf spot disease in some areas of the Garo hills. Purple root disease in seedling nursery was also reported but is under control.

A study to assess the ecology and distribution of microflora associated with rubber growing soils in West Garo Hills found that the quantitative distribution of microbial population varied widely in different aged rubber plantations. Another study found, the fungal, bacterial and mycorrhizal populations to decrease significantly in deeper soil layers and the study on horizontal distribution of bacterial showed maximum activity in the region of higher root concentrations. The study on the effect of AM fungi on the growth and development of rubber saplings found that all the inoculated mycorrhizal seedlings gave a better girth, height, leaf numbers and whorl number over the uninoculated control plants.

The study on the prospects and feasibility of mushroom cultivation under the agro-climatic conditions of Meghalaya found paddy straw to be the best substraction for the production of Oyster mushroom which yielded upto 1.8 kg per block.

Seventy soil samples and 60 leaf samples were collected from different rubber growers of South, East and West Garo hills of Meghalaya and analyzed for Soil- pH, organic carbon, available P and K for fertilizer recommendation to the different rubber growers of Meghalaya State.

Ongoing Research Programmes

The Station continued its research activities on evaluation of clones, polyclonal population, evolving suitable

exploitation system and aspect of slopes and crop management.

1. Crop improvement

In 1985 trial, RRIM 600 showed the same trend as the previous year with the highest girth (92.7 cm) and yield (55.1 g/t/t) while lowest girth was recorded in PB 5/51 (68.4 cm) and yield in RRIM 605 (36.0 g/t/t) . In 1986 trial, among the ten clones PB 310 registered the highest girth (95.9 cm) closely followed by RRIC 102 (93.2 cm) while lowest girth was recorded in PR 255 (72.6 cm). Highest yield was registered in PB 311 (50.4 g/t/t) and the least in RRIC 105 (32.7 g/t/t).

Polyclonal population attained an average girth of 76.85 cm with a yield of 35.0 g/t/t. Among the population the highest yield was 52.3 g/t/t.

2. Crop management

On assessing the performance of rubber clone (RRIM 600) and tea at 600 m altitude, the rubber growth (81.1 cm) and yield (53.9 g/t/t) was found to be satisfactory. During the year total tea production was 422.6 kg.

Results from the on-farm nutritional studies at Borgang, Assam during reporting year showed that a combination $N_{60}P_{30}K_{45}$ kg /ha gave highest girth (74.22 cm), girth increment (1.97 cm), yield (73.32 g/t/t), DRC (34.92 %) and total volume of latex (216.0 ml/t/t) followed by the treatment combination of $N_{60}P_{30}K_{30}$ kg /ha and minimum was in control plot ($N_0P_0K_0$). After 16 consecutive years of plantation, the soil fertility status improved significantly over their initial values. Organic carbon content of the surface soil increased significantly due to high accumulation of litter and balanced fertilization. A building-up of soil available P and K was also observed. The trends clearly emphasized the need for balanced fertilization of mature rubber for consistent productivity and also maintained the soil quality through improvement of soil fertility.

Collected 24 soil samples from the 12 rubber growing areas of Meghalaya and analyzed for available nutrients. Soil samples were also collected for soil moisture study during stress period from West Garo hills of Meghalaya. The results of the soil moisture retention under rubber showed the same trend for organic C, available P and K. Soil moisture showed synergistic effect with increasing depth of soil and seen between field capacity and Permanent Wilting Point (PWP) – 20.14 to 24.45 per cent.

3. Crop physiology and exploitation

Growth and yield components data recorded for RRIM 600 clone at monthly intervals revealed that low temperature adversely affected the growth but enhanced the total volume of latex and yield. Lowest DRC (25 %) was recorded during January and February while 25-27 per cent DRC recorded during defoliation and refoliation period.

Performance of clone RRIM 600 in West South West (WSW) and North North East (NNE) aspect of slope showed the same trend.

The different tapping systems in combination with tapping rest especially during winter season was studied. In 1/2 S d/2 tapping system maximum yield was observed in 10°-10° C temperature regime (60.3 g/t/ t) followed by control (58.9 g/t/t) while in 1/2S d/3 tapping system maximum yield was in control treatment (64.0 g/t/t) followed by 20°-20° C temperature regime (59.1 g/t/t). In 1/2S d/2 system TPD incidence was 5 per cent while in 1/2S d/3 system it was 3 per cent. ■

Regional Experiment Station, Nagrakatta, West Bengal

Contributions since establishment

The Regional Experiment Station was established in 1989 at Grassmore, Nagrakatta in an area of 47.5 ha, which is located at latitude 26° 54'N, longitude 88° 25'E and at an elevation of 69 mmsl. The soils of the area is well drained sandy loam and acidic in reaction (pH 4 – 4.5) and high in organic carbon but deficit in available phosphorus and potash content. The climate of the Station is characterized by humid tropic with an average rainfall of 3200 mm, mainly concentrated between May and September with peak during July. Considering the specific requirement of the region, the mandate under which this Station was established is to find out suitable clones for the region, evolve appropriate fertilizer recommendations and to develop a suitable exploitation system for the region.

On the basis of girth at 5th year of tapping, it was observed that RRIM 612 is the best growing clone followed by SCATC 93/114, RRII 208 and RRIM 605 in this region. Rubber yield over a span of initial five years revealed that the best performing clone is SCATC 88/13, followed by RRIM 605. Screening of 22 wild germplasm along with three check clones at juvenile stage showed that only one ranked high in all aspects i.e., RO 5363. The RO 2890 and RO 5557,

though showing high girth with fairly high bark thickness, did not show high yield at juvenile stage. Similarly, AC 1950 and AC 763, though showed second highest test tap yield, did not show high bark thickness or girth. Thus, it seems that girth, bark thickness and juvenile yield are independent components and may not control the performance of the germplasm studied. The study on rainguarding indicated a loss of 27 tapping days due to rain in North West Bengal. Rainguarding in this region provided extra tapping of 21 days.

Application of 40 kg N per ha recorded significantly high girth, girth increment and per cent tappability where P and K failed to show any effect during immature phase. During maturity, positive response of N was found only up to 15 kg/ha but N, P and K had no significant effect on girth and yield of rubber. Interaction effect of different fertilizer combinations was also found non-significant. Two split applications of fertilizers recorded maximum yield whereas four split applications recorded higher growth. Cropping system studies observed that tea could be successfully grown as an intercrop with rubber with a change in crop geometry.

