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Rubber Research Institute of India

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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

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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

Crop improvement research undertaken in the Rubber Research Institute of India (RRII) was instrumental in bringing the country to the forefront of major natural rubber (NR) producing countries. The release of the high yielding clone RRII 105 during 1980 was a significant breakthrough. Most of the clones found in the rubber plantations of the country were introduced by RRII through breeding, selection and/or evaluation. Moving with time, RRII has evolved the high yielding RRII 400 series clones and the five top ranking selections viz., RRII 414, RRII 417, RRII 422, RRII 429 and RRII 430 were included in category III of the planting material recommendations of the Rubber Board in 2001. All the clones except RRII 429 were upgraded to category II of the planting recommendations during the year under report. Evaluation of more clones in the pipeline has also made significant progress.

Field conservation of wild *Hevea* accessions was continued. Evaluation of wild germplasm for the identification of accessions having tolerance to drought and cold as well as screening them for tolerance to Phytophthora, Oidium and Corynespora were in progress. RAPD profiles of selected wild accessions showed high degree of polymorphism.

Transgenic plants integrated with superoxide dismutase gene were multiplied by bud grafting. Experiments were continued to refine the methods for somatic embryogenesis and regeneration of healthy plantlets using immature inflorescence and anther explants of clone RRII 105. The role of recombinant b-1,3- glucanase enzyme in controlling *Phytophthora meadii* was confirmed through *in vitro* studies. The differentially expressed genes of healthy and tapping panel dryness affected trees were identified through suppression subtractive hybridization analyses. The rubber biosynthesis genes such as farnesyl diphosphate synthase, 3-hydroxy-3methylglutaryl Coenzyme A reductase-1 and rubber elongation factor were cloned.

Efforts to develop improved agromanagement techniques for rubber were continued. The major research areas were nutrient management, soil and water conservation, intercropping and cropping system experiments, nutritional requirement of high yielding clones, zinc nutrition, sequential skipping of fertilizers and phosphorus nutrition. Availability of P and Ca in the soil had shown significant improvement by liming. Conservation pits positively contributed to the growth of rubber and in conserving soils. Experiments to study the effect of the density of planting on growth and yield of rubber were also in progress. Fertilizer recommendations on the basis of soil and leaf analysis were provided to both large estates and smallholdings. In Dapchari, basin irrigation system resulted in higher girth compared to drip system. Experiments at RRS, Nagrakatta on intercropping of rubber with tea showed enhanced growth for both tea and rubber in the third and fourth years of planting respectively.

Evaluation of crop loss due to abnormal leaf fall over a period of fourteen years showed large scale crop loss in the clone RRIM 600 (31.60%). The dosage of both copper oxychloride and Bordeaux mixture could be reduced when rubber seed oil was used as an additive in the spray fluid. Modifications in micron sprayer for improving its efficiency by raising the height of fungicide discharge were successful. Addition of vegetable oils to Bordeaux paste improved its efficacy and gave better recovery from pink disease. Arrowroot extract was observed to give control of termites for a limited period. Honey production from rubber during the year was three times higher than that of last year due to favourable weather conditions during the refoliation period. Among the new clones, RRII 417 and 430 were observed to show low susceptibility to abnormal leaf fall disease. *Oidium* and *Phytophthora* tolerant clones have been short-listed from the rubber germplasm. In the survey on diseases of *Hevea* in the North East India, 10 clones showed higher degree of tolerance to powdery mildew disease. Survey on *Corynespora* leaf fall disease carried out in Karnataka and North Malabar region indicated that even though RRII 105 is severely affected by the disease, the level of incidence has not reached alarming levels as a result of the interventions through disease control campaign.

Investigations on developing a technique for early prediction of high yield using ATP concentration in latex progressed well. Experiments were initiated for the in vitro assessment of *Hevea* germplasm accession for their intrinsic drought tolerance potential. Wound induced production of ethylene and free radicals were high in low yielding clones and low in high yielding clones. The clones HP 53 and HP 92 were found relatively tolerant to oxidative stress and the Dapchari selection DAP 34 was found relatively drought tolerant. The energy status as revealed from the total latex ATP content in d/3 system of tapping was found better than that in d/2 system. In the field of exploitation technology, research on low frequency tapping, reduced spiral cuts, crop loss due to rain, panel change, low frequency CUT etc were in progress.

In the rubber processing area, development of an easy method to cream and coagulate skim latex, application of formalin treatment of field coagulum for improving the quality of TSR and development of NR based nanocomposites using intercalated clays were the significant contributions. The concept of ENR as silica reinforcement modifier was further utilised in carbon/ silica mixed filler reinforced NR and SBR vulcanizates. The use of small quantities of PP and HDPE for improving the gum vulcanizate properties of NR yielded promising results. The other areas of work included use of NR-g-PMMA copolymers as compatibiliser for NR/PVC blends, deproteinisation of NR latex using papain and raw rubber properties of the pipeline clones. Advanced anaerobic technology for treating wastewater from rubber processing were designed and tested. Rubber sheet processing effluent in combination with cow dung gave maximum gas production.

The project on the techno-economic feasibility of latex-timber clones explored the various strategies for promoting such concepts in India. The trends in adoption of low frequency tapping system showed a growing convergence in the shift towards the system during the 2000s in the estate sector. Exploration of the possibility of enhancing the ancillary income of farmers through sustainable apiary in rubber plantations underscored its vast unexploited commercial potential. Studies on NR global trade and tariff policy in the post reforms phase highlighted the need for drawing appropriate guidelines for maximising the share of NR producing countries in the net value added. Market uncertainties were characterised in the domestic market by the exit of a large number of dealers as well as downgrading of farmer produce and in the labour market through a 60 per cent reduction in demand for labourers.

The Institute hosted the *IRRDB International Workshop on Exploitation Technology* to take stock of the latest trends in the field of exploitation of *Hevea*. A total of 21 technical papers were presented in the Workshop of which 11 were from RRII. There were 45 delegates of whom 15 were representatives of nine IRRDB member countries. Recommendations of the Workshop include steps towards transfer of the latest technologies to smallholders, exchange of the know-how of various new methods among member countries and seeking international funding for multi-country projects.

Towards the dissemination of scientific information on NR, a combined volume of two issues of the *Indian Journal of Natural Rubber Research* was brought out. RRII published over 100 scientific articles in addition to participation and presentation of papers in conferences. The library continued to serve the NR industry for its information needs.

AGRONOMY/SOILS DIVISION

The Division carries out research on agromanagement practices and development of new technologies for profitable cultivation of natural rubber. The major research areas are nutrient management, soil and water conservation, intercropping and cropping system, nutritional requirement of high yielding clones, zinc nutrition, sequential skipping of fertilizers and phosphorus nutrition studies. Detailed studies on organic P status, soil organic matter, quantification and assessment of N fixation etc. were also taken up during the reporting year. Studies on rhizosphere biochemistry were initiated to understand the adaptive mechanisms at the rhizosphere for uptake of phosphorus and micro nutrients. Development of rubber information system for the traditional rubber growing zone and disease prediction through remote sensing and GIS were initiated. Experiments on immature and mature rubber were initiated for modifications in field lay outs.

Fertilizer recommendations on the basis of soil and leaf sample analysis were provided both to large estates and smallholdings.

1. Nutrient management

1.1. Nutritional studies

A nursery experiment was conducted to study the effect of sulphur addition on release of phosphorus from rock phosphate and its effect on growth of rubber seedlings was observed after six months of imposing the treatments. No significant differences were observed in the diameter of seedlings. The nursery experiment to evaluate the fertilizer value of sludge indicated that in the plots applied with sludge from crumb rubber factory, organic carbon and available Ca improved. A pot culture experiment was initiated to study N uptake pattern and N use efficiency by rubber seedlings.

The experiment to study the effect of advance applications of the fertilizer during the initial one to three years period in the planting pits, initiated in 2000 is being continued. Among the treatments, single application of pit manure with three year dose in planting pits gave significantly higher girth and was comparable to standard practice.

The results from field experiment in mature rubber, initiated in 1989, to study the fertilizer requirement of clone RRII 105 indicated no significant difference between treatments with respect to girth and yield of plants. Experiments to explore the possibilities of substitution of potassium fertilizer with sodium chloride in rubber plantations are in progress. In mature rubber, substitution of K with Na up to 50 per cent showed no difference in girth or dry rubber yield. In the nursery, for 25 and 50 per cent levels of required K application, an increase in K uptake was noted up to 50 per cent Na application. The total Na uptake increased with increasing levels of Na application up to 50 per cent substitution.

Studies on clonal and seasonal variations in the nutrient content of latex in 13 clones were continued.

1.2. Integrated nutrient management

The experiment initiated in 2001 to study the long term effect of inorganic and organic manures on growth and yield of rubber and on the physico-chemical properties of soil was continued. Data on girth and girth

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increment revealed no significant difference between treatments. However, it was observed that 25 % fertilizer + 75 % FYM gave numerically higher girth and consistent girth increment.

Experiment on comparison of soil organic matter under different ecosystems was continued. The concentration of nutrients and polyphenols in fresh and seven month old leaf samples of rubber, *Mucuna bracteata* and *Pueraria phaseoloides* were compared. Carbon, N and Ca were found highest in *Mucuna* litter whereas, P and K content were highest in *Pueraria* litter. After seven months of decay C, K, Mg and polyphenols were decreased in all the three litters. In the case of N and Ca no trend was observed.

Experiments were initiated to assess the quality of N fixed by the cover crops *P. phaseoloides* and *M. bracteata*. A field experiment was initiated to study the effect of cultivation of *P. phaseoloides* and *M. bracteata* on P mobilization.

1.3. Forms and methods of fertilizer application

Experiment to compare the different methods of fertilizer application in mature rubber was continued. Broadcasting in a patch at the center of four trees with and without forking, broadcasting in the narrow band in the inter-row area and pocket application around the plant basin were compared. No significant difference was noticed between treatments on girth increment and yield.

The experiments to study the response of rubber to graded levels of P application were continued. In Mooply Estate, Thrissur, where the soil is rich in P, the effect of P application was not significant on girth and yield. In Malankara Estate, with low P status, there was no significant difference in girth and leaf P content. However, significant increase in soil P availability was noticed by P application @ 30 and 40 kg P_2O_5/ha.

2. Physical and chemical properties of soils

Soil samples from five locations varying in gravel content from 28 to 65 per cent were collected and relative nutrient content of soil was assessed. Organic phosphorus status in ten major soil series in the traditional rubber growing tract was estimated by ignition method. Effectiveness of different liming materials was compared in a nursery experiment. Results indicated that the availability of P and Ca in the soil (0-15 cm) were significantly improved by liming. One year after the application the pH of the soil was reverted back to initial pH. Nutrient concentration in the leaves was not influenced by liming.

The field experiment (2002) to study the effect of pit size on growth and yield of rubber indicated no significant effect of planting pits of various dimensions. The soil survey data generated was being further grouped and analysed statistically to generate more information.

3. Soil and water conservation

The experiment started in 1997 at TR&T Estate, Mundakayam to evaluate the effect of conservation pits on soil and moisture preservation and yield of rubber is being continued. The quantity of soil conserved in the pits increased from 3.13 to 7.75 t/ha when the number of pits was increased from 100 to 250 per ha. The girth increment was significantly higher for 250 pits per ha. Significant difference was not obtained for yield (Table Ag.1)

Table Ag. 1. **Effect of density of silt pits on growth and yield of rubber**

Treatment (No. of pits/ha)	Yield (g/t/t)	Girth increment (cm) 1998-2004	Soil deposited in the pits (t/ha)
0	48.0	8.7	0.0
100	52.0	10.3	3.1
150	54.0	11.7	4.2
200	56.0	11.9	5.1
250	58.0	13.8	7.8
SE	2.8	0.8	0.3
CD (P=0.05)	NS	2.4	0.9

The possibility of applying fertilizer for rubber in silt pits was studied in another field experiment. Significant difference was observed for yield with respect to different treatments (Table Ag. 2).

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

Treatment (No. of pits/ha)	Girth increment (cm) 2001-2004	Yield (g/t/t) (2003 - 2004)
150 (S)	5.1	59.4
150 (P)	4.8	56.6
250(S)	5.3	64.9
250(P)	5.2	66.0
No pit & standard practice	4.8	53.4
No pit & no fertilizer	4.2	50.7
SE	0.49	3.64
CD (P=0.05)	NS	10.71

S: Surface application P: Pit application

The treatments with 250 pits per ha recorded significantly higher yield compared to control plots. No significant difference was noticed for girth increment.

Another field experiment laid out in 2002 to study the long term effect of different soil and water conservation practices on growth and yield of rubber is being continued.

4. Density of planting

Field experiment to study the effect of density of planting with two fertilizer levels (M1 & M2) on growth and yield of rubber was continued. The planting density ranged from 420 trees/ha (4.9 x 4.9 m) to 749 trees/ha (3.7 x 3.7 m) and its effect on growth is given in table Ag. 3.

Table Ag. 3. **Effect of density of planting on girth**

Density (tree/ha)	Mean girth (cm) at 150 cm		
	M_1	M_2	Mean
420	58.2	60.2	59.2
479	55.5	54.8	55.2
549	57.1	53.9	55.5
638	53.5	53.2	53.3
749	33.1	51.7	54.4
Mean	55.5	54.7	

Main plot treatment - SE – 0.98; CD (0.05) = 2.14
Sub plot treatment - SE – 1.21; CD (0.05) = NS

5. Intercropping and cropping system

Two field experiments initiated in 2001 to explore the possibility of including perennial crops like nutmeg, coffee, garcinia and vanilla with rubber in the immature plantation indicated no influence on growth of rubber plants. The possibility of intercropping coffee and cocoa in the later phase of the immature period was studied. Growth of rubber was not significantly affected by the presence of intercrops.

Density of wild jack showed significant effect on growth of rubber (Table Ag.4). Growth of rubber started declining significantly when the density of wild jack increased beyond 20 per cent of rubber. However, girth of wild jack did not vary with its density.

In the experiment on mixed cropping with wild jack, teak and mahogany (started in 2001) the performance of rubber was not significantly influenced by timber tree interplanting (Table Ag. 5).

Table Ag. 4. Effect of wild jack density on growth of rubber

Wild jack density (%)	Rubber girth (cm)	Wild jack girth (cm)
4	41.5[cd]	43.0
8	38.8[e]	41.3
12	40.4[d]	44.8
16	38.1[de]	42.9
20	38.5[e]	42.5
28	34.7[fg]	43.6
36	31.7[ab]	41.1
44	30.3[g]	47.9
48	34.0[ef]	35.9
Mean	36.4	42.6

6. Remote sensing and Geographic Information System (GIS)

Development of rubber information system for the traditional rubber growing zone using remote sensing and GIS was continued. A new project on application of remote sensing techniques to identify the development stages and spread of powdery mildew disease based on the quantitative spectral reflectance using satellite data was taken up.

Table Ag. 5. Girth (cm) and girth increment (%) of rubber during third year

Rubber spacing	Interplants				
	Wild jack	Teak	Mahagony	No interplants	Mean
(22 x 12)	13.5 (4.9)	14.7 (5.0)	14.2 (5.2)	13.8 (5.2)	14.0 (5.1)
(33 x 8)	15.3 (5.6)	14.6 (5.3)	14.8 (5.5)	13.5 (4.8)	14.5 (5.3)
Mean	14.4 (5.2)	14.7 (5.2)	14.5 (5.4)	13.7 (5.0)	14.3 (5.2)
	S.Em	C.D (5%)			
Spacing (A)	0.72 (0.2)	NS			
Intercrop (B)	0.58 (0.3)	NS			
A x B	0.82 (0.4)	NS			

(Figures in the parentheses are girth increment)

In the other experiment to study the effect of density of timber tree interplanting on growth of rubber (initiated in 2002), girth and height of rubber and intercrop were recorded.

The cropping system experiment initiated in 1993 has reached the tapping stage. Growth and yield of rubber plants was superior in the intercropped area compared to monoculture under normal spacing (445 plants/ha). Perennial intercrops like pepper, coffee, fodder grass and teak incorporated in the system were maintained. Pepper was having good vegetative growth but flowering and fruit setting continued to be very poor.

8. Rhizosphere chemistry

Two solution culture experiments and one rhizobox experiment were conducted to understand the special adaptive mechanisms at the rhizosphere on the uptake of P and micro nutrients by rubber. In P deficient plants the root growth was more and the shoot/root ratio was low compared to the P supplied plants.

9. Discriminatory fertilizer recommendation

Soil and leaf analysis based fertilizer recommendations were offered to large estates. During the year 1240 soil and 550 leaf samples were analysed and fertilizer recommendations were offered to 747 individual fields of 32 large estates who availed the facility.

BIOTECHNOLOGY DIVISION

Biotechnology programmes aim at development of transgenic plants integrated with desirable traits, *in vitro* propagation through shoot tip culture and somatic embryogenesis using different explants, development of haploid and triploid plants, standardization of *in vitro* fertilization techniques for controlled breeding, studies on the molecular control of growth and development, disease tolerance and tissue specific gene expression, isolation and characterization of genes controlling tapping panel dryness (TPD), rubber biosynthesis, biotic and abiotic stress and characterization of tissue specific promoters.

The transgenic plants integrated with superoxide dismutase gene under the control of CaMV 35S promoter as well as FMV 34S promoter developed earlier were multiplied by bud grafting. Extensive experiments were carried out to refine the nutritional and hormonal combinations for somatic embryogenesis and regeneration of healthy plantlets from immature inflorescence and immature anther explants of *Hevea* clone RRII 105, to improve the efficiency. A new field evaluation programme was initiated with such plants obtained from immature inflorescence of clone RRII 105 at Central Experiment Station, Chethackal in a statistically laid out field, keeping bud-grafted plants of the same clone as well as monoclonal seedlings as control. Methods were standardized for plant regeneration from leaf and root explants of somatic plants. Experiments were also initiated to standardise the technique using other explants like, meristem, ovule as well as explants from other clones such as RRII 414, RRII 422 and PB 311. The preliminary results were promising. The recombinant β-1,3- glucanase enzyme was purified and its role in controlling the overgrowth of *Phytophthora meadii* was confirmed through *in vitro* studies. The minimal promoter region with CAAT and TATA boxes for β-1,3- glucanase and rubber elongation factor genes were characterized. The differentially expressed genes of healthy and tapping panel dryness affected trees were identified through mRNA differential display and suppression subtractive hybridization analyses. The rubber biosynthesis genes such as farnesyl diphosphate synthase, 3-hydroxy-3-methylglutaryl Coenzyme A reductase-1 and rubber elongation factor were cloned and studied the expression pattern, and binary vectors were developed for *Hevea* genetic transformation.

1. Micropropagation

Shoot tips of *Hevea* clones (RRII-105 and RRIM-600) and seedlings were cultured for *in vitro* growth. Good growth of explants was noticed in the initial cultures with sprouting of apical buds. Higher concentrations of triacontanol (1.0 – 5.0 mg/L) were tried to improve the *in vitro* growth of cultures. Though in earlier experiments 10% increase in shoot growth was observed with lower concentration (0.8 mg/L), higher concentrations did not give any beneficial effects. Sprouting of axillary buds and multiple shoot formation was observed in some clonal explants, which were cultured for about 50 days in nystatin containing medium. Polyacrylamide gel electrophoresis showed difference in protein profile of immature shoots of both seedlings and clones (RRII 105 and RRIM 600) taken from green house and clonal materials after one month in culture. Isozyme staining for peroxidase was carried out for three different stages of *in vitro* grown shoot tips such as, before root induction, at the time of root induction and after root induction. Higher level of peroxidase was noticed at the time of root induction.

2. Somatic embryogenesis

2.1. Immature anther explants

Experiments were continued to refine the plant regeneration system developed earlier through somatic embryogenesis using immature anther as the explants of clone RRII 105. The basal medium was modified with varying concentrations of calcium both in chloride and nitrate forms. Results showed that 9.0 and 12.0 mM concentrations of $CaCl_2$ $2H_2O$ and $CaNO_3$ $4H_2O$ were found to be optimum and further maintenance on these combinations produced large number of embryos. However, the quality and morphology of embryos were found to be good with $CaNO_3$ rather than $CaCl_2$. Influence of malt extract was also tested on embryo induction. Results indicated that 9 and 12 mM $CaNO_3$ with malt extract responded very well and optimum combination was found to be with 750 mg/L malt extract and this combination will be very useful for improving the embryo induction.

Experiments were also initiated to extend this study with other clones like RRII 414, RRII 422 and PB 311. An experiment with different concentrations of NAA (1, 2, 3, 4 & 5 mg/L) was tried to enhance the rate of callus induction and immature anther was inoculated. Results indicated that addition of 3.0 mg/L NAA was found to be very promising for callus induction in the clone PB 311. Sub-culturing of calli of clones RRII 414, RRII 422 and PB 311 to embryo induction medium, the embryogenic calli were initiated and few embryos were obtained for RRII 414 and PB 311. For RRII 414, the embryogenic calli were proliferated and transferred to embryo induction medium for producing embryos in a large scale

2.2. Immature inflorescence explants

Utilising the system standardised for somatic embryo induction and plant regeneration from immature inflorescence of clone RRII105, plants were raised, acclimatized in the glass house and transferred to polybags for field planting. A statistically laid out field experiment was initiated at Central Experiment Station with such plants along with bud grafted plants as control. Observations on growth parameters were regularly recorded.

2.3. Root explants of somatic plants

Experiments on embryo induction and plant regeneration from root explants of somatic plants were initiated. Actively growing roots of germinating somatic embryos were used as the initial explant for callus induction. Proliferated calli were transferred to embryo induction media fortified with GA_3 and BA along with NAA. The embryos developed were transferred to maturation and plant regeneration media containing GA_3 and BA. Regenerated plants were planted in earthenware pots and maintained in the glass house for acclimatization. Acclimatized plants were later transferred to polybags for field planting. This system could provide a continuous supply of sterile target tissue throughout the year and hence may be highly useful in transformation experiments. Also this pathway, after appropriate modification, may be utilized for mass multiplication of elite root stock materials for propagation of elite *Hevea* clones through bud grafting.

2.4. Leaf and meristem culture

Attempts were also made to induce direct somatic embryogenesis from leaf explants as well as callus mediated somatic embryogenesis from leaf and meristem cultures. Callus induction in cultured leaf discs occurred three weeks after culture initiation. The calli formed were yellowish white and these were detached from the leaf surface and subcultured for proliferation. The proliferated calli were subcultured in different media combinations for embryo induction. Both MS and WPM media with major ele-

ments modified and different phytohormone combinations were tried for embryo induction. The calli when subcultured for embryo induction turned black. Modified MS medium with B5 vitamins and hormones BA (0.5 mg/L), KIN (0.3 mg/L), IAA (0.1 mg/L) and NAA (0.1 mg/L) could produce embryos. Embryo induction could also be obtained in modified WPM medium with increased levels of potassium phosphate and magnesium sulfate. This medium also contained B5 vitamins, amino acids and organic supplements along with phytohormones BA (0.5 mg/L), NAA (0.1 mg/L), GA (0.3 mg/L), KIN (0.3 mg/L) and IBA (0.3 mg/L). New yellow embryogenic calli emerged from the dark calli kept for embryo induction and the whole new clump after two weeks became pro-embryos. After two weeks these pro-embryos developed into normal embryos with well formed cotyledons. Embryos after 40 days were transferred to regeneration medium. Among the different media 1/2 WPM with B_5 vitamins, addition of organic supplements such as coconut water and malt extract and phytohormones BA (0.5 mg/L), TDZ (0.3 mg/L) and GA (0.8 mg/L) helped the apex induction of the embryos. After apex induction these were again sub cultured in hormone free ½ MS medium for plant regeneration. Embryos obtained are under various stages of plant regeneration.

Meristems were cultured for callus induction and direct somatic embryogenesis in MS medium. Of the different media tried, callus of good quality could be obtained in modified MS medium containing phytohormones BA (0.8 mg/L), KIN (0.5 mg/L), 2,4 D (1.0 mg/L) and NAA (0.2 mg/L). Casein hydrolysate at a concentration of 800 mg/L along with 5% coconut water was found good for improving the quality of calli formed. Calli obtained are being experimented for proliferation and embryo induction.

2.5. Ovule culture

During the current year, effect of proline, yeast extract, mannitol, sorbitol and ABA on the maturation of the embryos developed through ovule culture were studied. Basal components of the Woody Plant Medium with $CaCl_2$ and supplemented with Mannitol (4%), yeast extract (50 mg/L) and growth regulators like NAA (0.4 mg/L), KIN (0.5 mg/L) and GA_3 (0.5 mg/L) were found to be ideal for embryo maturation (Table Biotech.1). Bipolarly differentiated embryos were observed in MS medium with malt extract (500 mg/L), Zeatin (2.0 mg/L) and IBA (1.0 mg/L). Cytological studies were conducted and confirmed the diploid nature of the germinating plantlets.

Table Biotech. 1. **Effect of Kinetin and Mannitol on embryo maturation**

Conc of KIN (mg/L)	Mannitol (%)				
	2	4	6	8	10
0.2	24.4	33.0	30.8	22.2	—
0.3	33.6	35.2	37.6	33.2	11.6
0.4	37.8	41.8	40.4	37.8	17.8
0.5	53.0	65.8	57.6	44.0	15.4
0.6	45.0	46.2	37.8	19.8	10.6

CD (P=0.05) 2.83

2.6. Haploid plant production through the microspore culture

Experiments were continued to refine the protocol developed earlier for the establishment of microcolony from cultured microspores and its further poliferation. N_6 basal medium supplemented with 2.0 mg/L 2, 4 D & 1.0 mg/L KIN induced microspore division. Ovary co-culture increased the frequency of micro calli formation from 5 % to 20 % as well as reducing the duration from 3 months to 14 days.

To overcome the explant derived microbial contamination, different antibiotics were tried in the liquid callus induction medium. Antibiotics like Nystatin (10-50 mg/L) Amphotericin-B (5-25 mg/L), Rifampicin (5-25

mg/L) and Streptomycin (5-25 mg/L) were tried. Nystatin (25mg/L) and Amphotericin B (10mg/L) were effective in controlling the contaminants.

The effect of sugars and growth regulators on the proliferation of the callus in the solid medium was attempted (Table Biotech. 2).

Table Biotech. 2. **Effect of different sugars on the proliferation of the haploid callus in the N6 basal medium**

Sugar concentration (%)	% callus proliferation			
	Sucrose	Lactose	Galactose	Maltose
3	-	-	-	-
4	-	-	-	-
5	++	-	-	++
6	+++	+	+	+++
7	+++++	+	+	++++
8	++++	++	+	+++

Of the different sugars tried, 70g/L sucrose promoted the growth of haploid callus in the N6 solid basal medium containing the growth regulators, KIN (2.0 mg/L) and NAA (1.0 mg/L).

2.7. Endosperm culture

Endosperm culture was attempted with a view to develop a regeneration system from endosperm and to utilise the system for the production of triploids. Embryogenic calli obtained earlier were proliferated and experiments for embryo induction were performed. High frequency embryo induction were obtained in MS basal medium, supplemented with 0.3 mg/L ABA and 0.5% phytagel. The concentration of sucrose for embryo induction was optimized and found to be 50 mg/L.

3. Genetic transformation

The ongoing experiments were continued to develop transgenic plants with increased tolerance to tapping panel dryness, drought and different types of environmental stresses. The genes coding for superoxide dismutase under the control of CaMV 35S and FMV 34S promoters separately. Sorbitol-6-phosphate dehydrogenase with separate sequences expressing in the cytoplasm as well as targeting to the chloroplast, isopentenyl transferase and antisense gene for ACC synthase were used in this study. The transgenic plants integrated with the SOD gene under the control of CaMV 35S and FMV 34S promoters developed earlier were multiplied by bud grafting.

In order to identify more appropriate antibiotic for selection, the lethal dose for the antibiotic hygromycin was determined using *Hevea* friable callus derived from immature anther. The optimum concentration of hygromycin required for the selection of transformed cell lines was found to be 40 mg/L. Calli derived from immature anther (clone RRII 105) was transformed with *Agrobacterium* strain harboring GUS as the reporter gene and both hygromycin phosphotransferase and neomycin phosphotransferase as the selectable marker genes. Kanamycin and hygromycin were used separately for the selection of transformed cell lines, to identify the transformants obtained with which antibiotic is performing better for transgenic plant regeneration. The transgenic cell lines were kept for proliferation.

Transgenic *Hevea* embryogenic callus integrated with the SOD gene under the control of FMV 34S promoter was subjected to water and salinity stress by culturing the samples in hormone free Murashege and Skoog medium supplemented with different concentrations of phytagel (0.2-0.6%) and sodium chloride (100-500 mM) respectively. Total RNA was isolated from the normal and stress induced callus. Northern hybridization analysis was carried out with a 702 bp *Hb* SOD fragment as the probe. An increase

in SOD transcript level was observed in transgenic callus subjected to stress (0.4% phytagel or 100 mM NaCl). At higher concentrations, the transcript level was also found to be low. The SOD enzyme activity was also found to be higher at these concentrations.

In order to produce more transgenic plants integrated with SOD gene under the control of CaMV 35S promoter through independent transformation events, fresh *Agrobacterium* mediated genetic transformation experiments were carried out with ovule derived calli of *Hevea* clone RRII 105 as the explants. With the above explants the transformation frequency could be enhanced upto 30% and 23 GUS positive cell lines were obtained. The embryo induction could be enhanced up to 85 percent. Modified MS medium supplemented with 2.0 mg/L 2ip and 6.0 percent PEG was found to be ideal for embryo maturation. Germination of embryos was observed in the medium supplemented with 5.0% sucrose, 0.3 mg/L abscisic acid and 0.2 mg/L thidiazuron.

Fresh genetic tansformation experiments were repeatedly done to overcome the problem of production of abnormal transgenic plants integrated with the gene coding for isopentenyl transferase and to produce normal plants. Embryogenesis was obtained from transgenic calli that were proliferated in selection medium containing the antibiotic combinations Paramomycin & Cefatoxime and Kanamycin & Cefatoxime. Experiments on plant regeneration were tried from embryos obtained from transgenic tissues that emerged from newly regenerated callus clumps. Apex induction of the embryos that regenerated from calli formed in selection medium containing both kanamycin and paramomycin occurred in medium containing growth regulators GA (0.3 mg/L) and BA (0.3 mg/L). Apex induced embryos were transferred to ½ MS medium containing organic supplements, coconut water (20%), malt extract (50 mg/L) and phytohormones TDZ (0.1 mg/L), GA (0.3 mg/L) and IBA (0.8 mg/L). Several developmental abnormalities were found in developing embryos. About 200 embryos were cultured in different media for plant regeneration and leaf formation could be achieved in about 50. After leaf formation these plantlets were subcultured in modified ½ MS with hormones, BA (1.0 mg/L) and IAA (1.0 mg/L) for leaf maturation. Normal plantlet formation with complete leaf maturation could be obtained in five of them. After two weeks senescence of these mature leaves occurred suddenly as if some signal has triggered it. Once leaf fall occurred the plant could not survive further and gradually died. This confirmed that problems in plant regeneration was not due to deleterious effect of antibiotics in selection medium. Representative samples of each plantlet, which developed leaves was subjected to X-gluc test and they proved to be positive. It was confirmed that problems in complete plant development are due to the effect of incorporated gene and its expression. *Ipt* levels measured in transgenic materials were found to be 2 to 50 fold higher than normal.

Genetic transformation with the gene coding for sorbitol-6-phosphate dehydrogenase was initiated for the production of drought tolerant *Hevea* plants. Transgenic cell lines that were developed from earlier experiments were subcultured for callus proliferation. New experiments were also going on to develop more transgenic cell lines through independent transformation events.

4. Molecular studies

4.1. Molecular mechanism of disease tolerance

The *Hevea* gene coding for the anti-fungal protein, β-1,3-glucanase was cloned in a bacterial expression vector called pET32a+. Sequencing of the vector ensured correct ori-

entation and reading frame of the cloned insert. The recombinant plasmid was transformed into an expression host of *E.coli* and conditions were optimized for the induction of the recombinant protein in soluble form. Under optimum conditions, a band of expected size (55.6 kDa) was detected in SDS-PAGE of the soluble protein fraction, isolated from the induced colonies. The target protein, formed in fusion with an N-terminal affinity tag, was purified by passing through an affinity column. Western blotting and thrombin cleavage of the N-terminal fusion tag confirmed its identity. Hydrolysis of its substrate, laminarin, ensure that the purified recombinant protein is in active form.

The purified *Hevea* β-glu was assayed for its anti-fungal activity against the ALF causing *P.meadii* using filter paper disc method. The possible role of host β-glu in resisting the *Phytophthora* attack in *Hevea* that has been evident by its over-expression during fungal infection is being confirmed through the direct fungicidal action of the purified glucanase.

4.2. Tissue specific gene expression and charactrisation of promoters

The two PCR products corresponding to the gene β-1,3- glucanase were cloned in to plasmid vectors. Further the nucleotide sequences were elucidated. It was found that the 513 base pair fragment obtained from Dra 1 digested DNA contains a 198 base minimal promoter . The CAAT and TATA boxes, which are characteristic of eukaryotic promoters were present in this region. The CAAT box was located at the position 139 and the TATA box was seen at 82 from the translation initiation *ATG* codon. This is the first report on the isolation of promoter elements of β-1,3- glucanase gene from *Hevea* and the sequence data was submitted to the gene bank (Accession No. AY325498).

A 750 base pair DNA fragment corresponding to the promoter region of the gene, rubber elongation factor (REF), was amplified, cloned into plasmid vector and the nucleotide sequence was elucidated. The sequence consists of 378 bases upstream of the translation initiation codon ATG. The CAAT box is located at 217 and TATA box at 145 position upstream of the ATG site.

