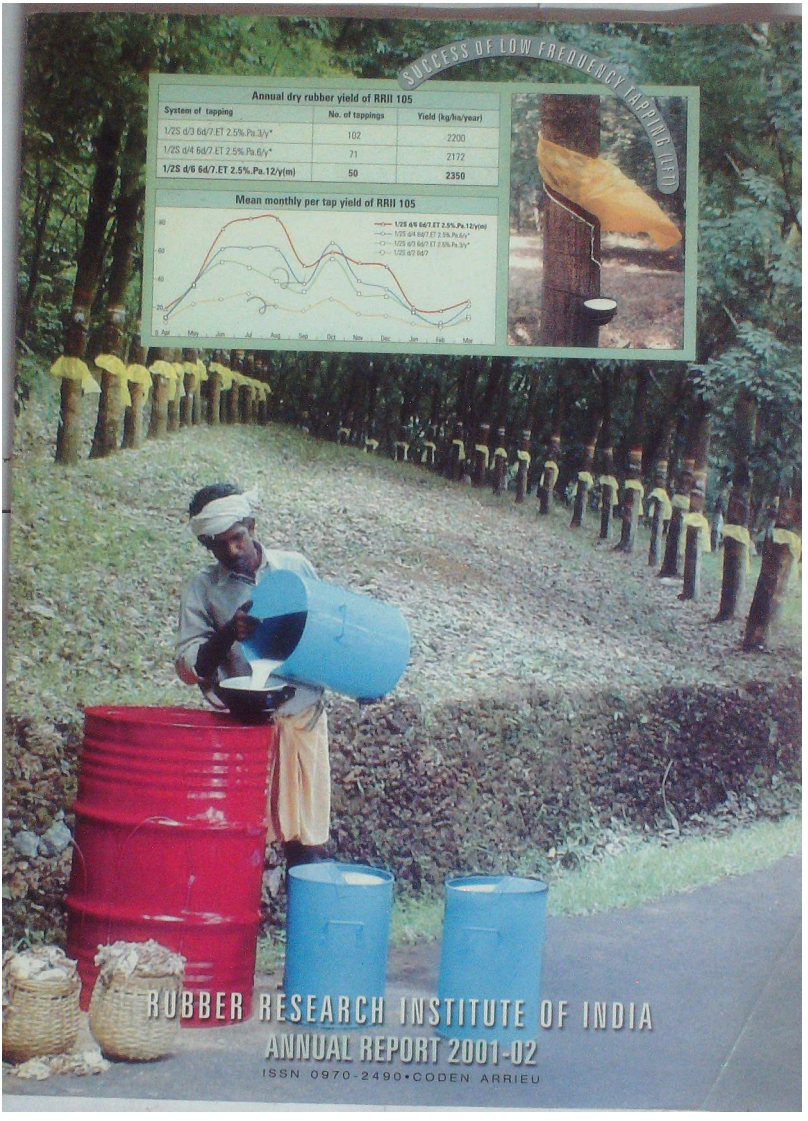

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Success of low frequency tapping (LFT)

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

ANNUAL REPORT
2001-02

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THE RUBBER BOARD

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

Organization

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

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DIRECTOR'S REVIEW

The unprecedented growth achieved by the natural rubber (NR) industry in India has been the result of sustained research and development (R & D) efforts in various sectors of the industry by fixing priorities in tune with the policy packages over time. Under the protected policy regime, the initiatives in the NR sector were moulded with the perceived objective of attaining self-sufficiency in the production sector. However, the launching of economic reforms in India since 1991, exposed the NR sector to international competitions. Reformulating the R&D priorities in the NR sector with a shift from self-sufficiency to relative economic viability of various sub-sectors within the rubber sector has thus become imperative. Enhancing the efficiency in production and marketing in terms of cost-effectiveness has become the main objective to be achieved. In this context, apart from achieving productivity enhancement, other means of cost reduction have assumed greater importance in NR research.

The Rubber Research Institute of India (RRII) has made substantial achievements in the field of exploitation research by evolving low frequency tapping (LFT) systems without any reduction in yield that has been obtained under third daily tapping systems. The introduction of LFT systems such as fourth daily and weekly with stimulation has enabled the NR production sector to reduce the cost of exploitation which accounts for a major share in the total cost of production of NR. Under the third daily tapping system, yield can be enhanced upto 30% with three or four stimulations per year and the same yield can be achieved by fourth daily or weekly tapping with increased frequency of stimulation. During the year under review, LFT was extended to more than 20,000 ha. Controlled upward tapping (CUT) of 1/4S cut at the third daily frequency, with stimulation at 20 days interval, was found successful for medium yielding clones in all the onfarm trials. Mini and reduced spiral cuts were found useful for early opening of trees. The International Rubber Research and Development Board (IRRDB) has recognized RRII as the centre for co-ordinating international research efforts in exploitation technology.

The crop improvement programmes, both in the traditional and non-traditional regions, focussed on evaluation and selection of clones with higher yield and better secondary characteristics. The five promising clones *viz.*, RRII 414, RRII 417, RRII 422, RRII 429 and RRII 430 continued to record superior yield under small-scale trials and 49 hybrid clones and eleven ortets yielded better than RRII 105. Characterization and evaluation of the wild accessions at morphological and molecular level were in progress. The budded plants raised in root trainers at Paraliar, Tamil Nadu exhibited superior results over normal polybag plants both in terms of growth and cost-effectiveness. Under Tripura conditions, RRII 203 recorded maximum yield and the Brazilian wild accessions available there were maintained well. In Assam, RRII 203 and RRIC 102 showed better growth and RRIM 600 had maximum yield. Polyclonal seedlings also performed well. At Nagrakatta, West Bengal, SCATC 88/13 and SCATC 93/114 recorded the highest yield and girth respectively.

After extensive optimization experiments, embryo induction and plant regeneration frequency of embryogenic callus cultures of RRII 105 could be enhanced considerably. Small scale field evaluation of tissue culture plants developed through somatic embryogenesis using immature anthers of *Hevea* (clone RRII 105) was initiated at CES, Chethackal. Another 200 plants were made available for field planting. The plant regeneration frequency of transgenic RRII 105 integrated with SOD gene under the control FMV 34S promoter could be enhanced and 10 transgenic plants were hardened and transferred to polybags. The genomic and cDNA sequences coding for β-1, 3 glucanase have been sequenced and found to be a single exonic gene. The gene is expressed constitutively in latex vessels of all the clones studied.

It was observed that 250 silt pits per ha are ideal since it could conserve 34 kg N, 18 kg P and 25 kg K annually. Application of translocated herbicides through Controlled Droplet Applicators (CDA) reduced the cost of weed control. Soil nutrient has improved the status and physical properties. Rubber litter decomposition and addition of biomass of leguminous cover crops. Sludge from crumb rubber factories has been

identified as a source of nitrogen suitable for seedling nursery application. Discriminatory fertilizer recommendations were issued to 4400 small holdings and 580 individual fields from 20 large estates.

In the non-traditional region of Assam, 60 kg N per ha has resulted in the highest yield, latex volume and DRC. In Tripura, the studies on NPK and their interaction revealed that 60 kg each of N and P has significant effect on growth and yield. The trials on the ecological impact of rubber plantation on physico-chemical properties of soil have showed maximum amount of organic C, available P and K in soils under rubber compared to other plantation species, *viz.*, teak and gamair. To generate additional income from rubber plantations, sustainable cropping systems with rubber, tea and orange were under evaluation at Tura in Meghalaya.

A survey conducted in the traditional regions in clone RRII 105 to assess the incidence of abnormal leaf fall disease indicated that prophylactic spraying can be judiciously avoided only in South Kerala and Kanyakumari regions. Partial substitution of spray oil with rubber seed oil was found to be effective. High intensity of powdery mildew disease was noticed in all the clones in Kanyakumari district. With regard to pink disease Mundakayam and Thodupuzha are the most disease prone areas and RRII 105 and PB 255 are the highly susceptible clones. Screening of germplasm could identify accessions showing resistance to *Phytophthora, Oidium and, Corynespora*. Corynespora leaf disease in Karnataka was observed to start during the first fortnight of March, become severe by April and recede in May. Dusting with hexaconazole (2%) was found effective in disease management. Association of a viroid in tapping panel dryness is suspected, based on the evidences obtained from molecular studies. Bee keeping using *Apis cerana indica* was found to be more remunerative than *A. mellifera*. An extensive survey in the northearstern states indicated incidence of powdery mildew disease in most of the locations and Periconia leaf blight in some locations in Assam, Arunachal Pradesh and Meghalaya.

Physiological investigations showed that high intensity light caused more damage to membrane systems when combined with drought or high temperature stresses. Measurement of photosynthetic oxygen evolution in leaves was identified as a screening technique for drought and high light stress tolerance in rubber. The photosynthetic light use efficiency and quantum yield for photosynthesis were lower in powdery mildew affected *Hevea* leaves. It has been established that down regulation in PSII activity is associated with low temperature-induced cold injury in rubber plants. High yielding clones showed a significantly higher ATP and glutamine synthase activity in the c-serum.

In the rubber processing area, ENR was identified to be a compatibilizer in rubber – silica composites, leading to the possibility of replacing the more expensive silane coupling agent. A method was developed for the production of deprotenised latex in a single stage centrifuging process using a proteolytic enzyme preparation. A study was conducted on the storage behaviour of sheet rubber. A preliminary survey was carried out on the quality of sheets from rubber growing regions of Kerala and Tamil Nadu.

The study on the impact of the WTO Agreement provided a comprehensive assessment of its implications on the NR sector in India. A study on the impact of new trade control measures imposed during 2001 indicated that as long as the difference in prices between domestic and international market is attractive, NR imports through the duty free channel will continue, as there are well defined limitations in backtracking from the liberalized trade policy initiatives pursued since 1991. The study on the timber yield potential of certain *Hevea* clones in India reported the highest timber yield for the RRII 200 series clones, compared to RRIM 600 and irradiated clones.

The Institute continued its academic liaison with national and international research institutes and universities. The Indian Journal of Natural Rubber Research continued as the main dissemination channel for scientific information and Volume 14, 2001 was brought out during the year. RRII has published more than 60 scientific articles in addition to participation and presentation of papers by scientists in national and international conferences. The library through its services and publications continued to serve the NR industry for their information needs.

AGRONOMY AND SOILS DIVISION

The research efforts to develop suitable agromanagement techniques for profitable rubber cultivation remained the primary objective of the Agronomy/Soils division. In depth studies on nutritional requirement, integrated nutrient management through organic and inorganic fertilizers, soil acidity management through liming and zinc nutrition were continued for improving the fertility and productivity of the soil. Experiments on soil and water conservation, weed management, density of planting etc. were continued. Possibilities of intercropping coffee and cocoa during the immature and mature phases were envisaged through three separate field experiments. Similarly, cultivation of perennial intercrops like coffee, garcinia, nutmeg and vanilla were also initiated through two new field experiments. The feasibility of interplanting timber species in rubber as well as the effect of density of timber plants on growth of rubber were investigated through separate field experiments.

Studies on the physical and chemical properties of rubber growing soils *viz.*, characterization of soil organic matter, characterization of soil acidity, organic phosphorus status, soil solution chemistry, gravel content and effective soil volume were continued. Studies on rhizosphere biochemistry were initiated to understand the special adaptive mechanisms at the root level for uptake of phosphorus under low plant available P status. Development of Rubber Information System using remote sensing and Geographic Information System (GIS) techniques was initiated. Two uniformity experiments, one in immature rubber and the other in mature rubber were continued and individual tree observations on soil properties and plant performance were recorded to suggest suitable modifications in the design of field experiments, recording of observations and statistical processing of the data.

Advisory service to the rubber growers were provided through discriminatory fertilizer recommendation. Studies on Diagnosis and Recommendation Integrated System (DRIS) approach is being continued for further refinement of the discriminatory fertilizer recommendation.

1. Nutrient management

1.1. Nutritional studies

The seedling nursery experiment at Central Nursery, Karikkatoor was repeated for the third year to study the residual effect of applied Zinc(Zn). Results from the second experiment indicated significant positive effect of Zn application on growth of seedlings.

No significant difference in yield and girth of plants was noticed between treatments in the 1989 field experiment with RRII 105. The application of NPK at the rate of 90:30:40 kg/ha recorded the highest yield of 90.92 g/t/t. The highest girth of 73.34 cm was attained by the application of NPK at the rate of 60:30:40 kg/ha.

A long-term experiment in mature rubber was initiated to evaluate the effect of sequential skipping of fertilizers for one or more seasons/years on growth and yield. Pretreatment girth, yield and soil nutrient status were recorded.

Experiments to find out the possibility of substituting K with Na in the nutrition of rubber was conducted through two experiments, one in seedling nursery and another in mature rubber. Results from the seedling nursery experiment indicated that growth of seedlings were not influenced by

different levels of substitution. In the mature rubber also growth and yield were not influenced by substitution of K with Na or with additional application of Na along with K.

Mineral nutrient concentration in the lattices of 14 clones was estimated in different seasons during the second year of the study. Significant clonal difference in P, K and Mg content was noticed. Similarly monthly variation in P content was noticed in all the clones. The annual nutrient removal through latex was also calculated.

1.2. Integrated nutrient management

Integrated nutrient management in rubber through organic and inorganic fertilizers were attempted. The field experiment initiated in 1994 compared the application of organic manure alone or in combinations with inorganic fertilizers; supplying varying levels of N, P and common dose of K were conducted for seven years. The data on girth did not show significant difference between treatments. Among the various levels of N and P no significant difference in girth of plants was observed. Application of 50 Kg P_2O_5/ha registered the highest girth of 51.27 cm. Another experiment in immature rubber comparing organic manure and inorganic fertilizers alone and/or their combinations indicated no significant difference between treatments on mean girth of plants, height of plants and number of leaf whorls.

Characterization of soil organic matter under *Pueraria*, *Mucuna* and rubber alone were conducted through litter bag experiments. Litter bags were retrieved at monthly intervals. Dry weights were recorded and the weight loses were estimated (Table Ag. 1). In the case of rubber litter the rate of decomposition was significantly higher in the initial five months of decay than the later periods.

In the case of *Mucuna* and *Pueraria* the decomposition rate was significantly faster during the months of June and July and the remaining periods it was less. Effect of rubber cultivation on soil organic matter status, physico-chemical and biological properties of the soil was studied through one field experiment. Characterization of soil organic matter under rubber-based ecosystem was initiated in another experiment. Litter samples from a 10 year old mature rubber plantation and immature rubber with *Pueraria* and *Mucuna* were collected through litter traps. Humic and fulvic acid fractions were estimated. The experiment comparing *Pueraria phaseoloides* and *Mucuna bracteata* under different age groups were compared. In all age groups, except in one year old field the cultivation of cover crop improved the cation exchange capacity of the soil compared to the adjacent bare land.

Table Ag 1. **Cumulative loss of dry matter (%) with time**

Month (2001-2002)	Rubber	*Mucuna*	*Pueraria*
March	0	0	0
April	32.57	41.36	45.59
May	42.62	43.49	49.52
June	57.50	57.96	60.46
July	64.05	70.44	75.89
August	80.22	75.88	78.27
September	81.60	77.59	82.71
October	82.42	81.54	86.18
November	83.37	84.95	89.23
December	84.35	86.57	90.91
January	85.32	88.66	92.28
February	87.20	90.48	94.02
March	90.74	91.37	96.58
SE	1.57	1.62	1.71
CD (P=0.05)	4.41	4.55	4.80

1.3. Forms and methods of fertilizer application

The experiment conducted at CES, Chethackal for comparing the efficiency of controlled release fertilizers with conventional fertilizers was continued. The residual effect of controlled release fertilizers was studied during the year. Data on growth and yield showed that both conven-

tional and controlled release fertilizers recorded significantly higher girth and yield than the control. No statistical difference was observed between the different controlled release fertilizer treatments and standard practice with respect to growth and yield.

Comparative efficiency of Rajphos (RAP) and Mussoorie rock phosphate (MRP) as P source for young rubber was compared through field experiments at two locations. Results indicated that girth of rubber was not influenced by P application through either of the sources. Significant difference in girth increment was noticed for both sources over control in Boyce Estate. In Malankara Estate, RAP was found to be significantly superior over MRP. No difference was noticed between RAP and MRP at Boyce Estate (Table Ag. 2). Leaf analysis indicated no significant difference for leaf N, P and K between treatments. In the case of leaf Mg, treatment effect was significant over control, but no difference was indicated between RAP and MRP. Soil analysis data indicated no significant difference between treatments.

Table Ag. 2. **Effects of different rock phosphates on girth and girth increment in 2002 (Jan)**

Treatment	Girth (cm)		Girth increment (cm)	
	Malankara	Boyce	Malankara	Boyce
RAP	33.60	39.60	8.94	9.94
MRP	34.00	39.20	7.96	9.61
No P (control)	32.40	38.70	7.35	9.11
GM	33.30	39.20	7.88	9.55
SE	0.65	0.29	0.25	0.14
CD (P=0.05)	NS	NS	0.84	0.41

Two field experiments in mature rubber initiated in 1997 to study the response of rubber to P application at different levels supplied through sources *viz*., RAP and MRP were continued. No significant difference was observed in girth, girth increment, yield, leaf P and Mg between different levels of P application and also between two sources of P supply.

Experiment on nutrient value of sludge from crumb rubber factory on growth of seedlings was repeated during the second year. Significant difference between treatments on diameter of seedlings was noted. In general, application of N @ 500 kg /ha as urea alone, sludge alone and the combinations are comparable. Nitrogen at 500 kg level and above irrespective of sources are comparable. Combination of urea and sludge are more efficient than urea alone in increasing the diameter of seedlings.

Field experiment initiated to study the effect of advance manuring in planting pits for the initial one to three years was continued. It was observed that enhanced pit manuring of rubber did not significantly influence the girth of plants.

Movement of phosphorus in the soil was studied through soil column experiments. The results indicated that though there was increase in available P up to 60 cm depth, most of the applied P was concentrated in the 0-10 cm layer of the column even after 30 days indicating slow downward movement of applied P.

The downward movement of surface applied N and K was studied through soil column experiments. Highest availability of ammoniacal nitrogen was observed on the 5th day of fertilizer application in the 0-10 cm layer of the soil column. On the other hand, significantly higher nitrate N content was noticed in the lower segment (below 30 cm), indicating considerable downward movement of nitrate. In the column experiment, K availability was improved up to 30 cm indicating slow downward movement of applied K in the controlled conditions. In the field situation, influence of K fertilizer application on K availability was reflected only in the 0-10 cm layer of the soil at the 15th day of application and decreased downwards.

2. Physical and chemical properties of soil

A new project on effective soil volume and fertility assessment of rubber growing soils was initiated to quantify the gravel content and effective soil volume in rubber growing soils and to relate it with soil and leaf nutrient status and growth and yield of rubber. The project on characterization of soil acidity was continued. Soil samples from eight dominant soil series were collected and the acidity parameters *viz.*, exchange acidity, potential acidity, total potential acidity, extractable acidity etc., were estimated. Lime requirement of the surface soil by four methods was also estimated. Response of rubber to liming at different growth phases was evaluated through separate field and pot culture studies. One nursery experiment for comparative evaluation of liming materials on growth of rubber seedlings is being initiated. Similarly a pot culture experiment was conducted to study the effect of liming on growth of budded stumps and translocation and movement of Ca in the plant system. Field experiment initiated in 1998 to study the influence of liming on growth of rubber in the immature phase and availability of nutrients in the soil is being continued. Effect of liming on girth of plants recorded during December 2001 indicated that all the treatments were numerically superior to the absolute control. Application of lime alone was also comparable with the fertilizer alone or fertilizer plus lime treatments, but the effect was not statistically significant. One new experiment in mature trees was initiated to study the response of rubber to liming in the mature phase.

Soil samples from the dominant soil series were analyzed for the organic P status to relate it with P availability. Distribution of total and different forms of zinc in the rubber growing soils were assessed through the analysis of profile soil samples from the dominant soil series.

Studies on soil solution chemistry and nutrition of *Hevea* were continued. Multivariate statistical techniques were applied to the soil survey data. The 62 soil series could be grouped into ten clusters and the statistical exploration of soil survey data is being continued for further refinement of the classification.

To study the effect of planting pit size on growth and yield of rubber, one new experiment was initiated and polybag plants were planted in pits of varying dimensions.

3. Soil and water conservation

Effect of conservation pits on soil and moisture conservation and yield in mature rubber was studied through two field experiments. The first experiment is a block trial and the number of pits ranged from 100 to 250 per ha. It was observed that around 4.02 to 9.02 t/ha of soil was conserved and thus prevented from being lost through erosion when the number of pits was increased from 100 to 250 per ha. All the treatments except 100 pits per ha recorded significantly higher girth increment than control. Positive effect on yield was also obtained though not statistically significant (Table Ag. 3).

In the second experiment with smaller plot size, the fertilizers were applied in the silt pits and the combined effect on growth and yield was monitored. The quantity of soil conserved ranged from 4.66 to 10.34 t/ha as the number of pits increased from 150-250. Increasing the number of pits from 150 - 200 significantly increased the quantity of soil conserved (Table Ag. 4). Significant difference was not observed on the growth and yield of plants with respect to different treatments (Table Ag. 5). However, the girth was lowest in the no pit, no fertilizer control. One more experiment was initiated during this year to study the effect of

Table Ag. 3. **Effect of silt pits on growth and yield of rubber and quantity of soil deposited in pits**

Treatment (No. of pits/ha)	Yield (April, 2001 to March, 2002) (g/t/t)	Girth increment 1998-2002 (cm)	Quantity of soil deposited in the pits(t/ha)
0	31.10	5.39	0.00
100	30.99	6.63	4.02
150	33.43	7.68	6.09
200	33.59	8.42	6.89
250	35.15	9.14	9.02
SE	2.16	0.58	0.30
CD (P=0.05)	NS	2.00	1.00

Table Ag. 4. **Quantity of soil conserved by pits**

No. of pits / ha	Quantity of soil conserved (kg/ha)
150 (S)	4.66
150 (P)	5.34
250 (S)	9.34
250 (P)	10.34
SE	0.57
CD (P=0.05)	1.62

S – Surface application; P - Pit application

Table Ag. 5. **Effect of conservation pits on growth and yield of rubber**

No. of pits / ha	Girth (cm)	Yield (g/t/t)
150 (S)	55.74	39.77
150 (P)	55.32	40.81
250 (S)	56.55	42.06
250 (P)	55.65	43.06
No pit and standard practice	55.37	40.25
No pit and no fertilizer	53.45	41.12
SE	1.43	2.90
CD (P=0.05)	NS	NS

different soil and water conservation practices on growth and yield of rubber.

4. Density of planting

The experiment at CES, Chethackal initiated in 1994 with five densities of planting and two levels of fertilizer application was continued. Girth data indicated no significant difference between treatments. However, girth increment for the period 2001-2002 showed that plants at the lowest density (420 trees/ha) with less competition for light and nutrients had significantly higher girth increment.

5. Intercropping and cropping systems

The experiment initiated during 1993 at CES, Chethackal with rubber planted in paired rows of 5-10 m apart is being continued. Now, pepper, coffee and fodder grass are remaining in the system. Growth and yield of rubber and intercrops were monitored. Girth as well as girth increment were slightly superior in the inter-cropped area compared to mono-culture under normal spacing. Flowering and fruit setting continued to be very poor for pepper. Yield of coffee was also poor.

Feasibility of intercropping coffee and cocoa in the later immaturity phase and in mature rubber were envisaged through three separate field experiments.

Growth or yield of rubber was not significantly affected by growing intercrops. In the experiment in mature rubber, intercropped with coffee and cocoa, yield and the PAR availability were recorded. The mean PAR intercepted in the system was only 10.14% of that in the open (Table Ag. 6).

Growth and yield of rubber were not significantly affected by growing coffee. The mean PAR intercepted in the system was only 6.78% of that in the open (Table Ag. 7).

Table Ag. 6. **Effect of intercropping coffee and cocoa on growth and yield of rubber and PAR availability**

Treatment	Yield 2001-2002 (g/t/t)	Girth 2002 (cm)	PAR (% of open)
Rubber alone	48.45	55.52	9.7
Rubber + Robusta- 100% fertilizer for coffee	52.47	56.15	9.7
Rubber + Robusta - 50% fertilizer for coffee	48.61	54.50	12.3
Rubber + CxR - 100% fertilizer dose for coffee	53.69	54.12	8.0
Rubber + CxR - 50% fertilizer for coffee	49.65	58.57	10.7
Rubber + Cocoa -100% fertilizer for cocoa	51.99	55.62	10.0
Rubber + Cocoa - 50% fertilizer for cocoa	47.83	56.92	10.6
SE	5.10	0.95	1.2
CD (P=0.05)	NS	NS	NS

Table Ag. 7. **Effect of intercropping coffee on growth and yield of rubber and PAR availability**

Treatment	Yield 2001-2002 (g/t/t)	Girth 2002 (cm)	PAR (% of open)
Rubber alone	54.41	60.60	7.75
Rubber + Robusta - 100% fertilizer for coffee	59.95	60.55	8.50
Rubber + Robusta - 50% fertilizer for coffee	61.59	59.90	6.50
Rubber + CxR - 100% fertilizer dose for coffee	64.20	63.05	5.25
Rubber + CxR - 50% fertilizer for coffee	52.16	62.42	7.50
Rubber with 100% of fertilizer for rubber and intercrops	51.00	59.57	7.25
Rubber with 100% of fertilizer for rubber and 50% of the fertilizer dose for intercrops	51.99	58.32	4.75
SE	4.36	1.01	1.75
CD (P=0.05)	NS	NS	NS

Feasibility of growing timber crops along with rubber is envisaged through different field experiments. Interaction between Anjili and rubber in mixed stand and the growth of rubber is assessed through an on farm trial.

It was observed that Anjili had significant negative effect on growth of rubber. Girth increment of rubber with Anjili was significantly low compared to rubber without Anjili (Table Ag. 8). One new field experiment was initiated to study the performance of rubber interplanted with three timber trees *viz.*, Anjili, Teak and Mahagony, and perennial intercrops *viz.*, coffee (robusta), garcinia, nutmeg and vanilla. Another experiment was initiated to study the effect of densities of timber trees interplanted with rubber on the growth of rubber.

Table Ag.8. **Effect of Anjili on growth of rubber**

Treatment	Girth Increment (cm)
Rubber with Anjili	2.50
Rubber without Anjili	3.00
SE	0.21
CD (P=0.05)	0.41

6. Weed management

The field experiment initiated in 1998 to study the effect of herbicide rotation on weed regeneration and to find out the optimum number of rounds of herbicide spraying for the control weeds in rubber was continued. Though there was significant difference in the mean percentage of weed infestation, the growth of the plants was not af-

fected by repeating the treatments at 75% regeneration of weeds indicating that treatments need be repeated only at 75% regeneration of weeds (Table Ag. 9). Through a separate field experiment initiated in 1998, the efficacy of Controlled Droplet Applicators and Knapsack sprayers were evaluated. The relative efficiency of Touch Down (a newly introduced systemic broad spectrum herbicide) in controlling weeds in the planting strips of immature rubber was also evaluated through this field experiment. Mean percentage weed infestation did not differ significantly among treatments indicating that all treatments were effective in controlling weeds. The weed dry matter production (DMP) was minimum in the scrapped plots followed by Glyphosate and Touch Down @ 2 L/ha with CDA, which were comparable. There was no significant difference among treatments with respect to the growth of plants.

7. Design of field experiments

Uniformity trials initiated in 2000, one each in immature rubber and mature rubber were continued. In immature rubber, the variations in the experimental unit were documented and observations were recorded to identify the most appropriate plot size for field experimentation and to standardize the frequencies of recording observations. From the girth measurements it has been observed that a sample size of 8-12 trees was necessary to keep the standard deviation and coefficient of variation at reasonable levels. The plant to plant variations in girth, yield and yield attributes were recorded in the mature rubber.

8. Remote sensing and Geographic Information System

Development of Rubber Information System in traditional region of cultivation was attempted using remote sensing and GIS techniques. Rubber Information System containing rubber distribution map in 1:50,000 scale, soils under rubber, disease map, socio-economic conditions in a given region etc., put in GIS environment will be developed.

9. Rhizosphere chemistry

A new project on studies on adaptive mechanisms at the rhizosphere involved in the acquisition of phosphorus and micronutrients by rubber was initiated. Steps were initiated to set up hydroponic and

Table Ag. 9. **Mean percentage of weed infestation and growth of rubber in different weed control treatments**

Treatment*	MWI (%) April'01-March02	Girth 2002 (cm)
Scraping	29.93	23.37
Scraping followed by Glyphosate	37.83	24.56
Scraping followed by Touch down.	35.17	25.95
Glyphosate followed by Gramoxone + Fernoxone	38.28	25.62
Touch down followed by Gramoxone + Fernoxone	39.54	25.33
Scraping	41.93	23.37
Scraping followed by Glyphosate.	47.31	24.65
Scraping followed by Touch down.	47.76	24.37
Glyphosate followed by Gramoxone + Fernoxone	46.95	25.11
Touch down followed Gramoxone + Fernoxone	48.87	24.48
SD	2.66	0.74
CD (P=0.05)	7.89	NS

* Treatments 1-5 are repeated at 50% regeneration of weeds and treatments 6-10 are repeated at 75% regeneration of weeds.

rhizobox experiments with rubber seedlings.

10. Discriminatory fertilizer recommendation

Twenty two large estates availed the facility of soil and leaf analysis based fertilizer recommendation. A total of 690 soil and 450 leaf samples were analyzed for assessing the nutrient status and on the basis of this fertilizer recommendations to 580 individual fields were provided. On perusal of the individual recommendations it was observed that in general a high degree of saving was noted on the nutrient P followed by N. In 50% of the situations K requirement was found to be higher than the general recommendation. For further refinement of fertilizer recommendation, work on Diagnosis and Recommendation Integrated System (DRIS) approach, is being continued.