Ongoing Research Programmes

1. Crop improvement

In clone trial (CT) I, SCATC 93/114 showed highest girth (73.0 cm) followed by Haiken 1 and RRIM 703 (70.1 and 70.0 cm); in CT II, RRIM 612 showed highest girth (70.9 cm) and in CT III, PB 235 (68.4 cm) followed by Haiken 1 (65.1cm). In CT IV, PB 280 showed highest girth (61.0 cm). In terms of yield, SCATC 88/13 showed higher value (47.6 g/t/t) followed by PB 235 (44.2 g/t/t) and PB 311 (40.4 g/t/t) in CT I. In CT II, RRII 208 showed highest yield (47.6 g/t/t) followed by RRIM 605 (41.6 g/t/t). Haiken 1 and RRII 105 ranked high (39.2 and 37.4 g/t/t) in CT IV.

Among the 22 genotypes tested for adaptability, only one accession scored the highest position on the basis of girth, bark thickness and juvenile yield. In the test tap yield for three consecutive years also, it showed stable high yield.

During 2005-06 about 128 polyclonal seedlings showed above 3 kg/t/year yield, out of which 23 plants showed yield more than 6 kg/t/year. Promising selections were cloned and maintained in the budwood nursery for future use.

2. Crop management

As observed during previous years, different combinations of fertilizers have no significant effect and there was no significant difference among different split treatments.

It was observed that tea intercroppped with paired row planting of rubber was doing well. The trial on growing arecanut as an intercrop with rubber has shown that girth was maximum under pure arecanut indicating an adverse impact of rubber on growth of arecanut.

3. Crop physiology and exploitation

It was observed during 2005-06 also that 1/2S d/2 system with 12-12 °C regime of temperature rest treatment was the best combination of tapping system for this region. ■

Regional Research Station, Dapchari, Maharashtra

Contributions since establishment

The Regional Research Station set up in the North Konkan region of Maharashtra (Western India) 15 °N to 20 °N at Dapchari, Dahanu Taluk of Thane District, in 1981, towards 145 km north of Mumbai, is one of the less congenial but potential regions selected for trying rubber cultivation in view of the limited scope for expansion of area under rubber in the traditional belt.

The land for the Station was leased from the Diary Development Project of Maharashtra State Government. The Station is having 50 ha of land planted with various field experiments. The Station was elevated to the status of Regional Research Station during 1986. Presently rubber area under tapping is around 22.28 ha and 36 ha of land is under plantation with 18 clones by the various research divisions of RRII. This Station has lateritic clay loam (well drain) soil with pH range of 6.0 to 6.5. The type of climate is humid with seasonal dry period with average rainfall of 2499 mm (wet period June to October). Maximum temperature ranges between 22 to 43 °C and minimum temperature between 6 to 29 °C and the sunshine duration reaches as high as 12 hours.

Mandate of establishment of the Station is to find out the feasibility of rubber cultivation in North Konkan region, study the yield performance of various clones, workout economic feasibility of rubber cultivation in this area and to evolve suitable clones and specific agro technology for the region.

Prolonged drought with very high photosynthetic active radiation intensity, sunshine hours, temperature and low relative humidity and rainfall are major constraints for rubber productivity in North Konkan region of Maharashtra. Evaluation of suitable clones and polyclones for this agro-climatic condition with desirable characters like tolerance to water and high temperature stress conditions and agro management technique is given prime consideration through research projects. The growth and yield parameters of different clones under different experiments are being monitored and recorded. Low frequency exploitation system is also monitored. In polyclone seedling evaluation trial, a close monitoring of soil moisture percentage by soil moisture meter was carried out to study the tolerance of the selected polyclonal trees to low soil moisture. 235 accessions were screened for drought tolerance potential in three different experiments from 2001-2003.

In the irrigation experiment, basin irrigation system has proved to be better than drip irrigation system for growth and yield. Eighty per cent tappability was achieved in the sixth year with adequate irrigation, while rainfed plants attained tappability only in 11th year of planting. In the clone evaluation experiments, the performance of various clones were evaluated and RRII 208 and RRIM 600 were found to be most suitable for this agro-climatic condition. Evaluation of polyclonal seedling population resulted in the selection of desirable drought tolerant genotypes which yield more than 1.2 tonnes/ha/yr without life saving irrigation. Evaluation of wild *Hevea* accessions resulted in 18 potential drought tolerant accessions

Table Dap. 1. Growth and yield of *Hevea* clones

Treatment	Girth (cm)	Dry rubber yield (g/t/t)
RRII 5	59.24	25.19
RRII 6	62.86	36.47
RRII 105	56.49	34.13
RRII 208	64.69	44.51
RRII 308	55.65	14.83
RRIM 605	57.17	17.63
PB 260	59.84	23.80
PB 310	59.23	25.13
PB 311	56.75	20.78
RRIC 52	65.25	17.44
RRIC 100	58.75	26.48
RRIC 102	59.40	26.57
RRIC 105	55.41	16.74
PR 255	57.24	25.89
PR 261	56.61	19.17
SE	0.42	5.97
CD (P=0.05)	0.86	12.21

based on 3 – 4 years performance.

Ongoing Research Programmes

The thrust areas of this Station are development of suitable planting materials and location specific agro technology for this drought prone region.

1. Environmental physiology

The highest girth (70.80 cm) was recorded in 1.00 ETc basin treatment. Highest yield (33.03 g/t/t) was recorded in 0.75 ETc level of drip irrigation as compared to all treatments. The results of the study, the effect of different levels of irrigation on yield and yield components of two clones *viz.*, RRII 105 and RRII 118 indicated that clone RRII 118 performed better in terms of growth in response to different levels of irrigation treatments. The trials for the evaluation of economics of irrigation continued. All irrigation trails were affected due to failure of irrigation system during summer.

2. Exploitation studies

Implementation of stimulation and irrigation schedule got affected for the two trials (which were initiated for evolving optimum stimulation schedule under irrigation due to failure of irrigation system) from March 2005 onwards.

Implementation of stimulation was stopped for the experiment to study the effect of tapping rest-cum-stimulation under low frequency tapping system (1/2S d/3) in clone RRII 105 under rain fed condition due to drying of trees from January 2005 onwards.

