FIFTY GOLDEN YEARS OF RUBBER RESEARCH

1955-2005

RUBBER RESEARCH INSTITUTE OF INDIA

ANNUAL REPORT 2004-2005

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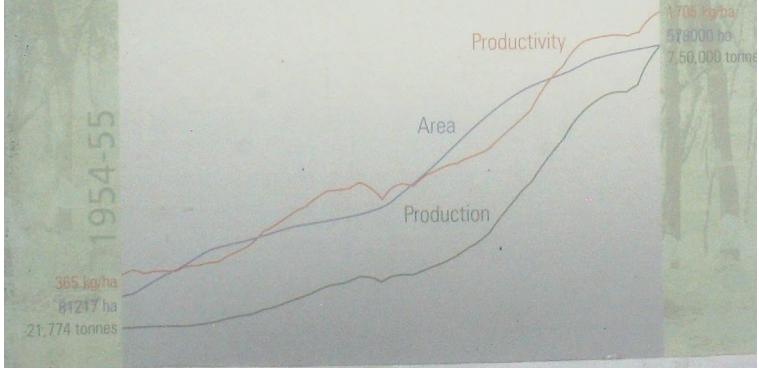

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Indian Rubber Plantation Industry (1955-2005)

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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.

Continued on inside back cover

ANNUAL REPORT
2004-2005

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THE RUBBER BOARD

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

Organization

The Chairman is the principal executive officer and exercises control over all departments of the 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.

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DIRECTOR'S REVIEW

The year 2005 marks the Golden Jubilee of the Rubber Research Institute of India (RRII). Systematic research undertaken in RRII during the past 50 years has paid rich dividents. Consequent to the wide adoption of the clone RRII 105 since its release in 1980, India has achieved the highest reported rubber yield among the major NR producing countries and during the current year the average yield was 1745 kg per ha. Development of five clones in the RRII 400 series *viz.*, RRII 414, RRII 417, RRII 422, RRII 429 and RRII 430 is yet another landmark in the history of rubber research in India. Out of the above five clones, RRII 414 and RRII 430 have successfully completed almost all the evaluation for yield and secondary attributes and are ready for commercial planting.

In the large-scale trial, clones RRII 402 and RRII 52 continued to show higher yield than RRII 105. Studies on different planting materials showed the highest growth rate of plants produced from green buds. There was no reduction in the wet weight of wood per unit volume as a result of ethrel stimulation. Evaluation of the 1981wild germplasm accessions was continued in the traditional rubber growing regions and in the non-traditional regions of Maharashtra, West Bengal, Assam and Tripura. The wild accessions showed more polymorphism. High resistance to abnormal leaf fall disease was observed in 95 accessions and three accessions were identified for resistance to powdery mildew disease.

Studies on development of molecular markers for biotic and abiotic stress tolerance along with cloning and characterization of agronomically important genes were continued. A plant regeneration pathway from the leaf explants of *Hevea* clone RRII 105 was standardized. Experiments were continued to refine the methods standardized earlier for the production of uniform and healthy plantlets through somatic embryogenesis using immature anther and inflorescence as explants. The b-1,3-glucanase DNA sequence from five clones tolerant to abnormal leaf fall (ALF) and five clones susceptible to ALF was PCR amplified and cloned. The genomic and cDNA sequences coding for Hevein gene was characterized. Attempts were continued for the isolation of laticifer cell specific promoters through random amplification of genomic DNA ends. All the 352 clones identified from the subtracted cDNA library between the healthy and TPD affected trees were sequenced. Twenty eight novel cDNA sequences of unknown identity at nucleotide level in GenBank databases were identified. The Myb1 transcription factor gene and TCTP gene were found to be down regulated in the TPD affected tissues.

Research on agro-management techniques involving intercropping and cropping systems, water conservation, weed management, nutrient management *etc.* was continued. Exchangeable aluminium method was found to be most suitable for calculating lime requirement. A large extent of the rubber growing soils was found highly erodable.

Physiological investigations showed that free radical level sin the bark tissues ignificantly increased with ethephone application leading to increase in TPD. Results of RAPD analysis showed no significant difference in variability between monoclonal and polyclonal seedling populations. Study on photosynthetic energy acquisition in the high yielding clone RRII 105 revealed that the clone has effective light utilization and photo-protection mechanisms under favourable agro-climate. Differentially expressed cDNAs due to drought were eluted, precipitated and amplified. Four wild accessions of *Hevea* with better intrinsic drought tolerance traits than clone RRIM 600 were identified. The genotype selected based on better growth and rubber yield from the polyclonal field trial at RRS, Dapchari maintained better photosynthesis under drought conditions. Experiment on low frequency controlled upward tapping (LFCUT) showed good results. Under weekly CUT, groove application of ethephon was found more effective than lace application. An exploratory trial was initiated on tapping once in 10 days (d/10). Low frequency tapping was extended to more than 20,000 ha.

Management of diseases and pests of rubber by chemical and biological means with increased efficiency and reduced cost were thrust areas of pathological research. Diesel is a good carrier for spraying copper oxychloride against abnormal leaf fall disease. Cupric oxide (Kocide) 0.2% was on par in efficacy with Bordeaux mixture in controlling shoot rot disease. Coptrel was

the most effective fungicide for pink disease control. Maximum recovery of patch canker was observed with mancozeb treatment. Molecular studies of the *Phytophthora* isolates from rubber collected during the reporting year showed the occurrence of *P. citrophthora* in India. The occurrence of *Cylindrocladium* leaf disease was also noticed for the first time in India. Pink disease was more in clone RRII 429. An international project on *Corynespora*, co-ordinated by the International Rubber Research and Development Board (IRRDB), was started during the reporting year. Rubber seedlings treated with selected endophytic bacteria showed tolerance against *C. cassiicola*. A prototype bench model high rate reactor was designed and fabricated for anaerobic treatment of sheet processing effluents. Bee keeping and control of mould growth in stored sheet were other priority areas of pathological research.

A survey on the quality of sheet rubber produced in different rubber growing regions was conducted. Factory evaluation of de-proteinised natural rubber latex (DNRL) prepared using Anilozyme P for the production of surgical gloves was completed with satisfactory results. A procedure for easy processing of skim latex was standardized. Evaluation of raw rubber properties of RRII 400 series clones was initiated. NR latex nano-composites using layered silicates were found to reduce air permeability of the vulcanized films. Epoxidised NR was used as modifier in carbon / silica mixed filler reinforced NR and SBR and also in NBR / clay systems. Addition of small quantities of polypropylene or high density polyethylene was found to be effective in reinforcing natural rubber. Addition of recycled plastics in small proportions to NR improved the ageing resistance of vulcanizates. A phenolic resin was evaluated in silica filled NBR / ENR blend for the production of rice de-husking roller. Technology for the production of sprayable adhesive for footwear application and transparent rubber connector for medical application were developed.

Studies on rubber wood processing industry in India identified the need for a national policy for the promotion of rubberwood incorporating appropriate R&D support, statutory control on quality standards of end products and measures to optimize recovery from log level to maximize the value of output. An analysis of the economic feasibility of plant protection measures for abnormal leaf fall in rubber plantations underlined the need for region and clone specific recommendations for plant protection measures. Study on sustainability of beekeeping in rubber plantations in India highlighted the possibility of popularising bee keeping through RPS network to supplement the income of rubber growers facing market uncertainties in the context of liberalization. Another study revealed that the changes resulting from market uncertainty would leave the cultivation of NR in marginal areas economically unviable and labour relations in the NR smallholdings sector hostile in such areas.

Evaluation of location-specific clones and agromanagement techniques were the prime activities of the Regional Research Stations. Clones RRII 203, RRII 208 and PB 235 were selected for planting in Tripura. Clone RRIM 600 continued to give higher growth and yield than other clones in Assam. In Meghalaya, clones RRIM 600 and RRII 203 continued to give the highest growth, whereas RRIM 600 and PB 311 were the highest yielders. In Nagrakatta, West Bengal, the Chinese clones SCATC 88/113 and HK1were superior in terms of yield. In HBSS, Nettana, Karnataka Dist, the clone PB 235 continued to be the highest yielder, while among the new RRII 400 series clones RRII 414 was the most vigorous one, followed by RRII 429 and 430. In HBSS, Paraliyar, Kanyakumari Dist, Tamil Nadu, PB 314 and IRCA 109 gave superior yield. In Orissa, GT1 and RRIM 600 recorded high yield. In RRS, Dapchari, RRII 208 continued to be the best in terms of yield.

In RRS, Nagrakatta and Tura, intercropping of tea with rubber gave satisfactory results. The root trainer plants continued to exhibit better growth than poly bag plants at HBSS, Parliyar. In clone RRII 105 combined effect of irrigation and stimulation resulted in very high yield of (2550 kg/400 trees/year) under d/3 frequency of tapping in Dapchari. The first issue of the new journal *Natural Rubber Research*, formerly published as *Indian Journal of Natural Rubber Research* was brought out during the year under review. RRII published over 70 scientific articles in addition to 30 presentations in conferences. The library continued to serve the NR industry for its information needs.

A National Organizing Committee was constituted for evolving programmes to celebrate the golden jubilee of RRII in a befitting manner. Construction of a new Golden Jubilee Laboratory building was started on the RRII campus.

AGRONOMY/SOILS DIVISION

Development of site-specific agro-management technologies for profitable and sustainable rubber production has been the major research theme of the Division. To achieve this goal, the thrust areas of research have been identified as nutrient management, soil and water conservation, intercropping/cropping systems, density of planting, management of natural resources etc.

Intercropping experiments were conducted in mature and immature rubber to assess the feasibility of interplanting perennial crops such as coffee, garcinia, nutmeg, vanilla and timber species such as wild jack. Experiments on soil and water conservation and density of planting were continued. Effect of conservation pits on growth and yield of rubber was studied. Development of rubber information system using remote sensing, GIS and digital elevation model is in progress.

1. Nutrient management

The field experiment initiated in 1989 to study the nutrient requirement of clone RRII 105 recorded highest yield of 6.74 kg/tree/year with NPK @ 60:60:40 kg/ha and was comparable to 60:30:40, 30:30:20, 30:60:20, 60:60:20, 90:30:40 and 30:30:40 kg NPK/ha. No significant difference was observed between treatments with respect to girth, girth increment and leaf nutrient status. Varying levels of P application in mature rubber indicated no significant difference in girth and yield. Trees without P application had higher root surface acid phosphatase, phosphoenol pyruvate carboxylase (PEPC) and malate dehydrogenase (MDH) activities in fine roots and lower rhizosphere pH. Leaf nutrient status was not influenced by application of P. Studies on adaptive mechanisms involved at the rhizosphere in the acquisition of phosphorus indicated that the root growth was more and the root/shoot ratio was low in P deficient plants compared to the P supplied plants. Removal of P through latex was slightly less than addition through litter.

Possibilities of partial substitution of potassium with sodium in rubber plants were studied. In the nursery, growth of seedlings as well as uptake of N, P, K, Ca and Mg were not influenced by the substitution of K with Na upto 50 per cent and Na application encouraged the uptake of K. In mature rubber, substitution of K with Na upto 50 per cent showed no difference in girth, girth increment, dry matter content or yield. The fertilizer value of sludge from crumb rubber factory was evaluated. Combinations of urea and sludge were more efficient in increasing the growth of seedlings in nursery than urea alone. An accumulation of organic matter and available Ca content was noted in sludge applied areas. Study on clonal and seasonal variations in the nutrient content of latex showed significant variation for Zn and Ca.

In the field experiment to evaluate the effect of skipping of fertilizers for one or more seasons/years on growth and yield of mature rubber, the data for the period 2002-2005 indicated that the growth and yield of rubber were not significantly influenced by skipping of fertilizers upto a period of three years (Table Ag.1).

Response of rubber to liming was studied. Liming alone or in combination with fertilizer significantly improved the growth of immature plants and the highest girth was recorded by 100 per cent lime requirement + fertilizer treatment. Positive response to liming was indicated in mature rubber. NPK+dolomite recorded the highest yield followed by NPK+Mg. Availability of P, K and Ca were improved by liming. Applica-

Table Ag.1. **Effect of skipping of fertilizers on yield of rubber (2002-05)**

Treatment	Yield (kg/tree)	Girth increment (cm)
Standard practice	17.67	17.21
Application of full dose every year (Pre-monsoon)	17.21	5.9
Skipping pre-monsoon fertilizer application	16.65	6.0
Skipping post monsoon fertilizer application	17.52	5.9
Skipping for one complete year	18.10	5.4
Skipping for 2 complete years	18.05	6.0
Continuous no manuring	17.88	5.9
SE	0.90	0.3
CD (P = 0.01)	NS	NS

tion of dolomite significantly improved the exchangeable Ca status of the soil.

The study on long term use of inorganic and organic manures showed higher girth of rubber plants in the treatment 25% fertilizer + 75% farm yard manure. A study to compare the effect of farmyard manure and coirpith manure as pit manure indicated significant influence on girth for farmyard manure over no pit manure control, but no significant difference was observed between FYM and coirpith manure.

Fine root production of rubber trees was quantified by core sampling before the onset of rains and after rains, and highest root density was observed 21 days after rainfall.

1.1. Forms and methods of fertilizer application

Experiment to compare the impact of different methods of fertilizer application on girth and yield of mature rubber did not indicate significant difference between the treatments. However, highest girth and yield was noticed for broadcast method.

The effect of enhanced manuring in planting pits compared to top-dressing during the initial three years was studied. Girth during 2004 and girth increment over four years was not significantly influenced by pit manure treatments. However, application of pit manure plus two year fertilizer dose in the planting pit showed higher girth and girth increment compared to other treatments including standard practice. Leaf N and Ca content of rubber during 2004 did not vary significantly with different pit manure treatments.

2. Physical and chemical properties of soils

In the experiment on effective soil volume and fertility assessment of rubber growing soil, correlations were worked out between gravel content in soil and leaf nutrient status and yield. The study on charactarisation of soil organic matter in rubber plantations indicated, significant reduction in fulvic acid status in mature plantation in the absence of litter addition.

Total nutrients in profile soil samples from five different ecosystems *viz*, mature rubber, *Pueraria* established immature rubber, *Mucuna* established immature rubber, teak and forest were compared. The surface layer of the profiles had the highest total N content and the distribution showed a decline with depth. Total N in the surface layer of different systems was in the order forest > teak > *Mucuna* > rubber > *Pueraria* and total P status (in the different systems) was in the order *Mucuna* > *Pueraria* > rubber > forest > teak. Total K increases down the profile and was in the order forest > rubber > *Pueraria* > teak > *Mucuna*.

3. Soil and water conservation

The experiment to study the effect of conservation pits on growth and yield of rubber showed that the total yield for the period December 2004 to March 2005 varied significantly among treatments. The highest yield was recorded for 250 pits/ha followed by 200 and 150 pits/ha, which were on par. The soil moisture content increased with increase in the number of pits. A notable difference was observed in the soil moisture content among treatments especially at the lower depths (Table Ag.2). Presence of pits favourably influenced the leaf water potential, the highest being in the plots with 250 pits/ha. Significant difference for girth increment and yield was not noticed between surface and pit application of fertilisers. The yield and the girth increment were higher in the plots with pits at the rate of 250/ha. The experiment to study the effect of planting pits of various dimensions showed no significant difference in girth of rubber plants among the treatments.

4. Density of planting

Experiment on effect of density of planting on growth and yield of rubber was continued. Mean yield for the year is shown in Table Ag. 3.

The yield (g/t/t) was significantly higher in the lowest density of 420 trees/ha and the plants had significantly higher girth and girth increment compared to all other treatments. Density of 549 trees/ha gave significantly higher annual yield.

Table Ag. 3. **Mean yield for the period from April 2004-March 2005**

Treatment (trees/ha)	Yield (g/t/t)	Yield (kg/ha/year)*
420	61.30	1548.8
479	51.06	1785.1
549	55.07	2214.2
638	48.10	2138.1
749	45.46	2069.9
SE	3.6	192.2
CD (P=0.05)	7.8	418.8

*Yield based on actual stand

5. Intercropping and cropping system

Higher growth and yield of rubber were recorded in the intercropping system at CES, Chethackal compared to monoculture. Growth and yield of rubber was not influenced by intercropping with coffee and cocoa but yield of coffee was very low. The same trend was also seen in the trials at Ponkunnam and Parathodu with coffee and cocoa as intercrops.

By intercropping perennial crops such as coffee, nutmeg, vanilla and garcinia and annual intercrops *viz.*, tapioca, pineapple and banana, the growth of rubber was not affected. A higher accumulation of P and K was found in tapioca intercropped area.

Interaction between rubber and wild jack (*Artocarpus hirsute*) in mixed stand indicated significantly low girth of rubber with wild jack compared to rubber without wild jack. Distance of wild jack from the rubber had significant effect on rubber growth

Table Ag. 2. **Effect of silt pits on soil moisture status**

No. of pits/ha	Mean soil moisture (%) Soil depth (cm)					
	10	20	30	40	60	100
0	19.4	18.7	18.6	19.8	21.0	22.5
100	18.9	19.5	19.2	19.6	22.6	24.1
150	20.1	19.9	19.7	20.2	23.1	24.8
200	20.3	22.1	22.8	23.2	24.8	26.2
250	21.3	21.1	22.3	24.6	26.2	29.3

(Table Ag. 4). Wild jack standing closer (<1.5 m) to the rubber significantly reduced the growth of rubber compared to rubber without wild jack.

Table Ag.4. **Effect of wild jack distance on girth of rubber**

Distance of wild jack planting	Ponthenpuzha		Pala	
	Rubber	Wild jack	Rubber	Wild jack
Upto 1.5 m	40.8 [a]	51.5 [ns]	36.8 [a]	49.8 [ns]
1.5 to 2.0 m	44.6 [a]	51.6	42.4 [abc]	41.6
> 2.0 m	49.0 [ab]	49.8	40.1 [ab]	57.9
No wild jack	52.2 [b]	——	47.4 [c]	——

Girth of rubber showed a declining trend with increase in wild jack density. On an average a rubber added 13.8 kg litter compared to 5.3 kg added by a wild jack. Nutrient content of rubber litter was less compared to wild jack. However there was no difference in C/N ratio of the litter of wild jack and rubber. Girth and girth increment of rubber and timber intercrops was not significantly influenced by row spacing, type of timber inter crop and their interaction. Among the intercrops, growth performance of wild jack was better followed by teak and mahogany.

Leaf Area Index of timber intercrops was comparatively better in wider row spacing compared to narrow row spacing and was higher with wild jack followed by mahogany and teak. Leaf N and P content of rubber did not vary significantly (Table Ag. 5). Leaf K content of rubber inter-planted with wild jack and mahogany was significantly low compared to that of rubber without any intercrop.

6. Remote sensing and Geographic Information System (GIS)

Development of rubber information system for the traditional region of rubber cultivation using remote sensing and GIS is being continued. The digital elevation model for Puthuppally village was extracted using images of SRTM in 90 m resolution. Using visualization technique, a 3D image could be created to understand the terrain in Puthuppally village, which gave an idea of hills and valleys and other kinds of undulations. Similarly, GPS based surveys of rubber plantations in the same village could yield site specific reflectance values (BV i.e., Brightness Values) which help in supervised classifications.

The experiment on application of remote sensing techniques to identify powdery mildew disease was continued. The GPS based surveys in different fields in various estates helped in locating various fields with

Table Ag. 5. **Rubber leaf nutrient content (%)**

Intercrops	N			P			K		
	Normal spacing	Wide spacing	Mean	Normal spacing	Wide spacing	Mean	Normal spacing	Wide spacing	Mean
Wild jack	3.2	3.2	3.2	0.20	0.15	0.17	0.82	0.67	0.75
Teak	3.0	3.0	3.0	0.17	0.18	0.17	0.85	0.84	0.85
Mahogany	3.2	3.1	3.2	0.19	0.18	0.18	0.79	0.83	0.81
No intercrops	3.1	3.0	3.1	0.18	0.20	0.19	0.89	1.04	0.97
Mean	3.1	3.1	2.5	0.18	0.18	0.14	0.84	0.85	0.68
	S.Em	CD		S.Em	CD		S.Em	CD	
Spacing (A)	0.05	NS		0.01	NS		0.03	NS	
Intercrop (B)	0.09	NS		0.01	NS		0.06	NS	
A x B	0.13	NS		0.02	NS		0.08	NS	

different rubber clones and ages. Temporal changes in the reflectance from rubber canopy could be studied from two satellite images on 24 February and 19 March which was due to wintering and/or disease development.

7. Rainfall interception

During 2004 (Jun-Nov.) total rainfall was 1634.84 mm and interception as per cent of rainfall ranged from 1.21 to 72.4 with a mean of 16.57. Through fall and stem flow showed very good relation with rainfall compared to interception. Quantity of interception (mm) showed positive relation with rainfall, through fall and stem flow, where as per cent of interception showed negative relation.

Total concentration of ammonical and nitrate nitrogen, Fe, Cu, and K were comparatively higher in stem flow than through fall and rainfall. On the other hand concentration of Ca, Mg, and Zn were more in through fall compared to rainfall and stem flow. The order of net addition of nutrients through rainfall, through fall and stem flow was N>K>Ca>Fe>Mg>Cu (Table Ag. 6). Except N, net addition of all other nutrients was mainly by through fall.

Observation on rainwater pH and EC had indicated that chemistry of rainwater got changed after passing through rubber canopy. Rain water pH was slight acidic (pH 4.6). Through fall acidity (pH 5.0) was less than rain water indicating the role of canopy in reducing the acidity of rain water. Similarly EC of rainwater (6.3 mmol/cm) was less compared to through fall (7.0 mmol/cm) and stem flow (8.5 mmol/cm).

Table Ag. 6. **Nutrient addition by precipitation and its component (kg)**

	Ammon. N	Nitrate N	Ca	Mg	Fe	Zn	Cu	K
Rainfall	9.8	16.7	8.2	1.5	0.0	0.29	0.34	3.9
Through fall	4.9	3.0	12.6	3.4	0.12	0.33	0.47	8.9
Stem flow	1.8	2.0	1.3	0.3	0.087	0.027	0.07	1.39
Net addition	9.8	16.7	4.4	1.9	0.21	0.04	0.13	5.0

8. Estate advisory service

1200 individual fertilizer recommendations were offered to 45 large estates on the basis of soil and leaf analysis. Net saving through the adoption of discriminatory fertilizer recommendations was found to be Rs. 378/ha/year.

BIOTECHNOLOGY DIVISION

The major research programmes of the Division are development of large scale *in vitro* propagation methods for elite *Hevea* clones, superior transgenic plants for better latex yield, disease tolerance, adaptation to environmental stresses, recombinant protein production in latex etc., production of haploids, triploids and *in vitro* fertilization techniques to compliment conventional breeding programmes, study of molecular mechanism and characterization of genes controlling tolerance to diseases, abiotic

(Table Ag. 4). Wild jack standing closer (<1.5 m) to the rubber significantly reduced the growth of rubber compared to rubber without wild jack.

Table Ag.4. **Effect of wild jack distance on girth of rubber**

Distance of wild jack planting	Ponthenpuzha		Pala	
	Rubber	Wild jack	Rubber	Wild jack
Upto 1.5 m	40.8 ^{a}	51.5 ^{ns}	36.8 ^{a}	49.8 ^{ns}
1.5 to 2.0 m	44.6 ^{a}	51.6	42.4 ^{abc}	41.6
> 2.0 m	49.0 ^{ab}	49.8	40.1 ^{ab}	57.9
No wild jack	52.2 ^{b}	——	47.4 ^{c}	——

Girth of rubber showed a declining trend with increase in wild jack density. On an average a rubber added 13.8 kg litter compared to 5.3 kg added by a wild jack. Nutrient content of rubber litter was less compared to wild jack. However there was no difference in C/N ratio of the litter of wild jack and rubber. Girth and girth increment of rubber and timber intercrops was not significantly influenced by row spacing, type of timber inter crop and their interaction. Among the intercrops, growth performance of wild jack was better followed by teak and mahogany.

Leaf Area Index of timber intercrops was comparatively better in wider row spacing compared to narrow row spacing and was higher with wild jack followed by mahogany and teak. Leaf N and P content of rubber did not vary significantly (Table Ag. 5). Leaf K content of rubber inter-planted with wild jack and mahogany was significantly low compared to that of rubber without any intercrop.

6. Remote sensing and Geographic Information System (GIS)

Development of rubber information system for the traditional region of rubber cultivation using remote sensing and GIS is being continued. The digital elevation model for Puthuppally village was extracted using images of SRTM in 90 m resolution. Using visualization technique, a 3D image could be created to understand the terrain in Puthuppally village, which gave an idea of hills and valleys and other kinds of undulations. Similarly, GPS based surveys of rubber plantations in the same village could yield site specific reflectance values (BV i.e., Brightness Values) which help in supervised classifications.

The experiment on application of remote sensing techniques to identify powdery mildew disease was continued. The GPS based surveys in different fields in various estates helped in locating various fields with

Table Ag. 5. **Rubber leaf nutrient content (%)**

Intercrops	N			P			K		
	Normal spacing	Wide spacing	Mean	Normal spacing	Wide spacing	Mean	Normal spacing	Wide spacing	Mean
Wild jack	3.2	3.2	3.2	0.20	0.15	0.17	0.82	0.67	0.75
Teak	3.0	3.0	3.0	0.17	0.18	0.17	0.85	0.84	0.85
Mahogany	3.2	3.1	3.2	0.19	0.18	0.18	0.79	0.83	0.81
No intercrops	3.1	3.0	3.1	0.18	0.20	0.19	0.89	1.04	0.97
Mean	3.1	3.1	2.5	0.18	0.18	0.14	0.84	0.85	0.68
	S.Em	CD		S.Em	CD		S.Em	CD	
Spacing (A)	0.05	NS		0.01	NS		0.03	NS	
Intercrop (B)	0.09	NS		0.01	NS		0.06	NS	
A x B	0.13	NS		0.02	NS		0.08	NS	

different rubber clones and ages. Temporal changes in the reflectance from rubber canopy could be studied from two satellite images on 24 February and 19 March which was due to wintering and/or disease development.

7. Rainfall interception

During 2004 (Jun-Nov.) total rainfall was 1634.84 mm and interception as per cent of rainfall ranged from 1.21 to 72.4 with a mean of 16.57. Through fall and stem flow showed very good relation with rainfall compared to interception. Quantity of interception (mm) showed positive relation with rainfall, through fall and stem flow, where as per cent of interception showed negative relation.

Total concentration of ammonical and nitrate nitrogen, Fe, Cu, and K were comparatively higher in stem flow than through fall and rainfall. On the other hand concentration of Ca, Mg, and Zn were more in through fall compared to rainfall and stem flow. The order of net addition of nutrients through rainfall, through fall and stem flow was N>K>Ca>Fe>Mg>Cu (Table Ag. 6). Except N, net addition of all other nutrients was mainly by through fall.

Observation on rainwater pH and EC had indicated that chemistry of rainwater got changed after passing through rubber canopy. Rain water pH was slight acidic (pH 4.6). Through fall acidity (pH 5.0) was less than rain water indicating the role of canopy in reducing the acidity of rain water. Similarly EC of rainwater (6.3 mmol/cm) was less compared to through fall (7.0 mmol/cm) and stem flow (8.5 mmol/cm).

Table Ag. 6. **Nutrient addition by precipitation and its component (kg)**

	Ammon. N	Nitrate N	Ca	Mg	Fe	Zn	Cu	K
Rainfall	9.8	16.7	8.2	1.5	0.0	0.29	0.34	3.9
Through fall	4.9	3.0	12.6	3.4	0.12	0.33	0.47	8.9
Stem flow	1.8	2.0	1.3	0.3	0.087	0.027	0.07	1.39
Net addition	9.8	16.7	4.4	1.9	0.21	0.04	0.13	5.0

8. Estate advisory service

1200 individual fertilizer recommendations were offered to 45 large estates on the basis of soil and leaf analysis. Net saving through the adoption of discriminatory fertilizer recommendations was found to be Rs. 378/ha/year.

BIOTECHNOLOGY DIVISION

The major research programmes of the Division are development of large scale *in vitro* propagation methods for elite *Hevea* clones, superior transgenic plants for better latex yield, disease tolerance, adaptation to environmental stresses, recombinant protein production in latex etc., production of haploids, triploids and *in vitro* fertilization techniques to compliment conventional breeding programmes, study of molecular mechanism and characterization of genes controlling tolerance to diseases, abiotic

stresses, tapping panel dryness and latex biosynthesis and laticifer cell specific gene expression and characterization of tissue specific promoters.

1. Micropropagation

1.1. Shoot tip culture

The multiple shoots from RRII 105, RRIM 600 and seedlings were infected with three wild strains of *Agrobacterium rhizogenes* and cultured for rooting. Attempts were continued to identify specific proteins that appeared during rhizogenesis. In fresh clonal shoots many protein bands were observed and most of them disappeared during *in vitro* culture. However, in the shoot tips of seedlings, most of the bands were retained in culture also.

2. Somatic embryogenesis

2.1. Immature anther explants

Extensive optimization experiments were carried out to obtain a regeneration pathway for the production of uniform plants from immature anthers. Modified MS medium containing 2.0 mg/l 2,4-D and 0.5 mg/l KIN for callus induction and modified MS medium supplemented with 400 mg/l casein hydrolysate, 150 mg/l glutamine and growth regulators such as 0.2 mg/l NAA, 0.7 mg/l KIN and 2.0 mg/l GA_3 for embryo induction were identified. Plant regeneration could be obtained in modified MS medium lacking hormones. But the addition of 0.5-1.0 mg/l BA and 2.0 mg/l GA_3 or 0.25 mg/l TDZ and 2.0 mg/l GA_3 were found to enhance plant regeneration. Utilizing this protocol, to produce a large number of *in vitro* plants, immature anthers from the clone RRII 105 was inoculated on callus induction medium. Calli were subcultured for proliferation and transferred to embryo induction medium. Experiments were also initiated for production of RRII 400 series clones through this method.

2.2. Immature inflorescence explants

Somatic embryo induction and plant regeneration using the established system was continued and refinement experiments to improve the efficiency of the system were carried out.

Effect of growth regulators on secondary embryogenesis revealed that a combination of 1.0 µM 2,4-D and 1.5 µM NAA in the embryo induction medium was giving maximum secondary embryogenesis.

Somatic embryos at various developmental stages *viz.* embryogenic mass with pro embryos, globular, heart shaped, cotyledonary and mature somatic embryos were tested for their ability to induce secondary embryos. Globular embryos were giving maximum secondary embryos followed by heart shaped embryos. Frequency of secondary embryogenesis decreased as the developmental stage advances. Numerous embryos could be developed by serial sub culture of the globular embryos at three weeks interval.

Growth performance of the immature inflorescence derived somatic plants planted during 2000 and 2003 showed no significant difference in girth compared with the bud grafted control plants.

2.3. Leaf explants

Embryogenesis could be achieved in modified MS medium (KH_2PO_4 170 mg/l and CaNO3 360 mg/l), which contained B_5 vitamins, organic supplements and phytohormones BA (2.0 mg/l), GA_3 (1.0 mg/l), NAA (0.2 mg/l) and 2,4-D (0.1 mg/l) (Table Biotech. 1). Addition of abcisic acid (0.2 mg/l) along with other hormones increased the rate of embryogenesis. The embryo induction medium also contained the amino acids, proline (100 mg/l), cysteine (20 mg/l), serine (20 mg/l) and arginine (37 mg/l) along with organic supplements such as coconut water (10%) and casein hydrolysate (400 mg/l).