BIOTECHNOLOGY DIVISION

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

After extensive experiments, the plant regeneration frequency of transgenic *Hevea* clone RRII 105 integrated with SOD gene under the control of FMV 34S promoter could be enhanced and 10 such transgenic plants were hardened and transferred to polybags. The antibiotic, paramomycin was identified as superior to kanamycin for the selection of transformed *Hevea* cells. Germination frequency of somatic embryos derived from immature anther could be enhanced upto 85%. A small-scale field evaluation experiment was started at CES, Chethackal. About 200 plants are now ready for field planting. The genomic and cDNA sequences coding for β-1, 3-glucanase have been sequenced. The *Hevea* β-1, 3-glucanase gene is a single exonic gene. The gene is expressed constitutively in latex vessels of all clones. In the leaves it is expressed in the tolerant clones only on induction with the pathogen.

1. Micropropagation

In the shoot tip explants of RRIM 600, RRII 105 and seedlings cultured for *in vitro* development, continued growth of the shoots with formation of new flushes and multiple shoot induction was achieved in both seedling and clonal explants. Rate of growth and maturation of multiple shoots derived from seedlings were faster compared to clonal explants. Comparison of the rooting response between explants derived from seedlings and clonal materials were also made. Root induction was obtained within one month. There were no significant difference between the time taken for rooting in seedling and clonal materials. Clonal shoot tips when subcultured for rooting in low sucrose and hormone free medium exhibited an abrupt shoot elongation as an indication of shoot rejuvenation. The root induction frequency in seedlings was more than 70% while in clonal materials it was 20% only. The mature shoots obtained from seedling multiple shoots rooted easily in half MS medium containing IBA (1.0 mg/l).

Experiments were carried out to enhance the frequency of somatic embryo induction and further plant regeneration, es-

tablishment of plantlets and hardening. Germination frequency of somatic embryos derived from immature anthers of clone RRII 105 could be enhanced to 80% using the cytokinin TDZ. A culture protocol for retaining the embryogenic capacity for over 3 years was established using primary embryogenic callus aggregates as explants. A culture density of 100 mg callus/tube with 50 days subculture interval was found to be ideal for maintenance of embryogenic potential. In the plantlets produced, the number of lateral roots were enhanced by incorporation 5 mg/l IAA in the germination medium. Scanning electron microscopic studies revealed a very low level of cuticle deposition in the leaves of plantlets before hardening. However, in hardened plants the cuticular wax pattern was almost identical to the mature field grown plants. Sand and soil along with dried cowdung (1:1:1) under sterile conditions was found to be the most suitable planting substrate. A small-scale field trial with plants produced through somatic embryogenesis from immature anthers of clone RRII 105 was initiated. About 200 such plants are now ready for field planting in the coming season.

Effects of various levels of different sugars, sugar alcohol, boric acid, adenine sulphate, inclusion of liquid phase etc. on induction of embryos and plant regeneration frequency in the immature inflorescence derived callus cultures were carried out. Results have shown that the presence of sucrose is highly essential at all the stages of the pathway. None of the other sugars when tried alone could promote embryogenesis as effectively as sucrose. However, incorporation of maltose (50 mM) along with sucrose significantly enhanced embryo induction and further development. Among the different sugar alcohols tried, mannitol and myoinositol were found to have significant effect on callus proliferation, embryo induction and maturation. It was observed that culturing the proembryogenic mass in suspension cultures had a stimulatory effect on further proliferation and maturation. Boric acid at 20 mg/l was found to promote embryo induction and faster growth of the embryogenic callus. Adenine sulphate at 50 mg/l was found to enhance plant regeneration. Hardening of the plants and survival rate were found to be better when the plants were transferred to regeneration medium fortified with 4% PEG about two weeks prior to transplanting. While hardening, the use of earthenware pots was found to be beneficial in controlling the water retention of the plants resulting in better survival of the plants.

2. Genetic transformation

Agrobacterium mediated genetic transformation experiments were continued with the genes coding for superoxide dismutase, isopentenyl transferase, antisense ACC and Sorbitol-6-phosphate dehydrogenase to develop transgenic *Hevea* plants tolerant to tapping panel dryness, drought and different types of environmental stress. Two transgenic plants integrated with the gene coding for SOD under the control of Ca MV 35S promoter obtained earlier could be grown upto four whorl stage. Efforts are in progress to produce more such plants.

Experiments to develop transgenic *Hevea* integrated with the gene coding for SOD under the control of FMV 34S promoter were continued. WPM medium with half strength major and full strength minor nutrients supplemented with the hormones GA_3, BA and IBA was found to be better. For embryo germination and plant regeneration 200 mg/l paramomycin was found to be superior to kanamycin. About 20% embryo germination was obtained with a hormonal combination of 2.0 mM GA_3 and 1.5 mM each BA and IBA (Table Biotech. 1).

Table Biotech. 1. **Effect of GA_3 BA and IBA on germination of transgenic embryos integrated with the gene coding for SOD under the control of FMV 34S promoter**

BA /IBA(mM)	GA_3(mM)					
	0.5	1	1	2	2.5	3
0.0 / 0.0	1*	3	3	5	2	0
0.5 / 0.5	2	4	7	10	9	3
1.0 / 1.0	3	6	14	17	11	4
1.5 / 1.5	3	9	16	20	12	5
2.0 / 2.0	1	4	8	11	5	2
2.5 / 2.5	0	0	1	2	1	0

* Percentage of embryo germination

The survival rate of plants while hardening, was enhanced by dipping them in 0.1% Akomin for 5 minutes. After hardening 10 such transgenic plants were transferred to bigger polybags. Estimation of total SOD, glutathione reductase and ascorbate peroxidase enzyme activity of the normal and transgenic *Hevea* tissues during different stages of somatic embryogenesis was carried out. It was observed that SOD activity was higher in the embryogenic callus and germinating embryos. On embryo maturation the SOD activity started declining. The transgenic callus expressed a high glutathione reductase activity than the normal callus. The transformation events in the SOD transgenic plants were confirmed by molecular analysis. PCR analysis was carried out with GUS specific and cDNA based SOD specific primers using genomic DNA as the template. Southern analysis was also carried out with GUS and npt-II gene as the probe using genomic DNA from normal and transgenic plants.

In order to study the role of SOD in the regulation of various plant functions, an attempt was made to develop transgenic plants integrated with the antisense gene coding for SOD. Twenty five transgenic calli lines were produced with this gene. By using embryogenic calli as the explants, the transformation frequency was increased to 20%. Embryo induction was obtained in medium supplemented with high sucrose (60 g/l), 0.5% phytagel and 2.0 mg/l zeatin. The embryos are under different stages of maturation.

Attempts were continued to develop transgenic plants incorporated with the antisense gene coding for ACC synthase for the regulation of ethylene biosynthesis and thereby to reduce the incidence of TPD. Various levels of different microelements such as Cu^{2+}, Co^{2+}, Mn^{2+}, Zn^{2+} and Bo^{2+} were incorporated in the embryo induction medium of the transgenic calli keeping MS micro nutrient level as the control. These experiments revealed that Mn^{2+} has got a stimulatory effect. Embryo induction was favoured when Co^{2+} concentration was reduced to 1/10 of that in the control. Boric acid at 30 mg/l enhanced the percentage of embryo induction as well as proliferation of the embryogenic calli.

In the earlier attempts to regenerate transgenic plants integrated with isopentenyl transferase, development of many abnormal embryos were observed probably due to the over production of cytokinin. Therefore, further experiments were carried out for the induction of normal embryos. Modification of the concentration of the major nutrients like Ca, Mg and K by the addition of potassium sulphate and clacium nitrate favoured embryo induction. Addition of amino acids such as asparagine, proline, cysteine hydrochloride, serine and glutamine and organic supplements like malt extract and casein hydroly-

sate helped in embryo induction and enlargement. Addition of stress inducing compounds like polyethylene glycol (40 g/l) and mannitol (20 g/l) also increased the embryo induction frequency. Embryo induction could be obtained in media devoid of cytokinin but presence of abscisic acid (0.2 mg/l) increased embryo induction by 30% and gibberellic acid (0.8 mg/l) helped embryo enlargement. About 500 embryos with apex induction after maturation could be obtained and continued growth of apices was obtained in 50 of them. Leaf formation was obtained in 25 of them. PCR and southern blotting were done with different transgenic calli lines, embryos and germinating embryos. Stable integration of the ipt gene in all of them was confirmed.

In order to develop drought tolerant *Hevea* clones by the accumulation of sorbitol in the tissues, fresh genetic transformation was carried out with two different vectors carrying the gene coding for sorbitol-6-phosphate dehydrogenase (S-6-PDH). One of the vectors carrying a gene sequence for S-6-PDH which is cytoplasm specific and the other with the sequence for a transit peptide directing to chloroplasts and making it chloroplast specific. Transgenic calli were developed and maintained for embryo induction.

3. Haploid plant production through microspore / ovule culture

Experiments were continued to enhance micro colony formation from microspores. Static liquid cultures were found to be advantageous for micro calli formation. Micro calli from microspores of RRIM 600 formed faster than RRII 105. The embryo induction frequency of ovule derived calli was found to be enhanced by the addition of zeatin (1.0 mg/l) and ABA (0.2 mg/l). Medium supplemented with glutamine (500 mg/l) and asparagine (150 mg/l) promoted maturation of embryos. N_6 basal medium supplemented with banana powder (200 mg/l), casein hydrolysate (400 mg/l) and growth regulators such as TDZ (0.4 mg/l) and GA_3 (2.0 mg/l) promoted bipolar differentiation of embryos.

4. *In vitro* fertilization and plant recovery

The nutritional and hormonal factors in the culture medium for ovule were optimized for effective *in vitro* fertilization and growth of embryos. Addition of boric acid (100 ppm) in to the initial medium was found to improve fertilization. Embryo development was promoted by the addition of *Hevea* endosperm extract 1.0 mg/l GA_3 and 2.0 mg/l Kn in the culture medium. Embryos could be grown up to the heart shape stage. Anatomical studies of the developing ovules, 30 days after pollination, revealed the presence of a 2-layered outer wall. The abundance of starch and lipids were observed in the nucellar area. The longitudinal section of a developing ovule, 90 days after pollination, showed a well developed seed coat with a thin walled outer zone and a thick walled inner zone with sclerified radially elongated cells. The embryos were not visible at this stage as it is suspended in liquid phase.

5. Endosperm culture

Optimization of the composition of nutrients and growth regulators in the culture medium for the induction of embryogenic callus were carried out. High levels of sucrose and phytagel were found to be essential for embryogenic calli formation. A combination of growth regulators such as NAA (0.4 mg/l), BA (0.4 mg/l), Kn (0.5 mg/l), GA_3 (0.3 mg/l) and 2-4-D (0.2 mg/l) along with 400 mg/l casein hydrolysate promoted induction of embryogenic callus.

6. Molecular studies

6. 1. Molecular mechanism of disease tolerance

Based on the published cDNA sequence of β-1,3- glucanase from *Hevea*, two primers were designed and synthesized:

G1- 5'TGC CCA GGT AGG TGT TTG C 3' and G2- 5'CCC AGT TCT TTT CTG CAC C3'. Under optimal PCR conditions a 968 bp band was amplified from the genomic DNA. Total RNA from the latex and leaves were used as template for the synthesis of cDNA. The above primers were used for the amplification of cDNA and a 968 bp band was amplified from the cDNA also. Cloning of the PCR products were carried out at the *Sma*I restriction site of the plasmid vector pUC 18 through blunt end ligation and the nucleotide sequence was elucidated. Both genomic and cDNA were found to have similar sequence and has shown homology with the reported cDNA sequences. The amplified fragment contains all the nucleotides for the final functional protein. As no introns were present in the coding region of the mature protein, the *Hevea* β-1,3- glucanase can be called as a single exonic gene. Absence of introns may facilitate the strong expression of the gene. To confirm the presence of the gene a genomic southern was performed with DNA isolated from abnormal leaf fall tolerant and susceptible clones. About 3 - 4 bands were obtained with the restriction enzymes tested, indicating the presence of a low copy number gene. As no difference was observed between tolerant and susceptible clones, the difference in tolerance to disease may not be due to the presence/absence or difference in the copy number of the gene but depends on the regulation of gene expression.

Northern blot hybridization studies were conducted to see the expression of β-1, 3- glucanase gene in different tissues. It was found that in the laticiferous tissues this gene is constitutively expressed. This constitutive expression of defense related genes may provide an important contribution to the plant defense mechanism by sanitizing and sealing the wounded areas on the tree.

Fungal infection studies were carried out with susceptible and tolerant clones. A virulent strain of *Phytophthora meadii* was grown in PDA medium and was inoculated to the oats medium for sporulation. The spores formed after two days were liberated through heat shock and were inoculated to young detached leaves of *Phytophthora* tolerant (RRII 105) and susceptible (RRIM 600) clones of *Hevea*. RNA was isolated after 48 and 72 hrs from the infected zones and northern hybridization was performed with the β-1,3- glucanase gene probe. The gene was found to be induced in leaf tissues in response to fungal infection as strong signals were obtained in inoculated leaves compared with control. However, timing and magnitude of induction was different in the case of tolerant and susceptible clones.

6. 2. Tissue specific gene expression and characterization of promoters

Attempts were made to amplify the promoter of rubber elongation factor, a gene highly expressed in the laticiferous cells. DNA was isolated from *Hevea* clone RRII 105, restriction digestion was carried out with *Sau 3A1 & Bgl II* restriction enzymes and the fragments were purified. Adapters were prepared with oligonucleotides synthesised based on restriction sites and ligated to the restriction digested DNA. Amplification of the upstream element was carried out with adapter specific forward primer and REF specific reverse primer following standard PCR conditions. Fragments were amplified between 400 bp and 1.2 kb in size.

The gene coding for rubber elongation factor cloned earlier was sequenced completely. A total of 1364 base pairs were sequenced. Total RNA was isolated from latex of clone RRII 105. RT-PCR was performed according to standard protocol. Amplified cDNA was purified and cloned into pUC 19 vector. Comparison of the sequence of cDNA and genomic DNA shows

that two introns were present in the genomic clone corresponding to the 624 base pair coding region of the cDNA. The size of the introns were 299 and 452 bp.

6. 3. DNA polymorphism in *Hevea*

Few distinct polymorphic bands were identified during RAPD analysis with 37 clones and these DNA bands were cloned into plasmid vector. One RAPD marker (1.4 kb) was sequenced completely. The sequence data showed 42% homology with the gene coding for a proline specific permease. Out of 37 clones used for RAPD analysis, the DNA marker was present in 14 clones and absent in 23 clones. Two polymorphic bands (1.2 kb and 1.3 kb) related to gene introgression were identified which were cloned into pGEM vector. Of the two cloned fragments, the 1.2 kb fragment was completely sequenced.

Farnasyl diphosphate synthase (FDP) catalyses the synthesis of the last common substrate in the isoprenoid biosynthesis and hence is a branching point and a likely regulatory enzyme in the pathway. Total RNA was isolated from latex (RRII 105 clone) and full length cDNA was synthesized by RT-PCR using FDP gene specific primers. After PCR amplification of FDP gene, gel purified and cloned into pGEM vector. The cloned FDP gene was completely sequenced and the sequence data has shown 100% homology with the earlier published FDP synthase gene from *Hevea*.

BOTANY DIVISION

The Division continued its research activity on the thrust areas like hybridisation and clonal selection, ortet selection, evaluation of clones for monoclonal and multiclonal planting, stability studies, breeding for biotic and abiotic stresses, evolving clones for both latex and timber yield, compact canopy type and incorporation of wild Brazilian germplasm in hybridization programmes. Priority was given for selection and evaluation of clones having more yield and better secondary characters than RRII 105. Emphasis was also given for cytogenetic and floral biology studies, bark and wood anatomical investigations, studies on budding techniques and their modifications, stock scion relationship and morphological characterisation of clones.

1 Evolving high yielding clones for the traditional area

1.1. Hybridization and clonal selection

In the 1985 small-scale trial (SST) of RRII 400 series clones, five promising clones *viz.*, RRII 414, RRII 417, RRII 422, RRII 429 and RRII 430 included in category III of the planting recommendations of the Rubber Board, were found superior to RRII 105 for yield in the first year of tapping from renewed bark (Table Bot. 1). Clone RRII 429 was significantly superior to RRII 105. Nucleus quantities of the budwood of these clones were supplied to 24 growers for establishing experimental on-farm trials.

Scrutiny of yield data of the 1989 SST revealed that two of the 49 hybrid clones

Table Bot. 1. **Initial yield and standard heterosis of promising hybrid clones in the renewed bark under 1/2 S d/3 6d/7 tapping system**

Clones	Mean yield (g/t/t)	Standard heterosis (%)
RRII 414	55.10	20.20
RRII 417	63.63	38.80
RRII 422	57.45	25.32
RRII 429	72.86	58.94
RRII 430	52.81	15.23
RRII 105	45.84	——
CD (P=0.05)	24.92	

excelled RRII 105 with more than 20% yield improvement during the 4th year of tapping. In another trial out of 49 hybrids, six clones exhibited more than 20% yield improvement over RRII 105 during the 3rd year of tapping. In the trial 1989C, out of 25 hybrid clones one clone was found to excel RRII 105. In the 1990 SST's, during the second year of tapping, 19 hybrids showed better performance than RRII 105 as control. During 2001, three new trials were laid out where 46 hybrids and five parents are under evaluation.

In the hand pollination programme-2002, a total of 3001 crosses involving eight selected wild genotypes and eleven Wickham clones were carried out. Female parents used were RRII 105, RRII 118, RRII 208, RRII 300, RRII 308, RRII 414, RRII 429, PB 260, PB 310, PB 330 and RRIM 605.

1.2. Ortet selection

At Cheruvally Estate, five ortets continued to exhibit more yield than RRII 105 (Table Bot. 2). A source bush nursery of all high yielding ortets was established at CES, Chethackal.

In the ortet trial at Mundakkayam Estate, six ortets showed better yield over RRII 105 ranging from 3.19 to 44.68% in the 4th year of tapping. Clone MO 45 was the highest yielder with 72.02 g/t/t while RRII 105 recorded 49.78 g/t/t. In a study on disease reaction, 22 clones showed low disease incidence. A source bush nursery of all high yielding ortets and promising selections from the Mundakkayam and Koney trials was established at CES. Yield recording was initiated in the trial where selections from Kodumon Estate were planted. Three selections are showing better performance in growth than RRII 105.

Table Bot. 2. **Mean yield and girth of promising selections over five years of tapping**

Clone	Average girth (cm)	Mean Yield (g/t/t)	Percent increase over RRII 105
CyO 41	99.90	64.20	21.36
CyO 48	85.70	60.86	15.04
CyO 35	77.20	60.30	13.98
CyO 72	60.40	57.48	8.65
CyO 30	67.40	55.61	5.12
RRII 105	56.71	52.90	——

1.3. Special techniques in breeding

In the trial on the clones resultant of polyploidy and mutation, six clones showed higher girth than RRII 105. One clone showed yield comparable with RRII 105. Annual girth recording was done in the 1992 trial. Clone 294 which recorded highest girth during immaturity period recorded the highest yield also.

2. Evaluation of clones

2.1. Large scale evaluation

In the large-scale mixed clone trial, regular recording of yield and secondary characters were carried out. Among the clones, PB 310 and RRIM 600 recorded better yield and RRII 44 showed vigorous growth (Table Bot. 3).

In the trial at North Konkan, mean monthly dry rubber yield of the clones during 2001 indicated better yield in clone RRII 6 (39.9 g/t/t) followed by RRII 208 (39.0 g/t/t). RRII 105 was third in rank with 33.5 g/t/t. Lowest yield was recorded by RRIC 105 and RRIC 52 (20.0 g/t/t). In the

Table Bot. 3. **Performance of clones during the 12th year of tapping**

Treatment	Girth (cm)	Yield (g/t/t)
RRII 44	102.79	57.54
RRII 45	76.64	40.45
RRII 105	76.03	49.84
PB 235	88.34	50.86
PB 260	77.62	41.53
PB 310	92.58	62.69
PB 311	86.37	55.00
PR 255	83.80	47.23
PR 261	91.76	40.28
RRIM 600	90.30	61.41

multi-disciplinary evaluation trial, fourth year yield data revealed PB 255 to be the highest yielder (89.92 g/t/t) followed by PB 314 (80.47g/t/t) and PB 280 (74.2 g/t/t). In the large-scale clone trial 1989A, PB 312 gave the highest yield of 70 g/t/t while RRII 105 recorded 48 g/t/t. In the second trial planted in the same year, among the eight clones RRII 105 recorded highest yield of 56.7g/t/t followed by SCATC 88/13 (41.8 g/t/t) and RRIM 600 (38.3 g/t/t). SCATC 93-114 recorded yield of 20.9 g/t/t in the third year of tapping.

Influence of weather parameters on growth of *Hevea* trees during immature phase both in the traditional as well as non-traditional rubber growing zones was also studied. Preliminary analysis indicated evaporation to be the most important factor influencing girth. Linear regressions indicated that if the monthly evaporation exceeds 6 mm, growth stops completely under rainfed conditions. Thus, evaporation appears to be a promising meteorological parameter for further exploration.

2.2. Onfarm evaluation

At Chithelvetty, where 12 clones are under evaluation, RRII 105 recorded highest yield (1396 kg/ha) followed by PB 310 (1310 kg/ha).

At Manickal Estate, of the eight clones in the seventh year of tapping, RRII 105 ranked highest in yield (2736 kg/ha) followed by RRII 4 (2014 kg/ha) and PB 235 (1745 kg/ha). Of the eight clones at Koney, PB 260 showed the best performance (2015 kg/ha) followed by PB 314 (1852 kg/ha) and RRII 105 (1693 kg/ha) during the fourth year of tapping. Evaluation of seven clones at Shaliakary Estate revealed RRII 105 to be the highest yielder (1497 kg/ha) followed by PR 255 (1472 kg/ha) and RRII 176 (1217 kg/ha). In the onfarm trial at Chemony, PB 260 was the highest yielder (1148 kg/ha) in the third year of tapping. Among nine clones under evaluation at Sasthankotta, six clones showed better girth than RRII 105.

2.3. Investigations on genotype x environment interaction

Quarterly girth recording of the trials in two locations *viz.*, Kanyakumari and Nagrakatta revealed that trees can be opened for tapping during 2003.

2.4. Studies on clonal composites

The trial at CES was opened for tapping. Mean yield over the first six months revealed that the clones in all the blends were comparable with each other (Table Bot. 4).

Table Bot. 4. **Mean yield of the different combinations over the first six months**

Blend	Mean yield (g/t/t)
1	35.41
2	35.79
3	35.94
4	36.38
5	38.24
RRII 105 (monoclone)	37.19

3. Breeding for other specific objectives

3.1. Compact canopy

Among the four morphotypes in the trial on genetic variants, normal morphotype yielded 54.5 g/t/t, which was comparable with RRII 105 (53.8 g/t/t). Other morphotypes did not show satisfactory growth and yield. Ten progenies, resultant of crosses involving dwarf with RRII 105 and RRIM 600 as female parents and their reciprocals were selected based on test tap yield and a small scale evaluation trial was laid out at CES, Chethackal.

3.2. Drought tolerance

There was significant variation in girth of clones in the five SST planted in 1998 and 1999. Thirty-nine clones showed greater vigour than RRII 105. Incidence of pink dis-

ease ranged from 0 to 25% with 32 clones remaining unaffected. Fortythree hybrids evolved by crossing drought tolerant parents were planted in two SST during 2001. A polybag nursery of these clones has been established for studying physiological parameters of drought tolerance. Two more trials, one with 30 hybrids and six parents and another with 14 clones were laid out at CES, Chethackal.

3.3. Disease resistance

The experiment on nursery screening for *Oidium* was wound up. Clones having stable tolerance to *Oidium* disease (PB 86, SCATC 93-114, RRII 208 and RRIM 703) were crossed with high yielding clones RRII 105 and PB 260.

3.4. Latex timber clones

Hybridisation programme using selected parents was carried out and recorded observations on morphological parameters of seedlings in the nursery.

3.5. Polycross progeny evaluation

Yield of 150 clones belonging to 10 progenies being evaluated in field trials ranged from 10.30 to 75.74 g/t/t in the first year of tapping. Of these, 50 clones showed improved yield over RRII 105. Early results indicated great promise for pursuing the polycross breeding approach for evolving superior clones. Half sib seedling progenies of 11 popular clones showed significant variation for test tap yield, girth and bark thickness. Progenies of clones PB 255, RRII 203, PB 260, RRII 105 and GT 1 showed high performance index coupled with a high recovery of superior seedlings indicating prepotency.

Yield of polyclonal progenies at RRS, Dapchari, varied from 720 kg to 960 kg/ block. Mean yield over eight years of tapping works out to about 800 kg/block (Table Bot. 5).

Table Bot. 5. **Annual rubber yield from two blocks of polyclonal seed trees over eight years of tapping**

Year of tapping	Dry rubber yield (kg)		Annual totals
	From latex	From FC	
4	716.0	44.5	760.5
5	714.3	35.9	750.1
6	677.9	42.0	719.9
7	880.8	80.6	961.4
8	734.5	81.4	815.8
9	690.6	100.7	791.3
10	741.8	84.8	826.6
11	640.9	87.7	728.6
Mean	724.6	69.7	794.3
Share (%)	91.2	8.8	100.0

* About 300 trees per block FC = Field coagulum

It appears that even though North Konkan experiences more than three months of high temperature and drought conditions, yield is not suffering much. This indicates scope for planting polyclonal seedlings in drought-affected areas.

4. Cytogenetics and floral biology

4.1. Cytogenetical investigations

A detailed cytopalynological study of the clone SCATC 93-114 was done. The results indicated that it is a male sterile clone. The morphology of the male flower was similar to that of the normal fertile clone but the flowers were comparatively smaller in size except that the anther column seems to be shrunken in appearance. Female flowers were normal. Cytological studies revealed that meiotic division was normal up to the formation of tetrad stage after which there was complete degeneration of cytoplasm and nucleus in the microspore resulting in sterility.

In vitro pollen germination and pollen stainability studies of three clones *viz.*, RRII 300, RRII 308 and SCATC 93-114 were carried out. Pollen stainability and germination was 92% and 25% in RRII 300 while in RRII 308 it was 83.5% and 40.78%. Pollen tube of RRII 308 was highly coiled but in

RRII 300 it was straight, narrow and elongated. In SCATC 93-114, none of the pollen grains germinated.

4.2. Studies on storage of *Hevea* pollen

A study on cryo-storage of *Hevea* pollen grains at –196 °C was carried out. Pollen of the clones RRII 105, RRII 118, PB 260 and RRIM 600 was used in the study. The results indicated retention of viability of the pollen up to four weeks. The percentage stainability recorded was 32, 50, 55 and 60 respectively. Post-storage germinability ranged from 8 to 20% after one month of storage. In a field study, pollen grains of RRII 105 stored for one month was used in pollination on female parents (PB 260 and RRII 118). Fruit set realised was 2%. Further studies on optimisation of pollen storage are in progress.

5. Anatomical investigations

5.1. Bark anatomy

To study the effect of seasonal changes in bark anatomy and latex yield, an experiment was initiated with six clones each at CES, Chethackal and RRS, Dhenkanal (Orissa). Monthly bark sampling was done and microscopic observations were carried out. To study the subcellular changes associated with TPD, bark samples together with cambium from normal, TPD affected and regenerated bark on the debarked TPD affected area were collected and processed for transmission electron microscopy.

Bark anatomical features of 11 modern clones planted in Kanyakumari region was studied. IRCA 111 recorded highest values for bark thickness and six clones recorded higher values for LVR than general mean. In another study on the progenies of 1982 HP, latex vessel rows and ray characteristics showed significant clonal variation while bark thickness was not significant (Table Bot. 6).

Anatomy of 30 and 90 days old *in vitro* fertilised ovules were studied. Localization of starch and lipids was noticed in the nucellar area. A longitudinal section of 90 day old developing ovule showed a well developed seed coat with thin wall inner zone with radially elongated cells. The seed was single layered in the chalazal region. The

Table Bot. 6. **Bark anatomical features of 11 modern clones**

Clone	Bark thickness (mm)	Latex vessel rows	Ray dimension (mm)	
			Height	Width
RRII 403	8.06	36.36	439.74	52.73
RRII 410	8.36	26.67	476.09	52.80
RRII 414	8.43	32.38	477.95	56.44
RRII 415	7.22	13.73	496.68	67.26
RRII 417	8.49	29.88	490.19	53.86
RRII 421	8.02	30.01	411.14	57.38
RRII 422	7.58	28.96	480.36	54.19
RRII 423	8.49	21.68	510.06	46.35
RRII 425	8.63	26.25	481.17	53.74
RRII 427	7.96	21.27	519.19	51.60
RRII 428	6.87	21.66	474.76	57.46
RRII 429	6.93	31.99	527.57	47.75
RRII 430	7.97	28.68	452.64	57.24
RRII 105	8.24	32.08	446.42	53.60
CD (P=0.05)	NS	7.11	35.69	5.89

embryo was suspended in the liquid phase. Scanning electron micrographs of the leaf of the *in vitro* plants before and after hardening showed cuticle covering on epidermis on the abaxial side of the leaf almost similar to that of RRII 105.

5.2. Wood anatomy

Monthly ethrel application (5%) in clones RRII 105 and RRIM 600 in connection with the studies on effect of ethrel stimulation on rubber wood quality has been completed. Wood logs were collected from both normal and stimulated trees during summer. Standard size specimens were prepared to study physical and mechanical properties of the wood. Samples were also collected and preserved for wood anatomical studies.