3. Evaluation of planting materials

The results of the clone evaluation trial (1985) indicated that clone RRII 208 is continuing to perform better in terms of growth and yield (Table Dap. 1). ■

Regional Research Station, Dhenkanal, Orissa

Contributions since establishment

The Regional Research Station, Orissa was established in 1987 at Kadalipal, Kamakhynagar in Dhenkanal city, 60 km away from Cuttack and 90 km from Bhubaneswar, the capital city of Orissa. This Station lies between 19 and 22° N latitude and is clearly outside the traditional rubber growing regions. The Station concentrates in research activities to develop suitable clones and agromanagement techniques for specific drought prone areas of this region.

Field trials revealed that clones RRII 208, RRII 105, SCATC 88/13, RRIM 600, RRII 5 and polyclonal seedlings performed better in growth and yields, showing stress tolerance in this region. In the other clone trials RRII 208, RRII 105, RRII 5, RRIM 600, SCATC 88/13 and polyclonal seedling trees recorded significantly higher yield (1294 – 1580 kg/ha) in this region. The juvenile yield of RRII 400 series clones showed that RRII 429 was the high yielder (14.9 g/t/t) followed by RRII 422 (13.8 g), RRII 105 (10.6 g), RRII 417 (9.8 g) and RRIM 600. No incidence of powdery mildew disease was noticed so far in this region.

In weed control trial, Glyphosate (3 l/ha) was effective in controlling the growth of the noxious weed (*Imperata*

cylindrical) and other grassy weeds in this region. In soil moisture studies on the growth and yield of rubber, maximum growth of rubber was observed during July to November, while in rest of the months lower girth was noticed in this region.

Ongoing Research Programmes

The Station continued its research activities on nutritional studies and clone evaluation to identify clones suited to this dry sub-humid region.

1. Crop improvement

In the 1987 clone trial, both GT 1 (65.5 cm) and RRIM 600 (64.0 cm) recorded significantly higher mean girth over RRII 105 (59.9 cm). RRIM 600 has recorded highest mean yield of 30.6 g/t/t followed by RRII 105 (27.7 g/t/t) (Table Ori. 1). In the 1990 clone trial, no significant difference in girth among the clones was recorded. Highest mean girth was recorded in SCATC 93/114 (72.0 cm), the highest annual girth increment in RRIM 600 (2.9 cm) and the highest mean yield in RRII 208 (37.1 g/t/t). In the 1991 clone trial, the performance of *Hevea* clones with polyclonal seedlings was compared. Among the clones GT 1 (73.0 cm) recorded highest girth closely followed by RRIC 102 (68.7 cm) and RRII 208 (68.3 cm). However, polyclonal seedlings with a mean girth of 78.9 cm showed better tolerance. Maximum mean girth increment was noticed in RRII 208 (3.5 cm). RRII 208 recorded higher mean yield (39.6 g/t/t) followed by RRII 105 (35.5 g/t/t). In the 1996 onfarm clone trial, at RRL, Bhubaneswar, RRII 430 (48.23 cm) and RRII 417 (45.11 cm) showed higher girth over the other clones. In the 1999-2000 clone trial, highest mean girth was recorded in RRII 105 (32.8 cm) followed by IRCA 111 (32.7 cm), RRII 300 and RRII 352. The lowest girth was recorded in RRII 51 (24.2 cm).

In the polyclonal seedling trial (1989), the highest mean girth was recorded in tree No.32 (119.1 cm), followed by tree No.471 (117.0 cm). Maximum annual mean yield was recorded in tree No.154 (69.4 g/t/t) followed by No. 452 (60.0 g/t/t), and minimum in tree No. 280 (23.4 g/t/t).

Table Ori. 1. Mean girth and yield of three elite clones

Clone	Girth (cm)	Yield (g/t/t)
RRII 105	59.9	27.7
RRIM 600	64.0	30.6
GT 1	65.5	22.3

2. Crop management

The 1999 trial laid out with RRIM 600 to study the effect of water soluble and water insoluble forms of P on growth of *Hevea* revealed that water soluble P fertilizer and split applications were better than water insoluble source in young rubber plants and highest girth was observed in 60 kg N, 60 kg P_2O and 24 kg K_2O per ha. ■

Regional Research Station, Padiyoor, Kerala

Contributions since establishment

The Regional Research Station at Padiyoor in Kannur District started functioning in an area of 40 hectare in 1994. The Station is situated at latitude of 11°58'N and longitude of 75°36'E. The Station receives an average annual rainfall of 3500 mm with 70 per cent of the total rains during the SW monsoon season. Summer showers are relatively less and the region is characterized by a prolonged dry spell of 4 to 5 months from December to May with a cumulative water deficit ranging from 500 mm to 600 mm along with high temperatures. The high gravel content of the soils in general coupled with low to moderate levels in per cent base saturation and the low cation exchange capacity of the soils indicate the susceptibility of the soils to rapid decline in soil fertility thereby demanding specific management measures to maintain soil fertility.

The working of the Station commenced with the major objective of identifying clones suited to the region, development of specific agro-management techniques and evaluation of clonal tolerance to drought and diseases. A total of 14 research projects are in progress in the Station. The Station has a well established meteorological observatory and maintains a budwood nursery of promising clones of rubber.

The germplasm accessions are screened for yield and other secondary attributes

Table Pad. 1. Influence of different levels of irrigation on growth

Treatment	Number of irrigations	Girth (cm)					
		Dec	Jan	Feb	Mar	Apr	May
IW/CPE 1.2	16	39.5	38.8	38.6	38.8	38.9	40.4
IW/CPE 0.9	12	37.6	37.6	37.2	37.5	37.6	39.0
IW/CPE 0.6	9	39.0	38.9	38.7	38.6	38.7	39.9
IW/CPE 0.3	4	34.6	34.5	34.3	34.2	33.9	35.4
Control	Nil	33.8	33.6	33.5	33.4	33.3	34.4
SE		1.22	1.29	1.25	1.26	1.3	1.34
CD (P= 0.05)		3.75	3.97	3.85	3.87	4.02	4.12

such as disease tolerance and timber characteristics. A trial of germplasm accessions showing good timber characters has been initiated separately for selection of accessions with good timber quality coupled with yield. The superiority of the 400 series clones with respect to growth was established in the region. These clones have been screened for powdery mildew tolerance, abnormal leaf fall and pink disease. Pink disease was found to be higher in clone RRII 429 in the region.

The effect of irrigation on clone RRII 105 has indicated that the girth of plants recorded a significant superiority with irrigation (deficit irrigation at 50 per cent level) during the immature phase compared to the unirrigated plants.