5. Isolation and characterization of wound/stress inducible cDNAs by mRNA differential display and subtractive hybridization analysis

5.1. mRNA differential display analysis

The study was aimed to identify genes associated with TPD syndrome in *Hevea* by mRNA differential display/suppression subtractive hybridization analysis. An experiment was initiated for identification of differentially expressed genes by mRNA differential display technique. Total RNA was isolated from latex samples of healthy tree as well as TPD trees and first strand cDNA was synthesized. For first strand cDNA synthesis degenerate oligo dT (dTTTTTTTTTTTTTM: M-represents A, G, C or T bases) primers were used to get good representative gene amplification. The cDNA was used for mRNA differential display with 18 mer arbitrary primers. There was significant difference in the mRNA differential display profile of healthy and TPD trees. About 5 differentially expressed mRNA transcripts were noticed as unique for healthy tree cDNA sample and one mRNA was found to be unique for TPD tree. These cDNAs were eluted from PAGE and reamplified by using the respective primer combinations. Further characterization is in progress.

5.2. Suppression subtractive hybridization analysis

To identify the differentially expressed genes between healthy and TPD trees, two subtracted cDNA libraries of *Hevea brasiliensis* from healthy and TPD trees were

constructed using the suppression subtractive hybridization (SSH) technology. Initially, a reciprocal experiment was designed to determine the efficiency of the subtraction procedure to clone differentially expressed genes in two types of trees. Poly A+ RNAs from healthy and TPD affected trees were used to generate tester and driver cDNAs respectively, for the healthy tree library (forward subtracted library) and vice versa for the TPD tree (reverse subtracted library). Clearly distinctive patterns of differential transcripts abundance could be observed when these two cDNA libraries were compared. More than 342 recombinant clones were obtained from the forward subtracted cDNA library and about 737 clones were noticed from reverse subtracted cDNA library. All those colonies were picked up and their inserts were amplified using M13 primers by colony PCR. The size distribution of the 352 clones was 0.2 kb to 1.2 kb. The small size insert was discarded from analysis and all the clones were sequenced. Table Biotech. 3 summarizes the total number of isolated, sequenced and analysed clones, differential and identical gene sequences.

With the information gathered from the GenBank database and protein domain searches, identifed or assigned putative functions to some of the genes in the cDNA library collection. In healthy tree SSH cDNA library, 31 out of 112 clones were found to be unique genes and 11 were identical cDNAs. There was no sequence homology found with the database for 3 sequences, which were considered as novel cDNAs. From the TPD affected SSH cDNA library, 240 clones were sequenced, where 36 were found to be known cDNAs, 11 were classified as identical cDNAs and 25 were novel sequences which are not found in the public GenBank database. All the known genes and their frequency of identification during the differential screening are listed in Table Biotech. 3. All the known gene sequences from reverse subtracted library were related to stress induced cDNAs and the remaining 25 cDNAs had not previously been reported. A total of 31 sequences out of 112 from forward cDNA library showed significant similarity to known gene sequences which were related to stress, metabolism, transporters, amino acid synthesis, transcription factors etc. These results indicate that the length of the sequences reported in this study is good enough to retrieve significant hits in GenBank database. Stress related cDNAs were highly abundant in subtracted library of TPD tree while these sequences were absent in subtracted cDNA library of healthy tree. About 11 cDNAs associated with abiotic and biotic stresses and rubber biosynthesis were also highly represented in both the cDNA libraries.

Agronomically important sequences related to wound stress/response, cell proliferation and apoptosis such as Myb1 transcription factors, Translationally controlled tumor protein (TCTP) were found to be ex-

Table Biotech. 3. **Number of differentially expressed gene sequence analysis from forward and reverse SS cDNA libraries of *Hevea***

Total cDNA sequences	Forward SS cDNA Library (Healthy rubber tree)	Reverse SS cDNA Library (TPD rubber tree)
	112/342	240/737
Isolated	112	240
Sequenced	112	240
Analyzed	31	36
Differential sequences between Healthy & TPD tree	11	11
Identical sequences	3	25
Novel sequences	200-1200	200-1200
Average insert size (bp)		

pressed only in healthy tree subtracted cDNA library which are newly reported EST sequences for *Hevea*. Preliminary results showed that those putative cDNAs related to stress revealed differential expression between healthy and TPD tress. In the reverse northern analysis, the duplicate dot blots of PCR-amplified clones that were probed with total mRNA derived from first strand cDNA of TPD tree revealed very low expression. When forward subtracted cDNAs were used as probe for hybridization strong signal for the same cDNA could be obtained. The results recorded from two hybridizations for each clone clearly indicates that there was differential gene expression between healthy and TPD trees of *Hevea*. The first screen identifies cDNAs corresponding to only the most abundant differentially expressed genes, while the second screen identifies genes that are expressed less abundantly but still differentially. Although differential expression of every gene has not been tested under healthy and TPD conditions, of the more than 78 genes tested, roughly 80% have exhibited differential expression by reverse Northern analysis.

Table Biotech. 4. **Summary of the subtracted healthy and TPD trees cDNA clones that were sequenced**

cDNA	Clones sequenced
Known genes*	78
Uncharacterized sequences	110
Unknown sequences** (Novel sequences)	28
Redundancy	136
Total clones sequenced	352

*Sequences with >85% identity to known genes**Sequences not found in the GenBank database

6. Molecular cloning and expression of the genes related to rubber biosynthesis in *H. brasiliensis*

6.1. Cloning and characterization of farnesyl diphosphate (HFDP) synthase gene in *Hevea brasiliensis*

A study was initiated to clone and characterize the HFDP cDNA from *Hevea*. The full-length functional HFDP cDNA of size 1.2 kb was cloned and sequenced. The copy number was also confirmed by Southern blot analysis using *Hevea* genomic DNA digested with HindIII, EcoRI, EcoRV and XbaI enzymes. In Southern blot, there were 2 to 3 bands noticed with FDP gene probe and this result indicates that more than one copy of FDP gene was found in the *Hevea* genome. A gene construct was developed in binary vector with HFDP gene for genetic transformation experiments. The full-length functional FDP gene was cloned and sequence characterized. The FDP cDNA was cloned into pCAMBIA binary vector under the 35CaMV constitutive version promoter.

6.2. Cloning and differential expression pattern of a functional gene coding for 3-hydroxy-3 methylglutaryl-coenzyme A reductase (HMGR 1) from *H. brasiliensis*

The present study is aimed to clone the HMGR 1 gene. Total RNA was isolated from latex and RT-PCR was performed. Then the cDNA was used for PCR amplification of HMGR 1 gene fragment, which was cloned into plasmid vector. The HMGR1 cDNA size was 1.8 kb. The HMGR 1 cDNA gene sequence showed 100% homology with the earlier reported *Hevea* HMGR 1 cDNA sequence followed by HMGR genes from other plant species. The deduced amino acid sequence of HMGR 1 genomic gene was aligned with the sequences deduced from various plant species. Southern blot analysis was performed to confirm the presence of the cloned HMGR 1 gene fragment. Two strong and one weak bands were noticed which indicate that there are three members for HMGR gene in the *Hevea* genome. Further, to conduct genetic transformation experiments, HMGR1 gene was amplified and cloned into a binary vector pBIB under the control of super promoter.

BOTANY DIVISION

The Division continued research on genetic improvement of *Hevea* aimed at evolving high yielding clones for the traditional region, evaluation and selection of clones for high yield and better secondary attributes than RRII 105 and breeding for specific objectives including biotic and abiotic stresses. Breeding for latex timber attributes, evaluation of clones for monoclonal and multi-clonal plantings, studies on prepotency and G x E interactions were also pursued. Other activities included estimation of wood availability of clones, stock-scion interaction and propagation techniques.

1. Evolving high yielding clones for the traditional area

1.1. Hybridization and clonal selection

In the 1988 small scale trial, clone 24 recorded the highest yield (81.5 g/t/t) followed by clone 35 (60.0 g/t/t). From the 1989 small-scale trial 43 hybrid clones were selected based on yield and growth performance.

Of the clones under small scale trial 1992A at CES, Chethackal, clone 772 recorded the highest mean yield of 105.3 g/t/t followed by clones 380 (82.0 g/t/t) and 424 (75.3 g/t/t) (Table Bot.1). RRII 105 recorded 58 g/t/t. Lowest yield was recorded in clone 789 (22.4 g/t/t). Clone 948 though had better girth (76.6 cm) than clone 772 (74 cm), its yield was less than half of the latter. After four years of tapping, clone 772 recorded the highest mean yield of 78.9 g/t/t followed by clone 424 (54.5 g/t/t) and 380 (44.4 g/t/t). RRII 105 recorded 39 g/t/t.

In another small scale trial 1992B at CES, Chethackal, clone 575 gave the highest yield of 78 g/t/t while the lowest was recorded for clone 894 (18.4 g/t/t/) during 2003 (Table Bot.2). Control clones RRIM 600 and RRII 105 recorded 74.3 and 54.5 g/t/t respectively. Pooled data on four years of yield indicated clone 575 to be the leading clone with an yield of 53 g/t/t followed by clones 756, RRIM 600 and RRII 105 with an yield of 41, 40 and 35.7 g/t/t respectively.

Table Bot. 1. **Growth and yield of clones over four years of tapping in the small-scale trial 1996A at CES, Chethackal**

Clone	Girth (cm) January, 2004	Mean yield during 2003 (g/t/t)	Mean yield (2000-2003) (g/t/t)
772	74.1	105.3	78.9
424	64.2	75.3	54.5
380	69.3	82.0	44.4
RRII 105	56.6	58.1	39.2
450	63.2	45.1	36.8
764	56.3	39.8	34.9
789	46.3	22.4	33.4
779	64.0	42.8	32.5
948	76.6	40.9	30.9
583	61.0	39.7	29.5
761	58.2	39.0	29.3
459	49.9	32.1	28.6
356	58.8	43.3	26.6
337	51.4	27.9	17.7
CV (%)	10.1	28.3	23.3
CD (P=0.05)	10.2	23.6	14.5

In the 1999C small scale trial, highest girth was observed in clone 186 and 412 (28 cm) and the lowest girth observed was in clone 94/70 (19.5 cm). Compared to the hybrid clones, girth of control clone RRII 105 was low (23.7 cm). In the 1995A SST 17 clones showed higher yield than control and the mean yield ranged from 11.8 to 50.4 g/t/t.

Forty hybrid seedlings from the 1997 hybridization programme incorporating the wild germplasm were selected based on test tap yield, girth, number of latex vessel rows and disease incidence. A clonal nursery of these clones with RRII 105 as check was established. The seedling nursery of the progenies of HP-2002 programme was properly maintained. Observations on growth and disease incidence were recorded.

Table Bot. 2. Growth and yield of clones over four years of tapping in the small-scale trial 1996B at CES, Chethackal

Clone	Girth (cm) January, 2004	Mean yield (g/t/t) during 2003	Mean yield (g/t/t) (2000-2003)
575	74.1	78.0	53.1
756	68.1	65.3	41.0
RRIM 600	72.2	74.3	39.8
RRII 105	48.2	54.5	35.7
618	57.0	44.9	35.6
592	57.3	30.2	31.9
368	74.1	34.7	28.1
916	53.6	25.7	26.8
264	55.2	29.0	24.1
894	48.2	18.4	18.9
CV (%)	13.1	37.2	25.3
CD (P=0.05)	12.1	35.1	15.8

1.2. Ortet selection

A comprehensive evaluation of 43 ortets at Mundakkayam Estate in comparison to three check clones RRII 105, RRIM 600 and GT 1 over the first five years of tapping was carried out based on rubber yield, timber yield, response to stimulation, growth attributes and yield components. The ortet clones exhibited significant variation, which could be effectively explored for clonal selection with respect to specific traits. Five clones exhibited good yield (37.2 to 45.3 g/t/t) on par with RRII 105, coupled with promising timber yield (0.12 to 0.18 m^3). These are the potential latex timber clones. Clone MO 15 is a timber clone with highest bole volume. Clone MO 49, a medium yielder, exhibited good response to stimulation. A total of 11 new primary clones with promising traits were selected. From the small scale trials at Cheruvally, Koney and Mundakkayam estates 15 promising ortets were multiplied for the next stage of field evaluation. In the ortet trials (1992, 1993 and 1994) at CES, Chethackal, six ortet clones recorded high initial yield compared to RRII 105.

2. Evaluation of clones

2.1. Large-scale evaluation

Significant clonal variation was evident among the RRII 400 series clones being evaluated at CES, Chethackal. Yield of the 22 clones ranged from 9.02 – 47.56 g/t/t in the second year of tapping while the check RRII 105 recorded 29.74 g/t/t. Nine clones recorded 11.6 to 59.92 per cent improvement in yield over RRII 105. Five clones *viz.*, RRII 414, RRII 417, RRII 422, RRII 429 and RRII 430 which were included in Category III of the planting recommendation maintained better performance than RRII 105 with 11.6 to 54.8 per cent improvement in yield. Two other clones *viz.*, RRII 402 and RRII 52 recorded more than 46 per cent improvement in yield over RRII 105.

In the trial at North Konkan, clone RRII 208 continued to give better yield (50.1 g/t/t/) than other clones. RRIC 52 and RRIC 105 with 20 g/t/t were the lowest yielders (Table Bot.3.). Regarding the performance of the clones over six years of tapping, RRII 208 gave the maximum yield

Table. Bot. 3. Girth and mean yield of clones over six years of tapping (1998-2003)

Clone	Girth (cm) January, 2004	Mean yield (g/t/t) during 2003	Mean yield (g/t/t) (1998-2003)
RRII 208	63.3	50.1	42.6
RRII 105	55.6	34.6	39.3
RRII 6	60.7	32.4	38.2
PR 255	55.4	26.9	37.1
RRIC 100	58.3	32.4	34.0
PB 311	55.8	29.9	32.3
PB 260	58.1	27.6	32.2
RRII 5	57.7	27.5	31.6
RRIC 102	58.8	33.8	31.5
PB 310	58.5	26.4	31.2
RRII 308	54.7	21.3	30.1
PR 261	55.7	22.0	29.9
RRIM 605	55.6	21.7	28.3
RRIC 105	55.8	20.0	22.9
RRIC 52	62.9	20.3	22.1
CV	3.8	15.2	12.2
CD (P=0.05)	3.7	7.2	6.5

(42.6 g/t/t) followed by RRII 105 (39.3 g/t/t) and RRII 6 (38.2 g/t/t). Lowest yield observed was in clones RRIC 52 (20.3 g/t/t) and RRIC 105 (20.0 g/t/t). In growth vigour, even though RRII 208 and RRIC 52 had similar girth, their rubber yield was contrasting.

In the multidisciplinary evaluation of clones 1989A, clone RRII 5 recorded highest yield of 65.6 g/t/t followed by RRII 118 (54.0 g/t/t) in the fifth year of tapping. In the other trial (1989 B) PB 312 recorded the highest yield (82.3 g/t/t) followed by PB 314 (80.4 g/t/t) , PB 255 (80.2 g/t/t), PB 280 (79.0 g/t/t) and KRS 163 (77.8 g/t/t). In the trials at CES, Chethackal also PB 312 and PB 314 recorded higher yield with 68.4 and 60.4 g/t/t/ respectively. The trees of the 1994 trial were opened for regular tapping and yield recording was started. Clone 61 in the large scale trial 1996A and Clone 897 in trial 1996 B recorded maximum girth after seven years of growth at RRS, Padiyoor. In the 1999 trial clone 12 exhibited good girth after 5 years of growth.

2.2. Onfarm trials

Among the 12 clones that are under evaluation at Chithalvetty, PB 260 recorded the highest yield over 10 years of tapping (1345 kg/ha) followed by RRII 105 (1330 kg/ha). From the trial at Chemoni, highest yield obtained was in RRII 105 (1424 kg/ha) followed by PR 255 with 1250 kg/ha. Fifteen years after planting bole volume of the clones ranged from 0.041 to 0.172 cu. m. At Shaliakary after 5 years of tapping PB 280 recoded 2848 kg/ha followed by clone PR 255 (2339 kg/ha). Control clone RRII 105 recorded a yield of 1905 kg/ha. In the other trial at the same estate, RRII 105 recorded an yield of 1589 kg/ha followed by RRII 54 and SCATC 88-13 with 1300 kg/ha each.

2.3. Studies on clonal composites

Evaluation of the clones in various blends at different proportions in comparison with monoclonal plantation of RRII 105 indicated that girth and yield of the different composites are comparable. At CES, Chethackal mean yield of the trees was 45.6 g/t/t while at RES, Nagrakata it was 19.6 g/t/t (Table Bot.4).

2.4. Investigations on genotype x environment interactions

Girth was recorded at quarterly intervals. The trials at three locations *viz.*, Agartala, Nagrakatta and Kanyakumari were opened for tapping and yield recording is being carried out at fortnightly intervals. Yield attributes like DRC, plugging index, sucrose and inorganic phosphorous were recorded at quarterly intervals from the three locations. Disease screening was done in all the locations by the Plant Pathology Division, RRII and Plant Pathologist, at RRS, Guwahati. Lab screening for *Corynespora* sp.

Table Bot. 4. **Girth and mean yield of clonal blends at two locations**

Treatment	CES, Chethackal			RES, Nagrakata		
	Girth (cm) (Dec., 2003)	Current year yield (g/t/t)	Mean yield (g/t/t) of three years (2001-2003)	Girth (cm) (Dec., 2003)	Current year yield (g/t/t)	Mean yield (g/t/t) of two years (2002-2003)
Com-1	59.0	60.5	47.6	51.1	19.0	19.9
Com-2	59.7	55.0	46.7	51.9	21.3	19.2
Com-3	60.9	53.2	44.1	52.7	20.4	21.2
Com-4	58.9	52.3	42.6	53.1	19.1	18.4
Com-5	57.8	58.4	44.6	50.0	16.2	16.4
RRII 105 (pure)	57.8	61.1	48.0	50.1	24.1	22.2
Mean	59.0	56.8	45.6	51.5	20.0	19.6

was repeated by the Plant Pathology Division. It was observed that RRII 429 is showing maximum resistance to *Corynespora* species.

3. Breeding for other specific objectives

3.1. Compact canopy

Four different morphotypes have been identified from the open pollinated progenies of canopy mutant genotype. Of the four morphotypes in the trial, normal type yielded 70.4 g/t/t (RRII 105 45.2 g/t/t). Other morphotypes did not show significant growth and yield. The recombinants of cross between canopy mutant and high yielding popular clones *viz.*, RRII 105, RRIM 600 and RRII 118 are under small scale evaluation. Juvenile performance of progenies is shown in the Table Bot.5.

Table Bot. 5. **Growth performance of recombinants and their parents**

Cross combinations	Girth (cm) 2003	Height (m)	Diameter of the canopy (m)
Genetic Variant	5.7	2.5	0.7
RRII 118	15.7	5.4	3.0
RRII 105 x Compact	14.8	5.5	3.0
RRIM 600 x Compact	13.1	6.3	2.5
RRIM 600 x Compact	13.9	5.8	2.7
Compact x RRII 118	12.3	5.1	1.8
Compact x RRII 118	14.0	5.2	2.9
RRII 105 x Compact	14.2	5.6	2.9
RRII 105	10.8	4.5	2.1
Compact x RRII 118	14.8	5.7	2.7
RRIM 600 x Compact	13.5	6.1	2.5
RRIM 600 x Compact	14.7	6.8	2.5
RRIM 600	12.6	5.9	2.5
Compact x RRII 118	16.5	7.1	2.6
RRIM 600 x Compact	12.4	6.0	2.7
RRIM 600 x Compact	11.2	6.0	2.2
RRII 105 x Compact	16.7	6.2	2.8
RRII 105 x Compact	13.3	5.7	2.5
CV	14.4	9.6	13.6
CD (P=0.05)	3.17	0.89	0.56

3.2. Drought tolerance

Among 32 hybrid clones studied for growth rate in summer during the sixth year after planting, 15 were comparable to clone PB 260 which exhibited the highest summer growth rate of 30.29 percent of the annual growth. Results of the preliminary screening of hybrids based on test tap yield in summer months and some physiological parameters of drought tolerance indicated that the parent clone PB 217 and the hybrid entries H93/270, H93/105 and H93/184 were promising in terms of drought tolerance.

3.3. Latex timber clones

Test tapping was carried out in the hybrid seedlings. As a part of this project, a study for deriving prediction equations on timber volume of different clones was started in association with the KFRI.

3.4. Polycross progeny evaluation

There was significant clonal variation within and between the 10 half-sib progenies in respect of mean annual yield and summer yield during the third year of tapping. Among the 150 clones evaluated, 89 were comparable in yield to the high yielding check RRII 105. Thirty clones showed improvement in yield over RRII 105 to the tune of 0.3 to 97 per cent. The superiority of the parent clones PB 28/83, Ch 26, PB 215 and RRII 105 was evident from their progeny performance. The progenies also showed significant variation with respect to the intensity of powdery mildew and abnormal leaf fall diseases. In general, the progeny of AVT 73 showed low intensity of powdery mildew, while clones derived from the parent PB 5/51 were susceptible. Rubber and timber yield of a set of parents and their hybrid progenies were assessed at the age of 11 years. Clones PB 235, RRII 203 and RRII 118 showed the highest clear bole volume of 0.15, 0.10 and 0.10 m^3 respectively. The progeny of the cross RRII 105 x RRII 118 were in general superior in terms of rubber yield which ranged from 18.04 to 57.43 g/t/t in the third year of tapping.

4. Studies on storage of *Hevea* pollen

Pollen grains of RRII 105 stored under −80.0° C for different durations were analysed for the stainability and germinability under *in vitro* conditions. The result indicated that stored pollen grains retained viability up to 90 days with 30.7 per cent germination and 60.4 per cent stainability when compared to that of fresh pollen with 67.0 per cent stainability and 35 per cent germinability.

5. Anatomical investigations

5.1. Bark anatomy

A study on seasonal changes occurring in the bark and its relation to yield was initiated. Monthly bark sampling was carried out from six clones grown at the Regional Research Station, Orissa. Significant differences were noticed among the clones for the characters (Table Bot. 6).

Table Bot.6. Yield and anatomical parameters in a few high yielding clones

Clone	Yield (g/t/t)	Bark thickness (mm)	No. of latex vessel rows	Crystals
RRII 105	21.93	8.37	10.90	40.40
RRII 208	26.00	8.71	10.89	43.50
GT 1	24.34	8.37	11.61	40.57
PR 255	26.77	7.58	10.52	46.00
PR 261	25.87	7.19	12.15	48.14
RRIM 600	22.62	7.44	8.64	38.89
CD (P=0.05)	—	0.46	1.37	3.13

Bark anatomical characters from 47 ortets and three controls that are being evaluated at the Koney estate were recorded. Ortets 22 and 24 recorded significantly higher latex vessel rows compared to RRII 105.

5.2. Wood anatomy

Bole volume of five *Hevea* clones namely, RRII 105, RRII 203, RRII 208, GT 1 and RRIM 600 were assessed at the age of 25 years from onfarm trials at five locations (Punalur, Chittar, Ranny, Trichur and Balusseery) in the traditional rubber growing zone. RRII 203 had the highest bole volume of 0.52 m^3 followed by RRII 208 with 0.47 m^3 at Chittar. At Ranny, RRIM 600 has the maximum bole volume of 0.32 m^3 while GT 1 with 0.33 m^3 was better in North Kerala region. RRII 105 exhibited uniform pattern (0.22 to 0.33 m^3) in all the locations (Table Bot. 7).

Wood samples tested for physical properties in connection with the study on effect of ethrel stimulation on rubber wood quality indicated that there was no significant variation in moisture content (%), density in green condition and standard specific gravity (oven dry weight/green volume) between stimulated and unstimulated trees of the clone RRII 105. With respect to mechanical properties 10 important properties were tested. These include static bending, compression strength parallel as well as perpendicular to the grain, tensile, shear strength, hardness, nail and screw holding power and cleavage. Most of the properties were comparable in either clones RRII 105 and RRIM 600. In general clonal variations appear to exist on effect of long term stimulation on wood quality. So also there was no significant difference in wet weight of trees in both the clones following stimulation.

6. Studies on propagation

In the trial on different depths of planting, yield over first four years of tapping showed no significant difference between treatments. In the trial on comparative studies on single and double stock no significant difference was observed between the treatments at the time of opening of the trees.

Performance of certain modern clones in the trial on different root systems showed that different clones budded on their own stocks and assorted stocks did not show any

Table Bot. 7. **Girth (m) and bole volume (m^3) of five clones at different locations in the traditional rubber growing zone**

Clone	Location									
	Punalur		Chittar		Ranny		Trichur		Balussery	
	Girth	Bole Volume	Girth	Bole volume	Girth	Bole volume	Girth	Bole volume	Girth	Bole volume
RRII 105	0.82	0.24	0.92	0.27	1.09	0.30	0.76	0.22	0.91	0.25
RRII 203	1.00	0.33	0.97	0.52	1.22	0.43	—	—	—	—
RRII 208	0.95	0.31	0.96	0.47	1.10	0.27	0.82	0.25	0.85	0.23
RRIM 600	0.84	0.26	0.90	0.24	1.08	0.32	0.75	0.22	0.90	0.24
GT 1	0.94	0.25	0.98	0.32	—	—	0.77	0.23	1.03	0.33

significant difference in yield and growth. Vigorous clones like RRII 118 and GT 1 showed superiority in growth irrespective of the stock (Table Bot.8). In the 3 x 3 stock-scion combination trial vigour and yield of clones in all combinations were on par and depended on the genotype of clones rather than stocks.

7. Morphological characterization of popular clones

Advisory work on identification of clones was carried out. Sample seeds from different species of *Hevea* and indigenous and exotic modern clones were collected and conserved as type seeds.

Table. Bot.8. **Performance of certain modern clones on different root systems**

Treatment (Stock-scion)	Yield (g/t/t)	Girth (cm)
RRII 105 x RRII 105	66.7	77.4
RRII 118 x RRII 118	40.5	93.3
RRII 203 x RRII 203	59.5	92.9
RRII 208 x RRII 208	40.1	78.0
GT 1 x GT 1	47.8	85.0
Gl 1 x Gl 1	39.3	85.3
RRIM 600 x RRIM 600	41.1	83.6
Assorted x RRII 105	54.3	78.5
Assorted x RRII 118	49.9	94.6
Assorted x RRII 203	53.2	95.6
Assorted x RRII 208	36.8	76.8
Assorted x GT 1	42.6	81.9
Assorted x Gl 1	39.5	80.6
Assorted x RRIM 600	40.4	77.1
CV	11.09	6.39
CD (P=0.05)	17.4	18.18

GERMPLASM DIVISION

The Division carried out the introduction, collection, conservation and evaluation of *Hevea* germplasm. The *Hevea* germplasm collection comprises both the domesticated gene pool with clones derived from the original Wickham collection of 1876, and the wild germplasm belonging to the 1981 IRRDB collection. Apart from maintaining the Wickham collection, the wild germplasm was screened for many desirable characters for resistance to diseases, drought and cold. Timber latex traits and molecular characterizations were also carried out.

1. Conservation and documentation

1.1. Wickham collection from secondary centers

Eight clones supplied by the Botany Division were included in the clone museum. Screening for resistance to *Oidium* was carried out in Germplasm Gardens II, III, IV and V, comprising 75 Wickham clones. Data on growth and yield were collected.

Of the different species introduced from Sri Lanka and Indonesia, the one from Indonesia (*H. collina)* did not sprout at all. The establishment and growth of the remaining

accessions was monitored. One of the spp. *H. camaragoana* has shown precocious flowering at the age of three months after budding.

Among the 15 clones in Garden III, RRII 118 recorded the highest yield in panel BI – 2, followed by RRIM 300 and PB 310. RRII 118 recorded the highest girth (121 cm) followed by RRII 300 (113 cm), RRII 203 (113 cm) and RRII 206 (108 cm). Very early wintering was recorded on clones RRII 44, RRII 308 and PB 310 and early wintering was observed on clone RRII 2, RRII 4, RRII 300 and PB 311, whereas clone RRII 5, RRII 6, RRII 118, RRII 203 and RRII 208 recorded late wintering (Table Ger. 1).

Table Ger. 1. **Wintering pattern in Wickham clones**

Wintering pattern	Clone
Very early	RRII 44, RRII 308, PB 310
Early	RRII 2, RRII 4, RRII 300, PB 311
Intermediate	RRII 1, RRII 3, RRII 206, PB 260
Late	RRII 5, RRII 6, RRII 118, RRII 203, RRII 208

In Garden IV, IRCA clones maintained the same trend as in previous years where the maximum girth was recorded in IRCA 111 (63 cm) followed by IRCA 130 (61 cm) and IRCA 109 (58 cm). ANOVA revealed the girth values of IRCA 111 and IRCA 130 to be significantly high compared to that of the control clone RRII 105 (55 cm), whereas IRCA 109, IRCA 230 and IRCA 18 had their girth comparable with RRII 105. Mean dry rubber yield in the second year of tapping was the maximum in IRCA 130 (68.3 g/t/t) followed by IRCA 111 (52.8 g/t/t) and IRCA 18 (47.8 g/t/t). These three clones were statistically on par with RRII 105 (57.9 g/t/t) for yield. Results showed continued superiority of IRCA 111 and IRCA 130 in terms of their annual girth and dry rubber yield.

In Garden V trees were opened for regular tapping and dry rubber yield was recorded. Recording of annual girth to monitor the growth of the clones in the ninth year after planting has been carried out. Among the 20 clones RRIC 100 had the maximum girth (73 cm) followed by RRIC 178 (68 cm) and RRIC 102 (67 cm), significantly higher than that of the control clone RRII 105 (53 cm).

In the experiment on the feasibility of ratooning in rubber, girth was recorded in both ratoon and polybag plants in their third year of growth (Table Ger. 2). The ratoons continued to be superior. Comparison of the root systems of healthy stumps with ratoons and that of stump that did not sprout at all showed that while degeneration of the latter was almost complete, the roots of the stumps with ratoons were very healthy and showed no signs of decay.

Table Ger. 2. **Annual performance of the ratoons**

Character	Ratoons (51 clones)	Control (polybag plants; 35 clones)
Total no. of plants	161	215
Max. girth (cm)	49	40
Min. girth (cm)	12.5	4
Mean girth (cm) ±SD	32.87 ± 7.7	11.43 ± 4.74
CV	23.35%	41.39%
No. of plants with girth >30 cm	108 (67% of total ratoons)	2 (1% of total control plants)
No. of plants with girth greater than 45 cm	8 (5% of total ratoons)	0 (0% of total control plants)

1.2. Wild genepool

Field conservation of a total of 3576 wild accessions was continued in the nurseries. Selected accessions from the initial rounds of screening were further scored for *Oidium* and *Corynespora* resistance. Attempts were also made to introduce more wild accessions from the Malaysian Rubber Board. Reestablishment of the conservation nurseries was initiated and in the first phase 558 wild accessions were planted. Morphological characterization and cataloguing of the accessions were done. Data were recorded for girth and foliar characters including total leaf area at the end of one year growth. Field screening of the wild accessions for drought resistance in collaboration with the Plant Physiology Division was initiated.

2. Characterization and preliminary evaluation

Growth of the wild accessions in the preliminary evaluation trials (PETs) was monitored by recording their girth annually. In the PET 1994A, AC 757 recorded the highest girth followed by RO 895, MT 940 and AC 664. In the PET 1994B, AC 643 recorded the highest girth. Ten clones including RRII 105 had girth similar to that of AC 643. Nineteen clones in PET 1994C had a girth higher than that of the control clone, with RO 893 recording the highest girth followed by AC 465, AC 645, AC 605 and RO 278. Annual girth recorded in PET 2000A was the maximum in RO 3758 (23 cm), followed by MT 3078 (20 cm), MT 4379 (18 cm) and RO 2375 (17 cm). In PET 2000 B several accessions superior in growth were identified. In PET 2002, the accession AC 567 (10 cm) recorded the highest girth followed by MT 5269 (8 cm), RO 1231 (8 cm) and RO 1769 (8 cm). Accessions were morphologically characterized at juvenile phase using a set of descriptors. In PET 1994 A, B and C annual girth and dry rubber yield and wintering pattern were recorded monthly. The last round of scoring for *Oidium* resistance was carried out in the PETs in collaboration with the Plant Pathology Division.

3. Further evaluation and selection

In the 1995 evaluation trial no accession had significantly higher girth than RRII 105. Sixty-two accessions attained girth similar to that of RRII 105, of which 36 were from Mato Grosso, 14 from Rondonia and 12 from Acre.

Trees with 35 cm girth and above were opened for tapping, and yield collection was initiated by cup lump method.

In the collaborative experiment with Plant Physiology Division on wintering pattern, tissue composition and susceptibility to oxidative damage in a selected population of high girth and low girth accession lines (20 accessions), RAPD analysis was carried out.

A new trial with 22 selected accessions was field planted and early growth was recorded.

4. Screening

4.1. Biotic stress resistance

In collaboration with Pathology Division, second round laboratory screening of selected wild accessions for *Phytophthora* was completed and 105 accessions with tolerance and 30 accessions with moderate tolerance were selected for further screening. Screening for *Oidium* resistance was carried out in 35 short listed accessions for reconfirmation of the tolerance. Three accessions – RO 2361, RO 2871 and AC 3131 had high level of tolerance and will be screened in a laid out trial for final confirmation of their resistance levels. The second round of laboratory screening for *Corynespora* resistance was in progress.

4.2. Abiotic stress resistance

4.2.1. *Drought tolerance*

Data on growth parameters and after-

noon (AN) leaf water potential were recorded from 16 wild accessions along with four control clones, RRII 208, RRIM 600, Tjir 1 and RRII 105 in the pot experiment for screening for drought tolerance (Table Ger. 3). Accession MT 1623 was superior in growth and vigour during the pre stress period.