6. Studies on propagation

6.1. Budding techniques

Among the different treatments in the trial on budding height and depth of planting no significant difference was found. Girth and other secondary characters were recorded from the trees in the comparative study of twin stock and single stock. Polybag plants attained more girth than other treatments (Table Bot. 7)

Table Bot. 7. **Mean girth of plants in different treatments**

Treatment	Mean girth/tree (cm)
Twin stock in polybag plants	39.15
Single stock in polybag plants	38.82
Twin stock seed at stake plants	30.56
Single stock seed at stake plants	31.79
Twin stock budded stumps	30.91
Single stock budded stumps	35.61
Polybag plants (Control)	37.11

In the experiment to study the effect of delayed opening and pulling out on bud intake and establishment of plants in polybags, grafts opened after 20 days and pulled out after 15 days showed better growth performance (Table Bot. 8).

Yield and secondary characters of the trees from the field evaluation of bench grafts were recorded. Difference between the bench grafts and nursery grafts were not significant. Clone RRII 105 yielded better in both types of grafting. In the trial on deep planting of two whorled bag plants, bag plants planted 5 cm deep showed comparatively better yield and girth. Among the treatments in the the trial on effect of long snag and nicking of snag buds on the establishment of green budded stumps there was no overall difference.

6.2. Genetic basis of stock scion relationship

In a trial, RRII 105 recorded more yield and RRII 118 more girth irrespective of stock, however the differences were not statisti-

Table Bot. 8. **Growth performance of the plants on the effect of delayed opening and pulling out on bud intake and establishment of plants in polybags**

Bud grafts		Height (cm)	Diameter (cm)	Number of leaf whorls
Opened after (days)	Pulled out and planted after (days)			
20	10	53.88	10.26	2.93
20	15	62.97	11.38	3.19
20	20	55.85	10.05	2.74
20	25	54.63	9.76	2.73
20	30	46.74	9.74	2.43
25	10	61.73	9.90	2.71
30	10	61.42	4.49	2.73
35	10	44.89	9.13	2.63
40	10	44.87	9.10	2.42

cally significant. In the other trial on 3 x 3 stock-scion combination, both RRII 203 and RRII 105 performed better in yield while RRII 203 was better among the two in vigour.

7. Morphological characterisation of popular clones

A manual on *Identification of Hevea Clones* was published. This manual elaborates in an easily comprehensible form, the important distinguishable morphological features of a large number of rubber/*Hevea* clones, cultivated in India. The publication, is a very useful tool for clone identification to extension officers, estate managers, planters, nursery owners, small growers, scientists, researchers and others. The descriptions of technical terms and their lucid illustrations make this book unique and user friendly.

GERMPLASM DIVISION

The major activities of the division are introduction, collection, conservation and evaluation of *Hevea* germplasm. The *Hevea* germplasm collection comprises both the domesticated gene pool of clones derived from the original Wickham collection of 1876, and the wild germplasm collections from the 1981 IRRDB expedition. Apart from maintaining the Wickham collection, conservation of the wild germplasm, its agronomic evaluation, screening for disease, drought and cold resistance, timber latex traits and molecular characterization are also being carried out.

1. Conservation and documentation

1.1. Wickham collection from secondary centers of diversity

175 Wickham clones are being conserved in field gene banks consisting of a clone museum at RRII Farm, Kottayam and five germplasm gardens established at CES, Chethakal. Screening for resistance to *Oidium* was carried out in Germplasm Gardens II, III, IV and V, comprising 75 Wickham clones. Monthly cup lump yield was recorded from Gardens II and III, while annual girth was recorded from Gardens II, III, IV and V. Fifty one clones in one replication in Garden I were maintained for conservation. Clones were identified for establishing a nursery with all the domesticated Wickham germplasm, classified under category III of the Board's planting recommendations, as well as other interesting recombinants from hand pollination programs.

Among the 35 clones in Garden II, RRIM 604, RRIM 607, RRIM 612 and RRIM 703 recorded annual yield comparable with that of the control clone RRII 105. Twentyone clones had a higher average girth than RRII 105. There were significant differences between the 15 clones in Garden III for the annual yield and girth. RRII 203 recorded the highest yield (90.74 g/t/t) followed by PB 311 (86.29 g/t/t) and RRII 118 (81.91 g/t/t). RRII 118 had the highest girth (113.17 cm) followed by RRII 300 (108.62 cm), and RRII 203 (106.21 cm). These clones were also screened for resistance to *Phytophthora* disease in collaboration with the Pathology Division.

Of the five clones in Garden IV in their tenth year of growth, two clones, *viz.*, IRCA 111 and IRCA 130 had a significantly higher girth while IRCA 130 had girth increment comparable to that of RRII 105 (Table Ger. 1). All the five clones had a comparable bark thickness with RRII 105. IRCA 230 had the highest bark thickness (6.7 mm) and lowest in IRCA 111 (5.3 mm). The mean dry rubber yield for the peak season was computed. IRCA 130, and IRCA 18 had a significantly higher yield than the control RRII 105 while that of IRCA 109 and IRCA 111 were comparable.

Table Ger. 1. **Growth and yield performance of IRCA clones**

Clone	Summer girth increment (%)	Annual girth (cm)	Bark thickness (mm)	Mean peak yield (g/t/t)
IRCA 18	0.55	48.7	5.6	65.66
IRCA 111	0.37	57.4	5.3	52.86
IRCA 109	0.79	52.8	6.1	45.77
IRCA 130	1.01	56.1	6.4	71.93
IRCA 230	0.82	51.4	6.7	29.97
RRII 105	1.25	49.4	6.1	44.83
CD (P= 0.05)	0.36	6.01	0.80	12 .73

Among the 20 clones in Garden V, RRIC 100 showed significantly higher girth (61.55 cm) and the remaining clones were comparable with the control clone.

In the experiment on the feasibility of ratooning in *Hevea*, though the percentage of sprouting was higher in the polybag plants than in the tree stumps, the ratoons that sprouted from the tree stumps were much more vigorous and showed four times greater girth and height than the corresponding clones in the polybags in the first year of growth (Table Ger. 2).

In the experiment on multivariate analysis in Wickham clones, the data at juvenile and late mature stages of growth were analyzed and compared. At the immature stage, number of intact whorls in the second year, scion diameter, number of latex vessel rows, laticifer area index and inorganic phosphorous content of the latex showed relatively higher genotypic correlations with test tap yield. Number of latex vessel rows had the highest positive direct effect on yield and also a high genotypic correlation with yield in the late mature phase. Among the 34 parameters recorded in the juvenile phase, only number of latex vessel rows and bark thickness were correlated with late mature yield.

Genetic divergence assessed in the mature and immature phases resulted in five and seven clusters respectively (Table Ger. 3). One large cluster each comprising 18 and 19 clones in immature and mature phases respectively were obtained with 16 clones in common in the two phases. Factor analysis reduced the 27 traits recorded in the mature phase into 10 hypothetical factors

Table Ger. 3. **Clustering of clones in the mature phase**

Cluster	No. of clones	Clone
I	19	RRIM 501, RRIM 519, RRIM 526, RRIM 600, RRIM 602, RRIM 604, RRIM 605, RRIM 610, RRIM 611, RRIM 620, RRIM 622, RRIM 628, RRIM 636, RRIM 701, RRIM 703, RRIM 704, RRIM 705, IAN 873, Harbel 1.
II	2	RRIM 615, RRII 105
III	2	RRIM 607, RRIM 612
IV	1	RRIM 603
V	1	RRIM 706

Table Ger. 2. **Morphological characteristics of ratoon and polybag sprouts**

Trait	Ratoons	Polybag plants	t value
Time taken to sprout (months)	3.06	1.27	11.144**
Girth (cm)	12.02	2.77	23.222**
Height (cm)	359.21	87.17	23.912**
Total number of leaf whorls produced	7.35	3.42	15.397**
Number of whorls retained at the end of the first year	4.05	2.41	7.625**
Fresh weight of single leaflet (g)	2.6	0.62	13.688**
Dry weight of single leaflet (g)	1.18	0.27	13.929**
Leaf size (cm^2)	122.72	47.44	12.187**
Specific leaf weight (g/cm^2)(dry weight basis)	0.96	0.57	20.984**
Dry matter (%) of single leaf	45.8	44.64	1.759

while the 34 traits in the immature phase were reduced to 9 hypothetical factors. The performance of the clones in the two stages was also assessed. RRII 105 was ranked first in the mature phase and 7th in the immature phase (Table Ger. 4). Step- wise regression of mature yield on the immature traits showed that among the various morphological, anatomical and biochemical traits studied, number of latex vessel rows explained only 20% of the variability in mature yield.

To establish a garden with all the available species of the genus *Hevea*, Rubber Research Institutes of Sri Lanka, Malaysia, Cote d'Iviore and Indonesia were contacted of which, Sri Lanka has offered to supply two species. Indonesia and Cote d'Ivorie are willing to supply four and 10 accessions respectively. Further correspondence with these countries and NBPGR regarding the export/import and quarantine formalities are in progress.

Table Ger. 4. **Performance index for clones at the juvenile stage**

Clone	Index value	Rank
RRIM 501	214.0972	16
RRIM 519	221.8459	11
RRIM 526	218.5694	13
RRIM 600	221.8403	12
RRIM 602	232.9889	6
RRIM 603	206.4219	19
RRIM 604	215.7082	15
RRIM 605	240.3315	4
RRIM 607	184.7110	24
RRIM 610	224.3923	9
RRIM 611	204.8052	20
RRIM 612	164.8285	25
RRIM 615	223.9153	10
RRIM 620	207.5147	18
RRIM 622	213.1958	17
RRIM 628	216.8499	14
RRIM 636	185.1405	23
RRIM 701	191.2435	22
RRIM 703	268.0724	1
RRIM 704	241.9573	3
RRIM 705	227.2735	8
RRIM 706	204.4129	21
IAN 873	238.4124	5
RRII 105	228.6909	7
Harbel 1	260.4253	2

1.2. Wild gene pool

A fresh census of the wild germplasm in the conservation nurseries at CES, Chethackal indicated the existence of 3576 accessions. Annual maintenance like cutting back and identity mark renewal of the accessions were carried out. The third round of screening for *Oidium* resistance was completed in collaboration with Pathology Division and screening for *Phytophthora* disease resistance was continued.

During the flowering season, 186 specimens of 62 wild *Hevea* germplasm were collected and herbarium prepared. Provenance-wise sorting of 150 herbarium specimens comprising 50 accessions prepared during last year were done for easy identification. Fifty-eight wild *Hevea* accessions received from RRS, Agarthala were planted along with the control clones (RRII 105 and RRIM 600) at CES, Chethackal in an augmented RBD with five plants per genotype. Two hundred and eight wild accessions multiplied from SBN 1991a was established in a separate arboretum.

2. Characterization and preliminary evaluation

Annual girth was recorded from all the ongoing preliminary evaluation trials (PETs). Fifteen accessions recorded better girth than RRII 105 in (Table Ger. 5). Height of first branching was recorded for identifying accessions having high timber potentiality. Fourteen wild clones recorded a bole volume higher than the popular clone RRII 105. Screening for *Oidium* and *Phytophthora* resistance was carried out in collaboration with Pathology Division.

In the PET 1992 monthly dry rubber yield was very low. Screening for *Oidium* and *Phytopthora* was carried out. Thirty-six genotypes in experiment I and 12 in experi-

Table Ger. 5. **Accessions with higher girth than RRII 105 (10th year of growth)**

Accession	Girth (cm)	Genotype	Girth (cm)	Genotype	Girth
AC 633	62.80	MT 181	57.00	AC 698	54.50
AC 650	60.33	AC 628	56.33	AC 635	54.28
7.102	59.80	RO 95	55.70	AC 638	53.50
RO 9	58.50	AC 162	55.33	AC 750	53.00
MT 64	52.50	MT 185	55.06	RRII 105	44.69

ment II recorded higher annual girth than that of the control. Bark samples were collected from the trials for study of anatomical features.

In PET 1994A out of 24 clones, AC 757 had the maximum girth (45.44 cm), which was significantly higher than RRII 105 (32.99 cm). Fourteen accessions had girth comparable to RRII 105. In PET 1994B, 17 accessions were comparable to that of RRII 105 (37.13 cm). In PET 1994C seven wild accessions *viz.*, AC 726, AC 737, AC 636, AC 958, RO 353, RO 860 and RO 893 had significantly higher girth values (29.75 cm, 29.31cm, 28.97cm, 28.48cm, 32.63cm, 30.53cm and 40.66cm, respectively) compared to RRII 105 (27.93 cm). In the Ortet trial 1994, OM 1124 had a significantly higher girth (37.74 cm) than the control (40.80 cm) while the remaining ortets were inferior after eight years of growth.

In PET (Ortets) 1999 with 46 wild clones, OR 1180 and OM 1107 had higher growth than the control clones. Thirtytwo wild accessions had girth values comparable with RRII 105.

In PETs 2000 A, B and C vacancies were filled and all the genotypes were morphologically characterized at juvenile phase. In PET 2000C recording of data on girth, height, number of whorls and total number of leaves was done to compare the initial establishment and growth of the wild accessions. Morphological characterization of these genotypes was also completed as per the descriptor.

Fortyeight wild *Hevea* accessions along with the control clones (RRII 105, RRII 208 and RRIM 600) were multiplied and raised in nursery at RRS, Padiyoor for planting in the ensuing season.

3. Further evaluation and selection

In the Further evaluation trial with 80 accessions, summer girth and summer girth increment in the 6th year and annual girth in the 7th year were recorded and analysed. Out of the 80 accessions studied, 64 genotypes comprising 17 Acre, 17 Rondonia and 30 Mato Grosso had their summer girth comparable with the control, RRII 105. There were no significant differences between the accessions for summer girth increment. Girth of 73 genotypes (Acre-19, Rondonia-19 and Mato Grosso- 35) at the age of seven years was comparable with that of RRII 105.

Physio-biochemical studies have been initiated in collaboration with Plant Physiology Division. Based on girthing pattern, 20 genotypes were identified (10 genotypes each from high girth and low girth categories) and their wintering pattern examined. Leaf samples were collected and detailed biochemical analysis of the selected genotypes was in progress.

4. Screening

4.1. Biotic stress resistance

Screening for resistance to major diseases was conducted in collaboration with the Pathology Division. Screening for *Phytophthora*, *Oidium* and *Corynespora* resistance was initiated.

4.2. Abiotic stress resistance

4.2.1 *Drought tolerance*

For the evaluation and screening of wild *Hevea* germplasm for drought tolerance 25 selected accessions were multiplied for conducting a field experiment at RRII. For the proposed field planting at RRS, Dapchari a polybag nursery with 161 wild genotypes was raised. The sprouting success was recorded after one month of establishment to assess the genotypic difference in sprouting in drought prone area. While 22 accessions completely died off, 5 accessions showed 100% success in sprouting, while 0-10% success was recorded in 28 accessions, 11-50% success in 61 accessions and 51-90% success in 67 accessions. Out of this, field planting of 63 wild accessions was carried out for their screening, under Dapchari conditions in augmented RBD, with a plot size of 5 and spacing of 2.5 x 2.5 m.

Out of 63 wild accessions planted in the field, 22 accessions recorded casualties in the field ranging from 20-67%, four months after planting in (Table Ger. 6). Growth performance of the genotypes revealed wide variability in the early growth phase.

Ten accessions, which recorded very high girth increment compared to the three control clones, are listed in (Table Ger. 7),

Table Ger. 6. **Initial casualty status in the field (after 4 months)**

Accession	Percentage casualty	Accession	Percentage casualty
RO 141	66.67	MT 932	25.00
RO 20	50.00	AC 157	25.00
AC 448	50.00	MT 899	33.33
RO 1300	25.00	AC 2539	66.67
AC 153	50.00	AC 4266	25.00
MT 54	20.00	AC 161	33.33
MT 1649	20.00	RO 268	33.33
AC 649	20.00	RO 4184	50.00
AC 776	20.00	MT 1591	40.00
AC 609	60.00	RO 2524	20.00
MT 67	20.00	AC 404	25.00

Table Ger. 7. **Genotypes with high girth increment rate**

Accession	Girth increment (%)
MT 2594	223.82
RO 2704	180.03
AC 448	166.15
RO 1300	156.01
AC 2532	153.59
RO 2504	149.72
AC 609	144.58
MT 1619	141.55
AC 3307	136.38
MT 54	134.07
RRII 105	76.30
Tjir 1	88.29
RRIM 600	126.14

indicating the very vigorous girthing habit of these accessions.

Genotypes identified based on their superior performance in the early growth phase for a set of characters identified Mato Grosso genotypes for their superiority compared to the accessions from the other two provenances.

4.2.2. *Cold tolerance*

From the evaluation trials at RRS Nagrakatta, a set of growth characters such as girth, number of leaf whorls and total number of leaves were recorded during the pre winter period in October 2001 and in the post winter period in March 2002. Genotypes RO 2387, RO 2567 and MT 915 were the best in terms of their girth, while MT 3452, RO 3229, AC 3810 and RO 2908 were superior for number of leaves produced. Morphological characterization of the wild genotypes was completed using a descriptor.

4..3. Timber latex traits

Juvenile characterization of the accessions in the trial for screening for timber latex traits was done using 22 morphological traits at the age of 18 months. Wide variability was observed in the wild accessions for these traits. Data on juvenile girth of the

selected clones revealed that in general the wild accessions recorded comparatevely higher girth than that of the Wickham clones. Of the 19 wild accessions, 18 and 15 genotypes each were comparable with RRII 118 and RRIM 600 respectively while 14 and four wild genotypes showed significantly higher girth than the Wickham clones, PB 260 and PB 235. Among the wild accessions, AC/S/11-41/348 had a maximum girth (11.08 cm) followed by RO/OP/4-20/15 (10.12cm) and MT/IT/16-34/199(10.08 cm).

In order initiate the screening of the germplasm for timber quality traits through lignin biosynthesis studies, a laboratory Ball mill was fabricated locally for powdering wood samples for the preparation of Extractive free Xylem Residue (EXR). The standardization of protocol for the processing of wood samples prior to ball milling was completed and initiated the preparation of EXR for lignin estimation.

5. Molecular characterization

Leaf samples of 143 genotypes were collected from CES. DNA extraction from all the genotypes using the mini prep protocol was completed. RAPD analysis was run for a set of genotypes using four primers. Further refinement of the protocol was done during the period.

MYCOLOGY AND PLANT PATHOLOGY DIVISION

The Division continued investigations on protection of *Hevea* from pathogens, insect pests and root-knot nematodes by chemical and biological methods. Studies on diversity of pathogenic fungi, etiology of tapping panel dryness, crop improvement and management of effluent from rubber factories by using microorganisms were also continued.

A survey conducted to assess the incidence of abnormal leaf fall (ALF) disease in clone RRII 105 in the traditional rubber growing tract indicated that in most of the areas mature plantations require prophylactic spraying to avoid crop loss. It was observed that, Rajprol spray oil can also be used as an effective carrier for copper oxychloride (COC) for the control of ALF disease. Partial substitution of spray oil with rubber seed oil (RSO) was found to be promising. Fungicides namely hexaconazole 2% dust and carbendazim 0.05% spray gave better control of powdery mildew in field and nursery respectively. Occurrence of pink disease on different clones in various locations indicated that Mundakayam and Thodupuzha are highly disease-prone areas and that the clones RRII 105 and PB 255 are highly susceptible. A new fungicide coptrel was superior to Bordeaux paste for control of pink disease. Field and laboratory screening of *Hevea* germplasm for resistance to various diseases identified promising accessions for *Phytophthora, Oidium, Corynespora* and *Corticium* tolerance. RAPD analysis showed differences among *Phytophthora* and *Corynespora* isolates. Spread of TPD could not be arrested by sterilising tapping knife with various anti-viroid chemicals.

Natural infection of bark feeding caterpillar by an entomopathogenic fungus *Beauveria bassiana* was noticed in the field, which opens up a new avenue for biocontrol. Two larvae of *Meloidogyne incognita* per gram of soil was recorded as threshold level for root-knot nematode damage in host plants.

Bee keeping activity revived during this year and *Apis cerana indica* was found to be more remunerative than *A.mellifera*. Inoculation of rubber seedlings with different beneficial microorganisms stimulated plant growth. Irrigation with raw effluent from a TSR processing factory altered the

soil chemical and biological properties but did not have any deleterious effect on growth of test plant *(Capsicum* sp).

The Division provided training programme on apiculture, biogas and mushroom cultivation. Guidance to nine post graduate and a doctoral student was also given by the scientists of the Division.

1. Leaf diseases

1.1 Abnormal leaf fall

Rajprol, a new spray oil formulation developed and supplied by M/s. Ram Charan Co., Chennai was subjected to large-scale field testing in four locations. Recommended COC-spray oil ratio of 1:5 and the dosage of 40 L/ha was maintained in all locations. Currently recommended (IOC) spray oil was used as control. Leaf retention assessment showed that Rajprol spray oil is as effective a carrier for COC as the currently recommended spray oil for ALF control. The new formulation was recommended for use (Table Path. 1).

The trial on partial substitution of rubber spray oil (mineral oil) with RSO was continued. RSO and mineral oil mixed in the proportion of 1:2 was evaluated in comparison with mineral oil alone as carrier for COC. Results indicated that the use of rubber seed oil for partial substitution of spray oil was promising (Table Path. 2).

Table Path. 2. **Evaluation of RSO for partial substitution of spray oil**

Treatment	Leaf retention (%)		
	Pudukad	CES	
	RRIM 600	RRII 105	GT 1
RSO + spray oil	48.08	75.97	65.50
Spray oil alone	42.58	71.38	63.16
Unsprayed control	5.93	52.83	41.54
CD (P=0.05)	22.93	14.68	16.05

The experiment to evaluate the efficacy of micron sprayers by attaching Micronair AU 8120 atomiser for spraying in mature rubber plantations was repeated. The use of Micronair atomiser gave comparable protection to that of micron atomiser. This attachment was observed to give higher throw and finer particles as reported earlier.

Effect of leaving areas unsprayed on the crop yield was studied over a full tapping cycle. The normal tapping in the clone RRIM 600 has been completed during 2001. The area has been included under slaughter tapping prior to felling. The leaf retention and yield recorded in the experimental plots are presented in (Table Path. 3). There was significantly higher leaf retention in sprayed plots in clones RRIM 600, GT 1 and RRII 118 but the crop loss was high in the former two.

The experiment to evaluate the dosage of COC on disease severity and yield was continued. The recommended dose of

Table Path. 1. **Evaluation of spray oils for spraying COC in rubber**

Location	Clone	Treatment	Method of application	Leaf retention (%)	CD
Kanjirappally	PB 311	IOC	Micron	87.53	
Kanjirappally	PB 311	Rajprol	Micron	89.55	NS
Thodupuzha	RRIM 600	IOC	Micron	66.64	
Thodupuzha	RRIM 600	Rajprol	Micron	62.29	NS
Ranni	RRIM 600	IOC	Micron	52.44	
Ranni	RRIM 600	Rajprol	Micron	61.28	NS
Ranni	GT 1	IOC	Micron	63.16	
Ranni	GT 1	Rajprol	Micron	68.64	NS
Punalur	RRIM 600	IOC	Aerial	82.31	
Punalur	RRIM 600	Rajprol	Aerial	75.03	NS

NS: Not significant

Table Path. 3. **Crop loss due to abnormal leaf fall disease**

Clone	Leaf retention (%)		CD	Yield (g/t/t)		Crop loss (%)
	Sprayed	Unsprayed		Sprayed	Unsprayed	
RRIM 600*	50.34	28.02	20.40	129.70	115.17	25
RRII 105	64.28	52.83	NS	64.21	70.62	—
GT 1	58.74	41.54	16.49	55.27	30.00	49
RRII 118	73.37	48.28	18.68	51.36	44.88	6

* Under slaughter tapping from April 2001 NS: Not significant

8 kg/ha gave highest leaf retention and consequently better yield. Yield was very low in the area sprayed with 2 kg/ha compared to all other treatments though the reduction in leaf retention was statistically significant only when compared with 8 kg/ha dosages. This could be due to the cumulative effect of low leaf retention in the past that might have affected the subsequent crop.

Attempts were made to spray combinations of Bordeaux mixture, RSO and spray oil with low volume spray applicators. Micronair atomiser was attached to the micron sprayer for obtaining maximum vertical throw. Only one pre-monsoon spraying was carried out. The spray fluid was delivered to more than 20 m height with fine particle size (50-100µm). The spray fluid requirement was only 800 L, which is only 25% of the recommended spray volume. Severe abnormal leaf fall was noticed in the plots sprayed with Bordeaux mixture or Bordeaux mixture + oil combinations using low volume sprayers suggesting its ineffectiveness.

Though the commercial biofungicide Bioflora was effective in controlling growth of the pathogen under laboratory conditions, it was not effective in controlling ALF disease in the field (Table Path. 4).

Yield recording in the crown budded experimental area with clone PB 311 was continued. No definite trend could be noticed so far on yield. *Phytophthora* incidence was severe in PB 311, whereas the crowns with RRII 33 and Fx 516 retained more leaves. Girth of crown-budded trees (1970 trial) in clone GT 1 was measured and the trees crown-budded with F 4542 (*Hevea benthamiana*) recorded significantly lower girth (77 cm) compared to trees crown-budded with Fx 516 (114 cm) and control (108 cm)

Table Path. 4. **Evaluation of bioflora for ALF control (RRIM 600)**

Treatment	Leaf retention (%)		
	Kumarankudy	Malankara	Pudukad
Bioflora	10.46	6.95	14.78
COC	88.68	59.68	51.05
Control	14.90	32.11	5.93
Bioresume only	—	—	5.10
CD (P=0.05)	17.82	23.27	20.77

Samples from crown-bud experimental area in Kaliyar Estate with trunk clone RRIM 628 and crowns RRII 33, Fx 516, F 4542 and control were analysed for latex properties such as specific gravity, DRC, total solids, Mg, acetone extract, ash content, nitrogen, initial plasticity (P_0), plasticity retention index, accelerated storage hardening (ASHT), Mooney viscosity, copper and iron contents. Variations in these parameters were observed depending on crown clones.

The clone RRII 105 which has high level of leaf retention under normal spraying, was found to be severely affected in the traditional rubber growing areas when majority of the areas were left unsprayed. To assess the incidence of the disease, a survey was conducted in the traditional rubber growing zone. The study indicated that in most of the areas, mature plantations of RRII 105

need protection by prophylactic spraying, to avoid crop loss. Spraying can be judiciously avoided only in South Kerala and Kanyakumari regions where leaf fall was less than 25%. However individual disease-prone pockets in this region need prophylatic protection.

Field screening of *Hevea* germplasm for resistance to ALF disease in evaluation trials 1992 and 1994 were carried out. Nine accessions in evaluation trails 1992, and one in evaluation trial 1994 were identified to be consistently resistant. Sixty one accessions that gave more than 50% leaf retention in the field were screened against *Phytophthora* in the laboratory by detached leaf technique. Twenty accessions showed moderately-tolerant to tolerant reaction. The experiment is being repeated for confirmation.

Screening for ALF, was also done in the two trials at RRII. In Trial I, the highest leaf retention was recorded in clone RRII 118 (71.86%) and the lowest in RRIM 703 (33.30%). In Trial II, the highest leaf retention was recorded in RRII 105 (78.46%) and the lowest was in PB 280 (42.80%).

Eight new isolates of *Phytophthora* from different locations were collected during the last year, of which five were subjected to RAPD analysis. Among the isolates tested, an isolate found infecting the inter-specific hybrid Fx 516 at Malankara Estate showed a difference in the banding pattern when screened with three primers.

1.2. Shoot rot

A field experiment was initiated at Malankara Estate, Thodupuzha to compare the efficacy of Bordeaux mixture when used with adjuvants including rubber seed oil in controlling shoot rot disease. The retention of copper on leaves was also assayed. There was no significant difference in the copper retention between the treatments.

A field study was carried out using five bacterial antagonists against shoot rot disease at Malankara Estate. The bacterial antagonist RP 6 gave better disease control.

1.3. Powdery mildew

An experiment to control this disease in mature plantation was conducted at Cheruvally Estate in a field planted with clone PB 5/51. Application of systemic fungicide, hexaconazole dust was tested at 1% and 2% concentrations in comparison with sulphur. Significant control was obtained with 2% hexaconazole followed by 1% hexaconazole.

A nursery trial was carried out at CES, Chethackal on polybag plants of RRII 105 to evaluate benzothiadiazole (Bion), chelated zinc, flowable sulphur, carbendazim and wettable sulphur. Carbendazim recorded better control while all other treatments were comparable.

A survey was conducted to assess the intensity of powdery mildew disease in Kanyakumari District. High disease intensity was noticed in all the clones evaluated.

Screening of germplasm accessions planted at CES in source bush nurseries, germplasm gardens and evaluation trials against powdery mildew disease was undertaken. A total of 22 and 37 accessions showed less than 25% disease intensity in evaluation trials 1992 and 1994 respectively.

Observations were made on the incidence of powdery mildew disease in the two clone trials laid out in RRII farm. In Trial I, the lowest disease intensity was noticed in the clone RRII 308 (30.08%) and the highest in the clone RRII 300 (67.16%). In Trial II, the lowest disease intensity was noticed in the PB 311 (36.86%) and the highest in the clone PB 310 (58.88%).