Trial on cropping systems with rubber and cashew planted in 2001 showed no inhibition of tree growth. A trial on evaluation of *Hevea* clones and ortet selections under high altitude situations (974 m msl) in Wayanad district is monitored by this Station. The trial has shown promising results with the ortet selection Iritty 1 showing the highest degree of disease tolerance to powdery mildew followed by the ortet selections P 90 and P 270 while clones RRII 105 and RRII 203 were highly susceptible to the disease.

Ongoing Research Programmes

The Station continued with research programmes to identify clones suited to the region with drought and disease tolerance.

1. Crop management

In the study on physico-chemical characterization of soil, the basic analytical work has been completed. The soils in general were moderately deep to very deep in most of the profiles studied and had sub-angular blocky surface horizons and weak angular to sub-angular blocky sub-surface horizons. The soils contained higher quantity of clay fractions irrespective of geo-morphic conditions. The soils were strongly acidic with considerably high organic matter contents which decreased with depth. Per cent base saturation of soils was low to moderate (17 to 76%) and the cation exchange capacity of the soils was low and varied from 5.4 to 15.0 cmol (p+)/ kg suggesting that they are subject to very rapid decline in fertility demanding specific management practices. The presence of 1:1 layer silicate clays and oxides of Fe and Al in the clay fractions

indicate poor release of nutrients through mineral wintering. Work on digital elevation mapping is being undertaken.

The experiment initiated in immature rubber with different irrigation levels indicated that irrigation significantly influenced the girth and girth increment of the plants (Table Pad. 1).

Results of the trial on rubber and cashew cropping system initiated in 2001 indicated that interplanting of cashew in rubber has not affected the girth of the trees in the combination. The average per tree yield of cashew in the treatments ranged from 1.7 kg to 2 kg. The highest yielding tree recorded an yield of 5.5 kg. The treatments of the 2002 experiment comprising 3 clones with four fertilizer levels, found that there was no significant difference in girth of plants due to different doses of fertilizer applied. ■

Hevea Breeding Sub-station, Nettana, Karnataka

Contributions since establishment

The Station was established in 1986 for carrying out location specific research activities. Office-cum-laboratory complex of the Station is located at Kadaba in the Puttur taluk of Dakshina Kannada District. The Station conducts most of its research activities in a 50 ha farm located 12 km away and the location falls under coastal region (Region VI) of the major agro-climatic regions of Karnataka. The rain fall pattern is characterized by four to five dry months, followed by pre-monsoon, monsoon and post-monsoon periods. Most of the rainfall is received during May to August. The major soil type is of lateritic and coastal alluvium. Annual average rainfall received is around 4524.70 mm. The maximum temperture ranges from 21.5 °C to 43 °C and minimum temperature from 6.4°C to 30°C.

In three small scale trials consisting of 57 ortets clones GT 1, T2, C 1/2, C 42, O 17, T 1, O 40, O 56, O 39A, and RRII 105 are the high yielders over four years of tapping.

In two large scale clone evaluation trials incorporating 14 and 15 clones each mean yield over four years of tapping

showed that RRII 203, KRS 25, KRS 163, PB 260, PB 235 and RRII 105 are the leading clones. Another set of 62 clones of both indigenous and exotic origin are being evaluated in three trials. Based on mean yield over two years of tapping PB 314, PB 235, PB 280, PB 312, PB 311, RRII 105, RRII 5, Nab 17, HP 83/224, HP 83/225 and PR 261 were the top yielders. In the experiment on estimation of genetic parameters, 12 clones and their progenies are under evaluation. In general, yield of half-sibs of high yielding clones was higher and yield of half-sibs of low yielding clones was lower.

A clone trial of six RRII 400 series clones along with their parents was established. Apart from the above a polycross garden with nine clones was established in 1995 for producing open pollinated seeds.

Effect of different exploitation systems on yield performance indicated that compared to d/2 and d/3 systems without stimulation, d/4 system with stimulation was better for RRII 105, RRII 300, PB 235, PB 260, PB 311 and RRIC 45.

Severe out break of Corynespora leaf fall (CLF) disease was first observed in mature rubber in HBSS, Nettana, Dakshinakannada District, Karnataka and adjoining regions of Kerala during 1996 - 97. Survey on disease intensity, spread and clonal susceptibility in major rubber growing regions of Karnataka and North Malabar region of Kerala revealed that the CLF disease incidence is spreading towards traditional rubber growing regions of Kerala and disease intensity varied from region to region. This Station has undertaken many disease management projects in this region to face the possible threat. Experiment was carried out to study the efficacy of oil-based, water-based and dust fungicides in CLF disease control. Among the oil-based fungicides mancozeb 75% (ODP), mancozeb 50% liquid formulation @ 7 kg/ha and COC 56% ODP @ 8 kg/ ha were found to be effective for the disease control. COC 56% (ODP) is recommended in mature rubber plantations. Hexaconazole 2% dust formulation @ 7 kg/ha was found to be more superior in mature rubbers among the dust fungicides tested. Carbendazim @ 1g/l, mancozeb @ 2.66 g/l and SAAF @ 2 g/l are found to be effective for disease control in nursery as well as in immature rubbers.

Screening of *Hevea* clones against CLF was done at HBSS, Nettana. Clone RRII 105, PR 255, PR 261 and PB 28/83 showed more disease intensity and the intensity was comparatively less in GT 1, RRIM 600, KRS 163, RRII 5, PB 86, IAN 45/873 and KRS 25. Among the 10 pipe line clones in Karnataka region RRII 427 and 422 recorded disease intensity of > 10 per cent. Screening of *Hevea* clones for powdery mildew disease at higher elevation revealed that the clones RRII 118, GT1 and Tjir 1 are less susceptible and PB 235, RRIM 501 are highly susceptible to powdery mildew disease.

A field study on pattern of disease development of CLF and *Colletotrichum* leaf spot (CLS) revealed that both the diseases appeared in the rubber plantations and caused more damages to younger leaves. CLF disease intensity peaked during second fortnight of March to first fortnight of April. The disease decreased considerably after the onset of rains. CLS disease did not cause considerable economic damages to mature rubbers but it poses serious problems in nurseries and in very young rubbers.

Experiment to study the impact of different fertilizer levels and ground spraying of herbicides and fungicides in CLF disease development was initiated in rubber plantation owned by Karnataka Forest Development Corporation Ltd.