Table Biotech. 1. **Effect of BA and GA_3 in presence of 0.1mg/l NAA on somatic embryo induction of leaf derived callus***

BA (mg/l)	GA_3 (mg/l)				
	0.5	1.0	1.5	2.0	2.5
0	0	0	0	0	0
0.5	25.00	25.00	28.00	26.60	24.33
1.0	35.50	48.00	36.11	55.00	48.00
1.5	51.66	63.75	58.75	58.55	55.11
2.0	62.50	65.00	63.75	62.50	58.55
2.5	56.50	58.00	55.11	55.11	52.50
3.0	35.50	38.55	38.55	35.50	35.00

CD (P= 1.36)

*Values given are mean of 20 replications and repeated thrice

Maturation and apex induction of embryos could be achieved in WPM medium containing organic supplements CW (10%), malt extract (100 mg/l), casein hydrolysate (400 mg/l) and phytohormones BA (0.3 mg/l), TDZ (0.5 mg/l) and GA_3 (1.5 mg/l). Embryo development was favorable in a hormone combination of BA (0.3 mg/l), TDZ (0.5 mg/l), GA (1.5 mg/l) and IBA (0.1 mg/l). Coconut water (10%), malt extract (50 mg/l) and banana powder (300 mg/l) also had significant effect on embryo germination.

Embryos on enlargement and apex induction were transferred for plant regeneration in both MS and WPM medium containing organic supplements *viz.* coconut water and malt extract. Good plant development occurred in ½ MS media devoid of hormones and containing organic supplements such as coconut water and malt extract and with 40 g/l sucrose. Gelling of the media with bacto agar was found to have a favourable impact on plant regeneration. Complete plant development with 2-3 leaves occurred within 30-40 days.

2.4. Ovule culture

MS basal medium was found to be optimum for germination than the woody plant medium. Organic supplements like malt extract (800 mg/l) and CW (20%) had a beneficial effect on plantlet development. Regeneration medium supplemented with glutamine (200 mg/l) and proline (100 mg/l) promoted germination. It was noticed that GA_3 had a negative effect on germination of the embryos. A combination of BA (1.0 mg/l) and IBA (2.5 mg/l) favored germination and plantlet formation.

2.5. Microspore culture

Refinement experiments were performed to obtain profuse growth of haploid callus from cultured microspores. Inclusion of $CaCl_2$ in the pre treatment medium had a positive effect on callus formation. Moving liquid cultures in the presence of diffused light promoted the microspore division compared with static liquid cultures. Rubber tree medium (RT) with the growth regulators zeatin (3.0 mg/l) and kinetin (3.0 mg/l) helped in callus production. Increase in callus formation was noticed with high levels of sucrose (150 g/l). Fast growth of the callus in cultures treated with 0.1% colchicine for 24 h confirmed its growth promoting effect. Treatment of the cultures with Actinomycin D (0.08%) for 48 h effectively controlled the fungal contamination. Experiments for embryo induction were performed using different basal media, growth regulators, lower levels of sugars, organic supplements etc.

2.6. Endosperm culture

Effect of phytagel, sucrose and growth regulators on embryo induction, maturation and germination were studied. The maximum frequency of embryo induction (50%) was obtained in a medium supplemented with GA_3 (0.5 mg/l) + ABA (0.3 mg/l) + Kinetin (0.3 mg/l). The highest embryo maturation frequency (24%) was obtained with 0.5% phytagel while maximum germination frequency of 8.6% was achieved with 0.2% phytagel. The germination frequency decreased and maturation frequency increased

with increase in phytagel concentration. The mitotic studies of a few embryos germinated revealed that they are triploids with 2n=3x=54.

Callus induction was obtained from both mature and immature *Hevea* endosperm. Immature endosperm also responded for organogenesis. Direct embryogenesis was observed in few of the cultures with the growth regulator combination, 3 mg/l NAA and 4 mg/l kinetin.

2.7. *In vitro* fertilisation and plant recovery

Effect of immersing ovules in $CaCl_2$ solution (0.1%) for 24 h before pollination had a positive effect on fertilization. Boric acid (100 mg/l) was effective during fertilization but for embryo growth no significant influence was noticed. Organic supplements promoted embryo development. The use of growth regulators resulted in callusing of the integuments and nucellar tissue, which in turn arrested the development of the embryo while very high levels of sucrose (180 g/l) prevented the callusing. A combination of growth regulators *viz.*, GA_3 (2 mg/l) + Zeatin (2 mg/l) + NAA (4 mg/l) promoted embryo growth in presence of 180 g/l sucrose. The use of natural plant extracts (20%) was highly beneficial during all the stages of development. Carrot and beet root extracts were ideal during the initial stages of embryo development. The embryos could be grown up to the cotyledonary stage in MS with sucrose (180 g/l), malt extract (500 mg/l), casein hydrolysate (400 mg/l), banana powder (600 mg/l), coconut water (20%), NAA (4 mg/l), GA_3 (2mg/l) and zeatin (2 mg/l).

3. Genetic transformation

Experiments to develop transgenic plants with increased tolerance to tapping panel dryness, drought and environmental stresses were continued. Superoxide dismutase gene expression was studied in transgenic plants integrated with SOD gene under the control of CaMV 35S promoter. Mn-SOD transcript level was found to be higher in the transgenic plants than in the untransformed plants with and without induction of stress. Similar results were obtained with the SOD enzyme assay with leaves taken from transgenic and control plants subjected to water stress.

To select the best transgenic plant with maximum tolerance to environmental stress and TPD, two month old calli and embryogenic calli was transformed with SOD gene under the control of FMV 34 S and CaMV 35 S promoters, through *Agrobacterium tumefaciense*. Many transgenic cell lines were observed from which embryo induction could be obtained. The transformation frequency was found to be very high when embryogenic callus was used as the explant. The transgenic cell lines obtained were subjected to molecular confirmation for the presence of transgene and these cell lines are under different stages of development. Transformation experiments were also carried out with the gene coding for sorbitol-6-phosphate dehydrogenase. The transgenic cell lines were checked for GUS activity and the positive lines were selected for further proliferation.

To enhance rubber biosynthesis, attempts were initiated to develop transgenic plants integrated with genes coding for important enzymes in the pathway. Initially, the genes coding for HMGR1, farnesyl-diphosphate synthase (FDP) and rubber elongation factor (REF) were selected. The HMGR1 and REF genes were cloned into the binary vector pBI 121 for the genetic transformation which contains the antibiotic genes neomycin phosphotransferase (npt II) and hygromycin phosphotransferase (hpt). The FDP gene is cloned into the binary vector pCAMBIA under the control of CaMV 35S promoter. Three *Agrobacterium* strains such as EHA 105, LBA 4404 and PGV 1303 were

used for infecting the tissue for the transformation of HMGR1 gene while EHA 105 alone was used for FDP and REF genes. Two month old calli has been infected with different *Agrobacterium* strains carrying the HMGR1 and FDP genes. The transformed cell lines integrated with the FDP gene has been selected and further work is in progress.

4. Molecular studies

4.1. Molecular mechanism of disease tolerance

A detailed investigation was carried out to understand the role of β-1, 3-glucanase (β-glu) gene in the control of abnormal leaf fall disease caused by *Phytophthora*. To understand the β-glu expression in tolerant and susceptible clones, the plants raised in polybags were infected with the pathogen and maintained in controlled conditions, keeping uninfected plants as control. Northern analysis and relative quantitative RT-PCR were carried out at 0, 24, 48 and 96 h after infection. Part of the sequences coding for 18S RNA and β-actin genes from *Hevea* were PCR amplified for using as internal control in northern hybridisation and relative quantitative RT-PCR experiments. The 1.7 kb 18S RNA gene fragment and 260 bp actin gene were cloned in pGEM vectors and sequenced to confirm their identity. Both fragments showed nearly 100% similarity with published sequences from other species in the databank and are reported for the first time from *Hevea*.

Northern hybridization analysis indicated that the 18S RNA content did not vary with the treatments and time course. This uniform expression of rRNA indicated that there was no non-specific shift in the relative amounts of mRNA but β-glu mRNA levels changed dramatically. Analysis of the accumulation of mRNAs encoding β-glu demonstrated that activation trends are different between the two clones. Control plants sprayed with dist. H_2O and maintained in similar conditions as infected ones, also did not exhibit the induction of glucanase mRNAs till 96 h. However, the transcript levels of β-glu in the infected plants showed a marked increase 48 h after inoculation. From the pattern of expression a faster rate of increase appears to have occurred in tolerant clone as more intense signal was generated. At 96 h, although the level of β-glu transcripts remains almost the same in tolerant clone, the hybridisation signals observed for susceptible clones dropped to drastically low levels.

In the relative quantitative RT- PCR anaysis, the β- glu gene and part of house keeping actin gene were co-amplified from the first strand cDNA synthesised from the total RNA isolated from different samples. Actin gene is used as internal control in RT-PCR. Transient levels of the internal control remains almost the same in control as well as treated samples, at all time intervals in both tolerant and susceptible clones. But as observed in northern blots, β-glu appear to be differentially regulated. However, in contrast to northern blots, amplification of β-glu mRNAs with low intensity in control (uninfected samples) was also observed.

The net intensities of β-glu bands amplified from control samples of both clones were more or less same. In the infected samples, the band intensities begin to increase 24 h after inoculation and an exponential increase was observed at 48 h, which can be correlated with the increased gene activity.

The higher and more rapid accumulation of β-glu transcripts was observed in the case of tolerant clone RRII 105. The β-glu levels reached a peak with almost 25-fold increase than its basal level at 48 h after inoculation, in tolerant clones. At the peak level, only 15-fold increase was seen in susceptible clone. The induction was observed to be more prolonged in tolerant clone, remaining

higher than basal levels for four days after inoculation, but slightly lower than the peak value. While in susceptible clones, the transcript levels of β- glu decreased drastically and it was only 4-fold higher than the basal levels at 96 h.

To understand the possible reasons for the differential expression in the tolerant and susceptible clones, the genomic sequences coding for β-1, 3-glucanase were PCR amplified from five each of relatively tolerant and susceptible clones (RRII 105, GT 1, RRII 33, Gl 1, FX 516, RRIM 600, Tjir 1, PB 86, RRIM 701 and PR 107). The PCR fragments were gel purified, cloned into TOPO cloning vector (M/S Invitrogen) and submitted for sequencing.

4.2. Tissue specific gene expression and characterization of promoters

Attempts were made earlier to amplify the laticifer specific promoters of the genes REF, β-1, 3-glucanase and hevein. Specific primers were used to amplify reported sequences and 5′ RAGE analysis for the amplification of unknown sequences. A minimal promoter sequence of β-1,3-glucanase was amplified through 5′ RAGE, cloned and sequenced. A minimal promoter of REF was PCR amplified using specific primers.

The genomic and cDNA sequences coding for hevein, which is over expressed in the latex cells is PCR amplified, cloned and sequence characterized. A nucleotide sequence of 680 bps was observed with genomic DNA and 577 with cDNA. On comparison with the cDNA sequence it was found that the genomic DNA sequence is having a single AT rich intron of 103 nucleotides with GT at the 5′ splice site and AG at the 3′ splice site. Both sequences were compared with the published sequence of Broekaert *et. al* (1990).

Experiments were carried out to amplify the full length promoter regions of β-1,3-glucanase, REF and hevein genes through 5′ RAGE analysis and to amplify the reported promoter sequences using specific primers. An upstream promoter sequence of about 1300 nucleotides of hevein gene was amplified using specific primers based on reported sequences. Nucleotide sequence, upstream to the reported promoter sequence was amplified by adopting RAGE (Random Amplification of Genomic DNA ends) technique. A series of PCRs with change in parameters like annealing temperature, template concentration, number of reaction cycles and enzyme concentrations were also tried. A 600 bp upstream fragment of hevein gene promoter was amplified, cloned to the TOPO cloning vector and submitted for sequencing.

The 750 base pair REF promoter amplified earlier were sequenced. The 0.75 kb fragment contains 378 base pairs upstream to the ATG site. The TATA and CAAT boxes were located in the sequence. In order to understand the efficiency of its expression in the heterologous system, binary vectors were developed with REF promoter-GUS fusion and tobacco was transformed using *Agrobacterium*. GUS expression was observed in the transgenic tobacco leaves indicating that the 378 base pair upstream elements could drive the GUS gene.

5. Isolation and characterization of wound/stress inducible cDNAs

During the current year 352 clones were sequenced and compared with GenBank database for homology. In healthy tree SS cDNA library, 31 out of 112 clones were found to be unique genes and 11 clones were identical sequences. There were no sequence homology found with the database for three sequences that was considered as novel cDNA. From the TPD affected SSH cDNA library, 240 clones were sequenced of which 36 were found to be unique but known

cDNAs and 11 were classified as identical cDNAs. There were 25 novel sequences, which are not found in the GenBank database. Altogether 28 novel cDNA sequences do not share any identities at nucleotide level in GenBank databases and thus they are likely to be variants of gene families. It was for the first time a significant number of novel sequences related to TPD syndrome (wound or abiotic stress) and biotic stresses as well as low abundant transcripts with high similarity to transcription factors and signaling components, were reported in *Hevea*.

A detailed investigation has been carried out with Myb 1 transcription factor gene and a translationally controlled tumour protein (TCTP) gene. Total RNA was isolated from healthy and TPD trees and used for northern blot analysis. Both TCTP and MYB transcription factor genes were used as probe. There were significant differences in mRNA transcript accumulation between TPD and healthy trees. Both TCTP and MYB gene expression level was very low in TPD trees compared with healthy tree and this indicates that these two genes are having some regulatory role in TPD syndrome development.

BOTANY DIVISION

Crop improvement through hybridization, ortet selection and polycross breeding remained the thrust area of research in the Botany Division. Large scale and on farm evaluation of both indigenous and introduced clones were among the mainstream activities. Clone evaluation programmes were undertaken in a multidisciplinary manner. Other areas include anatomical investigations of bark and wood, propagation studies, investigations on floral biology, evaluation of clones and clonal composites in traditional and non-traditional areas.

1. Evolving high yielding clones for the traditional area

1.1. Hybridization and clonal selection

The RRII 400 series clones in the small sale trial were characterized for Mooney viscosity and it was found that RRII 407 is a low viscosity clone (Table Bot.1).

In the small scale trial (SST) of hybrid clones (1989), 22 clones exhibited higher yield than RRII 105. The estimates of standard heterosis ranged from 11.11 to 246.46 per cent. Selected clones were multiplied for raising source bushes for the next stage of evaluation.

Table Bot. 1. **Characterization of RRII 400 series clones based on Mooney viscosity**

Clone	Mooney viscosity
RRII 407	Very low (<50)
RRII 421 RRII 430	Low (50-65)
RRII 422	Moderate (65-75)
RRII 105 RRII 410 RRII 414 RRII 417 RRII 429	High (75-85)
RRII 403 RRIC 100	Very high (>85)

The yield data during the fifth year of tapping in the small scale trial (SST) 1990 was summarized and the performances of 10 promising hybrids are given in Table Bot. 2.

In the SST 1992A, clone 772 recorded maximum yield of 98.90 g/t/t followed by

Table Bot.2. **Yield performance of promising hybrids in the fifth year of tapping**

Clone	Yield (g/t/t)
86/312	93.25
86/213	69.42
86/390	88.94
86/959	71.45
86/392	75.73
86/29	72.72
86/6	79.44
86/65	73.19
86/928	65.28
86/584	69.52
RRII 105	64.72

clone 380 (69.0 g/t/t). RRII 105 recorded 56.4 g/t/t. In the trial 1992 B, clone 575 recorded maximum yield of 73.4 g/t/t, followed by the check clone RRIM 600 with 69.8 g/t/t/. RRII 105 recorded 30.0 g/t/t. Four hybrid clones recorded higher yield than the check RRII 105 in SST 1994 with yield ranging from 56.19 to 57.27 g/t/t. In the three SSTs laid out in 1995 with W x W and W x A hybrids, ten hybrid clones out yielded RRII 105 in the second year of tapping with mean yield ranging from 38.65 to 60.33 g/t/t. Tapping was initiated in the two small scale trials planted in 1998.

Among the 776 seedlings from the W x W and W x A crosses of the 2002 HP, progenies of the cross combinations RRII 414 x PB 330, RRII 429 x PB 330, PB 330 x RRII 414 and PB 330 x RRII 429 recorded a mean girth of 10 cm while the clonal half-sibs recorded a mean girth of 9.0 cm. Among the W x A

Table Bot. 3. **Growth performance of full-sib and half-sib progenies of HPP-2002 in nursery at the age of 26 months**

Type of seedling	Girth (cm) November 2004					
	No. of seedlings	Mean	Minimum	Maximum	SD (±)	CV(%)
W x A Progenies						
RRII 105 x AC 2004	2	6.0	5.8	6.2	0.28	4.7
RRII 105 x AC 2584	2	7.4	5.9	8.8	2.05	27.9
RRII 105 x RO 1739	2	6.2	5.5	6.8	0.92	14.9
RRII 105 x MT 1057	4	10.0	5.5	16.0	4.94	49.5
RRII 414 x AC 2004	2	7.8	4.9	10.6	4.03	52.0
RRII 414 x MT 2226	28	10.4	3.5	17.5	3.32	32.0
RRII 429 x RO 1739	2	8.8	8.3	9.2	0.64	7.3
RRII 429 x MT 1021	3	10.4	7.8	13.5	2.87	27.6
RRII 429 x MT 2226	19	7.1	4.0	10.8	1.70	24.0
Pooled	64	-	-	-	-	-
W x W Progenies						
RRII 105 x PB 330	8	7.2	4.5	11.5	2.22	30.8
RRII 105 x IRCA 130	2	6.3	5.8	6.7	0.64	10.2
RRII 414 x PB 330	16	11.3	6.4	17.2	3.68	32.5
RRII 414 x RRIM 600	2	5.6	4.8	6.4	1.13	20.2
RRII 429 x PB 330	6	10.0	5.5	12.4	2.51	25.2
PB 330 x RRII 414	102	10.1	3.4	21.6	3.92	38.8
PB 330 x RRII 429	74	10.3	3.0	16.5	2.80	27.1
Pooled	210	-	-	-	-	-
Clonal half-sibs						
RRII 105 x ?	176	8.3	2.5	17.9	3.17	38.3
RRII 414 x ?	109	9.7	4.0	18.3	3.48	35.7
RRII 429 x ?	95	9.0	3.0	16.8	3.30	36.7
PB 330 x ?	122	9.5	3.6	18.0	3.71	38.9
Pooled	502	-	-	-	-	-
All pooled	776	9.3	2.5	21.6	3.47	37.2

progenies, RRII 105 x MT 1057, RRII 414 x MT 2226 and RRII 429 x MT 1021 recorded comparable girth with that of W x W progenies (Table Bot. 3). Six cross combinations were attempted under 2005 HP. A total of 4000 hand pollinations were attempted with a mean initial fruit set of 5.15 per cent. The cross combination PB 330 x RRII 105 showed the highest fruit set of 13.7 percent followed by PB 330 x RRII 414 (12.7%).

1.2. Ortet selection

Anatomical parameters of all the ortets in the small scale trials at Cheruvally and Koney estates were analysed statistically and significant differences were noted. Twenty four clones recorded higher number of latex vessel rows and 11 clones recorded higher bark thickness than the general mean. A polybag nursery comprising 25 selected ortet clones from Cheruvally, Koney and Mundakkayam estates were properly maintained at CES Chethackal for the proposed large scale trial during 2005. In the trial on small scale evaluation of ortets selected from PCK estate, Kodumon, yield, annual girth and secondary characters were recorded. Two clones viz., O39 and O28 recorded better yield compared to RRII 105 over 28 months of tapping. Three clones, O11, O75 and O25 recorded very good girth increment during the third year of tapping (12.1, 10.1 and 10.2 cm respectively).

Evaluation of the ortets in small scale trial (1994) showed clones O17 and O4 to be more vigorous than RRII 203 with moderate yield. In the trial on small scale evaluation of the ortets selected from various smallholdings (1995) tapping was initiated. The clone O81 recorded better growth (68.03 cm) in the first year of tapping compared to RRII 203 (65.40 cm), a vigorous clone.

The ortet clones under evaluation in small scale trials at Koney estate were screened for tolerance to *Phytophthora* and *Oidium*. Seven clones showed more than 70 per cent leaf retention indicating tolerance to *Phythophthora* but none of the clones showed *Oidium* tolerance.

2. Evaluation of clones

2.1. Large scale evaluation

The RRII 400 series clones in the large scale trial at CES were evaluated for yield in the fourth year of tapping and clear bole volume (CBV). There was significant clonal variation for both the traits (Table Bot. 4). The clones RRII 414, 417, 429, 402, 430 and 422

Table Bot. 4. **Rubber and timber yield of clones**

Trial I			Trial II		
Clone	Rubber yield 4th year (g/t/t)	CBV (m^3/tree)	Clone	Rubber yield 4th year (g/t/t)	CBV (m^3/tree)
RRII 446	29.90	0.052	RRII 454	37.44	0.058
RRII 55	55.94	0.052	RRII 430	79.71	0.092
RRII 54	21.52	0.072	RRII 434	27.96	0.051
RRII 417	69.70	0.078	RRII 427	64.39	0.055
RRII 407	50.26	0.065	RRII 53	19.98	0.054
RRII 403	57.69	0.050	RRII 422	78.42	0.074
RRII 449	28.88	0.060	PB 330	54.88	0.165
RRII 429	62.09	0.055	RRII 410	43.70	0.065
RRII 403	60.94	0.074	RRII 52	57.79	0.074
RRII 453	33.60	0.045	RRII 105	64.81	0.061
RRII 414	73.57	0.082			
RRII 105	56.12	0.056			
VR	25.01**	5.93**	VR	68.38**	9.45**

performed better than the high yielding check RRII 105 in the respective trials. PB 330 and RRII 430 were superior for clear bole volume.

In the large scale trial of modern clones in the North Konkan, RRII 208 (48.6 g/t/t/), recorded the highest yield in the seventh year of tapping followed by RRII 105 (39.0 g/t/t). RRIC 105 recorded the lowest yield (23.6 g/t/t) in the drought prone region.

Clones in the multi-disciplinary evaluation trials were in the sixth year of tapping. RRII 5 in trial I and PB 314 in trial II recorded the highest yield (74.71 and 80.43 g/t/t, respectively).

Pooled analysis of data over five years of tapping in LST (1989) confirmed the superiority in yield of PB 312 (68.44 g/t/t) followed by PB 314 (60.32 g/t/t) and PB 280 (57.98 g/t/t). The Chinese clone SCATC 88/13 had a yield of 48.78 g/t/t which was on par with the check clone RRII 105 (51.05 g/t/t).

In the large scale evaluation of exotic and indigenous clones, initial yield recording for 17 months showed that the hybrid 44 (PB 242 x RRII 105) was superior in yield with more than 50% yield increase over RRII 105. Vigour of RRII 44 was also found to be high, recording mean girth of 64.31 cm during the 2nd year of tapping.

2.2. On farm evaluation

In the onfarm evaluation of selected 12 clones at Chithelvetty, PB 260 recorded the highest yield over 10 years of tapping (1345.2 kg/ha) followed by RRII 105 (1329.7 kg/ha). RRIC 52 recorded the highest girth during the 10th year of tapping (92.35 cm). Incidence of brown bast was highest in PB 260 (19.48%) (Table Bot. 5).

Among 15 clones under onfarm evaluation at Chemoni, Trichur, data on yield in the seventh year of tapping revealed the superiority of clone RRII 105 (Table Bot. 6). The other clones which showed promising per-

Table Bot. 6. **Yield of clones at Chemoni estate**

Chemoni Division		Echippara Division	
Clone	Yield * (kg/ha/yr)	Clone	Yield* (kg/ha/yr)
RRII 5	1489.33	RRII 300	838.89
RRII 203	1424.44	PR 255	1083.33
RRII 206	1366.67	PR 261	1083.33
RRII 208	1317.78	PB 311	1366.67
Nab 17	1208.89	PB 310	1210.67
RRII 308	1300.00	PB 260	1300.00
RRIC 102	1572.22	GT 1	1244.41
RRII 105	1472.00	RRII 105	1877.78

* Seventh year of tapping

Table Bot. 5. **Yield and secondary characters of the clones at Chithelvetty**

Clones	Incidence of brown bast (%)	Incidence of *Oidium*	Virgin bark	Renewed bark	Girth at 10th year (cm)	Yield over 10 years (kg/ha)
PB 260	19.48	High	Smooth	Rough	75.44	1345.2
PR 255	12.42	Moderate	Rough	Rough	77.06	1092.1
PB 311	18.22	Low	Rough	Rough	76.66	1259.8
PB 310	6.04	Moderate	Smooth	Rough	75.60	1076.8
RRII 300	17.79	Low	Smooth	Rough	76.12	710.9
RRII 43	5.84	Moderate	Rough	Smooth	68.11	967.9
RRII 44	5.62	Low	Smooth	Smooth	83.81	737.9
RRII 105	16.00	Low	Smooth	Smooth	71.28	1329.7
RRIC 52	6.22	High	Smooth	Rough	92.35	733.6
RRII 1	11.28	Moderate	Smooth	Smooth	78.67	1244.7
PR 261	2.31	Low	Smooth	Smooth	71.50	980.3
PB 235	13.33	High	Smooth	Smooth	77.73	1031.0

formance in this region are PB 260 and PB 311.

Among the eight clones under onfarm evaluation at Koney estate, PB 314 registered the highest yield in the sixth year of tapping followed by RRII 105. Clones PR 255 and PR 261 showed only a mild incidence of powdery mildew (Table Bot. 7).

Table Bot. 7. **Performance of clones at Koney estate**

Clone	Mean yield* (kg/ha/yr)	Incidence of *Oidium*
RRII 105	1640.17	Medium
PR 255	1549.00	Mild
SCATC 88-13	1052.38	Very severe
PB 260	1714.76	Severe
PR 261	1718.00	Mild
RRII 300	1719.04	Severe
PB 314	2117.64	Medium
RRII 5	2106.60	Medium

* Sixth year of tapping

In the onfarm trial at Sasthamkotta, clone PB 314 registered the highest yield (1637 kg/ha/yr) in the second year of tapping followed by RRII 105 (1602 kg/ha/yr).

2.3. Genotype x environment interaction

The clones under simultaneous evaluation in five locations were studied for initial yield performance and growth. Trials in three locations were under tapping. The yield of clones varied across locations. Clone RRII 429 was most vigorous in Kanyakumari, Nagrakatta and Agartala. Clone RRII 422 recorded very low incidence of powdery mildew (10.83%) in Kanyakumari.

2.4. Studies on clonal composites

A comparison of the yield of various clonal composites and monoclonal population of RRII 105 in the traditional area (Chethackal) and non-traditional area (Nagrakata) showed that the yield levels were in general lower in the latter. The monoclonal block of RRII 105 registered the highest yield in both locations. Composite 1 was comparable to RRII 105 in Nagrakata while composite 3 was the highest yielder among various clone combinations in Chethackal (Table Bot. 8).

Table Bot.8. **Yield of the clones in the trials on clonal composites at CES, Chethackal and RES Nagrakatta during 2004**

Treatment	Mean rubber yield (g/t/t)	
	CES, Chethackal	RES, Nagrakatta
Composite -1	53.7	24.0
Composite -2	53.4	18.2
Composite -3	60.3	21.0
Composite -4	55.1	19.5
Composite -5	52.8	19.7
RRII 105*	67.7	24.8
Mean	57.2	21.2

*Monoclone block

3. Breeding for other specific objectives

3.1. Compact canopy

The recombinants of crosses between the genetic variant and high yielding clones such as RRII 105, RRIM 600 and RRII 118 as female parents are under evaluation. Early growth of progenies in the small scale trial showed high variability with respect to height and canopy diameter. Some of the progenies exhibited normal growth with compact canopy in the fourth year of observations. In the case of evaluation of half-sibs of genetic variant, progenies like semi compact and intermediate types did not show any yield improvement. The normal type progeny recorded a rubber yield of 88 g/t/t compared to 60 g/t/t of control clone RRII 105.

3.2. Drought tolerance

Seasonal variation in growth rate was studied in 175 hybrid clones under evaluation in seven small scale trials. Clonal variation for girth was significant but there was no significant variation among clones with respect to the growth rate in summer months in the sixth year after planting. Leaf and twig

samples of hybrid clones were processed and the trend in variability for the proportion of intraxylary phloem and stomatal density was studied. Twenty hybrid clones developed by crossing high yielding and drought tolerant parents were screened for physiological parameters such as epicuticular wax and cell membrane stability. Ten clones were short listed based on these parameters and subjected to further screening for PSII activity under drought and high light intensity.

3.3. Latex timber clones

Data on timber volume from clones in different locations were collected from a large number of plantations at the time of felling of trees. Test tapping was carried out in hybrid seedlings and 20 promising hybrids were identified.

3.4. Polycross progeny evaluation

Evaluation of progenies of prepotent clones in two trials in the fourth year of tapping showed that mean yield ranged from 32.63 to 47.83 g/t/t. There was significant variation for growth and yield among and within progenies. Progeny of PB 28/83 gave the highest mean yield (Table Bot. 9).

Table Bot. 9. **Yield of progenies in the fourth year**

Progeny	Trial I		Trial II	
	Yield (g/t/t)	Variance ratio within progenies	Yield (g/t/t)	Variance ratio within progenies
RRII 105	47.83	5.66*	45.72	13.13*
PB 242	35.24	9.86*	39.25	0.36
AVT 73	29.26	7.76*	26.87	1.42
PB 252	33.36	3.59*	56.56	8.80
PB 217	33.17	0.54*	35.88	11.70*
PB 28/83	43.09	8.14*	58.53	0.82
PB 5/51	35.45	12.09*	43.88	2.94
PB 215	41.28	4.15*	45.26	2.22
Ch 26	40.99	2.76*	50.46	26.00**
PB 5/76	32.63	8.81*	34.47	6.81
VR (between progenies)	21.59**		8.36*	
CD (P=0.05)	3.70		10.20	

* Significant at P<0.05 ** Significant at P<0.01

In comparison with the high yielding check clone, RRII 105 which gave 57.76 g/t/t, 22 clones belonging to eight of the progenies proved to be better in terms of rubber yield. The progeny of PB 28/83 showed the highest recovery of high yielding clones, indicating the prepotent ability of the parent clone. More than 66 per cent of clones within this progeny had over 10 latex vessel rows in the year of opening which is higher than that of clone RRII 105.

A study of genetic parameters in 11 full sib progenies showed high heritability for yield (68%), girth at opening (44%), clear bole volume (36%) and number of latex vessel rows in the soft bast (44%). Clear bole volume showed a significant positive correlation (Table Bot. 10) with rubber yield ($r = 0.54$; $P<0.05$), girth at opening ($r=0.54$; $P<0.05$) and forking height ($r =0.24$; $P<0.05$). The proportion of laticifers in the soft bast showed a significant positive correlation with annual mean yield ($r=0.20$; $P<0.05$).

4. Cytogenetics and floral biology

4.1. Cytogenetical investigations

Cytopalynological investigations were attempted on TPD affected trees. Pollen sterility ranging from 10 to 40 per cent was observed in samples collected from TPD affected trees in Central Kerala.

4.2. Studies on storage of *Hevea* pollen

Possibility of storing *Hevea* pollen grains under -80°C was investigated. Pollen grains of RRII 105 were stored in deep freezer after reducing the moisture content to a range of 10 to 20 per cent. Pollen samples were recovered after one year, tested for viability using staining method and the germinability was assessed. Pollen grains stored under -80°C retained 25 per cent viability and 55 percent stainability under *in vitro* conditions when compared to the fresh pollen as control. These pollen grains were used for field pollinations on female flowers of PB 330 and resulted in 2 per cent fruiting success.