Observations on wintering/refoliation pattern and incidence of powdery mildew

disease in the 1993 large-scale trials (Trial I and Trial II) at CES indicated that all the clones are susceptible to the disease with more than 60% disease intensity. In Trial I, the clone RRII 414 recorded the lowest disease intensity. Since the wintering and refoliation were relatively early in this clone, the leaves matured early and was less affected. In Trial II, RRII 410 recorded the highest and RRII 422 the lowest disease intensity. The clones RRII 410, RRII 434 and RRII 454 showed late wintering. Powdery mildew disease intensity was also assessed in the 1981 clone evaluation trial. All the clones showed more than 82% disease intensity except PB 310 (53.55%.)

1.4. Colletotrichum leaf disease

A field experiment was undertaken at Malankara Estate for the evaluation of fungicides for control of Colletotrichum leaf disease in clone RRII 105. Fungicide application was made at weekly intervals. Minimum disease intensity was observed in Saaf (carbendazim + mancozeb) followed by mancozeb and carbendazim.

The compatibility of the six *Trichoderma* isolates from different sources with three fungicides *viz.*, carbendazim, mancozeb and metalaxyl MZ was studied. None of the isolates could grow in the presence of carbendazim even at the lowest concentration (10 ppm) tried whereas the isolates grew even at the levels of 1000 ppm of the other two fungicides.

In the physiological studies using two species of *Colletotrichum* namely *C. acutatum* and *C. gloeosporioides*, showed good sporulation and maximum dry mycelium weight at pH range of 5.5 to 7.5. At pH range of 2.0 to 3.5 both the species showed slow growth and poor sporulation.

1.5. Corynespora leaf disease

Pathogenicity of 12 different isolates of *C. cassiicola* collected during 2000-2001 disease season was studied. Pathogenicity was estimated by measuring the size of necrotic lesions developed after 72 h of conidial inoculation in the clones RRII 105 (susceptible) and in GT 1 (tolerant). RRII 105 showed susceptible reaction while GT 1 was tolerant to all the isolates. However, two isolates were found to be more pathogenic on tolerant clone GT 1 compared to others.

The production of toxin by these isolates was estimated by leaf wilting bioassay using their crude culture filtrates. All the isolates showed higher per cent wilting intensity in the susceptible clone RRII 105 and variation in intensity was observed between isolates. Wilting intensity was less in GT 1 compared to RRII 105.

Sixteen isolates of *C.cassiicola* were tested for their sensitivity to two fungicides *viz.*, carbendazim and mancozeb using poisoned food technique. All the isolates were highly sensitive to carbendazim at 25 ppm. At 15 ppm and 5 ppm carbendazim, the isolate 235 showed 88.88 and 94.40% inhibition and the isolate 305 showed 83.33 and 93.33% inhibition respectively, while all the other isolates showed 100% inhibition. With 250 and 100 ppm of mancozeb, the isolate 235 showed maximum inhibition. The inhibition of isolates 305 and 309 was also high when compared to other isolates. At 5 ppm carbendazim, the isolate 303 was fungistatic.

For screening of *Hevea* germplasm, 669 accessions were tested against *Corynespora* in the laboratory by detached leaf technique. Observations on lesion size was recorded after 72 h of inoculation. Among the accessions, 19 from Mato Grosso, 83 from Acre and 101 from Rondonia showed moderately-tolerant/tolerant reaction to *Corynespora*.

Phenylalanine ammonia lyase (PAL) activity was tested against *C.cassiicola* induction in four clones of *Hevea*, *viz.*, GT 1, RRII 105, PR 107 and RRIM 600. In GT 1, 40 µm Prot/min of PAL activity was estimated in

24 h, while only 10 µm activity was observed in RRIM 600. In the clones RRII 105 and PR 107, lower enzyme activity was observed than uninoculated control. Maximum (60 µm Prot/min) of PAL activity was estimated in GT 1 at 96 h, while a decrease in enzyme activity was observed in RRIM 600 (Table Path. 5).

Genetic variability of thirteen isolates of *C. cassiicola* was studied and all the isolates except the one collected from the clone GT 1 during 2002 gave uniform amplification with the three primers tested. The GT 1 isolate gave a distinct banding pattern with all the primers.

Another study on detection of genetic variability of isolates consequent to the interaction with fungicides was initiated. Four isolates of *Corynespora* were screened *in vitro* by using both systemic and contact fungicides. Carbendazim (Bavistin) and mancozeb (Dithane M- 45) were used. These isolates were grown on graded levels of the fungicide-amended media and their DNA isolated and subjected to RAPD analysis.

2. Stem diseases

2.1. Pink disease

Survey on pink disease distribution was undertaken in the different regions of traditional area of rubber cultivation. Disease occurrence on different clones in various locations indicated that Mundakayam and Thodupuzha were the high disease - prone areas and the clone RRII 105 remained highly susceptible in all the regions. The clone PB 255 was also observed to be highly susceptible.

In the field experiments on disease management, it was observed that addition of RSO, linseed oil or neem oil to Bordeaux paste enhanced the disease control. A new fungicide Coptrel (1%) was evaluated using three different carriers *viz.*, Vinofan, Indtron and Dipicol. Recovery was 85, 85 and 80% respectively compared to 60% for Bordeaux paste. Pink disease incidence in the 1998 clone evaluation trial at Cheruvally Estate was recorded. Higher pink disease incidence was recorded in RRII 429 with 55.5% disease incidence followed by RRII 105 (37.19%), RRII 414 (24.6%) and 417 (23%). RRII 410 (5.38%) recorded lower disease incidence.

2.2. Bark rot disease

Field evaluation with different systemic and non-systemic fungicides against bark rot disease was initiated in Lahai Estate. Treatments comprised chorothalonil (Kavach) 2.5g/L, cymoxinil M8 (Curzate M8) 2.0g/L, strobilurin (Amistar) 4ml/L, metalaxyl + mancozeb (Ridomil MZ) 1g/L and mancozeb (Indofil M 45) 5g/L of water.

3. Root diseases

3.1 Brown root disease

A field trial for the control of brown root disease was conducted at Mayilallampara, Calicut using tridemorph

Table Path. 5. **PAL activity (µm Prot min)**

Clone	Time (h)							
	24		48		72		96	
	C	IN	C	IN	C	IN	C	IN
GT 1	20	40	20	46	20	55	20	60
RRIM 600	10	20	10	15	10	10	10	10
PR 107	30	20	30	15	30	15	30	10
RRII 105	20	15	20	15	20	10	20	5

C-Control; IN- infected

(Calixin) 1% & 0.2%, thiram (Thiride) 0.75%, propiconazole 0.1% & 0.5%, hexaconazole (Contaf) 0.02%, hexaconazole + captan 0.25% and a bio-control formulation (Bioresume + Bioflora). The base and soil around the collar of the infected and two neighbouring plants on the same contour row were drenched with fungicide solution. No differences among the treatments were observed six months after application.

4. Retention and residual studies of copper in rubber plantations

The experiment was conducted at Pudukkad Estate, RRII Nursery and CES, Chethackal to study the retention of copper on the leaves, the copper content in the soil and its effect on soil microflora. There was a reduction of copper on the leaves from 40-50% within a month after spraying. There was not much variation in the copper content in the soil and the soil microflora.

5. Pathological aspects of TPD

Bark and leaf samples of diseased and healthy trees from various locations were tested using the R-PAGE technique to confirm the presence of viroid. Eight diseased trees were continuously showing the presence and six healthy trees the absence of viroid. As a part of the transmission studies, 16 rubber seedlings were screened for viroid of which nine were negative.

A field experiment to study the various aspects of bark scaling of rubber trees was initiated. Bark scaling, normal TPD and healthy trees were marked in a plantation and monthly recording of girth, TPD incidence, DRC and latex volume was done. The trees showing bark scaling had lower girth compared to others. The volume of latex was also very less but the DRC was comparable.

R-PAGE analyses of various plant parts from trees showing bark scaling were carried out. Presence of viroid bands could be observed in the samples collected from the remnants of the bud wood plants from which all the bark scaled plants are suspected to have originated. TPD trees with bark necrosis were also analysed for viroid and out of 12 plants, 8 showed the presence. Bark sloughing with drying of plants was observed in clone PB 28/59 in Nagercoil area. Among four such trees one showed the presence of viroid and among the healthy two showed viroid bands .

In order to study the effect of various anti-viroid chemicals in preventing the possible disease spread through tapping knife an experiment was initiated at Malankara and Vaniampara Estates. The chemicals used were Glutaril, Combatan, Sodium hypochlorite and triSodium orthophosphate. Tapping knife was dipped in these chemical solutions before each tap. The disease spread was monitored by counting and assessing the fresh occurrence of TPD. In both the locations arrest in the spread of disease could not be observed even after six months (Table Path. 6).

6. Pests

The bark feeding caterpillar (*Aetherastis circulata*) infestations could not be effectively controlled with spraying E.C formulations of insecticides by using a long lance. Spraying could be done only up to 6m height and this resulted in the control of the pest for only less than 45 days. Two rounds of dusting with 2% methyl parathion gave 34% control after 7 days. It was observed that up to 35% of the caterpillars were naturally infected by an entomopathogenic fungus *Beauveria bassiana* in April just before pupation. The life history studies indicated that the eggs of *A. circulata* hatched during September to November. The larval, pupal and adult periods lasted for 134, 14 and 4 days respectively.

Table Path. 6. **Tapping knife sterilization and TPD occurrence**

Treatment	No of TPD trees			
	Malankara		Vaniyampara	
	Initial	Final	Initial	Final
Control	1	5	7	13
Glutaril	4	2	5	7
Combatan	10	4	1	5
Sodium hypochlorite	7	4	2	2
Trisodium orthophosphate	9	10	8	12

To find out the effect of temperature and rainfall on the population and incidence of nematodes on *P.phaseoloides*, three sites were selected and soil samples collected at monthly intervals from September to June and the nematode population estimated. Plants were also assayed for presence of galls. Total monthly rainfall and mean temperature were also recorded (Table Path. 7).

Nematode population declined from September to December. From December there was an increase in nematode population with peak population in March. The nematode population and its incidence declined in succeeding months after a heavy rainfall.

Soil samples were collected at random from a depth of 10 to 30 cm from different rubber growing areas and root-knot population was estimated. The density and frequency of root-knot nematodes was also calculated (Table Path. 8).

Table Path. 7. **Mean monthly temperature, total rainfall, nematode population and root knots in *P. phaseoloides***

Month	Temperature (°C)	Rainfall (mm)	Population per 250 g soil	No. of galls/ plant
September	27.3	414.8	533	6.25
October	27.0	353.2	488	5.67
November	27.2	149.6	366	3.56
December	27.4	30.0	710	7.54
January	27.7	8.6	976	9.34
February	28.7	12.4	1000	10.04
March	29.2	61.7	1400	17.17
April	29.4	123.1	1200	11.88
May	28.6	477.1	976	8.71
June	26.7	456.7	350	3.00

Infectivity of soil samples were tested by using indicator plants. The incidence of *Meloidogyne* sp. is indicated by the relative extent to which the roots get infested. Soil samples showed variations in infectivity with respect to gall indices. A minimum population of two larvae within one gram of soil could induce galls on rootlets of indicator plants and is regarded as an optimum damaging threshold level of root-knot nematode, *M.incognita* on host plants.

Seedlings of *Hevea* (15 days old) were inoculated with juveniles of *M. incognita* in log series of 0, 10, 100, 1,000 and 10,000 and their effect on the growth of the seedlings were monitored.

Table Path. 8. **Density and frequency of root-knot nematode, *M.incognita* in rubber plantations**

Location	No. of samples collected	No. of infested sample	Absolute density	Relative density (%)	Absolute frequency	Relative frequency (%)	Level of infestation
Malankara	18	14	700	14.29	70	10.81	++
Manjeri	10	6	700	14.29	60	9.27	++
Kanjikulam	15	15	2050	41.86	100	15.44	+++
Ulickal	10	7	434	8.86	70	10.81	++
Alakode	15	15	96	1.96	100	15.44	+
Perumpulickal	10	10	300	6.13	100	15.44	++
Peruvannamoozhy	15	12	868	17.72	80	12.35	++
Paraliar	10	3	95	1.94	30	4.63	+
Dapchari	5	2	36	0.74	40	6.18	+
Nettana	10	2	50	1.02	20	3.08	+

+ 1-100 nematodes/250 g soil ++ 101-1000 nematodes/250 g soil +++ 1001-5000 nematodes/250 g soil

7. Bee keeping

During 2001-02, bee keeping with *Apis cerana indica* was more remunerative than *A. mellifera*. Honey yield per hive during the year in *A.cerana indica* was 8 kg and that of *A.mellifera* was 11 kg/hive. Nectar flow continued up to the end of April. Bee keeping activity had revived during the year. A long and favourable honey flow season prevailed in Palakkad and Malappuram districts. The colony development and honey production of *A.mellifera* declined. *A.mellifera* is less preferred for migratory bee keeping.

8. Vermiculture

The experiment to compare effect of vermicompost and chemical fertilizer on growth of rubber showed that there was no significant difference in height and girth in the first year.

9. Microorganisms for improving growth of rubber and cover crops

In the experiment to study the effect of *Bradyrhizobium* inoculation on the cover crop *Mucuna bracteata*, fresh *Mucuna* and litter added by it were collected from the trial area and the biomass from unit area estimated. Biomass production was more in the *Bradyrhizobium* inoculated plots and the entire area was covered by the cover crop. In the uninoculated area small patches of weeds remained.

The effect of four commonly used fungicides *viz.*, Bavistin, Indofil M-45, Sulfex and Fytolan at concentration ranging from 50 ppm to 1000 ppm on nitrogenase activity (µ mole ethylene produced/h/100 ml broth) of five *Azotobacter* isolates was studied. While Fytolan and Indofil M-45 were found to inhibit nitrogenase activity Bavistin was found to be least inhibitory. Sulfex also reduced nitrogenase activity at higher concentrations.

Growth of rubber seedlings inoculated with four *Beijerinckia* isolates at 50, 75 and 100% of recommended levels of nitrogenous fertiliser was monitored for one year and girth and height of the plants were compared to uninoculated plants with 100% N as control. Results showed that at 75% N application growth of the plants inoculated with two *Beijerinckia* isolates was higher than uninoculated control plants and the growth of the plants at lower levels of N was comparable with control plants. When full dose of N fertiliser was applied there was lesser effect of inoculation. The rhizosphere microbial population increased upon inoculation with various *Beijerinckia* isolates.

Growth of rubber seedlings inoculated with mycorrhizal fungi was monitored for one year. Even though during the early stages of growth combined inoculation gave better growth response, in 12 month old plants those inoculated with *Acaulospora* also gave comparable growth response to that of combined inoculation at 50 and 75% of recommended rock phosphate levels. Response to inoculation was lower when full dose of P fertiliser was applied. Mycorrhizal colonisation in roots of mature trees from 16 locations were studied. Plants showed 67 to 92% colonization. Roots collected from Mundakayam area showed highest AM infection.

The study on the effect of continuous application of phosphobacteria on the building up of their population in soil and on the growth of rubber seedlings was continued at Central Nursery, Karikatoor. Treatments included 50 and 75% of recommended rock phosphate application in phosphobacteria inoculated plots and 100% rock phosphate in uninoculated control plots. The increase in phosphobacterial population of the inoculated plots got gradually reduced over a long time. Girth and height of the phosphobacteria inoculated plants at low

levels of rock phosphate was comparable with uninoculated control plants grown with full dose of fertiliser.

10. Waste management in rubber processing

Water samples collected from various stages of treatment from the anaerobic immobilized growth digestor in the RSS processing unit were analysed for pollution parameters in comparison with raw effluent. Considerable reduction in total solids, biochemical oxygen demand, chemical oxygen demand and total nitrogen was noticed

The raw effluent and the water from model TSR factory after each stage of treatment from an effluent treatment plant (ETP) with activated sludge system were analysed for the various physico-chemical and bacteriological properties. Reduction in all the parameters was achieved due to the treatment, which was within the recommended safe limits (Table Path. 9). Presence of coliforms especially the *E.coli* in the final effluent warrants the chlorination of the same before disposal.

In order to study the effect of TSR effluent on soil properties and plant growth characters, a pot culture study was initiated. Analysis of soil for physico-chemical and microbial properties were carried out at different intervals. Increase in pH, available P and K was noted in treated, raw and 50% raw effluent. Increase in microbial populations due to the irrigation of raw effluent was also observed after 56 days (Table Path 10).

Effect of the effluent at two concentrations (50 and 100%) and the treated effluent on the growth characters of *Capsicum* sp. was studied. No significant difference in plant height, number of leaves and girth was noted due to the various treatment. At the same time, no deleterious effect was observed due to irrigation of TSR effluent.

An anaerobic upflow filter, which is a packed bed reactor, was fabricated. This unit consists of 120 x 40 x 30 cm container with packed bed of TSR granules. The effluent is let in at the bottom of the filter and an upward flow passing through the bed of inert support medium is maintained. The bacteria would normally proliferate on the surface of the medium as well as in the void. The treated effluent overflew from the top of the bed. The biogas collected was measured.

Table Path. 10. **Population of microorganisms in soil**

Name of organism	0th day	After 56 days			
		RE_{100}	RE_{50}	TE	Control
Total soil bacteria (cfu/gx10^5)	7.5	306.5	168.5	36.5	30.0
Total fungi (cfu/gx10^4)	7.0	44.5	24.0	13.0	8.5
Phosphate solubilizer (cfu/gx10^4)	7.0	7.0	2.5	2.0	5.0
Actinomycete (cfu/gx10^4)	2.5	4.0	5.0	3.5	5.5
Nitrogen fixing bacillus (cfu/gx10^5)	58.0	92.5	202.5	178.0	106.0

RE = Raw effluent; TE= Treated effluent

Table Path. 9. **Pollution parameters in the ETP of TSR factory**

Effluent Source	pH	EC (ms/cm)	TS (mg/L)	DS (mg/L)	SS (mg/L)	BOD (mg/L)	COD (mg/L)	TN (mg/L)	Ammo.N_2 (mg/L)	O_2G (mg/L)	Sulphide (mg/L)
Composite tank	7.24	0.625	865	552	307	22.90	46.06	13.01	8.83	1.6	3.69
Aerator	7.35	0.663	690	540	155	11.22	29.40	9.04	5.25	1.1	3.67
Clarifier	7.48	0.636	592	500	93	7.49	28.28	8.42	4.24	1	1.76
Polishing tank	7.57	0.636	577	498	79	6.37	26.34	6.65	3.72	0.6	-
Upflow sand filter	7.57	0.608	509	450	60	4.97	25.05	6.03	3.60	0.5	-
Pressure sand filter	7.64	0.589	429	397	32	3.92	24.21	4.26	2.10	0.45	-

PLANT PHYSIOLOGY DIVISION

Experiments were carried out in six major areas, *viz.*, environmental physiology, physiology of growth and yield, stock-scion interaction, tapping panel dryness, secondary metabolism and ecological impact of natural rubber cultivation. Laboratory and field experiments were carried out in traditional and non- traditional areas.

High light intensity caused more damage to membrane systems when combined with drought or high temperature stresses. Measurement of photosynthetic oxygen evolution in leaves was evaluated as a screening technique for drought and high light stress tolerance in rubber. The photosynthetic light use efficiency and quantum yield for photosynthesis were decreased in powdery mildew affected *Hevea* leaves. It has been established that down regulation in PS II activity is associated with low temperature induced cold injury in rubber plants. The unaccountable biomass loss in a tapped tree of rubber was attributed to the presence of more non-phosphorylating alternative respiration in the laticiferous tissue. The high yielding clones showed a significantly higher ATP content in the latex.

Several molecular biology experiments were conducted to study the molecular basis of various physiological processes such as mechanism of drought tolerance, genetic conflict between rootstock and scion and identification and characterization of wintering related genes, TPD etc.

1. Environmental physiology

1.1. Drought tolerance

Composition of the stable isotopes of carbon and oxygen in the stem (~2.5 cm diameter) and leaves of high and low girth trees (collected from RRS, Dapchari during the stress period of 2001) were carried out at the Crop Physiology Department, University of Agricultural Sciences, Bangalore.

In general the high girth trees showed more carbon discrimination than that of low girth trees (Table Phy.1). However three trees namely Tree nos. 34,19 & 48 had their Δ values less than their mean for the high girth trees. Among these trees Tree No. 34 had a Δ value in its stem that was less than the mean Δ values of high girth as well as low girth categories indicating that it has drought tolerance characteristics.

1.2. Identification of the molecular basis for drought tolerance in *Hevea*

To understand the molecular basis of drought tolerance several molecular biology protocols have been standardized. Leaf samples were collected from plants (high girth and low girth trees) of the seedling population at RRS, Dapchari and RAPD analyses were done. Isolated the genes *HaDhn1 and HaDhn2* (responsible for drought tolerance in *Helianthus annuus*) from plasmid to perform Southern/northern hybridization analyses using the DNA/RNA isolated from *Hevea* leaf tissue.

Table Phy. 1. **Carbon isotope discrimination (Δ) in the stem and leaves and oxygen isotope discrimination ($\delta^{18}O$) in the leaves of high and low girth trees (n=8)**

Category of trees	Δ_{stem} (‰) (Summer 2001)	Δ_{leaf} (‰) (November 2001)	$\delta^{18}O$ leaf (‰) (Summer 2001)
High girth	-26.86 ± 0.27 *	-21.35± 0.42	13.4± 0.33
Low girth	-25.51± 0.40	-20.59± 0.27 ns	12.6± 0.39 ns

1.3. Irrigation requirement of mature rubber in North Konkan

The study aim at examining the extent to which irrigation can be reduced in a mature yielding plantation with no adverse effect on its physiology and no significant reduction in rubber yield. The treatments were rainfed trees (A), partially irrigated (deep soil area) (B) and 1.0 ETc irrigation (shallow soil) (C).

During summer 2002 in the treatment B, the irrigation level was continued as in summer 2001 (1/5 ETc) *i.e.*, one irrigation in three weeks.

Measurement of photosynthetic O_2 evolution rate reconfirmed that reduced irrigation did not reduce the photosynthetic activity. Further reduction of the irrigation level from 1/4 to 1/5 ETc did not reduce the yield in deep soil. In shallow soil continuous 1 ETc irrigation for one more year during this year did not give any yield improvement over the previous year yield (Table Phy.2). The delta 13_c values for mature leaves revealed that the rain fed trees were more efficient in using water for growth during severe water deficit stress in summer.

1.4. Combined effects of drought and high light stress on nursery plants

1.4.1. Growth and PS II activity

The study was undertaken to evaluate the influence of water deficit and high light stress on chlorophyll degradation in leaves and to establish clonal variation in *Hevea*. Laboratory studies showed that high light caused more damage to membrane systems when combined with drought or high temperature stresses. The photosynthetic oxygen evolution in leaves decreased with increasing water deficit and high light.

1.4.1.1. Effect of Polyethylene glycol (PEG) and high light stress on chlorophyll degradation

Leaf discs (1 cm diameter) collected from RRII 105, GT 1 and RRIM 600 were incubated in various concentrations of PEG solutions *viz.*, 0, 40, 60 and 80% (with water potentials of 0, -15, -40, and -60 bars, respectively) and exposed to open sunlight (maximum PFD observed was 1400 µmol m^{-2} s^{-1}) from 10 A.M. to 4 P.M. In mature leaves the degradation due to high light stress was slow compared to young ones. There was a concentration dependent reduction in chlorophyll content in all clones. Leaf discs kept in water and in 40% PEG did not show any variation from the control. However significant decrease was observed in 60 and 80% PEG treated leaf samples. The leaf discs turned partially yellow.

The reduction in chlorophyll content of mature leaves was found to be more in RRII 105, supposed to be a drought susceptible clone compared to GT 1 and RRIM 600, the drought tolerant clones. On exposure to open sunlight in the presence of PEG on second successive day the chlorophyll content drastically reduced in all clones. The leaf discs were more yellowish and the clonal

Table Phy. 2. **Dry rubber yield of clone RRIM 600 under different levels of irrigation in Dapchari (summer 2001 and summer 2002)**

Irrigation	Projected yield* (Kg/ha)		Yield (g/t/t)	
	2001	2002	2001	2002
Unirrigated	302.68	279.24	21.62± 2.89	17.9 ± 1.90
Partial irrigated (deep soil)	481.60	561.00	34.4 ± 2.14	35.96±3.94
1.0 ETc irrigated (shallow soil)	387.80	402.00	27.65± 1.10	25.75±3.30

* January – May

difference was not prominent.

When young leaves were exposed to high light in the presence of PEG, the process of degradation was faster. The clonal variations were not prominent as that of mature leaves. The percent reduction in chlorophyll content was between 30-35. On the second day of exposure the leaf discs were completely yellow. More than 60% of the chlorophyll content degraded in young leaves of RRII 105 and GT 1.

Clonal variations were further studied using 60% PEG and exposed to sun light from 10 A.M to 4 P.M. Percentage reduction in chlorophyll content was estimated from the control values and significant clonal variations were observed. The clone Haiken 1 was less affected compared to the PB 235 and PB 260, which exhibited an increased degradation under stress. The clone SCATC 93/14 was intermediate among the treated clones.

1. 4. 2. Structure and function of photosynthetic apparatus of natural rubber in relation to its adaptation to high light and drought stress.

The dark respiration rate was comparatively higher in open light grown plants than shade pants. The photosynthetic O_2 evolution rate gradually increased as the measurement actinic light (red LED) increased in all light grown plants. In shaded plants the light saturation level reached earlier than open light grown plants. The light compensation point was progressively declined as the growth light intensity decreased in both RRII 105 and RRIM 600 and it was attributed to less dark respiration in the shade leaves. The apparent quantum yield of oxygen evolution also decreased in shade plants. This result revealed that the light use efficiency of shade grown plants were better than open plants under low measurement light but it was lesser than open light plants in high measurement light condition.

1. 4.3. Photosynthesis and respiration in powdery mildew affected leaves

Oidium infection severely inhibited the rate of photosynthetic oxygen evolution in both young and mature leaves (Table Phy.3). *Oidium* infection resulted in substantial increase in the dark respiration rates of leaves and this increase was more in mature leaves (37%) than in young leaves (24%). This increase in tissue respiration was possibly contributed by the pathogen in addition to stress-associated changes in the leaf metabolism.

Table Phy. 3. **Dark respiration and photosynthetic oxygen evolution rate (at 400 µm/ m^2/s^1) of healthy and *Oidium* infected leaves of *Hevea***

Sample	Respiration (µm $O_2/m^2/s^1$)	Photosynthesis (µm $O_2/m^2/s^1$)
Young healthy	2.98 ± 0.28	7.60 ± 0.33
Young infected	3.70 ± 0.23	2.80 ± 0.38
Mature healthy	2.80 ± 0.18	8.61 ± 0.41
Mature infected	3.85 ± 0.24	4.00 ± 0.32

The light compensation point was substantially increased in the disease-affected in both young and fully mature leaves (Table Phy.4). The maximum potential quantum yield for PS II photochemistry was similar in the uninfected young and mature leaves, but *Oidium* infection led to a substantial reduction in Fv/Fm in both the leaf age groups.

Chlorophyll content of the leaves decreased due to *Oidium* infection. *Oidium* infection increased Chl a/b ratio in mature leaves but not in young leaves suggesting that the fungal infection preferentially depleted chlorophyll *b* in mature leaves. Thus, the over all effect of the *Oidium* infection in terms of the reductions in rate and efficiency of photosynthesis of young as well as mature leaves and the eventual shedding of the young leaves (loss of total photosynthesizing area) can lead to a substantial biotic stress to the trees.

Table Phy.4. **Light compensation point, apparent quantum yield of photosynthetic oxygen evolution (QY), maximum potential quantum yield of PS II activity (Fv/Fm) and concentration of chlorophyll pigments in healthy and *Oidium* infected young and mature leaves of *Hevea*.**

Sample	Light compensation point ($\mu m / m^2 / s^1$)	QY(mol O_2/mol photon)	Fv/Fm	Chl *a* (mg/g)	Chl *b* (mg/g)	Total Chl (mg/g)	Chl *a/b*
Young healthy	69 ± 5.3	0.026± 0.0010	0.78±0.009	1.17±0.070	0.48±0.040	1.65±0.106	2.46±0.110
Young infected	152 ± 6.9	0.014± 0.0005	0.64±0.028	0.945±0.048	0.394±0.021	1.34±0.068	2.4±0.050
Mature healthy	58 ± 8.6	0.027±0.0015	0.78±0.007	1.64±0.180	1.39±0.360	3.03±0.320	1.2±0.058
Mature infected	125 ± 9.4	0.018±0.0127	0.75±0.006	1.28±0.040	0.66±0.023	1.94±0.062	1.96±0.048

1. 4. 4. Studies on mechanism of drought tolerance

The experiment has been initiated with six clones *viz.* RRII 105, RRII 208, PR 261, RRIC 100, RRIM 600 and RRIM 605. Drought treatment and partial shade (50% incident light) were imposed during summer months of 2002. On the basis of the growth performance up to May-2002, RRIM 600 and RRII 208 were selected as good and RRII 105 as not doing well. Diurnal variation in CO_2 assimilation was studied. The maximum potential quantum yield of PS II (dark adapted Fv/Fm) was measured during predawn, forenoon and afternoon hours. Quenching analysis and energy utilization was studied through the measurement of chlorophyll fluorescence. Data analysis is on progress.