Table Kar. 1. Performance of top yielding ortets in the 1988A, B and C ortet trials

Trial	Clone	Girth (cm) at age 18 years	Mean yield (g/t/t)	Mean yield over four years of tapping (g/t/t)
1988A	T 2	93.1	64.5	64.8
	C 1/2	82.0	64.9	64.4
	C 42	87.7	62.4	62.3
	O 17	92.1	61.4	60.8
1988B	T 1	93.7	63.2	68.8
	O 40	81.6	58.2	59.9
	O 53	81.2	56.5	58.2
1988C	O 56	72.7	82.3	75.6
	O 39 A	65.8	88.8	75.0
	O 55	50.6	61.7	65.7
	C 140	88.5	57.1	64.9
	O 64	77.2	59.5	59.3
Control clones*	GT 1	83.0	65.0	66.9
	RRII 105	72.1	63.0	62.6
	RRIM 600	74.6	55.8	53.3

*Mean of three trials

Table Kar. 2. Performance of clones

Trial	No. of clones	2004-05 Highest	2004-05 Lowest	2005-06 Highest	2005-06 Lowest
1989	14	RRII 203 (62.4 g) KRS 25 (53.11 g)	SCATC 93/114 (14.57 g)	RRII 203 (64.3 g) KRS 25 (58.8 g)	RRIM 600 (27.9 g)
1990	15	PB 260 (62.49 g) PB 235 (56.54 g)	-	PB 260 (59.0 g) PB 235 (52.5 g)	Tjir 1 (17.3 g)
1991 A	36	PB 235 PB 280	-	PB 314 (91.9 g) PB 235 (88.3 g)	Ch 4 (13.8 g) Haiken 1 (15.8 g)
1991 B	13	RRII 5 Nab 17	-	RRII 5 (70.6 g) Nab 17 (55.9 g)	Ch 3 (25.4 g) RRIC 52 (29.8 g)
1991 C	13	HP 83/224 HP 83/225	-	HP 83/224 (64.0 g) HP 83/225 (48.8 g)	Pil B/84 PB 5/51

and private plantations in Karnataka. Corynespora leaf fall disease awareness programme was arranged to make growers aware of the threat caused by the disease. As a part of the programme demonstration spraying was carried out using effective fungicides in severely infected mature and immature rubber plantations in this region during 1996 -97.

Ongoing Research Programmes

The major thrust areas of research of the Station are evaluation of clones under different biotic and abiotic stress factors and to develop appropriate ex-

ploitation and crop protection schedules for this region.

1. Crop improvement

Performance of top yielding ortets from the three clone trials is given in Table Kar. 1.

The high and low yielders in the four clone trials showed almost the same trend during the last two years (Table Kar. 2).

The trial initiated in 2000 revealed that clones RRII 430 and RRII 414 recorded maximum growth (50.0 cm) followed by RRII 429 (43.2 cm) after six years of growth. Parent clones RRII 105 and RRIC 100 recorded a girth of 38.7 and 38.0 cm respectively. RRII 422 was the least vigorous clone (31.6 cm).

Results of the trial initiated in 1990 with 12 clones and their progenies for estimating genetic parameters revealed that PB 235, RRII 105 and RRII 203 were leading in yield with 72.1, 56.0 and 50.4 g/t/t respectively. Among the progenies, half-sibs of RRII 203, GT 1 and PB 235 recorded a yield of 45.3, 41.3 and 40.3 g/t/t respectively. Trends in mean yield over three years of tapping were similar to that observed in the year 2005. In general, yield of half-sibs of high yielding clones was higher and that of low yielding clones was lower.

2. Crop protection

Disease survey was carried out to assess the *Corynespora* leaf fall disease intensity, spread and clonal susceptibility in major rubber growing regions of Karnataka and North Malabar region of Kerala. Survey revealed that diseases intensity varied from region to region. Maximum of 36.5 per cent disease intensity was recorded in Belthangady region of Karnataka followed by Puttur and Kundapura. Less disease intensity was recorded in Sagar and Thirthahalli region. Among the regions surveyed in Kerala, Kanhangad registered a maximum of 32 per cent disease intensity followed by Taliparamba and Kasaragod.

Screening of new *Hevea* clones against different leaf disease tolerance was done at HBSS, Nettana farm. Among the 10 pipe line clones assessed, clones RRII 427 and 422 recorded less than 10 per cent disease intensity. Clones RRII 430 and 429 recorded slightly higher Gleosporium leaf spot disease (>15%). Preliminary observations on *Corynespora cassiicola* epidemiology study showed periodicity/ variation in the spore release in infected rubber plantations. More number of spores were deposited during the cooler climate than warmer weather. Regular observations on weather, changes in soil nutrients, disease intensity and growth parameters were recorded. Experiment to study the impact of different fertilizer levels on *Corynespora* leaf fall disease under the CFC funded project.

3. Exploitation systems

In the 1988 trial, yield observed under $^{1}/_{2}$S d/3 system without stimulation and $^{1}/_{2}$S d/4 with stimulation were comparable in clones RRII 118, PR 255, PR 261 and RRIC 36. ■

Hevea Breeding Sub-station, Paraliyar, Tamil Nadu

Contributions since establishment

Kanyakumari District of Tamil Nadu is characterized by a climate favourable for good seed set and the area is well known for the low incidence of *Phytophthora* and Pink diseases. Under the above circumstances, the *Hevea* Breeding Sub-station, Kanyakumari was established during 1986 to concentrate on the breeding activities in *Hevea*. In order to facilitate hand pollination two systematically laid out breeding orchards were established consisting of 51 modern clones as parents. By constant pruning and pollarding of branches the canopy of all the parental clones were maintained at a low profile so that hand pollination could be attempted conveniently from the ground. Wintering pattern and detailed floral biology of all the parental clones were characterised and methods were standardized to improve the turn over of hand pollination and also to get enhanced fertility of hand pollinated flowers. Crossing at various parental combinations are being attempted at every flowering season and the resultant hybrids are under different stages of evaluation.

At present advanced planting materials of *Hevea* are being produced in polybags. But, polybag planting tech-

ploitation and crop protection schedules for this region.

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At present advanced planting materials of *Hevea* are being produced in polybags. But, polybag planting tech-

nique was found to have a number of drawbacks like coiling of tap root, spiral growth of lateral roots etc. In order to avoid these drawbacks an alternative planting technique, known as root trainer planting technique, was standardised at this Station. Advanced planting materials of *Hevea* could be raised in root trainers at half the cost of production of polybag plants and the cost towards transportation, field planting etc. could be saved up to 66 per cent. The root trainer plants showed 100 per cent establishment success in the field and the root trainer derived plants were found to outperform polybag plants in the initial years.