Table Bot. 10. **Correlation among yield and related attributes**

Traits	Annual mean yield	Summer yield	Girth at opening	Clear bole volume
Girth at opening	0.558*	0.585*	1.000	0.541*
Summer yield drop %	0.242*	0.097	-0.117	0.126
Volume of latex	0.479*	0.547*	0.450*	0.289*
Girth increment (immaturity)	0.489*	0.450*	0.670*	0.437*
Girth increment (tapping)	0.160	0.150	0.099	0.154
Girth 10th year	0.573*	0.532*	0.832*	0.573*
Forking height	0.124	-0.050	0.053	0.242*
Total bark thickness	0.200*	0.200*	0.052	0.089
Soft bast thickness	0.050	-0.097	-0.083	0.065
Hard bast thickness	0.146	0.200*	0.141	0.124
Total LVR	0.040	-0.019	-0.134	-0.057
LVR in soft bast	0.143	0.035	-0.091	-0.019
% of LVR in soft bast	0.200*	0.120	-0.024	-0.007
Clear bole volume	0.536*	0.342*	0.541*	1.000

* Significant at P< 0.05

5. Anatomical investigations

5.1. Bark anatomy

Monthly bark sampling was carried out from RRS Orissa and recorded the structural parameters related to yield. Total bark thickness (TBT), latex vessel rows (LVR), calcium oxalate crystals and yield showed significant clonal and seasonal variations. RRII 105 was more consistent than RRIM 600 for the parameters selected.

Bark samples collected from the ortet clone evaluation trials at HBSS Nettana revealed significant variation among the clones for bark anatomical parameters related to yield (Table Bot. 11). Highest values for bark thickness and LVR respectively were

Table Bot. 11. **Bark anatomical parameters of ortet clones selected from smallholdings**

Experiment I			Experiment II			Experiment III		
Clone	TBT	TVLR	Clone	TBT	TVLR	Clone	TBT	TVLR
O 12	5.87	8.17	O 14	7.19	9.58	O 11	6.74	13.25
O 15	6.48	7.25	O 16	6.94	7.50	O 26	7.19	12.33
O 17	7.26	16.42	O 22	6.08	8.17	O 30	6.51	11.92
O 19	5.67	9.83	O 23	4.73	11.92	O 39 A	6.69	10.00
O 34	6.93	14.25	O 37	7.14	12.42	O 49	7.04	10.17
O 41	6.65	17.50	O 38	6.69	12.00	O 51	7.20	11.50
O 44	7.34	12.08	O 40	7.73	15.00	O 55	9.12	13.08
O 45	6.99	11.33	O 46	8.94	11.08	O 56	8.33	16.33
O 46	8.81	18.58	O 53	8.34	13.33	O 64	7.05	12.92
O 47	7.84	10.25	O 54	7.81	13.33	C 6	7.11	12.25
O 50	5.90	11.17	O 57	6.63	9.92	C 10/9	7.16	12.42
C 1/2	7.18	15.75	C 9	6.40	10.58	C 32	8.93	10.25
C 7/2	6.78	12.50	C 150	7.70	14.67	C 140	6.89	13.00
C 42	7.86	18.17	C 151	6.53	10.83	C 152	5.78	10.50
C 70	7.29	13.42	T 1	7.89	14.31	RRII 105	7.55	14.67
T 2	8.19	16.17	PO	7.32	10.33	RRIM 600	5.89	10.08
RRII 105	7.70	17.33	RRII 105	6.96	17.25	GT 1	7.39	13.25
RRIM 600	7.78	20.00	RRIM 600	6.81	12.00			
GT 1	6.45	13.75	GT 1	7.63	15.08			
CD P=(0.05)	2.01	6.32	CD	1.74	4.75	CD	1.90	4.55

recorded from clones O 46 (8.81 mm) and RRIM 600 (20) in Expt. 1. In Expt. II, O 46 (8.94 mm) and RRII 105 (17.3) and in Expt. III, C 32 (8.9 mm) and RRII 105 (14.7) recorded highest values respectively for TBT and LVR.

Fifteen TPD affected trees of clone RRII 105 at the age of 22 years were selected and removed the dry unproductive bark through successive tappings leaving the cambium undisturbed. The wounded area was coated with wound dressing compound, to study the cambial activity and bark regeneration.

5.2. Wood anatomy

Over 2400 wood samples of varying dimensions were prepared from experimental trees after felling, following standard procedures, for testing the physical and mechanical properties subsequent to ethephon stimulation. Physical properties of wood from ethephon stimulated trees of clones RRII 105 and RRIM 600 was compared with the respective unstimulated controls (Table Bot. 12). Though there was a numerical increase in moisture content following stimulation in both the clones the differences were not significant. The comparable moisture levels in either clones are indicative of no loss of green weight of the logs due to stimulation. This could be further substantiated by the estimated green density values. The green density values, which gives a basic indication of the general utility of green wood for the stimulated and control trees of RRIM 600 were also similar but it was slightly higher than that of RRII 105.

Basic density worked out at 12 per cent MC in stimulated trees was relatively lower than that of the control trees in both the clones. The density values of the stimulated trees of RRII 105 were within the limits of the control whereas a significant reduction in basic density was observed in stimulated trees of RRIM 600. The extent of variation in basic density due to ethrel stimulation appears to be a clonal characteristic.

Physical properties at different height levels of the bole (from base to top) examined for both the clones showed that the MC and density values for the stimulated trees of RRII 105 was on par with the control at all height levels where as RRIM 600 showed significant variation in basic density between the basal and middle regions.

6. Studies on propagation

6.1. Deep planting methods

Trials on deep planting of two whorled polybag plants showed no significant difference for yield and girth between the treat-

Table Bot. 12. **Physical properties of stimulated and control trees of RRII 105 and RRIM 600**

Treatment properties	RRII 105			RRIM 600		
	Control mean	Stimulated mean	't' value	Control mean	Stimulated mean	't' value
Moisture content (%)	60.21 (5.87)*	63.90 (6.29)	-1.38	67.27 (4.17)	71.80 (5.14)	-2.09
Green density (green t/green vol.) kg/m³	981.82 (47.15)	988.50 (31.85)	0.37	1026.07 (40.38)	998.80 (30.67)	1.60
Basic density (oven dry wt/ green vol.) kg/m³	621.90 (38.35)	603.00 (32.19)	0.47	610.55 (20.36)	585.80 (25.23)	2.48**

* Values in parentheses indicate standard deviation
** Significant at 0.1%

ments through out the period of study including yield over first five years of tapping.

6.2. Single stock and twin stock

In the comparative study of twin stock and single stock the trees of twin stock with double root system and single stock (normal type) were opened for regular tapping and yield recording. Initial growth rate after opening among the treatments showed no significant difference between twin stock and single stock.

6.3. Various forms of planting material

Observations on growth parameters in the fourth year after planting were recorded on all the plants raised from different forms of planting material to assess the girth increment. Significant variation was recorded for girth among different forms of planting materials after four years of growth in the field. Green budded plants recorded highest girth (29.21 cm) with better girth increment followed by young budded plants where budgrafting was done on the stock of 42 days old seedlings (27.83 cm). Lowest girth was recorded in the field budded plants.

6.4. Genetic basis of stock scion relationship

Data on growth and mean yield of trees budded on their own stock and assorted stock showed that the growth and yield over 10 years are mainly controlled by genotype of the scion rather than stock.

7. Morphological characterization of popular clones

Rubber planters were made aware of the methods of identification of popular clones based on morphological characters through a series of articles in the vernacular language. Advisory services on clone identification were also rendered.

GERMPLASM DIVISION

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

1.1. Wickham collection from secondary centers

183 Wickham clones are being conserved in field gene banks (one clone museum at RRII, Kottayam, and three germ plasm gardens at CES, Chethackal). Among the 15 clones in Garden III, RRII 203 recorded the highest yield (78.615 g/t/t) in panel BI –2, followed by PB 310 (72.97 g/t/t) and RRII 118 (67.59 g/t/t), while RRII 118 had the highest girth followed by RRII 203, RRII 300 and RRII 206.

Among the five IRCA clones, IRCA 130 and IRCA 111 continued to show superior performance, while the remaining three were on par with RRII 105 (Table Ger. 1).

Table Ger.1. **Girth and dry rubber yield of IRCA clones**

Clone	Annual girth (cm)	Dry rubber yield (g/t/t)
IRCA 111	65.8	53.02
IRCA 130	63.9	62.39
IRCA109	58.9	32.28
IRCA 230	56.4	40.04
IRCA 18	54.4	39.11
RRII 105	55.1	43.01
CD (P=0.05)	6.54	13.17

In Garden V, RRIC 100 maintained its superiority among the 20 clones in terms of girth (77.13 cm) and yield (57.90 g/t/t). Other clones showing high girth were RRII 178 (71.47 cm), RRIC 102 (68.81 cm) and PB 255 (67.81), while the control clone RRII 105 had a girth of 58.27 cm. PR 255 (48.77g/t/t) and RRIM 609 (46.74 g/t/t) also showed relatively high yield.

1.2. Wild genepool

Field conservation of a total of 3576 wild accessions was continued in nurseries. 24 wild accessions, selected on the basis of their performance in other countries, were imported from the base collection at the Malaysian Rubber Board and initial multiplication was carried out.

As part of the programme on re-establishing the wild germplasm nurseries, the second set of 975 accessions was planted in conservation nursery 2004. Annual girth and other quantitative traits were recorded in the first year of growth. Field screening of these accessions for drought resistance was initiated. 701 wild accessions were multiplied for planting in the next phase in 2005.

1.3. Other species

The accessions *H. pauciflora* and *H. nitida* from Sri Lanka, and *H. pauciflora* and *H. camargoana* from Indonesia have been successfully multiplied for generation of sufficient budwood. *H. camargoana*, continued to show precocious flowering in the further stages of multiplication also.

2. Characterization and preliminary evaluation

Growth of the wild accessions in the preliminary evaluation trials (PET) was monitored. In the PET 1994A, 8 accessions were superior to RRII 105 in girth, with the highest girth recorded by AC 757 (60.20 cm) followed by RO 895 (52.10 cm), AC 664 (48.30 cm) and MT 940 (46.33 cm). In PET 1994B, most of the clones had a girth on par with RRII 105 (Table Ger. 2) while AC 643 was superior. Branching height was lowest in RRII 105 and highest in AC 699. Yield ranged from 0.48 to 3.89 g/t/t, while the control RRII 105 showed 10 times higher yield. Girth increment (GI%) before tapping ranged from 88.42% (AC 971) to 175.97% (RO 856). GI% after tapping was highest in AC 643 (20.69%) and lowest in AC 971 (5.25%), with RRII 105 also showing very low growth rate on tapping. Though the rate of growth of AC 643 before tapping was on par with that of RRII 105, the significantly higher girth and GI% of this clone after tapping indicated its higher partitioning of assimilates towards biomass increment rather than yield. In PET 1994C, RO 893 recorded the highest girth of 56.10 cm followed by AC 465 (52.60 cm) and AC 645 (50.10 cm).

Among the nine wild germplasm clones in PET (Ortets) 1994D, RRII 105 showed the highest girth while OR 1130, OR 1181, OM 1124 and OR 1175 were on par with RRII 105 ten years after planting. Among the clones, RRII 105 had very low branching height, while OA 1094 and OR 1168 had significantly higher values. The correlation between the two traits was not statistically significant. In PET (Ortets) 1999, girth of the wild accessions ranged from 11 cm (OR 1145) to 39.5 cm (OM 1107), while that of the controls were 37.3 cm (PB 260), 40.6 cm (RRIM 600) and 43.5 cm (RRII 105). OR 1182 also had relatively high girth (37.7 cm) among the wild accessions.

Annual girth recorded in PET 2000A was the maximum in RO 3758 (25.40 cm), followed by MT 3078 (22.34 cm) and MT 4379 (21.22 cm). In PET 2000B (Table Ger. 3) with 166 wild accessions, several accessions were superior in growth and yield.

The accession with highest girth was AC 3638 whereas the highest girth increment was shown in AC 3591. Three AC accessions

Table Ger. 2. **Performance of 24 wild accessions two years after tapping in PET 1994B**

Sl. No.	Accession	Girth 2005**	Br Ht*	GI% (97-03)*	Tapping GI% (03-05) **	Yield**
1	AC 689	32.13	8.81	97.67	8.24	2.11
2	AC 699	38.70	13.01	142.15	7.46	0.91
3	AC 668	29.08	7.40	105.68	5.72	0.53
4	AC 643	50.95	9.79	135.11	20.69	0.75
5	AC 714	42.59	12.25	138.65	12.20	1.42
6	AC 775	38.37	8.59	166.79	10.66	1.73
7	AC 748	44.49	9.52	137.93	10.48	1.74
8	AC 606	42.45	11.76	149.66	8.80	3.89
9	AC 634	38.87	8.35	137.03	11.02	0.73
10	AC 971	33.52	8.14	88.42	5.25	0.59
11	AC 616	30.69	9.03	97.64	5.83	0.56
12	AC 618	45.99	2.96	145.43	11.85	3.56
13	AC 438	38.57	5.42	140.95	9.30	2.46
14	AC 961	36.35	10.99	116.18	8.06	1.87
15	RO 856	41.05	4.73	175.97	8.33	1.82
16	RO 372	39.99	5.43	147.19	9.76	1.02
17	AC 773	43.26	11.24	139.86	13.33	3.85
18	AC 458	41.54	8.56	113.81	9.59	1.57
19	AC 669	38.48	7.40	124.46	7.90	1.01
20	AC 662	44.82	9.81	156.88	13.91	1.30
21	AC 709	39.94	9.74	122.85	9.99	0.48
22	AC 670	39.34	7.29	147.46	12.30	1.28
23	RO 863	36.48	8.95	100.25	10.23	1.32
24	AC 962	38.95	6.91	131.75	15.59	1.78
25	RRII 105	41.82	2.93	137.43	7.04	36.27
CD (P=0.05)		6.975	3.353	49.391	6.19	8.246

* Significant at 0.05%
** Significant at 0.01%

Table Ger. 3. **Accessions superior for girth, girth increment and test tap yield in PET 2000B**

Accession	Girth (cm)	Accession	Girth increment (%)	Accession	Test tap yield (g/t/t)
AC 3638	30.90	AC 3591	105	AC 3307	8.27
RO 3669	29.04	AC 153	94	AC 3055	7.60
RO 3647	27.03	AC 3595	91	AC 3638	6.84
MT 39	26.93	AC 1083	90	MT 4351	3.23
AC 542	26.40	MT 79	62	MT 182	2.44
RO 2883	26.08	RO 149	62	RO 341	2.32
MT 3705	24.90	MT 39	62	AC 2027	2.11
RO 3261	23.80	AC 3638	58	MT 3705	1.03
AC 2004	23.75	AC 4160	57	AC 647	1.01
RO 394	23.37	AC 647	56	RRII 105	4.18
AC 596	23.25	RO 136	53	RRII 208	2.30
MT 936	23.20	MT 4248	51	RRIM 600	2.45
RO 248	22.70	AC 4107	51		
RRII 105	22.85	AC 591	51		
RRII 208	17.45	RO 2565	50		
RRIM 600	16.77	AC 3941	50		
		RRII 105	55.4		
		RRII 208	46		
		RRIM 600	43.3		

viz., AC 3307, AC 3055 and AC 3638 recorded higher test tap yield than the control clone RRII 105. In PET 2002, AC 567 recorded the highest girth (13.50 cm) followed by MT 5269 (10.50 cm) and RO 1769 (10 cm) whereas the control clones RRII 105, RRII 208 and RRIM 600 recorded a girth of 8.95 cm, 9.81 cm and 9.79 cm respectively.

3. Further evaluation and selection

The annual girth, percentage girth increment and bark thickness at the age of 9 years and dry rubber yield at fortnightly intervals in the first year of tapping were recorded. The girth of the wild accessions ranged from 29.84 cm (MT 188) to 53.77 cm (AC 2004), while that of RRII 105 was 42.61 cm. Six accessions (Acre - 1; Rondonia – 1; Matogrossa – 4) had significantly higher girth over RRII 105. The percentage girth increment ranged from 4.35% (MT 1599) to 21.71% (AC 638). 10 accessions (Acre – 1; Rondonia – 2; Matogrossa – 7) had significantly higher GI% over control (6.76%). Bark thickness was minimum in AC 651 (3.82 mm) and maximum for MT 2233 (6.03 mm) and the control clone RRII 105 recorded 5.68 cm. The mean dry rubber yield for four months (average of eight tappings) was comparatively less in all clones than in RRII 105 (23.13 g/t/t). Four accessions showed around 50% of the yield of RRII 105.

In the further evaluation trial (FET 2003), MT 1707 recorded the highest plant height (2.31 m) in the second year of growth followed by MT 1002 (2.14 m), MT 196 (2.11 m) and MT 2233 (2.09 m). Control clones RRIM 600, RRII 208 and RRII 105 recorded a height of 2 m, 1.71 m and 1.69 m respectively.

4. Screening for resistance

4.1. Biotic stress resistance

Screening of the wild accessions for resistance to *Phytophthora*, *Oidium*, *Corynespora* and *Collototrichum* was continued in collaboration with the Pathology Division. 151 wild accessions were reported to be resistant to *Phytophthora* sp. and 171 accessions tolerant to *Corynespora* under *in vitro* conditions. Three accessions have been shortlisted for resistance to *Oidium*.

4.2. Abiotic stress resistance

4.2.1. Drought tolerance

Summer girth and annual girth increment were recorded from16 wild accessions along with 4 control clones (RRII 208, RRIM 600, Tjir 1 and RRII 105) in the pot experiment for screening for drought tolerance planted at RRII, Kottayam. The highest girth increment was shown by the accession MT 81 (60.4%) followed by MT 200 (57.9%). Among the control clones, RRIM 600 showed the highest girth increment of 79.8%.

MT 1623 and MT 1681 did not show any mortality whereas in the remaining accessions the mortality rate ranged from 20- 80%. Among the control clones, RRII 105 showed 100% mortality followed by Tjir 1 (60%).

From the 2001 screening trial for drought tolerance at RRS, Dapchari five accessions viz., MT 1616, MT 54, MT 1649, MT 1619, MT 1627 were selected for further evaluation. In the field screening trial planted in 2002 at RRS, Dapchari, growth performance of 42 accessions was assessed along with control clones RRIM 600, RRII 105 and Tjir 1 after exposing the plants for two years drought period. The potential drought tolerant accessions identified are MT 40, MT 41, MT 43, MT 945 and MT 80.

In the 2003 field trial at RRS, Dapchari, growth performance of 130 wild accessions was assessed during the pre and post drought periods. Potential accessions were identified during the first year pre-drought period. Most of the potential accessions belonged to MT and RO provenances indicating their superiority. Wide variability in growth performance was noticed among the accessions. After exposing the plants to one

drought season, MT 1623 showed more foliar production, while RO 2387 and MT 1697 were superior for height and girth. Leaf shedding was minimum in MT 4222. Among the control clones, RRIM 600 continued to be superior as in the previous periods. The top 10 accessions for various growth parameters over the control clones during the post drought period are listed in Table Ger. 4.

The accessions RO 2387, MT 1681 and MT 72 indicated superior and stable performance in the drought prone area. In the drought evaluation trial 1996 at RDC, Sukma, RRII 208 recorded the highest girth of 60.75 cm followed by RO 5430 (58.67 cm), RO 2635 (58.55 cm), RO 5554 (57.20 cm) and MT 196 (56.77 cm), whereas control clone RRII 105 recorded a girth of 51.11 cm. RRII 208 recorded the highest yield of 31.89 g followed by RO 5363 (20.79 g), RO 5430 (11.85 g) and MT 196 (10.08 g). RRII 105 recorded an yield of 19.57 g.

In the project on rapid *in vitro* screening of *Hevea* germplasm lines for intrinsic drought tolerance traits, four potential drought tolerant accessions were identified viz., MT 5100, MT 5078, MT 4788 and MT 4856. A preliminary field level scoring for drought tolerance was conducted based on drought related morphological parameters and 23 accessions out of 967 were found to be superior.

4.2.2. *Cold tolerance*

In the two trials with a total of 64 wild accessions for screening of wild germplasm for cold tolerance at RRS, Nagrakata, statistically significant variation in growth was observed from the pre and post winter period. In the pre winter period, in trial 1, maximum girth was recorded in MT 3452 (36.59 cm) while the control clones SCATC 93/114 and RRIM 600 had lower girth values (31.61 cm and 28.72 cm respectively). Five accessions had significantly higher girth than RRIM 600 and one accession (MT 3452) than that of SCATC 93/114. In trial 2, maximum girth was recorded by MT 915 (36.36 cm), which was higher than the girth of the control clones RRIM 600 (31.51 cm) and Haiken 1 (36.11 cm).

In the post winter phase, in trial 1, only eight and fourteen accessions had a higher girth value compared to SCATC 93/114 (32.81 cm) and RRIM 600 (30.14 cm) respectively. In trial 2, MT 915 retained its vigour with a girth of 37.24 cm compared to RRIM 600 (31.56 cm) and was on par with Haiken 1. Nine accessions had girth higher than RRIM 600. In trial 1, AC 486 had the

Table Ger. 4. **Potential accessions for various characters during first year post-drought (2003 trial)**

Height (cm)	Girth (cm)	No. of whorls	No. of leaves	Senescence (%)
RO 2387 (304.0)	MT 1697 (8.16)	RO 3660 (5.6)	MT 1623 (71.2)	MT 4222 (32.7)
MT 1697 (300.0)	RO 3626 (8.07)	RO 1526 (5.0)	RO 1575 (67.2)	MT 1623 (35.5)
RO 2889 (293.0)	RO 1260 (8.05)	RO 96 (4.7)	RO 1526 (63.0)	RO 3660 (37.6)
RO 3229 (284.0)	RO 2889 (7.98)	MT 1623 (4.6)	RO 1454 (62.3)	RO 2889 (38.1)
AC 1495 (281.0)	MT 1681 (7.88)	MT 4222 (4.6)	RO 3660 (62.2)	MT 60 (39.2)
RO 93 (275.0)	RO 1751 (7.85)	MT 60 (4.5)	MT 3686 (61.8)	RO 2835 (39.4)
RO 1260 (275.0)	MT 82 (7.82)	RO 1758 (4.5)	AC 1495 (60.6)	RO 1540 (40.0)
RO 1229 (274.0)	AC 3057 (7.79)	MT 1584 (4.5)	RO 3043 (60.6)	MT 3696 (40.1)
MT 181 (272.0)	RO 1229 (7.76)	MT 3693 (4.4)	MT 4222 (60.4)	RO 224 (40.9)
MT 710 (272.0)	RO 1204 (7.75)	RO 1313 (4.3)	MT 60 (60.0)	AC 1205 (41.6)
RRIM 600 (277.4)	RRIM 600 (59.96)	RRIM 600 (4.64)	RRIM 600 (69.4)	RRIM 600 (42.83)
RRII 105 (162.74)	RRII 105 (52.52)	RRII 105 (3.42)	RRII 105 (41.17)	RRII 105 (49.7)
Tjir 1 (175.15)	Tjir 1 (51.43)	Tjir 1 (3.78)	Tjir 1 (54.94)	Tjir 1 (43.52)
RRII 208 (197.35)	RRII 208 (54.87)	RRII 208 (3.89)	RRII 208 (52.76)	RRII 208 (49.63)

highest girth increment of 1.91 cm. These five accessions with the highest girth values during the stress period, showed superiority in their overall performance. In trial 2, maximum girth increment over the stress period was in RO 2727 (1.83 cm). Four accessions with highest annual girth in the pre winter phase had high girth increment during the stress period also.

Based on the overall growth performance for the first three years, 33 accessions comprising two extreme classes of tolerance and susceptibility were selected from the two trials for DNA profiling and genetic divergence studies using RAPD markers.

5. Screening for timber characteristics

5.1. Field screening

Annual girth was recorded from the timber screening trial at the age of 56 months and percentage girth increment computed. Alternate trees in the trial (12 trees per accession comprising a total of 300 trees from 19 wild accessions and 6 Wickham clones) were clear felled for destructive sampling and analyzed for the parameters viz., bole height, bole volume, basic wood density, aerial biomass (trunk / branch wood biomass) and proportion of tension wood (Table Ger. 5).

The maximum trunk biomass (wet) in the wild accessions (17.56 kg), the dry weight biomass (7.38 kg), branch wood biomass and total biomass (both wet and dry) were recorded by RO 322. Among the Wickham clones the total biomass was the highest in PB 260 and lowest in RRII 118. In general, majority of the wild accessions were statistically on par with all the six Wickham clones for the aerial biomass. The girth showed positive correlation with total wood biomass and trunk biomass whereas the total biomass and trunk biomass were negatively correlated (Table Ger. 6).

Table Ger. 5. **Wood density and proportion of tension wood at the age of 56 months**

Accession	Wood density (kg/m^3)	Tension wood (%)
Wild accession		
RO 322	564.71	36.91
MT 999	563.36	50.79
MT 915	635.00	45.98
MT 1021	586.37	23.28
MT 919	627.30	40.76
MT 1032	533.34	34.41
MT 922	607.00	52.24
MT 941	504.31	31.01
RO 879	607.69	36.08
AC 650	557.00	36.36
AC 635	527.67	36.78
AC 707	508.64	37.62
MT 1020	565.67	44.95
AC 685	581.00	34.91
RO 255	538.31	40.60
AC 637	597.67	47.06
MT 935	604.00	45.15
AC 655	594.00	44.18
AC 651	593.33	48.65
Wickham clones		
RRII 33	586.00	41.91
PB 235	569.33	41.24
RRII 118	544.33	38.35
PB 260	599.33	31.14
RRIM 600	599.33	42.73
RRII 105	586.00	29.51
CD (P=0.05)	61.48	12.71

5.2. Screening for timber quality traits

On estimation of the cell wall residue (CWR) of 18 wild accessions and 2 Wickham clones, the percentage of lignin was seen to vary considerably between different height levels within plants as well as between accessions. The variation between positions within plants was highly significant in all the accessions. The lignin content gradually increased from top to bottom in association with the secondary thickening and wood formation. Regarding the plant average, the lignin content (percentage) ranged from 21 – 27.43%. Nine wild accessions had a significantly higher lignin content than that of the control clones, RRII 105 and RRIM 600. (Table Ger. 7).

Table Ger. 6. **Aerial biomass on wet weight and dry weight basis**

Accession	Aerial biomass (kg) (wet weight)			Aerial biomass (kg) (dry weight)		
	Trunk	Branch	Total	Trunk	Branch	Total
RO 322	17.56	21.21	38.77	7.38	9.46	16.84
AC 635	13.51	14.94	28.45	3.39	3.98	7.37
MT 941	12.74	8.27	21.01	5.83	4.45	10.29
MT 915	11.69	25.00	36.69	5.79	7.43	13.22
AC 707	11.60	10.41	22.01	7.17	2.39	9.56
MT 919	11.73	16.51	28.24	5.93	6.02	11.92
MT 922	11.34	14.68	26.02	5.69	7.35	13.07
AC 650	10.49	7.61	18.10	4.87	2.63	7.50
MT 1021	10.22	10.22	20.44	6.24	2.89	9.12
AC 685	9.84	8.09	17.93	4.41	5.48	9.89
AC 655	8.67	7.98	16.65	4.50	2.67	6.76
AC 637	8.69	6.79	15.48	4.44	2.88	7.32
MT 1032	8.50	13.73	22.23	5.48	5.83	11.23
RO 255	7.84	10.08	17.92	3.74	3.22	6.96
MT 935	7.84	7.19	15.03	4.41	3.62	8.03
MT 999	7.37	13.11	20.48	4.95	4.87	9.82
AC 651	6.53	5.01	12.54	3.02	2.20	5.22
RO 879	6.69	5.80	12.49	3.11	1.59	4.88
MT 1020	6.58	6.26	12.84	3.57	2.16	5.72
RRII 33	20.34	27.52	47.86	9.44	11.34	20.78
PB 260	16.74	26.83	43.74	8.13	13.03	21.16
PB 235	15.32	22.58	37.90	6.86	9.88	16.53
RRII 105	13.59	30.05	43.57	6.75	13.74	20.49
RRII 118	12.96	25.17	38.12	6.13	7.95	14.08
RRIM 600	11.73	23.22	34.95	5.85	11.39	17.24
CD (P=0.05)	6.60	13.12	17.75	4.44	6.29	8.25

Histochemical localization of the lignin precursor enzyme, cinnamoyl alcohol dehydrogenase (CAD) was carried out in these clones. The distribution pattern of enzyme localization and lignification from the tissue prints and *in situ* preparations were captured and documented to quantify and correlate the enzyme activity and lignification.

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

The tree felling and wood sampling of 10 clones were completed. The bole volume, basic wood density, volumetric shrinkage and proportion of tension wood were recorded and analyzed (Table Ger. 8).

Among the ten clones, PB 235 had the maximum bole volume (0.82 m^3) and was superior to RRII 105 (0.42 m^3). The wood density was highest in RRII 105 even though the quantity of wood produced was numerically less in the clone.

The proportion of tension wood formation increased from base to top of the tree truck in majority of the clones. The percentage of tension wood formed in these ten clones was within the range of 16.68% (RRIM 600) - 25.91% (RRII 45) but the difference was not statistically significant.

The wood of PB 235 showed the maximum volumetric shrinkage, which was significantly higher than eight clones and on par with RRII 105. In general, the volumetric shrinkage in green to air dry condition of rubber wood is below 5 % which is comparable to that of teak wood as 6.9%.

Table Ger. 7. **Lignin percentage at the age of four years**

Accession	Lignin (% wt. of EXR)			
	I[st] Interwhorl	2[nd] Interwhorl	3[rd] Interwhorl	Accession mean
RO 5022	26.35	27.58	28.36	27.43
AC 4830	25.49	27.13	29.16	27.26
AC 4654	24.96	27.23	28.98	27.06
MT 6180	22.56	26.34	28.40	25.77
MT 4697	23.18	25.34	28.37	25.63
MT 5085	23.24	25.38	28.26	25.63
RO 4911	21.18	26.12	29.42	25.57
AC 4638	22.04	24.97	27.29	24.77
MT 4859	21.65	24.79	26.90	24.45
MT 4804	21.52	25.14	26.43	24.36
RO 4617	22.04	24.33	26.28	24.22
AC 4937	19.53	23.03	28.58	23.71
RO 4574	19.77	22.38	25.01	22.39
AC 4833	19.74	23.36	24.19	22.43
RO 4605	18.29	20.03	28.33	22.22
AC 4677	19.72	21.61	23.96	21.76
RO 4942	19.11	21.22	23.12	21.15
MT 5091	18.51	20.32	24.34	21.06
RRIM 600	20.35	22.50	26.15	23.00
RRII 105	18.31	20.20	24.51	21.00
t: Inter whorl	Inter whorl	Inter whorl		
1 - 2 = 5.56 **	2 - 3 = 6.75**	1 - 3 = 13.10 **	CD (P = 0.05)	1.42

** Significant at 0.05%

Table Ger. 8. **Bole volume, basic wood density, proportion of tension wood and volumetric shrinkage of 10 clones at the age of 23 years**

Clone	Bole vol. (m^3)	Basic density (kg/m^3)	Tension wood (%)	Volumetric shrinkage (%)		
				GAD	GOD	ADOD
PB 235	0.82	568.94	21.56	4.93	7.71	2.86
PR 255	0.65	532.00	23.77	2.39	7.00	4.87
PB 260	0.64	518.33	24.08	1.89	7.41	5.29
RRIM 600	0.64	563.94	16.68	2.05	7.79	5.85
PR 261	0.63	531.44	24.32	2.82	8.11	5.42
PB 310	0.60	556.50	17.50	2.00	7.63	6.09
PB 311	0.55	566.83	18.87	1.72	8.78	6.11
RRII 44	0.54	543.28	19.25	1.87	7.65	5.88
RRII 45	0.49	565.34	24.91	1.25	7.81	6.40
RRII 105	0.42	604.94	18.98	3.15	7.70	4.96
CD(P=0.05)	0.25*	25.47 **	NS	1.84 *	NS	1.65*

GAD : Green, air dry ; AD- OD : Air dry, oven dry; GOD : Green, oven dry.