1. 5. Studies on low temperature stress

Detailed studies on photosynthesis, chlorophyll fluorescence and biochemical aspects were conducted in different seasons on different clones in RRII, Kottayam and Mattupetty. Forenoon CO_2 assimilation rate (A) in saturating light was reasonably good in PR 261 and RRIM 600, but relatively low in RRII 105 at Mattupetty. However, this was comparable in these clones at RRII. Reduction in afternoon A was more in RRII 105 than the other two clones at Mattupetty, whereas that in control plants of all clones at RRII, Kottayam was marginal. Maximum potential of PSII quantum yield (dark adapted Fv/Fm) of PR 261 was higher than the other two clones at Mattupetty and comparable with all the control plants at Kottayam. Reduction in Fv/Fm was more in RRII 105 during afternoon hours than the other two in Mattupetty, whereas such reduction in Kottayam was marginal. Energy utilization and dissipation through photochemical and non-photochemical quenching has been studied in both the locations. The clones RRII 105 and RRIM 600 could not tolerate the heavy chilling weather and these plants lost almost all of their leaves. Under such a strong winter condition clone PR 261 maintained relatively higher net photosynthetic rate. Though some photoinhibition in PS II in PR 261 due to low temperature is noticed in terms of Fv/Fm, the inhibition in other two clones were very substantial indicating the tolerant nature of PR 261 to low temperature.

Pre-dawn and post-dusk Fv/Fm data suggest that recovery from the low temperature induced photoinhibition in PS II was higher in PR 261. This strongly indicates the photosynthetic acclimation and adaptive feature of PR 261 in chilling temperature (Table Phy.5).

An empirical assessment of their recovery potentialities after one month of frost damage revealed the following order - PR 261>RRIM 600>GT 1>PB 260>PB 235>PB 217>RRII 105>RRII 208 indicating that PR 261 was the best performer.

CO_2 assimilation rate (A) in all the

clones increased in the post-winter season than the winter at Mattupetty. This was also evident from the dark adapted Fv/Fm ratio (Table Phy. 5). Studies on energy capture and partitioning to photochemical and non-photochemical events have also been carried out in both the locations in these clones. Biochemical analysis of the leaf samples collected is in progress.

2. Physiology of growth and yield

2.1. Yield and yield components

High incidence of TPD was observed in clones RRII 105, GT 1, PB 235, RRII 300, Tjir 1, and RRIM 703. The low incidence was observed in RRIM 501, RRIM 612, RRIM 600, PR 107 and Gl 1 (Table Phy. 6). The observations on biomass accumulation on tapped and untapped trees, yield and yield components were continued. In untapped trees highest biomass was observed in clone PB 235, followed by RRII 118 and RRII 300 (Table Phy. 6). Clones RRIM 501 and PR 107 accumulated very low biomass compared to other clones. The high yielding clone RRII 105 lost more than 50% of its biomass due to tapping. No variation in bark thickness was observed in virgin (V) bark of tapped and untapped trees measured at 155 cm height. However significant variation was observed in renewed bark (BI-1 panel) of tapped trees.

Table Phy.5. **Pre-dawn and post-dusk maximum potential of PSII quantum yield (dark adapted Fv/Fm) during winter and post-winter period in Mattupetty**

Season	Clone	Pre-dawn Fv/Fm	Post-dusk Fv/Fm
Winter	PR 261	0.756	0.719
		(0.018)	(0.007)
	PB 260	0.716	0.693
		(0.014)	(0.007)
	RRII 208	0.648	0.615
		(0.016)	(0.026)
Post-winter	PR 261	0.788	0.769
		(0.004)	(0.008)
	PB 260	0.777	0.762
		(0.005)	(0.006)
	RRII 208	0.756	0.710
		(0.012)	(0.007)

Values under parentheses are standard errors

Clone PB 235 was the highest yielder and RRIM 612 the lowest. The dry rubber content was high in clones RRII 105, RRII 118, RRII 300 and PR 107 and low in RRIM 600, RRIM 703 and Gl 1. Plugging index was low in high yielders like RRII 105, PB 235, RRIM 600 and high in low yielders like PR 107, RRIM 612 etc.

2.2. Mechanisms of tapping induced loss of biomass

The annual girth increment in d/2 tapped trees was lesser than that of untapped trees from the first year of tapping

Table Phy. 6. **Variations in biomass and bark thickness of tapped (T) and untapped (UT) trees and percentage of TPD in twelve clones of *Hevea* (March, 2002)**

Clone	Biomass (kg/tree)		Bark thickness (mm)			TPD (%)
	Tapped	Untapped	T (v)	T (c)	UT (v)	
RRII 105	468.0± 53	959.2 ± 133	9.4	8.1	9.1	29
GT 1	547.8± 51	932.4 ± 120	8.8	7.0	9.3	33
PB 235	967.3±132	1202.3 ± 131	9.2	7.5	8.7	29
RRII 118	866.4± 79	1080.9 ± 207	8.9	6.9	8.1	26
RRIM 600	556.3± 45	747.3 ± 140	9.1	7.7	8.2	13
RRIM 703	449.4± 53	505.4 ± 67	9.9	8.1	9.7	30
RRIM 501	313.4± 23	485.7 ± 97	8.0	6.3	8.1	9
Tjir 1	555.0± 78	—	9.5	7.5	8.3	30
RRII 300	628.3± 46	1054.5 ± 213	9.2	7.5	8.8	31
PR 107	384.2± 33	448.3 ± 108	8.7	7.0	8.2	13
Gl 1	480.2± 35	615.3 ± 94	9.2	7.6	8.6	14
RRIM 612	610.6± 65	—	9.5	7.6	10.5	10

onwards in all the five clones studied.

The shoot biomass increment during the fourth year of tapping in d/2 and d/3 trees was lesser than untapped trees in all five clones. The annual biomass increment in d/3 system was higher than d/2 in clones PB 235, RRII 105 and RRII 300.

The total sugar content in tapping panel area of clones RRII 105 and PB 260 was significantly higher than their respective untapped trees in summer. But in post monsoon, d/2 trees of all the clones recorded higher sugar in the soft bark tissues than untapped. In summer, except in PB 235, there was no significant difference in starch content of tissues between tapped and untapped trees.

When compared to untapped trees the tapped trees recorded higher rate of cytochrome-c and alternative oxidase (AO) mediated respiration (Table Phy.7).

2.3. Clonal variation and effect of stimulation in the ATP pool and regeneration mechanism of latex

Analysed the contents of ATP and glutamine synthatase activity in latex of different clones *viz.*, RRII 105, RRIM 600 (high yielding) and HP 20, RRII 38 (Low yielding). Total volume and DRC were also recorded. The results showed that among the high yielding clones RRII 105 showed a significantly higher glutamine synthetase activity in the c-serum compared to low yielding clones. No significant difference was noticed in clone RRIM 600. Latex ATP content showed a significant difference between high and low yielding clones.

2.3.1. Physiology of leaves of tapped and untapped trees of Hevea brasiliensis during refoliation, maturation and wintering

Changes in the physiology of the leaves were monitored for their entire lifetime in tapped and untapped trees of *Hevea brasiliensis*. At periodic intervals measured the contents of chlorophyll, soluble proteins, free amino acids (FAA), starch, soluble sugars and malondialdehyde (MDA) and also the extent of membrane leakage of leaves. FAA and MDA contents in the leaf increased during maturation and remained fairly constant before their concentrations increased drastically during wintering. The total chlorophyll/soluble protein ratio decreased

Table Phy. 7. **Dark respiration (n mole O_2 g^{-1}. dry wt. min^{-1}) rate of soft bark tissues measured in tapped and untapped trees of five *Hevea* clones during summer (A) and post-monsoon (B) in HBSS, Nettana.**

Respiration (n m O_2 / g dry wt tissue/min

Clone	Untapped			d/2			d/3		
	Total	Cyt-c	AO	Total	Cyt-c	AO	Total	Cyt-c	AO
A. Summer									
RRII 105	235±14.9	165±11.40	81.0±9.2	621±43	449±24.7	188.0±14.1	565±31	426±14	141±15
RRII 300	349±11.8	297±08.64	101.1±6.2	574±15	398±41.0	163.4±13.0	-	-	-
PB 235	293±19.7	230±14.30	85.2±7.8	699±32	480±24.0	266.0±21.6	584±31	443±27	171±16
PB 260	236±23.0	185±20.10	73.0±7.4	510±23	367±17.0	196.0±12.6	-	-	-
PB 311	172±15.0	120±09.20	75.0±7.6	461±41	343±28.0	181.0±07.6	-	-	-
B. Post-monsoon									
RRII 105	247±12.3	194±06.4	99.0±8.6	611±26	430±27	289±16.5	550±25	332±13	201±9
RRII 300	339±15.0	301±14.3	118.3±9.0	551±18	423±28	183±07.4	-	-	-
PB 235	256±18.0	189±15.0	88.0±9.3	676±38	504±35	213±14.0	618±37	487±25	218±15
PB 260	218±22.0	179±18.0	58.0±8.0	541±23	379±22	168±13.0	-	-	-
PB 311	244±21.0	181±09.1	82.0±9.6	574±28	450±28	189±13.0	-	-	-

± SE is shown, n= 6-10

sharply and FAA/soluble protein and MDA/total chlorophyll ratios increased abruptly during wintering. Accumulation of MDA indicated severe peroxidative damage of membrane systems leading to increased membrane leakage during wintering. Results also show that tapping led to increased concentrations of starch and soluble sugars in the leaves possibly due to the increased photosynthesis as a result of increased sink activity (harvesting of latex). There was more accumulation of MDA and increased membrane damage suggesting increased stress in the leaves of the tapped trees compared to the untapped trees.

3. Stock-scion interaction

3.1. Stock – scion interaction (Upward tapping)

The incidence of TPD in normal and upward tapping in TPD affected and normal healthy trees of RRII 105 at CES, Chethackal was recorded once in every month. A new experiment was started at CES, to study the influence of different tapping systems (normal and upward tapping at different heights from the budunion on incidence of TPD. About 2.5 hectares was planted with polybag plants of RRII 105.

3.2. Air layering with own and double rooted plants

Own-rooted, double rooted and budgrafted plants of three clones were planted in field at CES, Chethackal during July-August 2001.

3.3. Genetic conflict in budgrafted *Hevea*

Bark samples from rootstock and scion portions of twelve trees of healthy and TPD affected trees of the clone GT 1 were collected from CES, Chethackal and the RAPD analysis is being carried out.

3.4. Scion to scion communication in terms of the wintering behaviour of *Hevea*

Four clones were selected (RRII 105, RRIM 600, GT1 and PR 107) which have distinct wintering patterns. A complete wintering clone (RRIM 600) and a partial wintering clone (RRII 105) are budgrafted to one single rootstock. Similarly a late wintering clone (GT 1) and an early wintering clone (PR 107) are budgrafted to one single rootstock. They have been field planted. After pruning the dominant scion twice growth was monitored to check whether both the clones reached almost same level of growth.

4. Tapping panel dryness

4.1. Involvement of ethylene in *Hevea* yield and TPD occurrence

Protocols were standardized for the assays of ethylene and ethylene biosynthesising enzymes (ACC synthase) in the *Hevea* bark tissue for studying the endogenous ethylene activity in the bark tissues of normal trees and TPD trees having varying degrees of TPD incidence.

An experiment was designed at RRII plantation to study the effect of ethylene inhibitors in TPD trees. Twelve year old RRII 105 plants were selected and the TPD incidence in these trees were classified further into 100%, 60-90% and less than 50% TPD. Healthy trees were selected as normal controls. An ethylene action inhibiting compound, silverthiosulphate (STS), was applied on the bark (10 cm wide) below the tapping panel of the experimental trees in 10 days intervals for a period of one month. Untreated control trees were maintained in all the groups including healthy trees. Tapping rest was given to all these trees during the treatment time. A period of 2 weeks after the last treatment, tapping observations were made on the TPD status and latex yield in individual trees. The observations were continuing at weekly interval. The initial data indicated some positive effect on the reduction of the TPD incidence.

4.2. Relationship of biochemical and ionic composition of latex with yield and susceptibility to TPD in different *Hevea* clones

The trees belonging to seven clones were monitored for the occurrence of tap-

ping panel dryness. Out of the 12 trees in each clone, two trees of clone Tjir 1 and one tree each of clones RRII 38, RRII 105 and Gl 1 became completely dry. Partial dryness was observed in one tree each of clones RRII 308, RRII 38, RRII 105 and Gl 1.

4.3. Studies on Free radicals (FRs) and FR scavenging systems related to TPD incidence in *Hevea* tissues

Thiourea is reported to be capable of quenching the free radicals produced in biological system. An experiment was therefore designed at RRII plantation to investigate the effect of thiourea in normal and TPD trees. The experimental tress were selected as mentioned in 4.1. The antioxidant compound, thiourea, was applied on the bark (10 cm wide) below the tapping panel of the experimental trees in 10 days intervals for a period of one month in 4 groups of experimental trees (normal, 100%TPD, 60-90% TPD and less than 50% TPD tree groups). Untreated control trees were maintained in all the groups including normal trees. Tapping rest was given to these trees during the treatment time. A period of 2 weeks after the last treatment, tapping observations were made on the TPD status and latex yield in individual trees. The observations are continuing at weekly intervals.

5. Secondary metabolism

5.1. Quantification and identification of inositols in *Hevea brasiliensis*

For the study, 13 clones (RRII 105, RRII 118, RRII 208, RRII 300, RRII 308, RRII 5, RRIM 703, RRIM 600, PR 255, PR 261, SCATC 88/13, SCATC 93/114, Haiken 1) from field III trial were selected. Data collected at monthy intervals on total inositol content, initial volume, total volume and yield were analyzed clonewise and season wise.

During the first phase of the experiment A- serum was concentrated by lyophilization. For concentrating large quantities, spray-drying technology was tried. From seven litres of A- serum 38g of dried sample was obtained. (pH=8.3) From this 0.5g samples with 6 replicates were taken for biochemical analysis and found that the spray dried material contained 0.4% phenol, 1.2% free aminoacids. The total sugar and total inositol were not detected in the spray-dried sample.

RUBBER CHEMISTRY, PHYSICS AND TECHNOLOGY DIVISION

The division continued its research activities on primary processing, chemical modification, blends of NR with other elastomers and plastics, rubber composites and latex technology. Effect of long tem storage of sheet rubber on its raw rubber properties and processing behaviour was evaluated. The quality survey of the sheet rubber obtained from different locations of the country was also continued. The use of graft copolymers of NR as impact modifiers for SAN was established. Attempts were also made for the industrial utilization of the 'coupling' properties of ENR.

1. Primary processing and storage

1. 1. Primary processing

In connection with the survey on quality of sheet rubber, samples collected from 40 locations in four regions were tested and the results were analyzed statistically. Second round of collection of the samples was done and the testing was completed. Studies to prevent degradation of field coagulum were continued.

1.2. Storage of NR

Studies on storage of sheet rubber at different warehouses were completed. It

was observed that Mooney viscosity and Initial plasticity increased and plasticity retention index decreased during storage up to one year (Table Chem. 1). However, the technological properties remained more or less unaffected during the above storage period. After three months storage mould growth was observed in all the samples.

Table Chem. 1. **Effect of storage on Mooney Viscosity (ML (1+4) at 100°C)**

Storage period (Months)	Location 1		Location 2		Location 3	
	Dealer	RRII	Dealer	RRII	Dealer	RRII
0	82	82	83	82	83	82
3	83	85	87	84	86	85
6	86	88	90	88	90	89
12	92	95	96	93	95	95

2. Chemical modifications

Studies on improving the quality of SGNR showed that by increasing styrene content and by using cenex as the starting material instead of preserved field latex, the properties of SGNR could be improved.

Conditions for the preparation of NR/PMMA core shell particles were optimized. MMA was polymerized in NR latex using a redox initiator system in a semi-continuous method. The particles so prepared were melt blended with SAN to improve its impact strength. Maximum impact strength of 15.6KJ/m^2 was obtained for the blend at 20% rubber content. The improvement in toughness depended on percentage grafting and cross-link density of the rubber core and the rubber content in the blend.

3. Blends

Studies on the ageing resistance of the blend of NBR with ENR-25 and ENR-50 showed that ageing resistance could be improved by blending NBR with ENR.

Reinforcement characterization of sulphur cured NR-silica compounds with and without modifiers (ENR and Silane) at different filler loadings were conducted. ENR or silane modified NR/silica system showed higher reinforcement than the unmodified. Studies on the effect of temperature of cure on ENR modified silica filled NR showed that increase of temperature above 150 °C decreased modulus, tensile strength, abrasion resistance and tear strength.

NR and ENR-50 blends were prepared at different ratios up to 50:50. Silica reinforcement of these blends were compared with that of silane modified NR/silica system. Cross link density, modulus, hardness and heat build up increased as the concentration of ENR increased in the blend and abrasion resistance showed a maximum at about 10 to 20% ENR content. Addition of ENR in silica filled SBR improved the ageing resistance of the vulcanizates.

Effect of cure systems and vulcanization temperatures on the mechanical properties of NR/ENR-50 blends were studied. Vulcanizates were prepared from a 50:50 blend of NR and ENR-50 using CBS-DPG, CBS-TMTM and MBS-MBTS cure systems at temperatures 140, 150, 160 and 170 °C. The effect of cure temperature on the vulcanizate properties were marginal and best properties were given by CBS – TMTM cure at 150°C.

The melt rheological behavior of SAN/NR-g-SAN blends was studied using capillary rheometer. The viscosity of SAN as well as the blends (containing 10 and 20% rubber) decreased with increase in shear rate, shear stress and temperature. At higher shear stresses (>1.6 x 10^5 Pa) or shear rates (> 400 s^{-1}) the influence of rubber modification of the SAN on viscosity was so small that it could be neglected in describing the processing operations. The activation energy at constant shear rate and shear stress remained constant.

4. Rubber composites

Rubberized bitumen samples were prepared using latex and tyre crumbs to study the changes in properties on storage at elevated temperature.

Studies on coconut shell powder (CSP) filled NR composites showed that better mechanical properties are imparted by CSP of lower particle size. (Table Chem. 2). CSP increased the electrical resistivity with improvement in modulus and hardness maintaining the good tear behaviour of NR vulcanizates. However, it increased the abrasion loss and heat build up especially at higher loadings. It was concluded that CSP could be used as a low cost, less reinforcing filler for NR products which require low electrical conductivity.

5. Latex technology

5.1. Enzymatic deproteinisation of NR latex (EDPNRL)

The technical feasibility of the process is being evaluated in collaboration with a latex goods manufacturing unit. The EDPNR latex produced and products made from it are being evaluated.

5.2. Radiation vulcanization of NR latex (RVNRL)

The mechanical properties of NR latex films subjected to gamma irradiation before and after creaming were analysed (Table Chem. 3). Films prepared from creamed latex after irradiation (Method 1) showed better mechanical properties as compared with films prepared from latex irradiated after creaming (Method 2).

Table Chem. 3. **Properties of the irradiated latex**

Properties	Method 1	Method 2
Tensile strength, MPa	24.94	23.49
Modulus, 300%, MPa	2.30	2.09
Modulus, 500%, MPa	2.99	2.41
Elongation at break,%	1010.00	1100.00
Tear strength, kN/m	27.9	24.1

6. Characterization of molecular parameters of latex

Testing and statistical analysis of 13 selected clones were completed. Significant clonal and seasonal variations were observed on the latex and raw rubber properties.

7. NR processing

The R&D activities on NR processing included studies on drying of NR, up-gradation of low quality sheets, development of solar cum smoke dries, thermoplastic natural rubber, accelerated test for early prediction of latex quality parameters and development of rubber products.

Studies on the drying of three forms of NR coagulum *viz.*, latex coagulum crumbs, field coagulum crumbs and latex coagulum

Table Chem. 2. **Physical properties of NR vulcanizates containing CSP**

Parameter	CSP, phr					
	0	10	20	30	40	50
Tensile strength, MPa	28.00	26.20	24.60	22.30	17.60	14.80
Modulus, 300%, MPa	1.47	2.07	2.37	2.81	2.83	3.34
Elongation at break,%	1070.00	950.00	860.00	790.00	700.00	600.00
Tear strength, kN/m	30.40	28.90	30.50	30.30	31.00	28.90
Hardness, shore A	34.00	38.00	42.00	44.00	50.00	52.00
Din abrasion loss, cc	138.00	192.00	206.00	241.00	279.00	301.00
Heat buildup, °C	4.00	5.00	6.00	8.00	10.00	12.00
Resilience,%	80.00	78.00	77.00	72.00	70.00	69.00

Formulation of mixes : rubber- 100, ZnO -4, stearic acid -2, HSL- 1, CSP- 0, 10, 20, 30, 40 and 50, CBS-0.6 and sulphur 2.5 phr.

for sheets indicated that the effect of humidity and temperature on drying depends on the nature of coagulum. The initial and final drying stages of the coagulum were influenced both by humidity and temperature and also by porosity deliberately created to increase the surface area. A semiautomatic machine for cleaning of surface contaminations and fungus on rubber sheets was developed. A patent application has been filed for this item. A modified design of the machine has been prepared by incorporating new features based on the evaluation of the performance of the first machine. Fabrication of the modified machine is in progress.

Thermoplastic natural rubber (TPNR), prepared by melt blending of polypropylene and NR showed improved processing characteristics when the molecular weight of NR was reduced. Better ageing resistance could be achieved by using quinoline type antioxidant. Sample pieces of caps, rings, bush and root trainer were prepared by injection moulding, using the TPNR developed by RRII. Initial results on early prediction of some of the quality parameters such as MST, viscosity and KOH number of centrifuged NR latex concentrate indicated good correlation between the parameters determined by an accelerated test developed by RRII and the actual values of these parameters, after storing the latex for three to six months. The results are being reconfirmed by testing more samples collected from different sources.

Installation of one solar cum smoke drier each at RRS, Dapchari and HBSS, Nettana was completed. Evaluation of these driers is in progress. The furnace of the drier at RRS, Dapchari was modified to improve the performance.

Developed axil pad and rubber grip used in crutches and transferred the know-how to M/s Dynamic Elastomers, Kalady, which is a small scale rubber products manufacturing unit.

AGRICULTURAL ECONOMICS DIVISION

During the period under review, the Division has reported the results of one research project in the farm management sector, two each in foreign trade, primary marketing and ancillary products sectors and one under collaborative programme with the Agronomy Division. Apart from the above, seven projects in the Division are in different stages of progress. The observations/findings of the completed projects are given below.

1. Implications of WTO agreement on Indian NR sector

The study is a pioneering attempt to provide a comprehensive assessment of the implications of the WTO Agreement on the NR sector in India in the larger context of the evolutionary dynamics of GATT and the consequent trade policy measures initiated by the Government of India since 1995. The monograph is organised in two volumes. Volume I titled, *The Genesis of WTO and the Aftermath* deals with the major milestones in the evolutionary process of multilateral trading system. This volume contains five chapters: (1) Globalisation, (2) Genesis of GATT, (3) Geneva to Tokyo, (4) Uruguay to Marakesh and (5) Progress, Compliance and Implications. Volume II titled, *WTO and Natural Rubber Sector in India* attempts to focus on the major provisions relevant to the NR sector and formulate compatible policy options. This volume consists of three chap-

ters: (1) WTO Agreements and Structure, (2) Major WTO provisions relevant to Trade in Goods and Trade Policy in India and (3) WTO Agreement and the NR Sector. The scope of the study on the trade policy measures initiated in India is limited to the year 2001-02. Based on the findings of the study the Division has so far provided 15 detailed explanations and policy inputs to the Ministry of Commerce on various aspects related to external trade policy on rubber and rubber products.

2. An analysis of stockholding practices of the rubber small growers in Kerala

The study analysed the stockholding practices of rubber growers at different levels of price expectations during the two phases of price changes. It was observed that stockholding prevailed among growers during both the phases of price changes. During the phase of higher price expectations, the stock held as a proportion of production was 27% compared to 16% in the context of price uncertainty. The major contributing factors influencing stockholding behaviour of the growers were asset levels, price expectations, liquidity position and growers perception about the market. While the main motive of stockholding during first phase was higher price expectations, asset levels and consumption requirements influenced stockholding during the second phase. Therefore, it is difficult to generalise the stockholding behaviour under different price levels and price expectations across and within the size classes.

3. Changing dynamics of Indian NR marketing

In the post-reforms phase, the major developments affecting the prevailing structure of the primary marketing have been the market integration and declining prices with uncertain market prospects since 1997. Another notable change has been the futility of market intervention schemes pursued by the institutional agencies since 1997, to a large extent strengthened by the prominence accorded to the private dealer network even in the procurement operations. In the changed scenario, there has been considerable internal restructuring in the network of primary marketing as well as discrimination of small growers' RSS grades so as to maintain the marketing margin at the desired levels. The emerging trends highlight growing concentration of big dealers in the primary market and uncertain farm gate prices vis-à-vis the respective quality differences of RSS grades.

4. NR in the post-QRs regime

The impact of the new trade control measures imposed during 2001 for containment of the crisis arising from the cumulative effect of lower NR prices and the potential free imports of NR, is analysed in this study. The new control measures are: (1) declaration of statutory minimum prices for RSS 4 and RSS 5 effective from September 12, 2001; (2) restriction of NR imports only through the designated ports of Kolkata and Visakhapatnam effective from December 10, 2001 and (3) mandatory quality standards for both domestically processed and imported NR in conformity with the standards specified by the Bureau of Indian Standards (BIS) effective from December 12, 2001. But the trends in imports after December 10, 2001, indicate that as long as the difference in prices between domestic and world market is attractive, NR imports through the duty free channel will continue as there are well–defined limitations in backtracking from the liberalized trade policy initiatives pursued since 1991. However, the absence of nexus between exported products and

imported inputs in the DEPB scheme requires thorough scrutiny in order to prevent unhealthy trade practices. In a comparative sense, the mandatory quality control measures have to be pursued with the required support to ensure the export promotion of value added rubber products for more meaningful results.

5. Type of planting materials and immature phase of natural rubber: A comparative analysis of polybag and budded stump planted fields

The database of the study consisted of information collected from the regional offices of Rubber Board on 2285 fields planted during 1986 and 1987. The polybag and budded stump planted fields recorded an immature phase of 6.99 and 7.19 years respectively and the difference was statistically significant as budded stump planted fields reported a higher annuity. Polybag planted fields required an immature phase of 6.75 years to attain an annuity equivalent to that of budded stump planted fields. Alternatively, an assumed higher yield of 2.6% for polybag planted fields was sufficient to attain an annuity equal to that of budded stumps. Hence the study revealed that the economic advantage of the adoption of polybagged plants cannot be exclusively assigned to shorter immature phase alone but to the cumulative impact of different positive virtues such as lower vacancy, uniform establishment, higher tappability, shorter immature phase, higher yield, etc.

6. Monitoring of ancillary products

The monitoring of ancillary products sector was continued. The estimated availability of sawn timber suitable for processing was 0.42 million m^3 during 2001-2002. The production of rubber seed and cake were estimated to be 1100 and 1700 t respectively. Decline in production during the current year was mainly due to the weather conditions unfavourable to seed production. Production of rubber honey during the year was 4500 t, depicting a 3.6 times rise in production compared to the previous year which was mainly due to favourable weather conditions. Consumption pattern of stem rubber wood shows that the major share is consumed by the packing case industry (59%) followed by plywood industry (20%), secondary processing industry (14%), safety matches (4%) and others (3%). The increase in the share of secondary processing industry appears to be the result of a growing commercial importance of units with large scale processing capacity.

6.1. Timber yield potential of *Hevea* Clones in India: A preliminary assessment

The study is a pioneering attempt to estimate the timber yield potential of *Hevea* clones in India. It brings out some important aspects of a few *Hevea* clones grown in Indian conditions, *viz.*, irradiated clones, RRIM 600 and RRII 200 series, with respect to the timber yield and related attributes. Assuming a final stand of 250 trees per ha at the time of felling, the timber yield has been the highest for RRII 200 series (193 m^3/ha) followed by RRIM 600 (167 m^3/ha) and irradiated clones (112 m^3/ha). An essential pre-requisite of a perspective plan for an integrated planting policy is a detailed multi-disciplinary analysis on the region and clone-specific latex timber potential of the popular as well as the pipeline clones. This proposition assumes added significance in the context of a liberalised policy regime in which priority shall be on maximisation of net income per unit area rather than the unilateral focus on latex yield potential as promulgated under a protected policy regime.

6.2. Commercial exploitation of rubber honey: Problems and prospects

The study examined the issues confronting production, procurement, processing and marketing of honey from rubber plantations in Kerala. The results of the study indicated that the indigenous variety, *viz.*, *Apis Cerana Indica* is more popular compared to *Apis Mellifera* (exotic variety). The reported commercial yield of the indigenous variety is only 12 kg per hive per annum, whereas, the Mellifera variety reported an average yield of 39 kg per hive per annum. The primary marketing is dominated by local societies and price determination depended largely on the purchase policies of the Khadi and Village Industries Commission (KVIC). The average procurement price of raw honey was Rs. 42 per kg and the selling price of processed and bottled honey was Rs. 108 per kg. The estimated net income varied from Rs. 3000 to Rs. 9000/ha depending on the variety of honeybee and region. Bee keeping in rubber plantations is found to be feasible in those areas where the size of holding, multiple-cropping and use of family labour are higher. Since the northern region of Kerala complies with many of these conditions, popularisation of bee keeping has to be focused in this region.

EXPLOITATION TECHNOLOGY

Based on extensive long-term experiments and onfarm trials, low frequency tapping (LFT) with stimulation using ethepon was launched for adoption by planters. Unlike the earlier approach of break-even yield, where the objective of LFT was to maintain the net return, the present achievement is low frequency tapping without any reduction in yield so that cost of production could be substantially reduced. In this respect, the results, particularly that of weekly tapping, are novel. It was found that sustainable yield increase (15 to 30%) can be achieved under 1/2S d/3 6d/7 frequency of tapping with 3 to 4 stimulations per year and that the same yield level of more than 2200 kg of dry rubber per 400 trees can be achieved by fourth daily or weekly tapping with increased frequency of stimulation. LFT was extended to more than 20,000 ha area under lab to land programme. Various LFT experiments and trials were continued in various locations in Kerala, Karnataka and Tamil Nadu.