In the post stress period also MT 1623 maintained the maximum girth (6.30 cm) whereas maximum height was recorded by MT 60 (181.0 cm) and maximum number of leaves by MT 200 (38.25). Among the control clones RRIM 600 showed the superiority for girth (6.3 cm), height (211.5 cm) and number of leaves (40.75) compared to the other clones RRII 105, Tjir 1 and RRII 208.

Superior accessions in terms of girth increment and after noon leaf water potential during the post stress period were identified and Mato Grosso accession was found to be superior for these characters (Table Ger. 4).

Morphological characterization of these accessions was carried out based on drought related parameters. The accessions MT 1623 and MT 1681 had narrow curved leaves combined with high vigour and low percentage of yellowing, revealing their drought tolerance potential.

In the 2001 screening trial for drought tolerance at RRS, Dapchari five wild accessions *viz*. MT 1616, MT 54, MT 1649, MT 1619 and MT 1627 were identified for detailed studies.

Table Ger. 4. **Superior accessions in terms of girth increment and AN Leaf water potential in the post stress period**

Accession	Girth increment (%)	Accession (Dec. 03-March-04)	AN Leaf water potential (-Mpa) (April 04)
MT 3714	8.16	MT 3714	-4.27
MT 81	6.00	MT 1631	-4.4
MT 1623	5.00	MT 48	-4.67
MT 4242	4.17	MT 1681	-4.93
MT 1584	4.08	MT 1584	-5.06
RRII 208	0	RRII 208	-5.07
Tjir 1	0	Tjir 1	-5.34
RRIM 600	8.62	RRIM 600	-4.8
RRII 105	2.22	RRII 105	Dried

In the field screening trial of 2002 at RRS, Dapchari data on various growth and physiological characters were recorded in the first year of growth of pre and post drought periods. Superior accessions were identified for various growth parameters (Table Ger. 5).

In the second year of pre drought period also, MT 41 maintained its superiority with the maximum number of leaves produced (60.0) from maximum number of standing whorls (4.0) besides height (370 cm). This indicates the potential of this accession in the drought prone area. Another superior accession was RO 2524. Among the control clones, RRIM 600 continued to be superior in performance in terms of height (327.3cm), girth (7.91 cm), number of standing whorls (2.63) and number of standing leaves (25.0).

Majority of the wild accessions identified in the pre and post drought season were from Mato Grosso provenance *viz*. accessions

Table Ger. 3. **Range and mean of growth characters in the pre stress period**

Characters	Min.	Accession	Max.	Accession	G. Mean	Control			
						RRII 105	RRIM 600	Tjir 1	RRII 208
Height (cm)	84	MT 1584	165	MT 60	113	94	173	145	140
Girth (cm)	5	MT 1631	6	MT 1623	5	5	6	6	5
No. of whorls	1	MT 1631	3	MT 1623	2	2	3	2	3
No of leaves	8	MT 1631	27	MT 200	19	18	35	27	28
Inter nodal length (cm)	7	MT 1584	28	MT 1623	19	15	14	18	11
Petiole length (cm)	9	MT 60	23	MT 3714	15	9	12	12	14

Table Ger. 5. **Superior accessions identified for various characters in the first year of growth in trial 2002**

Character	Pre-drought		Post-drought		Pre-drought		Post-drought	
	Acces-sion	Value	Acces-sion	Value	Control	Value	Control	Value
Height (cm)	MT 179	186.70	RO 1248	180.00	RRIM 600	145.87	RRIM 600	175.81
	RO 95	148.30	AC 765	177.50	RRII 105	105.97	RRII 105	127.50
	MT 196	141.70	MT 945	173.80	Tjir 1	111.24	Tjir 1	146.18
	MT 194	141.70	MT 58	170.00				
	RO 4184	135.00	RO 4184	165.00				
Girth (mm)	MT 179	46.47	AC 765	54.73	RRIM 600	40.88	RRIM 600	43.20
	MT 58	46.16	MT 58	53.69	RRII 105	39.78	RRII 105	42.34
	MT 78	44.59	RO 3655	50.24	Tjir 1	41.35	Tjir 1	45.12
	AC 765	43.02	MT 41	49.61				
	MT 56	41.45	RO 4184	48.36				
No. of whorls	RO 4184	3.50	MT 41	4.00	RRIM 600	2.92	RRIM 600	21.00
	MT 56	3.50	MT 56	4.00	RRII 105	2.32	RRII 105	2.57
	MT 41	3.50	AC 765	3.75	Tjir 1	2.32	Tjir 1	3.17
	MT 194	3.33	RO 4184	3.75				
	MT 196	3.33	MT 191	3.67				
No. of leaves	MT 56	39.75	MT 41	64.00	RRIM 600	33.91	RRIM 600	40.97
	MT 196	37.67	MT 56	53.00	RRII 105	19.18	RRII 105	26.63
	MT 179	37.00	AC 728	40.00	Tjir 1	25.45	Tjir 1	36.32
	AC 765	32.80	MT 945	40.00				
	MT 40	31.67	AC 765	39.75				
RWC (%)	MT 38	95.02	MT 80	92.77	RRIM 600	89.26	RRIM 600	83.12
	RO 2524	94.66	RO 1248	90.07	RRII 105	89.49	RRII 105	81.44
	RO 1248	94.23	RO 2524	88.78	Tjir 1	89.63	Tjir 1	77.18
	MT 193	93.85	MT 191	88.43				
	RO 4184	93.45	RO 300	88.00				

MT 41, MT 58, MT 191 and MT 56 which showed superiority for more than one character. In the pre drought period the senescence percentage of the leaves was also worked out and the minimum senescence was recorded in MT 179 (21.28%) followed by MT 191 (21.49%), MT 196 (22.60%), RO 4184 (23.84%) and MT 40 (25.20 %). Senescence percentage in these accessions were lower than that of the control clones RRIM 600 (30.02%), RRII 105 (43.93%) and Tjir 1 (35.67%).

At the age of 18 months, accessions *viz.*, MT 41, MT 945, MT 58, MT 179, RO 2524 and AC 728 were found superior for the growth characters reaffirming the overall superiority of Mato Grosso accessions in drought conditions. Ten superior accessions were identified based on their high girth and RWC (Table Ger. 6).

Table Ger. 6. **Superior accessions in terms of girth increment and change in RWC at the age of 18 months**

Girth increment (%)	Change in RWC (%)
RO 2524 (217.48)	MT 41 (+1.39)
MT 193 (176.60)	AC 405 (+0.41)
AC 676 (170.83)	MT 73 (-1.72)
MT 40 (149.17)	MT 184(-2.55)
AC 728 (146.09)	MT 80 (-2.80)
MT 945 (140.68)	RO 4184 (-3.38)
RO 3655 (126.72)	MT 191 (-3.52)
MT 38 (122.88)	AC 661 (-3.86)
AC 650 (122.20)	AC 650 (-4.09)
MT 41 (121.43)	AC 765 (-4.30)
RRIM 600(93.73)	RRIM 600 (-6.88)
RRII 105 (60.0	RRII 105 (-8.89)
Tjir 1 (61.77)	Tjir 1 (-13.81)

Field planting of another set of 130 wild accessions was completed at RRS, Dapchari, in 2.5x2.5 m spacing, adopting an augmented RBD, with a plot size of 5. The first set of data on growth parameters were recorded in the pre drought phase (Table Ger. 7). The accessions showed wide variability for all the characters studied with a general superiority shown by Mato Grosso accessions, for almost all the growth characters with less leaf senescence.

Girth increment in the juvenile phase and leaf senescence percentage indicates the growth performance of accessions in the juvenile phase. Accordingly, the accessions with the higher values for girth increment and with the lesser leaf senescence are shown in Table Ger. 8, indicating the potential of these accessions in the juvenile stage, in the drought prone area. Among the control clones, RRII 208 showed highest girth increment and RRII 105 showed the lowest leaf senescence.

In the drought evaluation trial of 1996 annual girth and crotch height were recorded. RO 2625 recorded the highest girth of 52 cm followed by RO 5430 (51 cm), RO 5556 (49 cm) and MT 196 (49 cm) where as control clones RRII 208 and RRII 105 recorded 54 cm and 41 cm, respectively. Lower crotch height was noted in AC 685 (227 cm), RO 5463 (243 cm) and AC 707 (256 cm) where as higher crotch height was in RO 5430 (350 cm), AC 68 (329 cm) and MT 53 (324 cm).

In the collaborative project on rapid screening of *Hevea* germplasm lines for intrinsic drought tolerance traits, initiated the standardization of the protocol for the rapid screening of the entire wild germplasm accessions, and conducted a preliminary field level scoring for drought tolerance in 600 wild accessions during the summer months.

Table Ger. 8. **Outstanding accessions in the juvenile phase based on girth increment and senescence**

Girth increment (%)	Senescence (%)
MT 81 (81.52)	MT 47 (24.38)
MT 3693 (68.42)	RO 3078 (31.22)
RO 1758 (66.67)	MT 3693 (33.54)
MT 48 (64.91)	RO 2835 (36.17)
RO 86 (61.52)	RO 2889(37.15)
AC 1875 (59.24)	RO 2902 (37.89)
MT 82 (56.38)	MT 4222 (38.08)
RO 1776 (56.32)	MT 1645 (40.70)
RO 1540 (54.90)	RO 3660 (41.18)
MT 72 (54.12)	RO 1278 (41.36)
RRIM 600 (36.47)	RRIM 600 (39.79)
RRII 105 (30.91)	RRII 105 (35.42)
Tjir 1 (36.48)	Tjir 1(37.35)
RRII 208 (52.58)	RRII 208 (44.77)

4.2.2. Cold tolerance

In the two trials for screening of wild germplasm for cold resistance at RRS, Nagrakata the maximum girth was recorded in MT 3452 (26.05 cm) while the control clones SCATC 93/114 and RRIM 600 had lower girth values (22.29 cm and 19.9 cm respectively). The accession MT 1072 recorded the maximum test tap yield of 8.74 g/t/t in the pre-winter period while the control clones SCATC 93/114 and RRIM 600 recorded a lower yield of 0.78 g/t/t and 3.01 g/t/t respectively. In Trial 2, maximum girth

Table Ger. 7. **First year (pre drought) data on range and mean of growth characters in 130 accesssions**

Characters	Min.	Accession	Max.	Accession	G. Mean	Control			
						RRII 105	RRII 208	RRIM 600	Tir 1
Height (cm)	75.0	AC 1797	284.00	MT 1697	192.78	140.9	170.58	191.19	49.10
Girth (mm)	27.9	RO 2809	63.74	MT 1681	49.51	41.00	40.59	42.69	39.50
No. of whorls	1.0	MT 49	4.00	RO 1526	2.49	2.54	2.78	3.51	2.84
No. of leaves	3.4	RO 1301	56.80	MT 3686	37.90	31.80	37.62	50.03	45.10
Senes-cence (%)	24.4	MT 47	92.45	RO 1301	45.75	35.42	44.77	39.79	37.30

was recorded by MT 915 (27 cm), which was higher than the girth of the control clones RRIM 600 (22 cm) and Haiken 1 (25 cm). Maximum test tap yield in this trial was recorded by AC 3514 with 8.03 g/t/t while that of RRIM 600 was 3.72 g/t/t and that of Haiken 1 was 3.65 g/t/t.

In Trial 1 in the post winter phases only three accessions MT 3452 (27.82 cm), RO 2272 (26.67 cm) and RO 3028 (26.59 cm) had a significantly higher girth compared to RRIM 600 (22.56 cm), while no accession had a higher girth compared to SCATC 93/11 (24.61 cm). In the trial, 29 accessions were found statistically comparable with RRIM 600 and 23 accessions with SCATC 93/11 for their post winter girth. In Trial 2, MT 915 retained its vigour in the post winter period also, with a girth of 28 cm compared to RRIM 600 (24.14cm) while it was on par with Haiken 1. The post winter girth of 13 accessions were on par with RRIM 600 and 10 accessions with Haiken 1.

Accordingly in Trial 1, five accessions *viz.*, MT 3452, RO 2272, RO 3028, RO 2889 and AC 3057 were identified as superior in vigour in terms of their higher post winter girth values of 27.82 cm, 26.67 cm, 26.59cm, 25.51 cm and 25.05 cm. In Trial 2 the accessions MT 915, AC 3514, RO 2727, MT 1020 and MT 2229 were identified superior in terms of their post winter girth.

Response in growth to the cold stress was assessed using the girth increment values over the stress period in the two trials. In Trial 1, RO 2272 had the highest girth increment of 2.95 cm (Table Ger.9). The five accessions, which showed highest girth values in their annual growth, had only medium rate of growth during the stress period as indicated by their girth increments showing their superiority for their overall performance. In Trial 2, maximum girth increment over the stress period was in RO 2727 (2.24 cm). Four of the first five accessions with highest annual girth recorded in the pre winter phase had high girth increment during the stress period while the fifth accession, AC 3514 had a medium girth increment of 1.51 cm only.

Table Ger.9. **Response of selected accessions to cold conditions in terms of girth increment in trial 1 and trial 2.**

Accession	Increment (cm)	Increment (%)
RO 2272	2.95	12.43
AC 486	2.58	12.35
RO 3078	2.37	12.07
RO 322	2.33	10.40
RO 3229	2.33	10.40
AC 3057	2.04	8.87
RO 2889	1.76	7.41
MT 3452	1.77	6.79
RO 3028	1.62	6.49
Trial 2		
RO 2638	2.28	10.64
RO 2727	2.24	8.93
RO 3169	1.88	8.07
MT 2229	1.88	7.63
MT 915	1.97	7.54

Growth of the wild accessions during the first three years (2001-2003) in the cold conditions of Nagrakata in terms of their girth and girth increment during the pre and post winter periods was assessed in Trials 1 and 2. Ten accessions in Trial 1 and five in Trial 2, showed stability in their growth during the pre and post winter periods over three years.

4.2.3. *Timber latex traits*

In the field evaluation trial for screening of 19 selected wild accessions and six Wickham clones for timber-latex traits, annual girth, girth increment, bole height and bole volume were recorded and analysed at the age of 42 months. The mean girth of wild accessions ranged from 12.99 to 18.36 cm and the maximum was recorded in RO 322 (18.36 cm). Among the six Wickham clones, RRII 33 (20.48 cm) showed the highest girth and the lowest in RRII 105 (15.15 cm) (Table Ger. 10).

Table Ger. 10. **Annual girth, girth increment, bole height and bole volume at the age of 42 months**

Wild accessions	Girth (cm)	Girth incre. (cm)	Bole ht. (m)	Bole vol. (m^3)
RO 322	18.34	6.28	2.93	0.005
MT 1021	17.75	7.49	3.10	0.007
MT 999	16.53	6.46	3.17	0.007
MT 915	16.48	6.98	3.20	0.006
AC 650	15.94	2.95	3.23	0.006
MT 1032	15.24	5.89	3.36	0.004
AC 637	15.24	2.17	2.90	0.004
AC 635	15.13	4.07	2.90	0.004
MT 941	15.12	4.19	3.50	0.005
MT 919	14.79	4.09	2.20	0.005
AC 707	14.65	1.89	2.92	0.004
RO 255	14.53	5.97	3.13	0.004
MT 922	14.17	2.73	2.83	0.004
MT 1020	14.12	5.31	3.16	0.004
MT 935	13.59	3.44	2.86	0.003
AC 685	13.55	1.34	2.82	0.005
AC 651	13.42	1.45	3.21	0.005
RO 879	13.19	1.93	2.70	0.003
AC 655	12.99	3.50	2.86	0.003
Wickham clones				
RRII 33	20.48	9.18	3.17	0.008
PB 235	20.27	8.58	3.13	0.008
PB 260	19.33	9.04	3.13	0.007
RRIM 600	18.64	9.37	3.03	0.006
RRII 118	18.34	7.77	2.86	0.006
RRII 105	15.15	5.88	2.97	0.004
CD (P = 0.05)	3.06	3.29	0.39	NS

Analysis of variance indicated that Rondonian accession, RO 322 showed a significantly higher girth over RRII 105 and all others were statistically comparable with RRII 105. One accession (MT 1021) was similar to RRII 33 while five accessions (RO 322, MT 1021, MT 999, MT 915 and AC 650) were comparable with RRII 118 and RRIM 600. Four accessions (RO 322, MT 1021, MT 999 and MT 915) were similar to PB 260 and two accessions (RO 322 and MT 1021) were comparable with PB 235.

Analysis of variance for the girth increment indicated that none of the wild accessions showed a significantly higher girth increment over all the Wickham clones. Girth increment of four accessions (MT 999, MT 915, MT 1021 and RO 322) were on par with RRIM 600. Six accessions (MT 1020, MT 999, MT 915, MT 1032, RO 322 and RO 255) had the girth increment similar to that of RRII 33, PB 260, and PB 235. Seven accessions (MT 1020, MT 999, MT 915, MT 1032, MT 1020, RO 322 and RO 255) had the girth increment on par with RRII 33, PB 260, PB 235 and RRII 118, while 14 accessions had their girth increment similar to clone RRII 105.

The average bole height was significantly higher in two accessions (MT 941 and MT 1032) over RRII 105 and RRII 118 while MT 941 was statistically superior to RRIM 600 and 17 accessions were similar to RRII 33, PB 235 and PB 260 for this character.

The bole volume at the age of 42 months ranged from 0.003 m^3 to 0.007 m^3 in the wild accessions with the maximum value for MT 999 and MT 1021. No significant difference was observed among the clones for this character. Among the Wickham clones, RRII 33 and PB 235 ranked top for bole volume. Morphological characterization was done in this trial and documented through digital photography. Wide variability was observed in the branching pattern and canopy architecture.

In the experiment on screening of germplasm for timber quality traits, 18 wild accessions (Acre – 6; Rondonia – 6; Mato Grosso – 6) and two Wickham clones (RRII 105 and RRIM 600) were selected from the SBN 2000 for the identification and localization of lignin precursor enzymes.

Localization of Cinnamyl Alcohol Dehydrogenase (CAD) and Peroxidase in nitrocellulose membranes was done in four wild accessions (AC 4679; RO 4606; MT 5686, MT 4859) and two controls. Stem samples (180 samples) were collected from all the experimental plants in triplicate at three height positions and freeze dried at –80° C . The frozen samples were ball milled and prepared the xylem powder for lignin estimation.

In the study on variability in structure and properties of wood of *Hevea* clones felling and wood sampling of 42 trees (6 trees per clone *viz*. RRII 105, RRIM 600, PB 260, PB 235, PB 310 , PR 261 and PB 311) were completed. The 630 wood samples (size - 6x 43 cm) collected from 42 trees were processed for testing the physical and mechanical properties *viz*. shrinkage, density, static bending, compressive stress, tensile stress and hardness in the wood testing laboratory, Manganam

5. Molecular characterization

In the experiment on RAPD profiling and evaluation of genetic diversity in wild *Hevea* accessions, in collaboration with Genome Analysis Laboratory, RAPD reactions in 110 selected accessions, with 17 primers were completed and RAPD profiles scored. Profiles exhibited a high degree of polymorphism. Data was analyzed and a UPGMA dendrogram constructed based on genetic dissimilarity, which grouped the wild accessions into 7 genetically divergent clusters.

MYCOLOGY AND PLANT PATHOLOGY DIVISION

The major research areas of the division included chemical and biological control of pathogens and pests of *Hevea brasiliensis*, molecular characterisation of pathogens, host pathogen interaction, etiology of tapping panel dryness, microorganisms in plant growth and management of effluent from rubber processing.

1. Leaf diseases

1.1. Abnormal leaf fall

The experiment on evaluation of crop loss due to abnormal leaf fall disease was concluded. It was observed that clone RRIM 600 suffered heavy crop loss (31.66%) due to the disease with annual loss varying from 15.39 to 46.41%. In the case of RRII 105 there was no overall crop loss although the loss during individual year was up to 24.94%. This clone although suffered crop loss during monsoon season, compensated for the loss in the succeeding months after refoliaiton. Overall crop loss of clones GT 1 and RRII 118, were 8.21 and 7.15% respectively. Timber yield was higher in the sprayed plots of RRIM 600, GT 1 and RRII 118 while the total timber yield in the clone RRII 105 was not affected. In clone RRII 118, increase in timber yield due to spraying was significant (Table Path 1).

Table Path 1. **Effect of protection against abnormal leaf fall disease**

Clone	Treatment	Tree stand	Latex yield* g/t/tap	Timber yield (m^3/ha)	Cumulative crop loss (%)
RRIM 600	Sprayed	234	74.65	126	31.66
	Unsprayed	300	59.96 (87.98)	111	
RRII 105	Sprayed	219	82.82	93	-2.95
	Unsprayed	169	83.94 (83.47)	114	
GT 1	Sprayed	240	57.14	120	8.21
	Unsprayed	260	55.36 (60.32)	111	
RRII 118	Sprayed	237	58.38	174	7.15
	Unsprayed	235	49.92 (53.53)	132	

· Potential yield given in parentheses

New experiment on crop loss evaluation in clones RRII 414, RRII 422 and RRII 429 with PB 260 as control has been initiated.

The survey on incidence of abnormal leaf fall disease in clone RRII 105 was repeated for the third season covering 2,40,603 hectares under 162 field offices under 28 regional offices in the traditional regions. Majority (83.26%) of the areas had less than 25% leaf fall. The area with leaf fall above 50% was confined to central and northern regions. There was improvement in the area under spraying (9.28%) over previous years.

The scope for reducing the dosage of copper oxychloride (COC) when rubber seed oil (RSO) and spray oil (SO) were mixed (1:2 proportion) and used as diluent for spraying against abnormal leaf fall disease was investigated in two clones, (RRIM 600 and RRII 105), in a disease-prone area. Lower doses of COC was found comparable to the recommended dose of 8kg/ha when RSO + SO was used as carrier. RSO + SO alone is not effective for disease control (Table Path 2).

High-speed diesel was evaluated as a carrier for COC for micron spraying. The fungicide was well dispersed in diesel and there was no difference in the height of spray particle deposition. The leaf retention in both treatments were comparable. Diesel has higher USR value (more pure) and is cheaper than spray oil. The lower flash point of diesel is not relevant in micron spraying unlike in aerial spraying.

The new spray oil formulation developed by M/s. Hindustan Petroleum Corporation was field-tested in four locations and the test sample was found as effective carrier for COC as currently recommended spray oils and was recommended for use.

In order to confirm the effectiveness of micronair atomiser for micron spraying it was fixed on micron sprayer and used for COC spraying (at the rate of 8 kg/ha in 40 L spray oil). The leaf retention observed was 70% with more retention in the upper canopy, confirming the effectiveness of micronair atomiser. A prototype micron sprayer was fabricated for use with a 2.5 HP engine to reduce the weight and labour requirement. Further improvements in blower case design and atomiser are required for its effective use.

A 5HP imported mist blower was modified by attaching a pump to achieve vertical discharge of spray fluid and was tested in the field. The spray height achieved was 15 meters. The sprayer can be carried by single worker and will be useful for young plantations (up to 12 years).

The field trial conducted in Palappilly region on highly susceptible clone RRIM 600 was continued for testing the efficacy of Bor-

Table Path 2. **Effect of dosage of COC on ALF control**

Location	Clone	Treatment	Leaf retention %	CD
Pudukad Estate, Trichur	RRIM 600	RSO+ SO+ 8 kg COC/ha	50.94 (45.56)	
		RSO+ SO+ 6 kg COC/ha	45.39 (41.74)	
		RSO+ SO+ 4 kg COC/ha	41.25 (39.51)	
		RSO+ SO	29.33 (31.57)	
		Unsprayed	7.92 (15.78)	12.62
Chemoni Estate, Trichur	RRII 105	RSO+ SO+ 8 kg COC/ha	65.32 (56.22)	
		RSO+ SO+ 6 kg COC/ha	59.53 (51.33)	
		RSO+ SO+ 4 kg COC/ha	50.65 (45.36)	
		RSO+ SO	22.08 (27.16)	13.74

Values in parentheses are arc-sine transformation

deaux and oil combinations in controlling *Phytophthora* leaf fall. Being disease-prone area, the disease intensity was severe in that locality. However, good leaf retention could be achieved by fungicide application. Addition of 1% rubber seed oil (RSO) or spray oil (SO) to 0.5% Bordeaux could provide a control comparable to that with 1% Bordeaux mixture.

Another experiment was undertaken on susceptible clone RRIM 600 to test the efficacy of Bordeaux spraying using tractor-mounted low volume mist blowers, which could deliver the fungicide spray up to 70 ft. High volume spraying using Horizontal Double Piston (HDP) sprayer served as control. Two rounds of spraying at an interval of 20 days was undertaken in the former, whereas only one spraying was given with HDP sprayer. Even with two rounds of spraying with low volume spray applicator satisfactory control comparable to high volume spraying could not be achieved.

Recording of yield in the crown budded experimental blocks was continued. High yield and less intensity of abnormal leaf fall was recorded in crown-budded plants. Girth and branching pattern were recorded and bole and branch volume were estimated prior to felling. Trees crown-budded with clone Fx 516 and RRII 33 on RRIM 628 recorded significantly high total wood volume while trees crown budded with Fx 516 on GT1 only gave a high wood volume (Table Path. 3).

For the proposed new crown budding experiment in clone PB 260, and polybag plants are being developed for budding in nursery itself for subsequent field planting.

Laboratory screening of germplasm accessions for *Phytophthora* resistance by detached leaf technique was undertaken. Out of 550 accessions screened, 252 showed moderate to tolerant reaction. Among this, 109 were found as tolerant as RRII 105.

The severity of abnormal leaf fall disease in various clone evaluation trials was assessed. In 1993 LST at CES Chethackal, RRII 453 was the most susceptible and RRII 417 and RRII 430 the least. In G x E interaction trial at RRS, Padiyoor RRII 430 was the most tolerant clone recording 80% leaf retention as against 43% in the susceptible clone RRIM 600. In Kanyakumari, where abnormal leaf fall is less prevalent, RRII 429 retained more leaves (74%). In the trials with prepotent clones, progenies of clones PB 215 and PB 252 were found to retain good canopy. In the trial at Sasthamcotta, leaf fall was mild irrespective of clones whereas in the ortets planted at Koney Estate, severe leaf fall was recorded in susceptible clones.

The rDNA RFLP of *Phytophthora* iso-

Table Path 3. **Bole and branch volume in crown-budded trees**

Location	Crown/clone	Bole volume (m^3)	Branch volume (m^3)	Total wood volume (m^3)
Kinalur	Fx 516	0.52	0.23	0.75
(Calicut)	RRII 33	0.26	0.11	0.37
	F 4542	0.22	0.05	0.27
	GT 1 (Control)	0.29	0.13	0.42
	CD	0.10	0.06	0.10
Kaliyar	Fx 516	0.61	0.31	0.92
(Thodupuzha)	RRII 33	0.51	0.31	0.82
	F 4542	0.23	0.10	0.33
	RRIM 628 (control)	0.17	0.13	0.30
	CD	0.06	0.06	0.08

lates collected from the traditional rubber growing areas were amplified with ITS4 and ITS6 primers. Amplified rDNA restricted with two different restriction endonucleases gave uniform pattern confirming their identity as *P. meadii*.

Tagging *Phytophthora* resistant genes was attempted. DNA was isolated from RRII 105 and its parental clones. RAPD analysis of the isolated DNA was carried out with 20 random primers of which OPA 1, OPF 10, OPA 10 primers showed a polymorphic-banding pattern with susceptible parent.

1.2. Shoot rot

Five bacterial antagonists were tested for their efficacy against shoot rot disease caused by *Phytophthora* spp in the field. One of the antagonists (PB 8) could reduce the disease intensity compared to others.

Efficacy of Bordeaux mixture + oil combinations in controlling shoot rot disease was compared with Bordeaux mixture + other adjuvants in the field experiment laid out at Thodupuzha in one-year-old plants. Treatments with addition of 1% rubber seed oil or neem oil to 0.5% Bordeaux were found as effective as the recommended 1% Bordeaux mixture (Table Path. 4).

Copper retained on leaves between two sprayings was estimated and no significant difference was noticed among the treatments

1.3. Powdery mildew

A field experiment in one year old RRII 105 plants was carried out at TR & T Estate, Mundakayam to evaluate a systemic triazole fungicide, difenconazole and a systemic acquired resistance (SAR) inducing principle, benzothiadiazole alone and in combination with difenconazole and carbendazim in checking powdery mildew disease. Difenconazole (0.025%) was found to be effective against the disease when sprayed at weekly intervals. Combined application of benzothiadiazole (0.05%) + carbendazim (0.05%) recorded minimum disease intensity followed by benzothiadiazole (0.05%) + difenconazole (0.025%) (Table Path. 5).

Table Path. 5. **Effect of fungicides for control of powdery mildew disease**

Fungicides	PDI
Carbendazim (0.05%)	14.3
Difenconazole (0.025%)	14.2
Benzothiadiazole(0.1%)	13.0
Benzothiadiazole(0.05%)	13.7
Benzothiadiazole(0.05%)+Carbendazim (0.05%)	11.3
Benzothiadiazole(0.05%)+Difenconazole (0.025%)	12.3
Control	24.7
CD (P=0.05)	4.2

Table Path 4. **Incidence of shoot rot disease**

Treatment	Shoot rot incidence (%)
1% Bordeaux mixture	15.33 (3.90)
1% Bordeaux mixture + 1% Rubber seed oil	8.67 (2.94)
1% Bordeaux mixture + 1% Neem oil	10.33 (3.21)
1% Bordeaux mixture + Sandovit	13.33 (3.63)
1% Bordeaux mixture +Apsa	12.33 (3.46)
0.5% Bordeaux mixture	19.33 (4.39)
0.5% Bordeaux mixture + 1% Rubber seed oil	13.33 (3.63)
0.5% Bordeaux mixture + 1% neem oil	15.33 (3.89)
0.5% Bordeaux mixture + Sandovit	21.33 (4.61)
0.5% Bordeaux mixture + Apsa	18.00 (4.24)
Unsprayed control	26.00 (5.08)
CD (P=0.05)	0.71

CD for transformed values in parentheses

In the nursery evaluation of fungicides for control of powdery mildew disease, minimum disease intensity was recorded in benzothiadiazole(0.05%) + carbendazim (0.05%) followed by difenconazole (0.025%).

The clones in G x E interaction trial were evaluated for powdery mildew disease tolerance at two locations. In Padiyoor, maximum disease was noticed in the clone RRII 203 (48.33%) and minimum in the clone RRIC 100 (17.92%). However, in Kanyakumari, the differences were not significant.

In the trial for the evaluation of prepotent clones, minimum disease was noticed in the progenies of the family PB 5/76 (34.83%) and AVT 73 (40.0%). The seedling progenies of prepotent parent clones were also evaluated and the results were non-significant. The seedlings of HP 2002 were also evaluated for powdery mildew disease tolerance. A total of 207 seedlings out of 1030 recorded ≤ 25% disease. Powdery mildew disease intensity in germplasm accessions in Source Bush Nurseries, Evaluation Trials and Germplasm Gardens was assessed and 35 accessions with tolerant traits were short-listed. Severity of powdery mildew was also assessed in the 3 trials to evaluate selected ortets at Koney Estate and Clone evaluation trial at Sasthamcotta. Disease intensity was severe in susceptible clones at both the locations. Incidence of powdery mildew was also assessed in crown budded trees. Powdery mildew was moderate in RRII 33 and mild in Fx 516 crowns.

1.4. Colletotrichum leaf disease

Colletotrichum gloeosporioides has earlier been reported as the causative agent of Colletotrichum leaf fall disease. However recent study revealed that the fungus *C. acutatum* also plays a significant role in the development of the disease. Hence a study has been initiated to confirm the major cause of the disease in India. Diseased specimens were collected from different regions and clones during 2003 disease season. Leaf bits showing different symptoms like, typical raised spots, dark brown or black spots and dried margins were taken and the pathogen was isolated on Potato dextrose agar. The emerging colonies from each bit were grouped into two based on the growth characters (slow growing/fast growing) and conidial shape (fusiform/cylindrical). In total 65% of the colonies were of slow growing with fusiform conidia i.e., *C. acutatum* and only 35% were fast growing with cylindrical conidia i.e., *C. gloeosporioides*. Both the species could be isolated from all types of symptoms. However all the isolates from North East India were of *C. gloeosporioides*.

Selected colonies were further characterized based on growth rate at 25°C, conidial shape and fungicide sensitivity for confirming the species. Studies on fungicide sensitivity revealed that all the fast growing isolates (*C. gloeosporioides*) were highly sensitive to carbendazim and less sensitive to mancozeb while slow growing isolates (*C. acutatum*) were less sensitive to carbendazim (Table Path. 6).

A field experiment for Colletotrichum leaf disease control was carried out at TR&T Estate, Mundakayam on one-year-old plants of clone RRII 105 for the evaluation of fungicides. Fungicides were sprayed at weekly intervals. The disease control was superior with azoxystrobin (0.025%) followed by difenconazole (0.025%) (Table Path. 7).