6. Molecular characterization

The study was completed in 110 accessions with 16 random primers. Very high level of polymorphism was observed for all the primers showing the wide extent of DNA polymorphism available in the wild germplasm. The pair wise genetic distances were used for clustering the 110 wild accessions (Table Ger. 9). The origin of the accessions to the three distinctly different geographic zones of the provinces Acre, Rondonia and Mato Grosso did not have a significant contribution in the basic cluster-

Table Ger. 9. **Cluster wise distribution of the wild accessions when grouped by UPGMA method**

Cluster no.	No. of wild accessions	Province wise distribution in each cluster
1	47	Acre- 16 Rondonia – 30 Mato Grosso - 1
2	23	Rondonia – 3 Mato Grosso -20
3	39	Acre- 13 Rondonia – 7 Mato Grosso - 19
4	1	Acre (AC 959)

ing pattern where each cluster included accessions from all the provinces. At 60 per cent dissimilarity, the 110 wild accessions were classified into three large clusters, which contained highly diverse sub clusters. The three major clusters had 47, 23 and 39 accessions each. In Cluster 1, all the accessions except one (MT 899 from Mato Grosso province) were from Acre and Rondonia. Accessions from Mato Grosso dominated Cluster 2, along with three accessions from Rondonia. Cluster 3 did not show any general trend, with a mixture of accessions from the three provinces of Acre, Rondonia and Mato Grosso with 13 Acre, 7 Rondonia and 19 Mato Grosso accessions. The lone accession from Acre, AC 959 was found to be have the maximum divergence with all the remaining 109 wild accessions as it stood separately and had the least similarity matrix value of 0.1587 with the Rondonian accession RO 401. The maximum similarity matrix coefficient was between the accessions MT 1007 and MT 1010 (0.8077).

In the 35 accessions selected from the cold screening trial at RRS, Nagrakata, DNA extraction and RAPD assay using 19 primers were completed.

Molecular level studies on genetic diversity using RAPD markers were initiated in 114 wild accessions. RAPD analysis of genetic distance among 18 wild accessions (9 each from high and low girth categories) indicated that the genetic distance of the trees between the low and high girth categories was greater than the trees within a girth category.

7. Utilisation of *Hevea* germplasm

7.1. W X A Open pollination garden 2005

Twenty-four selected Amazonian (A) and 11 Wickham (W) clones were further multiplied to plant a small open-pollination garden at RRS, Padiyoor in 2005, with the objective of providing a perennial source of W X A OP seeds (which will be subjected to rigorous selection), for broadening the genetic base of *Hevea*.

8. Ratooning in *Hevea*

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. The ratoons registered a mean girth of 35.48 cm as against 13.19 cm for the budgrafted control. 77.4 per cent of the ratoons recorded a mean girth of more than 30 cm. No correlation has been observed so far between girth of the original plants in 1987, and the girth of their ratoons. In another observation plot in a farmer's field at Aluva comprising 90 trees of uncertain age and clone, felled in October 2003, ratoons were found to have an average girth of 10 cm after one year of growth.

9. Characterisation of TPD on the basis of bark symptoms

An experiment on the histological symptoms leading to abnormal tissue growth in bark of TPD affected trees was initiated. Bark samples were collected from TPD affected trees having various external symptoms and healthy trees and processed for histological and histochemical investigations.

MYCOLOGY AND PLANT PATHOLOGY DIVISION

Control of pathogens and pests of rubber through chemical and biological means has been the major area of research of the Division. Other areas being etiology of TPD, role of microorganisms in plant growth, bee keeping, pollution control and waste material utilization.

1. Leaf diseases

1.1. Abnormal leaf fall disease

Field experiment was continued in high disease prone area, Palappilly, on highly susceptible clone RRIM 600 to compare the efficacy of diesel as such and in combination with the recommended agricultural spray oil (1:1), as diluent oil for copper oxychloride (COC) for spraying against abnormal leaf fall (ALF) disease. The leaf retention assessment indicated that diesel is as good as spray oil (SO) for spraying in rubber plantations (Table Path. 1).

Various physical parameters such as unsulphonated residue (USR) value, kinematic viscosity, specific gravity, pour point, suspensibility with COC (1:5 proportion) etc. of diesel and spray oil did not differ and were conforming to the specifications prescribed. However, flash point was low for diesel indicating its suitability only for ground spraying and not for aerial (helicopter) spraying.

An oil emulsion developed by R & D division of Indian Oil Corporation Ltd., Faridabad was used while mixing water-dispersible powder formulations of copper oxychloride with water to reduce the cost of spraying. The emulsion oil was used @ 3% in clone GT 1. Leaf retention assessment showed that water-based copper fungicide with emulsion oil could be effective in moderately susceptible clones.

Table Path.1. **Leaf retention**

Treatment	% leaf retention
Micron sprayer	
COC in diesel	82.0
COC in diesel + spray oil (1:1)	78.0
COC in SO	83.0
Unsprayed control	19.0
Tractor-mounted sprayer	
COC in diesel	86.0
COC in diesel + SO (1:1)	83.0
COC in SO	68.0
CD (P=0.05)	10.5

Clones RRII 414, RRII 422, RRII 429 and PB 260 were planted in 2 ha each for the evaluation of crop loss due to ALF disease.

A field trial was laid out with clone RRIM 600 at Pudukad Estate and with clone RRII 105 at Chemoni Estate in Trissur to find out whether COC can be reduced when spray oil and rubber seed oil mix (RSO) was used for spraying.

There was no significant difference in leaf retention between plots which applied COC at 8 and 6 kg/ha in both the locations. The yield also was comparable for RRII 105 in which clone its was monitored (Table Path. 2).

Different combinations of oils were evaluated as carrier for COC based on their viscosity and spray throw achieved by field-testing. Based on viscocity measurements the carriers were arranged in the increasing order as follows: spray oil, spray oil + rubber seed oil (2:1), spray oil + rubber seed oil + neem seed oil (1:1:1), rubber seed oil alone and neem seed oil alone. Vertical spray throw was maximum while spray oil alone was used. None of the spray oil combinations were found phytotoxic to the leaves of rubber plants sprayed.

A study on the evaluation of spraying Bordeaux mixture using micron sprayer was undertaken at Pudukad Estate, Trichur using the clone RRIM 600. Micron spraying was undertaken as one, two and three rounds

Table Path. 2. **Leaf retention in low volume spraying**

Treatment	Pudukad Estate (RRIM 600)	Chemoni Estate (RRII 105)	
	Leaf retention (%)	Leaf retention (%)	Yield (g/t/t)
4 kg COC+ SO + RSO	67.43[b]	64.58[a]	4.82
6 kg COC+ SO + RSO	73.77[ab]	71.38[a]	5.24
8 kg COC+ SO + RSO	81.73[a]	71.99[a]	5.31
SO + RSO	48.30[c]	39.64[b]	4.42
CD (P=0.05)	8.091	16.65	

from the last week of May to June at an interval of 10 days and compared with Horizontal Double Piston (HDP) spraying and unsprayed control. Results showed that the leaf retention was not satisfactory in the micron sprayed plot.

Yield recording in the crown budding experimental blocks at Malankara Estate in clone PB 311 was continued. Yield was higher in plants crown-budded with clone RRII 33. Severity of abnormal leaf fall and powdery mildew diseases and incidence of Tapping Panel Dryness (TPD) were assessed. Leaf retention was maximum in plants with RRII 33 crown however, powdery mildew was severe. TPD incidence was high in plants with Fx 516 crown (Table Path. 3). No significant difference in girthing was noticed between different crown budded plants.

Table Path. 3. **Yield and disease situation in crown bud trees at Thodupuzha**

Crown	Yeild (g/t/t)	Leaf retention (%)	TPD (%)	Powdery mildew
Fx 516	73.5	69.0	41.0	Mild (<25%)
RRII 33	98.2	85.0	9.0	Severe (>50%)
PB 311 (Control)	74.6	67.0	25.0	Moderate (<50%)
CD (P=0.05)		17.0		

In another experiment, two plots of one ha each were planted in CES, Chethackal with and without crown budded plants. The crown budding was done in nursery with the resistant clones Fx 516 on PB 260 at a height of 6 to 7 ft. Budding success of about 90% was noticed and the plants were field planted after cutting off the portion above the crown bud grafting. The girth, height and number of whorls after one year growth were higher in crown budded plants than control.

The clones in G X E trial were evaluated for ALF disease at RRS, Padiyoor and Kanyakumari district. In both the locations, leaf retention significantly varied among the clones. In Padiyoor, maximum leaf retention was noticed in RRII 430 (74.00%) and minimum in RRIM 600 (25.92%). In Kanyakumari maximum leaf retention was observed in RRII 203 (77.15%) and the minimum in RRIM 600 (46.33%).

The progenies of the same families in prepotent trial were screened for ALF disease at CES. In Trail I, maximum leaf retention was noticed in RRII 105 (65.38 %) and minimum in PB 5/51 (47.11 %). In trial II, maximum leaf retention was noticed in PB 252 (66.93%) and minimum in CH 26 (45.40%). The short-listed 159 germplasm accessions from CES, Chethackal and 54 accessions from the 2000 Source Bush Nursery at RRII showing moderate resistance to *Phytophthora* were subjected to further screening for confirming the results. A total of 152 accessions (99 MT, 32 AC, 16 RO and 5 others) showing resistance reaction against *Phytophthora* were selected.

RAPD analysis of parental clones (Tjir1 and Gl 1) of RRII 105 and F2 population were carried out. Of the 30 primers screened, two

showed polymorphic banding pattern with susceptible parent. Results generated through molecular studies of *Phytophthora* isolates collected during 2004 from different estates showed existence of two major groups revealing variability among the isolates. The rDNA from representative isolates of both the groups was cloned and sequenced. Sequence alignment with the databank revealed homology with *P. citrophthora*, which has not been reported from India.

1.2. Shoot rot

A field experiment was conducted on one-year-old plants to evaluate the efficacy of cupric hydroxide against shoot rot disease. It was found to be on par in efficacy to 1% Bordeaux mixture.

1.3. Powdery mildew

An experiment was initiated at Maruthi Estate in Kanyakumari to evaluate crop loss due to powdery mildew disease in clones RRII 105 and PB 28/59. Pre-treatment application of sulphur was undertaken at recommended dose at an interval of 7 -10 days. Monthly block yield was recorded. Intensity of powdery mildew was assessed in the clones RRIM 600, RRII 105, PB 235 and PB 5/51 at RRS Padiyoor and it was severe in PB 235 and PB 5/51. The disease was very mild in the three germplasm accessions short-listed.

Clones in G X E trial were evaluated. In RRS Padiyoor, disease incidence was low in RRIC 100 (22.91%) and high in RRII 203 (80.83 %). In Kanyakumari, it was low in RRII 422 (10.83%) and high in PB 217 (50.00%).

The progenies of the families in prepotent clones trial were evaluated for powdery mildew disease. In trial I, maximum disease intensity was noticed in clone PB 217 (78.25%) whereas minimum was in clone PB 242 (48.80 %). In trial II, maximum disease intensity was noticed in clone PB 215 (83.50%) and the minimum was in clone PB 252 (47.50%).

1.4. Colletotrichum leaf disease

Evaluation of fungicides for the control of colletotrichum leaf disease on two-year-old plants of clone RRII 105 was carried out. Minimum disease intensity was observed in plots sprayed with azoxystrobin followed by mancozeb (Table Path. 4).

Table Path. 4. **Effect of fungicides on colletotrichum leaf disease**

Treatment	Chemical used	Concentration	PDI
Indofil M-45	Mancozeb	0.2%	19.7
Bavistin	Carbendazim	0.05%	22.1
Score	Difenconazole	0.05%	21.7
Kavach	Chlorothalonil	0.2%	23.6
Antracol	Propineb	0.2%	20.6
Amister	Azoxystrobin	0.025%	18.6
Sheild	Copper sulphate	0.2%	30.8
Control	—	—	35.9
CD (P= 0.05)			7.2

Field screening of 300 germplasm accessions in source bush nurseries in CES, Chethackal identified 24 accessions with low disease incidence (<20%).

1.5. Corynespora leaf disease

Pathogenicity of 24 *Corynespora* sp. isolates collected during 2003 disease season from different regions of Kerala and Karnataka was studied by detached leaf technique. All the isolates showed infection on RRII 105 and no infection on GT 1. Antagonistic biocontrol agents were evaluated for their bio-efficacy through detoxification of phytotoxin from *C. cassiicola*. Two *Trichoderma* isolates, (*T. harzianum* and *T. viride*) four rhizobacterial isolates and one endophytic bacteria were used for detoxification of cassiicolin. With the metabolites from one rhizobacterial isolate (RB 16) reduction in lesion size was observed at a dilution of 1:3.

Toxin from the crude culture filtrate of *Corynespora* was purified and tested by leaf

puncture bioassay to prove its toxicity. The purified toxin could produce symptoms on the leaves. Leaf samples of clones GT 1 and RRII 105 artificially inoculated with *C. cassiicola* showed marked symptom expression, 96 h after inoculation. Chitinase assay of the leaf samples revealed a marked rise in the enzyme activity. In GT 1 and RRII 105 plants treated with salicylic acid on analysis for chitinase showed similar trends. Gene Specific primers were designed for chitinase and cDNA was amplified from the tolerant clone GT 1. For the susceptible clone RRII 105, however the enzyme activity was constant from 72 to 120 h after inoculation (Table Path. 5).

C. cassiicola in the laboratory and 171 accessions showed tolerance.

1.6. Cylindrocladium leaf disease

The occurrence of a leaf disease caused by *Cylindrocladium quinqueseptatum* Boedijn and Reitsma was noticed for the first time on rubber in India. Detailed survey on the *Cylindrocladium* disease incidence in different fields of Kaliyar Estate indicated that the disease intensity varied with the clones.

2. Stem diseases

2.1. Pink disease

Field experiment was conducted on four-year-old plants to evaluate the efficacy

Table Path.5. **Chitinase activity (in units) in resistant and susceptible clones of *H.brasiliensis* inoculated with *C.cassiicola***

Clone	72 h after treatment		96 h after treatment		120 h after treatment	
	Control	Treated	Control	Treated	Control	Treated
GT 1	20	46	20	58	20	72
RRII 105	10	16	10	16	10	16

Genetic relationships among the 26 isolates of *Corynespora* collected from different regions of Kerala and Karnataka illustrated the divergence existing among the isolates. Two of the isolates showing greater degree of variation (>75%) were identified as *Alternaria* sp. causing a similar disease as the Corynespora leaf disease.

Fiftyfour endophytic bacteria were isolated from internal tissues of stems, bark, leaves and petioles of two rubber clones (GT 1 and RRII 105). Out of these, 14 showed antagonism against *C. cassiicola*. Nine isolates caused mycelial lysis. ERIC-PCR analysis showed variation among the isolates. 2,4 DAPG gene was amplified from two strains. The rubber seedlings when treated with endophytes showed tolerance against *C. cassiicola*.

A total of 308 germplasm accessions were screened for resistance against

of cuprous oxide (Coptrel) and cupric hydroxide (Kocide) in the control of pink disease. Coptrel was the most effective fungicide recording maximum recovery from disease (80%) compared to Kocide (70%) and Bordeaux paste (60%). Disease survey was conducted in the traditional and non-traditional rubber growing regions. The disease intensity was maximum in Central Kerala, minimum in South Kerala and Kanyakumari District of Tamil Nadu. Most of the non-traditional regions are free from the disease, except for some pockets. In the RRII 400 series clones high disease incidence was noticed in RRII 429 and the lowest in RRII 430 in different locations.

2.2. Bark rot disease

Field evaluation of different fungicides on the clone PB 28/59 showed minimum disease intensity in the plot treated with cymoxanil M8, followed by mancozeb.

2.3. Patch canker disease

Among the different combinations tried to control patch canker on clone PB 28/59, maximum recovery was noticed in the treatment involving mancozeb, which was very closely followed by cymoxanil M8.

2.4. Dry rot disease

The causal fungus was successfully isolated and identified. It was confirmed as *Ustulina deusta* by the Forest Research Institute, Dehradun.

3. Brown root disease

A field trial for the control of brown root disease was carried out using tridemorph (0.5%) and propiconazole (0.1%) along with hexaconazole (0.2%) and thiram (0.75%). Fungicides were drenched at the collar region of plants showing disease symptoms. The neighboring trees were also treated similarly. The recovery was found to be very less. Calixin recorded better performance in checking the spread of the disease.

In vitro screening of bio-control agents against *Phellinus noxious* was carried out and isolates of *T. viride* and *T. harzianum* and a rhizobacteria were selected for the field study. *In vitro* studies on the mass multiplication of *Trichoderma* was undertaken using different substrates (cow dung, wheat bran, neem cake, rice bran and rubber wood sawdust) at various combinations. The combination of cow dung and wheat bran (1:1) was found to be good at a moisture level of 50 –60 per cent.

4. Maintenance of Pathogens

4.1. Long-term storage of fungal cultures

Three techniques were adopted: (i) storage of fungal discs in sterile distilled water. (ii) desiccation on inert substrates such as sterile sand and filter paper discs and (iii) cryopreservation. All these storage techniques were efficient as evidenced by the revival of the culture with virulence after six months of storage.

4.2. Development of a fungal databank

A computer based diagnostic system for the fungal pathogens of *H. brasiliensis* is being developed containing all the details of the fungus. The databank includes details of 282 isolates.

5. Tapping panel dryness (TPD)

Chemical treatment on TPD affected trees using tetracycline, penicillin, bavistin and flagyl continuously for three years at Malankara and Vaniampara Estates have shown no remission of symptoms. TPD symptoms were noticed also in trees where prophylactic injections were given irrespective of the treatments. 100 seedlings were planted at CES, Chethackal with 25 plants in each of the four treatment combinations to investigate the transmission of viroides through budding. Tapping knife sterilization experiment to study the transmission of TPD through tapping knife was carried out at Vaniyampara Rubber Estate, Thrissur. Spread from the affected tree to the nearby tree was observed in all the treatments except Glutaril. An attempt was made to study the transmission of viroids and expression of TPD symptoms by grafting bark from 12 complete panel dried and 12 partially dried trees on to healthy trees and *vice versa*.

R-PAGE screening of diseased and healthy plants to check the presence of viroids, showed LMW-RNA similar to that of viroid. R-PAGE analysis of seedlings showed 52 viroid positive plants out of 98 plants tested. Out of 37 apparently healthy trees, which showed positive bands 17 trees, expressed TPD symptoms. Attempts were made to isolate the RNA and perform RT-PCR with PSTVd specific primers to characterize the viroid associated with TPD.

A survey on the TPD incidence was undertaken in the N.E. India (Assam, Meghalaya, Tripura and West Bengal). In Assam, TPD incidence in RRII 105 was recorded as 62.9% followed by Meghalaya

(37.6%), Tripura (31%) and West Bengal (25%). Similarly, in the clone RRIM 600, the TPD incidence was 30.4% in Assam, 30.4% in Meghalaya, 24% in Tripura and 41% in West Bengal.

A small scale survey was also carried out in North Kerala and Karnataka regions to study the incidence of TPD. Soil samples collected from TPD affected and healthy trees of clones RRII 105 and PB 235 showed no significant difference in total bacteria, phosphobacteria, actinomycetes and fungi in rhizosphere and association of VAM. The pH of the soil, organic C, total N, available P, and K, biomass C, P and N also did not show significant variation.

6. Pests of rubber

Arrowroot extract at 2% (*Curcuma zedoria*) was found to be effective against termites for three months. Dipel, (*Bt. Kirstaki*) was found effective against bark feeding caterpillar (*Aetherastis circulata* Meyer) at a concentration of 0.25%. Chemical control of bark feeding caterpillar indicated that deltamethrin 0.0056% and fenpropathrin 0.06% had given 98.50% and 96% control of caterpillars. Borer beetles on standing rubber trees were effectively controlled with a combination of carbaryl 0.50 + deltamethrin 0.02, carbaryl 0.50 + lamdacyhalothrin 0.02. The combination was brushed on the affected portion of bark twice at an interval of one week.

The growth of *H. brasiliensis* seedlings was observed to be decreasing as the inoculum density of *Meloidogyne incognita* increased (Table Path. 6).

Initiated studies on the mass culturing of entomopathogenic nematodes in laboratory. Screening of TPD affected plants for the incidence of root-knot nematode was initiated. Screening of 20 germplasm accessions of *Hevea* for the incidence of root-knot nematode was carried out by recording number of galls and larvae/g. of root as well as population of root-knot nematode per 100-cc soil. Out of the 20 accessions, 6 showed the symptoms of nematode infestation.

7. Bee keeping in rubber plantations

Bee keeping in rubber plantation was profitable only through family labour utilization giving net income of Rs. 583/- and 1482 for *A. cerana indica* and *A. mellifera*. The honey yield during the year was 12 kg *for A. cerana indica* and 31 kg for *A. mellifera* per hive. The annual honey production from rubber plantations was 3400 tonnes. The performance of 8-frame and 6-frame hive colonies was evaluated. The details are given vide Table Path. 7.

8. Vermiculture

Analysis of nutrients (OC, N, P, and K) of pre and post decomposed substrates of rubber factory sludge, rubber wood saw dust and cow dung mixture for compost and vermicompost indicated that the values increased after decomposition. The pH of composts were more acidic than vermicompost after decomposition. The microbial counts of

Table Path. 6. **Effect of of root-knot nematode, *M. incognita* on the seedling growth of *H. brasiliensis* (Mean of five replications)**

Level of nematode inoculum	Shoot length (cm)	Girth at collar region (cm)	No. of leaves/ plant	Root length (cm)	Root weight (Fresh)	Nematode population/ g. root	Nematode Population / 100 cc soil
0	211.5	6.20	64.4	125	92.0	—	0
10	208.2	6.14	58.8	100	60.8	200	2480
100	201.6	5.96	58.2	85	55.0	150	1890
1000	189.5	6.03	56.5	72	45.0	125	1550
10000	176.4	5.26	48.2	45	46.2	73	1022

Table Path. 7. **Evaluation of 8-frame and 6-frame hives of *A. cerana indica***

Activity	8-frame hive	6-frame hive
Brood development	September, October	September
Super development	January 25–February 15, (slow)	January 15–February 5 (quick)
Absconding during July, August and September	Absconding	Absconding
Swarming during January and February	Swarming	Swarming
Super development	Only one super	Two supers
Mean honey yield (kg/hive)	7.33	10.50

compost and vermicompost prepared from rubber factory sludge showed that phosphobacteria, fungi and *Azotobacter* were higher in vermicomposts.

9. Microorganisms for improving growth of rubber and cover crops

Seven bacterial isolates nodulating *Mucuna bracteata* collected from North Eastern State of India were studied for their diversity and symbiotic characteristics. They differed in their colony morphology and time for development. The pH of the growth medium of the isolates ranged from pH 4.4 to 7.6. The growth pattern differed with the isolate and nutrient source. All the isolates produced indole acetic acid and polysaccharides and only five had shown siderophore production.

All the isolates were found to infect *M. bracteata* and stimulate plant growth. Maximum root length, shoot length and shoot weight were shown by the plants inoculated with bacterial isolates from Tura while root weight and nodulation were more for the plants inoculated with the isolate from Agartala. More nitrogenase activity was shown by the plants inoculated with Nagrakatta isolate.

Studies conducted using 10 phosphofungi from rubber growing soils showed that most of the isolates preferred temperature range of 20°C to 25°C for rock phosphate solubilisation. Carbendazim even at 50 ppm inhibited the growth of 7 isolates while mancozeb at 250 ppm inhibited the growth of 9 isolates. Wettable sulphur had no adverse effect on any of the phosphofungal isolates up to the concentration (250 ppm) studied. Isolates of *Azotobacter, Beijerinckia* and rhizobacteria differed in their compatibility with phosphofungi. The efficiency of different phosphofungi to stimulate plant growth was evaluated using *Pueraria phaseoloides*. High shoot weight, root weight and nitrogenase activity were shown by the plants inoculated with the isolate PSF_2. Sixteen isolates of rhizobacteria were tested for their ability to solubilise three soruces of phosphate *viz.*, ferric phosphate, aluminium phosphate, tricalcium phosphate and the fertiliser form – Rajphos. All the isolates were found to solubilise ferric phosphate and tricalcium phosphate. Rajphos was solubilised by only 4 isolates. Out of the 50 rhizobacteria collected during previous years four isolates were found to antagonise the growth of 5 major pathogens of rubber in dual culture. They were also found to produce volatile antagonistic compounds. Eight rhizobacterial isolates selected after primary screening for beneficial activities did not show any antagonism among them as well as to 5 *Azotobacter* and 4 *Beijerinckia* isolates, but 2 isolates inhibited the growth of *Bradyrhizobium* from *P. phaseoloides* and one from *M. bracteata*. Two isolates inhibited the growth of *T. viride* and one inhibited the growth of *T. harzianum*.

Table Path. 8. **Biogas production, methane content and reduction in COD and BOD**

	UAHR		UASB	
	96h HRT	24h HRT	96h HRT	24h HRT
COD reduction (%)	91	75	90	73
BOD reduction (%)	96	80	95	76
Biogas (l/kg of BOD_5)	56.4	56.7	55.8	47.8
Methane content (%)	60.8	60.0	60.8	60.0

Out of the 60 bacteria collected from roots and rhizosphere of rubber and 60 endophytes collected from aerial plants parts, 30 isolates were found to enhance the growth of *P. phaseoloides*.

The effect of mycorrhizal fungi *Glomus mossae* and *G. fasciculatam* on growth of rubber seedlings was studied. The growth of rubber seedlings was found to be higher in mixed inoculum of the two fungi as compared to single inoculum. The plants inoculated with a local isolate of *G. fasciculatam* were found superior compared to those with other inoculum collected from UAS Bangalore.

10. Waste management in rubber processing

The laboratory experiments under the project on 'Design and development of High rate reactors and its field evaluation for treating waste water from rubber processing' were carried out in collaboration with TNAU. Based on the results from the bench model experiments, a reactor was set up at Elavampadom model RPS, Vadakancherry, Palakkad. Physical and chemical properties of the natural rubber sheet processing wastewater were assessed and BOD and COD were found to be high enough for biomethanation. A preliminary batch digestion experiment showed that RSS effluent and cowdung in 1:1 ratio gave more gas with higher methane content. Two laboratory scale high rate reactors namely Upflow Anaerobic Sludge Blanket (UASB) and Upflow Anaerobic Hybrid Reactor (UAHR) were fabricated and fed with the RSS effluent. The reactors were operated for 75 days and total biogas production and methane percentage were measured (Table Path. 8). A maximum gas production of 8.4 and 7.2 litre of gas per litre of effluent were produced at 24 h HRT in UAHR and UASB respectively.

Effluent samples from 9 different sources from PCRF, RRII, Kottayam were estimated for pH, total solids, total dissolved solids, COD, BOD and sulphide content. The total bacterial counts and the presence of coliform and *E. coli* were also assessed. It was observed that all the parameters were high in the fresh rubber, composite and scrap samples. Coliform and *E.coli* were present in all the effluent samples. Different concentrations of two commercial antimicrobial agent viz., Nimbidine M and Lizol were tested in the laboratory against the bacterial growth in the effluent samples. It was observed that Lizol even at 2 per cent concentration was very effective against the bacteria, while Nimbidine M was not useful even at 25 per cent concentration.

11. Post harvest storage

Fifty three isolates of bacteria were collected from different rubber planes viz., cup lumps, scrap rubber, dried sheet rubber and latex. A talc based bio formulation prepared with the two efficient isolates applied on storage sheet in a warehouse showed prevention of mould growth upto 8 months.

PLANT PHYSIOLOGY DIVISION

The Division continued its research activities in six major areas such as environmental physiology, physiology of growth and yield, stock-scion interaction, tapping panel dryness, secondary metabolism and ecological impact of NR cultivation.

1. Environmental physiology

1.1. Identification of the molecular basis for drought tolerance

Out of the one-year-old polybag plants of clones RRII 105 and RRIM 600 kept in the field, one set from each was subjected to water stress by withholding water for 28 days and the other set was watered on alternate days to maintain field capacity through out. Leaves were harvested after assessing the drought status of the plants by measuring the net CO_2 assimilation rate (A) and the stomatal conductance. Both clones subjected to water stress exhibited highly significant reduction in net CO_2 assimilation rate. The net CO_2 assimilation rates of leaves, when collected for extracting RNA, were 0.31 µ mol $m^{-2} s^{-1}$ in RRII 105 and 0.73 µ mol $m^{-2} s^{-1}$ in RRIM 600.

cDNA bands were detected in RNA samples from both water-stressed and irrigated plants during differential display reverse transcriptase (DD RT-PCR) analysis. Under water stress conditions, a total of 77 differentially expressed transcripts (44 up and 33 down regulated) with 24 primer combinations, were identified for clone RRII 105 and 109 differentially expressed transcripts (76 up and 33 down regulated) for RRIM 600. Out of this, 82 (mostly larger size transcripts) were re-amplified and 18 transcripts from this group were cloned into PCR-TRAP cloning vector.

1.2. Rapid screening of *Hevea* germplasm lines for intrinsic drought tolerance traits

Out of the composite samples collected from five plants from each genotype maintained in the germplasm source bush nursery at RRII, leaf discs were prepared immediately (2.0 cm size), washed and were floated in PEG solution (60 %) with a known osmotic potential of –39.0 bars and exposed to 350 mmols $m^{-2} s^{-1}$ of fluorescent light for four hours at a constant temperature of 25°C. Similar sets of samples were maintained in distilled water in dark (*ie.*, without imposing any stress). Fluorescence parameters like Fo (initial fluorescence), Fm (the maximum fluorescence) and Fv/Fm (ratio of variable fluorescence to maximum fluorescence) were measured. The samples were then exposed to an actinic light of 100 mmols $m^{-2} s^{-1}$ and the effective quantum yield of PS II, (Y) and Fv'/Fm' were measured at a constant fluorescence emission in the steady state. Percent reduction in PS II activity under stress was calculated and the genotypes were ranked accordingly.

Drastic reduction in maximum photochemical efficiency of PS II (dark Fv/Fm) was observed and a maximum of 55 per cent inhibition was noticed in the wild accession MT 4694. Similarly under light the genotype MT 4900 showed the highest inhibition in Fv'/Fm' followed by the genotype MT 4694.

The genotypes that consistently appeared in the top ten ranks in all three traits were selected as the most intrinsic tolerant ones and those appearing consistently in bottom 10 ranks were considered the most susceptible ones (Table Phy. 1).

Four MT accessions were found superior among the wild accessions screened for their intrinsic tolerance to drought stress and two accessions were identified as most susceptible ones. The accession MT 5100 ranked first with minimum inhibitions followed by MT 5078, MT 4788 and MT 4856 (Table Phy. 2).

Table Phy. 1. **Ranking of germplasm accessions based on percent inhibitions in dark Fv/Fm, quantum yield and Fv'/Fm'**

Rank	Fv/Fm	Quantum yield	Fv'/Fm'
Top ten			
1	MT 4713	MT 4859	MT 4787
2	RO 4580	RO 4913	AC 4833
3	MT 4856	AC 4689	MT 4772
4	MT 5100	MT 4788	MT 5152
5	MT 4772	MT 4856	MT 4856
6	MT 5078	MT 4756	MT 5100
7	MT 4802	MT 5078	MT 4713
8	MT 4788	MT 5100	MT 4788
9	MT 5152	MT 5089	AC 4689
10	MT 5114	MT 4747	MT 5078
Bottom ten			
1	MT 4694	MT 4694	MT 4900
2	RO 5072	RO 5068	MT 4694
3	AC 3636	RO 4604	RO 4615
4	MT 4697	RO 5047	MT 4861
5	RO 4593	AC 4677	AC 3636
6	MT 4771	MT 4697	RO 4915
7	AC 4677	RO 4614	MT 4693
8	MT 4693	RO 5014	MT 4795
9	MT 5012	RO 5001	RO 5061
10	RO 4615	RO 4615	MT 4794

Empirical field scoring of 976 germplasm accessions from Central experiment Station, Chethackal was carried out. Leaf senescence, leaf yellowing, surface waxiness, nature and orientation of leaves and vigor were scored visually (when drought combined with high light was experienced in field). Twenty-three accessions were identified as superior to the drought tolerant clone RRIM 600 (Table Phy. 3). Accession RO 2864 was ranked first in field tolerance followed by MT 1673 and RO 2524.