Mini and reduced spiral cuts can be used for early opening of trees so that the immaturity period of 7 years can be reduced by one year. Trees of clone GT 1 opened at 45cm girth with 10cm cut gave 787 kg/400 trees (88% of a 1/2S d/4 block) in the first year. These trees attained tappable girth of 50cm within one year.

Among various methods of stimulation, panel application (1.5 to 2 cm band just above the tapping cut) on the freshly tapped area was found to be the most effective. Stimulation at 20 days interval in controlled upward tapping (CUT) of 1/4S cut at third daily frequency was found successful for medium yielding clones in all the onfarm trials. Tapping on reduced spiral cut (1/3S) under d/3 or d/2 frequency also resulted in good yield, but with slightly higher incidence of TPD.

1. Low frequency tapping (LFT) system

The experiment on effects of different tapping and stimulation frequencies on

clone RRII 105 (BO-1 panel) showed comparable yield under d/3, d/4 and d/6 (weekly) frequencies during the fourth year (2000-01) also (Table Ex.1). Yield obtained under these low frequencies are sustainable whereas that under d/2 frequency declined from the third year.

Experiments in estates in different locations under d/3 frequency of tapping with stimulation also showed sustainable yield increase of 15 to 30% (Table Ex. 2). Annual dry rubber yield in various block trials under d/4 frequency of tapping in clones RRII 105, GT 1, RRIM 600 and PB 217 continued to record good yield in all the locations. Among the 3 levels of stimulation, medium level of six to seven stimulations/year is found optimum to achieve good performance. Results of all the onfarm trials conducted in a large number of blocks in Kerala (34 blocks) and Karnataka (28 blocks) confirmed the experimental results.

Data of the 1997-2001 period on the yield performance of clone RRII 105 under weekly tapping showed much better average yield than all the other systems with the lowest cumulative incidence of TPD (Table Ex. 3). However, it became comparable to those under higher frequencies of tapping from fourth year. Ten month's yield from clone RRII 105 under weekly tapping at CES, Chethackal was 2.4 t/400 trees with average per tap yield of 57 kg and the highest per tap yield of 132 kg for 400 trees. Estate trial at Malankara on d/7 frequency of tapping on various clones at different stages of exploitation of basal panels indicated the feasibility of successfully introduc-

Table Ex. 1. **Effects of different tapping and stimulation frequencies on mean annual dry rubber yield of clone RRII 105**

Treatments	Mean annual dry rubber yield (kg/ha)			
	1st year	2nd year	3rd year	4th year
T0- 1/2S d/2 6d/7	1810 ab	2817 a	2085 b	1690 b
T1- 1/2S d/3 6d/7 ET 2.5%. Pa. 3/y	1919 ab	2590 ab	2602 a	2933 a
T2- 1/2S d/3 6d/7 ET 2.5%. Pa. 4/y	1805 ab	2880 a	2809 a	2965 a
T3- 1/2S d/3 6d/7 ET 2.5%. Pa. 5/y	1967 a	2829 a	2743 a	2774 a
T4- 1/2S d/4 6d/7 ET 2.5%. Pa. 5/y	1420 cde	2385 bc	2589 a	2427 a
T5- 1/2S d/4 6d/7 ET 2.5%. Pa. 7/y	1739 abc	2498 abc	2395 ab	2489 a
T6- 1/2S d/4 6d/7 ET 2.5%. Pa. 9/y	1618 bcd	2578 ab	2606 a	2658 a
T7- 1/2S d/6 6d/7 ET 2.5%. Pa. 10/y	1170 e	2148 cd	2581 a	2567 a
T8- 1/2S d/6 6d/7 ET 2.5%. Pa. 12/y	1268 e	1931 d	2458 ab	2399 a
T9- 1/2S d/6 6d/7 ET 2.5%. Pa. 15/y	1361 de	2264 bcd	2652 a	2713 a
CD (P=0.05)	328	405	465	684

Table Ex. 2. **Mean annual dry rubber yield under d/3 frequency of tapping with stimulation**

Estate	Clone	Panel	Mean annual dry rubber yield (kg/400 trees)			
			T0	T1	T2	T3
Vengathanam	RRII 105	BO-1	2001	2353	2428	2578
Kalarickal	RRII 105	BO-2	2199	2549	2558	—
Palampra	RRII 105	BO-1	2097	2302	2434	—
Cheruvally	PB 217	BO-1	1328	1425	1528	1567
New Ambadi	GT 1	BO-2	1863	2364	2351	2265
New Ambadi	RRIM 600	BO-1	1573	1936	1827	1991

T0: Unstimulated control T1, T2 & T3 : Different levels of stimulation; minimum 3 replication

Table Ex. 3. **Performance of tapping systems in clone RRII 105 at Mullumala Estate (1997-2001)**

Tapping system	Mean annual dry rubber yield (kg/ha)*					
	97-98	98-99	99-00	00-01	Mean	TPD (%)
1/2 S d/6 6d/7**	2199	2779	2313	2109	2350	8
1/3 S d/3 6d/7**	2066	1683	2478	1843	2017	13
1/2 S d/2 6d/7	2387	1951	2127	2149	2154	26
1/3 S d/2 6d/7	2376	1633	1700	2407	2029	19
1/2 S d/3 6d/7	1366	1052	2044	1493	1489	22

* 375 trees per block of one hectare without re-blocking to date ** ET5% La 12/y(m)

Table Ex. 4. **Dry rubber yield of various clones under 1/2S d/6 6d/7 system of tapping (April 2001 - February 2002)**

Clone/ Field	Year of planting	No. of trees	Yield (kg/400 t)
RRII 105			
44A	1977	1360	1643
37A	1978	2040	2010
47A	1979	1775	2007
48	1980	1471	2132
25	1981	5647	1711
28	1982	3938	1783
1A	1994	1611	1129
PB 217			
14A	1984	1723	1727
10B	1985	2500	1992
11A	1985	1212	1435
12A	1986	1607	1651
36A	1990	683	1540
PB 235			
14B	1984	1600	1556
49	1984	420	1881
45	1985	708	2036
21	1986	3136	1684
30B	1987	1262	2160
11B	1988	3125	1542
6E	1989	1322	1570
PB 260			
9	1988	1118	1977
6B	1989	674	2351
36	1990	1890	999
PB 311			
36B	1990	617	851
PB 5/51			
30A	1987	605	1972
GT 1			
44B	1977	5180	1433
37	1978	1796	1338
47	1979	2557	1182

ing weekly tapping in many clones (Table Ex. 4).

In the on-farm trials with weekly tapping in newly opened RRII 105 trees in Manikal Estate (6 blocks) and Vijayadri Estate (5 blocks) expected yield of 1.5 t/400 trees was obtained in the first year of tapping with fortnightly stimulation.

From the experiment on interval between stimulation and tapping, it is evident that under weekly frequency of tapping stimulant must be applied between 48 to 72 hours before tapping (Table Ex. 5).

Table Ex. 5. **Effect of different intervals between stimulation and tapping on dry rubber yield of weekly tapped newly opened trees of clone RRII 105**

Treatment	Cumulative yield (kg/400 trees)*
T1 – Two days before tapping (48 h)	1548a
T2 – Three days before tapping (72 h)	1494a
T3 – Four days before tapping (96 h)	1176b
T4 – Five days before tapping (120 h)	1136b
T5 – Six days before tapping (144 h)	1286b

Values sharing the common letter/s do not differ significantly at P<0.05, LSD = 203.
* 10 months yield

In newly opened trees tapped under d/7 frequency of tapping, fortnightly stimulant application at is required to overcome the low yield problem in the first two years (Table Ex. 6).

Table Ex. 6. **Yield response of weekly tapped newly opened trees of clone RRII 105 to different frequencies of stimulation**

Tapping and stimulation frequency	Dry rubber yield (kg/400 trees)*
1/2S d/3 6d/7	1710
1/2S d/6 6d/7 ET 2.5%.Pa.12/y (m)	1492
1/2S d/6 6d/7 ET 2.5%.Pa.24/y (2w)	1714
1/2S d/6 6d/7 ET 2.5%.Pa.36/y (10 days)	1760
1/2S d/6 6d/7 ET 2.5%.Pa.48/y (w)	2002

* 10 months yield

Among various methods of stimulant application conducted in RRII 118 on panel BO-2, panel application (1.5 to 2 cm band just above the tapping cut) on the freshly tapped area was found to be the best (Table Ex. 7).

Table Ex. 7. **Effectiveness of different methods of stimulant application on dry rubber yield**

Method of application	Yield* (g/t/t)		
	ET 2.5%	ET 5.0%	ET 10.0%
Lace	84.3	83.5	76.7
Groove	73.8	81.6	77.9
Panel	115.4	102.4	87.8
Bark	66.9	93.9	81.5
Control	63.9		

* Mean of 6 years; weekly tapping

2. Other experiments

2.1. Effect of panel change on yield

The experiment on panel change on yield performance of clone RRII 105 shows that annual yield can be considerably increased from third year on wards under alternate daily (1/2S d/2 6d/7), third daily (1/2S d/3 6d/7) and fourth daily (1/2S d/4 6d/7) frequencies of tapping, with stimulation in the later two frequencies. Yield of clones RRII 105 can be further increased by around 20% by adopting panel change. Adverse effect of higher frequencies of tapping and stimulation are also reduced. Incidence of panel dryness is reduced by 50% by panel change.

2.2. Crop loss due to rain and recovery by stimulation

The experiment to study yield loss due to rain and extent of recovery possible under d/2 and d/3 frequencies of tapping was continued. The crop loss is more than 30% under alternate daily tapping and nearly 40% under third daily tapping. Under alternate daily tapping, stimulation did not result in recovery of crop loss. However, under 1/2S d/3 6d/7 system, 50% of the crop loss could be recovered through stimulation. It is also observed that in the absence of rain guarding comparable yield to that of alternate daily tapping (1/2S d/2 6d/7) can be obtained by third daily tapping (1/2 d/3 6d/7) with stimulation.

2.3. Performance of mini and reduced spiral cuts

The experiment for evaluation of the performance of stimulated mini and reduced spiral cuts under d/3 frequency of tapping with that of unstimulated 1/2S d/3 6/d7 system show that good yield can be obtained from mini cuts (more that 80% of 1/2 S d/3 6/d7). With appropriate stimulation, 10 cm spiral cuts or 1/4S cuts can be tapped once in three days without compromising yield compared to that of 1/2S d/3 6d/7 with stimulation. Other advantages are more girthing compared to the girthing of trees under 1/2S d/3 6d/7 tapping system with possibilities of early opening, increased task, increased duration of tapping on virgin bark and increased economic life. There are three on farm trials on reduced spiral cut.

3. Studies on latex diagnosis

Base values of latex diagnosis parameters were fixed for clone RRII 105 under

Table Ex. 8. **Average productivity and latex diagnosis parameters of small holdings under three RPS (2000)**

RPS	No.of plots	Yield g/t/t	Tapping days	Thiol (mM)	Pi (mM)	Sucrose (mM)	DRC (%)
Aimcompu	25	54.31	136	0.24	23.83	8.91	39.67
Chirakadavu	25	57.23	129	0.32	19.31	13.31	39.54
Edakunam	36	61.18	140	0.42	25.44	10.43	37.35
Base values		67.50-75.00		0.30-0.45	20.70-30.15	5.22-10.37	35.00-44.00

1/2S d/3 frequency of tapping which ensures an optimum production regime in the central zone of the traditional rubber growing tract (Table Ex. 8). The base values were subjected to field testing for assessing the exploitation status of 86 smallholdings under three Rubber Producer's Societies (RPS) in the central zone of the traditional rubber growing tract during 2000.

The average productivity of the small holdings were lower than the optimum limit which could be due to the intensive exploitation practiced by the small holdings. Latex diagnosis test values of individual holdings is required for assessing the productivity status of respective holdings

Field studies are being conducted in more number of smallholders plots to arrive at a model to predict over exploitation leading to TPD. Studies on fixing of base values (region wise) of latex diagnosis parameters in RRII 105 are being continued in the north and south zones of the traditional rubber growing tracts.

CLONE EVALUATION

To assess the regional performance of clones field experiments were in progress in different locations.

1. Large scale trials

1.1. 1994 trial at Arasu Rubber Corporation, Tamil Nadu

In the 1994 trial for the large scale evaluation of clones at Arasu Rubber Corporation, Keeriparai, Tamil Nadu, monthly girth recording was continued. The field was opened for tapping. Data on girth of the clones, at opening and mean girth increment over six years (Table Ce. 1) show that IRCA 111 continued as the highest girthing clone followed by IRCA 230 and PB 255. No incidence of pink disease was observed in the field. Highest girth increment was recorded for PB 255 and IRCA 111 followed by PB 314.

Table Ce. 1. **Girth at opening and girth increment over six years at Kanyakumari region**

Clone	Girth (cm)	Girth increment* (cm)
RRII 105	44.6	7.7
IRCA 18	47.0	8.0
IRCA 109	50.1	8.8
IRCA 111	54.9	9.4
IRCA 130	46.5	7.9
IRCA 230	53.9	9.3
PB 28/59	43.1	7.7
PB 255	54.1	9.4
PB 314	52.7	9.0
PB 330	50.5	8.6
RRIM 703	51.4	8.8
Mean	49.9	8.6
SE	1.90	0.4
CD (P=0.05)	5.60	1.1

* Mean of six years

1.2. 1996 trial at Padiyoor

The1996 clone trial at Padiyoor was maintained well and monthly girth recording of the clones was continued. IRCA 230 continued as the highest girthing clone followed by PB 314 and IRCA 130. Pink disease was prevalent in this region. IRCA 18, PB 330 and IRCA111 showed some sort of tolerance (Table Ce. 2).

Table Ce. 2. **Girth of 11 *Hevea* clones at Padiyoor (March 2001)**

Clone	Girth (cm)	Pink(%)
RRII 105	23.9	30.5
IRCA 18	29.6	13.0
IRCA 109	29.1	24.0
IRCA 111	29.4	20.5
IRCA 130	26.6	37.0
IRCA 230	31.4	41.5
PB 28/59	25.3	25.0
PB 255	27.0	22.0
PB 314	31.1	25.6
PB 330	26.6	17.0
RRIM 703	23.1	29.4

1.3. 1999 trial at Orissa

In the large scale trial at Orissa includes 11 clones planted in RBD, RRII 357 followed by PB 28/59 continued as the vigorous clones in terms of stem diameter, plant height and number of leaf whorls.

2. On-farm trials

The trial at Arasu Rubber Corporation, Keeriparai, Tamil Nadu, monthly girth recording was continued. Six clones recorded better growth than the control (RRII 105). Annual recording of wintering and flowering was also done.

In the trail initiated in 1996 at different agroclimatic regions, RRII 51 and RRII 357 continued as vigorous clones. At this location pink disease was high in RRII 51 and RRII 105. Clone RRII 357 continued as the vigorous clone at Malabar region also.

3. Intraclonal variations and associations in RRII 105

The two experiments to assess the nature and magnitude of intraclonal variations in RRII 105 and to evaluate the importance of stock in clonal performance are in progress. One is a nursery study for the comparison of stock sources for establishment and growth of grafted plants in the field, grown over one year in the field. A part of the data was analysed. Field establishment recorded significant variability due to stock.

In the other experiment, growth observations at six monthly intervals and yield recordings on mature plants at monthly in-

Table Ce. 3. **Bark anatomical characters of tapping trees: Comparison of tapping and untapped sides**

Characters	Sides	Mean	SD	CV	't'
Total bark thickness (mm)	Tapped	5.44	0.4889	9.00	0.65896
	Untapped	5.35	0.4703	8.79	
Hard bast (%)	Tapped	71.95	5.0838	7.07	0.71296
	Untapped	70.92	5.2550	7.41	
Latex vessel rows (No.)	Tapped	13.28	1.2619	9.50	2.13246**
	Untapped	12.62	1.1637	9.23	
Latex vessel density (nos/2.5mm)	Tapped	5.54	0.3622	5.54	1.90813
	Untapped	5.35	0.4154	7.77	
Width of latex vessels (m)	Tapped	22.00	2.1655	9.84	0.05675
	Untapped	21.95	4.7407	21.60	
Ray height/width ratio	Tapped	7.87	1.1617	14.77	1.30000
	Untapped	8.29	1.3732	16.56	
Tanniferous cells /unit area (%)	Tapped	46.91	3.3620	7.17	3.229547**
	Untapped	43.32	5.0672	11.70	

** P< 0.01

tervals were being continued. Bark anatomical characters of tapping side and untapped side of the trees under tapping stress were recorded. The data on anatomical characters (Table Ce. 3) showed that tapping side recorded slightly greater values than the untapped side. For two characters, number of latex vessel rows and percentage of tanniferous cells the differences were statistically significant. The results indicated a stimulating effect on growth with significant high formation of laticifer rows.

GENOME ANALYSIS

The genome analysis laboratory has been established as a central facility for molecular characterization of *Hevea* genome and fungal pathogen. The research projects initiated at the Genome laboratory and results achieved so far in each project have been described.

1. Establishment of genetic relationships among wild *Hevea* germplasm through RAPD studies

Genetic diversity, as the measure genetic variation among the wild genotypes of *Hevea* has been assessed following polymerase chain reaction (PCR) based RAPD technique. Sixty wild Brazilian genotypes representing the three provinces (Acre, Rondonia and Mato-Grosso) have been used in the initial studies and work has been completed successfully. Acquired knowledge about genetic variability exists among the selected wild Hevea genotype could be exploited further in Hevea improvement program.

2. Development of RAPD marker(s), for resistance to Phytophthora leaf fall disease

Development of RAPD marker for resistance to Phytophthora leaf fall disease in cultivated *Hevea* clones as well as in wild germplasm has been continued. In the disease screening studies, RAPD fragment generated in tolerant *Hevea* genotypes was cloned in a plasmid. Recombinant plasmid was then isolated and purified for further characterization of the cloned fragment through restriction analysis and sequencing. More Operon primers are being screened simultaneously to identify polymorphism between tolerant and susceptible *Hevea* clones. Putative molecular marker developed for Phytophthora disease resistance may have valuable role in the diagnostic prediction of the plant performance against fungal pathogen at the very early stages of development and very useful in perennial crop like rubber.

3. Molecular characterization of the fungal pathogens

3.1 Corynespora leaf disease

Results generated through molecular studies of *Corynespora* isolates, revealed the existence of seven different genotypes of *Corynespora cassicola* between the Kerala and Karnataka isolates with variable pathogenecity. Putative virulence specific RAPD profile of *Corynespora* was identified among the isolates where the disease became epidemic in Karnataka.

3.2 Colletotrichum leaf disease

Molecular studies, RAPD and ribosomal DNA RFLP, revealed the existence of two different species of *Colletotrichum* associated with *Hevea* and involving in the development of three different disease symptoms upon infection. The species were identified as *Colletotrichum acutatum* causing

raised spot symptom and *C. gloeosporioides* causing both anthracnose and circular lesions. Association of *Colletotrichum acutatum* with *Hevea* has been reported for the first time from India and now believed to be the major pathogen of *Colletotrichum* leaf disease of *Hevea* besides *C. gloeosporioides*.

DRIS FERTILISATION

The DRIS unit, formerly under World Bank Aided Rubber Project is presently engaged in four major projects in addition to advisory service to small holding sector.

1. DRIS fertilization

To test the efficacy of DRIS fertilization (a modern approach in fertilizer recommendation), field experiments conducted at four locations indicated that there was a significant difference among the various treatments *viz.*, Discriminatory Fertilizer Recommendation (DFR), Diagnosis and Recommendation Integrated System (DRIS) General Fertilizer Recommendation (GFR). However response to fertilizer was obtained only in Pala and Kanjirappally.

2. Refinement of discriminatory fertilizer Recommendation (DFR)

Based on the implications of resource soil survey report of rubber growing soils of Kerala, field experiments were undertaken to formulate soil series based fertilizer recommendation in different locations comprising North, Central and Southern regions of Kerala.

The preliminary results revealed that there was a significant increase in rubber yield due to fertilizer application in Kanjirapally, Kunnathur and Kadambanad soil series while in Thiruvanchoor soil series, there was no significant difference in yield among the treatments. In Kunnathur and Kadambanad soil series at Adoor, application of 54:54:54 kg NPK/ha registered significantly higher yield as compared to all other treatments.

3. Hydrological functions and the erodability characteristics of soils under *Hevea*

The project is initiated to study the hydraulic properties and the erodability of major soils under *Hevea* in relation to varying slope conditions. During the reporting year, a detailed topographic survey was conducted on terraced hill slopes to identify sites for study as per the programme of research. Topographic variables (Table Dri. 1) and soil samples from three depths *viz.*, surface soil (0-15 cm), soils at 30 cm and 60 cm under different slope conditions were collected.

Results on physico-chemical properties of soils (Table Dri. 2) under *Hevea* varying terrain revealed that there was a decrease in sand content and corresponding increase in clay content from the upper to lower slope gradient. The organic matter content and cation exchange capacity of soils were decreased with increase in slope gradient.

4. Phosphorus fixation study

Phosphorus fixation by three different soil series was studied and results show that phosphorus fixation was highest in Kanjirapally soil series followed by Kadambanad and lowest was in Thiruvanchoor soil series.

5. Small holders advisory service

In central (RRII), regional and satellite laboratories, a total of 8220 soil and 953 leaf samples were analysed and 4400 discrimi-

Table Dri. 1. **Topographic features of soil sites**

Topographic variables	Location			
	Mundakayam	Valikulam	Kadanad	Pizhaku
Slope aspect	South-north facing	West-east facing	South-west facing	East-west facing
Slope length	60 m	30 m	45 m	35 m
Slope gradient				
Range, degrees	15°6'-20°98'	8°82'-14°01'	7°41'-11°31'	0-2°29'
Mean, degrees	18°69'	11°41'	7°97'	1°41'
Slope length factor†	0.50	0.46	0.40	0.40
Land use	Mature rubber	Mature rubber	Mature rubber	Mature rubber
Floor structure	Micro terraces	Terraced	Terraced	Terraced
	Dispersed grass patches	Grass patches	Grass patches	Dispersed grass patches

†Renard *et al.* (1997) i.e., m=b/(1+ b), where b = (sin q/0.0896)/3.0 sin q+0.56)

Table Dri. 2. **Physico-chemical properties of surface soil under rubber varying slopes**

Mean slope	Sand (%)	Silt (%)	Clay (%)	pH (1:2.5 w/v)	OM* (g/kg)	CEC (cmol(p+)/kg)
18°69'	51.26	11.53	29.85	4.35	29.00	12.30
11°4'	42.02	12.50	37.50	4.20	42.93	15.50
7°97'	40.06	13.30	43.20	4.30	27.40	12.00
1°41'	30.90	14.65	49.85	4.30	43.92	14.50

* Organic matter (organic carbon x 1.724)

natory fertilizer recommendations were offered. In addition, 15950 latex samples were analysed for DRC and 107 samples for Volatile Fatty Acid (VFA). Fertilizer recommendations were also offered on the spot by conducting 58 mobile soil-testing programmes at different locations in Kerala and Tamil Nadu.

CENTRAL EXPERIMENT STATION, CHETHACKAL, KERALA

The Central Experiment Station is conducting experimental projects on intercropping trails, progeny trails, exploitation studies, density trails etc. of the different research divisions of RRII. The station has a total area of 254.8 ha. The station is of about 50 km from Rubber Research Institute of India. A nursery of about 4000 genotypes of wild Brazilian Germplasm has been established and these genotypes are being systematically screened for disease resistance and other desirable characters. The total crop realized was 144462.22 kg. A total of 296 tapping days was possible in the year and 66 tapers were engaged for tapping. The total mandays engaged in the station were 61520.

A dispensary with a full time doctor and a part time lady doctor caters to the needs of the workers and 8615 patients were attended during the period.

REGIONAL RESEARCH STATION, GUWAHATI, ASSAM

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

1. Crop improvement

1.1. Evaluation of clones

In the 1985 clone trial of ten clones, highest girth over 16 years was observed in the clones RRIM 600 (71.60 cm), RRII 203 (71.56 cm) and RRII 118 (71.00 cm) and lowest was in PB 5/51 (51.39 cm). The clone RRIM 600 recorded highest annual average yield (37.88 g/t/t) followed by GT 1 (34.28 g/t/t) and minimum was in PB 5/51 (23.76 g/t/t) under 1/2S d/2 6 d/7 system of tapping without tapping rest and with taping rest the maximum yield was recorded in RRIM 600 (44.92 g/t/t) and minimum was in PB 5/51 (25.99 g/t/t). Highest rubber content was recorded in RRIM 605 (32.89%) and minimum was in Gl 1 (30.27%) in the trees tapped without rest while in normal tapping trees, a maximum of 33.49% (RRII 118) and a minimum of 29.68% (PB 5/51) was recorded.

In the 1986 clone trial the clone RRIC 102 recorded highest average girth (75.1 cm) and the least by RRII 105 (62.3 cm) with a general mean girth value of 66.7 cm. One group of plants were tapped throughout the year (test tapped plants) and other group of plants were tapped from April to December giving tapping rest from January to March (Normal system of tapping). In both the cases, cup lump yield (g/t/t), latex volume (ml/t/t) and DRC (%) were recorded and analysed statistically. Significant differences in mean yield were observed among the clones under both systems of tapping. Under normal system of tapping, RRII 105 registered highest average yield (37.7 g/t/t) and RRII 5 the least (25.97 g/t/t). In test-tapped plants, the clone PB 311 registered highest yield (29.3 g/t/t) and RRII 5 the lowest (22.2 g/t/t). Though normal tapped plants produced more latex (130.1 ml/t/t) than test tapped plants (96.1 ml/t/t).

1.2. Evaluation of polyclonal population

Evaluation of polyclonal population in terms of growth and yield was continued at RRS, Sorutari farm. Ten promising polyclonal trees were selected based on yield efficiency (g/cm) and multiplied for raising in budwood nursery. Amongst the selections, maximum annual mean yield was recorded in selection S_2 (111.18 g/t/t) and minimum in selection S_3 (58.67 g/t/t). Highest girth over 14 years was observed in selection S_8 (105.6 cm) and minimum in selection S_6 (74.5 cm).

1.3. Evaluation of wild germplasm

Incidence and severity of powdery mildew disease assessed in 246 wild accessions conserved at RRS, Taranagar Research Farm, Agartala. Seventy accessions did not show any symptom of powdery mildew disease.

2. Crop management

2.1. Nutritional studies (Mature phase)

The 1987 nutritional trial at Nayekgaon in Kokrajhar, to find out the optimum requirements of N, P and K for the growth and yield of *Hevea* was continued. Effect of N application on girth was increased with higher doses and response is mainly confined to 40 kg N/ha (57.79 cm). However, highest dose of 60 kg N/ha resulted in highest yield (58.52 g/t/t), volume (199.82 ml/t/t) and DRC (35.85%). In case of P, application of highest dose (40 kg P_2O_5/ha) was found numerically superior in terms of average girth (56.99 cm). Its effect on average yield (44.95 g/t/t) and volume (153.06 ml/t/t) was found significant. In case of potassium,

significant increase in yield was observed due to imposition of the treatments. The effect of treatments on annual girth and interaction effects among the treatments on girth, girth increment, yield and DRC were found to be non-significant.

A new experiment on the influence of NPK combination, on mature rubber was initiated during the year 2000 at Bargang, Sonitpur (about 300 km from Guwahati) in a grower's field to study the optimum requirement of NPK fertilizers for the popular clone RRIM 600. The current year results showed that there were no significant effects with any treatment combination on girth, girth increment, mean volume and DRC. Maximum of absolute girth (65.27 cm), girth increment (4.33 cm) mean yield (38.78 g/t/t), mean volume (113.55 ml/t/t) and DRC (30.88%) were observed under the treatment combination of N_{60} P_{30} K_{45} kg/ha.

2.2. Interaction between K and Mg

Trails, laid out in two locations (Sarutari and Nayekgaon) in 1987 showed that highest doses of K (40 kg K_2O/ha) and Mg (15 kg MgO/ha) significantly increased the yield. Maximum yield (63.15 g/t/t) was found under the treatment combination of 40 kg K_2O/ha with highest doses of Mg (15 kg MgO/ha) followed by K40 Mg 7.5 kg/ha (56.40 g/t/t) and minimum was in control (K_0 Mg_0). Application of K and Mg influenced the total mean volume significantly. Interaction between K and Mg on average girth, annual girth increment as well as on average yield and mean volume were found non-significant.

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

Two trials, laid out Sarutari and Nayekgaon on mature rubber are being continued with water soluble and water insoluble phosphatic fertilizers and their combinations. The result at Sarutari showed that absolute girth and girth increment were highest under water insoluble P (70.41 cm) followed by combination of water soluble and water insoluble P (67.94 cm) and minimum was in control (64.03 cm). No significant increase in yield was noticed in treated plots and maximum yield was recorded under MRP: SSP = 50:50. A building up of soil available P was observed and yield/tap was improved due to application of P-fertilizer. The result at Nayekgaon showed that application SSP at the rate of 60 kg/ha numerically increased the mean girth (61.40 cm) but MRP at the rate of 20 kg/ha effected highest girth increment (1.5 cm) during the reporting year compared to other treatments.

2.4. Effect of sulphur on growth of *Hevea*

The study on the effect of different doses of sulphur on growth of *Hevea* under nursery condition was repeated for the second time. No significant differences of girth, plant height and number of leaf whorls were recorded during the initial growth period.

2.5. Comparative efficiency of cover crops

There was significant effect on dry matter yield, number of nodules/plant and dry nodule weight. Maximum dry matter yield, number of nodule and dry nodule weight were recorded under *Mucuna bracteata* in 1 m^2 patches followed *Pueraia phaseoloides* planted in 1m^2 patches and minimum was in *P. phaseoloides* cover crop planted in double strips. Improvement of the soil moisture was also observed during the winter/summer period for *M. bracteata* and *P. phaseoloides* planted in patches.