In order to identify planting materials suitable for the particular agro-climate, a total of 23 modern clones are being analyzed at this Station under three large scale clone evaluation trials. Block evaluation of hybrid clones belonging to the 400 series were initiated at three large plantations in the private sector. A polyclonal seed garden consisting of nine modern popular clones as parents was established in an area of 9 ha of land in a private estate during the year 2000.

Ongoing Research Programmes

The research activities of the Station include hybridization and selection, clone evaluation, maintenance of polyclonal seed garden and studies on plant propagation techniques.

1. Crop improvement

Pruning/pollarding of branches of parental trees of the breeding orchard were done regularly to avoid growth of branches to undesirable heights. Hand pollination was attempted with different parental combinations aimed at evolving latex timber clones. The hybrid seeds were raised in a nursery for preliminary evaluation. The hybrids selected from hand pollination carried out in previous years were maintained as source bush for multiplication and further evaluation. The seeds collected from the breeding orchards were rised separately in a nursery for evaluation and selection of high yielding ortets.

In the large-scale trial (1994) yield recording was continued in the fifth year by cup coagulation method at every month. Unlike in the previous year PB 255 (83.51 g/t/t) had the maximum yield closely followed by PB 314 (81.30 g/t/t) and IRCA 109 (81.17 g/t/t). The mean dry rubber obtained from the remaining 8 clones included in the trial is presented in Table Par. 1. In the block trial (1994) consisting of 13 modern popular clones, PB 311 (2.17 g/t/t) could be ranked first in terms of yield obtained during 2005-06 followed by PB 235 (53.34 g/t/t). The mean dry rubber yield obtained from the remaining clones did not show much variation from the control clone RRII 105 (47.81 g/t/t), except for RRII 51 which has given a mean yield (36.66 g/t/t) much less than the remaining clones included in the trial. In the evaluation of clonal composites (1994) the composite consisting of RRII 5 (15 %), PB 235 (35 per cent) and RRII 105 (50 %) has presented a comparable yield (52.18 g/t/t) to control plot with RRII 105 alone (47.81 g/t/t). Abnormal leaf fall and pink disease were not observed during 2005-06.

In the G x E interaction trial of *Hevea* clones (1996), RRII 203 registered a mean yield of 83.16 g/t/t, which is 8.3 per cent more than the mean yield obtained from RRII 105 (76.77 g/t/t). The hybrid clone RRII 422 (78.80 g/t/t) showed numerically better yield than RRII 105. The initial yield trend of RRII 429 (47.80 g/t/t) was found to be very poor compared to its performance in the agroclimate of Kerala.

The observational trial established at Vaikundam Estate (2000) has attained tappable girth at 5 ½ years and the

plot was opened for regular tapping. In the block trial at New Ambady Estate (2002), RRII 414 exhibited the maximum growth (27.35 cm) at the fourth year. At Velimalai Estate (2002), RRII 429 (28.34 cm) was found to grow as vigorously as the control clone PB 260 (28.44 cm) at fourth year of planting.

Table Par. 1. Performance of clones in the large-scale clone trial (1994)

Clone	Girth (cm)	Yield (g/t/t)
RRII 105	67.39	49.13
RRIM 703	72.63	61.90
PB 255	76.65	83.51
PB 314	71.93	81.30
PB 330	70.76	59.13
PB 28/59	64.24	51.34
IRCA 18	67.70	63.39
IRCA 109	70.64	81.17
IRCA 111	77.83	77.50
IRCA 130	67.17	72.20
IRCA 230	76.61	52.03
GM	71.23	66.6
CD	4.27	6.47

The block trial at Bethany Estate (2006) was initiated to represent an agro climate having an annual rainfall of 2000 mm or less. The microclimate of Palazhi estate is found to be most suitable for rubber.

2. Crop management

The root trainer plants were noticed to grow more vigorously at all the three locations at Churulacode (2001), Velimalai (2002) and Thirunanthikarai (2002) up to the fifth year of planting. One block each of root trainer and polybag plants of the 400 series clones were transplanted at Kanjirappally during the month of July 2005.

3. Polyclonal seed garden

The polyclonal seed garden was well maintained and the early fruit set is being closely monitored. The bud wood nursery was further expanded during 2005-06 and the bud wood of RRII 105, RRII 414 and RRII 430 and RRIM 600 were supplied to planters belonging to southern districts of Kerala and Kanyakumari district of Tamil Nadu. ■

Library and Documentation Centre

Contributions since establishment

The Library attached to the Rubber Research Institute of India (RRII) was established in 1963 with a view to disseminate information on rubber research and rubber industry. The main objective of the library is collection, storage, organization and dissemination of information on rubber and allied fields to support natural rubber research, natural rubber industry and other related areas. RRII library with its vast resources and service facilities, occupies unique place among the agricultural libraries in the country.

At present the Library has a total collection of 56,590 documents which consists of 22,810 books, 21,128 bound volumes of periodicals, 2500 reprints, 152 theses and about 10,000 standards. Library subscribed to 145 journals in addition to the CAB and RAPRA CDs.

As part of documentation work and bibliographic services, library publishes various information bulletins such as *Documentation List, Rubber Alerts, List of New Additions, Current List of Periodicals, SDI Bulletins* etc. Also provides CD-ROM literature searches, online access of journals, press clipping, docu-

ment delivery, interlibrary loan, reprographic service etc. The library maintains adequate linkage with leading libraries *viz.*, NISCAIR, New Delhi; NCL, Pune and IISc, Bangalore for strengthening information resources.

The book collection covers various aspects of natural rubber and related areas like crop management, crop improvement, biotechnology, crop physiology, exploitation, crop protection, entomology, rubber technology, rubber processing, rubberwood, agricultural economics, statistics and general reference books. Conference proceedings and symposia from other rubber research institutes and international rubber organizations are available in the library. Some of the old and rare books on rubber are kept in reference collection. The library follows the Universal Decimal Classification scheme.