1.3. Screening of HP clones of *Hevea* for drought and high light tolerance

The top ten HP clones in the preliminary rank list were selected and subjected to osmotic stress. Based on the degree of tolerance in photosynthetic oxygen evolution activity the clones HP 92 and HP 105 were ranked within top five clones.

Table Phy. 2. **Percentage inhibitions in chlorophyll fluorescence parameters of selected acccessions**

Accession	% inhibition (Fv/Fm)	% inhibition Q.Y.	% inhibition (Fv'/Fm')	Σ score (%)
MT 5100	6.0	4.3	4.2	14
MT 5078	12.6	4.5	7.6	20
MT 4788	10.0	8.8	10.7	28
MT 4856	14.0	10.0	20.0	44
MT 4694	54.0	37.0	47.0	138
RO 4615	30.0	30.7	24.5	85

Table Phy. 3. **Performance of wild germplasm accessions found superior to clone RRIM 600 in empirical field scoring for drought**

Sl. No	Accession	Adj. Σ Score	Sl. No.	Accession	Adj. Σ Score
1	RO 2864	15.00	13	RO 1229	13.50
2	MT 1673	14.50	14	RO 2390	13.50
3	RO 2524	14.00	15	RO 4421	1350
4	AC 1904	13.95	16	RO 1259	13.50
5	AC 612	13.95	17	RO 2356	13.50
6	RO 855	13.95	18	RO 3245	13.50
7	RO 271	13.95	19	AC 4475	13.50
8	MT 1621	13.50	20	AC 1886	13.50
9	MT 196	13.50	21	AC 2090	13.50
10	MT 1692	13.50	22	RO 3793	13.45
11	MT 2229	13.50	23	AC 3445	13.45
12	MT 1669	13.50	Clone	RRIM 600 (Control)	13.38

1.4. Structure and function of photosynthetic apparatus of NR in relation to its adaptation to high light and drought stress

Budded stumps of RRII 105, RRIM 600, GT 1 and PR 255 were grown under open sunlight and 70% light. One set of plants was imposed with four weeks water stress during summer season (March-2005) by withholding irrigation in the polybags. The drought plants of RRII 105, a susceptible clone, recorded highest MDA/chlorophyll ratio (50.5) whereas RRIM 600, a tolerant clone, recorded lowest ratio (26.5).

The 23 kD stress protein which was consistently expressed in high light and drought affected plants was eluted from gel and digested with trypsin. The extracted peptides were analysed by mass spectrometer scan combined with mascot searching at Dept. of Biochemistry, University of Western Australia, Australia.

1.5. Photosynthesis and respiration in trench irrigated plants

Budded stumps of three clones namely RRII 105, RRIM 600 and DAP 34 (Dapchari selection) were planted on either side of a trench (two feet width and two feet depth) in such a way that 50% shade was provided in one side of the trench and other side was left open. Planting was done with a distance of six feet from each plant in a position away from the central trench. Irrigation was provided only in the trench for three weeks period in the month of May 2004. The nearest and farthest plants were about two and thirty feet away from the trench, respectively. The dark respiration and photosynthetic oxygen evolution rates were recorded in nearest (irrigated) and farthest of trench covering open and shade plants.

Compared to nearest trench plants farthest plants showed significant reduction in photosynthetic oxygen evolution rate in open light. DAP 34 and RRIM 600 were comparatively drought tolerant than RRII 105 (Table Phy. 4). The drought (farthest from trench) mediated inhibition in photosynthetic rate in shade grown plants was comparatively lesser than sun plants in RRII 105.

2. Physiology of growth and yield

2.1. Yield and yield components

The growth and yield of twelve clones were monitored during the year. Annual girth was recorded from both tapped and untapped trees and biomass was calculated. The vigorous clone PB 235 produced maximum biomass (1160 kg/tree) followed by clone RRII 118 (1036 kg/tree). The minimum was in clone RRIM 501 (335 kg/tree). However, clone PB 235 (76.7 g/t/t) and RRIM 612 (16.8 g/t/t) continued as high and low yield-

Table Phy.4. **Photosynthetic O_2 evolution (μ mole O_2 evolution m^{-2} s^{-1}) and dark respiration (μ mole O_2 uptake m^{-2} s^{-1}) in trench irrigated, open light and shade plants of different clones**

Treatment	Clone	Irrigated (nearer to trench)		Drought (farthest from trench)	
		Respiration	Photosynthetic O_2 evolution	Respiration	Photosynthetic O_2 evolution
Light	RRII 105	2.9±.0.20	8.8± 1.0	2.8±0.30	3.7±0.7 (58)
	RRIM 600	3.4±0.35	9.4±0.20	4.1±0.21	6.8±0.6 (28)
	DAP 34	3.4±0.30	7.5±0.60	3.0±0.24	6.0±0.5 (20)
Shade (50%)	RRII 105	3.5±0.50	8.1±0.60	4.1±0.90	4.6±1.1 (43)
	RRIM 600	3.5±0.70	8.3±0.80	4.6±0.20	4.3±0.4 (48)
	DAP 34	3.1±0.34	6.6±0.32	4.1±0.23	5.5±0.5 (17)

± SE is shown, n= 5

(Figures in parentheses indicate percentage reduction of photosynthesis from the respective nearest trench plants).

ers respectively. Clones RRII 300, PB 235, PR 107 and RRII 118 exhibited 40% drc and RRIM 703, RRIM 600, Gl 1, RRIM 501, Tjir 1 and RRIM 612 exhibited low drc in latex.

2.2. Studies on biomass accumulation in untapped trees

Thirteen *Hevea* clones planted during 1988 were monitored for annual girth and biomass and their influence by tapping. After six years of tapping the untapped trees of clones RRII 118 and PB 311 produced maximum biomass of 904.8 kg/tree and 783.5 kg/tree respectively and Gl 1 (277.6 kg/tree) and RRIM 623 (298.3 kg/tree) the minimum. Clone RRII 43 continued as a maximum loser followed by PB 311.

2.3. Estimation of water content in dry cup lumps

To estimate the water content in dry cup lumps an experiment was conducted using the filed latex collected from a mixed clone trial at RRII. Fresh latex collected from field was processed into rubber sheets and cup lumps at various proportions ranging from 25 ml latex to 2000 ml latex. The wet and dry weight of sheets and cup lumps were recorded and the mean water content estimated. The percent water content in dried cup lumps varied from 3% to 17.8% and the mean was 11.2% (Table Phy. 5).

Table Phy. 5. **Water content in dry cup lumps**

Weight of dry cuplump (g)	Weight of dry sheet (g)	Water content (g)	Water content (%)
10.8±0.03	10.5±.09	0.31	3.0±0.95
22.5±0.12	21.5±0.12	0.96	4.5±0.72
45.8±0.17	43.0±0.12	2.80	6.6±0.49
93.0±0.12	85.4±0.22	7.50	8.8±0.30
185.9±0.10	167.7±0.20	18.20	10.8±0.21
286.6±0.50	253.0±0.30	33.60	13.3±0.16
395.2±0.80	341.0±0.10	54.10	15.8±0.22
490.5±0.50	425.9±0.60	64.50	15.1±0.17
727.9±0.30	624.3±0.20	103.60	16.5±0.08
990.2±0.40	840.3±0.20	149.90	17.8±0.04
Mean			11.25±1.76

2.4. Tapping induced loss of biomass

Tapped trees recorded comparatively lesser annual biomass increment than untapped trees. At the end of seven years of tapping RRII 105 lost around 32 per cent biomass in d/2 system of tapping. In general the annual biomass increment in d/3 tapping system was higher than d/2.

The latex ATP content was estimated in d/2 trees of five clones and d/3 trees of two clones (RRII 105 and PB 235). The results showed that d/3 trees recorded more ATP than d/2 trees of RRII 105. There was a direct positive correlation between total latex ATP content and latex yield (r=0.5) during postmonsoon but no significant relationship was observed during summer.

To understand the extent of tolerance of an alternative oxidase (AOX) under-expressed plant to oxidative stress, a study was carried out at University of Western Australia. Soybean lines which have already been transformed with AOX antisense genes were screened for the presence of AOX 2a and 2b antisense sequences. The results showed that the antisense technique employed here did not suppress the expression of the genomic copies of the AOX genes effectively. Therefore the antisense plants were considered as AOX under-expressed plants.

The respiratory analysis showed that around 55- 60 % AOX activity was reduced in antisense plants. After 5 hrs of leaf disc-incubation with paraquat, both cytochrome oxidase and AOX mediated activities were significantly inhibited owing to the oxidative stress. The degree of reduction in AOX activity was more in antisense plants.

The lipid peroxidation product MDA was significantly increased in all the paraquat incubated samples. The level of MDA content was significantly higher in antisense plants compared to the wild plants (Table Phy. 6). The degree of inhibition of PS

Table Phy. 6. **MDA content and reduction in PS II rate (inhibition of dark Fv/Fm) in wild and AOX antisense plants incubated with water (control) or paraquat**

Plant type	(MDA) (μ mole/g fr. Wt)		Dark Fv/Fm		
	Control	Paraquat (5 hrs)	Control	Paraquat (2.5 hrs)	Paraquat (5 hrs)
Wild-type	15 ± 0.15	31 ± 0.25	0.79± 0.02	0.34 ± 0.01	0.15 ± 0.02
2a antisense	13 ± 2.2	40 ± 1.8	0.8 ± 0.05	0.26 ± 0.03	0.04 ± 0.015
2b antisense	18 ± 1.5	37 ± 1.8	0.79 ± 0.06	0.30 ± 0.01	0.05 ± 0.007

II was significantly higher in antisense plants. These results indicated that those plants with reduced AOX content and activity would be more susceptible to the oxidative stress.

The results support the fact that AOX has an important role in plants experiencing abiotic stress. The present work with transgenic soybean plants having altered AOX expression were used to test the hypothesis that the alternative respiration functions as a protective mechanism to decrease the formation of reactive oxygen species during stress.

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

Monthly analysis of latex ATP in high, medium, low yielding and 400 series clones were carried out. The results showed that during peak yielding and stress season the latex ATP was higher in high yielding clones and 400 series clones. The two medium yielders GT 1 and Tjir 1 also have high latex ATP. A field trial with the same clones was initiated at CES, Chethackal to study this parameter at an early age.

2.5.1. *Clonal variation and effect of stimulation in the regeneration mechanism of latex*

Standardised a method for ^{35}S methionine incorporation into proteins in C-serum to study the rate of reconstitution of latex intracellular components. Maximum incorporation was obtained when 100 μl C-serum was incubated with 1μCi ^{35}S methionine with continuous stirring for two hours at room temperature. Protein biosynthetic capacity of different clones was also measured.

2.5.2. *Effect of stimulation in the laticiferous tissues of* Hevea

Normal healthy RRII 105 trees were used for stimulation experiment. The biochemical components like proline, total phenol, catalase, peroxidase, glutathione were analysed in C-serum of the latex, two times before and two times after the stimulant application, at an interval of 10 days.

Proline content increased in the bark tissue with the application of ethephon which indicates a stress response. A significant decrease in the thiol was noticed in the latex immediately after stimulation and then attained the normal level by 10 days time. Due to stimulation, it was observed that the total phenol content in the C-serum increased considerably and maintained almost at the same level throughout the experiment. Stimulation also induced the activities of the enzymes peroxidase and catalase enzymes within 3 days and both attained the normal levels within a week.

Wound induced ethylene produced by the bark tissues of both experiment and control trees were more or less in same levels before stimulation. But after stimulation, the trees showed high ethylene content in the tissue (approx. 160%), which may be due to the autocatalytic action of the endogenous ethylene. In general, a single dose of ethepon stimulation could induce enhanced levels of certain stress indicators along with high tissue ethylene content for several days.

2.6. Rubber biosynthesis in *Hevea* clones

HMG Co-A reductase (HMGR), an enzyme related to the initial stages of rubber biosynthesis was studied. Specific antibodies were prepared against HMGR protein and the enzyme content was analysed through ELISA. Since the HMGR protein used for antibody production was *Arabdopsis* origin, the cross reactivity of the antibody was made with the *Hevea* HMGR. It was found that the antibody raised for *Arabdopsis* can be used for the analysis of *Hevea* HMGR. The work is in progress.

2.7. Identification and characterization of wintering related genes

Expression pattern of senescence associated genes such as *din2 and din6* in *Hevea* was studied through northern analysis. Total RNA was isolated from young polybag plants and mature tree leaves of RRII 105, which was collected during pre wintering and wintering stage of *Hevea*. The expression of these two genes (*din2 and din6*) was more in leaves collected during wintering than those collected before wintering. There was no expression of these two genes in young polybag plant leaves.

3. Stock-scion interaction

3.1. Intraclonal variability

Plugging index, dry rubber content and yield of 13 clones of *Hevea* were recorded. Girth of the trees was also recorded. Biochemical analysis of latex was carried out. There was considerable intraclonal variation in these clones with respect to yield and girth.

3.2. Upward tapping

The incidence of TPD in normal and upward tapping in TPD affected and normal healthy trees of RRII 105 at CES, Chethackal was recorded once in two months.

Bark samples were collected from different heights from the bud-union in high girth and low girth trees of RRII 105 and in TPD affected and normal healthy trees of RRII 105 from CES, Chethackal for phenol analysis.

3.3. Air-layering studies with own and double rooted plants

Growth parameters were recorded in own-rooted, double rooted and budgrafted plants of three clones planted in field at CES, Chethackal during 2001.

3.4. Genetic conflict in budgrafted *Hevea*

DNA was extracted from 50 trees of 25 year old RRII 105 trees from CES, Chethackal and RAPD analysis was carried out using three primers to find out whether there is any variation in the RAPD profile in the scion portion in old trees.

4. Tapping panel dryness

4.1. Free radicals (FRs) and FR scavenging systems related to TPD incidence

TPD affected soft bark tissue showed significantly high H_2O_2 content compared to the normal healthy tissue indicating the possible oxidative stress during TPD. The high peroxidase and H_2O_2 content in the TPD affected tissue may be the result of increased production of superoxide radical (O_2^-). Analysis of melondialdihyde (MDA) content in these tissues showed increased MDA content in TPD affected tissues, suggesting an enhanced lipid peroxidation in the bark tissue probably due to the ROS action.

4.2. Ethylene and TPD occurrence

Wound induced ethylene production in the bark tissues of RRII 105 (high yielder) and RRII 38 (low yielder) was carried out at periodic intervals to study the fluctuation of ethylene production during different seasons. Wound induced ethylene production was more in low yielding clone than in the high yielding clone. As noticed earlier the ethylene production in both the clones was the maximum in the drought season and minimum during the monsoon season. How-

ever, the differences in the ethylene levels between these clones were uniform during all the season. The analyses of thiols, peroxidase and superoxide dismutase in the bark tissues during summer season showed that these stress indicators were more in the low yielding clone than the high yielding clone.

The TPD affected bark tissue showed a significantly high peroxidase activity and ethylene content and high cyanide content. In the ethylene synthesis pathway, ACC is converted to ethylene by liberating cyanide and CO_2 through the action of ACC oxidase.

4.3. Relationship of biochemical and ionic composition of latex with yield and susceptibility to TPD

The trees were monitored for TPD occurrence and concentrations of ions in the latex was determined. 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 and three trees each of clones RRII 105 and RRII 308 showed TPD syndrome. TPD occurrence was found to be less in clones with high concentration micronutrient Mn^{++} in the latex.

4.4. Molecular basis of TPD

An attempt was made to identify TPD specific genes by subtractive hybridization. RNA from healthy and TPD affected trees were used for subtraction. The subtracted clones are being characterized. The clone which was found down-regulated under TPD conditions by differential display RT-PCR method was found similar to glutamate dehydrogenase (E = 9e-10), manganese superoxide dismutase (E = 4e-09) and transcription factor MYB109 (E = 6e-08).

5. Secondary metabolites

5.1. Quantification and identification of inositols

Latex samples collected from RRII 105 and RRIM 600 were extracted with 80% alcohol and extracts were then deproteinized, centrifuged and concentrated (rotary evaporator). Purification of sample was attempted with a silica gel column. The elutent was concentrated and was dissolved in a solution containing 24 ml deionized water and 10 ml chloroform. This was kept at 2°C for phase separation. The aqueous phase was pipetted out and lyophilized. The sample was passed through an ion exchange resin column (Amberlite MB 150 column). The eluate was freeze-dried and made ready for the confirmation of the results.

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

Latex samples were collected from relatively drought susceptible (RRII 105, RRII 43, RRII 308, PB 311) and relatively tolerant clones (GT1, Gl1, RRII 118, RRIM 600) during the peak and summer seasons. Bursting Index, Plugging Index, dry rubber content, total solid content, yield, sugar estimation and aminoacid estimation were done. Latex samples have been prepared for analysis of various ions. It was found that during peak yielding season and summer season the thiol content, total sugar and phenol were high in drought tolerant clones and low in drought susceptible clones. Reducing sugar was found high in drought susceptible clones during the peak-yielding season (stress free) but during the summer season (stress) it was found to be high in drought tolerant clones.

6. Ecological impact of NR cultivation

With the entry of Kyoto protocol into force on 16 February 2005, there is increasing interest in carbon trading under the Clean Development Mechanism (CDM). Under the protocol carbon sequestration by rubber plantation is in principle eligible for CDM, although there are no approved methodologies at the moment. Several groups are working on developing CDM methodologies for sink project.

RUBBER TECHNOLOGY DIVISION

Factory evaluation of deproteinized Natural Rubber latex prepared using anilozyme, development of a simple method for production of NR/NBR blend nanocomposite using creamed skim latex, pilot plant production of skim rubber, evaluation of NR/PP, NR/HDPE, NR/ENR 50 blends, replacement of small proportion of CR by NR in CR based adhesives and quality survey of sheet rubber were the main areas of work.

1. Primary processing

Using the standardized conditions of creaming followed by quick coagulation, pilot plant production of skim rubber was attempted and it was found that cure characteristics of skim rubber were comparable to those of ISNR 5 and ISNR 20.

Adoption of formalin treatment at CES, Chethackal resulted in improvement in the quality of field coagulum with subsequent reduction in the proportion of lower grades of ISNR prepared from it. In connection with quality survey of sheet rubber from different regions of Kerala, determination of raw rubber and vulcanizate properties were completed.

2. Chemical modification

Two batches of ENR 50 were prepared and 25 kg sent for evaluation in products. A study on the effect of polymerization conditions on percent grafting and grafting efficiency of PMMA onto NR in latex by gamma radiation was initiated.

3. Blends

Attempts were made to replace a portion of CR by NR in CR based adhesive formulation. To study the effect of blend ratio and resin type, 50 phr of different PF resins were used in different blend ratios of CR and NR (80:20, 70:30 and 60:40). Adhesion strength of these were compared with a locally available chloroprene based adhesives. It was observed that 40 parts of CR could be replaced by NR when a particular grade of PF resin was used (Table Chem.1).

Table Chem. 1. **Adhesion strength of chloroprene based adhesive**

Type of resin	Adhesion strength (kg/cm)		
	80:20*	70:30*	60:40*
PF resin 1	2.4	2.4	2.5
PF resin 2	3.6	3.6	2.9
PF resin 3	1.5	1.9	1.5
PF resin 4	3.0	2.5	2.3
Control		3.1	

* CR:NR

Blending ENR 50 with NR showed good vulcanizate properties and ageing resistance along with improved oil ageing characteristics as compared with NR. Addition of recycled plastics in small proportion (5 to 20%) to NR improved the ageing resistance of vulcanizates. Better retention in tensile properties was observed for both NR/PP and NR/HDPE at different temperatures.

4. Latex technology

Factory evaluation of deproteinized NR latex prepared using anilozyme as deproteinizing agent was completed. The results indicated that there was a significant reduction in extractable protein content, and physical properties were within acceptable limits even though the gloves appeared to be slightly yellowish. Pilot plant evaluation of papain in powder and liquid form indicated that it was effective for the production of deproteinized NR latex.

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Natural rubber nanocomposites were prepared from latex and dry rubber with organically modified silicates and the properties compared with those from a

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5. Nanocomposites

Natural rubber nanocomposites were prepared from latex and dry rubber with organically modified silicates and the properties compared with those from a

nonlayered one. It was found that the nanocomposites exhibited excellent mechanical and barrier properties. The property improvement was attributed to the intercalation/exfoliation of the organically modified silicates due to their high initial interlayer distance. A patent was filed in this respect.

A simple and environmental friendly procedure was standardized for the production of NR and NR/NBR blend nanocomposites from skim latex by a creaming process. Different dosages of organoclay dispersions were incorporated in creamed skim latex and in a blend of creamed skim latex/NBR latex followed by coagulation, drying and vulcanization. The nanocomposites were evaluated by X-ray diffraction technique and mechanical properties determined. Creaming of skim natural rubber latex resulted in a reduction of the rubber particle size and also in easy coagulation by acids.

XRD results revealed that there was an increase in the basal spacing between clay layers due to intercalation of rubber molecules in both NR and NR/NBR blend nanocomposites, which resulted in enhanced mechanical properties. Among the NR vulcanizates containing different dosages of clay, 5 phr organoclay loaded vulcanizate showed comparatively better mechanical properties as shown in Table Chem. 2.

In the case of NR/NBR blend nanocomposites NR/NBR 25/75 blends showed better mechanical properties than other NR/NBR blends.

Table Chem. 2. **Mechanical properties of NR nanocomposites**

Parameters	Loading of clay, phr				
	0	3	5	10	15
Modulus 100%, MPa	1.62	1.98	2.11	2.79	2.98
Modulus 200%, MPa	2.24	2.58	2.73	3.63	3.67
Modulus 300%, MPa	2.78	3.23	3.30	4.5	4.63
Tensile strength, MPA	22.5	24.6	25.8	24.8	24.2
Elongation at break, %	770	730	780	710	700
Hardness, Shore A	55	60	65	70	75

AGRICULTURAL ECONOMICS DIVISION

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

1. Rubber wood processing industry in India

The study was based on a five year data (1995-96 to 2000-01) from 21 rubber wood processing units located in Kerala and Karnataka. Despite an increase in the number of processing units and volume of rubber wood processed for value added products manufactured since the early 1990s, the existing ones are beset with a variety of

operational level constraints. Unlike in Malaysia and Thailand, raw material procurement in India has been dominated by the presence of intermediaries leading to higher log prices from the angle of the processing units. There are considerable differences across units in terms of possession of technology for secondary processing. The extent of adoption of technology for value added products' manufacturing have been comparatively lukewarm. *Prima facie* it is due to the incompatibility between lower scale of operation and higher initial investment required for import of capital intensive technology. The capacity utilization attained at seasoning stage was only 60 per cent. The product orientation of the surveyed units has been dominated by RSKD/S4S materials rather than value added finished products. The reported value addition from the log level is 668 per cent compared to the potential of 1500 per cent. In this backdrop, a national level policy for the promotion of rubber wood incorporating appropriate R&D support, statutory control on quality standards of end products and measures to optimize recovery from log level has to be formulated so as to maximize the value of output.

2. Crop loss in rubber plantations due to abnormal leaf fall

This inter-divisional project was an attempt to assess the extent of crop loss in terms of loss in latex and timber output and thereby to examine the comparative economics of control measures against abnormal leaf fall (ALF) caused by *Phytophtora* in rubber plantations based on region specific disaggregate level data. The study highlighted that there existed significant clonal differences in loss of latex and timber output in the absence of prophylactic spraying against ALF. The observed clonal differences in latex and timber yield between sprayed and unsprayed plots underline region and clone-specific recommendations for plant protection measures in India instead of the currently followed unilateral prescription with due allowance to the costs and potential benefits accrued from the control measures. The study also brought out the need for evolving R & D interventions and agro-management/plant protection measures in India for minimising the incidence of tree casualty in rubber plantations, as it amounts to loss of potential income from latex and timber from rubber.

3. Sustainability of income through beekeeping under rubber plantations

Beekeeping under rubber plantations in India is a potential source for maximising the net income and employment of rubber growers. But only less than three per cent of the actual potential is being commercially exploited. The structure of rubber honey market has been dominated by co-operatives and their inherent constraints like low working capital and institutional rigidities are the major factors attributed to the low level of popularisation and adoption of beekeeping among rubber growers. Within these limitations, the achievements made in beekeeping by the Elevampadom Rubber Producers' Society (ERPS) provide useful guidelines. This case study highlighted the possibilities of popularising bee keeping through the RPS network to supplement the income of rubber growers facing market uncertainties.

4. Impact of market uncertainty in rubber smallholdings sector

The study has revealed that the domestic price of NR has been moving in close association with the international price since 1991. The post reforms period marked a total deviation from the pre-reforms phase during which the price of NR in the domestic market had remained higher than the price in the international market. Opening up of the domestic market, which had remained insulated from the external market for more than half a century, has changed the

unique characteristic feature of the NR price, *viz.*, from a remunerative and stable, into a highly volatile price since the second half of the 1990s.

Plummeting of NR price to unprecedented levels has left notable changes in agro-management practices with implications in production relations, productivity and economic viability of the crop. Farmers responded to the uncertainty in the NR market by resorting to cost-saving measures such as reduction in fertilizer application, curtailment of weeding practices in rubber holdings and near-total stoppage of other cultural practices such as spraying fungicides and rainguarding. Reduction of cultural practices has saved labour cost to farmers leaving the dependent labour households unemployed. In the absence of countervailing mechanism to improve yield, such forced cost-saving measures have adversely affected the positive rate of growth of productivity, posing serious threat to the staying capacity of marginal and small farmers. If the situation continue, the farmers may opt to lease out their holdings for a lump sum and such developments have already begun in certain pockets in Central Kerala. The situation arising from decline in days of employment due to dilution of cultural practices has been aggravated by reduction in the number of days of tapping. In the labour front, wage rates for tapping labourers in real terms have stagnated or declined. Moreover, pecuniary benefits such as wage advance, which were unique to the tapping sector, have disappeared. In short, the changes that resulted from market uncertainty would leave, if the trends continue unabated, the cultivation of NR in marginal lands economically unviable and the labour relations in the NR smallholdings sector inimical.

EXPLOITATION TECHNOLOGY

Exploitation Technology Division continued applied research on crop harvesting techniques. Ongoing experiments and trials on low frequency tapping (LFT) and various on farm trials were continued during the period. Trials on Low Frequency Controlled Upward Tapping and a new exploratory experiment on d/10 frequency of tapping were initiated. Exploratory trials on LFT (1/2S d/4 & d/7) with rainguarding were continued in Kulasekharam, Tamil Nadu. Under the lab to land programme, LFT and other modern exploitation techniques were extended to growers in different parts of the country.

1. Low Frequency Tapping (LFT) systems

The experiment to evaluate the response of RRII 105 to LFT with different levels of stimulation (from panel BO-1) continued to give encouraging results. Higher yield was observed under d/6 and d/4 frequencies of tapping. Low yield under 1/2S d/2 can be due to its proximity to bud union (Table Exp. 1).

The experiment on response of clone RRII 105 to LFT with different levels of stimulation (commencing from panel BO-2) continued to give good results from renewed bark also. Yield was comparable under d/2, d/3 and d/4 frequencies of tapping.

On farm experiment on LFT (1/2S d/4 6d/7) was continued in 24 tapping blocks in clone GT 1 at Appella Estate, South Karnataka and promising results (1729-2227 kg/400 trees/yr) were obtained.

The on farm experiment on weekly tap-

Table Exp. 1. **Performance of low frequency tapping systems with stimulation in RRII 105**

Treatment	Tapping system	Yield (kg/ha)	No. of stimulations	DRC (%)
T0	1/2S d/2	1740 c		40
T1	1/2S d/3 + 1 level stim.	2437 b	3	39
T2	1/2S d/3 + 2 level stim.	2543 b	4	39
T3	1/2S d/3 + 3 level stim.	2741 ab	5	39
T4	1/2S d/4 + 1 level stim.	2877 ab	5	39
T5	1/2S d/4 + 2 level stim.	2530 b	7	40
T6	1/2S d/4 + 3 level stim.	3231 a	9	39
T7	1/2S d/6 + 1 level stim.	2961 ab	10	40
T8	1/2S d/6 + 2 level stim.	2852 ab	12	40
T9	1/2S d/6 + 3 level stim.	3209 a	15	38

CD (P=0.05) = 541

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

ping with different levels of stimulation was continued in the second year in 24 tapping blocks of clone GT 1 at Neria Estate, South Karnataka. Compared to first year, yield was higher under all treatments. Yield of >3.5 kg/tree in the 2nd year of tapping is good for clone GT 1. Mean girth was 61.7 cm, annual bark consumption was 12.3 cm and cumulative TPD was below one per cent.

The trial to compare and evaluate long term impact of stimulation under d/3 and d/4 system of tapping in RRII 105, continued successfully in the ninth year at Vijayadri Plantation, Kottayam. Promising yield was obtained by judicious stimulation under d/4 system of tapping. Dry rubber yield of 2217 kg/400 trees was obtained under d/4 system of tapping over a period of ten months. Higher yield was observed under d/3 system of tapping in the second year of panel change also.

The exploratory trials on introducing LFT with rainguard in Kulasekharam region, Tamil Nadu initiated during 2003-04 continued successfully in the second year also. Promising yield (2500kg/400 trees) under d/7 system of tapping with rainguarding was obtained in clone RRII 105 at Kanthimathy Estate. This was also reflected in other parameters studied. Mean annual dry rubber yield (kg/400 trees/tap) was 50 kg (in the range of 25 kg to 69 kg).

In the second trial under d/4 frequency of tapping with rainguard, dry rubber yield of 1956 kg/400 trees was obtained over a period of 11 months. Under d/4 frequency of tapping mean annual dry rubber yield (kg/400 trees/tap) was 30 kg.

In the demonstration plot (1993 C) at Central Experiment Station, Chethackal, weekly tapping progressed well during 2004-05 also. In the plot 1987 A, after two years of weekly tapping, d/10 frequency of tapping was introduced during 2004-05. In both fields, dry rubber yield (kg/400 trees) was more than two tonnes.

1.1. On farm trials on LFT

Stimulation recommendations are also evaluated in onfarm trials on LFT, being conducted in various locations. Onfarm trial on 1/2S d/3 system of tapping in clone RRII 105 at Thrithala, Palakkad and Beria Estate in South Karnataka were continued and progressed well. At Thrithala dry rubber yield under stimulation was 2567 kg/ha as against 2141 kg/ha under control condition. Cumulative yield for six years (1999-00 to 2004-05) was 15,737 kg/ha as against 12,400 kg/ha in control blocks. Stimulation has resulted in 27 per cent yield increase over the unstimulated control.

At Beria Estate, annual yield (kg/400 trees) was 2470 under stimulation compared

to 2018 in control. Similarly, in the onfarm trial in clone GT 1 at Neria Estate, South Karnataka, promising yield of 2784 kg/ha under stimulation and 2125 under control was recorded during the year 2004-05 (first year tapping on BI-1 panel). Yield stimulation has resulted in 31 % yield increase over the control.

Various onfarm trials on d/6 frequency of tapping mainly 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 at all locations. Clones like PB 260, PB 311 and PB 235 also showed good performance under weekly tapping.