2.6. Potassium dynamics in the rubber growing soils of Assam

In continuation of the work on general survey and status of potassium in the rubber growing soils of Assam, samples were collected to assess the availability of potassium and its mobility down the profile.

K-fixation capacity of the soils (0-30 cm) was determined in portion of 5 g soil by adding K in the form of KCl solution at the levels of 10,20,50 and0 100 ppm. All the soils showed an increasing trend in K-fixation with increasing levels of applied K though the per cent of K fixation with added K tended to decrease gradually with increased levels of K application.

2.7. Weed control

Weed survey study was initiated to identify different weed species in rubber plantations of Assam under different age groups and also to find out noxious weed species during early groth period.

3. Crop protection

3.1. Survey on diseases and pests

Survey on pests and diseases was carried out in 74 locations in the north eastern part of India covering 38 different rubber growing tracts in Assam, Meghalaya, Arunachal Pradesh, Tripura and northern part of West Bengal. The incidence of powdery mildew disease was noticed in most of the locations surveyed. The severity of powdery mildew disease was high in block plantations of NRETC at CMC para, Laxmandepha, Rishidas Colony, Nagichera, Tulakona, Madhuban, private growers plantation of such locations in Tripura and also at DDC, Jenggitchakgre and Umsiang in Meghalaya and at Sorutari in Assam. Minor incidence of brown root disease was observed in immature rubber plants at Konabam, K.C. Para, Madhuban, Rishidas Colony except Thaibong where incidence of this disease was high as compared to that of other locations in Tripura, Assam, Meghalaya and Arunachal Pradesh. High incidence of Periconia leaf blight disease was observed in nursery at some locations in Assam, Arunachal Pradesh and Meghalaya. Minor incidence of purple root disease (below 10%) was observed in seedling nursery at DDC, Jenggitchakgre in Meghalaya and also in private grower's nursery at Avayapuri in Assam. A herbaceous plant (*Eupatorium odoratum*) was observed in the field adjacent to nursery at DDC, Jenggitchakgre as an alternate host with fructification of the fungal pathogen near root base. Incidence of pink disease was observed in immature rubber plants (RRII 105 and RRIM 600) of private growers at Jiti and Rongo Rubber Estate and also at RES, Nagrakata in northern part of West Bengal during September, 2001. High incidence of pink disease was noticed only in nursery at Sorutari farm in Assam. Minor infestations of scale insect, termites, slugs and snails were also noticed in most of the locations surveyed in N.E. region and northern part of West Bengal.

3.2. Isolation, identification and maintenance of fungal pathogens

Amongst five morphologically different isolates of *Colletotrichum gloeosporioides* causing secondary leaf fall disease of *Hevea* in N.E. region, two distinct strains were identified by RAPD analysis.

3.3. Control of powdery mildew disease

Evaluation of economic efficacy of sulphur dusting for the control of powdery mildew disease was continued at RES, Nagrakata in mature trees of clone RRII 105. Severity of powdery mildew disease was very high in undusted control block (3.0) as compared to the dusted block (1.3), which resulted in an annual crop loss of 28.52%. The benefit cost ratio (10.1:1) indicated that the cost of dusting for the control of powdery mildew disease is economical.

Evaluation of chelated Zinc (Chelazin liquid) against the management of powdery mildew disease was continued at RRS, Nagrakatta (clone RRIM 600). The incidence and severity of powdery mildew disease were 100% and 4.1% respectively in

undusted control plots. Plants showed poor growth vigour. Experimental plants treated with Zinc chelate (at the rate of 5ml/litre of water) plus dusting of sulphur and without sulphur showed very low incidence and severity of powdery mildew disease and also registered high growth vigour as compared to control and the other treatments. Analysis of Zinc status in pre and post-treatment leaf and soil samples are in progress.

4. **Exploitation technology**

The experiment on tapping rest and frequency interaction studies initiated during 1999 with clone RRIM 600 was continued. The tapping system 1/2S d/2 6d/7 with and without rest is being compared with other tapping systems *viz.* 1/2S d/3 6d/7 and 1/2S d/4 6d/7 where stimulation has been imposed. The data on girth, girth increment, mean yield, projected yield and number of tapping days revealed that treatments were not significant with respect to girth increment. Maximum girth (66.03 cm) and girth increment (1.96 cm) were recorded in 1/2 S d/4 6d/7 system with seven stimulations and three months rest (T12) and minimum in 1/2 S d/2 6d/7 system with one month rest. Maximum yield (76.63 g/t/t) was recorded for the treatment T12, and minimum (30.13 g/t/t) in 1/2S d/3 6d/7 system with two months rest (T3). Maximum projected yield (2018.88 kg/ha/year) was noted for treatment T7 (1/2S d/3 6d/7 with five stimulations and two months rest) and the minimum (1349.82 kg/ha/year) for treatment T3.

REGIONAL RESEARCH STATION, AGARTALA, TRIPURA

The Station continued to engage in the investigations on various aspects of natural rubber cultivation. Emphasis was given for soil nutrient mapping in NR cultivated areas of North East region. Studies on nutrition management, intercropping, crop improvement through breeding and selection, *etc.*, were also in progress. Work on Biotechnology was mainly concentrated on anther culture, immature embryo culture and *in vitro* propagation through shoot tip culture. Studies on effect of low temperature stress on growth of rubber and latex outfort were continued. The study on identification of suitable rubber growing areas based on annual rainfall index was in progress. Support to the rubber growers of North East region through advisory and discriminatory fertilizer recommendation was continued.

1. **Agronomy and soils**

Fertility status of the rubber growing soils of the North-Eastern states was evaluated and classified as low, medium and high, based on the nutrient index value. The nutrient index value for organic carbon is 1.78 and fertility rating is medium for the region. Nutrient index value for organic carbon was highest in Mizoram and lowest in Tripura. The available P status is low in the region and the nutrient index value is 1.03. Nutrient index value for available K is 1.77 and fertility rating is medium for the region. Potassium is low in Tripura and Assam, and medium in rest of the states in the region.

In the study on the effect of different fertilizer doses on different densities of two RRII clones *viz.*, RRII 105 and RRII 118, the highest per tree yield (45.6 g/t/t) was observed in lowest density compared to the other two higher densities. No difference in yield was observed due to fertilizer doses and clones. However, significant difference was observed among the densities. Data obtained from the trial on the effect of NPK and their interactions on growth and yield of *Hevea* revealed that 60 kg N and 60 kg

P_2O_5 have significant effect on the girth and yield. Effects of different levels of K on girth and yield was not significant. The trial on ecological impact of rubber plantations on physico-chemical properties of soil has showed maximum amount of organic carbon, available P and K in soil under rubber compared to other plantation species *viz.*, Teak (*Tectona grandis)* and Gamair *(Gmelina arborea)* (Table Net. 1). Significantly higher amount of available nutrients was observed in surface as well as sub-surface soil under all plantation crops compared to barren land.

Three different rubber based multi-species field experiments were in progress under sustainable farming system project. Pineapple, coffee, tea and turmeric were intercropped in these experiments. Growth performance of coffee as intercrop in rubber was better than monocrop without shade. Average girth (at 5 cm height) of intercrop and monocrop coffee were 4.8 cm and 3.7 cm, respectively. Higher yield of pineapple was in strip intercropping (1532 kg/ha) compared to alternate row intercropping system (1034 kg/ha). Average girth of tea plans was 9.1 cm at 5 cm height. Monthly average yield of tea leaves was 36 g/m^2 and the highest yield (59.4 g) was recorded in the month of October. Area intercropped with tea occupied 18% of total area rubber plantation. Turmeric cultivated under five-year-old rubber plantation yielded only $0.5kg/m^{-2}$ whereas monocrop yielded $3.4 kg/m^{-2}$. Analysis of soil samples showed sufficient organic carbon availability to all the crops irrespective of the model. Concentration of nitrogen in rubber leaves also corroborated this observation. Available K concentration in soil was within the range of sufficiency.

2. Biotechnology

Immature anthers of RRII 105 and SCATC 93/114 were cultured on different media supplemented with different organic nutrients and phytohormones. Successful callus development was observed in the medium using MS macro-and micro-nutrients in half the concentrations. Induction of somatic embryogenesis was observed from the yellowish white callus using different concentration and combinations of phytohormones. Kinetin 1.0 mg/L along with IAA 0.1 mg/L produced maximum somatic embryos. Clone RRII 105 was better than that of SCATC 93/114 for somatic embryogenesis. Histological studies of the globular and torpedo shaped somatic embryos were performed to confirm the origin of somatic embryos.

Shoots obtained by culturing immature embryos of RRII 105 in the previous year were cultured on the media modified for development of lateral roots. Phytagel was found to be better gelling agent than agar

Table Net. 1. **Available nutrient status and pH of soil under different plantations and barren land**

Location	Depth (cm)	OC(%)	P (mg/100g)	K (mg/100g)	pH (1:2:5)
Rubber	0-30	0.95	1.04	5.53	4.86
	30-60	0.73	0.63	4.24	4.64
Teak	0-30	0.88	0.81	5.02	4.58
	30-60	0.68	0.61	4.27	4.29
Gamair	0-30	0.86	0.81	4.81	4.38
	30-60	0.56	0.40	4.34	4.38
Barren land	0-30	0.53	0.29	4.56	4.67
	30-60	0.40	0.20	3.89	4.52
CD (P=0.05)	0-30	0.12	0.16	0.64	0.18
	30-60	0.07	0.13	ns	0.21

and promoted lateral root development when supplemented with 8% sucrose and 4% activated charcoal. Immature zygotic embryo culture studies were extended to RRII 417, RRII 429 and RRIC 100 clones.

3. 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. There are four clone evaluation trials supported by two on-farm trials and a clonal demonstration trial. Progenies of recombination breeding are being evaluated in three sets *viz.*, 1933-94, 1998 and 1999.

3.1. Evaluation of clones

In the clone trial with 15 clones, RRII 203 (70.9 g/t/t) recorded highest yield followed by PB 235 (63.9 g/t/t), RRIM 600 (56.19 g/t/t), RRIM 703 (54.7 g/t/t) and RRII 105 (46.8 g/t/t). RRII 203 showed a steady increase in yield over the year. In the second trial with 12 clones RRII 208 was the high yielder (38. 7 g/t/t) followed by RRII 118 (30.6 g/t/t), PB 86 (28.9 g/t/t) and RRIM 600 (28.7 g/t/t). In the third clone trial laid during 1995 with 10 clones, highest and lowest girth was recorded for PB 311 (38. 1 cm) and SCATC 93/114 (29.4 cm) respectively. In the fourth clone trial to assess GxE interactions with 13 clones, girth data showed RRII 429 to be the high vigour clone.

In the on farm trials conducted at Killamura, Tripura, girth data (at 150 cm) indicated better growth in RRII 203 (15.4 cm), followed Haiken 1 (14.9 cm), RRII 208 (13.7 cm), RRIM 600 (13.4 cm), PB 235 (11.3 cm) and PB 260 (11.2 cm). In another trial, eight potential clones *viz.*, RRII 118, RRII 203, RRII 208, PB 235, PB 260, RRIM 600, RRIM 703 and Haiken 1 are under evaluation at Bagafa. The clonal demonstration trial (BRTF – 1994-95) with PB 235, RRIM 600, RRII 105 and GT 1 has attained tappable girth. PB 235 exhibited higher girth followed by RRIM 600, RRII 105 and GT 1. Action has been taken to commence tapping.

3.2. Evaluation of polycross progenies

Among the full sib progenies of 26 combinations progenies PB 86 x SCATC 88/13, Gl 1 x RRIM 600, PB 86 x RRII 105 and PB 86 x GI 1 exhibited higher girth. The combinations with higher unit yield (g/cm) Gl 1 x RRIM 600 and PB 86 x SCATC 88/13 have been multiplied for an evaluation with RRIM 600 as check.

3.3. Evaluation and utilization of wild germplasm

The Brazilian accessions available at this Station are being maintained in the gene pool garden. Field grown plants of germplasm evaluation garden of 1993 attained a mean girth of 38.44 cm with an annual girth increment of 6.85 cm. Mean girth of plants of 1994 germplasm garden was 39.57 cm increment of 7.0 cm.

4. Studies on exploitation and physiology

4.1. Exploitation systems

Average annual yield for the three different tapping systems *viz.*, 1/2 S d/1, 1/2S d/2 and 1/2S d/3 in combination with four different winter temperature rests 0-0 °C, 10-10 °C, 15-15 °C and 20-20 °C showed that, in d/2 system of the 15-15 °C tapping, showed significant increase in yield (Table Net. 2). Due to higher incidence of

Table Net. 2. **Trend of yield (g/tree/month) in different tapping systems**

Month	1/2 S d/1	1/2 S d/2	1/2 S d/3
March	565	508	369
April	773	623	468
May	603	546	420
June	571	473	416
July	839	758	561
August	621	532	430
September	708	562	473
October	710	889	762
November	702	721	627
CD (P=0.05)	38.8	50.9	48.2

TPD and exhaustion of tappable bark, the d/1 tapping system was discontinued.

A tapping rest experiment in growers' field in RRII 105 under 1/2S d/2 system of tapping with different low temperature based rest reveled that the 12-12 °C rest treatment, considering the effective months, resulted in significant higher yield than that of the other combination of rest treatments *viz.*, the control, 10-10 °C and 15-15 °C. The occurance of TPD was negligible.

The experiment on tapping rest and frequency interaction studies was continued with two clones *viz.*, RRIM 600 and RRII 105. The results revealed that the yield was significantly different among the treatments. Maximum annual yield was 1605 kg/300 trees for RRII 105 and 2277 kg/300 trees for RRIM 600 were recorded for 1/2S d/2 6d/7 tapping system with two months rest (February and March). However, 1/2S d/3 6d/7 tapping system (5 stim) with two months rest (February and March) was comparable to 1/2S d/2 system.

4.2. Physiological studies

The experiment to assess the variability in polyclonal seedlings to withstand low temperature was continued. Based on certain growth parameters, a few seedlings contrasting in their growth (High vigour, HV and Low vigour, LV seedlings) were selected to comparative growth during winter season. Gas exchange studies were conducted on third fully expanded leaves from shoot apex. A higher mean assimilation rate of 8.27 mmole $CO_2/m^2/s$ was observed in HV seedlings compared to 2.9 mmole $CO_2/m^2/s$ in LV seedlings with the stomatal conductance of 0.26 mole and 0.22 mole respectively. At a given g_s, average low Ci (1065 ppm) in HV seedlings implies better mesophyll efficiency when compared to 1363 ppm of Ci in LV types. Selected seedlings were exposed to *in vitro* low temperature of 10 °C for two days to assess the chlorophyll degradation as an index of stress. The chlorophyll degradation was 7.2% over control in HV types where as 33.3% in LV types. A study on membrane leakage during the exposure of these selected seedlings to low temperature of same severity and duration revealed that LV plants suffer severe membrane leakage (56.6%) where as the HV plants recorded 40.5% of leakage.

5. Processing

A survey on processing of raw rubber in the north-eastern region was conducted and found that sheet making is the only method adopted in these regions except a centrifuging unit in Tripura owned by Tripura Forest Development and Plantation Corporation. It was also observed that 95% of the growers are processing the latex without sieving. Also 34% of the growers are still sun drying the sheets. Only 56% of the growers in the small growers sector are using the correct dosage of acid for processing. About 24% of the growers are not collecting the scarp rubber and the earth scrap is not at all collected anywhere in these regions. Processing campaigns were conducted in Guwahati, Tura, and Orissa. Quality sheet making was demonstrated at Tripura, Assam, Meghalaya, Mizoram, West Bengal and Orissa. Advisory service in processing and product manufacturing had been rendered to the interested parties. Over 2000 tones of imported rubber at Kolkata port was inspected for quality as per the standards.

6. Advisory services

The Mobile Soil and Tissue Testing Laboratory caters the needs of the growers of the entire north-eastern region. Soil and leaf samples were collected and analyzed and discriminatory fertilizer recommenda-

tions (DFR) are given based on the test results to the growers of the region. During the reported period DFR were given to 395 growers based on analysis of 790 samples collected from the growers' fields from West, South and North Tripura districts (Tripura), Cachar and Karimganj (Assam), Kolasib (Mizoram) and Jiribam (Manipur).

REGIONAL RESEARCH STATION, TURA, MEGHALAYA

The Regional Research Station, Tura conducts research on evaluation of clones, selection from polyclonal population, evolving suitable exploitation systems, aspects of slopes for plantation and disease and pest management under the agroclimatic conditions of Meghalaya.

1. Crop improvement

In the 1985 clone trial, girth and yield of 10 clones were recorded and results indicated highest girth in RRIM 600 (82.56 cm) followed by PB 235 (79.58 cm), RRII 203 (79.29 cm), RRII 18 (78.76 cm). PB 86 (75.8 cm) GT 1 (72.30 cm), RRIM 605 (71.65 cm), RRII 105 (68.69 cm), GT 1 (64.69 cm) and PB 5/51 (64.13 cm). RRIM 600 (45.40 g/t/t) ranked first yield in BO-2 panel and PB 5/51 (20.90 g/t/t) ranked lowest. In the 1986 clone trial, among the ten clones, PB 311 registered the highest girth (80.96 cm) and yield (37.90 g/t/t) while PR 255 and RRIC 105 registered the lowest girth and yield respectively. Average girth of clonal population was 62.0 cm while average yield of the population was 25.50 g/t/t and it varied from 12.0 g/t/t to 61.0 g/t/t. Budwood nursery of selected mother plants has been established for conducting further studies.

2. Cropping systems

Performance of rubber (RRIM 600) planted with tea and orange were evaluated. Rubber plants attained an average girth of 67.3 cm and the dry rubber yield was 23.5 g/t/t. About 601.5 kg of green tea leaves, which fetched a net income of Rs. 4511/- was harvested from 0.25 ha. The total expenditure for different operations in tea plantation was Rs. 4125/-.

During the year an experiment on the effect of different mulching on the growth of rubber seedlings was carried out. The rubber seedlings of the paddy straw-mulched plots were showed better growth, followed by mulching with broad leaves, bamboo leaves, black polythene and white polythene mulch respectively.

3. Plant physiology

In Garo Hills of Meghalaya, low winter temperature is one of the stress conditions, which adversely affect growth, yield and prolonged refoliation pattern. The share of girth increment in winter was 8% while that of summer, monsoon and post monsoon are 25, 50 and 17% respectively. Low yield also was recorded in winter period (19%) and 36% yield was recorded in post monsoon period. During winter period from November second week to last week of January the suitable time for tapping is 8.00 to 9.00 am. Clone RRII 203 showed maximum TPD (27.5%) while in RRIM 600 it was only 2.8%.

Performance of clone RRIM 600 was assessed at west-south-west (WSW) and north-north-east (NNE) aspects of slopes. Plants in WSW aspect of slopes showed vigorous growth (72.9 cm) and low yield (21.90 g/t/t) while NNE aspect plants showed lower growth (69.0 cm) and higher yield (23.30 g/t/t). In soil, organic carbon, P and K content was higher in NNE than WSW aspect and uptake of nutrients was more at NNE aspect of slope than WSW aspect of slope.

4. Pathology and microbiology

Visual survey for rubber diseases was carried out regularly during the year. It was observed that the outbreak of powdery mildew disease was severe in four locations and the PDI of powdery mildew at Jenggltchakgre, DDC, Danakgre and Damjonggre was 97.7, 97.5, 93.6 and 68.4% respectively. Repeated defoliation was noticed in these locations.

REGIONAL RESEARCH STATION, KOLASIB, MIZORAM

The Regional Research Station, Kolasib is conducting experiments mainly to identify suitable clones of rubber under Mizoram condition. In addition, the Station is also engaged to find out suitable tapping systems and optimum fertilizer dose to make rubber cultivation more economical.

1. Evaluation of clones

An experiment to identify suitable clones for this region, was in progress. Seven clones were planted in RBD design and the performance of these clones in different land forms *viz.*, foot hill, mid hill and hill top were recorded in terms of growth and yield. The highest mean girth was observed in the mid hill condition and the clone SCATC 93/114 showed the highest girth (Table Nez. 1). Though mean values are comparable, there was clonal variation in growth and yield in different land forms. Among the clones SCATC 93/114 did well in all the land forms.

2. Nutritional trial

This experiment was initiated to find out the optimum fertilizer dose of NPK combination in the foot lull condition. There are four fertilizer treatments in RBD design and the clone is RRIM 600.

Girth of RRIM 600 was highest (54.0 cm) with fertilizer combination of 35 : 35 : 35 kg N:P:K per ha. However, the annual girth increment was not significant among the treatments.

3. Effect of tapping systems on yield

The main objective of this experiment was to identify the suitable tapping system under Mizoram condition. The highest per tap (55.9 g/t/t) yield was observed in 1/2S d/4 system. However, the annual yield was highest (848 kg/300 trees) in 1/2S d/2 system due to higher number of tapping days.

Table Nez.1. **Clonal difference in girth (cm) and yield (g/t/t) in different land forms (February 2002)**

Clone	Foot hill		Mid hill		Hill top	
	Girth	Yield	Girth	Yield	Girth	Yield
RRII 105	70.9	38.2	64.5	36.8	64.7	34.5
RRIM 600	61.9	28.9	62.9	37.1	66.8	34.5
SCATC 93/114	73.9	49.9	77.9	42.3	82.8	43.3
RRII 300	73.1	47.5	71.3	42.0	70.0	42.4
RRII 118	72.1	38.0	76.3	38.9	67.2	34.2
GT 1	72.4	38.7	72.9	39.1	77.8	43.7
PB 235	79.2	39.7	77.3	42.0	71.0	45.8
Mean	71.1	40.1	71.9	39.7	71.5	39.4

REGIONAL EXPERIMENT STATION, NAGRAKATTA, WEST BENGAL

The Station is conducting experiments mainly to find out the suitable clones for the region, evolving appropriate fertilizer recommendations, suitable rubber based sustainable cropping systems and optimum exploitation systems. Thirteen experiments are in progress, out of which eight are on crop improvement, two each on crop management and cropping systems and one on exploitation system.

1. Crop improvement

In the 1990 clone evaluation trial with 11 clones, girth varied significantly among the clones. Clone SCATC 93/114 recorded highest girth (64.36 cm) and the lowest (52.97 cm) was in PB 5/51 (Table Nag. 1). The clones did not show any significant variation in rubber yield. However, maximum yield was recorded in SCATC 88/13 (67.79 g/t/t). In the trial started in 1990 with seven clones, girth increment and mean yield varied significantly among the clones. Clone RRIM 612 recorded highest girth (65.73 cm) and the clone RRII 208 recorded maximum yield (49.81 g/t/t/). During the second year of tapping annual mean yield varied significantly among the clones. RRIM 600 recorded maximum yield (37.68 g/t/t) and minimum was for SCATC 93/114 (17.87 g/t/t).

Table Nag.1. **Growth and yield of clones (1990 trial)**

Clone	Girth (cm)	Annual girth increment (cm)	Mean yield (g/t/t)
RRII 118	60.88	1.83	31.79
RRII 203	60.68	1.11	38.55
RRII 300	57.48	2.20	32.48
Haiken 1	63.30	1.65	23.03
SCATC 88/13	59.55	1.89	67.79
SCATC 93/114	64.36	2.74	40.37
GT 1	57.43	1.15	37.06
PB 5/51	52.97	0.91	30.52
PB 235	59.81	0.90	40.62
PB 311	57.85	0.06	46.79
RRIM 703	61.76	0.84	41.21
CD(P=0.05)	4.15	NS	12.84

The 1992 trail on the performance of different clone blends and in the Genotype x Environment (GxE) interaction trial started in 1996 with 12 clones the plants were maintained properly. Observations from the trial to evaluate germplasm for cold tolerance, indicated higher girth in MT 196 (28.81 cm) followed by RO 2629 (26.46 cm) and RO 5408 (26.18 cm) and the lowest (15.77 cm) was in AC 763.

2. Crop management

The nutritional trial with NPK, started in 1989, did not showed significant differences in girth, annual girth increment and rubber yield. In the 1993 trial to evaluate the effect of split applications of fertilizer on *Hevea* growth and yields showed that split doses could not induce any significant effect on girth, and rubber yield.

3. Cropping system

Two rubber based intercropping trials are in progress. The first experiment to study the feasibility of intercropping tea with rubber was continued. Difference in growth of tea was found to be non-significant among the treatments. Tea plants are growing well in all treatments irrespective of different spacing of rubber. Maximum tea collar diameter (23.98 mm) was recorded, where rubber was planted at a spacing of 10 m x 5 m. Maximum tea green leaf yield (2135 kg/ha) was recorded in pure tea area followed by T3 where rubber was planted at a spacing of 2 m x 2 .4 m along with tea. Another rubber based intercrop trial with areca nut was initiated during 2002. Rubber has established well where as areca nut plants are establishing slowly.

REGIONAL RESEARCH STATION, DAPCHARI, MAHARASHTRA

The major thrust areas of research of this station are the development of suitable planting materials and location specific agro-technology for this drought prone region. Experiments to evaluate low frequency tapping systems, irrigation requirement, screening of wild *Hevea* accessions for drought, studies on the growth and yield potential of various clones, polyclonal seeding trees etc. were continued.

1. Effect of irrigation on growth and yield

In the irrigation experiment started in 1987 observations on fortnightly cup lump weight, monthly girth measurements and seasonal DRC, PI and TP were recorded. The trees with basin irrigation system recorded comparatively high girth. Highest yield was recorded in 1.0 ETc basin irrigation (Table Dap. 1).

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

Treatment	Mean girth (cm) (April 01 – March 2002)	Mean dry rubber yield(g/t/t)
Control*	55.94	35.54
1.00 ETc basin	63.69	57.80
0.25 ETc basin**	64.47	37.40
0.50 ETc basin	61.26	38.81
0.75 ETc drip	61.77	38.94
0.25 ETc drip***	61.90	42.38
0.25 ETc drip	59.17	42.78
SE ±	0.949	2.770
CD (P = 0.05)	2.068	6.037

* No irrigation ** Earlier 0.75 ETc *** Earlier 0.50 ETc

In the other trial, fortnightly yield, monthly girth and seasonal DRC (%), PI, BI and TP were compared for two clones *viz.*, RRII 105 and RRII 118. Results indicated that RRII 118 performed better in terms of growth while RRII 105 showed better yield in response to different levels of irrigation treatments.

In the cost evaluation trial, the expense incurred towards various inputs, farm practices and irrigation were monitored since 1987 in irrigated and unirrigated trees of RRIM 600. Irrigated trees were divided into two parts with respect to soil depth and one being maintained under reduced irrigation to 1/5 ETc (deep soil) and 1.0 ETc (shallow soil) level on irrigation. No significant reduction in block yield and growth was observed in mature trees even after reducing the irrigation level to 1/5 of ETc of that under immature phase.

2. Exploitation studies

Two trials initiated for evolving the optimum stimulation schedule under 1/2S d/3 tapping system under irrigation were continued. Trial I was started in December 1999 with RRII 105. Stimulation treatments T0 (control, no stimulation), T1 (2/y), T2 (4/y) and T3 (6/y) were implemented as per schedule under irrigation (0.50 ETc). Observations on DRC before and after stimulation, annual girth increment and TPD were monitored. Among the various treatments cumulative yield kg/400 tree (kg/ha) was highest in T2 and T3 without significant effect in growth. Results indicated high rubber yield in the ethephon treated plants as compared to control. With a low incidence of TPD, ethephon stimulation (4/y) appeared to be optimum without any significant effect on growth under irrigation. No change in DRC was noticed after stimulation (Table Dap. 2).

During 1999, another experiment was started to study the tapping rest-cum-stimulation interaction under low frequency tapping system (1/2 S d/3) in clone RRII 105 under rain fed condition with an objective to find out best tapping rest period during summer. Observation on DRC before and

Table Dap. 2. **Performance of RRII 105 under 1/2S d/3 system of tapping with different stimulations**

Stimulation	Yield (kg/400 trees)	DRC		Girth increment (%)	TPD (%)	Yield (g/t/t)
		Before	After			
T0 Nil	1577.22	34.86	-	0.76	0	37.91
T1 (2/y)	1711.95	39.60	34.86	0.80	0	41.15
T2 (4/y)	2064.83	34.65	34.75	1.08	3.33	49.64
T3 (6/y)	2114.07	34.15	34.28	0.70	3.33	50.82
SE±				0.29		4.02
CD (P=0.05)				0.63		8.57

after stimulation, annual girth increment and TPD scoring are being monitored. Higher yield was observed in treatment with tapping rest in May and June with 4 stimulation/year, without any significant affect on the growth of trees. Results indicated that stimulation did not affect the DRC at all.

3. Evaluation of planting materials

In the clone trial, planted in 1985 fifteen modern clones are under evaluation. The trial was maintained under limited irrigation since 1985. Monthly girth, DRC, fortnightly yield recording was carried out. The result indicted that clone RRII 208 performed better in terms of growth (Table Dap.3) while RRII 6 recorded highest yield.

Two blocks of trees raised from polyclonal seedlings were planted in 1983 and 1985 to study the yield performance of polyclonal progeny under 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 categorized as high girth, low girth, high yielder, and low yielder trees. The selected trees were cut back to generate sprouts, which were used for multiplication by budding. Observation on fortnightly yield, seasonal girth increment, soil moisture measurement, and yield components were recorded. Based on the data good trees were identified multiplied for further evaluation in a small scale trial.