Field evaluation of systemic acquired resistance inducing compound, benzothiadiozole for the control of Colletotrichum leaf disease was carried out in TR & T Estate, Mundakayam on one-year-old plants of clone RRII 105. Benzothiadiazole was evaluated at two concentrations and in combination with carbendazim and difenconazole. Single application of benzothiadiazole (0.1% and 0.05%) was comparable with the recom-

Table Path. 6. **Sensitivity (% inhibition) of *Colletotrichum* isolates to fungicides**

Isolate No.	Carbendazim (ppm)			Mancozeb (ppm)		
	2	5	25	50	100	250
1	92.80	94.44	100.00	16.70	19.44	25.00
4	100.00	100.00	100.00	5.50	8.80	11.44
14 (1)	89.90	100.00	100.00	11.90	26.70	31.90
14 (2)	52.80	56.33	66.37	32.44	43.00	46.80
26 (1)	56.59	60.72	68.70	20.50	68.80	69.23
26 (2)	47.74	65.50	69.20	21.60	26.75	39.64
20 (2)	45.61	53.50	58.54	21.20	28.92	37.35
21 (1)	55.33	60.03	65.30	17.20	23.90	34.84
23 (2)	47.60	52.20	57.80	21.99	31.44	38.53
24 (2)	50.34	57.11	63.90	27.03	29.83	38.40
36	100.00	100.00	100.00	9.14	20.60	22.80
37	27.20	42.70	45.14	18.4	27.70	35.53

Table Path. 7. **Effect of fungicides on Colletotrichum leaf disease – field evaluation**

Fungicides	PDI
Mancozeb (0.2%)	20.1
Carbendazim (0.05%)	21.0
Difenconazole (0.05%)	12.3
Chlorothalonil (0.2%)	16.8
Propineb (0.2%)	21.2
Azoxystrobin (0.025%)	3.6
Difenconazole (0.05%) + mancozeb (0.2%) (alternate)	21.0
Control	27.6
CD (0.05)	7.1

mended fungicides. However, combination of benzothiadiazole (0.05%) + mancozeb (0.02%) recorded the lowest disease intensity followed by benzothiadiazole (0.05%) + carbendazim(0.05%). Nursery evaluation of benzothiadiazole on Colletotrichum leaf disease was undertaken at RRII on clone RRIM 600. The lowest disease intensity was noticed in difenconazole (0.025%) and hexaconazole + benzothiadiazole (0.05%) treatment.

In vitro studies employing dual culture technique indicated that six *Trichoderma* isolates showed antagonistic activity by overgrowing the pathogen and two bacterial isolates produced inhibition zone against the pathogen.

In the compatibility studies, carbendazim inhibited the growth of all the six *Trichoderma* isolates completely even at 10 ppm whereas with mancozeb all the isolates were compatible even up to 2000 ppm.

1.5. Corynespora leaf disease

Pathogenicity and toxin production of 60 different isolates collected during 2003 disease season from different regions of Kerala and Karnataka was studied. All the isolates showed susceptible reaction to RRII 105 and tolerant reaction to GT 1 with higher wilting percent in the former when estimated by leaf wilt bioassay using crude culture filtrate. Variation in pathogenicity and wilting intensity was observed among the isolates. All the isolates from GT 1 were found to be aggressive with high per cent wilting in both the test clones

Sixty isolates were tested for their sensitivity to two fungicides *viz.* carbendazim and mancozeb. Carbendazim was tested at 25 ppm, 5 ppm and 2 ppm concentrations and mancozeb at 250, 100 and 50 ppm concentrations. All the isolates were found to be sensitive to carbendazim The response of the isolates to mancozeb was highly variable. Four isolates showed complete inhibition in the presence of mancozeb even at the lowest concentrations tried. One isolate was found to be less sensitive to mancozeb at all the three concentration tested.

Salicylic acid-induced systemic resistance against *C. cassiicola* was tried in four

clones *viz*. GT 1, RRIM 600, PR 107 and RRII 105. Of the different concentrations of salicylic acid tried, 0.03% was found to be effective. Scorching of leaves was observed at higher concentrations.

In GT 1, on infection with Corynespora 30 units of chitinase activity was estimated in 24 h, while it was only 20 units in RRIM 600 and 15 units in PR 107 and RRII 105. A gradual increase in chitinase activity was observed up to 96 h in GT 1. Phenylalanine Ammonia Lyase activity was estimated spectrophotometrically using L-Phenylalanine as substrate. In GT 1, 40 µm $Prot^{-1}$ min^{-1} of PAL activity was estimated in 24 h where as it was 28 µm $Prot^{-1}$ min^{-1} in RRIM 600 and 20 µm $Prot^{-1}$ min^{-1} in RRII 105 and PR 107.

One hundred isolates of *C. cassicola* isolates collected from different rubber growing areas in Kerala and Karnataka region during 2001-2003 disease seasons were analysed for their genetic variability using enterobacterial repetitive introgenic consensus sequences (ERIC) for the DNA fingerprinting. The isolates could be grouped into four groups

RAPD analysis did not show any genetic variability in the isolates which were exposed to carbendazim and mancozeb for five generations. Five clones *viz*., RRII 414, RRII 417, RRII 422, RRII 429 and RRII 430 were screened for resistance to *C. cassiicola*. Chitinase and PAL activity were high in RRII 429. A total of 744 accessions were screened against *C. cassiicola* in the laboratory by detached leaf technique. Of these, 390 (29 MT, 135 AC, 134 RO, and 2 OR accessions) showed tolerant/ moderately tolerant reaction.

2. Stem diseases

2.1. Pink disease

Field experiments to compare the efficacy of adding vegetable oils to Bordeaux paste was continued. Addition of rubber seed oil, neem oil and 'punna' oil to Bordeaux paste improved the efficacy and better recovery was recorded (Table Path. 8).

Table Path. 8. **Recovery of plants from pink disease**

Treatment	Recovery of plants (%)
Bordeaux paste alone	65.0
Bordeaux paste + 10 % Rubber seed oil	85.0
Bordeaux paste + 10% neem oil	90.0
Bordeaux paste + 10% Punna oil	80.0
Bordeaux paste + 1% Rubber seed oil	75.0
Bordeaux paste + 1% neem oil	80.0
Bordeaux paste + 1% Punna oil	85.0

Efficacy of a new copper fungicide, *Coptrel* (Cuprous oxide) was evaluated in three-year-old plants. Treatment with Coptrel resulted in 90% recovery as against 65% in Bordeaux paste.

Disease survey was continued in traditional regions and commenced in non-traditional areas. PB 260 and RRIC 100 were found less susceptible, whereas RRII 105 remained as the most susceptible clone followed by PB 217. Mundakayam, Pathanamthitta and Thodupuzha regions were highly disease-prone, whereas Kanyakumari region was the least affected in the traditional belt. Among the non-traditional regions, few incidence was noticed in Tripura, whereas Nagrakata region in northern part of West Bengal had higher disease incidence.

Pink disease incidence in the RRII 400 series clones was recorded in various trials at different locations. The clone RRII 429 was the most susceptible, whereas RRII 410 and RRII 422 were the least.

2.2. Bark rot disease

Field evaluation of different systemic and contact fungicides against the bark rot disease was carried out on the clone PB 28/ 59 at Lahai Estate. The results showed lower disease incidence with mancozeb (9.21%)

and Cymoxanil M8 (10.75%) treatments.

Two panel protectant formulations *viz.*, Cresent rubber coat and Rubmate were found good for use in rubber plantations and where recommended to planters.

3. Root diseases

3.1. Brown root disease

Observations on disease progress in the brown root disease control trial at Mayilellampara, Kozhikode were continued.

Lower doses of tridemorph (0.2%) and propiconazole (0.05%) were found effective. No further spread of the disease to the neighbouring plants was observed. Another brown root disease control experiment was initiated in a mature rubber plantation in TR & T Estate, Mundakayam to observe the effect of fungicide treatment on advanced stages of disease incidence.

A study was undertaken on artificial inoculation and induction of brown root disease in polybag plants and trees. The artificially infected stem/root bits were used for inoculation on roots. No symptom of brown root infection was observed on trees but polybag plants showed infection after eight months.

4. Retention and residual studies of copper in rubber plantations

Water samples were collected from wells and streams of RRII, Lahai Estate, CES, Chethackal and Pudukkad Estate. The copper content of these samples ranged from 0.019 to 0.0057 ppm, well within the safe limits prescribed.

5. Tapping Panel Dryners (TPD)

Rubber trees injected with Tetracycline, penicillin, carbendazim and Flagyl injected during 1998 to 2001 at Malankara and Vaniampara estates were continuously monitored for symptom remission. At both locations no remission of symptoms of TPD was noticed. TPD symptoms were noticed also in status 1 and 0 stages of tapping where prophylactic injection was given, irrespective of the treatments.

Many trees that showed the presence of low molecular weight RNA (viroids) in R-PAGE but with no apparent symptoms of TPD at the time of sampling two years earlier showed symptoms of TPD when observed recently (Table Path. 9) confirming the occurrence of symptom less carrier trees for the viroid (LMWRNA).

A total of 1700 seedlings were successfully budded and transferred to polybags at CES Chethackal. Out of 233 leaf samples tested from these seedlings by R-PAGE analysis 64 showed viroid bands.

Tapping knife sterilization experiment was continued at Vaniyampara Estate, Thrissur to study the transmission of viroids from tree to tree through tapping knife. The tapping knife was dipped in any of the chemicals *viz.* Tri sodium orthophosphate, Combatan, Sodium hypochlorite and Glutaryl before tapping and the trees were

Table Path. 9. **Results of R-PAGE Analysis**

Location	Total no. of diseased trees tested	Test result +ve	Total no. of apparently healthy trees tested	Test result +ve	Test result -ve
Vaniyampara	13	9	14	8 (4)	6
Malankara	19	14	8	3 (3)	5
RRII	10	7	10	6 (2)	4
CES Chethackal	25	23	15	13 (8)	2

Figures in parenthesis indicate the number of trees that were apparently healthy at the time of testing but showed viroid bands and later turned TPD affected.

observed periodically for the appearance of TPD. The disease spread was monitored by the appearance of TPD in the trees tapped immediately next to TPD affected trees. Even though fresh incidence of TPD was noted in the experimental area, spread from the affected tree to the nearby tree could not be observed irrespective of the treatments.

A field experiment to study the various aspects of bark scaling of rubber trees was carried out at Anchal. Bark scaled, normal TPD, trees next to bark-scaled trees and healthy trees were marked in a plantation and monthly recordings of girth, intensity of TPD based on length of dry portion of taping cut, DRC and latex volume were done. The bark-scaled trees showed lower girth, DRC and volume of latex.

A small-scale survey was carried out in northeastern region of India to study the incidence of TPD. In all the locations in this non-traditional area where the plantations are new, TPD was observed.

6. Pests of rubber

Drenching chlorpyriphos at 0.20, 0.25 and 0.30 % gave 76 to 96% control of termites for 3 months. Arrowroot extract gave 85 per cent control for one month.

Different doses of the entomopathogen, *Beauveria bassiana* were sprayed on tree trunks infested with bark feeding caterpillar, *Aetherastis circulata*, during February, but the infection did not take place due to the low humidity There was no natural occurrence of predators, parasites and entomopathogens on larvae or pupae.

Experiments carried out on pest affected mature trees in the field showed that spraying deltamethrin 0.0056% was very effective giving 96 per cent reduction of caterpillars. Fenpropathrin 0.06% and cypermethrin 0.05% were the next effective treatments giving 93% reduction of caterpillars.

Efficacy of certain insecticides against mooply beetles, *Lyprops corticollis* ,was evaluated. It was found that deltamethrin, cypermethrin and fenvalerate were effective giving 70 to 82% mortality in 24 hours. In the field, an average of 20% beetles were observed to be naturally infected with *B. bassiana*.

Effect of *Meloidogyne incognita* on the nodulation, gall formation and symbiotic nitrogen fixation in *Pueraria phaseoloides* was studied and significant reduction in nodulation was observed by infection of nematodes. In treatments where nematode inoculation preceded *Rhizobium* inoculation, the reduction in nodule formation was more. Number of galls was also reduced significantly in the plants inoculated with *Rhizobium* and nematode simultaneously, and ten days prior or later to each other when compared to those inoculated with nematode alone.

Soil samples were collected from Kanhangad, Nilambur, Kottayam and Kadackamom for isolating entomopathogenic nematodes (EPN) using *Corcyra cephalonica* (Rice meal moth) and *Galleria mellonella* (Greater wax moth) as baits. The samples collected from Nilambur and Kadackamon yielded the EPN, *Steinernema* sp.

7. Bee keeping

Studies indicated that between the bee keeping with *Apis cerana indica* and *Apis mellifera*, the keeping of *A. cerana indica* using family labour was more remunerative. The production of honey was 12 kg per hive for *A. cerana indica* and 30 kg for *A. mellifera*. The honey production in the rubber sector was estimated as 6700 tonnes. The honey production during the year was three times higher than that of the previous year due to favourable weather conditions that prolonged the nectar secretion in rubber trees (Table Path 10).

Table Path. 10. **Cost, net income and BCR of *A.cerana indica* and *A.mellifera* colonies (2004)**

Item	A.cerana indica	A.mellifera
Establishment cost Rs./hive/year	325	706
Maintenance cost Rs./hive/year	660	1890
Gross cost Rs./hive/year	985	2596
Cross income Rs.hive/year	1131	3030
Net income Rs.hive/year	146	434
BCR	1.15	1.17
Family labour net income Rs./hive/year	679	1394
BCR (with family labour employment)	2.5	1.85
Honey yield (kg/hive)	12 (7-16)	30 (19-38)

Figures in parenthesis represents range of honey yield (kg/hive)

9. Microorganisms for improving growth of rubber and cover crops

Rhizobium isolates nodulating *Mucuna bracteata* were isolated from soil samples collected from North East India. Two types of *Rhizobia* were collected from nodules of *Mucuna* collected from Nagrakatta.

In order to study the diversity of *Rhizobia* that nodulate *P. phaseoloides*, isolates were collected from five leguminous plants *viz.*, *Calopogonium mucunoides Centrosema pubescens, Clitoria* sp, *P. phaseoloides* and *M. bractiata* from RRII farm and studied their morphological, cultural and symbiotic characteristics using *P. phaseoloide* as test plants. The isolates varied in their colony morphology, duration of colony development, pH and nutrient requirements of the growth media, production of growth promoting substances and sensitivity to antibiotics.

The effect of different nutrient source on growth of the isolates was studied. The growth pattern varied with the isolates and nutrient sources. Production of Indole acetic acid, exopolysacchradies and siderophore also varied with the isolates. The isolates also showed variations in the pattern of antibiotic resistance.

The effect of inoculation with Rhizobial isolates collected from different leguminous plants on growth and nodulation of *P.phaseoloides* plants was studied using sterilized soil. All the isolates were found to infect and produce nodules. The various growth parameters like shoot length, root length, shoot weight, root weight, nodule and leaf numbers were found to be enhanced upon inoculation but varied among isolates.

A total of 12 isolates of *Azospirillum* were collected from rubber plantations using rubber roots in malate semi-solid media and purified. Their nitrogenase activity varied from 81.70 to 156.30 (µ mol.ethylene produced/h/100 ml).

A study was conducted to compare the effect of inoculation of *Azotobacter* sp. and *Beijerinckia* sp. on growth of rubber seedlings. One-week-old rubber seedlings were dipped in culture broth containing 10^8 cells/ml and planted in polybags. The results are presented in Table Path 11.

The seedlings inoculated with both the isolates did not show much difference in growth. Combined inoculation also did not yield higher growth than single isolate inoculation. The rhizosphere colonisation of the isolates after 5 months was more for *Azotobacter* isolates.

Nine isolates of phosphate solubilising fungi were collected. The solubilisation of

Table Path. 11. **Effect of *Azotobacter* and *Beijerinckia* inoculation on rubber seedlings**

Treatment	After 2.5 months		After 5 months	
	Height (cm)	Girth (mm diameter)	Height (cm)	Girth (mm diameter)
Azotobacter sp	66.50	6.50	113.67	8.33
Beijerinckia sp	67.83	6.83	115.83	9.00
Azotobacter + *Beijerinckia*	64.50	5.92	107.16	7.83
Uninoculated control	61.67	5.67	96.16	7.35
CD (P=0.05)	8.37	0.73	12.29	0.87

insoluble phosphate by the isolates was studied using Aluminium phosphate and Ferric phosphate (the insoluble forms of phosphate present in acidic soil) and Mussoorie rock phosphate and Rajphos (the fertiliser forms) using Pikovskaya's broth. Five isolates were found to release phosphorus from Al PO_4 while six isolates released P from Fe PO_4. Four isolates solubilised both Al PO_4 and Fe PO_4. Mussoorie rock phosphate and Rajphos were also solubilised by five isolates each.

Extra-cellular and intra-cellular production of the enzyme, acid phosphatase by the nine phosphofungi was estimated using cultural filtrate and fungal mycelia respectively in terms of P-nitrophenol (PNP) released from PNP phosphate. Eight isolates showed the secretion of both extra-cellular and intra-cellular phosphatase enzyme.

Twentythree fluorescent rhizobacteria were collected from rubber plantations during the year. All the isolates showed positive results to siderophore production by $FeCl_3$ test. Production of HCN was also studied using 23 isolates. Based on the change in the colour of picric acid reagent, five isolates were identified as medium while three isolates as high HCN producers. Antagonistic activity of the 23 isolates against the five major pathogens viz., *Corticium salmonicolor*, *Phellinus noxius*, *P. meadii*, *C. cassiicola* and *C. acutatum* was studied using dual culture technique. Nine isolates showed growth inhibition of *Corynespora*. One isolate showed antagonistic activity against all the five pathogens.

The ability of the 23 isolates to solubilise insoluble phosphate was studied in agar media and 19 isolates showed indication of phosphate solubilisation.

The potential of 7 rhizobacterial isolates collected during previous year, to stimulate plant growth was studied using *P. phaseoloides* in polybags. After 50 days, the plants were uprooted and growth parameters like length and weight of shoot and root, nodule number and weight, nitrogenase activity and rhizosphere colonisation. were recorded (Table Path. 12).

Among the seven-rhizobacterial isolates studied, maximum growth improvement was by RB 23 while RB 24 favoured higher nodulation and nitrogenase activity. Inoculated plants also showed a significant increase in the fluorescent rhizobacterial population compared to uninoculated control.

10. Waste management in rubber processing

Work on the research project on 'Design and development of high rate reactor' and its field evaluation for treating waste water from rubber processing in collaboration with TNAU, Coimbatore, was initiated. The

Table Path. 12. **Effect of rhizobacterial inoculation on growth, nodulation, nitrogenase activity and colonisation on *P.phaseoloides***

Isolates	Shoot length (cm)	Shoot Weight (g)	Root length (cm)	Root weight (g)	Nodule No.	Nodule weight (g)	Nitrogenase activity*	Fluorescent Rhizobacteria (x106cfug-1)
RB 3	33.67	5.01	21.83	1.24	18.00	0.34	503	13.00
RB 12	32.73	4.91	20.67	0.95	15067	0.28	399	14.33
RB 16	34.33	5.23	21.89	1.24	25.00	0.36	748	15.67
RB 20	29.76	5.02	21.13	0.98	18.00	0.29	383	16.00
RB 22	34.33	5.86	19.23	1.42	19.33	0.48	913	18.00
RB 23	44.5	6.38	22.27	1.72	20.00	0.48	943	15.33
RB 24	36.13	5.17	20.03	1.34	24.67	0.53	1358	14.33
Control	30.60	4.53	21.03	0.84	15.33	0.28	382	9.67
CD (P=0.05)	4.58	0.36	NS	0.18	4.27	0.06	71	4.58

*μ moles ethylene produced $h^{-1}plant^{-1}$

quantity and quality of effluents from a RSS group processing centre were studied and bench models of UASB and hybrid reactors were designed and tested. The reactors were fed with effluents from different waste water treatment plants (Sewage, Sago factory, RSS processing) and goat rumen for build-up and thickening of sludge.

Thirty four anaerobic digesters in the rubber small holdings in and around Paika near Pala were evaluated. Total gas production, various substrates used in the digesters, quantity of the slurry produced and the quality of the final effluent were studied.

The RSS effluent in combination with cowdung gave the maximum gas production irrespective of the size of the reactor. It was observed that all the reactors where rubber processing effluent is used were overfed.

Slurries from three types of biogas plants *i.e.*, (1) Biogas plant with RSS effluent alone, (2) with cowdung and effluent and (3) with cowdung alone were characterized. The highest nitrogen and phosphorus contents were observed in the slurry where effluent along with cowdung was used as the substrate. Available potassium was maximum in cowdung slurry. The anaerobic microbial count was maximum when effluent and cowdung were used as the feed materials.

Effect of these slurries on the growth of the leafy vegetable *Amaranthus retriflexus* and soil microbial and chemical properties were studied. An increase in available nitrogen, phosphorus and potassium contents in soil was observed due to the application of the slurries. The microbial population was more in the treatment with cowdung and fertilizer. A steady increase in microbial population was noted in all the treatments.

Various growth parameters in *Amaranthus retriflexus* were recorded. The shoot length was higher in cowdung and fertilizer applied fields while the lower in the effluent treated.

PLANT PHYSIOLOGY DIVISION

The major research areas of the division are environmental physiology, physiology of growth and yield, stock-scion interaction, tapping panel dryness (TPD), secondary metabolism and ecological impact of rubber cultivation. Molecular biology experiments were conducted to study the mechanism of various physiological processes such as drought tolerance, genetic conflicts between root-stock and scion, identification and characterisation of wintering related genes and TPD.

1. Environmental physiology

1.1. Drought tolerance

The first phase of the experiment on physio-biochemical comparison of drought tolerant and susceptible trees of *Hevea* identified from the polyclonal field trials at RRS, Dapchari was concluded.

1.2. Identification of the molecular basis for drought tolerance

Genomic DNA from high and low girth trees of the polyclonal seedlings from Dapchari and from wild germplasm accessions were isolated. RAPD analyses were performed using 10 operon primers and the genetic distance between the high and low girth and within the categories in both cases was computed. Genetic distance (GD) of the trees between the two girth categories was greater than the trees within a girth category in the case of wild accessions. In the case of polycolonal seedlings from Dapchari, there was not much change in GD.

1.3. Combined effect of drought and light on nursery plants

The clones selected by preliminary screening will be further evaluated for drought tolerance. Preliminary screening of a large number of wild germplasm material will be carried out in a phased manner in collaboration with the Germplasm Division.

1.3.1. Effect of methyl viologen and high light stress on Hevea leaf tissues

Methyl viologen (MV) in the presence of light can induce oxidative stress and cause damage to cellular organelles. Experiment to study the possibility of using this compound for stress tolerance research in *Hevea* was initiated. MV at four concentrations (0.1, 1.0, 10 and 20 mM solutions) were tried by floating leaf discs (size= 2 cm diameter) of RRII 105 in petri dishes and exposing to open sunlight (approx. 1600 µmoles m^{-2} s^{-2}) for 2 hours. The effect on chlorophyll fluorescence, cell membrane stability and chlorophyll content were studied. To estimate the chlorophyll degradation, the leaf samples were exposed for five hours. Control samples were maintained in distilled water under darkness.

The total chlorophyll content in control leaves was estimated as 3.0 mg/g of fresh leaf tissue. In treated leaf discs chlorophyll content was found decreased. Reduction in total chlorophyll was associated with a narrow decline in chlorophylls *a* and *b* content without any significant variations in a/b. However, a significant variation from control was noticed only at 20 mM concentration of MV (Table Phy.1).

Cellular membrane stability as a measure of drought tolerance in *Hevea* was studied as percent cell membrane injury in leaf tissues after exposure to MV and high light. In dark the variation was insignificant. A drastic reduction in membrane stability was observed with the increase in concentration of MV and high light (Table Phy. 2).

Dark Fv/Fm was estimated in leaves after 30 minutes dark adaptation using a Chlorophyll flurometer. Initial fluorescence (Fo), maximum fluorescence (Fm) and Fv/Fm were measured from control as well as treated leaves. Highly significant varia-

Table Phy. 1. **Effect of MV and light stress on chlorophyll content in leaf discs of RRII 105**

Concentration (mM)	Chl a	Chl b	Total Chl	Chl a/b
Dark	2.15 ±0.02	0.85 ±0.03	3.01 ±0.01	2.53 ±0.1
Light	2.05 ±0.01	0.87 ±0.03	2.93 ±0.03	2.36 ±0.08
0.1	2.05 ±0.01	0.87 ±0.01	2.93 ±0.01	2.34 ±0.03
1	2.03 ±0.03	0.74 ±0.007	2.77 ±0.03	2.71 ±0.03
10	1.95 ±0.01	0.78 ±0.01	2.73 ±0.02	2.5 ±0.03
20	1.93* ±0.02	0.71* ±0.01	2.64* ±0.03	2.73 ±0.05

* significant at 0.05%

Table Phy. 2. **Cell membrane stability of methyl viologen and high light exposed leaves**

Concentration mM	Percent injury	
	Dark	Light
Control	00	2.51 ± 0.68
0.1	1.0 ± 0.27	27.2* ± 2.05
1.0	2.0 ± 0.30	37.5* ± 2.02
10	2.7 ± 0.38	44.9* ±.180
20	3.8 ± 1.13	65.8* ± 4.71

* significant at 0.05%

tions in Fo, Fm and Fv/Fm were noticed in light. A drastic reduction in Fm at higher concentrations of MV resulted in a larger decline in Fv/Fm. (Table Phy. 3 & 4).

Table Phy. 4. **Percent variations in fluorescence parameters of treated leaves**

Concentration mM	% increase in Fo	% decrease in Fm	% decrease in Fv/Fm
0.1	08.4	55.2	39.2
1	10.8	59.8	48.1
10	13.2	64.1	62.0
20	23.3	65.5	73.0

1.3.2. Rapid screening of Hevea germplasm lines for intrinsic drought tolerance

Over 600 germplasm accessions planted during 2003 at CES, Chethackal were selected for the study towards the first phase of *in vitro* assessment of *Hevea* germplasm population. Field enumeration was completed during the summer season (March, 2004) by visual scoring of few important drought tolerant traits such as leaf senescence and yellowing, wax content, narrow/broad shaped leaves, curved/flat leaves and vigor of the plant. Plants showing less senescence and yellowing with waxy, narrow, curved leaves and high vigor were considered as morphological adaptations for drought characterization.

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

Top ten HP clones selected were subjected to oxidative stress by incubating with 10 µM MV and light for four hours. On the basis of degree of tolerance in photosynthetic

Table Phy. 3. **Chlorophyll *a* fluorescence in MV and high light exposed leaves**

Concentration (mM)	Dark			Light		
	Fo	Fm	Fv/Fm	Fo	Fm	Fv/Fm
Control	53.5 ± 2.7	245.1 ± 12.7	0.79 ± .006	55 ± 1.06	191.6 ± 2.7	0.71 ± .02
0.1	54.6 ± 1.7	218.1 ± 17.2	0.74 ± .021	58 ± 2.5	109.6 ± 0.6	0.48* ± .03
1	55.5 ± 2.1	181.5 ± 9.1	0.72 ± .02	59.3 ± 1.1	98.3* ± 2.7	0.41* ± .01
10	57.5 ± 0.9	172.1 ± 8.0	0.68 ± .01	60.7 ± 0.9	87.8* ± 1.4	0.30* ± .14
20	58.5 ± 1.0	166.8 ± 8.8	0.66 ±. 009	66 ± 0.9	84.7* ± 1.5	0.24* ± .01

oxygen evolution activity the clones were ranked (Table Phy. 5) RRIM 600, PB 217, HP 53, RRIC 104 and HP 92 were found tolerant to oxidative stress.

Table Phy. 5. **Percentage reduction in photosynthesis in MV incubated leaf discs over their respective water control**

Clone	% reduction in Photosynthesis (5µM MV incubated)	% increase in MDA in MV sample	Ranking on the basis of tolerance
PB 217	54.2	23.7	2
RRIM 600	49.0	11.0	1
HP 225	65.2	89.0	10
RRIC 104	54.0	25.5	4
HP 105	57.2	16.0	6
HP 184	59.2	32.4	7
HP 53	57.0	15.0	3
HP 92	52.3	45.3	5
HP 270	61.0	93.0	9
HP 1	62.0	48.0	8

n=8

1.3.4. Photosynthetic apparatus and adaptation to high light and drought stress

The chloroplast polypeptide profile obtained from normal and drought experienced plants (for 21 days) in open sunlight and shade were compared. The 23 kDa protein was expressed in high light and drought affected plants of RRIM 600, RRII 105 and GT 1 in a high order and its expression was poor in PR 255. The stress protein was eluted from gel, purified and sent for N-terminal aminoacid sequencing.

1.3.5. Studies on mechanisms of drought tolerance in Hevea in relation to photoinhibition of photosynthesis, photooxidative damage, excess excitation energy management and photosynthetic adaptation

Experiments were conducted during the summer of 2003 using RRIM 600, RRII 105 and DAP 34 (a selected cloned plant from a polyclonal plantation at RRS, Dapchari). A gradient of soil moisture was created from nearest to the farthest plants by restricting irrigation in canals for three weeks before the measurements. In control plants of all the clones, CO_2 assimilation rate (A) were almost comparable to the exposed as well as in partial shade. But in drought, a reduction of 46 per cent in A was noticed in RRII 105 compared to control. Reduction in A was marginal in the other two clones. Similar trend was also noted in PSII activity. Reduction in effective quantum yield of PSII (ϕPSII) was also more in drought stressed RRII 105.

Dark adapted Fv/Fm ratios also indicated drought and high light induced inhibition in PSII activity. More reduction in Fv/Fm in RRII 105 in drought suggested its susceptibility to drought and high light stress, whereas, reduction was not much in RRIM 600 and DAP 34. Photosynthetic performance of DAP 34 under drought condition was considerably good and comparable to RRIM 600. This study indicated the beneficial effects of partial shade during drought and high light stress.

1.3.6. Photosynthesis and respiration in trench irrigated plants

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, the farthest ones showed significant reduction in photosynthetic oxygen evolution in open light grown RRII 105 (35%), DAP 34 (29%) and RRIM 600 (14%). The results showed that RRIM 600 and DAP 34 were comparatively drought tolerant than RRII 105 (Table Phy. 6).

The drought (farthest from trench) mediated inhibition in photosynthetic oxygen evolution rate of shade grown plants was comparatively low in all the clones (8-16%)

The apparent quantum yield of oxygen evolution decreased in shaded plants. The quantum yield declined in farthest plants but

Table Phy. 6. **Photosynthetic O_2 evolution and dark respiration in trench irrigated open light and shade plants**

Treatment	Clone	Irrigated (nearest trench)		Farthest from trench	
		Respiration (μ mole O_2 uptake m^{-2} s^{-1})	Photosynthetic O_2 evolution (μ mole O_2 evolution m^{-2} s^{-1})	Respiration (μ mole O_2 uptake m^{-2} s^{-1})	Photosynthetic O_2 evolution (μ mole O_2 evolution m^{-2} s^{-1})
Light	RRII 105	2.9 ± 0.24	9.7 ± 0.24	3.2 ± 0.44	6.4 ± 0.83 (35)
	RRIM 600	2.1 ± 0.20	10.5 ± 0.35	3.5 ± 0.38	9.1 ± 0.40 (14)
	DAP 34	2.4 ± 0.25	11.1 ± 0.53	2.1 ± 0.20	7.6 ± 0.40 (30)
Shade (50%)	RRII 105	3.2 ± 0.50	8.2 ± 0.60	2.0 ± 0.34	7.04±0.40 (16)
	RRIM 600	2.2 ± 0.24	9.0 ± 0.70	2.3 ± 0.20	7.60±0.80 (15)
	DAP 34	2.1 ± 0.40	9.8 ± 1.40	2.0 ± 0.10	9.10 ±0.60 (8)

± SE is shown, n= 5 (Figures in parentheses indicate percentage reduction from the respective nearest trench plants).

the reduction was low in farthest open plants of RRIM 600 (7%). The results showed better light use efficiency in RRIM 600 than RRII 105 under drought conditions.

1.4. Studies on low temperature stress

Studies indicated low temperature and high light induced inhibition in photosynthetic apparatus (PSII activity). The reductions in dark Fv/Fm (under cold conditions) over their respective controls at RRII were about 13% in PR 261 (Fv/Fm of 0.81 and 0.70 for the control and the clone respectively), 27% in PB 260 (Fv/Fm of 0.81 and 0.59 for the control and the clone respectively) and 49% in RRII 208 (Fv/Fm of 0.813 and 0.41 for the control and the clone respectively). CO_2 assimilation rate (A) and effective PSII quantum yield (ϕPSII) were relatively higher in PR 261 than the other clones at Mattupetty corroborating their consistency in maintaining higher photosynthetic performance at low temperature. The photosynthetic performance of these clones at RRII was comparable.

1.4.1. Studies on low temperature effects in controlled environment chamber

A new controlled environment growth chamber was installed at RRII. Standardization of the growth chamber was continued. Initial optimisation of temperature, light and RH as control variables was carried out with polybag plants.

2. Physiology of growth and yield

2.1. Yield and yield components

Evaluation of growth and yield in 12 *Hevea* clones planted in 1982 at CES, Chethackal were continued. Plugging index, initial flow rate and dry rubber content were studied in panels BO-1, BO-2 and BI-1. The loss of tree biomass due to tapping was estimated in these clones and the maximum loss was found in RRII 105.

The growth pattern of 12 clones of *Hevea* was monitored for 21 years. Girth was recorded from the third year and yield from the initiation of tapping. Annual girth, girth increment, biomass and biomass increment were calculated. A sigmoid growth curve was observed in all tapped as well as untapped trees of all the clones. Vigorous growth continued for 17-18 years in most of the clones and thereafter a gradual decline was observed. Clones PB 235 and RRII 118 showed vigorous growth while PR 107 and RRIM 501 were the poorest. Overall 16 per cent increase in girth was noticed in untapped trees. The total biomass of the trees increased with age. Annual biomass increment increased with age initially and thereafter a gradual decline was noticed with a

marked increase in untapped trees. Panel difference in yield was not prominent. A sharp increase in yield was noticed immediately after the opening of a new panel.