1.2. Lab to land programme on LFT

Low frequency tapping was successfully extended to larger areas in the estate sector in Kerala, Tamil Nadu and Karnataka. Due to disciplined tapping and related operations and advisory service on stimulation schedule by the Division, production and productivity improved considerably in many places. This has also resulted in increased income of tappers through increased over poundage (Table Exp. 2 to 4).

2. Low Frequency Controlled Upward Tapping (LFCUT)

Many large and medium estates adopted LFT to an appreciable extent. These plantations have to adopt CUT on renewed basal panel tapping. Hence, experiments were initiated during 2003-04 to evaluate the performance of Low Frequency Controlled Upward Tapping (LFCUT) in clones RRII 105 and RRIM 600 with rainguarding. High yield was obtained under LFCUT in both the clones. Yield under LFCUT (d/4 and d/6) were comparable or better than d/3 frequency. Highest per tree yield ever reported (20kg/tree/year) was obtained from LFCUT in RRII 105 (Table Exp. 5).

In another experiment on LFCUT in RRII 105 with periodic panel change at EFU, RIT, highest yield was observed under 1/3S d/4 upward tapping followed by 1/3 S d/6 system of upward tapping with periodic panel change. When trees are tapped under d/3 or d/4 CUT, ethephon application can

Table Exp. 2. **Dry rubber yield in RRII 105 under Low Frequency Tapping during 2004-05**

Estate	Area (ha)	Tapping frequency	Yield kg/ tree	Yield kg/ 400 trees
Balanoor	11.35	d/6	4.53	1812
Pandallur	9.88	d/4	4.7	1880
Gokul	8.07	d/4	4.6	1840

Table Exp. 4. **Performance of low frequency tapping (d/4 and d/7) with rainguarding in Kanthimathy Estate, Kulasekharam**

Yield	1/2 S d/4	1/2 S d/7
kg/block	2200	2250
kg/tap	31	45
kg/tree	4.4	5.0
Tapping days	70	50

Table Exp. 3. **Annual dry rubber yield under LFT in Koyipathody Estate, Adivaram, Calicut**

Clone	No. of trees	Yield (kg) 2001-02	2002-03	2003-04	2004-05
RRII 105	3555	14956 (d/3)	17944 (d/3 & d/6)	18106 (d/4 & d/7)	22598 (d/4 & d/7)
RRIM 600, GT 1, PB 235	8500	26017 (d/2)	30764 (d/4)	34480 (d/4)	39485 (d/4)

Table Exp. 5. **Yield response of LFCUT with rainguard in RRII 105 at CES, Chethackal**

Treatment	Tapping system	Yield* (kg/400 trees)
T1	1/4S d/3 6d/7 ↑ with skirt rainguard + monthly (ET5% La)	6781
T2	1/4S d/3 6d/7 ↑ with tapping shade + monthly (ET5% La)	7899
T3	1/4S d/4 6d/7 ↑with Skirt rainguard + 3 weeks (ET5% La)	7104
T4	1/4S d/4 6d/7 ↑with skirt rainguard + fortnightly (ET5% La)	8022
T5	1/4S d/4 6d/7 ↑ with tapping shade + fortnightly (ET5% La)	8128
T6	1/3S d/6 6d/7 ↑with skirt rainguard + 3 weeks (ET5% Ga)	6624
T7	1/3S d/6 6d/7 ↑ with tapping shade + fortnightly (ET5% Ga)	7241
T8	1/3S d/6 6d/7 ↑with skirt rainguard + fortnightly (ET5% Ga)	7048

*NS

be done on lace. But, when the frequency is reduced further to d/6, stimulant has to be applied on the groove. Moreover, to get optimum yield under d/6, tapping on 1/3 spiral cut is more effective.

3. Other experiments

3.1. Effect of panel change on yield

In the experiment on panel change at EFU, Pampady higher yield was observed in general with panel change (Table Exp. 6).

3.2. Crop loss due to rain and recovery by stimulation

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 recovered by stimulation. However, under d/3 system, crop loss can be partly compensated by stimulation (Table Exp. 7).

3.3. Stimulation trial on TPD affected trees

In an experiment on clone RRII 105, no stimulation response could be obtained in BO- 2 panel of trees affected by TPD in its BO-1 panel.

4. Latex diagnosis studies in smallholders plots

Studies for revalidation of base values were conducted in 29 smallholdings under two RPSs (Aimcompu and Chirakkadvu) in central Kerala. Field testing of base values

Table Exp. 6. **Performance of LFT with stimulation in RRII 105 (with and with out panel change) under d/2, d/3 and d/4 frequencies**

Treatment	Tapping systems	Yield (kg/ha) *	No. of stimulations	DRC (%)
T1	1/2S d/2 without PC	2696 c	-	39.8
T2	1/2S d/2 with PC (CUT)	4717 a	-	39.0
T3	1/2S d/3 without PC+ 1 level stim.	2075 c	4	39.1
T4	1/2S d/3 with PC + 1 level stim.	3744 b	4	38.2
T5	1/2S d/4 without PC+1 level stim.	2141 c	7	39.8
T6	1/2S d/4 with PC + 1 level stim.	2392 c	7	39.9
T7	1/2S d/4 without PC + 2 level stim.	2556 c	9	39.4
T8	1/2S d/4 with PC + 2 level stim.	2106 c	9	38.9

CD (P=0.05) 851.3

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

Table Exp. 7. **Effect of stimulation under d/2 and d/3 frequencies of tapping in RRII 105 without rainguarding on recovery of yield loss**

Treatment	Tapping systems	Yield* (kg/400 trees)	No. of stimulations	DRC (%)
T1	1/2S d/2 with rainguard	2883 bc		39.2
T2	1/2S d/2 without rainguard	2388 c		39.8
T3	1/2S d/2 without rainguard + 1 level stim.	2524 c	3	39.4
T4	1/2S d/2 without rainguard + 2 level stim.	2222 c	5	38.5
T5	1/2S d/3 with rainguard	2418 c	3	40.2
T6	1/2S d/3 without rainguard	3845 a	3	39.3
T7	1/2S d/3 without rainguard + 1 level stim.	2544 c	5	39.9
T8	1/2S d/3 without rainguard + 2 level stim.	3621 ab	7	40.3

CD (P=0.05) = 894.8

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

was conducted in smallholders' plots for establishing functional relationships between LD parameters, TPD and yield. Studies revealed significant positive correlations between TPD incidence and Pi (0.37**) and between thiols and productivity (0.304*). Correlation studies revealed that Pi and thiols could be used as indicators for assessing exploitation status of smallholdings.

During 2004-05, LD studies were conducted in 110 smallholdings under 8 RPSs in the Central Zone of the traditional rubber growing region. LD parameters were estimated from the smallholdings during August to November. From each holding five trees were sampled. All the smallholdings were under 1/2S d/2 frequency of tapping and were in the BO-1 or BO-2 panels. Yield of individual holdings were derived from the RPS yield records. The exploitation status of holdings whose Pi levels were above/below the critical limits were classified as over/under exploited. The holdings whose thiol levels were below critical limits were classified as holdings under stress (Table Exp. 8). This technology would enable the holdings to detect over exploitation and optimize exploitation to achieve sustainable productivity.

The productivity levels of the well and over exploited holdings (coming upto 88 %) in the central zone ranged from 41 to 54 g/t/t against the optimum level of 67.5 to 76.5 (g/t/t) under optimum system (1/2S d/3). Well exploited holdings had an average productivity of 52.03 g/t/t, which is 25 per cent lower than the productivity achievable under 1/2S d/3 system (Table Exp.9). Over exploited holding showed a fall in productivity compared to well exploited holdings. Latex Diagnosis has been developed as a crop harvest management technology for

Table Exp. 8. **Exploitation status of smallholdings based on the levels of Pi and thiols**

Exploitation status	% plots	Pi (mM)	Thiols (mM)	Sucrose (mM)	DRC (%)
Optimum (1/2 S d/3)		20.70-30.50	0.30-0.45	5.21-10.37	35.00-44.00
Well exploited (WE)	54	26.34	0.42	8.07	37.49
WE under stress	12	25.80	0.27	6.02	39.18
Over exploited (OE)	17	35.04	0.40	8.46	37.47
OE under stress	5	34.58	0.24	6.43	40.80
Under exploited	12	15.98	0.38	6.11	40.38

Table Exp. 9. **Productivity status of the exploitation groups relative to optimum productivity under 1/2S d/3 frequency of tapping**

Exploitation status	% plots	Yield (g/t/t)	Tapping days	Yield (kg/t/y)	TPD (%)
Optimum (1/2 Sd/3)		67.50-76.51	100	6.75-7.65	5.99-7.62
Well exploited (WE)	54	52.03	111	5.77	7.00
WE under stress	12	54.28	110	5.97	8.00
Over exploited (OE)	17	48.50	135	6.54	8.00
OE under stress	5	41.30	136	5.61	9.00
Under exploited	12	61.00	81	4.97	4.00

Table Exp. 10. **LD Parameters of popular clones (RRII Farm)**

Clone	Thiol (mM)	Insoluble P (mM)	Sucrose (mM)	DRC (%)	Yield (g/t/tap)*
Trial 1					
RRII 5	0.36	13.40	4.28	40.34	61.42
RRII 105	0.44	12.79	5.12	42.84	47.11
RRII 118	0.51	11.68	4.12	42.44	46.00
RRII 208	0.44	19.44	7.06	42.04	43.04
RRII 300	0.52	12.50	5.61	41.08	37.22
RRII 308	0.61	11.36	4.96	39.25	45.19
RRIM 600	0. 42	13.89	4.47	37.09	38.14
RRIM 703	0.40	15.35	3.88	34.85	42.86
Trial 2					
PB 217	0.52	20.45	8.92	41.94	34.61
PB 235	0.33	20.07	4.21	42.28	58.60
PB 255	0.25	12.98	4.24	48.81	74.90
PB 260	0.41	22.34	3.19	39.31	60.46
PB 280	0.51	19.83	5.07	44.04	67.00
PB 310	0.60	11.53	6.00	43.13	49.40
PB 311	0.36	17.35	4.60	39.07	63.68
RRII 105	0.44	12.79	5.12	42.84	52.04
CD (P=0.05)	0.09	2.80	1.94	NS	

*Pooled mean of 5 years

Table Exp. 11. **LD parameters of RRII 400 series clones (2nd year)**

Clone	Thiol (mM)	Pi (mM)	Sucrose (mM)	DRC (%)	Yield (g/t/t)*
RRII 403	0.31	11.31	8.14	42.69	71.60
RRII 407	0.39	7.37	14.81	42.81	68.90
RRII 414	0.45	9.87	11.81	42.07	81.11
RRII 417	0.30	9.93	10.42	45.83	71.35
RRII 429	0.33	8.71	11.85	42.32	80.22
RRII 410	0.31	6.75	13.56	40.69	55.60
RRII 422	0.47	16.95	14.41	40.46	72.52
RRII 427	0.33	16.74	9.68	42.34	56.90
RRII 430	0.42	6.09	9.89	38.68	69.22
RRII 105	0.30	9.83	9.92	39.95	55.70
CD(P=0.05)	0.11	4.15	3.55	NS	

*mean yield of 7 years

assessing the exploitation status of smallholdings as well/over/under based on the levels of inorganic phosphorus (Pi) and thiols (R-SH) relative to critical limits.

5. LD for optimising exploitation in stimulation trials

During 2003-04, experiments were initiated in newly opened trees of clone PB 260 under 1/2S d/4 system at Cheruvally Estate, Erumeli for optimizing stimulation schedules using latex diagnosis. LD parameters of the experimental trees were recorded twice during the sampling season.

During 2004-05, the above experiments were continued and a new field experiment was initiated at Vaikundam Estate, Kulasekharam in clone RRII 105 (BO-1) under 1/2S d/3 system of tapping.

6. Clone characterization studies

Studies initiated to classify newly released and popular clones into different metabolic groups based on LD parameters were continued (Table Exp.10).

Clones RRII 422 and RRII 414 had significantly higher thiol levels and higher productivity than RRII 105 (Table Exp. 11).

LD studies were continued during 2004-05 in newly released 400 series clones and popular clones for evaluating the production potential of clones for evolving clone specific exploitation systems.

Clones RRII 414, RRII 429, RRII 422 and RRII 427, which had significantly higher thiol levels than RRII 105 reported lower TPD incidence in the third year of tapping.

GENOME ANALYSIS LABORATORY

In the Genome analysis laboratory, the major research areas are the development, optimization and validation of molecular tools for the assessment of genetic diversity in rubber, clonal identification and genome mapping and genetic markers for biotic and abiotic stresses.

1. Establishment of genetic relationships among wild *Hevea* germplasm using chloroplast markers

Genetic relationships among the wild *Hevea* germplasm have been assessed using a set of universal chloroplast microsatellite markers for getting an insight of the chloroplast genome differentiation among them. Two chloroplastic hyper-variable intergenic regions, *trnM-rbcL* and *tranC-trnD* have also been studied in detail to achieve more information regarding chloroplast genome differentiation.

2. Development of microsatellites and its applications in the characterisation of *Hevea* germplasm

Development of microsatellite markers in *Hevea* has been continued with the isolation and characterization of *Hevea* genomic clones containing microsatellite/ simple sequence repeats (SSR). Sequencing of the selected *Hevea* genomic clones revealed the presence of various repeat motifs comprising di-(TG/AC, AG/TC, TA/AT), tri-(AAG, AGG, ATT), tetra-(GAAA, AAGG, ATCC, TAAA, AAAT) and pentanucleotides (GAAAT). Primer-pairs synthesized based on the flanking sequences of the repeats were tested for amplification with their respective *Hevea* genomic clones containing the simple sequence repeats (SSR) and in all the cases successful amplification of the expected fragments was detected.

Microsatellite markers, developed in *Hevea* have been evaluated in wild accessions. Polymorphisms were detected among those accessions and in some cases genotype specific alleles were identified. Wild accessions appeared to be highly polymorphic than the cultivated clones as revealed through the amplification of more number of alleles. Cross-species amplification of the microsatellite primers using other two species of *Hevea* had also been tried.

3. Existence of retrotransposons/ retroelements in rubber genome

We have cloned a reverse transcriptase (RT) gene fragment in *Hevea*, which indicates the presence of retrotransposons – a class of mobile genetic elements in the genome. Retrotransposons are dispersed as interspersed repetitive sequences throughout the host genome and are exploited as genetic tools for plant genome analysis. Using the RT gene fragment as a probe a *Hevea* genomic library is screened to clone a full-length retroelements.

4. Genetic markers for biotic and abiotic stress tolerance

4.1. Disease tolerance

Resistance gene analogues (RGAs), an alternative approach to identify disease resistance gene in *Hevea* is in progress. Degenerated primers based on the conserved nucleotide sequences of the structural motifs/ domains- characteristic of the disease resistant genes (R-genes), were used to amplify similar sequences from *Hevea*. Several fragments were amplified in *Hevea* clones/genotypes including *Hevea benthamiana*. Seventeen putative RGA fragments have been sequenced so far. Nucleotide variability was detected among these sequences. Sequences were translated to look for motif characteristic of plant NBS (Nucleotide-binding site), common to many R-genes. Most of the encoded amino acid sequences showed the characteristic amino acid motifs of NBS regions, namely, P-loop, kinase-2 and GLPL. Amino acid alignment showed that the *Hevea* RGAs share homology with NBS regions of well–characterized R-genes from other plants.

4.2. Drought tolerance

Investigations to understand the molecular mechanism of drought tolerance in *Hevea* has been initiate in collaboration with Plant Physiology Division Experiments have been carried out to identify the m-RNA transcript variability among the treated and non-treated *Hevea* clones (RRII 105 and RRIM 600) with respect to water stress. Reverse transcriptase polymerase chain reaction technique (differential display) was employed to identify cDNAs corresponding to transcripts affected by water stress. Several m-RNA transcripts have been identified using 24 primer combinations (eight arbitrary primers and three anchored oligo-dT primers) that are up- or down- regulated following water stress. Using this technique, a total of 145 differentially expressed bands have been identified and eluted from the dried gel. Further amplification of these products is in progress.

5. Phylogenetic analysis of the fungal pathogen based on rDNA spacer sequences

Colletotrichum leaf fall disease in rubber caused by the *Colletotrichum spp.* produces three different disease symptoms, *viz.*, raised spots, anthracnose and circular papery lesions. Involvement of two different species of the pathogen namely *C. gloeosporioides* and *C. acutatum* were established through rDNA-ITS-RFLP analysis of the fungal isolates from rubber. Ribosomal DNA spacer sequences from both the *Colletotrichum* species infecting rubber were compared to get an idea about the nucleotide divergence existing among them in the spacer regions including

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5.8 S gene. Aligned sequence data of the spacer regions revealed the existence of more nucleotide divergence including base substitutions and indels in the ITS 1 compared to the ITS 2 region. Phylogeny of the rubber pathogen with the closely related fungal isolates from different hosts based on the rDNA spacer sequences clearly revealed their uniqueness. The bootstrapped consensus tree derived through neighbour-joining method comprised of two major branches having the fungal isolates belonging to two different species indicating clear species delineation of *Colletotrichum*. The fungal isolates belonging to *C. gleosporioides* and *C. acutatum* infecting *Hevea* appeared to be closely related to the pathogens infecting *Fragaria* and *Cyclamen*, respectively.

DRIS FERTILIZATION

The DRIS unit was engaged in studies related to hydrological and erodibility characteristics of soils of slope lands, phosphorus fixation studies, nutrient cycling in rubber and forest ecosystem and rooting pattern of *Hevea* in relation to different soil conditions. The unit had attended advisory service to smallholdings by providing discriminatory fertilizer recommendation. Mobile soil testing programmes were also arranged for giving on the spot fertilizer recommendation.

1. Hydrological and erodibility characteristics of soils of slope lands under rubber

Rubber growing soils developed on different landforms in Kerala were evaluated for erodibility. About 28 per cent of rubber growing soils in Kerala are in highly erodibile class. Water dispersible clays disturbed soil from different slope lands under rubber were varied from 23.29 to 28.50 per cent.

2. Phosphorus fixation studies

Studies on phosphorus (P) fixation in rubber growing soils was conducted in four series comprising three soil orders *viz.*, Ultisols (Lahai and Thrikkannamangal series), Entisols (Peruva series) and Inceptisol (Chandanikunnu series). The results indicated that the fixation of added P was highest in Ultisols (60-87%) followed by Entisols (52-75%) and Inceptisols (44-69%). Among the different forms of P, iron-P is the dominant P fraction in all the series.

3. Soil factors influencing yield in high and low yielding rubber plantations

Soil samples were collected from estate and smallholdings. The results indicated that the organic carbon content and cation exchange capacity were higher in soils of high yielding areas compared to low yielding areas.

4. Nutrient cycling studies

4.1. Nutrient cycling in rubber and forest ecosystem

Nutrient content was found to vary over season in soils under rubber and adjacent forest. Soils from forest showed differences in non-exchangeable potassium compared to rubber areas.

4.2. Nutrient uptake study

Biomas of fourteen year old tree of clone PB 311 was estimated by uprooting. Highest biomass (56%) was found in trunk followed by branches and twigs (26%), roots (13%) and leaves (5%). Nutrient concentration in different plant parts is given in Table Dri. 1.

Table Dri. 1. **Nutrient concentration (%) in plant parts of clone PB 311**

Plant parts	N	P	K	Ca	Mg
Leaf	4.70	0.40	0.88	1.13	0.36
Shoot	1.30	0.30	1.12	0.76	0.14
Twigs	0.70	0.07	0.27	0.43	0.18
Branch and small branches	0.60	0.05	0.20	0.45	0.06
Petiole	1.80	0.35	1.29	0.96	0.27
Tap root	0.70	0.17	0.25	0.55	0.17
Feeder root and lateral root	1.40	0.21	0.57	1.32	0.32

5. Root studies in *Hevea*

Distribution of fine and coarse roots of *Hevea* varied with the age of the trees. Maximum root density was observed in 0-10 cm depth and 1 to 1.5 m from the base of the tree.

6. Effect of relief on yield and growth of rubber

Experiments to study the effect of relief on yield and growth of rubber were being conducted in two locations with slope points of 4-60% and 8-60% respectively. Lowest girth was recorded in top and bottom plots of the hillocks. In the experimental plot in the second location lowest girth was recorded in hillocks facing south.

7. Characterization of soils of RRII Research Stations

Characterization of soils of RRII Research Stations was in progress. Soil pedons representing different landforms at Hevea Breeding Sub-Station, Nettana were examined and morphological features recorded.

8. Sulphur status in rubber growing soils

Studies indicated wide variations in sulphur content in rubber growing soils. Sulphur deficiency was also observed.

9. Smallholders advisory service

Discriminatory fertilizer recommendation to rubber smallholdings based on soil and leaf analysis was continued. In central and regional laboratories, 7726 soil and 682 leaf samples were analysed and 3900 fertilizer recommendations were offered. Mobile soil testing programmes were conducted at 39 locations and offered fertilizer recommendation. Besides, 51187 latex samples were analysed for dry rubber content and 593 samples for volatile fatty acid.

CENTRAL EXPERIMENT STATION, CHETHACKAL

The Central Experiment Station, Chethackal, situated at a distance of about 50 km from Kottayam, was established to cater research needs of the different divisions of the RRII. The station has a total land area of 254.8 ha which is planted for different research projects. During the reporting period the total crop realized was 150042.45 kg. Total of 293 tapping days was possible in the year and 61 tappers were engaged for tapping. Total man-days engaged were 61110. The CES Dispensary caters to the medical needs of the workers and the total patients attended to during the period under report were 7905.

REGIONAL RESEARCH STATION, GUWAHATI, ASSAM

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

1. Crop improvement

1.1. Evaluation of clones

The clone trial laid during 1985 with 10 clones showed the highest girth over 19 years in RRII 118 (77.3 cm) closely followed by RRII 203 (77.2 cm), RRIM 600 (75.2 cm) and the lowest in PB 5/51 (54.2 cm). Clone RRII 203 registered highest girth increment (1.85 cm) followed by RRII 118 (1.63 cm) and GT 1 (1.52 cm) while RRIM 600 recorded the lowest (0.73 cm). The annual mean yield (g/t/t) was maximum in RRIM 600 (44.5) closely followed by RRII 203 (44.3), GT 1 (40.7) and RRII 105 (40.5) and the minimum was in PB 5/51(25.6) over 11 years under the normal system of tapping (1/2 S d/2 with tapping rest). Among the trees tapped without rest (1/2 S d/2), the highest mean yield was recorded in RRII 118 (38.1 g/t/t) followed by RRIM 600 (37.5 g/t/t) and the lowest was in GI 1 (19.1 g/t/t). The annual average DRC was high (33.1 to 34.6%) in normal system of tapping compared to continuous tapping (31.5 to 34.4%).

In the second clone trial laid during 1986 with 10 clones the highest mean girth over 18 years was noticed in RRIC 102 (79.9 cm) followed by RRII 118 (77.9 cm), and PB 310 (72.9 cm) and the lowest was in RRII 105 (65.5 cm). The clone PB 310 showed highest girth increment (1.75 cm) followed by PR 255 (1.58 cm) and RRIC 102 (1.56 cm) and the lowest was for RRII 5 (0.87 cm). The annual mean yield (g/t/t) recorded over 10 years was highest in PB 311 (41.9) closely followed by PB 310 (41.6) and RRII 105 (40.6) and the lowest was in RRIC 105 (25) in normal system of tapping. In the case of continuously tapped trees, the highest annual average yield (g/t/t) was recorded for RRII 118 (38.1) followed by PB 310 (37) and the lowest was for RRII 105 (23.8). The annual average DRC in normal tapped trees was high (31 to 35.7%) compared to continuously tapped trees (31 to 33.4%).

1.2. Evaluation of polyclonal population

Evaluation of polyclonal population in terms of growth and yield was continued. Among the 10 promising polyclonal seedling trees, the highest annual mean yield (g/t/t) over 10 years of tapping was recorded in selection S1 (129.65) closely followed by S2 (128.76) and the lowest was in S5 (41.7). Maximum girth over 17 years was recorded in selection S2 (113 cm) followed by S10 (106.5 cm) and the minimum was in S1 (84.4 cm). The selection S2 recorded highest girth increment (5 cm) followed by S10 (4.7 cm) and S4 (4.3 cm) while S5 recorded lowest (2 cm). The highest yield potential (g/cm) among the selections was observed in S1 (2.59) followed by S2 (2.12) and S3 (1.56) and the lowest was in S5 (0.68). Except selection S4, all other promising polyclonal seedling trees showed high degree of tolerance to powdery mildew disease.

2. Crop management

Results of the experiment on effect of NPK fertilizers on growth and yield of *Hevea* (at Nayekgaon, Kokrajhar) have shown significant effect of N fertilizer (Urea) on girth and yield of rubber. Highest dose of N (60 kg/ha) resulted highest girth (62.84 cm) and yield (63.10 g/t/t) and both were significantly higher than those in other treatments (Table Ghy. 1). Phosphorus (P_2O_5) and potassium K_2O @ 40kg /ha resulted in significantly higher yield compared to other treatments though its effect on girth, annual girth increment and DRC was not significant. Results from the studies conducted at

Table Ghy. 1. **Effect of N, P and K fertilizer on average girth, mean yield and DRC**

Nutrient level (kg/ha)	Girth (cm)	AGI (cm)	Yield (g/t/t)	DRC (%)
Nitrogen (N)				
0.00	58.31	1.09	40.62	31.30
20.00	60.98	1.31	42.17	32.75
40.00	62.13	1.40	51.19	32.80
60.00	62.84	1.45	63.10	33.15
CD (P=0.05)	4.65	NS	4.89	NS
Phosphorus (P_2O_5)				
0.00	61.43	1.14	44.79	31.74
20.00	60.48	1.50	47.87	32.57
40.00	62.09	1.12	55.15	33.18
CD (P=0.05)	NS	NS	4.03	NS
Potassium (K_2O)				
0.00	60.92	1.10	43.91	32.20
20.00	61.25	1.36	48.62	32.25
40.00	61.86	1.69	55.28	33.05
CD (P=0.05)	NS	NS	3.42	NS

Sorutari and Nayakgaon, to evaluate the interaction effect of potassium and magnesium on growth and yield of rubber have shown that for 40 kg K_2O/ha and 15 kg MgO/ha growth and yield were significantly higher compared to other treatments.

In the experiments to study the influence of amount and forms of phosphatic fertilizers on growth and yield of *Hevea*, two forms of phosphatic fertilizers *viz.*, water soluble (Single Super Phosphate) and citrate soluble phosphorus (Rock Phosphate) were applied. Phosphorus as citrate soluble phosphorus @ 35 kg/ha resulted in highest girth (75.17 cm) and yield (59.45 g/t/t) among all the treatments.

The polybag experiment on length of cutting of budded stumps showed that sprouting success (89.6%) and plant girth (7 cm) were maximum where slanting cut was given 5 cm above the bud patch and sprouting success was minimum (61.8%) with the cut at 20 cm. Another experiment on alternate source of polybags for planting has shown that budded stumps planted in bigger bamboo basket (55 cm X 25 cm) resulted in maximum sprouting (92.6%) and plant girth (6.3 cm) among all the treatments.

3. Crop protection

Survey on diseases and pests was carried out in 95 locations covering 53 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. The severity of powdery mildew disease was in the infection grade between 1.5 to 2.5 in most of the locations except in certain locations where the severity was observed as high as 2.5 to 3.5. However, the severity of powdery mildew disease was confined to the lower branches of the affected trees in most of the locations and that might be due to the presence of high temperature (ie., above 32 °C) in February/March, 05. Out of 38 *Hevea* clones from different experimental trials in Assam, Meghalaya, Tripura and northern part of West Bengal, PB 86, SCATC 93/114, SCATC 88/13, PB 260, PR 107, RRIC 100, RRII 429, RRII 417, RRII 203, RRII 208, RRIM 600, RRII 176 and RRIM 703 are found tolerant to powdery mildew disease. Minor incidence of Periconia leaf blight disease (below 10%) was observed on tender leaves in nursery plants during December/January in Assam and Meghalaya. Incidence of pink disease (below 2%) was noticed on immature rubber plants (RRII 105 & RRIM 600) only in northern part of West Bengal. Incidence of brown root disease (below 5%) was observed in different smallholdings in South Tripura and caused a total loss of the affected trees. Incidence of purple root disease (below 5%) was noticed only in seedling nursery at DDC, Jenggitchakgre in Meghalaya. Minor infestation of scale insect (*S. nigra*), termites, slugs and snails and mealy bug were also noticed in most of the locations of this region.

Fungal pathogens *viz.*, *Bipolaris heveae*,

REGIONAL RESEARCH STATION, GUWAHATI, ASSAM

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

1. Crop improvement

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Fungal pathogens *viz.*, *Bipolaris heveae*,

Periconia heveae, Colletotrichum gloeosporioides, Fusarium solani, Phellinus noxius and *Helicobasidium compactum* were isolated from diseased samples collected during survey in different locations of this region. Cultures of *Periconia heveae* were studied for strain differentiation.

Incidence and severity of powdery mildew disease in different wild accessions of *Hevea* germplasm at Sarutari, RES, Nagrakata and Taranagar Research Farm under the agro-climatic conditions of Assam, northern part of West Bengal and Tripura respectively were assessed during peak time of the disease. Forty one wild accessions out of 540 and 66 out of 246 accessions of *Hevea* germplasm conserved at Sarutari and Taranagar farms respectively showed high degree of tolerance to powdery mildew disease. Fourteen wild accessions out of 64 accessions of *Hevea* germplasm showed high degree of tolerance to powdery mildew disease under the agro-climatic conditions of RES, Nagrakata. Minor incidence of *Corynespora* leaf spot and Colletotrichum leaf fall diseases were also noticed on different wild accessions. Incidence of pink disease was not seen so far on different accessions of *Hevea* germplasm under RES, Nagrakata conditions.

The trial for control of purple root disease was initiated at DDC, Jenggitchakgre in Meghalaya. The incidence and severity of purple root disease in different experimental plots were assessed after the completion of treatments with Tilt (0.1 & 0.2%), Calixin (0.15 & 0.3%) and Bavistin (0.15 & 0.3%) including Bioflora Natural and one year of fallow bed. Incidence of purple root disease was controlled in experimental plots treated with Tilt, Calixin and Bioflora natural and also in one year of fallow bed.

4. Exploitation technology

In the experiment on tapping rest and frequency interaction in *Hevea* initiated during 1999 with the clone RRIM 600, normal tapping (1/2S d/2 6d/7) with and without rest was compared with other tapping systems *viz.*, 1/2S d/3 6d/7 and 1/2S d/4 6d/7 where stimulation has been imposed. The data revealed that treatments are non-significant with respect to girth and girth increment. Maximum girth was recorded under the treatment T_{12} (1/2S d/4 6d/7 with 7 stimulants and three months rest) followed by T_7 (1/2S d/3 6d/7 with 5 stimulants and two months rest) and minimum was in T_2 (1/2S d/2 6d/7). However, the yield was significantly influenced by the treatments. Maximum yield (77.6 g/t/t) was recorded for the treatment T_{12} followed by T_7 (71.1 g/t/t) (1/2S d/3 6d/7 with 7 stimulants and one month rest) and minimum was in T_3 (31.1 g/t/t).

REGIONAL RESEARCH STATION, AGARTALA, TRIPURA

The Station was engaged in studies on intercropping, planting density and nutritional requirement in immature and mature rubber. Potassium bearing minerals and nutrient availability were also studied in rubber growing soils of NE region. The other aspects of investigation were clone evaluation, germplasm evaluation and exploitation schedules. Study on effect of low temperature stress on growth of rubber was also in progress. Studies were conducted on identification of suitable rubber growing areas in the NE region based on annual rainfall. Mobile Soil and Tissue Testing Laboratory were

in operation for the benefit of rubber growers of this region.