The Library has compiled and published a series of bibliographies and other publications for proper bibliographic control of literature on NR. The cumulative volume, *50 Years of Natural Rubber Research in India: A Bibliography* published in 2005 contains bibliographic details of scientific and technical contributions from the RRII and Rubber Board during the period 1955-2005. Bibliographies covering publications during 1955-1983 and 1984-1994 were published in two volumes, earlier. Five annotated bibliographies on *Rubberized Bitumen* (2001), *Rubber Seed and its Commercial Applications* (2003), *Exploitation Technology of Hevea* (2003), *Tapping Panel Dryness* (2005) and *Rubber Based Farming Systems* (2006) were brought out. Also published a *Directory of Rubber and Allied Organizations* (2001).

The publication *RRII Library Holdings: Serials 1922-2005* serves as a tool for easy retrieval of information regarding the availability of bound volumes of periodicals at the RRII Library. Its earlier edition published in 1997 provides details of bound volumes upto 1995.

The library is actively engaged in sales and distribution of publications from RRII. In addition to the above services, library facility is also utilized by students, research scholars, rubber growers and other stakeholders of rubber industry.

Ongoing Activities

During the reporting year, 108 books were added to the stock of the library. The library subscribed to 145 journals and about 30 journals were received as gift/exchange. The major achievement during this reporting period was the compilation and publication of the four publications in connection with Golden Jubilee celebrations of RRII. They are: (1) *50 Years of Natural Rubber Research in India: A Bibliography* (2) *Tapping Panel Dryness: An Annotated Bibliography* (3) *Rubber Based Farming Systems: An Annotated Bibliography* and (4) *RRII Library Holdings: Serials 1922-2005.*

Five issues of Documentation List, three issues of Rubber Alerts and 97 SDI bulletins were brought out. Photocopies of 27 articles were procured from other institutions/libraries and 21 articles were sent to institutions/individuals upon request during this period.

The first issue of Vol.18 of RRII journal, *Natural Rubber Research* was published during the year. Co-ordinated the publication of seven books/bibliographies brought out as part of the Golden Jubilee celebrations of RRII. A 16 page multicolour brochure on RRII was also brought out. As part of the sales promotion, organized the sales of RRII and Rubber Board publications worth Rs.50,000/- at International Natural Rubber Conference (INRC), held at Cochin in November 2005. ■

Statistics and Computer

Contributions since establishment

Statistics section which was established in 1990 is catering to the needs of planning an designing of research projects; statistical analysis and interpretation of data pertaining to field and laboratory experiments; analysis of secondary data for reducing error in the experimental designs; training scientists from Regional Research Stations and Regional Labs on design of field experiments and use of statistical tools and the development of computerized programmes for statistical analysis.

Computer Section is providing computer/system associated technical support to the different Departments of the Board functioning in the RRII campus, which includes:

- Network maintenance with system administration and reconfiguration of various n/w equipments like Routers, Layer III, Layer II switches etc. to maintain different VLANs configured in the heterogeneous network.
- System administration and fine tuning of Servers and Database installed in the LAN.
- Facilitates broadband internet facility in the LAN with ISDN backup to get trouble free net connection.
- Systematic scheduled backup of the servers in the LAN.

- System analysis, design and development of application programmes to meet immediate requirements.
- Design and creation of new databases for the research data storage.
- Daily updation and maintenance of official website with relevant data.
- Specification formulation, tabulation and product recommendations in computer and peripheral purchases.
- Facilitates e-journal and CD database access in the network.
- Provides common access facility as a computer lab with adequate network nodes and common shared peripherals for network related computing, data entry, data analysis and information access.
- Maintenance of all PCs in the campus as well as PC installations at the Research outstations
- Provides Individual e-mail ids to Departments, Divisions, Sections, Scientists and senior officers of the Board for speedy and efficient official communication under the domain mail rubberboard.org.in.

This Section is also catering to the research, analytical and survey based works of other departments of the Board *viz.*, Rubber Production, Training and Technical Consultancy and Processing and Product Development. ■

Instrumentation

Contributions since establishment

The Instrumentation Section was established under the Rubber Research Institute of India in the year 1973 with a view to look after the instruments and machineries attached to the Institute. The section now maintains around eighty sophisticated and a number of common instruments and electronic office equipments in different research divisions, regional research stations and laboratories in different parts of India.

In addition to the general repair and maintenance work, the section had designed and fabricated instruments for various testing purposes. The indentation hardness testers, flexing and cutting machineries and special ageing ovens for rubber foam and rubberized coir foam products were designed as per Indian Standards Institution's guide lines and fabricated locally. These machineries are used for testing these products at the Specification/ Technical Consultancy Division since 1983 for ensuring quality norms as per Indian Standards Institution.

Popularization of electric fences for the protection of rubber nurseries/ plantations from wild animals was an important contribution from this section. Electric fence systems were installed by the section at a private plantation in Thuttampara, Nelliampathy during 1988,

Hevea Breeding Sub Station (HBSS), Nettana in 1990 and at the Regional Research Station, Nagrakatta in 1994. These installations have proven that the young nurseries and plantations adjacent to forests can be protected from the attack of wild animals.

Software packages were developed for books/ periodicals movement in the Library and cross-link density measurements in the Rubber Technology Division. Design and fabrication of cyclic timers, temperature controllers for various applications, aging chamber and DRC determination were other contributions from the section.

Popularization of Solar Powered Systems in the rubber sector and establishment of a Centralized Sophisticated Instrumentation Centre under RRII are some of the projects taken up by the Instrumentation Section in the Jubilee year. ■

ANNUAL EXPENDITURE

Expenditure at a glance (2005-06)

Head of Account	Expenditure (Rs. in lakhs)
Non-Plan	
General charges	347.55
Projects (CES)	186.73
Total	534.28
Plan	
General charges	765.93
NERDS Research Component	159.02
Total	924.95
Grand Total	1459.23