Loss of tree biomass due to tapping, the 'k' factor and harvest index (HI) were analyzed in 13 clones. HI was the highest in clone RRII 105 showing that the clone has the maximum loss in biomass due to tapping. HI was found low in high biomass types *viz.*, RRIM 612, RRII 118 and PB 235. Generally, in high yielding clones both 'k' factor and HI were also found high (Table Phy. 7). No significant correlation was obtained between annual yield and annual biomass increment and total biomass produced and total dry rubber obtained from a tree. However, a positive and significant correlation was obtained between annual biomass and annual yield in majority of the clones.

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Clone	Actual biomass (kg/tree)	Missing biomass (kg/tree)	% loss in biomass	Harvest Index	'k'
RRII 105	475.6	596.4	55.5	0.34	0.32
PB 235	1044.1	359.9	25.5	0.18	0.08
RRIM 600	583.0	227.1	28.0	0.24	0.43
RRIM 703	463.2	126.8	21.5	0.28	0.10
GT 1	581.3	430.2	42.5	0.23	0.25
RRII 300	660.5	489.7	42.0	0.20	0.03
RRII 118	919.1	192.3	17.5	0.15	0.03
Tjir 1	572.1	—	—	0.22	—
RRIM 501	326.4	188.3	36.5	0.31	0.08
Gl 1	504.0	174.6	25.6	0.22	0.04
PR 107	408.1	65.7	13.7	0.21	0.10
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2.2. Response of growth and yield to tapping frequency

Influence of different tapping frequencies on growth, yield and biomass accumulation was studied employing d/1, d/2 and d/3 frequencies. A significant difference was observed in dry rubber yield between d/1, d/2 and d/3 tapping. No significant variation in biomass was observed (Table Phy. 8). Maximum per tree yield per tapping was obtained in d/3 system and minimum in d/1 system. Over 72 per cent of trees were affected by TPD in d/1 system followed by d/2 (57%) and d/3 (32%).

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Tapping Frequency	Tree girth (cm)	Biomass (kg/tree)	Rubber yield (g/t/t)	TPD (%)
1/2 S d/1	112.19 ±2.73	1408.18 ±95.17	62.16 ±3.82	72.3
1/2 S d/2	113.53 ±4.17	1552.79 ±159.03	68.44 ±3.93	57.1
1/2 S d/3	112.80 ±3.24	1476.21 ±108.2	85.85 ±3.85	32.0

2.3. Biomass accumulation in untapped trees

Thirteen clones planted in RRII during 1989 were selected and a set of trees was maintained as untapped since initiation of tapping. Annual girth, biomass and yield were recorded. Significant variation in biomass was noticed in untapped trees of clones RRII 43 and PB 311. Clones RRII 308 and Gl 1 recorded the minimum loss of biomass (Table Phy. 9).

Table Phy. 9. **Biomass accumulation in tapped and untapped trees**

Clone	Biomass (kg/tree)		% loss of
	Untapped trees	Tapped trees	biomass
Gl 1	275.6±33.2	257.5±25.6	6.5
RRII 43	450.1±50.9	305.2±41.3	32.1
RRIM 623	288.7±41.9	267.0±32.3	7.5
RRII 105	503.7±36.2	393.5±42.1	21.8
RRII 38	538.1±58.7	467.2±52.8	13.1
RRII 308	601.2±50.8	562.5±69.1	6.1
GT 1	566.6±46.5	470.6±34.3	16.9
RRII 118	857.9±30.5	745.6±45.5	13.0
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RRIM 600	301.7±24.0	258.0±26.0	14.4
HP 20	—	388.1±56.3	—

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The annual increment of shoot biomass in tapped trees was lesser than untapped trees. However, there was no biomass loss in trees under 1/2S d/3 system of tapping in RRII 300. After six years of tapping the highest biomass loss was observed in RRII 105 (30% in d/2 and 27% in d/3 frequencies of tapping). The annual biomass increment in d/3 frequency was higher than d/2 in all clones.

The tapped trees consistently recorded higher rate of cytochrome-c and alternative oxidase (AO) mediated respiration than untapped trees. Among the tapped trees PB 235 and RRII 105 recorded maximum and RRII 300 recorded the minimum total respiration. In RRII 105 in both trees under d/2 and d/3 frequencies recorded higher AO activity than in other clones. The unaccountable biomass loss in tapped trees can partially be explained by high AO activity in high yielding clones under high frequency tapping (d/2). The total sugar content in tapping panel area of clones RRII 105, PB 235 and PB 260 were significantly higher than their respective untapped trees.

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The ATP content in 400 series and ten other clones were analysed. The data showed that high yielding clones and GT 1 showed a higher ATP in latex when compared to low and medium yielders. Among the 400 series clones RRII 429 and RRII 422 showed higher latex ATP.

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Presence and expression of senescence associated genes such as *din*2 and *din*6 in *Hevea* was investigated. The Southern hybridization results confirmed the presence of these genes in *Hevea*. Standardization of northern experiment to study the expression of these genes was taken up.

3. Stock-scion interaction

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

A new experiment was started in two blocks of RRII 105. Different tapping systems were imposed (normal and upward tapping at different heights from the budunion) and incidence of TPD was recorded twice in the year.

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

Growth parameters were recorded in the own-rooted, double rooted and budgrafted plants of three clones.

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Bark samples from rootstock and scion portions of high girth and low girth (not attained tappable girth even after twelve years of planting) trees of the clone RRII 105 collected and RAPD analysis using 10 primers was carried out. The results showed no significant difference in genetic distance (between stock and scion) in high girth and low girth groups.

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RAPD analysis of monoclonal seedlings of three clones *viz.*, PB 86, RRIM 600 and GT 1 and polyclonal seedlings was carried

out to find the degree of homogeneity / heterogeneity existing in these two categories. There was no significant difference in the genetic distance between the seedlings among the monoclonal and polyclonal seedling population.

3.4. Scion to scion communication in wintering pattern

Growth measurements of double–budded and single budded field plants were taken. Double budded plants with more combinations of scion clones were planted at CES, Chethackal. Pattern of isozymes such as esterase and peroxidase was studied in stock with two different scions (RRII 105 and RRIM 600) and a single scion (control). Isozyme polymorphism in plants with two scions (be either same clone or different clones) was minimum while it was more among the plants with one scion in both the clones.

4. Tapping panel dryness

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

Previous studies had shown a relation between TPD and oxidative stress. Simultaneous application of thiourea (a free radical scavenging compound) and cobalt chloride (an anti-ethylene compound) did not show any remarkable change either in the latex volume or in the TPD incidence both in the treated and untreated trees. However, staggered application of thiourea and cobalt chloride with an interval of one week showed yield enhancement and a reduction in the TPD incidence in trees with >50%TPD. Though the yield was more or less steady there was no change in the TPD incidence in trees with < 50% TPD. In normal trees thiourea treatment improved the latex production compared to the untreated group.

4.2. Ethylene and TPD occurrence

As reported earlier in RRII 105, there was an increased production of wound induced ethylene in the TPD affected trees of GT 1. RRII 38 showed higher wound induced ethylene than RRII 105. In both the clones the ethylene production in the bark tissue was relatively high during March/April (drought season) and the level came down by May/June (monsoon season). However, the difference in the ethylene levels between these clones were uniform during all the seasons.

4.3. Biochemical and ionic composition of latex and susceptibility to TPD

The trees were monitored for the occurrence of TPD. Determined the concentrations of sucrose, thiols and inorganic phosphorus. Yield, DRC and plugging index were also recorded. TPD incidence was found to be lesser in clones with higher concentrations of thiols in the latex among the clones investigated.

4.4. Molecular basis of TPD

A differentially expressed band that was cloned and sequenced using DD RT-PCR did not show homology with any of the published sequences in the database when a BLAST analysis was performed. As a further step Subtractive Hybridization method was tried. Total RNA isolated from normal and TPD affected trees were reverse transcribed and a subtraction was done among both the TPD and normal cDNA. The subtracted cDNA were cloned onto cloning vectors and transformed into *E. coli*. Futher work is in progress.

5. Quantification and identification of inositols

A and C- serum from RRII 105 and RRIM 600 were prepared. HPLC analysis of the sera was carried out at the Indian Institute of Chemical Technology, Hyderabad. The individual components in the sample were identified with reference to the retention times of the standards. Contents of quebrachitol, sucrose and glucose as found

in C and A- sera of RRII 105 and RRIM 600 are shown in the Table Phy. 10.

Table Phy. 10. **Contents of quebrachitol, sucrose and glucose (on a % basis of the freeze-dried sample) in latex sera of RRII 105 and RRIM 600**

Compound	C-serum		A-serum	
	RRII 105	RRIM 600	RRII 105	RRIM 600
Quebrachitol	24.57	30.77	12.92	26.92
Sucrose	3.06	4.35	-	-
Glucose	-	-	1.22	-

6. Ecological impact of NR cultivation

6.1. Attitude of rubber planters to rubber monoculture

Many smallholders would allow a limited number of timber yielding species to grow in their rubber plantations. This was largely due to long-term economic considerations owing to instability of rubber price rather than any environmental concern for conservation of biodiversity. More than half of the 1550 smallholders interviewed in this study regretted having removed timber trees from their rubber plantations in the past. A quarter of the growers were willing to compromise rubber yield upto 20% for the sake of growing large timber species in their rubber plantations.

6.1.1. *Effect of large timber trees on growth of rubber trees in plantations*

Sixty four smallholdings (with a mean of 405 ± 57 plants per holding) that had appreciably large number of tree species (mean 29±2.84 per holding) were identified and studied. The mean age of the rubber trees was 15.4±0.62 years and the mean girth was 64.6±1.5 cms. The mean girth of the timber trees (except coconut and miscellaneous species) was at least twice more than that of the rubber trees. On an average, there were a total of 2.1±4.3 to 2.9±0.16 rubber plants under a given alien tree out of which growth of 1.7 ± 0.30 to 2.8± 0.14 rubber plants were only marginally inhibited (0 to 12%). Surprisingly there were far less number of rubber plants under a given alien tree (0.2 ± 0.06 to 0.81 ± 0.09) whose girth was severely inhibited (27.5 to 54.4%). The large difference in the size between the alien trees and the rubber plants and the spatial segregation of their canopies might have led to only small levels of competition and hence the less than expected inhibition in the growth of rubber.

6.2. Carbon sequestration by NR plantations and the Kyoto protocol

The 9th conference of Parties to the United Nations Framework Convention on Climate Change held at Milan during December 2003 has decided to include carbon sink projects under the Clean Development Mechanism (CDM) of the Kyoto protocol. It is now possible to attract CDM funding into the NR plantation sector. In this direction, accurate estimation of Certified Emission Reduction (CER) credits from NR plantations as per the methodologies of the CDM Executive Board was being attempted.

RUBBER TECHNOLOGY DIVISION

Development of an easy method to cream and coagulate skim latex, successful pilot plant scale application of formalin treatment of field coagulum for improving the quality of TSR and development of NR based nanocomposites using intercalated clays were the significant contributions. The concept of ENR as silica reinforcement modifier was further utilised in carbon/ silica mixed filler reinforced NR and SBR vulcanizates. An exploratory work on the use of small quantities of PP and HDPE for improving the

gum vulcanizate properties of NR yieded promising results. Use of NR-g-PMMA copolymers as compatibiliser for NR/PVC blends, deproteinisation of NR latex using papain, preliminary evaluation of the raw rubber properties of the pipeline clones, continuation of the quality survey of the sheet rubber produced in the country etc were the other major areas of work.

1. Primary processing

A laboratory method was standardised for easy processing of skim latex and reduction of its nitrogen content. The addition of dilute sulphuric acid leads to immediate coagulation of the creamed latex into a cohesive mass which could be further processed.

The standardised procedure for preservation of field coagulum (FC) by treating with 0.75% formalin solution for 16 h was extended to large scale evaluation at the Pilot Crumb Rubber Factory. The TSR produced could retain the PRI when the treated FC stored even up to one month. The percentage of various grades of ISNR produced at the pilot plant before and after the initiation of formalin treatment is shown in Table Chem. 1.

Table Chem. 1. **Effect of formalin treatment on the percent of TSR grades produced**

ISNR Grade	ISNR produced (%)	
	Before formalin treatment	After formalin treatment
10	41	77
20	36	17
50	17	6
OFF	6	Nil

Experiments carried out to prepare concentrated latex from field latex preserved with 1% ammonia (PFL) and stored for one month showed improved quality parameters when compared to that prepared from fresh field latex. The initial MST was higher (800 s) and remained high during storage (1600 s after 5 months) compared to that prepared from PFL which were 100 s initially and 1100 s after 5 months.

In quality survey of sheets, the final round collection of sheets was completed and the determination of its raw rubber properties and statistical analysis of the results were done.

2. Chemical modification

Though peroxide vulcanization substantially improved the thermal ageing properties of ENR well above that of NR vulcanizates, the set resistance of the former were inferior. In order to reduce the compression set, zinc dimethyl methacrylate (Saret 634) was used as coagent. The compression set was reduced from 19% to 8% at 70°C and from 29% to 21% at 100°C with the addition of 5 phr of the coagent. Substantial increase in tear strength and hardness along with excellent thermal ageing and oil resistance were observed.

3. Blends

Effect of blending lower proportions of PP and HDPE (5-20%) on the gum vulcanizate properties of NR was evaluated. The results indicated substantial improvement in the vulcanizate properties of the blends over the NR gum vulcanizates (Table Chem. 2).

In the studies on NR/PVC (70:30) blends replacing 15% NR with NR-g-PMMA copolymer (percent grafting = 30.6) substantially improved the vulcanizate properties of the blends. Compared with the uncompatibilised blends, tensile strength increased from 13 MPa to 22 MPa, tear strength increased from 24 N/mm to 48 N/mm and abrasion loss reduced from 289 mm^3 to 177 mm^3.

Table Chem. 2. Vulcanizate properties of NR/PP and NR/HDPE blends

Property*	NR	NR/PP				NR/HDPE			
		95/5	90/10	85/15	80/20	95/5	90/10	85/15	80/20
Tensile strength, MPa	29.9	33.2	37.1	34.9	32.7	33.6	35.8	34.3	30.9
Modulus, 100%, MPa	0.9	2.4	4.5	6.1	10.6	1.4	2.0	2.4	3.3
Modulus, 300%, MPa	1.7	6.4	12.3	16.4	19.2	4.0	5.1	7.3	8.7
Elongation at Break, %	637	574	549	482	419	627	623	595	602
Tear strength, N/mm	33.4	49.6	69.5	75.4	85.6	46.0	60.5	66.0	72.0
Hardness, Shore A	36	52	60	64	70	47	50	54	62
Resilience, %	73	70	66	65	60	74	71	67	62
DIN abrasion loss, mm^3	133	106	92	82	76	73	57	51	43
Heat build up, ΔT, °C	4	5	7	9	17	4	6	8	16
Compression set, %	21	24	29	31	32	24	28	30	32
Flexing									
Crack initiation (kcy)	92	87	73	43	12	87	77	62	21
Crack completion (kcy)	200	120	100	75	43	110	101	91	61
% retention in ageing (172 h at 100°C)									
Tensile strength	11	73	59	51	62	56	67	57	56
Modulus	80	133	95	-	-	154	187	115	137
Elongation at break	40	77	75	46	33	72	69	67	66

* Formulation: Polymer – 100, ZnO – 5phr, Stearic acid 2 phr, HS – 1 phr, CBS – 0.6 phr and S – 2.5 phr

4. Reinforcement

4.1. NR nanocomposites

NR latex nanocomposites using layered silicates (bentonite and flurohectorite) were prepared using the conventional compounding method and the vulcanised films were characterised using TEM. The intercalation/exfoliation of the layers resulted in 35-50 times reduction in air permeability of the vulcanised films.

4.2. ENR as modifier

Carbon/silica mixed filler reinforced NR and SBR were modified with ENR 50 and compared with the silane modified. Optimisation of ENR content and its viscosity and filler ratio were carried out. ENR modification up to a limited concentration improved the mechanical properties and wet grip without adversely affecting the rolling resistance. ENR and silane modified compounds exhibited comparable flow properties, especially at higher shear rates.

ENR was also tried as modifier in NBR/clay systems. The results indicated improved technological properties as well as ageing resistance, which were comparable to that of silane modified NBR/clay systems.

5. Latex technology

Experiments carried out on the consistency in viscosity on storage of the prevulcanised latex showed that latex prevulcanised at lower temperature (60°C) had better consistency than that prevulcanised at higher temperature (70°C). Plant scale evaluation of papain as a deproteinising agent for NR latex was initiated. The results indicated that the enzyme is effective in reducing the nitrogen content.

6. Raw rubber properties of new clones

The raw rubber properties of latex obtained from 9 new clones of RRII 400 series which outperform RRII 105 in yield were evaluated. Three clones gave rubbers with Mooney viscosity less than or equal to 60 and all others showed higher Mooney viscosity.

AGRICULTURAL ECONOMICS DIVISION

During the period under review, the Division continued its research activities confined 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. Seven projects were completed and reported during 2003-04.

1. Global trade and tariff policy on rubber and its products under WTO Regime

A study was conducted to capture the structural and sectoral compositions of world exports in rubber and rubber products and intra-NR producer trade in three major forms of processed NR and six selected rubber products among the five major NR producing countries, *viz.*, Thailand, Indonesia, India, Malaysia and China and three major consuming countries, *viz.*, USA, China and EU.

During 2000, the total value of world exports of rubber and rubber products was US $ 53.4 billion out of which the share of developed countries was as high as 69 per cent. However, at the disaggregate level the share of developing countries in total value of world NR exports was 96 per cent. The composition of the total value of world exports of the dominant rubber products subsector indicated a high degree of concentration by the developed countries in the case of tyres and allied products and non-tyre.

The total value of imports of selected nine products was the lowest for India among the five NR producing countries. The share of NR producing countries in India's imports was higher only in the case of surgical gloves (80%). India's composition of imports was more dispersed as evident in the combined shares of the three forms of NR (52%) and the six rubber products (48%) in the total value of imports.

The analysis on tariff policy indicated that only Indonesia and China have 100 per cent binding coverage on the nine products, whereas Japan, EU and the USA have bound all the nine tariff lines except conveyor belts and belting for maximum flexibility in protection. The lowest binding coverage was observed in India and Thailand. India has kept the tariff lines on NR latex and all the six rubber products unbound. Conversely, the unbound tariff lines of Thailand are on three forms of processed NR, belts and beltings, bicycle tyres, sheath contraceptives and surgical gloves. Malaysia has bound all the tariff lines except those on conveyor belts and belting, sheath contraceptives and surgical gloves.

The results highlighted the need for conception of an appropriate platform and guidelines for maximising the share of NR producing countries in the net value added beyond the NR production sector rather than singularly focusing on NR price stabilisation schemes in the post-reforms scenario.

2. Techno-economic feasibility of latex timber plantations

In the context of LT plantations becoming popular in Malaysia, a study was conducted to decide whether India should replicate the Malaysian strategies towards popularisation of LTCs or should device a strategy specific to the Indian conditions. LTCs in India should be based on a critical assessment of Malaysia's gains and pitfalls with respect to latex timber plantations. Important points that emerged are: 1) for the development of LTCs attention should be paid to the post-planting agro-management innovations, 2) A comprehensive database on

the region/clone-wise latex and timber yield potentials of the existing rubber plantations has to be developed and 3) LTCs with shorter life cycles should be identified and promoted in an agro-forestry perspective for afforestation programmes in marginal lands and non-traditional regions in India.

3. NR trade in the post-reforms phase

The important changes in the primary marketing of natural rubber (NR) in India in the post-reforms phase was examined. Market uncertainties since 1997 have resulted in the emergence of a new trading system in which, the terminal market dealers and major consumers attempt to stabilise their marketing margins at various stages either through internal restructuring process or by discriminating the small growers through downgrading. The process has led to a gradual elimination of the dealers at the middle level in the marketing network. Village level dealers have been functionally decimated to the status of agents of the terminal market dealers. At the level of major NR consumers, the changes initiated have been diversification of the source of purchase and evolving direct delivery systems to the factory sites rather than storing the raw-materials in the godowns.

The changes appear to be leading to the exit of a large number of dealers and the growing concentration in the primary marketing of NR. Only dealers with large resource base and re-processing facilities were able to withstand the changing dimensions of the marketing network. Many dealers operating from Kochi and Kottayam markets have become commission agents of the consumers located outside the state of Kerala.

There is growing discrimination of the small growers in terms of downgrading of their produce by ascribing new local names and grades so as to depress the prices, which adversely affected the farm gate price realisation. The trend has been observed to be more prevalent in Kanyakumari and South Kerala. This points to severe constraints on the effective interventions by the co-operative sector in the primary marketing operations.

4. Sustainability of beekeeping in rubber plantations

Though Kerala and Tamil Nadu together had an average honey production potential of 54000 MT per annum, only less than three per cent of the potential could be commercially realised so far. The major factor identified is the existing institutional mechanisms provided by the co-operatives and other agencies with rigid structural characteristics of the honey market. In this context the achievements made in beekeeping by the Elavampadam Rubber Producers' Society (ERPS) in Kerala, through ensuring collective action among rubber growers at the local level merits attention.

The institutional intervention made by the ERPS in beekeeping has been effective in terms of: a) popularising bee-keeping among the rubber growers through various training and support programmes; b) augmenting the income of bee-keepers through higher realisation of farm gate prices for honey than the prices offered by the co-operatives and other agencies. Based on the experience of the ERPS in popularising beekeeping it appears that there is a need for effecting a consortium of RPSs to replicate the model to other areas.

5. Dilemmas in adopting LFTS in smallholding sector

Though there have been considerable efforts to popularise LFTS in India since the late 1980s, the extent of adoption has varied across the estate and smallholdings sectors. The extent of adoption of LFTS was 66 per cent in the estate sector compared to as low as 6-9 per cent in the smallholder sector.

This is mostly due to: operational size and labour induced rigidities in tapping options, insignificant involvement of family labour and labour relations rooted in informal contractual arrangements. Although feasibility of the LFTS is evident, introduction of the system may go against the interests of the tapping labour market, which is otherwise caught up in a dilemma. In the prevailing scenario, the potential options are: (i) increased involvement of family labour; and (ii) setting up of a labour reserve pool attached to the Rubber Producers Societies (RPS) as a new institutional intervention mechanism.

In Kerala context, the feasibility of involving family labour for the adoption of LFTS is rather remote due to (i) the steady growth in the share of part-time farmers in the rubber smallholder sector over time (more than 50%); and (ii) dependence on hired labour for tapping to the extent of 78 per cent with significant regional variations. Given the specific socio-economic background of the smallholder community in Kerala, it is also difficult to attract female labour, as already the participation of women in tapping and related operations is as low as 22 per cent. Thus, institutional interventions appear to be imperative to mobilise the existing tapping labour attached to the smallholder sector and to attract younger generation.

6. Adoption of reduced tapping intensity systems (RTIS) in estate sector

The study explored the aggregate level trends in the adoption of reduced tapping intensity systems in the rubber estate sector in India with the objectives to: a) understand the status of RTIS *vis-à-vis* HITS (high intensity tapping systems) over decades; b) examine the trends in the adoption of exploitation systems across phases and decades; and c) assess the popularity of different exploitation systems across clones over decades, the trends in the adoption of reduced tapping intensity systems (RTIS) in the estate sector in India.

Monthly field-wise micro level information on yield and related variables from 45 estates under the corporate sector for the period 1968 to 2002 were analysed. In spite of the phase (age) and clone-wise differences in tapped area, there has been a growing convergence in the shift towards RTIS during the 2000s.

7. Market uncertainty and wage labourers in smallholdings

An analysis of the magnitude and economic dimensions of the price fall of NR in the post-reforms phase, the resultant investment effect on rubber smallholdings and the employment effect and its impact on labour relations was carried out. The price realised by farmers during 2002 was only 60 per cent of what they could fetch during 1994. Farmers have been compelled to substantially reduce fertiliser application and dilute other cultural practices pursued until the price slump. As a result, the demand for labourers in the rubber smallholdings has been reduced by 60 per cent during the period between 1997 and 2000. In the case of tapping labourers, the number of tapping days has been reduced and the number of trees available for tapping per tapper has also declined during the last five years. With the fall in prices, benefits enjoyed by the labourers in terms of interest free credit have also ceased to exist, dissuading labourers from rubber holdings.

In the coming years decline in tapping days is likely to affect the availability of labour for rubber holdings. If price uncertainty continues, there would be a possibility for the existing tapping labourers to leave the job resulting in severe shortage of labourers posing a threat to commercial exploitation of the crop.

EXPLOITATION TECHNOLOGY

In the field of exploitation technology, research on crop harvesting techniques was continued. Ongoing experiments on Low Frequency Tapping (LFT), reduced spiral cuts, crop loss due to rain, panel change, low frequency CUT etc were continued. New experiments were taken up on weekly tapping in clone GT 1 in Karnataka, low frequency CUT in RRIM 600 and RRII 105, response of TPD tree to tapping and stimulation in opposite panel etc. Exploratory trials were laid out on fourth (d/4) daily and weekly (d/6) tapping with rainguarding in Kulasekharam region of Tamil Nadu. Advisory work on d/4 and d/6 tapping, CUT, reduced spiral cuts etc were continued. Testing of materials for tapping, rainguarding and stimulation continued to be an activity.

1. Low frequency tapping (LFT) systems

Various LFT experiments laid out at RIT, Pampady, Kottayam were continued. Experiment to evaluate the performance of low frequency tapping systems with stimulation in clone RRII 105 (panel BO-1) continued to give encouraging results. Higher yield under d/3 and d/4 frequencies of tapping is due to 2nd and 1st year of panel change respectively. Low yield under 1/2S d/2 can be attributed to 3rd year of panel change, and TPD. Lower yield under d/6 frequency can be attributed to panel position, *ie.*, near bud union (Table Exp. 1).

LFT experiments to evaluate the performance of clone RRII 105 with stimulation from panel BO-2 onwards also gave encouraging results. Yield, comparable to that of d/2 system of tapping, could be obtained under d/3 and d/4 frequencies of tapping. Higher yield under d/4 frequency of tapping was due to panel change (Table Exp. 2).

Table Exp. 1. **Performance of LFT systems (RRII 105)**

Treatment	Tapping system	Yield* (kg/ha)	No. of stimulation	DRC (%)
T0	1/2S d/2	2016c		39
T1	1/2S d/3+ 1 level stim.	2588b	3	39
T2	1/2S d/3+ 2 level stim.	2783ab	4	39
T3	1/2S d/3+ 3 level stim.	3016a	5	39
T4	1/2S d/4+ 1 level stim.	2889ab	5	40
T5	1/2S d/4+ 2 level stim.	2654ab	7	40
T6	1/2S d/4+ 3 level stim.	2941ab	9	39
T7	1/2S d/6+ 1 level stim.	2014c	10	40
T8	1/2S d/6+ 2 level stim.	1892c	12	41
T9	1/2S d/6+ 3 level stim.	1870c	15	40

*Values followed by same letters are not critically different from each other LSD (P > 0.05)=391

Table Exp. 2. **Performance of LFT systems (RRII 105; Panel BO- 2)**

Treatment	Tapping system	Yield* (kg/ha)	No. of stimulation	DRC (%)
T0	1/2S d/2	2730b		42
T1	1/2S d/3+ 1 level stim.	2682b	3	42
T2	1/2S d/3+ 2 level stim.	2977ab	4	41
T3	1/2S d/3+ 3 level stim.	3179ab	5	41
T4	1/2S d/4+ 1 level stim.	3388ab	5	41
T5	1/2S d/4+ 2 level stim.	3552a	7	41
T6	1/2S d/4+ 3 level stim.	3353ab	9	41

*Values followed by same letters are not critically different from each other LSD (P > 0.05)=740.

Onfarm experiment on LFT in Appella estate and Neria estate, South Karnataka with d/4 and d/7 frequencies also gave encouraging results (Table Exp. 3 and 4). In Neria estate, the trials to evaluate the dry rubber yield under various levels of stimulation were in the first year of experiment.

Table Exp. 3. **Performance of clones under 1/2S d/4 6d/7 in Appella Estate, Karnataka**

Field/Clone	Yield (kg/400 trees)	Cumulative TPD%
72 RRIM 600	1908	3.84
84 GT 1	1745	2.81
88 GT 1	1751	2.99
89 GT 1	1586	3.42
90 GT 1	1526	3.47
94 RRIM 600	1221	0.83
94 GT 1	1341	0.73
94 RRII 105	1547	2.28

Table Exp. 4. **Yield under 1/2S d/7 6d/7 system in Neria Estate, South Karnataka**

	GT 1		RRII 105
Stimulation level	1990	1992	1992
T1	1405	1257	1419
T2	1388	1205	1503
T3	1385		

The experiment at Vijayadri Plantation, Vennimala comparing d/3 and d/4 systems of tapping was continued in panel BO-2 in clone RRII 105. Good yield could be obtained by judicious stimulation under d/4 system of tapping without deleterious effect as evident from good yield and lower incidence of tapping panel dryness. This was also reflected in other parameters studied, viz., DRC %, kg/ tap, kg/tree etc. (Table Exp. 5).

To explore the possibility of introducing low frequency tapping (d/7) with rainguard, a trial was initiated at Kanthimathy estate, Kulasekharam during 2003-04. Weekly tapping with monthly stimulation and rainguarding was imposed in seven tapping blocks. Estate practice of fourth daily tapping without rainguarding

Table Exp. 5. **Performance of 1/2S d/3 and 1/2S d/4 systems (RRII 105)**

Treatment	T1 (1/2S d/3)	T2 (1/2S d/4)
Dry rubber yield (kg/400 trees)	2729	2440
Dry rubber yield (kg/400 trees/tap)	25.40	31.0
DRC %	42	42.7
Scarp %	7.9	7.0
TPD %	3.4	4.2

and with six stimulations per year served as control. Preliminary results (2334 kg/400 trees) indicated success of introducing low frequency tapping (d/7) with rainguard in Kulasekharam region, Tamil Nadu (Table Exp. 6). Yield for the corresponding period from control blocks was 1898 kg/400 trees.

Data obtained from similar experiment under d/4 frequency of tapping at Hariharaputhra Estate, Kulasekharam, Tamil Nadu is given in Table Exp.7. These data show the requirement of rainguarding for the success of LFT. Rainguarding not only enables regular tapping but also prevents wash out of late drip that is associated with low frequency tapping.

Demonstration plot for the performance of weekly tapping initiated at Central Experiment Station, Chethackal progressed well during the period under report and encouraging results obtained (Table Exp. 8).

1.1. Onfarm trials on LFT

Besides various ongoing exploitation experiments on LFT, on-farm trial on 1/2S d/3 system of tapping in clone RRII 105 at Trithala, Palakkad and Beria estate South Karnataka were continued. At Thrithala, stimulation resulted in 35% yield increase over the unstimulated control during 2003-04. Cumulative yield for five years (1999-00 to 2003-04) was 13,170 kg as against 10,259 kg in control (Table Exp. 9).

Table Exp. 6. **Performance of LFT (1/2S d/7) with rainguarding (RRII 105)**

Month	Yield			Scrap %	DRC %
	kg/400 trees	kg/tap	kg/tree		
May 03	93	26.0	0.23	13.6	37.5
June	204	49.0	0.51	19.9	40.3
July	261	59.3	0.65	24.8	36.9
August	229	52.7	0.57	23.3	38.5
September	208	50.2	0.52	27.1	40.0
October	241	62.9	0.60	21.7	40.9
November	310	72.4	0.78	33.1	36.4
December	247	55.8	0.62	29.9	36.9
January 04	216	48.6	0.54	22.5	37.6
February	181	43.5	0.45	21.5	39.0
March	144	32.7	0.36	17.3	40.2
Total	2334	-	5.84	-	-
Mean	212	50.3	0.53	23.2	38.6

Table Exp. 7. **Performance of LFT (1/2S d/4 6d/7) with rainguarding (RRII 105)**

Month	Yield			Scrap %	DRC %
	kg/400 trees	kg/tap	kg/tree		
Jun 03	264	40.4	0.66	25.1	44.3
July	221	33.8	0.55	34.8	36.5
August	253	38.8	0.63	33.0	40.0
September	136	23.3	0.34	32.0	43.9
October	285	43.9	0.71	28.4	39.0
November	340	45.1	0.85	29.9	35.5
December	243	35.9	0.61	23.1	35.8
January 04	173	25.6	0.43	21.8	32.8
February	46	8.6	0.12	25.2	33.6
Total	1961	-	4.90	-	-
Mean	218	32.8	0.54	28.2	37.9

Table Exp. 8. **Annual dry rubber yield under 1/2S d 6 6d/7 system (RRII 105)**

Month	Trial 87 A		Trial 93 C	
	kg/400 trees	kg/tap	kg/400 trees	kg/tap
Apr 03	40	13.4	47	15.5
May	218	43.6	102	25.6
June	331	82.9	246	49.2
July	783	156.6	348	87
August	682	170.5	363	90.7
September	478	119.6	526	105.1
October	447	89.3	182	45.4
November	419	105	398	100
December	315	79	395	99
January 04	248	50	140	35
February	87	22	77	19
March	72	18	93	15
Mean	4120	79.1	2917	57.2
Yield (kg/tree)	10.3		7.3	

Table Exp. 9. **Yield under d/3 system of tapping (RRII 105)**

Year	Dry rubber yield (kg/ha)		No. of stimulation
	Control	Stimulated	
1999-00	2109	2500	2
2000-01	2091	2900	3
2001-02	2178	2599	2
2002-03	2040	2691	3
2003-04	1841	2480	3
Cumulative *	10259	13170	
increase over control (%)		29	

*58 months

Onfarm trial on d/3 system of tapping in clone GT 1 at Neria estate, South Karnataka also gave promising results. Average yield of 1752 kg could be obtained in

stimulated blocks. Stimulation resulted in 23% yield increase over the unstimulated control blocks during the period under report.