1. Crop improvement

1.1. Evaluation of clones

In clonal evaluation trial for stress tolerance, RRII 208 continued to be the high yielder (28 g/t/t) followed by RRIM 600 (24 g/t/t). Mean (six months) yield (g /t /t) was in the order of RRII 105 (60) RRIM 600 (57), PB 235 (49) and GT 1 (47). In another clone trial with ten clones including three Chinese clones, RRII 105 exhibited highest girth followed by RRIM 600 and RRIM 612.

The girth data of an onfarm trail at Killamura region showed that RRII 203 (47.6 cm) had the highest girth, followed by PB 260 (44.5cm. In another clone trial at Bagafa region PB 235 (23.5 cm) had the highest girth closely followed by RRII 118 (23 cm).

Sprouting success was studied in RRII 400 clones. It was observed that success of sprouting was in the order of RRII 414 (93%), RRII 417 (92%), RRII 430 (86%), RRII 422 (81%) and RRII 429 (73%).

1.2. Evaluation of polycross progenies

Twelve potential yielders from polyclonal seedling population were field planted during 2000 with RRIM 600 as reference clone. Selection 98 exhibited highest girth. Almost all selections were performing with higher girth compared to RRIM 600 (Table Net. 1).

Table Net. 1. Girth of polycross selections

Ortet	Girth (cm)
98	20.2
89	17.9
585	12.2
461	20.0
114	12.4
121	17.3
315	22.0
292	10.8
144	14.1
165	18.3
327	12.8
RRIM 600	12.7
Mean	15.9
SD	3.8

1.3. Conservation and evaluation of germplasm

In germplasm evaluation Trial I, mean girth was 53, 54 and 55 cm in Rhodonia (RO), Mattogrosso (MT) and Acre (AC) respectively. In Trial II the mean girth was 56, 54 and 58 cm in RO, MT and AC accessions respectively. Though MT 4796 (10 g/t/t) and MT 4788 (28 g/t/t/)accessions showed high yield in Trial I and Trial II respectively. RRIM 600 (control) was the highest yielder (38 g/t/t) in both the trials.

1.4. Isolation and culture of protoplasts from leaf mesophyll cell

Experiments were conducted to isolate leaf mesophyll protoplasts (RRIM 600) using different combination and concentration of the enzyme mixtures, incubation period, pH of the incubation mixtures and incubation temperature. Macerozyme 1 per cent along with 1.5 per cent Cellulase 'Onozuka R10' was found to act best at 35°C at pH 5.5 for 4.5 hrs. 95 per cent of protoplast were found to be viable, when viability test was conducted using Fluorescent-di-acetate (FDA).

2. Crop management

Different mulching systems such as paddy straw, polythene, FYM cover, FYM+straw, FYM+ polythene, polythene overhead cover and trench planting were undertaken to study the effect of mulching on growth of seedling in winter. During winter season (November-January) the average morning soil temperature of FYM+straw mulching system was 18.6°C as compared to 17.1°C in control plots. The mean above-ground biomass of 62g and 59g per seedling were recorded in case of FYM+ straw mulching and polythene overhead covering respectively. It was also observed that 42 per cent

seedlings under FYM+straw mulching treatment and 33 per cent seedlings under polythene overhead covering attained required girth for budding within five months of growth period.

In the study on the effect of different fertilizer doses on different densities of two clones, significant differences in yield were observed and the highest yield (60 g/t/t) was observed in lowest density. In tea intercropping trial, highest fresh tea leaf yield was observed during the month of June and total annual yield was 1037 kg/ha. In organic and inorganic manuring experiment, maximum immature girth continued to be on application of recommended dose of fertilizer with 20 kg of farm yard manure (FYM/plant/year).

No difference in girth was observed among the RRII 400 series clones in the second year in response to high dose of fertilizer. On growth of immature *Hevea*, similar result was also observed in response to different level and time of fertilizer application.

In the K dynamics study, the mineralogical make up of the rubber growing soils of NE region with special reference to their K-bearing minerals and nutrient availability were taken up. Representative soils from six locations *viz.*, West Tripura, South Tripura, Sonitpur (Assam), Garo Hills (Meghalaya), Dooars (West Bengal) and Bhubaneswar (Orissa) were collected and separated for their size fractions. Quartz is the dominant minerals in these soils. Kaolin is the major mineral present in clay fractions of the soils. Distribution of K among the three soil size fractions showed that little K is contributed by the sand fractions of West Tripura and Bhubaneswar, whereas in the other four sites, all the three soil size fractions contributed almost equally towards total K content of the soils. The soil test values for exchangeable and non-exchangeable K in these soils (Table Net. 2) are found low to medium though the mineral pool of soil contained an appreciable amount of K which suggests that the present extractant for plant available soil-K test values may not be a good indicator to correlate with crop growth.

3. Crop physiology

3.1. Exploitation systems

The 1/2S d/2 6d/7 system of tapping continued to give high yield in tapping rest and frequency interaction studies in clones RRII 105 and RRIM 600. However, 1/2S d/3 6d/7 tapping system (5 stimulation) with two month rest is comparable to that of 1/2S d/2 system. Shorter cut like 1/3S d/2 and 1/4S d/2 6d/7 system of tapping with three and five stimulations respectively has recorded reasonably high yield compared to 1/2S d/2 6d/7 system in different tapping cuts and tapping system experiment on clone RRII 105.

4. Latex technology

In the study on seasonal variations in properties of rubber, it was observed that DRC and TSC were very low in winter season compared to summer and rainy seasons (Table Net. 3). Though no differences were

Table Net. 2. **Soil potassium status and fertility rating in the experimental sites**

Location	WS-K (ppm)	Ex- K (ppm)	Non-ex K (ppm)	Mineral K (%)	Plant available K (ppm)	Fertility rating
West Tripura	2-7	54-60	251-434	1.37-1.56	56-67	Medium
South Tripura	6-9	65-89	388-501	2.39-2.56	71-98	Medium
Sonitpur, Assam	5-10	61-75	754-833	2.33-2.53	66-85	Medium
Garo Hills, Meghalaya	3-9	85-120	750-886	1.65-1.89	88-129	Medium to high
Dooars, W. Bengal	2-4	16-22	350-440	2.65-2.85	18-26	Low to medium
Bhubaneswar, Orissa	2-6	38-43	398-480	1.38-1.62	40-49	Low to medium

noticed in non-rubber contents, Magnesium content was high in winter season. Dry rubber parameters like initial plasticity and plasticity retention index was same in all seasons,

Table Net. 3. **Raw latex properties**

Parameter	March-April	Augt-Sept	Dec-Jan
TSC (%)	41.82	36.61	27.41
DRC (%)	39.72	34.49	25.25
NRC (%)	2.10	2.12	2.16
Ash (%)	0.11	0.09	0.12
N (%)	0.43	0.38	0.37
Mg (ppm)	40.00	42.00	44.00

whereas accelerated storage hardening was low in rainy season.

5. Advisory work

Soil and leaf samples were collected from the rubber growers of Tripura and 322 discriminatory fertilizer recommendations were offered during the period of report. At Kolkata port 1115 MT of imported rubber was inspected. In addition, 18 MT of rubber for export was inspected at Agartala. Quality sheet making and DRC measurement were demonstrated at different RPSs and to the trainees.

REGIONAL RESEARCH STATION, TURA, MEGHALAYA

The Regional Research Station, Tura continued its research activities on evaluation of clones, selection from polyclonal population, evolving suitable exploitation system and aspect of slopes and crop management.

1. Crop improvement

Girth and yield data were recorded from 1985 and 1986 clone trials. In 1985 trial, RRIM 600 showed the highest girth (90.36 cm) and yield (47.7 g/t/t) while lowest girth was in PB 5/51 (67.7 cm) and lowest yield in RRIM 605 (30.4 g/t/t). In 1986 trial, among the planted ten clones PB 310 registered the highest girth (89.21 cm) closely followed by RRIC 105 (86.61 cm) while lowest girth was recorded in PR 255 (69.55 cm). The clone PB 311 registered the highest yield (46.3 g/t/t) and least in RRIC 105 (26.9 g/t/t). The polyclonal population attained an average girth of 73.87 cm.

2. Crop management

2.1. Cropping system

To assess the performance of rubber (RRIM 600) and tea at 600 m altitude of Garo hills, growth and yield of rubber were recorded at different time interval. It has been found that rubber plants attained an average girth of 79.2 cm while average yield was 46.0 g/t/t. Tea growth was affected by leaf disease and total production was 195.5 kg.

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

Treatment-wise soil and leaf samples were collected and analyzed for available nutrients and N, P and K respectively. Monthly recording of cup lump yield (g/t/t), DRC (%) and total volume (ml/t/t) were undertaken. Periodic recording of data on girth were taken quarterly.

Results during the reporting year showed that a combination $N_{60}P_{30}K_{60}$ kg/ha gave highest yield (67.02 g/t/t), DRC (36.70%) and total volume of latex (189.59 ml/t/t) followed by the treatment combination of $N_{60}P_{30}K_{30}$ kg /ha and minimum was in control plot. Improvement of fertility status of soil and leaf nutrient contents with application of NPK fertilizers, significantly increased the O.C. content, available P and K and highest was recorded with the combi-

nation of $N_{60}P_{30}K_{45}$ kg /ha and minimum was in control plot.

2.3. Comparative efficiency of cover crops

Soil samples were collected for general microbial population and analyzed for microbial population ie., fungi, bacteria and actinomycetes in the soil. The bacteria and actenomycetes populations were much higher as compared to fungus populations. The number of the populations decreased with the increase of the soil depth. Less aeration, low nutrient and low organic matter contents at lower depths may be the reasons for low counts of populations. Qualitatively, however, not much difference was observed in the fungal species composition (Table Nem.1). A total of 28 fungal species were isolated, majority of which belonged to the group of fungi imperfecti.

2.4. Leaf nutrient concentration

The results during the year indicated that the N concentration in leaf showed low to medium ranges among the different *Hevea* clones and maximum N content was noticed in the clone RRIM 600 (3.38%) followed by PB 311, RRIM 605 and minimum was in clone Gl 1 (3.00%). The leaf-P content showed medium to high range and maximum P content was noticed in the clone RRIM 600 (0.31%) followed by PB 310, PB 311, GT 1 and minimum was in Gl 1 (0.25%). Leaf K content also showed medium to high ranges and maximum K content was noticed in the clone RRIM 600 (1.59%) followed by RRIM 605, PB 310 and PB 311 and minimum was in clone PR 255 (1.22%).

2.5. Soil moisture retention under rubber

124 soil samples collected from 31 rubber growing areas of Meghalaya were processed and analyzed for available nutrients. The results showed that organic carbon was in medium to high range (0.92- 1.59%), soil was acidic in all the locations. Available Phosphorus was very low (0.02 -0.69 mg/100 g soil) and available Potassium was in low to medium range (4.0 to 6.4 mg/100g soil). Soil samples were collected at the depth of 0-15 cm, 15-30 cm, 30-45 cm and 45-60 cm from RRS Ganolgre farm and analyzed the moisture content. It was found that soil moisture showed synergistic effect with increasing depth of soil and seen between field capacity and Permanent Wilting Point (PWP) - 18.38% to 26.57%.

3. Crop physiology and exploitation

Growth and yield components of clone RRIM 600 was recorded at different seasons to find out the seasonal variation. It has been observed that during winter season contribution of girth was minimum (11%) while

Table Nem. 1. **Vertical distribution of microbial population (cfu/g of soils) under different treatments of two cover crops**

Treatments	0-30 cm depth			30-60 cm depth		
	Fungi (10^3)	Bacteria (10^6)	Actino-mycetes (10^5)	Fungi (10^3)	Bacteria (10^5)	Actino-mycetes (10^5)
P. phaseoloides in single strip	44.29	7.84	5.24	20.26	2.53	1.12
P. phaseoloides in double strips	40.88	7.59	4.31	19.84	2.12	1.43
P. phaseoloides in 1m² patches	47.48	8.19	5.61	21.77	3.07	1.99
M. bracteata in single strip	42.36	7.85	4.52	18.23	3.04	1.82
M. bracteata in double strips	42.67	8.09	4.01	19.41	3.69	1.92
M. bracteata in 1m² patches	45.59	8.99	5.95	21.57	3.83	1.95
Natural cover	38.76	6.67	3.79	16.28	2.09	1.05
SE	0.786	0.233	0.077	0.665	0.040	0.041
CD (P=0.05)	2.387	0.706	0.234	2.017	0.121	0.125

maximum was during post monsoon season (56%). Contribution of maximum total volume of latex ml/t/t (31%) and dry rubber yield g/t/t (30%) was recorded in post monsoon season. During winter period DRC was 26 per cent.

To assess the performance of clone RRIM 600 in West South West (WSW) and North North East (NNE) aspect of slope, girth and yield data were recorded at different time interval. Results indicated that plants growing in WSW slope showed higher girth (79.2 cm), lower yield (46 g/t/t) and early defoliation while lower girth (75.9 cm), higher yield (51.8 g/t/t) and late defoliation occurred in plants at NNE slope. In both slopes TPD was 3-4 per cent.

The different tapping system in combination with tapping rest especially during winter season was studied. In 1/2 S d/2 tapping system, maximum yield (g/t/t) was observed in 15^0-15^0 temperature regime (56.3) followed by 20^0 - 20^0 temperature regime (54.1), control (46.7) and 10^0-10^0 temperature regime (45.2) while in 1/2 S d/3 tapping system maximum yield was in control treatment (54.4) followed by 15^0-15^0 temperature regime (50), 20^0 - 20^0 temperature regime (49.3) and 10^0-10^0 temperature regime (48.6). In both the tapping system TPD incident was 3.7%.

4. Analytical/Advisory work

46 soil samples and 35 leaf samples were collected from the 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.

REGIONAL EXPERIMENT STATION, NAGRAKATA, WEST BENGAL

1. Crop improvement

Experiment was laid out to screen clones, showing better performance in terms of yield with special reference to high-speed wind, cold and high-sunshine intensity tolerance. In terms of yield (kg/t/yr), SCATC 88/13 showed higher value (3.57) followed by PB 311 (3.15) and RRII 203 (3.01) in Trial I. In Trial II, RRIM 605 and RRII 208 showed high yield (3.85 & 3.61) followed by PB 86 (3.24). RRIM 600 showed high yield (3.11) followed by HK 1, RRII 208 (2.95 & 2.93). The clones PR 261, HK 1 and RRIM 600 ranked high (3.07, 3.03 & 2.93) in Trial IV.

In order to study the adaptability of 21 different genotypes including a few standard check clones in the climatic condition of North Bengal and also to conserve selected germplasm for this region, experiment was started in 1998. As per the juvenile yield data (g/cm /t/t) RRII 105 was the best performer (1.01) followed by RO 5363 (0.93) and the lowest yield was observed in AC 607 (0.01) and AC 619 (0.04).

Polyclonal seeds were procured from Kanyakumari seed nursery and 237 seedlings were planted in 1990 at Nagrakata Experimental Farm for screening the genotypes showing better performance in terms of yield, disease resistance and other agronomic traits. The plants were under tapping from 2000 in 1/2 S d/2 system of tapping with an annual rest from mid-January to mid-April. All the plants were rainguarded. Among

nation of $N_{90}P_{90}K_{45}$ kg /ha and minimum was in control plot.

2.3. Comparative efficiency of cover crops

Soil samples were collected for general microbial population and analyzed for microbial population ie., fungi, bacteria and actinomycetes in the soil. The bacteria and actenomycetes populations were much higher as compared to fungus populations. The number of the populations decreased with the increase of the soil depth. Less aeration, low nutrient and low organic matter contents at lower depths may be the reasons for low counts of populations. Qualitatively, however, not much difference was observed in the fungal species composition (Table Nem.1). A total of 28 fungal species were isolated, majority of which belonged to the group of fungi imperfecti.

2.4. Leaf nutrient concentration

The results during the year indicated that the N concentration in leaf showed low to medium ranges among the different *Hevea* clones and maximum N content was noticed in the clone RRIM 600 (3.38%) followed by PB 311, RRIM 605 and minimum was in clone Gl 1 (3.00%). The leaf-P content showed medium to high range and maximum P content was noticed in the clone RRIM 600 (0.31%) followed by PB 310, PB 311, GT 1 and minimum was in Gl 1 (0.25%). Leaf K content also showed medium to high ranges and maximum K content was noticed in the clone RRIM 600 (1.59%) followed by RRIM 605, PB 310 and PB 311 and minimum was in clone PR 255 (1.22%).

2.5. Soil moisture retention under rubber

124 soil samples collected from 31 rubber growing areas of Meghalaya were processed and analyzed for available nutrients. The results showed that organic carbon was in medium to high range (0.92- 1.59%), soil was acidic in all the locations. Available Phosphorus was very low (0.02 -0.69 mg/ 100 g soil) and available Potassium was in low to medium range (4.0 to 6.4 mg/100g soil). Soil samples were collected at the depth of 0-15 cm, 15-30 cm, 30-45 cm and 45-60 cm from RRS Ganolgre farm and analyzed the moisture content. It was found that soil moisture showed synergistic effect with increasing depth of soil and seen between field capacity and Permanent Wilting Point (PWP) - 18.38% to 26.57%.

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REGIONAL EXPERIMENT STATION, NAGRAKATA, WEST BENGAL

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Polyclonal seeds were procured from Kanyakumari seed nursery and 237 seedlings were planted in 1990 at Nagrakata Experimental Farm for screening the genotypes showing better performance in terms of yield, disease resistance and other agronomic traits. The plants were under tapping from 2000 in 1/2 S d/2 system of tapping with an annual rest from mid-January to mid-April. All the plants were rainguarded. Among

these 51 trees showed remunerative (>3 kg/t/yr) yield during the year and only 15 showed incidence of TPD (less than 50%).

2. Crop management

Results from the experiment to identify the best combinations of NPK fertilizer showed that different combination had no significant effect on growth and yield. However, maximum yield (g/t/t) as well as maximum girth (cm) were recorded in N15 P40 K40 kg/ha combination. In another nutritional trial to find out the effect of recommended dose of fertilizer in different splits per year, an experiment was laid out using RRIM 600 in RBD in 1993. The results for the current year showed that different splits had no significant effect on yield and girth. Maximum yield (37.67 g/t/t) was recorded in two splits while four split applications recorded maximum girth (57.95 cm).

In the experiment to find out the possibility of growing tea as an intercrop with rubber, maximum girth (43.96 cm) of rubber as well as of tea (13.92 cm.) was recorded in rubber with tea intercropping plots which was better than pure plots of rubber and tea. In another trial of rubber with arecanut intercropping, maximum (33.25 cm) and minimum (31.31 cm) girth of rubber were recorded in rubber with arecanut and pure rubber plots, respectively. In the case of arecanut, maximum girth (9.98 cm) was recorded in pure arecanut plot.

3. Crop physiology and exploitation

The experiment laid out to understand the trend in yield under different tapping systems (1/2S d/2 and 1/2S d/3) with temperature based tapping rest was continued. 1/2S d/1 system of tapping was discontinued after 4th year because of its excess bark consumption. For the first three years, yield under 1/2S d/2 system was higher but from 4th year onwards, 1/2S d/3 system gave higher yield. The five year average data showed that yield was higher under 1/2S d/2 than that of 1/2S d/3.

While analyzing the data on tapping rest treatment, it was observed that there was no significant difference between the yield of control and 12 rest but the yield of 15 rest and 18 rest treatments showed significantly low yield compared to the other treatments. Thus, the 1/2S d/2 with 12 rest could be the best combination.

REGIONAL RESEARCH STATION, DAPCHARI, MAHARASHTRA

The thrust areas of the Station are development of suitable planting materials and location specific agro technology for this drought prone region. Experiments to evaluate low frequency tapping systems, irrigation requirement, screening of wild *Hevea* accessions for drought, studies on the growth and yield potential of various clones/poly clones and a clone evaluation trial with 15 clones including RRII 105 are being carried out.

1. Environmental physiology

1.1. Effect of irrigation on growth and yield

The irrigation experiment initiated in 1987 with basin (1.00 ETc, 0.75 ETc and 0.50 ETc) and drip (0.75 ETc, 0.50 ETc and 0.25 ETc) irrigation treatments in clone RRII 105 was continued. On the 0.75 ETc basin and 0.50 ETc drip, irrigation was reduced to 0.25 ETc (basin and drip) from February 2000 onwards with an objective to test whether

irrigation requirement can be further reduced. Observations on the fortnightly cup lump weight, monthly girth and seasonal DRC, PI, TP were recorded. The trees from all levels of basin irrigation showed higher girth as compared to drip irrigation system. Highest yield was recorded in 0.50 ETc basin irrigation (Table Dap.1).

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

Treatment	Mean girth (cm)	Mean yield (g/t/t)
Control (No irrigation)	57.99	44.06
1.00 ETc basin	66.54	43.14
0.25 ETc basin (Earlier 0.75 ETc)	66.69	41.25
0.50 ETc basin	63.35	49.19
0.75 ETc drip	63.77	47.66
0.25 ETc drip (Earlier 0.50 ETc)	63.98	48.11
0.25 ETc drip	60.99	44.52
SE	0.89	3.40
CD (P=0.05)	1.93	7.41

The trial to study the effect of different levels of irrigation (1.00 ETc, 0.75 changed to 0.25 ETc from February 2000 onwards and 0.50 ETc) on yield and yield components of two clones *viz.*, RRII 105, RRII 118 was continued. Fortnightly yield, monthly girth and seasonal DRC, PI, BI and TP were monitored. Results indicated that clone RRII 118 performed better in terms of growth while RRII 105 showed better yield and yield related parameters in response to different levels of irrigation treatments (Table Dap. 2).

In the cost evaluation trial, the expenses incurred towards various inputs, farm practices and irrigation were monitored since 1987 in irrigated and unirrigated trees of RRIM 600. The result revealed that even with no irrigation during summer trees under restricted irrigation shows a high yield performance due to better soil depth.

2. Exploitation studies

Two trials were initiated for evolving optimum stimulation schedule under 1/2S d/3 tapping system in RRII 105 (Trial 1) and RRIM 600 (Trial II) under irrigation. In Trial I stimulation treatments T0 (control, no stimulation), T1 (2/y), T2 (4/y) and T3 (6/y) were implemented as per schedule under irrigation (0.50 ETc). Observations on DRC before and after stimulation, annual girth increment and TPD were monitored. Results indicated high rubber yield in the ethephon treated plants as compared to control. With no incidence of TPD, ethephon stimulation (4/y) appeared to be optimum without any

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

Treatment	Mean girth (cm)		Mean yield (g/t/t)	
	RRII 105	RRII 108	RRII 105	RRII 108
Control (No irrigation)	62.10	70.71	49.13	42.13
1.00 ETc	67.73	85.09	46.60	44.19
0.75 ETc*	66.34	77.77	44.69	50.72
0.50 ETc	65.62	73.96	50.75	46.40
For irrigation treatment				
SE		3.08		4.11
CD (P=0.05)		7.53		10.06
For clones				
SE		1.64		2.22
CD (P=0.05)		3.79		5.12

* Changed from 0.75 ETc to 0.25 ETc from Feb-2000 onward

significant effect on growth due to irrigation. Yield was highest (2555 kg/ha) for this treatment. No change in DRC was noticed after stimulation.

In Trial II stimulation treatments T1 (2/y), T2 (4/y), T3 (6/y), and T4 (8/y) were implemented as per schedule under irrigation (0.50 ETc) to all treatments. Observations on DRC before and after stimulation, annual girth increment and annual scoring of TPD were recorded. Among the various treatments, yield was highest in T3 (8/y) (1319 kg/ha) without significant effect in growth. No change in DRC was noticed after stimulation.

An experiment was started in 1999 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. Observation on DRC before and after stimulation, annual girth increment and TPD scoring are being monitored. Higher yield (45.8 g/t/t) was observed in treatment with tapping rest in May and June with 4 stimulations/year, without any significant effect on the growth of trees. Results indicated that stimulation did not affect the DRC.

3. Plant breeding

3.1. Evaluation of planting materials

Monthly girth, DRC and fortnightly yield recording were carried out in the clone evaluation trial initiated in 1985. RRII 208 is continuing to perform better in terms of growth and yield (Table Dap. 3).

Two experiments were laid out in 1983 and 1985 to study the yield performance of polyclonal progeny under conditions of North Konkan and to select ortet trees for further evaluation. Out of the population of nearly 1000 trees selected trees were cut back to generate sprouts, which were used for multiplication by budding. Observation on fortnightly yield, seasonal girth measurement, soil moisture measurement and yield component analysis are being recorded. The growth and latex yield were pooled and stable high yielder were identified. Trees with good yield throughout the year including drought season were selected as mother trees.

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

Treatment	Mean girth (cm)	Dry rubber yield (g/t/t)
RRII 5	58.67	34.90
RRII 6	62.05	34.67
RRII 105	55.75	39.69
RRII 208	64.00	46.77
RRII 308	56.06	24.91
RRIM 605	57.42	24.77
PB 260	59.51	26.70
PB 310	59.77	31.36
PB 311	56.83	31.81
RRIC 52	64.32	26.51
RRIC 100	58.23	32.27
RRIC 102	59.29	36.60
RRIC 105	56.55	24.87
PR 255	56.41	29.54
PR 261	57.07	28.74
SE	1.80	5.08
CD (P=0.05)	3.69	10.40

4. Evaluation of germplasm accessions

The trial for screening against drought tolerance using 130 wild accessions is being continued. The observation on pre and post drought growth and RWC % recorded wide variability among the accessions. In general, Mato Grosso accessions were superior to those from Randonia and Acre provenances for all the growth characters studied. Among the control clones RRIM 600 and RRII 208 were superior to RRII 105.

REGIONAL RESEARCH STATION, DHENKANAL, ORISSA

The Station concentrates its research activities on evaluation of clones, polyclonal seedlings and nutritional studies.

1. Crop improvement

In the clone evaluation trial (1987), GT 1 recorded the maximum mean girth (58.4 cm) followed by RRIM 600 (62.4 cm). The highest yield was recorded for RRIM 600 (30.5 g/t/t), followed by RRII 105 (27.7 g/t/t). In another clone evaluation trial (1990), clone SCATC 93/114 recorded the maximum mean girth (69.8 cm) followed by RRII 208 (65.5 cm). Clone RRIM 701 and SCATC 88/13 (61.9 cm) showed minimum girth. RRII 208 and SCATC 88/13 had higher mean yield (43.88 g/t/t and 38.73 g/t/t respectively). The lowest yield was in clone SCATC 93/114 (20.18 g/t/t).

In the clone trial started in 1991, clones did not differ significantly in girth. Clone GT 1 (70.5 cm) recorded highest girth closely followed by RRIC 102 (67 cm). Lowest girth was observed in RRIM 600 (59 cm). Among the clones RRII 208 recorded highest mean yield g/t/t (48.0) closely followed by RRII 105 (37.58) and polyclonal (35.57). The lowest mean yield was in RRII 300 (27.73). In an onfarm trial initiated during 1996 at RRL, Bhubaneswar with twelve clones, the clones PB 217, RRII 430 and RRII 417 recorded highest average girth.

In another trial on evaluation of modern clones laid out during 1990-2000, highest girth (cm) was recorded in RRII 105 (26.3) followed by RRIM 600 (26) and IRCA 111 (25.8). The lowest girth was in RRII 57 (19.2) and IRCA 109 (21.4).

In the polyclonal seedling trial (1989), based on initial growth performance the promising seedlings have been identified. Girth of promising trees varied from 88.7 cm to 110.1 cm. The highest average yield g/t/t was recorded in tree No.154 (87.0) closely followed by tree No.482 (81.2).

2. Crop management

In the trial to evaluate the effect of water-soluble and water insoluble forms of P on growth of young rubber laid down during 1999-2000, water soluble forms were found better than water insoluble forms at early stage. Application of 60 kg N, 60 kg P_2O_5 and 24 kg K_2O per ha was found to be superior in influencing the growth of *Hevea*.

REGIONAL RESEARCH STATION, PADIYOOR, KERALA

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

1. Crop management

1.1 Physico-chemical characterisation of soil

Analysis of soil samples for sodium content showed that it ranged from 0.17 to 0.52 cmhos/kg. Base saturation of soil was found to be low especially in the lower layers. Exchangeable Ca and Mg were domi-

nant cations followed by Na and K. However, no regular distribution pattern was observed. Soil classification on the basis of the data collected is being attempted. GPS readings from the profile sites to link the physiography and soil properties through digital elevation mapping were also monitored for geo- positional mapping.

1.2. Water requirement studies

The experiment initiated in immature rubber with irrigation levels at IW/CPE ratio's of 0.3, 0.6, 0.9, 1.2 and an unirrigated control was continued. Irrigation for the reporting period commenced from December. Growth recorded at periodic intervals indicated that irrigation significantly influenced the girth and girth increment of the plants (Table Pad. 1).

1.3. Rubber and cashew cropping system

The growth of rubber and cashew was monitored at regular intervals and was found to be satisfactory (Table Pad. 2).

1.4. Response of clones to fertilizers

The experiment laid out in June 2002 was continued. The treatments comprised of 3 clones (RRII 105, RRII 414 and RRII 429) with four fertilizer levels (30:30:20, 60:30:20, 90:60:40 and 120:60:40 kg per hectare of N, P_2O_5 and K_2O). No significant difference in girth of plants was observed due to different doses of fertilizer applied (Table Pad. 3)

Table Pad. 3. **Response of clones to different doses of fertilizer**

Treatment	RRII 105	RRII 429	RRII 414
30:30:20	9.4	8.6	8.6
60:30:20	10.1	8.6	8.6
90:60:40	9.5	8.3	8.6
120:60:40	9.2	8.8	8.9
CD(P=0.05)		NS	

Table Pad. 1. **Effect of different levels of irrigation on girth increment of young *Hevea***

Treatment	Number of irrigation	Girth (cm)					
		Dec	Jan	Feb	Mar	Apr	May
IW/CPE 1.2	17	31.0	31.0	31.2	31.8	32.2	32.8
IW/CPE 0.9	13	29.6	29.6	29.7	30.2	30.3	30.7
IW/CPE 0.6	9	31.1	31.1	31.1	31.4	31.7	31.8
IW/CPE 0.3	5	27.1	27.1	27.1	27.4	27.4	27.6
Control	Nil	25.7	25.7	25.7	26.0	25.9	26.2
SE		0.94	0.96	0.97	0.95	0.95	0.99
CD(P= 0.05)		2.89	2.95	2.99	2.94	2.93	3.04

Table Pad. 2. **Growth of rubber and cashew in the cropping system**

Treatment	Rubber		Cashew	
	Girth (cm)	Canopy width (m)	Girth (cm)	Canopy width (m)
Paired row rubber (4.5x4.5 m) + cashew (4.5 m)	27.1	4.8	40.0	4.9
Rubber(7.5x7.5m) + cashew (7.5m)	30.2	5.1	36.5	3.9
Paired row rubber(4.5x4.5m)	19.1	3.5	-	-
Rubber 7.5x7.5m	22.0	4.1	-	-
Cashew 7.5x7.5m			37.0	4.1

HEVEA BREEDING SUB-STATION, NETTANA, KARNATAKA

The thrust areas of research of the Station are 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.

1. Crop improvement

In the trial 1988 A, five ortets *viz.*, O 47, C 1/2, C 42, C 70 and T 2 recorded better average girth than all the three control clones. Similarly, one clone in the trial 1988 B (T 1) and four clones in 1988 C (O 26, O 55, O 56 and C 140) recorded higher growth in terms of average girth than the three control clones. The trees are in the fourth year of tapping. Yield data revealed that the clone GT 1 recorded the highest average yield among the control clones (80.50 g/t/t). Twelve clones recorded comparable or higher yield than the controls (Table Kar. 1).