Photo Gallery

RVNRL

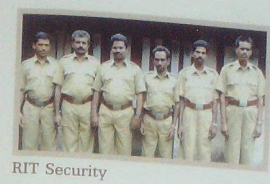
PCRF

Research Office

Research Accounts

Maintenance wing

RRII Security



RIT Security

Canteen staff

Functional Committees

Scientific Advisory

Scientific Seminar

Journal

Purchase

Canteen

RRII Farm

Factory and Farm workers with Supervisory Officers

Pilot Crumb Rubber Factory

RRII Farm

Central Experiment Station

RRS Agarthala

RRS Tura

RRS Paraliyar

RES Nagrakatta

RRS Dapachari

RRS Orissa

RRS Padiyoor

HBSS Nettana

RIT Pampady

Regional Soil Testing Laboratories

Taliparamba

Kozhikode

Thrissur

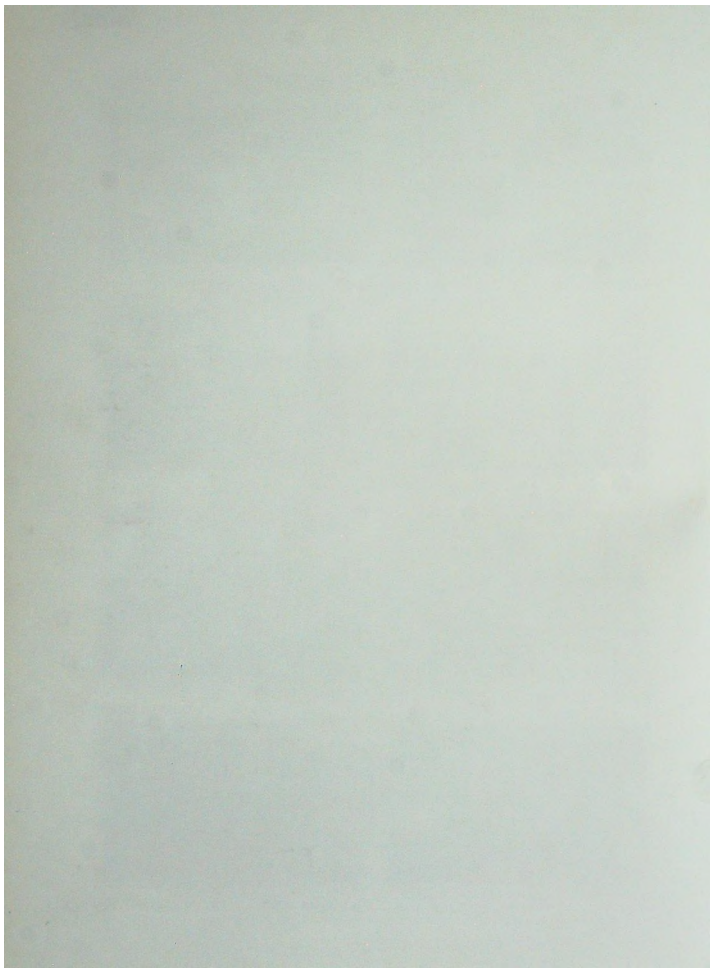
Muvattupuzha

Pala

Kanjirappally

Adoor

Nedumangad



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Joint Director (Research)
Vacant

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C. Madheswaran, B.A.	Technical Assistant (Glass Blowing)

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G Rajammal, M.Sc.	Rubber Technologist

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P.K. Viswanathan, M.A., Ph.D.	(study leave upto Feb 2007)	Economist
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* Holding additional charge of Joint Director (Research)

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Kurian K. Thomas, B.Sc., M.L.I.Sc.	Junior Publication Officer
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Pauleena George	Section Officer
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THE RUBBER BOARD

The Indian Rubber Board was constituted under The Rubber (Production and Marketing) Act, 1947, which came into force on 19 April 1947. This Act was amended in 1954, 1960, 1982 and in 1994. The 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 six departments under the Board *viz.*, Administration, Rubber Production, Processing & Product Development, Finance & Accounts, Training & Technical Consultancy and Licensing & Excise Duty.

Chairman
Mr. S.M. Desalphine, IAS (up to 31-07-05)
Mr. Sajen Peter, IAS (from 05-08-05)

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

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

Administration Department
Secretary

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

Finance & Accounts Department
Mr. Abraham Chacko (up to 31-07-05)
Mr. Viju Chacko (from 26-09-05)
Director

Training & Technical Consultancy
Mr. K.S. Gopalakrishnan (up to 30-06-05)
Dr. K.R. Vijayakumar (from 26-09-05)
Director

Licensing & Excise Duty Department
Mr. T.P. Sivankutty Achari (upto 30-06-05)
Mr. K. J. Joseph (from 26-09-05)
Director

ADVISORY PANEL OF EXPERTS

CROP MANAGEMENT

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THE RUBBER BOARD

The Indian Rubber Board was constituted under The Rubber (Production and Marketing) Act, 1947, which came into force on 19 April 1947. This Act was amended in 1954, 1960, 1982 and in 1994. The 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 six departments under the Board viz., Administration, Rubber Production, Processing & Product Development, Finance & Accounts, Training & Technical Consultancy and Licensing & Excise Duty.

Chairman
Mr. S.M. Desalphine, IAS (up to 31-07-05)
Mr. Sajen Peter, IAS (from 05-08-05)

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

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

Administration Department
Secretary

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

Finance & Accounts Department
Mr. Abraham Chacko (up to 31-07-05)
Mr. Viju Chacko (from 26-09-05)
Director

Training & Technical Consultancy
Mr. K.S. Gopalakrishnan (up to 30-06-05)
Dr. K.R. Vijayakumar (from 26-09-05)
Director

Licensing & Excise Duty Department
Mr. T.P. Sivankutty Achari (upto 30-06-05)
Mr. K. J. Joseph (from 26-09-05)
Director

Editorial Committee

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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 anther culture, systems for propagation and crop improvement of *Hevea* are the important areas in which the Biotechnology Division is engaged. The important fields of research of the Botany Division are breeding, evaluation and selection of new clones, propagation techniques, planting methods, anatomical studies and cytogenetic investigations. The Germplasm Division is concentrating on the introduction, conservation and evaluation of *Hevea* germplasm. The 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 Rubber Technology Division concentrates on improvement in primary processing of rubber, its chemical modification, rubber product manufacture and quality control of processed rubber. The Economics Division undertakes studies on economic aspects related to rubber plantations.

The research supporting sections include Library and Documentation, Instrumentation, Statistics and 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 in Tripura, Guwahati in Assam and Tura in Meghalaya. The RRII has also set up regional research establishments at Dapchari (Maharashtra), Dhenkanal (Orissa), Nagrakattra (West Bengal), Paraliyar (Tamil Nadu), Nettana (Karnataka) and Padiyoor (Kerala).

Regional soil testing laboratories have been established at Thaliparamba, Kozhikode, Thrissur, Muvattupuzha, Pala, Kanjirappally, Adoor and Nedumangad. Mobile units for soil and leaf analysis are available at the Kozhikode, Muvattupuzha and Adoor laboratories, apart from that at the headquarters.

National / International collaboration

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).

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 Sciences (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).

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