Onfarm trial on weekly tapping laid out in various agro climatic zones of the traditional area progressed well during the period under report. Estates, which have implemented the system, continued the practice with good results. In Manikal estate an average yield of 1780 kg and in Vijayadri estate an average yield of 2650 kg/400 trees were obtained under weekly tapping. Similarly in Balanoor estate, Perinthalmanna average yield of 2500 kg could be obtained in clone RRII 105 under 1/2S d/6 6d/7 tapping system.

1.2. Lab to land programme on LFT

LFT under lab to land programme started earlier in different locations of Kerala progressed well. Necessary advice on stimulation, collection *etc*. was given as and when required. Stimulation schedules as per the recommendation issued were implemented. Monthly yield data of various fields was provided by the estates. Low frequency tapping is successfully extended to very large area in the estate sector in Kerala, Tamil Nadu and Karnataka. Due to disciplined tapping and related operations, in many places production and productivity also improved considerably (Table Exp. 10).

2. Low frequency controlled upward tapping (LFCUT)

Experiments to evaluate the performance of LFCUT with rainguard in clone RRII 105 and RRIM 600 were initiated during the reporting period. Very good results were obtained.

3. Other experiments

3.1. Effect of panel change on yield

Experiment on annual panel change in basal panels increased the yield performance of clone RRII 105 under d/2, d/3 and d/4 tapping systems.

3.2. Crop loss due to rain and recovery by stimulation

Experiment on the effect of stimulation under d/2 and d/3 frequencies of tapping in clone RRII 105 without rainguarding to recover the yield loss was also continued. Data showed that yield loss under d/2 frequency cannot be recovered by stimulation. Higher yield from trees without rainguarding under d/2 frequency of tapping during the year may be due to low rain interference on tapping during the year (Table Exp. 11).

3.3. Performance of mini and reduced spiral cuts

The statistically laid out (CRD) experiment at RIT, Pampady to evaluate minicuts and reduced spiral cuts in comparison with

Table Exp. 10. **Impact of LFT on dry rubber yield**

	2001-02	2002-03	2003-04
a. Ambanad Estate			
Total production (t)	165.75*	196.54**	209.63**
Productivity (kg/ha)	997*	1183**	1276**
b. Manickal estate			
Total production (t)	463***	509****	592**
Productivity (kg/ha)	1421***	1367****	1634**
c. Plantation Corporation of Kerala Ltd			
Total production (t)	3753*	4570**	5128**
Productivity (kg/ha)	909*	835**	1127**

*d/2 & d/3; **d/4; ***d/3; ****d/3 & d/4

Table Exp. 11. **Effect of stimulation under d/2 and d/3 systems at EFU, RIT, Pampady (RRII 105)**

Treatment	Tapping system	Yield (kg/ha)	No. of stimulations	DRC (%)
T1	1/2S d/2with RG	2595		38
T2	1/2S d/2 without RG	3225		39
T3	1/2S d/2without RG+1level st.	3232	3	39
T4	1/2S d/2 without RG+ 2 level st.	3266	5	38
T5	1/2S d/3 with RG	3225	3	38
T6	1/2S d/3without RG	2905	3	40
T7	1/2S d/3 without RG + 1 level st.	2465	5	40
T8	1/2S d/3 without RG + 2 level st.	2872	7	39

conventional 1/2S d/3 was continued during the reporting period. Quarter spiral cut continued to give good performance.

From the past experience, as a practice, Neria estate is now opening their trees at 45 to 49 cm girth with ¼ spiral cut. As and when it attains 50 cm girth, the cut length is extended to ½ spiral. Similarly, three estates in Northern Kerala *viz.*, Badra (d/3), Pandallur and Gokul (d/4) opened blocks with mixed cuts, ie., trees above 50 cm were opened with ½ spiral and 45 cm to 49 cm with ¼ spiral cut. Here also, when the trees attain girth of 50 cm, the cut length will be extended to 1/2S. The average yield per tree was 2.5 kg (Gokul), 2.7 kg (Pandallur) and 3.2 kg (Badra).

GENOME ANALYSIS LABORATORY

The Genome laboratory works on the development and application of various molecular markers for the characterization of *Hevea* germplasm, which is essential for genetic relationship studies, clonal identity, identification of markers linked to desirable agronomic traits for early prediction of clonal performance against various stresses etc. The major research focuses are to develop a genetic linkage map of *Hevea* using molecular and trait markers, and to elucidate the molecular basis of plant resistance to fungal pathogen. Development of DNA markers that could identify the fungal pathogen infecting *Hevea* was also carried out as the continuation of the work on fungal genetic structuring. During the period the following research projects have been continued.

I. Establishment of genetic relationships among wild *Hevea* germplasm

Genetic relationships among the wild *Hevea* germplasm had already been assessed using RAPD markers and 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. PCR-RFLP has been carried out for the above two non-coding intergenic region. Based on this study it is concluded that these non-coding regions are not informative enough to establish any kind of relationship, as there is no detectable length polymorphism among the wild *Hevea* germplasm.

A set of eight microsatellite markers, developed in *Hevea* had also been evaluated using the same set of wild accessions. Polymorphisms were detected among those wild accessions and some genotype specific alleles were identified. Wild *Hevea* 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. All the four microsatellites showed amplification of alleles with both the species *H. benthamiana* and *H. spruciana*, within the size range observed in *H. brasiliensis*. Cross-species amplification clearly indicated that the flanking regions of the microsatellites are extremely conserved in other species. Inheritance of the parental alleles was detected in the interspecific hybrid FX516.

2. Development of microsatellites and its application in the characterization of *Hevea* germplasm

A small-insert genomic library of *Hevea* derived from a clone GT1, was screened for the presence of simple sequence repeats and consequently 204 positive clones were selected for AC/TG and CT/GA repeats. After a second round of screening, 154 clones were recovered individually for *in vivo* excision of the recombinant phagemid containing the insert. PCR amplification with vector-directed primers as well as with the repeat sequences confirmed 114 positive clones. Fifty positive clones were sequenced to validate the presence of microsatellites in *Hevea* genome. The sequence data revealed the presence of 59 microsatellites having characteristic simple and compound repeats. Various kinds of repeat motifs comprising of dinucleotides (TG/AC, AG/TC, TA/AT), trinucleotides (AAG, AGG, ATT), tetranucleotides (GAAA, AAGG, ATCC, TAAA, AAAT) and one pentanucleotide (GAAAT) were detected. Out of 4×10^9 bp, estimated to be the haploid genome size of *Hevea*, we sequenced approximately 48×10^3 bp (32×10^3 bp in GT1 and 16×10^3 bp in RRII 105) based on an average insert size of 650 bp per clone and identified various repeat motifs. However, twenty-nine new genomic sequences were registered with the NCBI genBank, USA (accession numbers: AY439286 to AY439314). Primer-pairs synthesized based on the above sequences, 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. A representative number of *Hevea* microsatellites were isolated from a genomic library for their ultimate use in the development of microsatellite markers.

3. Single nucleotide polymorphisms (SNPs) in *Hevea* – A new generation marker

SNP studies were undertaken for the first time in *Hevea* to identify polymorphism which could be used to get an insight of the complex biochemical traits that regulate some important phenomena in *Hevea*, such as tapping panel dryness, ethylene induction of latex production etc. The frequency of SNPs on 12 genes (cDNA) encoding important enzymes catalyzing several biochemical reactions in 16 cultivated rubber genotypes/clones was surveyed. Identification of polymorphism in the gene/loci of interest is very important as SNPs contribute directly to a phenotype or can be associated with a phenotype as a result of linkage disequilibrium. Screening for the presence of SNPs in 12 loci from 12 wild *Hevea* genotypes is in progress with the purification of the PCR products, amplified using the primer-pairs designed for the popular clones. Amplified fragments of the individual loci from wild *Hevea* germplasm appeared to be similar in size as that was observed in popular clones.

4. Development of RAPD marker(s) closely linked to the locus conferring resistance to fungal disease

Resistant gene analogues (RGAs) work, an alternative approach to identify disease resistance gene, is in progress. Degenerated primers based on the conserved nucleotide

sequences of the structural motifs/ domains-characteristic of the disease resistant genes (R-genes), had been 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 plant species.

5. Genetic structuring and assessment of molecular variability of *Colletotrichum* species

In continuation of the work on genetic characterization of the two different species of *Colletotrichum*, four sets of sequence-specific primers were used to amplify specific regions of the fungal genome in order to develop sequence characterized amplified region (SCAR) marker for easy identification of *Colletotrichum* at the species level. The amplification profiles clearly showed differences between the two species with two sets of primer-pairs out of four. Direct PCR analysis of the DNA samples isolated from both types of diseased symptoms (raised spots and anthracnose) clearly showed the presence of respective *Colletotrichum* species through the amplification of species-specific fragment using the SCAR primers. The identification was uniform for the different strains of the fungus (as detected through RAPD) belonging to individual species. Therefore, the molecular analysis of *Colletotrichum* using the developed SCARs provided a method for confirming the presence of the fungus at their species level. These markers (SCARs): OPB-17(874) for *Glomerella cingulata* (anamorph: *Colletotrichum gloeosporioides*) and OPI-06(788) for *Glomerella acutata* (*Colletotrichum acutatum*), developed recently, have been registered with the NCBI GenBank.

DRIS FERTILIZATION

The DRIS unit was engaged in several research projects besides advisory service to the smallholding sector.

1. Research activities

1.1. Refinement of discriminatory fertilizer recommendation (DFR)

To evolve soil series wise fertilizer recommendation, field experiments were started in four different soil series *viz.*, Kanjrapally, Thiruvanchoor, Kunnathur and Kadambanad. Kanjirapally and Thiruvanchoor series were selected in the central and north zones. Kunnathur and Kadambanad series were identified in south zone. Response of fertilizers including higher dose and lower dose of the discriminatory fertilizer recommendation showed that there is significant difference among treatments. No significant difference was found in the lower dose (18:18:18) of fertilizer in all treatments. In Kanjirapally series significant difference was noticed for higher dose (54:54:54). Statistical analysis of girth data and soil/leaf nutrient values are in progress.

1.2. Hydraulic conductivity studies

Hydraulic conductivity studies to understand the erodability and water availability in rubber are in progress. The study

showed that the soil hydrological functions and erodability characteristics of soils under rubber at varying slopes were related to the depth and slope of rubber cultivated area. Soil dispersion ratio and erodability index were higher in upper slope soils indicating higher susceptibility to soil loss, as compared to lower slopes.

1.3. Phosphorous fixation studies

Phosphorous fixation due to added fertilizer phosphorous was studied for more series. Initial properties of the soil series *viz.*, Peruva, Lahai, Chandanikunnu were studied and Thrikkannamangal. Results of the soil parameters showed that the organic carbon status and clay content (Table Dri.1) in Lahai series is higher than that of other soil series.

1.4. Effect of fertilizer P and farm yard manure (FYM) on available P

Influence of farm yard manure on fertilizer P in terms of P availability in the rubber growing soils of Kozhikode district was studied. The result indicated that incorporation of farm yard manure enhances the availability of fertilizer P.

1.5. Nutrient cycling studies

To study the nutrient turnover in rubber, nutrient cycling studies were initiated. A comparative study of nutrient cycling in rubber and forest was started in TR&T estate and investigations on seasonal variation in soil nutrient availability in rubber and forest were initiated. Variation in soil nutrient availability across different months was observed. During October there was higher nutrient concentration in soil, but there was a drastic decrease in the month of February. Statistical analysis of the data is in progress.

1.6. Effect of soil factors on yield of rubber in the same agroclimatic conditions

Within the same agroclimatic conditions itself variation in yield of rubber was noticed in estates. To know whether soil factors have any influence on yield, a project on the soil factors influencing the yield of rubber was initiated.

1.7. Relief/topography of rubber growing areas and its effect on yield of rubber

As most of the rubber cultivated area in estate sector includes high altitude with slope terrain, a study was initiated to know the effect of these factors on the yield of rubber. Significant effects of relief on yield of rubber was observed. The experiment is being continued.

1.8. Mechanistic model for nutrient uptake by rubber

A study was initiated to develop mechanistic model for nutrient uptake of rubber.

1.9. Root studies for efficient utilization of fertilizer

Root studies were initiated to know the rooting pattern and root characteristics of rubber. Observation on fresh and dry weights of fine, coarse and wood roots were completed at different depths for 29 year rubber trees at CES Chethackal.

2. Advisory service

2.1. Discriminatory fertilizer recommendation to smallholders

Discriminatory fertilizer recommendation programme of offering fertilizer recommendation based on soil/leaf analytical values, site characteristics, yield and associated parameters of the field were continued. During the reporting period a total of 8914 soil and 1420 leaf samples were analysed in central (RRII, Kottayam) and eight regional laboratories. 4600 discriminatory fertilizer recommendation were given for small holders. Besides these, as an analytical service, 39311 latex samples were tested for DRC and 257 latex samples for VFA.

2.2. Mobile soil testing programme

Mobile soil testing programme and offering of on the spot fertilizer recommendations were continued in different rubber producers societies all over Kerala. About 53 mobile soil testing programme were conducted in various regions.

CENTRAL EXPERIMENT STATION, CHETHACKAL

The Central Experiment Station, Chethackal is situated at a distance of about 50 km from Kottayam. The station was established to cater the 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 171912.70 kg. Total of 302 tapping days was possible in the year and 65 tappers were engaged for tapping. Total man-days engaged were 27019. The 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

1. Crop improvement

1.1. Evaluation of clones

In the 1985 clone trial with 10 clones the highest girth over 18 years was observed in RRII 118 (75.7 cm) followed by RRII 203 (75.3 cm), RRIM 600 (74.4 cm) and the lowest in PB 5/51 (53 cm) (Table Ghy. 1). RRIM 600 recorded maximum annual average yield (45 g/t/t) over 10 years followed by RRII 118 (44.4 g/t/t) and RRII 203 (44.2 g/t/t), the minimum was in PB 5/51 (21.2 g/t/t) under the normal system of tapping (1/2 s d/2 6 d/7 with tapping rest). Among the trees following 1/2 s d/2 6 d/7 tapping system without tapping rest, highest yield was recorded in RRIM 600 (37.5 g/t/t) followed by PB 86 (34.6 g/t/t), RRII 118 (34 g/t/t) and lowest in Gl 1 (23.5 g/t/t). Under normal system of tapping the annual average of DRC was high in most of the clones except Gl 1 and PB 235. In continuous system of tapping DRC was in the range of 30.5 to 33.3%.

In the 1986 clone trial the highest mean girth over 17 years was in RRIC 102 (78.4 cm) followed by RRII 118 (76.6 cm) and the lowest was in RRII 105 (64.2 cm) (Table Ghy. 2). Mean annual yield over 9 years was highest in RRII 118 (41.1 g/t/t) followed by PB 311 (40.3 g/t/t) and the lowest was in PB 260 (19.5 g/t/t) in normal system of tapping. In continuously tapped trees, the highest mean annual yield was in PB 310 (32.9 g/t/t) followed by PB 311 (31.8 g/t/t) and the lowest was in RRIC 102 (22.9 g/t/t).

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

Clone	Girth (cm)	DRC (%)		Annual mean yield (g/t/t)		Projected yield (kg/ha/yr)	
		Normal	Continuous	Normal	Continuous	Normal	Continuous
RRII 105	63.1	35.1	31.5	38.4	27.9	1397	1674
RRII 118	75.7	36.5	33.3	44.4	34.0	1616	2040
RRII 203	75.3	35.2	32.9	44.2	28.2	1608	1692
RRIM 600	74.4	35.1	30.5	45.0	37.5	1638	2250
RRIM 605	68.3	35.5	31.8	34.4	30.6	1248	1836
PB 86	71.5	35.7	31.3	38.1	34.6	1386	2076
PB 235	70.0	34.1	31.8	41.0	30.9	1492	1854
PB 5/51	53.1	35.3	31.3	21.2	25.4	771	1524
GT 1	70.7	36.1	32.8	43.4	33.2	1579	1992
Gl 1	59.4	34.8	31.6	28.0	23.5	1019	1410

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

Clone	Girth (cm)	DRC (%)		Annual mean yield (g/t/t)		Projected yield (kg/ha/yr)	
		Normal	Continuous	Normal	Continuous	Normal	Continuous
RRIC 102	78.4	34.7	33.7	40.0	22.9	1456	1374
RRIC 105	68.4	34.0	31.4	28.0	26.3	1019	1578
RRII 5	64.8	34.0	32.0	27.1	24.2	986	1452
RRII 105	64.3	34.2	31.5	37.9	31.8	1379	1908
RRII 118	76.6	35.9	31.8	41.1	24.8	1496	1488
RRII 208	68.2	35.7	32.7	36.7	29.6	1335	1776
PB 260	66.3	34.5	30.8	19.5	28.2	7.9	1692
PB 310	71.2	35.0	32.9	39.0	32.9	1419	1974
PB 311	68.2	33.4	31.9	40.3	31.8	1466	1908
PR 255	70.8	36.5	32.7	34.8	26.0	1266	1560

1.2. Evaluation of polyclonal population

Evaluation of polyclonal population in terms of growth and yield was continued. Among the 10 promising selections the highest mean annual yield over 9 years was recorded in selection S2 (116.19 g/t/t) followed by S1 (101.97 g/t/t) and the lowest was in S5 (25.2 g/t/t). Except selection S4, all other polyclonal seedling trees showed high degree of tolerance to powdery mildew disease.

1.3. Evaluation of wild germplasm

Incidence and severity of powdery mildew disease in different wild accessions of *Hevea* germplasm at Sarutari, RES, Nagrakata and Taranagar research farm under agro-climatic conditions of Assam, northern part of West Bengal and Tripura respectively were assessed. Nineteen out of 595 accessions at Sarutari and 28 out of 246 accessions at Taranagar showed high degree of tolerance to powdery mildew disease. Twenty two out of 96 accessions in germplasm trial under cold conditions and 9 out of 21 accessions under Hot Spot trial at Regional Experiment Station, Nagrakata showed high degree of tolerance to powdery mildew disease.

2. Crop management

2.1. Nutritional studies (Mature phase)

Nutritional trial at Nayakgaon in Kokrajhar, showed the influence of N, P and K on girth and yield of *Hevea* under the agroclimatic conditions of Assam. Highest girth (61.53 cm) and DRC (34.71%) were obtained with 40 kg N/ha. Highest doses of N (60 kg/ha) resulted highest yield (66.45 g/t/t). In the case of P, application @ 40kg P_2O_5/ha was found numerically superior in terms of average girth (60.47 cm) as well as yield (54.90 g/t/t) and DRC (34.28%). In case of potassium, significant increase in girth as well as yield was observed due to imposition of treatments and maximum girth (60.03 cm) and yield (49.31 g/t/t) were obtained with the application of 40kg K_2O/ha. Significant increase in soil available nutrients with increasing doses of N, P and K was also observed.

2.2. Interaction between K and Mg on growth and yield

Two trials laid out in Sorutari and Nayakgaon during 1987 were continued. Pottassium at 40 kg/ha and Mg at 15 kg/ha resulted in significant increase in yield (Table Ghy. 3). However, their influence on growth was not significant. Application of K and Mg fertilizer increased the organic carbon content, available phosphorus in soil and antagonistic effect was seen with the application of Mg on available K in soil. Interaction effect of K and Mg on average girth, annual

Table Ghy. 3. **Effect of K x Mg interaction on growth and yield of rubber**

Nutrient level (kg/ha)	Average girth (cm)		Yield (g/t/t)	
	Sarutari	Nayekgaon	Sarutari	Nayekgaon
Potassium (K_2O)				
0.0	61.1	60.9	44.7	40.9
20.0	59.7	61.1	52.9	45.4
40.0	62.3	60.9	64.3	53.3
CD (P=0.05)	NS	NS	5.2	3.3
Magnesium (MgO)				
0.0	62.3	59.4	45.8	34.0
7.5	61.0	6.7	53.7	45.7
15.0	59.5	61.2	60.5	58.2
CD (P=0.05)	NS	NS	4.4	3.4

girth increment as well as average yield was found non-significant. The results from Nayekgaon were similar to that of Soruthari.

2.3. Rock phosphate and super phosphate as source of P for mature rubber

Results of the experiment at Sorutari showed higher yield (59.50 g/t/t) with phosphorus @ 35 kg P_2O_5/ha as a mixture of rock phosphate and single super phosphate (1:1 ratio) while control plot had minimum yield of 43.10 g/t/t (Table Ghy. 4). However, no significant difference in growth was noted.

Table Ghy. 4. **Mean girth and yield as influenced by P fertilizer at Sarutari**

No	Treatment	Mean girth (cm)	Mean yield (g/t/t)
T1	35 kg P_2O_5/ha (MRP)	74.1	54.7
T2	35 kg P_2O_5/ha (MRP:SSP)	72.8	59.5
T3	35 kg P_2O_5/ha (SSP)	71.4	55.6
T4	Control	70.9	43.1
CD (P=0.05)		NS	8.0

At Nayekgaon, higher yield (49.70 g/t/t) was obtained with the application of 40 kg P_2O_5/ha (Table Ghy. 5). A significant improvement in soil available P status was recorded due to application of P compared to control. Rock phosphate affected more building up of soil available phosphorus than that of water soluble phosphorus. An increase in soil pH was also observed particularly due to application of rock phosphate.

Table Ghy. 5. **Effect of P fertilizer on growth and yield of rubber at Nayekgaon**

Treatment	Girth (cm)	Yield (g/t/t)
T1:Control	61.6	35.7
T2:20 kg P_2O_5/ha (SSP)	62.1	46.4
T3:20 kg P_2O_5/ha (MRP)	62.6	48.6
T4:40 kg P_2O_5/ha (SSP)	62.0	49.7
T5:40 kg P_2O_5/ha (MRP)	63.1	44.6
T6:60 kg P_2O_5/ha (SSP)	63.7	47.2
T7:60 kg P_2O_5/ha (MRP)	61.1	44.7
CD (P=0.05)	NS	6.8

2.4. Effect of varying snag length on scion sprouting

A snag of 5 cm above the bud patch resulted in maximum (80%) sprouting while a snag of 20cm resulted in minimum sprouting (42.50%) (Table Ghy. 6).

2.5. Evaluation of polybags and bamboo baskets for passing planting materials

The results showed that sprouting success (77.50%) from budded stumps planted in bamboo basket (55 cm X 25 cm) than in small polybags (43 cm X 23 cm).

3. Crop protection

3.1. Survey on diseases and pests of *Hevea* rubber

A survey on pests and diseases of *Hevea* rubber was carried out in 58 locations covering 26 different rubber growing tracts in Assam, Meghalaya, Tripura and northern part of West Bengal. The severity of powdery mildew disease was high (above 3.5) in Umsiang, Umling, Sarutari, Nagrakata,

Table Ghy. 6. **Effect of varying snag length on scion sprouting**

Treatment	Sprouting success (%)	Plant height (cm)	Girth (cm)	No. of leaf whorl
Control (Standard cutting)	62.5	49.2	4.07	2.7
1 cm above bud patch	60.0	63.6	5.28	2.8
5 cm above bud patch	80.0	59.5	5.54	2.7
10 cm above bud patch	77.5	57.5	5.02	2.7
15 cm above bud patch	62.5	50.5	4.53	2.3
20 cm above bud patch	42.5	49.8	4.65	2.3

Laxmandepha, Tulakona, Rishidas colony, Taranagar and Anandanagar areas causing repeated premature defoliation and die-back of twigs and branches. The clones SCATC 88/13, SCATC 93/114, PB 86, RRIC 100, RRII 429, RRII 417, RRII 208, RRII 203, RRIM 703 and Haiken 1 showed high degree of tolerance to powdery mildew disease. High incidence of Periconia leaf blight disease was noticed on tender leaves in nursery during November to March in Assam and Meghalaya causing repeated premature defoliation and die-back of shoots. Minor incidence of secondary leaf fall (SLF) disease was also noticed on tender leaves in nursery and immature and mature rubber plants during rainy months (June to September) in most of the locations. Low incidence (below 5%) of pink disease was observed on immature rubber plants (RRII 105 & RRIM 600) only at RES, Nagrakata, Jiti and Rongo estates (private) in northern part of West Bengal. Incidence of purple root disease (below 10%) was noticed only in seedling nursery plants at DDC, Jenggitchakgre, in Meghalaya. Minor incidence (below 5%) of brown root disease was noticed in private plantations in Assam and Tripura. The severity of brown root disease was found to be high in Tripura compared to other states in North East region. Mild attack of mealy bug on mature leaves at RES, Nagrakata, West Bengal and weevil (*Hypomeces squamosus*) in nursery at Sarutari farm were noticed. Minor infestation of scale insect (*S. nigra*), termites, slugs and snails were also noticed in most of the locations surveyed.

3.2. Isolation, identification and molecular characterisation of fungal pathogens of rubber

Isolation of fungal pathogens from diseased samples of *Hevea* rubber collected during survey in North East and northern part of West Bengal was carried out. Fungal pathogens *viz.*, *Bipolaris heveae, Cylindrocladium quinqueseptatum, Periconia heveae, Colletotrichum gloeosporioides, Corticium salmonicolor, Phellinus noxius and Helicobasidium compactum* were isolated and studied for strain differentiation.

3.3. Control of purple root disease

A trial for control of purple root disease in seedling nursery 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 3 systemic fungicides *viz.*, Tilt (0.1 & 0.2%), Calixin (0.15 & 0.3%) and Bavistin (0.15 & 0.3%) including Bioflora natural (biopesticides: 20 g/plot) and one year fallow treatment. Complete control of the disease was observed in experimental plots treated with Tilt, Calixin, Bioflora natural and also in one year fallow treatment (Table Ghy. 7).

4. Exploitation technology

The experiment on tapping rest and frequency interaction studies (started during 1999 with the clone RRIM 600) was continued. Normal tapping (1/2S d/2 6d/7) with and without rest is being compared with other tapping systems *viz.*, 1/2S d/3 6d/7

Table Ghy. 7. **Effect of systemic fungicides and Bioflora Natural on the control of purple root disease of rubber seedlings in nursery**

Treatment	Affected plants/ Plot (mean of 3 Replications)	DI (%) root disease over control	% reduction in purple
Control 5.6	14.0	-	
Tilt : 0.1 % 0.3	0.75	94.6	
Tilt : 0.2 % 0	0	100	
Tilt : 0.2 % alternate with Calixin : 0.3 %	0	0	100
Calixin : 0.15 %	0	0	100
Calixin : 0.3 %	0	0	100
Calixin : 0.3 % alternate with Bavistin : 0.3 %	0	0	100
Bavistin : 0.15 %	3.7	9.25	33.9
Bavistin : 0.3 %	1.5	3.75	73.2
Bavistin : 0.3 % alternate with Tilt : 0.2 %	0	0	100
Bioflora Natural	0	0	100
Fallow beds of 1 year	0	0	100

Table Ghy. 8. **Variation in growth and yield of rubber under different exploitation systems**

Treatment	Exploitation system	Average girth (cm)	DRC %	Yield (g/t/t)	No. of tapping days	Projected yield (kg/ha/yr)
T-1	1/2S d/2 6d/7 – regular tapping	66.5	30.8	35.3	109	1537
T-2	1/2S d/2 6d/7 – one month rest*	59.6	28.0	31.6	100	1262
T-3	1/2S d/2 6d/7 – two months rest**	63.0	29.4	30.1	89	1072
T-4	1/2S d/2 6d/7 – three months rest***	65.4	32.7	41.0	94	1153
T-5	1/2S d/3 6d/7 continuous tapping 5 stimulations	65.9	29.9	46.5	62	1125
T-6	1/2S d/3 6d/7 – one month rest*	68.6	31.9	50.2	56	1346
T-7	1/2S d/3 6d/7 – two months rest**	69.1	31.0	62.9	48	1290
T-8	1/2S d/3 6d/7 – three months rest***	67.7	31.5	57.9	65	1360
T-9	1/2S d/4 6d/7 continuous tapping 7 stimulations	68.2	31.6	61.8	55	1107
T-10	1/2S d/4 6d/7 – one month rest*	69.9	31.8	70.1	44	1504
T-11	1/2S d/4 6d/7 – two months rest**	64.9	33.5	64.5	50	1350
T-12	1/2S d/4 6d/7 – three months rest***	70.6	34.0	76.6	44	1350
	'F' test	NS	Sig.	Sig.		
	SE 2.7	0.8	6.4			
	CD (P=0.05)	NS	2.4	17.8		

* February; **February & March; *** January - March

and 1/2S d/4 6d/7 with stimulation. The data revealed significant influence of the treatments. Maximum yield (70.6 g/t/t) and DRC (34%) was recorded for the treatment T_{12} followed by T_{10} (69.9 g/t/t) and minimum DRC was in T2 (28 g/t/t). Maximum projected average yield (1537) kg/ha) was obtained under the treatment T1 followed by T10 (1504 kg/ha) and minimum was in T3 (1072 kg/ha/year) (Table Ghy. 8). However, differences in girth were not significant among the treatments.

REGIONAL RESEARCH STATION, AGARTALA, TRIPURA

Clone evaluation and studies on nutrition, exploitation techniques and intercropping are the major activities of the station. Advisory services on discriminatory fertilizer application and processing of better quality sheet rubber were provided to the growers of this region.

1. Agronomy and soils

In the study on the effect of different fertilizer doses at different densities on two clones, significant differences in yield were observed among the densities and highest yield per tree (50 g/t/t) was observed in lowest density. In the tea intercropping trial, total annual fresh leaf yield was 473 g/m^2. In the experiment on organic and inorganic manuring, maximum girth was observed in the treatment with 20 kg of FYM/plant/ year along with recommended doze of fertilizer.

In the study on potassium dynamics, it was observed that soils were low to medium in available K. Surface soil contained relatively higher amount of water soluble-K (WS-K) and exchangeable-K (Ex-K) and the concentration decreased with increasing depth. Non-exchangeable form of K (Non-ex K) showed a reverse trend and higher amount of K was found in the lower depths (Table Net. 1). Total K also increased and varied from 1.3 to 2.5% with depth.

A new experiment to study the response of high yielding *Hevea* clones to different doses of fertilizers in Tripura was initiated. Clones RRII 417, RRII 429, RRII 430 and RRIM 600 (control) with five fertilizer doses were included. In order to study the effects of different level and time of fertilizer application on growth of RRIM 600, an onfarm trial was taken up.

2. Breeding and selection

Evaluation of clones, recombination breeding and selection, evaluation of polycross progenies and evaluation of germplasm are the main lines of breeding research. Four clone evaluation trials, two on-farm trials and a clonal demonstration trial are in progress. Progenies of recombination breeding are being evaluated in three sets.

2.1. Evaluation of clones

Among the 15 clones evaluated comparatively higher yield was recorded for clones PB 235, RRII 203 and RRIM 600 (Table Net. 2). GGE Biplot analysis showed no

Table Net. 1. **Availability of different forms of potassium at different depths**

Depth (cm)	WS-K (ppm)	Ex-K (ppm)	Non-ex K (ppm)	Total K (%)	Available K (ppm)
0-15	5.2 - 10.2	40.4 - 78.6	510 - 750	1.3 - 1.7	45 - 95
15-30	4.3 - 8.2	30.1 - 44.6	580 - 840	1.7 - 1.9	38 - 55
30-60	3.9 - 6.7	14.1 - 33.7	715 - 980	1.98 - 2.5	18 - 40
60-90	3.0 - 5.4	14.0 - 31.7	750 - 1100	2.25 - 2.5	14 - 32

Table Net. 2. **Projected yield of 15 clones**

Clone	Yield (kg/ha)				Mean of 14 years
	2000-01	01-02	02-03	03-04	
PB 235	2810	2236	2628	1260	1979
RRII 203	2528	2481	2705	1662	1816
RRIM 600	2271	1963	1851	1582	1632
RRII 118	1856	1599	1844	1326	1510
RRIM 703	2177	1911	2250	1088	1519
RRII 105	2044	1631	1911	1165	1403
PB 86	1421	1330	1477	1025	1175
RRIC 105	1458	1242	1760	1064	1184
RRIM 605	1679	1379	1466	913	1153
GT 1	1718	1389	1627	1414	1190
RRII 5	2024	1634	2163	1081	1207
RRIC 52	1263	1414	1634	997	1076
PB 5/51	1204	913	1246	749	961
Harbel 1	924	780	1326	605	794
GL 1	805	577	542	388	594

½ S d/2 6d/7 tapping system; 100 tapping days; 350 trees/ha

grouping indicating divergent adaptation towards yield. RRII 208 followed by RRIM 600 were the high yielders in clone evaluation trial for stress tolerance.

In the clone trial laid out during 1995 with 10 clones, RRIM 612, RRIM 600 and PB 235 showed higher girth (Table Net. 3).

Table Net. 3. Girth of ten clones

Clone	Girth (cm)
RRII 105	41.7
RRIM 600	45.6
RRIM 612	46.7
PB 217	38.2
PB 235	45.2
PB 260	43.6
PB 311	38.1
SCATC 88/13	41.0
SCATC 93/114	30.4
HAIKEN 1	41.5
Mean	41.2
CD (P=0.05)	4.7

Six clones that were found to be promising as potential clones in the large-scale trials were raised in an on-farm trial at Killamura. The ranking of the clones based on girth data was RRII 203 (42.9 cm), Haiken 1 (40.4 cm), RRII 208 (40.3 cm), RRIM 600 (39.2 cm), PB 260 (35.6 cm) and PB 235 (33.6 cm). Eight potential clones were also raised in block trial at Bagafa to evaluate their potential. Girth (cm) of the clones were 23.0 (RRII 118), 16.5 (RRII 203), 15.7 (RRII 208), 23.5 (PB 235), 11.7 (PB 260), 10.0 (RRIM 600), 9.2 (RRIM 703) and 19.9 (HAIKEN 1).