Table Kar. 1.**Performance of high yielding ortets**

Trial	Clone	Mean yield over three years (g/t/t)
1988A	O 17	70.7
	C 1/2	70.3
	T 2	69.7
	C 42	71.3
1988B	T 1	72.5
1988C	O 26	72.5
	O 30	85.2
	O 39A	88.5
	O 55	89.9
	O 56	88.3
	O 64	80.3
	C 140	88.3
Control clones*	RRII 105	65.9
	RRIM 600	55.4
	GT 1	80.5

*Mean of three trials

Nine clones in trial 1991 A, *viz.*, RRII 6, RRII 203, RRII 300, PB 217, PB 235, PB 260, PB 310, PB 311 and RRIC 100 were better in growth than the control clones GT 1, RRII 105 and RRIM 600. In the second trial 1991 B four clones *viz.*, RRII 3, RRII 5, RRII 118 and Nab 17 recorded better girth than control clones, while in the third trial 1991 C clones HP 83/224, HP 83/225, HP 83/236 and PB 28/59 were better in girth than control clones. The control clone GT 1 recorded an average girth of 64 cm for all the experiments. Initial yield data revealed that four clones *viz.*, PB 235, PB 280, PB 312 and PB 314 in the trial 1991A, two clones RRII 5 and Nab 17 in trial 1991 B and two clones in trial 1991 C, HP 83/224 and HP 83/225 were found to be yielding higher than the control clones.

In the 1989 experiment, clone RRII 203 recorded better growth (88.78 cm), while Haiken 1 recorded poor growth (57.50 cm). Among the different clones, clone RRII 203 showed better yield (g/t/t) performance (62.49) followed by KRS 25 (53.11) in the fourth year of tapping. Clone SCATC 93/114 was the lowest yielder (14.57). In the 1990 experiment, clone PB 235 recorded the highest average girth (77.64 cm), while, the clone Tjir 1 showed poor growth (60.31 cm). The plants are in the second year of tapping. Yield (g/t/t) was highest for clone PB 260 (62.49) followed by PB 235 (56.54). In the trial initiated in 2000, RRII 414 recorded the highest girth, followed by RRII 430 and RRII 422 was the least vigorous.

In the trial for estimation of genetic parameters during 2004, PB 235 recorded the highest average annual girth (82.56 cm), while PB 86 showed poor girth (62.13 cm). Among the half-sibs, the progenies of the clone PB 235 recorded better average annual girth (100.29 cm), while the progenies of the clone PB 213 showed poor growth (81.11 cm). In yield (g/t/t) performance PB 235 recorded the highest average yield (65.59) over the rest of the parents, followed by RRII 203 (47.92). The performance of the clone Tjir 1 (20.77)

was poor. Progenies of clone RRII 203 recorded the highest average yield (44.79) and that of clone Tjir 1 was very poor (21.92) Among the clones, PB 235 recorded the highest average yield (65.59) over the rest of the parents, followed by RRII 203 (47.92).

2. Crop protection

Corynespora leaf fall (CLF) disease survey was carried out in major rubber growing regions of Karnataka and North Malabar region of Kerala. Eight locations in Karnataka and six locations in the North Malabar regions were assessed for disease during the peak disease season.

Table Kar. 2. **Incidence and severity of CLF disease in different locations**

Location	No. of fields visited	No. of fields infected	Percentage infection	PDI
Thirthahalli	6	1	16.7	3.0
Sagar	5	1	20.0	4.0
Kundapur	6	5	83.3	36.8
Belthangady	8	7	87.0	39.4
Puttur	10	10	100.0	29.0
Sullia	6	6	100.0	37.3
Madikeri	8	7	87.5	26.3
Subramanya	10	10	100.0	37.4
Kasaragod	9	8	88.9	33.8
Kanhangad	9	9	100.0	38.0
Nileshwar	6	5	83.3	28.8
Taliparamba	9	8	88.8	29.3
Sreekantapuram	6	5	83.3	22.0
Thalassery	7	6	85.7	24.3

Results of the CLF disease survey during 2005 (Table Kar. 2) indicated that the disease incidence widened year after year and is spreading towards traditional rubber growing regions of Kerala. A diseases intensity of > 30 per cent was recorded in Kundapura, Belthangady, Sullia, Kasaragod and Kanhangad. Thirthahalli and Sagar regions recorded very low disease intensity. Clone RRII 105 had very high disease intensity. The disease intensity was also more in the plantations surrounded by forest and swampy areas.

Field trials were carried out to evaluate new-generation water-based fungicides in CLF disease management. Fungicides such as SAAF, Bavistin, Contaf + Captan, Scor and Dithane M 45 were tested in immature rubber plantation. Results revealed that the SAAF @ 2 g/l was found to be more effective in CLF disease management in immature rubber as compared to the currently recommended fungicides like macozeb and carbendazim (Table Kar. 3).

Table Kar. 3. **Effect of new-generation water based fungicides in CLF disease management**

Treatment	Dosage	Final per cent disease intensity 2002	2003	2004
SAAF (Mancozeb+ carbendazim)	2 g/l	11.4	10.7	11.8
Bavistin (Carbendazim)	1 g/l	14.6	12.4	12.3
Contaf+Captan (Hexaconazol+Captan)	2 g/l	27.1	29.7	32.0
Score (Difenconazole)	0.4 ml/l	22.2	25.3	27.1
Indofil M-45 (Mancozeb)	2.55 g/l	15.8	13.4	14.6
Control	Unsprayed	41.4	38.6	43.3
LSD (0.050)		3.6	30.4	3.5

Experiments were carried out to evaluate the efficacy of Hexaconazole 2% dust formulations in different time duration for the control of *Corynespora* leaf fall disease. Hexaconazole 2% dust with four rounds, three rounds and two rounds of dusting were carried out in mature plantation. Hexaconazole 2% dust with four rounds dusting was found to be more effective. However, three rounds of dusting was also effective to control the disease.

A survey on CLF disease tolerance of pipeline clones was carried out at HBSS, farm, Nettana. Among the 10 pipeline clones

RRII 427 recorded comparatively higher disease intensity and the remaining ones recorded low disease intensity. Screening of *Hevea* clones for powdery mildew disease at Regional Research Station, Mudigere, UAS, Bangalore, indicated less disease intensity in RRII 118, GT 1 and Tjir 1 and maximum disease in PB 235 and RRIM 501. Remaining clones recorded the moderate disease intensity. An eexperiment was initiated to study the epidemiology of CLF disease in rubber plantation. Burkard spore sampler was installed and the sampling procedure was standardized.

3. Exploitation systems

Variation in performance of different clones under different tapping systems was observed in the 1987 experiment. All the clones, except PB 235 and PB 311 recorded higher yield under 1/2 S d/4 system with stimulation. Clone PB 235 and PB 311 recorded higher yield under 1/2 S d/3 system. In the 1988 experiment, RRII 118 performed better in all the tapping systems. Among the five clones, the response to stimulation was notable for RRII 118 and PR 261.

4. CFC–Funded project

The experiment on effect of different fertilizer levels on the severity of CLF disease was carried out in immature rubber plantation owned by Karnataka Forest Development Corporation, Subramanya Division, Karnataka, recognized as hot spot area of Corynespora leaf fall disease. Seven different levels of fertilizers was imposed in four replication and preliminary work on pre-treatment soils samples nutrient analysis were done.

HEVEA BREEDING SUB-STATION, PARALIAR, TAMIL NADU

Breeding and selection, clone evaluation, studies on plant propagation techniques and maintenance of polyclonal seed garden were the important research activities pursued during 2004-05.

1. Crop improvement

The breeding orchard consisting of 51 parental clones was well maintained in an area of 5 ha of land. With a view to evolve genetically improved latex timber clones and clones with high yield and tolerance to Oidium, hand pollination was continued at different parental combinations. The hybrid seeds were germinated and established in a nursery. The hybrids obtained on hand pollination carried out during 2003-04 were test tapped for evaluation and preliminary selection.

In the large-scale clone trial (1994), PB 314 continued to present the maximum yield g/t/t (68.23) followed by IRCA 109 (62.67). The clones IRCA 111 (59.00) and PB 255 (58.35) also gave significantly better yield than RRII 105 (36.92) (Table Par. 1).

Table Par. 1. **Performance of clones in the large scale trial (1994)**

Clone	Mean girth (cm)	Mean yield (g/t/t)
RRII 105	63.23	36.92
RRIM 703	69.84	48.74
PB 255	72.72	58.35
PB 314	68.69	68.23
PB 330	67.85	35.72
PB 28/59	60.64	47.70
IRCA 18	66.31	44.69
IRCA 109	68.63	62.67
IRCA 111	73.39	59.00
IRCA 130	63.16	53.74
IRCA 230	72.36	35.01
GM	67.84	50.09
CD (P=0.05)	3.08	6.57

In the block trial consisting of 13 modern popular clones PB 311 (54.45 g/t/t) was found to present the best initial yield trend closely followed by PB 235 (53.01 g/t/t). The control clone RRII 105 has given a mean dry rubber yield of 43.75 g/t/t. The initial yield trend in the trial on evaluation of clonal composites has indicated that the mixed planting of PR 261 (15 per cent), PB 235 (35 per cent) and RRII 105 (50 per cent) has presented yield (52.78 g/t/t) comparable to the control plot of RRII 105 alone (51.51 g/t/t).

In the multilocational clone trial on G x E interaction of *Hevea* clones. RRII 203 exhibited significant yield (g/t/t) difference (57.29) compared to RRII 105 (44.98) in the second year of tapping. The clones RRII 414 (45.99) and RRII 430 (48.41) also showed numerically better yield than RRII 105. Relatively high incidence of TPD (9 out of 36) was observed in RRII 51 in the second year of tapping.

In the observational trial for on farm evaluation of 400 series clone initiated at Vaikundam Estate, all the hybrid clones showed better vigour than RRII 105 till the fourth year of planting (Table Par. 2). The clone RRII 414 (40.82 cm) registered 12.35 per cent higher growth than the control clone RRII 105 (36.33 cm), closely followed by RRII 429 (39.31 cm). In the block trial initiated at New Ambady Estate (2002) also, RRII 414 (16.30 cm) has exhibited 9.4 per cent better initial growth compared to RRII 105 (14.9 cm) in the third year of planting. At Velimalai Estate, RRII 429 (18.9 cm) was found to grow more vigorously than the control clone PB 260 (17.20 cm).

Table Par. 2. **Growth performance of clones at Vaikundam Estate**

Clone	Girth (cm)	GI (%) over RRII 105
RRII 105	37.48	-
RRII 414	42.49	13.4
RRII 417	39.29	4.8
RRII 422	40.78	8.8
RRII 427	40.26	7.4
RRII 429	41.32	10.2
RRII 430	40.27	7.4
GM	40.27	
SE	2.74	

1.1. Root trainer planting technique for *Heavea*

The root trainer plants transplanted at Churulacode (2001), Velimalai (2002) and Thirunanthikarai (2002) were closely observed and growth parameters were recorded regularly. The better initial growth of root trainer plants (up to 14%) was attributed to proper growth and orientation of root system inside the root trainers. One block trial of root trainer and polybag plants was initiated at Vengachery near Ottapalam during the current year. Planting materials were also raised for initiating another field trial of root trainer plants of hybrid clones belonging to 400 series at Kanjirappally during 2005.

1.2. Polyclonal seed garden

The polyclonal seed garden consisting of nine modern high yielding clones as parents was well maintained in an area of 9 ha of compact block at New Ambady Estate. The initial fruit set and flowering pattern of the parental clones was closely observed.

The bud wood nursery was expanded by including five clones belonging to 400 series and the bud wood points of RRII 105 was further expanded. A seedling nursery was raised to generate planting materials for initiating one block trial each of the 400 series clones at Bethany Estate and Palazhi Estate during the year 2006.

Agrometeorological observations were recorded regularly and the data was provided to RRII, Kottayam and the Statistical Department, Government of Tamil Nadu.

LIBRARY AND DOCUMENTATION CENTRE

During the year, 163 books were added to the stock of the library. The library subscribed to 148 journals of which 61 are foreign. About 55 other journals were also received as gift/exchange. Literature searches from CDs of AGRIS, HORTCD and RAPRA etc were carried out.

Four issues of Documentation List, six issues of Rubber Alerts, one issue of New Additions List and 107 numbers of SDI bulletins were compiled and distributed to officials of RRII and Rubber Board. Photocopies of 22 articles were procured from other institutions/libraries and 13 articles were sent to other institution/individuals upon request during this period.

The *Indian Journal of Natural Rubber Research* is published under the title *Natural Rubber Research* since Vol. 17 (2004) and the first issue of *Natural Rubber Research* was published and its distribution arranged.

The centre was also engaged in the sales promotion of RRII publications. Arranged the sale of 24 copies of the book *"Natural Rubber: Agromanagement and Crop processing"*, 4 copies of the book *"Rubber wood: Processing and Utilization"* and 8 copies of the book *"Plant and Soil Analysis"* during this reporting year.

AGROMETEOROLOGY

1. Rainfall climatology of rubber growing areas

From daily rainfall charts of self-recording raingauge, hourly rainfall of each month and peak intensity have been worked out for the year 2004. Results showed that summer rains were maximum during 18 to 24 hours. Southwest monsoon rains were more during 24 to 6 hours and Northeast monsoon during12 to 18 hours. A total 75 hours of rain and 52 hours of trace was recorded during 6 to 12 hours followed by 104 hours of rain and 74 hours of trace during 24 to 6 hours.

Occurrence of high intensity rains was maximum during July (11) followed by May (9) and October (8). The intensity per hour was observed to be high during NE monsoon followed by summer. However, the highest per hour intensity of 120 mm/hr was observed at 15 to 16 hours during September.

2. Climatic influences on diseases

Intense leafall due to Oidium incidence for the clones RRIM 600 and RRII 105 were studied for four years in Agartala, Nagrakata and Guwahati. In the agroclimatic situations of Agartala and Nagrakata, both the clones showed strong correlation with daily weather parameters at a lag of 6 to 8 days. The mean values obtained for Agartala (Nagrakata) were: (a) maximum temperature of 24.5 ± 3.3 (25.6 ± 4.3) ^{0}C, (b) minimum temperature of 12.1 ± 3.3 (13.2 ± 4.3) ^{0}C, (c) Morning relative humidity of 92 ± 6 (91 ± 6) %, (d) afternoon relative humidity of 57 ± 17 (57 ± 2) %, (e) bright sunshine hours of 5. 8 ± 3 (6.1 ± 3) and (f) evaporative demand of 1.5 ± 0.8 (1.7 ± 0.9) ^{0}C. For RRII 105 very distinct features were found with atmospheric parameters and leafall compared to RRIM 600. Leafall occurrence had mixed responses in Agartala during the wintering period, due to partial reflushing and leafall associated with Oidium attacks. The correlation values of weather parameters were comparatively less in winter compared to the general occurrence period of March-April because of wintering, which is part of phe-

nology of the crop. The highest correlation was shown for the difference in relative humidity from the previous day afternoon to the present day morning of the leafall in both the places showing clearly the slope of the gradient with time which can definitely influence the onset of Oidium. Wintering is generally delayed in Nagrakata compared to the other places in the northeast, closely following the period of low temperature. Here again, maximum correlation of leafall was found with the atmospheric conditions 8 days prior to the occurrence of leafall. In Guwahati strong incidences were noted for the year 2005. But the low data duration gives little inference based on the effect of the atmospheric conditions.

In order to formulate location specific prediction model for powdery mildew disease, intensity of disease was recorded periodically at selected sites in the traditional region. Compared to 2004, disease intensity was higher during 2005 for both the clones at all locations investigated. During the disease period morning RH was more than 90% and afternoon RH was more than 60% which might be factors predisposing disease incidence.

3. Agroclimate in the NE region

Weekly analysis of rainfall data was carried out for 10 rubber growing stations in the northeast to determine the probability (chances of occurrence) of wet and dry spells at different periods of the season.

Probability of rainfall exceeding a certain amount was computed using Gringorten's formula. Periods of dry spells were the highest for Tura in Meghalaya during the winter and post-monsoon season, followed by Kolasib. Most stations experienced up to 50 per cent probability for the occurrence of dry spells of two weeks duration during the post-monsoon season. The probability of experiencing dry spells of above 5 weeks was more than 10 per cent for Lumding, Tura, Kolasib and Agartala. Generally consistencies are uniformly seen for all stations over the hot seasons. About 90 per cent probability is seen for two consecutive rainfall weeks during the monsoon season. Percentage occurrences of wet spells were higher for North Lakhimpur and Amguri during the winter season. High values for consecutive wet spells were noted in the case of Silchar, Amguri and Kolasib during the monsoon season.

Table Agromet. 1. Agrometeorological data from different research stations

Month & Location	Temperature (°C)		Relative humidity (%)	Wind speed (km/h)	Sunshine (h)	Rainfall (mm)	Evaporation (mm)
	Minimum	Maximum					
KOTTAYAM, KERALA							
January	33.8	21.8	66	2.2	9.1	19.1	4.9
February	34.6	22.6	64	2.4	9.4	0.0	4.7
March	35.5	23.9	69	2.7	8.7	35.6	4.6
April	34.3	23.2	75	2.3	8.1	180.9	4.9
May	30.3	22.6	86	1.7	4.5	739.3	2.6
June	30.0	22.3	86	2.0	4.1	461.4	2.7
July	29.1	22.1	88	1.8	3.2	347.4	2.5
August	29.9	21.9	83	2.4	4.8	393.0	2.9
September	30.6	22.0	83	1.6	5.0	213.2	3.1
October	31.6	21.8	82	1.6	5.9	474.4	2.7
November	32.0	21.5	77	1.3	5.5	132.5	2.9
December	33.2	20.1	65	1.7	7.5	0.0	4.1

Month & Location	Temperature (°C)		Relative humidity (%)	Wind speed (km/h)	Sunshine (h)	Rainfall (mm)	Evaporation (mm)
	Minimum	Maximum					
CES, CHETHACKAL, KERALA							
January	35.5	19.4	62	3.1	9.8	13.6	5.7
February	35.3	19.4	61	2.4	9.5	55.3	5.6
March	36.1	21.5	67	2.4	7.4	154.4	5.7
April	33.9	22.1	74	1.7	6.1	367.0	4.2
May	30.5	21.5	82	1.4	3.5	685.3	2.9
June	29.7	22.0	83	1.8	3.0	477.0	3.2
July	29.0	22.4	84	1.7	1.6	364.0	2.6
August	29.5	22.4	80	2.7	3.9	294.9	3.6
September	31.0	22.3	83	1.5	3.5	289.3	3.3
October	31.7	22.4	79	1.4	5.1	366.6	3.5
November	32.4	21.5	73	1.2	3.5	70.2	5.7
December	33.8	20.0	60	2.1	7.8	0.3	4.8
PADIYOOR, KERALA							
January	34.4	18.8	71	2.7	8.8	0.0	4.4
February	35.9	20.1	72	3.0	9.2	0.0	5.2
March	36.9	22.6	75	3.4	8.5	23.8	5.7
April	35.6	23.5	79	3.1	7.8	124	4.9
May	31.2	23.0	89	1.6	3.1	730.8	2.3
June	29.6	22.1	93	2.5	2.6	1140.4	1.8
July	29.1	22.0	88	1.5	2.2	836.7	1.7
August	29.3	21.8	86	3.2	4.2	768.6	2.4
September	31.2	22.0	82	2.1	4.5	323.2	2.5
October	32.3	21.6	85	1.8	6.2	263.1	2.7
November	33.5	20.8	85	1.5	6.6	182.2	2.9
December	34.1	17.9	80	1.9	8.8	0.0	3.3
PARALIYAR, TAMIL NADU							
January	34.3	20.6	68	-	8.2	2.8	5.0
February	35.8	20.1	67	-	8.3	2.2	5.6
March	36.9	22.6	75	-	6.5	75.8	5.5
April	35.8	24.4	77	-	6.2	107.3	4.5
May	31.8	24.1	84	-	5.2	405	3.2
June	31.3	23.9	84	-	4.8	233.5	2.9
July	31.0	24.3	85	-	3.3	104.9	2.5
August	32.4	23.7	79	-	6.4	77.8	3.6
September	32.0	23.1	85	-	5.2	203.9	2.6
October	31.3	23.2	85	-	4.5	265.3	2.8
November	31.2	22.9	84	-	5.1	187.2	2.7
December	32.8	21.2	79	-	6.2	14.5	4.2
NETTANA, KARNATAKA							
January	34.7	15.7	70	1.9	8.2	0.0	4.0
February	36.4	17.2	67	1.7	8.6	0.0	4.9
March	37.2	20.7	62	1.9	8.1	13.4	5.3
April	34.0	22.2	71	1.6	7.8	136.5	4.7
May	31.0	21.7	84	1.3	3.6	473.5	2.5
June	29.3	21.2	87	2.0	3.0	736.7	2.4
July	28.3	21.0	87	1.7	1.7	1055.8	1.9
August	28.0	20.7	88	2.3	2.6	937.9	2.0
September	30.8	20.8	81	1.6	4.7	171.2	2.8
October	32.5	20.3	76	2.7	6.2	334.4	2.9
November	34.0	18.4	66	4.0	7.0	120.4	3.0
December	34.5	14.1	62	2.3	8.1	0.0	3.5

Month & Location	Temperature (°C)		Relative humidity (%)	Wind speed (km/h)	Sunshine (h)	Rainfall (mm)	Evaporation (mm)
	Minimum	Maximum					
DAPCHARI, MAHARASHTRA							
January	31.3	13.8	54	1.1	7.6	0.0	3.0
February	34.2	15.0	54	0.5	9.4	0.0	4.3
March	38.8	19.7	47	0.5	8.4	0.0	5.9
April	38.6	23.6	50	0.9	9.1	0.0	5.5
May	37.1	26.0	48	1.0	7.3	39.8	5.9
June	32.7	25.4	54	1.6	3.3	389.4	2.9
July	29.8	23.8	58	0.3	2.2	358.4	1.9
August	28.2	23.4	59	1.3	1.3	1330.1	1.6
September	32.3	23.0	58	0.2	4.6	75.1	2.6
October	33.4	24.4	71	0.3	7.2	33.0	1.5
November	34.7	17.5	50	0.4	7.5	0.0	3.3
December	32.6	13.9	48	0.2	7.0	0.0	3.4
RRS, AGARTALA, TRIPURA							
January	23.7	11.5	77	1.3	5.8	6.8	1.3
February	28.4	13.2	67	1.9	7.9	0.0	2.5
March	32.8	20.6	68	4.6	7.4	0.8	3.2
April	31.4	22.2	76	4.5	6.3	299	2.1
May	34.2	25.0	78	3.2	6.4	123.5	2.9
June	31.8	24.7	84	2.9	3.3	447.4	2.4
July	31.1	24.8	87	3.6	3.7	579.6	1.5
August	32.8	25.5	83	3.1	6.5	179.0	2.3
September	30.7	24.6	86	2.0	3.0	325.0	1.6
October	31.0	21.7	81	1.6	6.8	151.9	2.0
November	29.4	15.5	74	0.6	7.9	0.0	1.7
December	27.6	13.1	76	0.8	7.0	0.0	1.5
RRS, GUWAHATI, ASSAM							
January	23.9	11.4	70	2.3	5.8	33.2	1.2
February	26.9	12.4	76	4.2	7.9	3.6	2.2
March	31.7	17.6	71	3.1	6.6	30.8	2.3
April	27.9	19.4	83	2.4	3.9	328.0	0.4
May	32.3	22.4	79	2.1	5.5	110.6	1.4
une	32.0	24.4	85	1.1	3.5	264.8	1.9
July	31.4	24.6	88	1.3	2.8	283.0	1.2
August	33.8	25.0	83	1.7	5.6	206.0	1.2
September	32.6	24.2	86	1.2	3.8	60.0	1.2
October	30.3	20.7	86	1.9	6.1	227.0	1.6
November	29.0	15.8	75	2.2	7.7	0.0	1.6
December	25.8	12.8	70	2.5	5.8	4.0	1.2
RRS, TURA, MEGHALAYA							
January	23.9	7.8	70	0.6	6.4	0.0	1.9
ebruary	26.9	9.1	63	1.5	7.3	0.0	2.9
March	31.9	12.6	63	2.2	7.3	50.0	3.7
April	32.0	13.3	77	0.7	4.9	293.1	3.1
May	31.7	19.7	75	0.9	6.8	443.5	3.8
June	31.6	21.6	86	0.4	1.9	114.0	3.0
July	30.9	21.9	89	0.5	1.6	1112.0	3.0
August	31.3	22.3	84	0.0	5.0	218.0	3.3
September	30.0	21.0	88	0.0	2.6	235.5	2.6
October	29.6	17.1	80	0.9	5.7	788.0	2.5
November	29.0	13.0	75	1.3	7.2	0.0	2.8
December	26.8	9.7	71	1.3	6.4	10.0	1.8

Month & Location	Temperature (°C) Minimum	Maximum	Relative humidity (%)	Wind speed (km/h)	Sunshine (h)	Rainfall (mm)	Evaporation (mm)
RES, NAGRAKATA, WEST BENGAL							
January	24.0	8.6	81	1.3	5.9	34.2	1.5
February	26.9	9.7	75	1.3	7.1	15.2	2.2
March	30.5	17.0	85	1.6	5.5	39.5	2.6
April	30.1	19.3	85	2.1	4.9	115.2	3.1
May	32.0	21.7	83	2.0	5.1	636.6	3.2
June	31.9	23.6	86	1.9	4.3	919.6	2.9
July	30.8	23.8	90	1.1	3.2	1159	1.8
August	32.8	24.4	88	0.8	4.6	756.6	2.3
September	31.3	23.5	91	0.3	3.4	422.9	2.2
October	30.7	18.4	84	0.2	7.0	87.2	2.1
November	28.8	12.4	80	0.2	7.8	8.3	1.7
December	26.0	9.9	79	0.3	5.9	26.3	1.3
RRS, DHENKANAL, ORISSA							
January	26.9	13.3	20	1.4	7.7	0.0	2.1
February	30.0	15.2	21	2.0	8.9	17.3	2.9
March	36.9	20.1	23	2.6	8.4	0.0	4.2
April	39.3	24.3	20	3.3	8.3	38.5	4.6
May	40.1	26.2	19	4.5	8.6	77.2	6.2
une	36.7	26.5	20	3.2	6.2	87.2	4.4
July	32.7	24.5	22	2.1	3.5	210.4	2.1
August	31.0	25.3	16	1.2	2.6	52.5	2.0
September	32.3	24.8	79	1.6	5.2	126.2	1.9
October	31.3	21.2	82	1.7	7.4	121.6	1.8
November	30.4	15.4	69	0.9	7.5	0.0	2.9
December	28.3	16.3	67	1.0	7.5	0.0	3.1

ANNUAL EXPENDITURE

Expenditure at a glance (2004-05)

Head of Account	Expenditure (Rs. in lakhs)
Non-plan	
General charges	290.89
Projects (CES)	175.31
Total	466.20
Plan	
General charges	855.79
NERDS Research Component	170.18
Total	**1025.97**
Grand Total	**1492.17**

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K.K. Kunjachan	Assistant Farm Superintendent

K.J. Joseph	Assistant Farm Superintendent
P.V. Suresh Babu	Assistant Security Officer
Regional Research Station, Padiyoor, Kerala	
Radha Lakshmanan, M.Sc.(Ag.), Ph.D.	Agronomist
Regional Research Station, Guwahati, Assam	
D. Chaudhuri, M.Sc.(Ag.)	Deputy Director
G.C. Mondal, M.Sc., Ph.D.	Plant Pathologist
M. Choudhury, M.Sc.(Ag.)	Scientist S3
A.K. Hazarika, M.Com., ICWA (Int)	Accounts Officer
Regional Research Station, Agartala, Tripura	
Sushil Kumar Dey, M.Sc., Ph.D.	Deputy Director
P. M. Priyadarshan, M.Sc., Ph.D.	Plant Breeder
Shammi Raj, M.Sc., Ph.D	Agrometeorologist
Krishna Das, M.Sc., Ph.D.	Scientist S3
Debasis Mandal, M.Sc.	Scientist S3
Joy Joseph, M.Sc.	Assistant Rubber Processing Technologist
Debabrata Ray, M.Sc.(Ag.)	Junior Scientist
Jiban Chakraborty, B.Com.	Assistant Director (Finance)
Amal Chandra Sarma	Senior Scientific Assistant
Tapan Kumar Pal, M.Sc.	Senior Scientific Assistant
Haradhan Bhowmik	Assistant Farm Superintendent
T.R. Divakaran, B.A.	Assistant Estate Superintendent
T. Sreekumaran Nair	Section Officer
Regional Research Station, Tura, Meghalaya	
A.P. Thapliyal, M.Sc., Ph.D.	Deputy Director
H.K. Deka, M.Sc., Ph.D.	Scientist S3
Bal Krishna, M.Sc., Ph.D.	Scientist (Germplasm Evaluation) (upto 11.03.2005)
R.P. Singh, M.Sc.(Ag.), Ph.D.	Scientist S3
M.J. Reju, M.Sc.	Scientist S2
Regional Experiment Station, Nagrakatta, West Bengal	
Gitali Das, M.Sc., Ph.D.	Plant Physiologist
R.S. Singh, M.Sc. (Ag) Ph.D.	Junior Scientist
K.G. Vijayan	Assistant Farm Superintendent
Regional Research Station, Dapchari, Maharashtra	
Meena Singh, M.Sc.(Ag. Bot.), Ph.D.	Plant Physiologist
Gawai Prakash Pandharinath, M.Sc.(Ag.)	Scientist S2
P.N. Devarajan, B.Sc.	Section Officer
P.A. Joykutty, B.A.	Assistant Farm Superintendent
Regional Research Station, Dhenkanal, Orissa	
Chandra Gupta, M.Sc.(Ag., Bot.), Ph.D.	Agronomist
P.G. Purushothama Das	Section Officer
T.V. Thomas	Assistant Farm Superintendent
Hevea Breeding Sub-station, Nettana, Karnataka	
K.K. Vinod, M.Sc.(Ag.)	Plant Breeder (on study leave)
M.J. Manju, M.Sc (Ag.)	Scientist S2
M. Suryakumar, M.Sc (Ag.)	Scientist S2
V.J. George	Assistant Estate Superintendent
Hevea Breeding Sub-station, Paraliar, Tamil Nadu	
T.A. Soman, M.Sc., M.Phil., Ph.D.	Scientist S3
V.T. Chacko	Assistant Farm Superintendent
Regional Soil Testing Laboratory, Adoor, Kerala	
Thomas Eappen, M.Sc., B.Ed.	Scientist S2
K.C. Jayasree, B.Sc.	Senior Scientific Assistant
Regional Soil Testing Laboratory, Muvattupuzha, Kerala	
C.P. Mary, M.Sc.	Assistant Technical Officer
Regional Soil Testing Laboratory, Calicut, Kerala	
Joyce Cyriac, M.Sc.	Scientist S2
P.K. Madhusooddhanan, B.Sc.	Senior Scientific Assistant
Regional Soil Testing Laboratory, Nedumangad, Kerala	
S. Sheela, B.Sc.	Senior Scientific Assistant

RESEARCH ESTABLISHMENTS

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REGIONAL RESEARCH STATIONS

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Hevea Breeding Sub-station
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Phone : 91 4652 289119

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Regional Research Station
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Tura - 794 001, Meghalaya.
Phone : 91 3651 32413

REGIONAL SOIL TESTING LABORATORIES

Regional Soil Testing Laboratory
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Regional Soil Testing Laboratory
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Kerala.
Phone : 91 472 803270

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Research divisions and functions

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

The thrust areas of research of Agronomy and 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 Mycology and Plant Pathology Division is engaged in investigations on the diseases and pests of rubber and associated cover crops and their control. The Plant Physiology 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 Agricultural Economics Division undertakes studies on economic aspects related to rubber plantations.

The research supporting sections include Library and Documentation, Instrumentation, Statistics, Computer and Art/Photography. There is also a small experimental farm of 33 ha at the headquarters of 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), Nagrakatta (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).

Correspondence

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