Tapping in the clonal demonstration trial consisting of four clones *viz.*, PB 235, RRIM 600, RRII 105 and GT 1 was started from October 2002. Initial yield showed RRII 105 (847 kg) and PB 235 (840 kg) as high yielding.

2.2. Evaluation of polycross progenies

Seventy five hybrids obtained during 1998 flowering season were maintained in the field. Two recombinants (RRIM 600 x PB 5/51 and RRIM 600 x 18/1) recorded highest girth (28.6 and 28.5 cm respectively). Evaluation of potential yielders from polyclonal seedling population and ortets from Kerala (field planted during 2000) were maintained.

2.3. Conservation and evaluation of germplasm

In the germplasm evaluation trial the Acre accessions showed maximum girth (52.7 cm in Trial I and 54.3 cm in Trial II). However, one (MT 4713) of the Matto Grosso accessions showed better girth (60.4 cm) than the control RRIM 600 (57.3 cm) in Trial I. In Trial II, RO 5004 and MT 4810 recorded higher girth of 61.9 and 61.3 cms respectively compared to the control RRIM 600 (59.8 cm).

3. Studies on physiology

3.1. Exploitation systems

The experiment on tapping rest and frequency interaction conducted on RRII 105 and RRIM 600 with ½ S d/2 6d/7 tapping system and one month rest (February) produced the highest yield in RRII 105 while in RRIM 600 no rest gave the best result. However, ½ S d/3 6d/7 tapping system (5 stim) with two month rest (February & March) was

comparable to ½ S d/2 system in RRII 105. Effect of different tapping cuts and tapping systems on yield of clone RRII 105 showed ¼ S d/2 6d/7 with 5 stimulation has recorded highest yield (1616 kg / 400 trees/year) followed by ½ S d/2 6d/7 system without stimulation.

3.2. Plant physiology

An experiment was initiated to study the extent of higher light induced damage under different levels of N supplementation. Two sets of *Hevea* polyclonal seedlings were grown under 0.25 M, 0.5 M, 1 M nitrogen mixed in Epstein's nutrient solution out of which one set was kept under full solar irradiance and other at 40% solar irradiance. The chlorophyll content index (CCI) measured by Chlorophyll meter (CCM-200) indicated that plants with 0.25 M and 0.5 M nitrogen supplementation showed almost similar response (60.1 and 59.8 CCI respectively) under low irradiance condition. However, there was decline in CCI under 1.0 M nitrogen condition. With high irradiance condition, average CCI readings were 44.5, 49.9 and 49.6 respectively.

4. Advisory services

Soil samples collected from West, South and Northern districts of Tripura, Assam, Nagaland and Arunachal Pradesh were analyzed for discriminatory fertilizer recommendation. A total of 456 discriminatory fertilizer recommendations were offered to growers of North Eastern Region. Advisory service in rubber processing was also provided. A total of 1972 tonnes of imported rubber was inspected at Kolkata port for quality standards.

REGIONAL RESEARCH STATION, TURA, MEGHALAYA

The Regional Research Station, Tura continued its research activities on evaluation of clones, polyclonal population, evolving suitable exploitation system and aspect of slopes and 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 (86.3 cm) and yield (47.7 g/t/t) while lowest girth (66.10 cm) and yield (28.1 g/t/t) were registered in PB 5/51. In 1986 trial, among the ten clones RRIC 105 registered the highest girth (83.18 cm) followed by PB 311 (83.10cm). PB 311 registered the highest yield (46.2 g/t/t). Polyclonal population attained an average girth of 68.45 cm with 25.6 g/t/t yield. Among the population highest yield recorded was 68.8 g/t/t.

2. Plant physiology

The effect of low temperature on growth and yield in RRIM 600 was studied. Low temperature adversely affected the growth but enhanced latex and yield resulting in higher recovery of rubber.

3. Crop management

3.1. Nutritional studies

From the nutritional requirement trials in Central Brahmaputra Valley Zone (CBVZ) of Assam at Borgang and Sonitpur NPK @ 60:30:45 kg/ha produced the best result (62 g/t/t). Application of NPK fertilizer significantly increased the organic carbon content, available P and K.

3.2. Interaction between K and Mg on growth and yield

Data of fifteen years showed that the

different levels of K and Mg increased the yield significantly. Maximum yield was found under the treatment combination of K and Mg at 10:15 kg/ha. However, the influence of treatments on growth was found to be non significant. The different levels of K and Mg significantly increased the N, P, K and Mg contents in leaf and organic carbon and available P, K and Mg contents in soil.

3.3. Leaf nutrient concentration in different clones

A new study was undertaken at West Garo Hills to find out the variation in leaf nutrient concentration among the different clones. Nitrogen (N) concentration in leaf showed low to medium ranges among the different clones and maximum N content was noticed in RRIM 600 (3.28%) and minimum in Gl 1 (2.98%). The leaf-P and K content showed medium to high range and maximum P content was noticed in clone RRIM 600 (0.29%) and minimum in Gl 1 (0.24%). Maximum K content was noticed in the clone RRIM 600 (1.56%) and minimum in PR 255 (1.20 %).

REGIONAL EXPERIMENT STATION, NAGRAKATA, WEST BENGAL

1. Crop improvement

The evaluation trials laid out with clones having better performance in terms of yield with special reference to high-speed wind, cold and high-sunshine intensity tolerance were continued. In the clone trial I (CT I), SCATC 93/114 and PB 5/51 were in the top position in terms of GI index (4.38 & 4.21 respectively) compared to other clones (Table Nag.1). Similarly, PB 86, RRIM 612 and Gl 1 showed higher GI index (2.58, 2.48 and 2.34) in CT II. In CT III, PR 107 and RRII 208 showed higher index value (4.26 and 3.86) and in CT IV, RRII 308 showed higher value (14.20) followed by PB 280 and PR 261 (9.92 and 9.16) in terms of GI index.

In terms of yield, SCATC 88/13 showed higher value (51.42 g/t/t) followed by RRIM 703 (42.69 g/t/t) in CT I. In CT II, RRIM 605, RRII 208 and RRII 105 showed similar but high yield (73.9, 73.88 and 71 g/t/t). The clones that showed high yield in CT III were RRIM 600, PB 235, RRII 208, HK 1 and PB 310 (53.43, 52.46, 49.93, 47.04 and 45.21 g/t/t respectively). The clones HK 1 and RRII 208 ranked high (56.5 and 51.1 g/t/t) in CT IV.

Table Nag. 1. **Ranking of clones in terms of GI index**

CT I Clone	GI	CT II Clone	GI	CT III Clone	GI	CT IV Clone	GI
HK 1	0.09	PR 107	0.59	PB 86	0.14	RRIM 600	0.62
PB 311	0.10	RRII 105	0.61	RRIM 600	0.50	RRII 208	0.97
SCATC 88/13	0.81	RRII 208	0.89	HK 1	1.15	HK 1	1.22
RRII 203	0.86	RRIM 605	1.84	PB 260	1.82	SCATC 93/114	1.65
RRIM 703	0.97	Gl 1	2.34	PB 310	1.83	RRII 310	2.84
RRII 118	1.28	RRIM 612	2.48	RRIC 102	1.90	RRIC 104	3.32
PB 235	1.70	PB 86	2.58	PB 235	2.05	PB 235	3.55
GT 1	1.85			RRIM 612	2.38	RRII 105	6.00
RRII 300	2.72			SCATC 93/114	3.26	PR 261	9.16
PB 5/51	4.21			RRII 208	3.86	PB 280	9.92
SCATC 93/114	4.38			PR 107	4.26	RRII 308	14.20
CD (P=0.05)	3.04		2.65		2.98		9.55

In the 1998 Germplasm trial to study the adaptability of 21 genotypes in the climatic condition of North Bengal and also to conserve selected germplasm for this region.

In terms of test tapping (yield) data, the RO 5363 is performing the best (220 g/t/t with 42 cm girth at 150 cm height and 47 cm girth at 30 cm height). This is followed by RO 105 (158-36-40) and Gl 1 (155-36-39). Lowest yield was observed for AC 607 (3-23-28), RO 3172 (4-38-41), AC 619 (7-36-41) and MT 2594 (12-28-33).

2. Crop management

In the 1989 trial effect of nitrogen on girth was found significant but different combinations of nitrogen, phosphorus and potash was found to have no significant effect on yield, girth increment and DRC. However, maximum mean annual yield was recorded up to the dose of nitrogen at the rate of 15.00 kg/ha. In the case of phosphorus, increasing trend of girth and mean annual yield was recorded but for potash, yield response was found up to 20 kg/ha. Interaction effect of their different combinations was found non-significant.

In the 1993 trial to evaluate the effect of split application of fertilizer no significant effect on girth, annual girth increment, mean annual yield and DRC was recorded for different split application of fertilizer. However, three split application of fertilizer recorded maximum girth (58.10 cm) and annual girth increment (3.10 cm). Mean annual DRC value was also found non-significant in different split application of fertilizer.

3. Intercropping

In the 1999 intercropping trial of rubber with tea the girth of tea was found significantly higher in intercropped tea than pure tea in T4 and T5 and at par with T2 and T3. Rubber girth was also found higher in all the intercropped rubber than pure rubber and it was significantly higher in T3 and T5. The 2000 trial with arecanut found no significant difference in different treatments with respect to girth and girth increment of rubber and arecanut.

4. Exploitation

In order to formulate appropriate tapping system for Dooars area of North-Bengal, experiment was laid out in split-plot design using tapping system as main treatment (½ S d/1, ½ S d/2 & ½ S d/3) and temperature rest as sub-treatment (control, 12 rest, 15 rest & 18 rest). However, as ½ S d/1 tapping system was showing maximum TPD and the bark from both the lower panels was consumed, this treatment was stopped from September, 03.

The two factor ANOVA in different tapping systems with rest treatment showed (Table Nag. 2) that there is no significant difference between the two main treatments *ie.* ½ S d/2 and ½ S d/3; however, between the sub-treatments, the difference is noticed for 15 rest and 18 rest compared to that of the control but not between the 12 and control.

Table Nag. 2. **Yield performance in different combinations of tapping**

Main Treatment	Yield	Sub-treatment	Yield (kg/ha)
		(kg/ha)	
½ Sd/2	1321	Control	1373
½ Sd/3	1150	12-12 rest	1207
		15-15 rest	1100
		18-18 rest	1082
CD (P=0.05)	192.09		

The study on TPD also showed that in ½ S d/2 the occurrence of TPD is more than that of the ½ S d/3. From the comparative study of the two treatments, it was observed that the ½ S d/3 being lower in number of tapping frequency with lower occurrence of TPD and 12 rest being low tapping days, the combination of ½ S d/3 with 12 rest might be the target of interest.

REGIONAL RESEARCH STATION, DAPCHARI, MAHARASTRA

Major thrust areas of research are development of suitable planting materials and location specific agro technology for this drought prone region. Ten research projects are undertaken by the station in five major areas *viz*. environmental physiology, exploitation studies, plant breeding, plant pathology and germplasm. Experiments to evaluate low frequency tapping systems and irrigation requirement, screening of wild *Hevea* accessions for drought, studies of 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

Three irrigation based experiments were conducted to study the effect of irrigation and irrigation system on yield of rubber. The irrigation experiment started in 1987 with ETC based Basin (1.00 ETC, 0.75 ETC and 0.50 ETC) and drip (0.75 ETC, 0.50 ETC, 0.25 ETC) irrigation treatments in clone RRII 105 was continued. The objective was to standardize and evaluate the advantages of drip irrigation system over basin irrigation in terms of water saving and total economy in the quantity of water and methods of irrigation. From February 2000 onwards on the 0.75 ETC basin and 0.50 ETC, drip were reduced to 0.25 ETC (basin and drip) to test whether irrigation requirement can be further reduced. Observations on the fortnightly cup lump weight, monthly girth measurements and seasonal DRC, PI and TP were recorded. The basin irrigation system showed the highest girth compared to drip irrigation system. Higher yield was recorded in all levels of basin irrigation as compared to drip irrigation treatments (Table Dap. 1).

Table Dap.1. **Effect of drip and basin irrigation on growth and yield in RRII 105**

Treatment	Mean annual girth (cm)	Mean dry rubber yield (g/t/t)	Projected yield (kg/ha)
Control (No irrigation)	58.07	42.53	1272.71
1.00 ETC basin	66.27	50.56	1513.00
0.25 ETC basin (Earlier 0.75 ETC)	66.60	46.75	1398.99
0.50 ETC basin	63.73	49.38	1477.70
0.75 ETC drip	63.95	47.16	1411.26
0.25 ETC drip (Earlier 0.50 ETC)	64.08	49.37	1477.39
0.25 ETC drip	61.14	44.96	1345.43
SE	0.91	3.59	
CD (P=0.05)	1.99	7.82	

Projected yield = g/t/t x no of tapping days x no of trees/ha x 0.9/1000

In 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, fortnightly yield, monthly girth and seasonal DRC percentage, PL, BL and TP are being monitored. RRII 118 performed better in terms of growth than RRII 105 in all irrigation treatments. On the contrary, RRII 105 recorded better yield and yield component characters in all irrigation treatments compared to RRII 118 (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 rainfed trees of RRIM 600. Analysed and monitored the effect of reduced level of irrigation (ie. 220 l) once in three weeks in January and February 2004 and 330 1 once in three weeks from March 2004 till monsoon in group B, keeping group A as rainfed and group C as full irrigated

Table Dap. 2. **Effect of irrigation on growth and yield in RRII 105 and RRII 118**

Treatment	Annual girth (cm)		Dry rubber yield (g/t/t)		Projected yield (kg/ha)	
	RRII 105	RRII 118	RRII 105	RRII 118	RRII 105	RRII 118
Control (No irrigation)	60.78	69.36	45.26	35.00	1354.40	1047.37
1.00 ETC	67.33	84.11	54.23	47.05	1631.81	1407.97
0.75 ETC *	66.63	84.30	48.76	48.74	1459.14	1458.54
0.50 ETC	65.72	76.69	54.61	43.52	1634.20	1302.34
For irrigation SE+	3.23		0.35		6.09	
Treatments CD (P-0.05)	7.91		0.86		14.91	
For clones SE +	1.46		0.19		2.06	
CD (P=0.05)	3.38		0.43		4.75	

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

(1ETC). The results revealed that even under restricted irrigation, trees recorded a high yield due to better soil depth.

2. Exploitation studies

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

Two trials were initiated for evolving the optimum stimulation schedule under 1/2S d/3 tapping system in clones RRII 105 (Trial I) and RRIM 600 (Trial II) under irrigation started in December 1999 and February 2000 respectively. Stimulation treatments T0 (control, no stimulation), T1 (2/y), T2 (4/y) and T3 (6/y) were imposed as per schedule under irrigation (0.05 ETC). Observations on DRC (%) before and after stimulation, annual girth increment and TPD were recorded. Among the four treatments yield was highest (2093 kg/ha) in T3 (6/y) without significant effect in growth. Results indicated high rubber yield in the ethephon treated trees as compared to control. No change in DRC was noticed after stimulation (Table Dap. 3).

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 (0.05 ETC) to all treatments. Observations on DRC (%) before and after stimulation, annual girth increment and TPD incidence were recorded. Among the various treatments yield was highest (1712 kg/ha) in T1 (4/y) without significant effect on growth. No change in DRC was noticed after stimulation (Table Dap. 4).

The experiment started in 1999 to study the tapping rest-cum-stimulation interaction under low frequency tapping system (1/2S

Table Dap. 3. **Stimulation schedule under 1/2S d/3 in clone RRII 105 (irrigated)**

Treatment	Yield (kg/400/trees)	DRC (%) before stimulation	% Girth after	TPD % increment stimulation	Yield (g/t/t)	
T0 – Nil	1786	38.47	—	1.16	0.0	42.51
T1 – (2/y)	1963	37.11	36.00	1.14	0.0	46.74
T2 – (4/y)	2275	34.60	34.50	0.57	0.0	54.18
T3 – (6/y)	2424	34.72	32.10	0.75	0.0	57.71
SE ±				0.19		4.23
CD (P=0.05)				0.40		9.02

Table Dap. 4. **Studies on stimulation schedule under 1/2S d/3 in clone RRIM 600 (irrigated)**

Treatment	Yield (kg/ 400 trees)	DRC (%) before stimu-lation	% Girth after stimu-lation	TPD % increment		Soil moisture (%) 0-30 cm	30-60 cm	Yield (g/t/t)
T0 – (2/y)	1667	34.21	32.13	0.69	0.0	15.1	17.5	39.68
T1 – (4/y)	1712	30.35	32.30	0.90	0.0	15.4	17.4	40.76
T2 – (6/y)	1607	31.37	30.70	1.16	0.0	16.0	25.0	38.27
T3 – (8/y)	1585	31.64	31.00	1.05	0.0	16.9	19.0	37.74
Variance				0.95				116.20

d/3) in clone RRII 105 under rain fed condition with the objective to find out best tapping rest period during summer was continued. Observations on DRC before and after stimulation (by gravimetric method), annual girth increment and TPD incidence were recorded. 75 per cent tapping panel area drying due to TPD syndrome was observed in 20 and 16 per cent trees of T1 and T2 treatment. Higher yield was observed in treatment (T3) with tapping rest in May and June with four stimulation/year, without any significant effect on the growth of trees. Results indicated that stimulation did not affect DRC %. Data also showed that tapping days can be reduced by stimulation (Table Dap. 5).

3. Plant breeding

In 1985 clone trial, to evaluate fifteen modern clones to select high yielding and drought tolerant clones, for North Konkan regions, all the clones were maintained under limited irrigation since 1985. Monthly girth, DRC % and fortnightly yield were recorded and RRII 208 performed better in terms of growth and yield followed by RRII 105 and RRIE 102 (Table Dap. 6).

4. Polyclone evaluation trial

Experiments were laid out in 1983 and 1985 to study the yield performance of polyclonal progeny under the environmental condition of North Konkan and to select ortet trees for further evaluation. Out of the population of nearly 1000 trees promising trees were selected during 1996 and were catagorised as high girth, low girth, high yielder and low yielder trees. The selected trees were cut back to generate sprouts, which were used for multiplication by budding. Observations on fortnightly yield, seasonal girth measurement, soil moisture measurement and yield components are being recorded. Data on growth and latex yield were pooled and stable high yielder identified for further selection.

Table Dap. 5. **Tapping rest cum stimulation interaction (1/2S d/3) in RRII 105 (rain fed)**

Treatment	Yield (kg/ 400/trees)	DRC (%) before stimu-lation	% Girth after stimu-lation	TPD % increment		Soil moisture (%) 0-30 cm	30-60 cm	Yield (g/t/t)
T0 – Nil	1638	35.78	-	1.04	0.00	15.80	19.70	37.40
T1 – (6/y)	1652	31.60	33.16	1.00	0.00	15.30	19.10	56.15
T2 – (6/y)	1397	31.06	30.00	1.26	0.00	16.00	19.30	45.48
T3 – (4/y)	1706	33.35	31.34	1.38	0.00	15.30	20.10	46.40
SE ±				0.16				4.52
CD (P=0.05)				0.35				9.64

Tapping days – T0 – 93, T1- 74, T2 – 77, T3 – 85

Table Dap. 6. **Growth and yield of 15 *Hevea* clones**

Treatment	Girth (cm)	Dry rubber yield (g/t/t)	DRC %	Projected yield (PY) (kg/ha)
RRII 5	58.56	27.53	40.53	823.8
RRII 6	61.70	32.39	40.22	969.27
RRII 105	55.49	34.62	41.60	1036.00
RRII 208	63.89	50.07	39.41	1498.34
RRII 308	55.73	21.28	37.17	636.80
RRIM 605	56.81	21.69	38.83	649.07
PB 26	58.94	27.57	39.27	825.03
PB 310	58.99	26.40	38.86	789.72
PB 311	56.54	29.85	35.66	893.26
RRIC 52	63.67	20.31	42.96	607.77
RRIC 100	58.07	32.42	40.36	969.86
RRIC 102	59.51	33.79	41.11	1011.16
RRII 105	56.24	20.02	41.16	598.79
PR 255	55.99	26.92	40.92	805.28
PR 261	56.33	21.98	39.04	657.75
SE±	1.98	3.54	1.15	
CD (P=0.05)	4.06	7.24	2.35	

PY = g/t/t x no of tapping days x no of trees /ha x 0.9/1000

5. Plant pathology

In the experiment to evaluate the susceptibility/tolerance of various *Hevea* clones and polyclonal seedling to powdery mildew, no incidence was recorded in this region. This might be due to prevailing high temperature.

6. Germplasm

One hundred and thirty eight wild *Hevea* accessions along with three selected controls *viz*. RRII 105, RRIM 600 and Tjir 1 were raised in poly bags for screening for drought tolerance. Survival per cent of young plants were recorded in nursery. These accessions were field planted for drought screening and pre and post drought growth parameters were recorded. In general, Mato Grosso accessions were superior for all the growth characters as compared to accessions from Acre and Rondonia provenances.

REGIONAL RESEARCH STATION, DHENKANAL, ORISSA

The Regional Research Station at Dhenkanal undertakes location specific research so as to develop a package suited for this region. The station concentrates its research activities on developing suitable agro management techniques, water conservation and clone evaluation of rubber for specific drought prone areas of this region. Research on crop management and crop improvement were continued in the experimental farms.

Crop improvement

1. Evaluation of clones

In the clone trial (1987), significant difference in girth was observed. GT1 (63.61 cm) and RRIM 600 (63.03cm) have recorded significantly higher mean girth over RRII 105 (57.95 cm) and highest annual girth increment was noticed in RRII 105 (1.15cm). among the clones, RRIM 600 and RRII 105 recorded significantly higher mean yield 30.50g/t/t and 27.51g/t/t, respectively than GT 1(23.00 g/g/t) (Table Ori. 1).

In the second clone trial (1990) no significant difference in girth was recorded. However, maximum mean was recorded in SCATC 93-114 (68.19 cm) closely followed by RRII 208 (64.03 cm) while, Haiken 1 and

Table Ori. 1. **Mean girth increment (GI) and yield of 3 elite clones**

Clone	Girth (cm)		GI	Yield
	Mar. 03	Mar. 04	cm	(g/t/t)
RRII105	56.8	57.95	1.15	27.51
RRIM 600	62.7	63.03	0.33	30.50
GT1	62.8	63.61	0.81	23.00
SE	1.39	0.71	-	1.06
CD (P=0.05)	4.29	2.61	-	3.17

RRIM 701 recorded the lowest girth. The highest annual girth increment (2.43 m) was recorded in PB 310. among the clones, RRII 208 and 88/13 had recorded significantly higher mean yield 35.89 and 34.81 g/t/t, respectively than rest of the clones. The lowest yield was recorded in SCATC 93/114 (17.23 g/t/t). In the third clone trial (1991) comparison of *Hevea* clones with polyclonal seedlings was studied. Among the clones GT 1 recorded high mean girth (67.26 cm) followed by RRIC 102 (64.76 cm) and RRII 208 (64.08 cm). However, polyclonal seedlings (69.61 cm) performed better showing stress tolerance in this region. Maximum mean girth increment was noticed in PR 255 (2.37 cm). Among the clones RRII 208 was the high yielder (34.61 g/t/t) followed by RRII 105 (32.91), and RRII 5 (32.0g/t/t), RRIM 600 (26.30 g/t/t).

In the fourth clone trial (1996) an on farm at RRI, Bhubaneswar, RRII 430 (46.1cm) indicated better mean girth followed by RRIC 100 (44.0 cm), RRII 417 (42.5 cm), RRII 203 (42.6 cm), RRII 422 (41.3 cm), RRIM 600 (41.9 cm and RRII 429 (40.2 cm) lowest girth was noticed in RRII 51 (35.8 cm). In the fifth clone trial (1999-00), highest mean girth was observed in RRII 352 (22.37 cm) closely followed by PB 28/59 (22.29 cm) and RRII 357 (21.72 cm). Lowest was in IRCA 109 (17.93 cm) and RRII 51 (18.71 cm).

2. Polyclonal trial

This experiment was laid out in 1989. based on the initial growth performance 11 promising polyclonal tree were identified for further selection and evaluation. Highest mean girth was recorded in selection tree No.471 (108.2 cm) followed by tree No.482 (106.8 cm) and tree No 32 (106.2 cm) and the lowest in tree No. 280 (88.7 cm). maximum annual mean yield was recorded in selection tree No. 154 (80.3 g/t/t/) followed by tree No 482 (75.4 g/t/t) and the maximum in tree No 451 (34.1 g/t/t).

Crop management

3. Nutritional studies

The experiment was laid out to assess the nutritional requirements (NPK fertilizers) on the growth of *Hevea* seedlings. The 27 treatments combination of 3 levels of NP and K fertilizers I e, @ N =0, 300, 600 Kg/ha; P=0,150,300 Kg/ha and K =0, 60, 120 kg/ha along with other culture practices as per the boards recommendation were carried out during the period. Soil and leaf samples were collected for physical and chemical analysis, treatment $N_2 P_1 K_2$ and $N_2 P_2 K_0$ were found superior for all the growth parameters (growth, height, and no. of whorls). In another trial laid out with RRIM 600 in 1999 - 2000, the effect of water–soluble and water in soluble forms of P on growth of *Hevea* and the effect of higher dose of NPK fertilizer with appropriate number of split application needed for optimum growth of rubber in Orissa was studied. Early growth parameters reveal that water soluble phosphatic fertilizers and split applications are better than water insoluble source in young rubber plants. Highest mean girth (19.54) was observed in 80 Kg N, 80 (40) Kg $P_2 O_5$ and 32 Kg $K_2 O$ per ha and lowest in control plots.

4. Weed management

A trial was laid out to study the control of noxious weed *Imperata cylindrical* and other weed in the rubber plantations. Treatment Glyphosate (3 L/ ha) followed by Glyphosate (1.5 L/ha) at 50 % regeneration of weeds was effective in controlling the growth of *Imperata cylindrical* and other grassy weed than the other treatments further observations on growth and weed infestation and its density are recorded.

5. Soil moisture studies

The trial was laid out, to study the effect of soil moisture stress on the growth and

yield of rubber. Maximum growth on rubber was observed during June to November months. In the rest of months lower girth increment was noticed.

Crop protection

6. Disease management

Disease survey on powdery mildew disease in rubber plantations of non-traditional areas was carried out. The objective was to evaluate the susceptibility/tolerance of various *Hevea* clones and polyclonal seedlings planted in these areas against powdery mildew disease. No incidence of powdery mildew disease was noticed so far in this region. High temperature prevailing during the summer months may be in the cause of non-occurrence of disease.

7. Weather

The climate of the region falls in dry and hot group. The place is characterized by warm dry sub-humid climate with severe heat and mild winter. The total rain fall during the period (2003) was 1697.2 mm with 82 numbers of rainy days. The highest mean maximum temperature of 45.0^{0} C was recorded during the month of May 2003 with annual mean of 39.7 C. the highest mean minimum temperature of 29.7 C was observed in October 2003, against the lowest mean relative humidity (37%) was observed during the month of April 2003 in after noon hours. The mean bright sunshine hours/day varied from 3.8 (July) to 8.8 (April) while, the evaporation lowest of 1.5 mm/day (July, August and September) and highest of 5.9 mm/day (May).

REGIONAL RESEARCH STATION, PADIYOOR, KERALA

The regional station located in Kannur District in an area of 40 ha continued with the long-term research programmes initiated with the objective of identifying clones suited to the region and evaluation of clonal variation in tolerance to drought/ disease incidence. The field trials laid out include evaluation of wild germplasm and clones for timber/latex traits, investigations on Genotype X Enviornment interaction, large scale testing of potential hybrid clones/clone evaluation, irrigation/water requirement studies, disease evaluation of clones and study of cropping systems.

1. Physico-chemical characterization of soil

The experiment initiated to generate a database on soil physico-chemical properties was continued. The soils are of gravelly sandy clay loam texture and with medium to high levels of organic carbon and potassium. Available phosphorus was generally low in all the profiles sampled. The soil was strongly acidic with pH ranging from 4.7 to 5.3.

2. Water requirement studies

The experiment in immature rubber with irrigation treatments of IW/CPE ratios of 0.3, 0.6, 0.9, 1.2 and an un-irrigated control was continued. The depth of rooting and depth of irrigation water was fixed at 75 cm and 5 cm respectively. The area of root zone to be wetted was taken as 6.3 m^2. The net plot size was 4x4 trees. Two border rows were left between treatments. Irrigation commenced from the month of December 2003 and continued till the commencement of rains in may 2004.

Growth recorded at periodic intervals indicated that irrigation significantly increased the girth and girth increment of plants (Table Pad.1).

3. Rubber and cashew cropping system

Observation on growth of inter-planted

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

Treatment	Number of irrigations	Girth (cm)						Girth increment (cm)
		Dec	Jan	Feb	Mar	Apr	May	Dec-May
IW/CPE1.2	18	21.5	21.5	22.2	23.3	24.4	25.4	4.14
IW/CPE0.9	13	20.5	20.5	21.0	21.7	22.7	23.6	3.58
IW/CPE 0.6	9	21.9	21.9	22.1	22.5	23.6	24.8	3.15
IW/CPE 0.3	4	18.3	18.2	18.4	18.7	19.3	20.5	2.51
Control	Nil	17.3	17.2	17.3	17.4	17.9	18.9	1.97
SE		0.77	0.85	1.0	0.82	0.84	0.85	0.21
CD (P=0.05)		2.4	2.6	3.2	2.5	2.6	2.6	0.63

cashew in rubber, initiated in June 2001 was continued. Yield was collected from banana and pineapple planted in the available interspaces. The growth of rubber and cashew monitored at regular intervals was found to be satisfactory (Table Pad. 2)

4. Response of clones to fertilizers

Growth in terms girth was monitored in the three clones *viz*. RRII 105, RRII 414 and RRII 429 with four fertilizer levels (30:30:20, 60:30:20, 90:60:40kg/ha of N, P_2O_5 and K_2O).

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 (4.5x4.5m)+cashew (4.5m)	16.8	2.8	27.1	2.9
Rubber (7.5x7.5m)+cashew (7.5m)	18.9	3.1	27.1	3.0
Paired row rubber (4.5x4.5m)	14.4	2.6	-	-
Rubber 7.5x7.5m	14.8	3.0	-	-
Cashew 7.5x7.5m	-		26.3	3.3

HEVEA BREEDING SUB-STATION, NETTANA, KARNATAKA

The major objectives of the Station are to identify high yielding as well as disease and stress tolerant clones suitable for commercial cultivation and to find out the best suitable exploitation techniques for this region. The research activities under the disciplines of crop improvement, exploitation technology and crop protection were continued in the experimental farm.

1. Crop improvement

In the trial for evaluation of ortet clones, GT 1 recorded better average girth than the other two control clones RRII 105 and RRIM 600 in all the three experiments. Five ortets (O 47, C 1/2, C 42, C 70 and T 2) in experiment 1, one ortet in experiment 2 (T 1) and four ortets in experiment 3 (O 26, O 55, O 56 and C 140) registered higher growth in terms of average girth than the three control clones. The third year yield data revealed that the clone GT 1 registered the highest average yield among the control clones (60.71 g/t/t). Among the ortets six clones (C 1/2, T 2, O 40, T 1, O 39 A and O 56) registered yields which were either slightly higher than that

of the controls or were comparable to them.

In the 1989 large scale clone trials, clone RRII 203 recorded better growth in terms of average girth (86.64 cm), while Haiken 1 registered poor growth (55.33 cm). In the 1990 experiment, clone PB 235 recorded the highest average girth while, Tjir 1 showed poor growth. The first experiment is in the third year of tapping and the second experiment is in the first year of tapping. Considering the clonal performance in the first experiment, clone RRII 203 out yielded the rest of the clones followed by KRS 25, while SCATC 93/114 registered poor performance (Table Kar. 1). The initial yield data of the second experiment revealed clone PB 260 to be promising followed by PB 311. The clones Hil 28, Tjir 1 and HP 204 recorded poor yield.

Table Kar.1. **Yield performance of clone in large scale trials**

Experiment I		Experiment I	
Clone	yield (g/t/t)	Clone	yield (g/t/t)
RRII 105	45.76 b-e	RRII 105	48.80 cd
RRII 203	63.68 e	PB 217	40.60 bc
RRII 300	27.95 ab	PB 235	49.12 cd
RRII 308	45.96 b-e	PB 260	54.02 d
RRIM 600	31.44 a-c	PB 311	49.30cd
PB 255	50.37 b-e	GT 1	35.68 b
PR 255	40.26 b-e	Gl 1	29.74 ab
PR 261	35.96 a-d	Tjir 1	19.67 a
KRS 25	59.98 de	Mil 3/2	21.92 a
KRS 128	53.28 b-e	Hil 28	19.63 a
KRS 163	57.57 c-e	HP 185	22.21 a
HAIKEN 1	36.40 a-d	HP 187	24.44 a
SCATC 88/13	43.28 b-e	HP 204	19.84 a
SCATC 93/114	14.57 a	HP223	36.71 b
		HP 372	36.48 b

Means followed by the same letters are not significantly different by Tukey's B test at 0.05

In the composite clone trial planted during 1991, the standard clone GT 1 recorded an average girth of 61.67 cm, 61.80 cm and 62.08 cm respectively in the three experiments. Nine clones in experiment 1 (RRII 6, RRII 203, RRII 300, PB 217, PB 235, PB 260, PB 310, PB 311 and RRIC 100), four clones in experiment 2 (RRII 3, RRII 5, RRII 118 and Nab 17) and four clones in experiment 3 (HP 83/224, HP 83/225, HP 83/236 and PB 28/59) showed better growth performance than GT 1, RRII 105 and RRIM 600.

In the trial on the estimation of the genetic parameters of 12 clones and their respective half-sib progenies planted during 1990, clone PB 235 registered the highest average girth (80.19 cm) among the parents, while, PB 213 showed poor growth (61.77 cm). Among the half-sibs, the progenies of the clone PB 235 registered better average girth (97.92 cm), while the progenies of the clone PB 213 showed poor growth (78.74 cm). The trees are opened for tapping and the initial yield performance revealed that among the half-sibs, the progenies of the clone PB 235 recorded the highest average yield (47.17 g/t/t). The progenies of the clone Tjir 1 registered poor performance (25.54 g/t/t). Among the clones, PB 235 registered the highest average yield (70.12 g/t/t) over the rest of the parents, followed by RRII 105 (61.37 g/t/t).

The polycross garden laid out during 1995 consisting of nine pre-potent clones viz., RRII 105, AVT 73, PB 215, PB 217, PB 28/83, PB 242, Ch 26, RRII 203 and PB 5/51 planted in a two dimensional design, was maintained well. The evaluation of the mother clones for the growth performance revealed that RRII 203 had better growth (64.57 cm) than the other mother clones, while, the growth of PB 215 was the poorest (46.25 cm). A total of 1,576 polycross fruits were collected during the season from all the clones and the seeds extracted have been planted at RRII, Kottayam for further evaluation of the progenies.

A small scale trial was laid out for evaluating the performance of the 400 series clones (RRII 403, RRII 407, RRII 414, RRII 422, RRII 429 and RRII 430) along with their parents RRII 105 and RRIC 100. Among the

clones evaluated, RRII 414 registered the highest monthly average girth (25.38cm), followed by RRII 430 (22.26 cm) while RRII 422 recorded the lowest girth.

2. Exploitation technology

In the first experiment planted in 1987 with five clones, PB 235 was found to have maximum growth in terms of average girth (82.15cm) while RRII 300 had minimum growth (67.01cm). In the second experiment planted in 1988 with five clones, RRII 118 recorded maximum girth (86.04 cm) while, PR 255 had the minimum girth (61.12cm). The growth pattern was similar to that of the previous years.

The exploitation systems (ES) being evaluated on the five clones in experiment I are ½ S d/2 6d/7, ½ S d/3 6d/7 without stimulation, ½ S d/3 6d/7 with stimulation and ½ S d/4 6d/7 with stimulation. Statistical analysis revealed significant variation in yield among the clones across months as well as in the interaction between these factors. However, there was no significant difference in yield among the tapping systems employed. There existed variation in the performance of the different clones under the different tapping systems employed. All the clones, except PB 235 and PB 311 registered the highest yield under ES 4. Clone PB 235 and PB 311 recorded the highest yield under ES 3 (Table Kar. 2). The peak yielding months were December, November and October.

The trial planted during 1988 was under third year of tapping. The systems of tapping employed on the five clones are ½S d/2 6d/7 (ES 1), ½ S d/3 6d/7 (ES 2) and ½ S d/4 6d/7 ET 7 (ES 3). There existed wide variation for all the clones under the three systems (Table Kar.3). However all the clones performed better under the low frequency tapping systems. RRII 118 performed better than the rest of the clones in all the tapping systems employed. Further, the response of

Table Kar. 2. **Annual yield performance (kg/400 trees) of different clones under different exploitation systems (1987 trial)**

Clone	Exploitation systems (ES)				Mean
	1	2	3	4	
RRII 105	2334	2243	3066	3150	2698 b
RRII 300	1545	1909	1757	1758	1742 a
PB 235	2994	2729	3079	3041	2961 b
PB 260	2925	2957	3005	3015	2976 b
PB 311	2404	2797	3160	2916	2819 b
Mean[es]	2440	2527	2813	2776	

Means followed by the same letters are not significantly different by DMRT at 0.05

Table Kar. 3. **Annual yield (kg/400 trees) of different clones under different exploitation systems (1988 trial)**

Clone	Exploitation systems (ES)		
	1	2	3
RRII 118	1901	1920	2972
PR 255	1167	1858	1963
PR 261	1173	2171	2547
RRIC 36	1272	1628	1829
RRIC 45	977	1599	1608

RRII 118 and PR 261 to stimulation was very significant. The performance of the clone RRIC 45 was poor in all the systems of tapping.

3. Crop protection

Corynespora leaf fall (CLF) disease survey was carried out in major rubber growing regions of Karnataka and North Malabar region of Kerala state. Disease intensity was recorded during the peak disease season in eight locations in Karnataka and six locations in North Malabar region. Results of the survey during 2004 (Table Kar. 4) indicated that even though RRII 105 is severely affected by the disease, the level of incidence has not reached alarming levels as a result of the interventions through disease control campaigns.

Experiments were carried out to study the effectiveness of water based fungicides in managing CLF disease in immature plantation (Table Kar. 5). Among the treatments

Table Kar. 4. **Incidence and severity of CLF disease in different locations during 2004 season**

Location	No. of fields visited	No. of fields infected	Infection (%)	PDI
Thirthahalli	9	2	22.20	4.00
Sagar	7	2	28.57	5.66
Kundapur	9	7	77.77	23.00
Belthangady	10	8	80.00	27.50
Puttur	9	8	88.88	26.00
Sullia	10	10	100.00	30.00
Madikeri	8	7	87.50	21.14
Subramanya	10	10	100.00	28.20
Kasaragod	8	7	87.50	26.28
Kanhangad	10	9	90.00	29.55
Nileshwar	7	6	85.71	24.00
Taliparamba	8	7	87.50	20.00
Sreekantapuram	5	4	80.00	17.50
Thalassery	8	7	87.50	19.42

Table Kar. 5. **Efficacy of water based fungicides for CLF disease management**

Treatment	Dosage	PDI
SAAF	2g/1	11.75
Bavistin	1g/1	14.85
Contaf +Captan	2g/1	27.10
Scor	0.4ml/1	32.00
Dithane- M 45	2.55g/1	12.25
Control	Unsprayed	43.30
LSD (P = 0.05)		3.48

SAFF was found to be superior for CLF disease control. Macozeb and Carbendazim also showed good control over the disease.

Experiment was conducted for testing the efficacy of different concentrations of dust formulations of hexaconazole in controlling CLF disease in mature plantation. Among the treatments tested in mature plantation hexaconazole 2 per cent dust showed better control over the disease while one per cent dust also was found to be useful in the disease management (Table Kar. 6).

Hevea clones available at HBSS, Nettana farm were screened against CLF disease in field condition viable to natural infection. Results indicated that the popular clone RRII 105 had higher disease intensity. Similar range of intensity was recorded in clones PR 261 and PR 255 and clones GT 1 and RRIM 600 recorded lesser intensity. Screening of

Table Kar. 6. **Efficacy of hexaconazole dust formulations in CLF disease management**

Treatment	Dosage	PDI
Hexaconazole 2%(dust)	9kg/ha	12.45
lHexaconazole 1 %(dust)	9kg/ha.	16.05
Control	(Untreated)	39.70
LSD (P = 0.05)		3.16

new *Hevea* clones was done for CLF disease resistance. Results indicated that all the 10 pipe line clones assessed had comparatively lesser disease intensity.

HEVEA BREEDING SUB STATION, PARALIAR, TAMIL NADU

Hybridization and clonal selection, clone evaluation, identification of clonal composites and standardization of root trainer planting technique were the major spheres of research activities at this Station.

1. Evolving high yielding clones

By regular pruning and pollarding of branches canopy of all the parental trees (a total of 51 clones in an area of 5 ha.) was maintained at a low profile so that hand pollination could be carried out conveniently from the ground. Hand pollination was attempted in various parental combinations aimed at evolving latex-timber clones, clones with *Oidium* tolerance and elite clones with high yield and promising secondary characters. The resultant hybrids were raised in nursery for preliminary evaluation. The hybrids obtained by hand pollination carried out in the previous years were also well maintained for field evaluation.

2. Clone evaluation

Among the 11 clones in the large-scale clone trial at the Government Rubber Plantation, Keeriparai, IRCA 109 recorded the highest yield in the second year followed by PB 314 and IRCA 111 (Table Par. 1).

Table Par. 1. **Mean girth and yield of clones in large scale trial at Keeriparai**

Clone	Girth (cm)	Mean yield (g/t/t)
RRII 105	59.39	39.49
RRIM 703	67.58	50.28
PB 255	66.80	53.00
PB 314	64.10	69.08
PB 330	63.25	32.73
PB 28/59	56.92	44.81
IRCA 18	60.01	42.47
IRCA 109	65.03	71.39
IRCA 111	68.69	67.01
IRCA 130	59.79	48.82
IRCA 230	67.93	28.93
General mean	63.59	49.81
CD (P=0.05)	3.06	6.14

In the second year of tapping in the block trial out of a total of 13 modern popular clones under evaluation, PB 311 exhibited the maximum yield (59.11 g/t/t) followed by PB 235 (59.07 g/t/t). The yield of RRII 105 showed significant improvement (47.97 g/t/t) over its performance in the first year of tapping (35.79 g/t/t).

Trial on clonal composites, initiated to identify an alternative to the increasing tendency of monoculture, has shown that of the eight treatments, the treatment consisting RRII 5 (15%), PB 235 (35%) and RRII 105 continued to exhibit the maximum yield (50.31 g/t/t) after the year of tapping.

The block trial (2002) consisting RRII 414, RRII 417, RRII 429, RRII 430 with RRII 105 as control was well maintained at New Ambadi Estate and the girth was recorded at every quarter. The block trial initiated at Velimalai Estate (consisting RRII 417, RRII 429, PB 217 with PB 260 as control) was also well maintained. The observational trial (2000) comprising six selections from the RRII 400 series at Vaikundam Estate was continued and growth measurements were recorded at quarterly intervals.

3. Polyclonal seed garden

The polyclonal seed garden laid out at New Ambadi Estate (9 clones in an area of 9 ha) during the year 2000 was well maintained. Most of the clones exhibited precocious flowering in the fourth year itself, but fruit set was very scanty.

4. Standardization of root trainer planting technique

The root trainer planting technique for *Hevea* has already been standardized and the results were communicated for recommendation to the benefit of the planting community. The performance of root trainer and

polybag derived plants on transplanting to the field was closely observed at Churulacode, Thirunanthikarai and Velimalai and the root trainer plants showed better growth than polybag plants at all the three locations.

LIBRARY AND DOCUMENTATION CENTRE

The library continued its important role of communicating and disseminating information on Natural Rubber (NR) and allied subjects through its library collection, information services and publications. The library facilities were also extended to all related to NR industry.

During the year, 138 books were added to the stock. The library subscribed 73 foreign journals and 83 Indian journals. About 85 other journals were also received as gift/exchange. Literature searches from CAB, and RAPRA databases were carried out.

Four issues each of Documentation List and Rubber Alerts and one issue of New Additions List were compiled and distributed. During the year 100 numbers of SDI bulletins were distributed to officials of RRII and Rubber Board. 28 numbers of photocopies of articles were procured from other institutions/libraries and 15 articles were sent to institutions/individuals upon request under this period.

The library compiled a bibliography namely *"Exploitation Technology of Hevea: An Annotated Bibliography"* consisting literature published during 1990-2003 on various aspects of exploitation systems and related areas such as tapping systems, stimulation, rain guarding, latex productivity, TPD etc. Vol.15 (2) and 16(1&2) of *Indian Journal of Natural Rubber Research* and *RRII Annual Report* for 2002-03 were published and distributed.

The centre also engaged in the sales promotion of RRII Publications like *Natural Rubber: Agro Management and Crop Processing (NRACP), Indian Journal of Natural Rubber Research, Rubber Wood: Processing and Utilization*, and *Plant and Soil Analysis*. During the period 43 copies of *NRACP*, 10 copies of the book *Rubber Wood* and 16 copies of *Plant and Soil Analysis* were distributed.

AGROMETEOROLOGY

1. Climate resource characteristics of rubber growing areas

Temporal and spatial variation of seasonal rainfall over highland and midland where rubber has replaced other crops was quantified. The southwest monsoon rainfall showed a waning tendency from 1901-40, an increasing trend for the next sub-period and after 1960 a steep decrease was noticed. The opposite trend was observed in the case of NE monsoon rainfall. An increasing trend up to 1940 and thereafter a diminishing trend till 1960. After 1960, practically no trend was noticed. Up to 1960, the first three sub-periods showed an increasing trend. After 1960 a waning tendency of summer rainfall was observed.

2. Forewarning, on pests and diseases of rubber

To study the influence of weather on the triggering of powdery mildew disease, leaf collection baskets covering an area of 1 sq.m

were placed in selected plantations at Nagercoil, Chethackal and Padiyoor. Clones selected were RRII 105 and RRIM 600 at Nagercoil, RRII 105, RRIM 600 and PB 5/51 at Padiyoor and RRIM 600 at Chethackal. Periodic disease incidence was assessed in dusted/undusted areas. Per cent disease intensity and mean leaf fall in the baskets were recorded.

3. Agroclimatic zones for rubber

Data on taluk wise productivity of rubber plantations was collected. Region wise distribution of rainy days was plotted and superimposed on the productivity. Demarcated the zones and superimposed the physiographical divisions over the productivity.

4. Agromet database management

Monthly rainfall data for the period 1870 to 2000 for Kerala, Konkan, Orissa, Kamataka and Northeast region has been computerised. Annual and seasonal trends and climatic normals of monthly rainfall for each region were worked out.

5. Studies in North East India

Rainfall trends (Cramer-von-Mises analogue) were worked out for all the Regional Stations in the Northeast and tested (Spearman's correlation) for significant trends. More than 50 per cent of the Stations showed no particular trend while less than five per cent showed negative trends.

Agrometeorology data from the Research Stations were processed and analyzed. Normalized Rainfall Curves showed a highly skewed nature of rainfall for RES Nagrakata. About 15 per cent variation was obtained for the mean monthly temperatures within these agroclimates.

Incidences of Oidium were recorded by the quadrant method from the Regional Stations at Taranager, Guwahati and Nagrakata during the wintering period. Oidium disease was observed during the second week of March, after the first rains. Weekly patterns of high relative humidity and favourable temperatures conducive for the development of Oidium disease at Guwahati, Nagrakata and Agartala were studied. During December-January period, even though the daily morning Relative Humidity was above 90 per cent, the disease incidence was recorded at less than 50 per cent for the lower leaves. Severity of the disease was high at Nagrakata where the refoliation was generally late compared to the other two Stations.

Table Agromet. 1. **Agrometeorological data from different Research Stations 2003**

Month & Location	Temperature (°C)		RH (%)		Wind speed (km/h)	Sunshine (h)	Rainfall (mm)
	Minimum	Maximum	Morning	Afternoon			
KOTTAYAM, KERALA							
January	22.3	33.7	84	47	2.0	8.1	0
February	23.6	34.1	89	51	2.3	8.4	12
March	24.1	34.8	89	50	2.1	8.7	166
April	24.8	34.0	90	59	2.1	8.3	217
May	25.4	33.2	91	65	1.9	7.1	96
June	23.7	31.5	92	69	1.9	5.6	487
July	22.9	29.7	94	81	1.8	3.2	552
August	23.3	30.3	95	74	1.9	4.6	491
September	22.9	31.5	92	63	2.0	7.7	57
October	23.1	30.9	93	72	1.6	5.4	521
November	23.0	32.3	90	63	1.2	5.9	135
December	21.4	32.9	85	52	1.6	8.1	4

Month & Location	Temperature (°C)		RH (%)		Wind speed (km/h)	Sunshine (h)	Rainfall (mm)
	Minimum	Maximum	Morning	Afternoon			
CES, CHETHACKAL, KERALA							
January	19.8	34.8	80	37	1.9	8.1	0
February	21.2	34.7	90	48	1.0	8.0	175
March	21.7	34.5	92	51	0.8	8.6	190
April	23.1	34.2	92	56	0.7	7.4	138
May	23.4	32.6	90	66	1.1	4.7	81
June	22.1	31.3	90	70	1.9	4.1	520
July	21.6	29.9	92	77	2.0	2.7	500
August	21.8	29.8	91	75	2.1	3.2	536
September	21.0	31.2	90	62	2.6	7.1	43
October	21.6	31.1	90	69	1.5	5.2	506
November	20.9	32.5	85	60	1.6	5.2	93
December	19.0	33.5	82	52	2.3	8.5	5
PADIYOOR, KERALA							
January	19.2	34.9	81	36	2.4	8.6	0
February	21.7	35.4	90	47	2.9	8.7	0
March	22.7	36.7	89	48	3.1	8.6	5
April	23.5	35.6	90	58	2.2	7.6	187
May	23.8	34.8	91	61	2.8	6.9	82
June	22.6	33.3	94	75	2.0	3.1	859
July	22.0	28.0	95	87	1.4	0.5	1062
August	22.3	29.3	94	83	1.8	2.7	580
September	21.4	31.1	94	75	2.2	6.4	123
October	21.9	31.6	95	77	1.2	5.4	264
November	21.0	34.2	87	61	0.9	7.5	26
December	17.7	34.4	83	48	NA	8.9	10
PARALIAR, TAMIL NADU							
January	20.3	33.2	83	49	—	7.9	0
February	20.9	35.3	95	48	—	8.1	14
March	21.8	35.6	93	57	—	6.9	53
April	23.8	36.2	91	67	—	5.5	89
May	25.1	34.3	88	68	—	5.9	59
June	24.1	33.7	86	66	—	5.8	112
July	23.9	32.2	91	73	—	4.8	89
August	24.2	32.4	87	69	—	5.9	65
September	23.2	34.8	89	53	—	5.0	36
October	23.2	31.5	97	78	—	4.4	802
November	23.2	31.8	93	72	—	5.6	127
December	21.0	33.4	92	53	—	7.9	38
NETTANA, KARNATAKA							
January	16.8	34.7	81	35	5.5	8.1	0
February	19.6	35.5	89	41	6.0	8.3	10
March	21.3	36.2	89	42	6.7	8.3	84
April	22.5	35.5	90	51	5.7	8.0	87
May	23.6	34.5	89	56	6.4	7.1	37
June	21.9	30.5	93	74	5.2	4.1	890
July	21.8	27.4	94	86	4.5	1.7	1151
August	21.7	27.9	93	84	5.5	2.1	945
September	21.4	30.0	92	71	4.1	5.1	347
October	21.4	31.5	91	71	1.9	5.7	415
November	19.2	34.5	81	51	NA	7.8	6
December	14.5	35.0	80	34	NA	8.4	0

Month & Location	Temperature (°C)		RH (%)		Wind speed (km/h)	Sunshine (h)	Rainfall (mm)
	Minimum	Maximum	Morning	Afternoon			
DAPCHARI, MAHARASHTRA							
January	14.4	33.6	91	55	0.9	7.2	0
February	15.9	36.3	89	51	1.1	9.2	0
March	18.0	38.7	87	62	1.3	8.7	0
April	23.7	39.7	89	78	1.7	9.2	0
May	25.7	37.2	89	68	2.6	8.7	0
June	25.7	32.8	93	80	2.4	3.6	695
July	24.8	30.0	95	83	1.2	1.4	945
August	24.4	29.8	96	93	0.5	2.5	863
September	23.7	29.7	94	80	NA	2.7	361
October	20.4	35.5	91	91	NA	8.4	0
November	18.6	36.9	88	70	NA	8.7	0
December	15.1	32.9	92	49	NA	7.3	0
RRS, AGARTALA, TRIPURA							
January	23.1	09.8	73		1.3	6.0	0
February	28.1	13.8	67		1.8	7.5	16
March	30.2	17.3	68		2.3	7.3	68
April	33.3	22.5	75		3.7	8.1	189
May	32.9	23.4	77		3.7	6.8	358
June	30.9	24.9	85		4.7	3.6	686
July	32.5	25.7	82		4.1	5.4	191
August	32.7	25.8	80		3.4	6.2	131
September	32.3	25.3	85		2.2	5.3	297
October	31.4	24.0	84		1.3	5.4	159
November	30.1	16.2	73		0.7	8.9	0
December	26.6	13.6	75		0.8	6.7	33
RRS, GUWAHATI, ASSAM							
January	22.5	10.4	75		2.5	5.3	0
February	26.0	13.0	71		3.3	7.2	29
March	28.2	15.4	70		2.6	6.4	58
April	29.8	19.5	78		1.5	6.0	207
May	31.9	21.9	79		1.6	6.7	161
June	32.8	24.2	84		0.7	3.2	288
July	32.9	25.1	84		0.2	4.0	348
August	33.4	24.9	83		0.9	5.3	326
September	32.8	24.1	85		1.5	5.0	239
October	30.4	22.1	86		1.2	5.0	166
November	28.4	17.3	77		1.6	6.9	0
December	25.7	13.6	73		1.9	5.8	17
RRS, TURA, MEGHALAYA							
January	23.3	05.8	66		0.7	7.0	3
February	25.9	09.4	63		1.8	7.1	0
March	27.9	12.5	65		1.7	7.1	121
April	30.9	16.6	75		1.2	7.3	206
May	31.7	19.3	77		1.4	6.9	194
June	31.2	21.3	85		1.2	3.3	654
July	31.6	22.3	88		1.6	3.3	496
August	32.0	22.9	85		0.7	4.9	207
September	31.4	21.8	84		0.4	4.0	88
October	30.2	19.0	87		0.6	3.7	412
November	28.1	13.3	74		0.3	6.8	0
December	25.6	10.8	71		0.6	5.8	0

Month & Location	Temperature (°C)		RH (%)	Wind speed (km/h)	Sunshine (h)	Rainfall (mm)
	Minimum	Maximum				
RES, NAGRAKATA, WEST BENGAL						
January	22.1	6.4	80	1.3	6.8	55
February	24.8	10.8	75	1.7	6.1	48
March	27.5	13.5	73	1.9	6.3	102
April	30.0	19.3	77	1.9	5.5	552
May	31.8	22.6	58	2.0	7.5	436
June	31.4	24.5	83	2.6	3.4	400
July	31.5	25.2	78	1.5	3.3	425
August	32.9	25.5	70	1.3	5.0	344
September	32.3	24.2	86	1.1	3.6	532
October	31.1	20.2	90	0.7	4.5	469
November	28.1	15.0	83	0.7	7.0	22
December	26.3	9.6	80	0.8	7.1	17
RDC, KOLASIB, MIZORAM						
January	25.8	10.5	78	0.4	6.3	0
February	29.7	14.7	79	0.4	8.1	0
March	32.5	14.4	84	0.4	7.3	69
April	32.7	17.0	82	0.0	6.9	208
May	33.5	17.0	81	0.0	0.0	212
June	33.8	16.9	82	0.4	0.0	215
July	34.3	23.0	81	0.0	8.1	83
August	35.0	23.6	80	0.0	6.7	769
September	34.9	23.4	81	0.0	5.4	111
October	-	-	-	-	-	-
November	-	-	-	-	-	-
December	-	-	-	-	-	-
RRS, DHENKANAL, ORISSA						
January	28.2	12.0	64	3.1	7.2	0
February	31.1	19.1	67	2.9	7.8	6
March	35.3	20.3	58	3.0	8.1	27
April	40.0	24.7	58	3.5	8.2	19
May	41.3	26.2	64	4.1	7.1	32
June	38.4	26.5	73	3.6	5.2	205
July	31.9	25.3	86	2.9	3.3	343
August	31.5	25.0	87	5.1	5.5	438
September	31.5	25.1	89	1.6	4.9	228
October	31.6	23.7	83	5.0	6.5	433
November	30.2	16.7	74	1.6	8.0	17
December	27.9	12.5	67	1.1	6.9	39

ANNUAL EXPENDITURE

Expenditure at a glance (2003-04)

Head of Account	Expenditure (Rs. in lakhs)
Non-plan	
General charges	263.81
Projects (CES)	159.17
Total	**422.98**
Plan	
General charges	938.31
NERDS Research Component	152.37
Total	**1090.68**
Grand Total	**1513.66**

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Thakurdas Saha, M.Sc.(Ag.), Ph.D.	Scientist (GA)
Mycology and Plant Pathology Division	
C. Kuruvilla Jacob, M.Sc.(Ag.), Ph.D.	Deputy Director
S. Thankamony, M.Sc.	Entomologist
Sabu P. Idicula, M.Sc.(Ag.)	Scientist S3
Jacob Mathew, M.Sc., Ph.D.	Scientist S3
Annakutty Joseph, M.Sc., Ph.D.	Scientist S3
V.T. Jose, M.Sc.(Ag.), Ph.D.	Scientist S3
Kochuthresiamma Joseph, M.Sc., Ph.D.	Scientist S3
T. Sailajadevi, M.Sc.	Agrometeorologist
Shaji Philip, M.Sc, Ph.D.	Scientist S3
P. Srinivas, M.Sc. (Ag.), Ph.D.	Plant Physiologist
E. Edwin Prem, M.Sc.(Ag.)	Assistant Mycologist
C. Bindu Roy, M.Sc., Ph.D.	Junior Scientist
Sadanand K. Mushrif, M.Sc.(Ag.)	Junior Scientist
P.M. Levy Joseph, B.Sc., Dip. N.R.P.	Assistant Technical Officer
K.G. Jayan	Assistant Farm Superintendent
Plant Physiology Division	
James Jacob, M.Sc.(Ag.), Ph.D., DIC, Ph.D.	Deputy Director
P. Sobhana, M.Sc., Ph.D.	Plant Physiologist
Molly Thomas, M.Sc., Ph.D.	Scientist S3
D. Bhuvanendran Nair, M.Sc., Ph.D.	Scientist S3
K. Annamalainathan, M.Sc., M.Phil, Ph.D.	Plant Physiologist
R. Krishnakumar, M.Sc., Ph.D.	Scientist S3
S. Sreelatha, M.Sc.	Scientist S3
Badre Alam, M.Sc., M.Tech., Ph.D.	Environmental Physiologist
M.B. Mohammed Sathik, M.Sc., M.Phil.	Scientist S2
Jayasree Gopalakrishnan, M.Sc., M.Phil.	Scientist S2
N. Geetha, M.Sc., Ph.D.	Junior Scientist
S. Visalakshy Ammal, B.Sc.	Assistant Technical Officer
C.C. Joseph	Assistant Farm Superintendent
Exploitation Technology	
*K.R. Vijayakumar, M.Sc.(Ag.), Ph.D.	Joint Director (Exploitation Studies)
N. Usha Nair, M.Sc.(Ag.), Ph.D.	Senior Scientist (BC)
K.U. Thomas, M.Sc., Ph.D.	Scientist S3
R. Rajagopal, M.Sc., M.Phil., Ph.D, Dip. Stat.	Plant Physiologist
K. Karunaichamy, M.Sc., Ph.D.	Scientist (ES)
P.M. Narayanan	Assistant Farm Superintendent
Rubber Technology Division	
Baby Kuriakose, M.Sc., LPRI, Ph.D., PGDPM	Joint Director (Rubber Technology)
K.T. Thomas, M.Sc., LPRI, M.Tech., Ph.D.	Deputy Director
N.M. Claramma, M.Sc., Ph.D.	Rubber Chemist
K. Mariamma George, M.Sc.	Scientist S3
N. Radhakrishnan Nair, M.Sc., M.Tech., MBA, Ph.D.	Scientist S3
Jacob K. Varkey, M.Sc., M.Tech.	Scientist S3
Rosamma Alex, M.Sc., LPRI, M.Tech, Ph.D.	Rubber Technologist
Siby Varghese, M.Sc., Ph.D.	Scientist (Rubber Technology)
K.N. Madhusoodanan, M.Sc.	Rubber Chemist
Leelamma Varghese, M.Sc., PGDHRM	Scientist S3

* Holding additional charge of Joint Director (Research)

Benny George, M.Sc., Ph.D.	Scientist S3
C.K. Premalatha, B.Sc., LPRI, Dip. NRP	Assistant Technical Officer
C. Madheswaran, B.A.	Technical Assistant (Glass Blowing)
Agricultural Economics Division	
Tharian George, K., M.A., Ph.D.	Deputy Director
Toms Joseph, M.A.	Economist (on deputation from August 2002)
Binni Chandy, M.A., B.Ed.	Scientist S3
S. Mohanakumar, M.A., M.Phil.	Scientist S2 (on deputation from 20.3.01)
S. Veeraputhran, M.A., M. Phil.	Scientist S2
P.K. Viswanathan, M.A., Ph.D.	Scientist S2
S. Lakshmi, M.Sc.(Ag.)	Scientist S2 (on EOL from 01.03.2002)
Project Monitoring	
M.A. Nazeer, M.Sc., Ph.D.	Joint Director (PM)
Regional Research Stations	
*Thomson T. Edathil, M.Sc., Ph.D.	Deputy Director
Agricultural Statistics	
Ramesh B. Nair, M.Sc.(Ag. St.)	Assistant Director (Stat.)
S. Naveenkumar, M.Sc., M.C.A.	Programmer-cum-Processing Assistant
B. Biju, M.Sc., PGDCA	Computer Assistant
P. Aneesh, M.Sc., PGDCA	Statistical Inspector
Library and Documentation Centre	
Mercy Jose, B.Sc., M.L.I.Sc.	Documentation Officer
Accamma C. Korah, B.Sc., M.L.I.Sc.	Senior Librarian
Kurian K. Thomas, B.Sc., M.L.I.Sc.	Junior Publication Officer
A.S. Ajitha, M.A., M.L.I.Sc.	Librarian (Documentation)
Instrumentation	
S. Najmul Hussain, M.Tech., AMIETE	Instrumentation Engineer
Thomas Baby, M.Sc., M.Phil, Ph.D.	Instrumentation Officer
R. Rejikumar, M.Sc., M.Tech.	Assistant Instrumentation Officer
Anilkumar M.R.	Assistant Instrumentation Officer
Maintenance	
K.P. Sajeev, B.E.	Estate Officer
T. Manoj	Assistant Engineer (Civil)
Administration	
T.R. Mohankumar	Deputy Secretary
T.M. George	Assistant Secretary
Vani Maralimohan	Assistant Secretary
N. Sundaresan	Section Officer
Accounts	
P.V. George	Dy. Director (Finance)
K. Vijayamma	Assistant Director (Finance)
Jose George	Accounts Officer
Aleyamma Chacko	Section Officer
Molly Kuriakose	Section Officer
Experiment Station at RRII	
T.V. Kurian	Assistant Estate Superintendent
Mary Mathew	Sr. Pharmacist
Security	
C.K. Abraham, B.A., B.Ed.	Assistant Security Officer
Central Experiment Station, Chethackal, Kerala	
Jacob Pothen, M.Sc.(Ag.)	Deputy Director
Jacob Abraham, B.Sc., M.B.B.S.	Medical Officer
M.D. Issac	Farm Superintendent
Zacharia Kurian, M.Com., A.C.A.	Assistant Director (Finance)
K. Kunhunni	Assistant Estate Superintendent
V.S. Govindankutty	Assistant Estate Superintendent
T.T. Varghese	Assistant Estate Superintendent
K.S. Thomas	Section Officer
Annamma Andrews, H.S.C.	Nurse (HG)
K.K. Kunjachan	Assistant Farm Superintendent

*In charge of RRS at Padiyoor, Dapchari, Dhenkanal and Sukma

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
V.J. George	Assistant Farm Superintendent
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
Debabrata Ray, M.Sc.(Ag.)	Junior Scientist
Joy Joseph, M.Sc.	Assistant Rubber Processing Technologist
Jiban Chakraborty, B.Com.	Assistant Director (Finance)
Amal Chandra Sarma	Senior Scientific Assistant
Haradhan Bhowmik	Assistant Farm Superintendent
M.J. Augustine	Assistant Estate Superintendent
O.V. Mathew	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)
R.P. Singh	Scientist S3
M.J. Reju, M.Sc.	Scientist S2
T. Parimelazhagan, M.Sc., Ph.D.	Junior Scientist (Resigned on 12.01.2004)
Regional Experiment Station, Nagrakatta, West Bengal	
Gitali Das, M.Sc., Ph.D.	Plant Physiologist
R.S. Singh, M.Sc. (Ag)	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.)	Junior Scientist
C.K. Thomas	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
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Thomas Eappen, M.Sc., B.Ed.	Scientist S2
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Regional Soil Testing Laboratory, Muvattupuzha, Kerala	
C.P. Mary, M.Sc.	Assistant Technical Officer
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RESEARCH ESTABLISHMENTS

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REGIONAL RESEARCH STATIONS

Central Experiment Station
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Regional Research Station
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REGIONAL SOIL TESTING LABORATORIES

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Regional Soil Testing Laboratory
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Kozhikode – 673 011, Kerala.
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Research divisions and functions

The major research divisions are Agronomy and Soils; Biotechnology; Botany; Germplasm; Mycology and Plant Pathology; Plant Physiology; 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 Chemistry, Physics and Technology Division concentrates on improvement in primary processing of rubber, its chemical modification, rubber product manufacture and quality control of processed rubber. The Agricultural Economics Division undertakes studies on economic aspects related to rubber plantations.

The research supporting sections include Library and Documentation, Instrumentation, Statistics, Computer and Art/Photography. There is also a small experimental farm of 33 ha at the headquarters of 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, Tura in Meghalaya and Kolasib in Mizoram. The RRII has also set up regional research establishments at Dapchari (Maharashtra), Dhenkanal (Orissa), Nagrakatta (West Bengal), Sukma (Chattisgarh), Paraliyar (Tamil Nadu), Nettana (Karnataka) and Padiyoor (Kerala).

Regional soil testing laboratories have been established at 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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