Table Dap. 3. **Growth and yield of *Hevea* clones in the 1985 trial**

Clone	Mean girth* (cm)	Mean dry rubber yield (g/t/t)
RRII 5	55.26	30.28
RRII 6	58.69	44.23
RRII 105	53.84	36.44
RRII 208	61.40	42.55
RRII 308	53.06	28.32
PR 255	53.28	31.61
PR 261	53.85	26.71
PB 260	56.06	28.09
PB 310	55.58	32.96
PB 311	53.83	33.09
RRIM 605	53.70	25.29
RRIC 52	60.64	23.07
RRIC 100	56.36	34.40
RRIC 102	56.91	31.42
RRIC 105	54.08	23.30
SE ±	1.98	4.33
CD (P=0.05)	4.06	8.85

* March 2002

4. Evaluation of germplasm accessions

Sixty four wild *Hevea* accessions along with three popular clones *viz.*, RRII 105, RRIM 600, Tjir 1 as a check were raised in polybags at nursery for screening against drought tolerance.

REGIONAL RESEARCH STATION, DAPCHARI, MAHARASHTRA

The major thrust areas of research of this station are the development of suitable planting materials and location specific agro-technology for this drought prone region. Experiments to evaluate low frequency tapping systems, irrigation requirement, screening of wild *Hevea* accessions for drought, studies on the growth and yield potential of various clones, polyclonal seeding trees etc. were continued.

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* March 2002

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REGIONAL RESEARCH STATION, DHENKANAL, ORISSA

The station concentrates its research activities to find out the suitable agromanagement techniques, water conservation, evaluation of suitable clones, tolerent to draught conditions, evolving appropriate fertilizer recommendations, etc.

1. Evaluation of clones

In the clone evaluation trial (1987) GT 1 recorded the maximum mean girth (59.7 cm) followed by RRIM 600 (58.4 cm) and lowest girth was observed in clone RRII 105 (54.4 cm) during March, 2002. The mean yield of 1072 kg/ha (RRIM 600), 944 kg/ha (RRII 105) and 828 kg/ha (GT 1) were recorded during 2001-2002.

In the clone evaluation trial (1990), clone SCATC 93/114 recorded the maximum mean girth (64.1 cm) followed by RRII 208 (60.0 cm), RRII 5 (58.5 cm), PR 255 (58.2 cm) and RRIM 600 (57.3 cm). Clones SCATC 88/13 (55.2 cm), RRIM 701 (54.6 cm) and Haiken 1 (55.5 cm) showed minimum girth. The mean maximum dry rubber yield of 1160 kg/ha was recorded in the clone SCATC 88/13 followed by RRIM 600 (1040 kg/ha), PR 255 (920 kg/ha), RRII 208 (892 kg/ha), RRII 5 (880 kg/ha) and the lowest yield was recorded in clone SCATC 93/114 (360 kg/ha).

In another trial started in1991, clones did not differ significantly on girth. Clones RRIC 102 (61.8 cm) and GT 1 (61.7 cm) recorded the highest mean girth closely followed by RRII 300 (59.6 cm). The lowest girth was observed in PR 255 (51.6 cm). The highest dry rubber yield in the first year of tapping was recorded in polyclonal trees (23.2 g/t/t) closely followed by PR 255 (23.0 g/t/t). In an on farm trial initiated during 1996 at RRL, Bhubaneswar with twelve clones, the clones PB 217, RRII 430 and RRII 417 recorded highest average girth. In the 1999 clone trial, the highest girth was observed in RRII 357 and IRCA 111 (both 12.6 cm) followed by PB 28/59 (11.9 cm).

2. Polyclonal trial

In the polyclonal seedling trial (1989), based on initial growth performance, 10 promising seedlings were identified for further selection and evaluation. Girth of the 10 selections recorded at 75 cm height from the plant base, varied from 85.8 to 101.2 cm. The performance of seedlings has been very good. Some 620 polyclonal trees have attained tappable girth (55 cm) at a height of 50 cm during August 2002. The mean yield of 1076 kg/400 trees was recorded in 100 tapping days during 2001-2002 (3rd year of tapping).

3. Nutritional studies

In the trial to study the effect of water-soluble and water-insoluble forms of P on growth of *Hevea*, application of 40 kg N, 40 kg P_2O_5 and 16 kg K_2O per ha was found to be superior in influencing the growth of *Hevea*. In another trial initiated during 2000-01 in seedling nurseries, maximum girth, plant height and number of whorls was observed in seedlings treated with 600 kg N, 150 kg P_2O_5 and 120 kg K_2O/ha.

4. Weed management

This trial was initiated to study the effect of herbicides on control of noxious weed *Imperata cylindrica* and other weeds in the rubber plantations. The treatment Glyphosate (3 L/ha) followed by Glyphosate (1.5 L/ha) at 50% regeneration of weeds was effective in controlling the weeds than other herbicide combinations. Further data on the efficacy of herbicides in control of *Imperata cylindrica* and other weeds is being generated. The experiment is in progress.

5. Soil moisture studies

This experiment was initiated in 2001 to study the effect of soil moisture stress on the growth and yield of rubber *Hevea* recorded maximum growth during June to November. During the rest of the months low girth increment was noticed due to soil moisture stress and high temperature.

6. Weather

Total rainfall during the period (2001) was 2116.8 mm with 85 rainy days. The highest mean maximum temperature of 43.4 °C was recorded during the month of May 2001. The highest mean minimum temperature of 25.9 °C was observed in May 2001, against the lowest minimum o f 11.5 °C in January 2001 at Kadalipal research farm. Lowest mean relative humidity (35%) was observed during the month of May in after noon hours. Mean bright sun shine hours/day varied from 1.8 (June and July) to 8.7 (April) while, the evaporation varied from 1.8 mm/day (July) to 5.8 mm/day (May).

REGIONAL RESEARCH STATION, SUKMA, CHATTISGARH

The station conducts experiments on evaluation of modern clones, polyclonal seedlings and screening of germplasm materials for drought/cold tolerance.

In the *Hevea* germplasm trial for drought tolerance, growth of various genotypes was satisfactory. Rondonia genotypes with the highest girth up to 44 cm showed best performance. The highest number of primary branching was recorded in RO 5069 and MT 196 and the lowest in AC 707.Hailstorm has severely affected the experimental area resulting in damage to a large number of trees. The Acre genotypes are showing poor growth. The polyclonal population showed good growth with large variation.

The station was redesignated as a rubber demonstration centre during 2002.

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 objectives of identifying clones suited to the region and evaluating clonal tolerance to drought/disease incidence. The field trials laid out include evaluation of germplam material, screening of clones for timber/latex traits, investigations on Genotype x Environment interaction, large scale testing of potential hybrid clones/clone evaluation, irrigation/water requirement studies, disease evaluation of clones and study of cropping systems.

1. Physico-chemical characterization of soil

The experiment was initiated to generate a database on soil physico-chemical properties. Physical and chemical analysis of soil sample collected from the different profiles is in progress.

2. Water requirement studies

The experiment initiated in immature rubber with irrigation levels at IW/CPE ratio's of 0.3, 0.6, 0.9, 1.2 and an unirrigated control was continued. A rooting depth of

Table Pad.1. **Performance RRII 105 under irrigation**

Treatment	Number of irrigations	Girth (days after irrigation)				
		Pre-treatment	45	75	105	135
IW/CPE 1.2	11	6.48	7.29	7.43	8.43	8.94
IW/CPE 0.9	8	6.50	7.19	7.52	8.32	8.88
IW/CPE 0.6	5	7.07	7.76	7.87	8.73	9.30
IW/CPE 0.3	2	6.36	6.79	6.95	7.74	8.27
Control	nil	6.28	6.64	6.47	7.12	7.71
SE		0.25	0.26	0.19	0.27	0.25
CD (P=0.05)		NS	NS	0.61	0.83	0.77

75 cm was considered for the second year and depth of irrigation water was fixed at 5 cm. The area of root zone to be wetted was taken as 180 x 200 cm^2. The net plot size was 4 x 4 trees. Two border rows were left between treatments. Growth observations recorded at periodic intervals indicated that irrigation significantly increased the girth of plants (Table Pad. 1). Irrigation at the rate of IW/CPE ratio 0.6 and above resulted in significant increase in growth of seedlings.

3. Performance of rubber + cashew cropping system

Observations on growth in the trial on inter-planting of cashew in rubber initiated in June 2001 was continued. Banana and pineapple planted in the available interspaces commenced yielding. Growth of rubber and cashew monitored at regular intervals was found to be satisfactory.

HEVEA BREEDING SUB-STATION, NETTANA, KARNATAKA

The major thrust areas of the Hevea Breeding Sub-Station, Nettana are to evaluate clones under different biotic and abiotic stresses, to identify clones suitable for commercial cultivation and to develop exploitation and crop protection methods suitable for the region. Research on yield improvement, exploitation systems, crop improvement and crop protection were continued in the experimental farm comprising of 47.6 ha area.

1. Exploitation systems

This constitutes two experiments, one planted in 1987 and the other in 1988 aiming at evaluating the effectiveness of different tapping systems in terms of yield and growth of clones. Each experiment comprises of five clones planted in a split-pot design. In the first trial, PB 235 was superior in growth in terms of average girth (79.34cm) while RRII 300 was poor in growth (64.21 cm). In the second trial, clone RRII 118 showed better growth (81.30 cm) while PR 255 registered poor growth (57.91 cm).

The trial planted during 1987 is in the fifth year of tapping. Results revealed significant variation for yield among the clones and months as well as interaction between these factors. However, there was no significant difference for yield among the tapping systems employed. Among the clones under study, PB 260 registered the highest yield of 583.05 g/tree/month while RRII 300 recorded the lowest of 341.63 g/tree/month. The peak yielding months were December (696.03 g/tree/month) followed by November (689.30 g/tree/month) and October (637.99 g/tree/month) (Tables Kar. 1 & 2).

Table Kar. 1. **Performance of clones**

Clone	Mean yield (g/tree/month)
RRII 105	543.80 b
RRII 300	341.63 a
PB 235	557.92 b
PB 260	583.05 b
PB 311	564.72 b

Means followed by same letters are not significantly different by Tukey's B test at 5% level (P=0.05).
ns-Non-significant

Table Kar. 2. **Average monthly yield performance (1987 trial)**

Month	Mean yield (g/tree/month)
2000	
April	336.441 a
May	470.052 cd
June	572.081 e
July	513.488 de
August	470.872 cd
September	423.975 bc
October	637.994 f
November	689.229 f
December	696.032 f
2001	
January	507.424 de
February	396.030 ab
March	504.997 de

*Months followed by same letters are not significantly different by Tukey's B test (P=0.05).

2. Crop improvement

In all the trial for evaluation of ortet clones, GT 1 recorded better girth compared to RRII 105 and RRIM 600. Five ortets *viz.*, O 17, O 47, C1/2 , C 42 and T2 in trial 1 recorded better growth in terms of average girth. Similarly, one clone in trial 2 (T1) and four in trial 3 (O 26, O55, O 56 and C 140) registered better average girth over the control clones. The initial yield data for three months revealed that RRII 105 had the maximum average yield of 52.72, 54.26 and 58.31 g/ tree/tap in the three experiments respectively, and it out yielded all the trial clones.

In the large scale clone evaluation trial RRII 203 recorded maximum growth (80.23 cm) while Haiken 1 registered poor growth (50.77 cm). In the 1990 clone evaluation trial, PB 235 registered maximum growth (67.23 cm) while Tjir 1 exhibited poor growth (53.51 cm). The 1989 experiment was opened for tapping. In the three composite clone trials planted during 1991, nine clones (RRII 203, RRII 300, PB 217, PB 235, PB 260, PB 310, PB 311, RRIC 100 and LCB/1320) in trial 1, five clones *viz.*, RRII 3 RRII 5, RRII 118, RRII 308 and Nab 17 in trial 2 and five clones (PB 5/51, PB 28/59, HP 83/224, HP 83/225 and HP 83/236) in trial 3 recorded higher average girth than the standard. Clone GT 1 recorded an average girth of 55.30 cm. All these clones exhibited better growth than the popular clones, RRII 105 and RRIM 600.

In the experiment for the genetic evaluation of 12 clones and their respective half-sib progenies planted during 1990, clone PB 235 registered the highest average girth of 74.51 cm while IAN 45/873 showed poor growth (48.87 cm). Among the half-sibs, the progenies of clone PB 235 registered the highest average girth (90.66 cm) while the progenies of PB 213 showed poor growth (74.18 cm).

For evaluation of 400 series hybrid clones in this regions, a trial was initiated during 2000 with 6 promising hybrid clones *viz.*, RRII 430, RRII 407, RRII 414, RRII 422, RRII 429 and RRII 430 along with the parents RRII 105 and RRIC 105. Observations on growth in terms of girth and other morphological characters were commenced.

3. Crop protection

Disease survey on *Corynespora* leaf fall (CLF) disease was carried out in different locations in coastal Karnataka and adjoining North Malabar region of Kerala. Results of the survey conducted during 2002 season indicated that the disease incidence was increasing and spreading towards tradi-

tional rubber growing regions of Kerala (Table Kar. 3). However, as compared to previous years intensity was found considerably reduced during 2002.

Table Kar. 3. **Incidence and severity of CLF diseases in 2002 season**

Location	Infection (%)	PDI
Thirthahalli	16.66	5.20
Sagar	20.00	4.40
Kundapur	60.00	14.88
Belthangady	60.00	17.60
Puttur	100.00	33.86
Sullia	100.00	35.66
Madikeri	80.00	19.75
Subramnya	100.00	20.33
Kasaragod	72.72	23.50
Kanhangad	81.81	26.22
Nileshwar	71.42	19.20
Taliparamba	73.33	19.09
Sreekantapuram	71.42	13.20
Thalassery	66.66	14.00

In coastal Karnataka, lower disease intensity was recorded in Thirthahalli and Sagar. Higher intensity was at Sullia followed by Puttur. In North Malabar region, Kanhangad recorded higher intensity followed by Nileshwar and Taliparamba. Comparatively lesser intensity was recorded in Sreekantapuram and Thalassery areas. The high yielding clone RRII 105 has occupied maximum area in these locations and was found to be highly susceptible for *Corynespora* leaf fall disease in all the locations surveyed.

In the continuing efforts to identify efficient control measures to CLF disease, a study was carried out to evaluate the new generation water based fungicides in immature plantation. Among the treatments tested SAAF @ 2g/L was found to be superior as compared to effective fungicides like Bavistin and Mancozeb.

Experiment on testing the efficacy of different concentration of dust formulations of Hexaconazole in controlling *Corynespora* leaf fall disease in mature plantation was continued. Results indicated that the 2% Hexaconazole dust afforded better control over the CLF disease as in previous years. Performance of 1% Hexaconazole was comparable with that 2% Hexaconazole dust (Table Kar. 4).

Table Kar. 4. **Efficacy of Hexaconazole* in CLF disease management**

Treatment	PDI
Hexaconazole 2%	14.60
Hexaconazole 1%	18.50
Control (untreated)	38.20

* Dosage 9 kg/ha dust

Screening of different *Hevea* clones for CLF disease infection was done under natural infection in field as well as in nursery and in laboratory by detached leaf method by artificial inoculation. Results of the study indicated that the intensity was comparatively more in nursery as compared to field condition. Among the recommended and popularly cultivated clones, clone RRII 105 showed higher susceptibility as compared to other clones. Similar range of disease intensity and susceptibility was noticed in the clones PR 255, PR 261 and PB 28/83.

HEVEA BREEDING SUB-STATION, PARALIYAR, TAMIL NADU

Kanyakumari district of Tamil Nadu is favoured by a climate suitable for good seed set and the area is well known for the rare occurrence of *Phytophthora* and pink diseases. In order to take advantage of these climatic factors, two systematically laid out breeding orchards consisting of a total of 51 parental clones were established in an area of 5.0 ha. Emphasis was also given to identify planting materials suitable for the particular agro-climate.

1. Evolving high yielding clones

With a view to evolve clones with high latex combined with higher yield of timber (Latex-timber clone) hand pollinations were attempted at different parental combinations with pollen of germplasm collections and pipeline clones. Hand pollinations were also attempted to evolve clones tolerant to *Oidium*. The resultant hybrids were raised for evaluation at nursery stage. The hybrids obtained on hand pollinations carried out during 2000 and 2001 were also maintained for preliminary evaluation.

2. Evaluation of Clone

The station maintained and monitored three large-scale clone evaluation trials at Government Rubber Plantations at Keeriparai. Out of the popular clones being tested in a block trial, RRIC 102 continued to exhibit the maximum growth in terms of average girth (64.4 cm) at the 7th year followed by PB 235 (63.26 cm). In the Large Scale Clone Trial, IRCA 111 was found to be the most vigorous clone (63.18 cm) closely followed by IRCA 230 (62.36 cm) (Table Par. 1). Both these trial areas were opened for regular tapping during the month of November, 2001 and the yield is being recorded every month.

The third trial on the identification of clonal composites was well maintained and observations are being recorded at quarterly intervals. Out of the eight combinations of clones the fourth combination consisting RRII 5 (15%), PB 235 (35%) and RRII 105 (50%) exhibited the maximum mean girth (59.13 cm) and maximum tappability percentage (93.45%) at seventh year.

Table Par.1. **Performance of clones at Keeriparai**

Clone	Girth (cm) (7th year)	Tappability (%) at opening
RRII 105	53.71	18.48
RRIM 703	61.22	64.12
PB 255	62.21	75.55
PB 314	60.65	74.55
PB 330	58.14	66.88
PB 28/59	53.05	31.44
IRCA 18	55.16	35.58
IRCA 109	59.66	74.39
IRCA 111	63.18	79.17
IRCA 130	55.56	36.11
IRCA 230	62.36	78.64
General mean	58.63	57.72
SE	2.17	11.73

The block trial of six pipeline clones at Vaikundam Estate was well maintained and observations on the growth parameters are being recorded at quarterly intervals. Advanced planting materials of the four clones namely RRII 414, RRII 417, RRII 429 and RRII 430 were raised for block trial in New Ambadi and Velimalai Estates.

3. Polyclonal seed garden

This project envisages to establish a series of polyclonal seed gardens in this region with modern high yielding clones as parents. One of such seed gardens with nine high yielding clones as parents, was established during the year 2000 at New Amabdi Estate. Stock seedlings were raised for producing planting materials of laying out a second seed garden during 2004 in an area of 20 ha at Keeriparai Division of Government Rubber Plantation.

4. Standardization of root trainer planting technique

A comparative study on the cost of production of root trainer and polybag plants have shown that advanced planting materials of *Hevea* could be raised in root trainers at less than half the cost of production of polybag plants. The cost towards transportation, distribution and field planting could also be reduced significantly, compared to polybag plants.

The performance of polybag and root trainer plants on transplanting to the field was closely monitored both at Churulacode and Thirunanthikarai. The root trainer plants were noticed to out perform the polybag plants in both these places. Planting materials were raised for field planting one block each of root trainer and polybag plants of RRII 417 and RRII 429 at Velimalai Estate during the planting season in 2002.

LIBRARY AND DOCUMENTATION CENTRE

The library continued its important role of communicating and disseminating information on natural rubber and allied subjects through its library collection, information services and publications. The library facilities were also extended to all who are related to natural rubber industry.

During the year, 254 books and 1722 bound volumes of journals were added to the stock of the library. The library subscribed 147 journals and about 85 other journals were also received as gift/exchange. Documentation List, Rubber Alerts, New Additions list and Current List of Periodical Publications were distributed. Literature searches from AGRIS, HORTCD and RAPRA CD were carried out.

The library compiled a directory namely *Directory of Rubber and Allied Organizations* consisting of postal addresses of 272 rubber and related organizations/institutions in India and abroad. Vol. 14 of *Indian Journal of Natural Rubber Research 2001* and *RRII Annual Report 1999-2000* were published and distributed under the period.

The centre also engaged in sales promotion/distribution of all RRII publications *viz., Natural Rubber: Agromanagement and Crop processing* (NRACP), *Indian Journal of Natural Rubber Research, Rubber Wood: Processing and Utilization, Plant and Soil Analysis* and *RRII Annual Report*. During the period, 95 copies of NRACP were distributed.

AGROMETEOROLOGY

1. Rainfall of the rubber growing areas

Steps were taken to assess the impact of shifting cultivation, deforestation *etc.* on the rainfall behaviour of the rubber growing areas. Rainfall data from raingauge stations were grouped into midland (east), midland (west), coastal stations, high ranges and special zone. The percentage decrease of rainfall from first to second half of the century was calculated. The midland (east) showed a decrease of 20% followed by high range (18%), midland (west; 12%), special zone (8%) and coastal stations (3%).

2. Studies on the crop-weather relations

At HBSS, Nettana, influence of local weather on triggering and subssequent development of CLF disease has been studied. A maximum temperature of 34 to 36 °C and a minimum temperature of 17 to 20 °C, a morning humidity of more than 85% and an afternoon humidity of less than 40% with a minimum sunshine duration of 8 hours per day are the essential pre-requisites for the triggering and development of CLF disease at Nettana.

3. Studies in NE India

Attempts were made to evaluate and identify areas in the Northeast India conducive for rubber plantation on the basis of spatial patterns of annual volume, concentration and inter-annual variability of rainfall. The study was conducted with the help of 120 raingauge stations selected from a total of 335 stations in the North-East and data was collected for a duration of 15 to 67 years of monthly rainfall.

The stations were plotted on to a map grid with the respective parameters of Mean Annual Rainfall, Mean Precipitation Concentration Index (PCI-which gives the homogeneities of rainfall at a station). Normalized Precipitation Anomalies and their respective Coefficients of Variation were plotted against each station. Land areas based on different values of PCI and the mean annual rainfall were demarcated and subsequently four subdivisions were identified for the relative performance of rubber plantation in the non-traditional belt. These were classified as Optimal, Sub-optimal, Moderate and Marginal. These were construed with the base value of optimum rainfall fixed as 2000-3000 mm (non-traditional optimum).

Most of the area in the north-east lie in the above 2000 mm mark of mean annual rainfall. This includes about 36% of the area under the 2000-3000 mm mark. With respect to homogeneities of rainfall, less than 7% of the area showed low seasonality of rainfall distribution.

The meteorological data recorded at different stations are summarized in Table Agromet. 1.

Table Agromet. 1. **Agrometeorological report from different research stations (2001)**

Month	Temperature (°C)		RH (%)		Wind speed (km/h)	Rainfall (mm)	Sunshine (h)
	Maximum	Minimum	Morning	Afternoon			
KOTTAYAM, KERALA							
January	32.9	22.5	85	53	1.4	7.0	023.0
February	33.1	23.4	91	56	1.5	8.0	047.6
March	34.5	24.3	88	52	2.0	8.3	027.6
April	33.6	24.1	93	66	1.5	6.5	367.0
May	32.1	24.6	92	69	1.5	6.4	240.0
June	29.5	22.9	96	86	1.3	3.3	657.2
July	29.1	22.8	95	79	1.2	4.6	600.7
August	29.7	23.4	96	75	1.6	5.6	284.9
September	31.4	23.1	93	68	1.3	6.4	414.8
October	30.6	23.3	94	71	1.1	6.2	353.7
November	31.7	23.1	94	65	0.9	6.2	149.6
December	32.8	22.0	88	58	0.8	7.8	030.0

Month	Temperature (°C)		RH (%)		Wind speed (km/h)	Rainfall (mm)	Sunshine (h)
	Maximum	Minimum	Morning	Afternoon			
CES, CHETHACKAL, KERALA							
January	33.6	20.4	87	53	1.5	7.1	065.5
February	34.3	21.2	91	59	1.0	8.6	068.8
March	35.3	22.3	92	57	1.3	-	069.0
April	33.5	22.3	94	61	0.8	-	458.5
May	33.0	23.0	93	68	0.9	7.4	144.0
June	29.5	20.9	93	81	1.2	3.6	567.1
July	28.9	21.7	94	80	1.5	4.4	661.0
August	29.5	22.2	94	77	1.9	4.8	335.5
September	32.0	21.9	96	71	1.4	5.7	244.9
October	31.2	22.2	94	71	0.9	5.0	503.9
November	32.4	21.8	94	65	0.8	5.6	291.1
December	33.8	20.4	89	52	1.4	7.8	012.0
DAPCHARI, MAHARASTRA							
January	31.4	13.8	91	71	1.5	8.6	000.0
February	33.2	12.9	86	60	1.4	9.2	000.0
March	33.9	17.7	89	80	1.7	9.2	000.0
April	37.9	21.4	86	70	2.1	9.9	000.0
May	36.1	22.9	84	68	4.0	9.5	003.8
June	31.0	21.6	91	80	3.8	4.1	753.1
July	29.9	19.9	96	83	2.0	2.0	718.3
August	30.2	19.9	97	85	0.6	3.5	655.3
September	33.5	21.9	16	80	0.2	3.9	125.2
October	34.5	21.3	91	70	0.2	6.6	096.9
November	35.6	16.6	85	39	0.7	7.7	000.0
December	34.5	14.3	87	41	0.8	6.8	001.9
NETTANA, KARNATAKA							
January	34.8	16.8	87	34	3.6	7.8	000.0
February	35.6	19.9	89	40	1.3	8.0	000.0
March	36.0	20.1	87	36	4.2	8.3	000.0
April	35.4	23.0	90	49	2.0	7.3	148.0
May	33.5	23.5	91	66	1.7	6.3	095.2
June	28.5	22.7	93	84	-	1.8	907.8
July	28.2	22.4	93	86	-	2.0	1217.3
August	27.4	22.8	93	84	-	1.6	1109.1
September	31.4	22.2	91	67	-	5.4	320.7
October	31.4	22.3	91	70	-	5.6	271.3
November	33.5	20.9	89	55	-	6.9	138.2
December	33.8	17.3	82	39	-	7.6	003.0
PARALIYAR, TAMIL NADU							
January	32.4	21.5	90	55	-	6.2	087.3
February	34.2	20.9	93	54	-	7.9	012.0
March	35.8	22.1	92	54	-	8.1	034.6
April	33.5	23.1	96	71	-	4.7	314.5
May	32.9	24.4	90	68	-	3.6	099.4
June	30.8	24.2	88	74	-	4.9	235.4
July	30.8	23.3	88	69	-	5.5	195.3
August	30.4	23.8	91	73	-	5.0	110.6
September	32.0	22.3	93	67	-	6.4	361.7
October	30.8	22.6	94	76	-	5.0	258.4
November	31.3	22.1	97	76	-	5.1	289.0
December	31.9	21.5	95	65	-	7.4	044.1

Month	Temperature (°C)		RH (%) (Daily mean)	Wind speed (km/h)	Rainfall (mm)	Sunshine (h)
	Maximum	Minimum				
AGARTALA, TRIPURA						
January	25.8	7.8	66	1.3	0.0	8.1
February	29.0	12.9	69	2.5	58.8	7.9
March	32.7	17.3	64	2.4	54.2	8.4
April	34.5	22.1	69	5.8	51.4	8.3
May	31.4	22.5	82	2.6	467.7	5.3
June	31.0	24.6	83	4.6	486.8	3.7
July	32.2	25.1	82	4.8	173.6	5.0
August	32.8	25.3	81	3.0	295.8	5.3
September	32.2	24.8	82	2.9	187.0	6.0
October	31.4	23.2	84	1.4	195.6	6.0
November	29.7	18.2	80	0.9	53.0	6.8
December	26.6	11.6	73	0.8	0.0	7.3
GUWAHATI, ASSAM						
January	24.3	11.2	71	2.4	0.0	6.5
February	27.1	13.5	69	3.5	23.0	6.9
March	30.9	14.6	65	3.2	9.0	8.0
April	33.0	18.4	76	2.2	154.0	6.5
May	32.3	22.2	81	1.6	404.4	5.8
June	32.9	24.7	86	1.1	110.3	3.7
July	33.3	24.9	87	0.9	518.4	4.3
August	33.8	24.5	85	0.9	298.1	7.0
September	32.1	23.6	88	0.9	326.2	4.2
October	30.8	20.9	87	1.0	173.4	5.3
November	29.5	16.7	78	1.2	0.0	6.2
December	25.7	12.3	76	1.6	0.0	6.1
TURA, MEGHALAYA						
January	23.8	7.8	66	1.2	5.0	6.7
February	26.5	9.5	60	1.8	2.0	6.5
March	30.5	12.8	52	2.0	0.0	8.3
April	32.7	16.4	63	2.0	71.0	8.2
May	30.6	19.3	80	1.4	341.0	5.5
June	30.6	21.6	84	1.6	179.0	4.7
July	31.1	22.1	86	1.4	254.0	3.0
August	31.3	21.1	84	0.8	393.0	3.6
September	30.4	19.2	83	0.9	265.0	3.8
October	29.9	17.1	80	1.4	327.0	4.8
November	28.0	13.3	77	0.8	0.0	5.0
December	25.5	8.9	66	0.6	0.0	6.3
NAGRAKATTA, WEST BENGAL						
January	23.7	7.3	74	1.7	4.5	5.9
February	26.7	10.9	72	2.0	0.0	4.9
March	30.4	13.1	66	2.9	190.0	6.3
April	32.0	18.2	72	3.4	88.5	7.1
May	31.8	22.1	79	2.6	434.4	5.7
June	32.2	24.0	84	2.8	434.2	4.1
July	32.1	25.0	89	2.3	552.9	3.1
August	32.8	24.8	86	2.0	650.6	4.2
September	31.1	23.8	87	1.7	460.4	4.3
October	30.8	19.1	82	1.3	522.0	7.0
November	28.8	15.0	76	1.2	43.3	7.7
December	25.4	8.8	76	1.0	5.4	6.7

Month	Temperature (°C)		RH (%) (Daily mean)	Wind speed (km/h)	Rainfall (mm)	Sunshine (h)
	Maximum	Minimum				
KOLASIB, MIZORAM						
January	27.1	9.5	72	0.6	0.0	7.3
February	28.9	11.8	70	1.3	91.8	6.3
March	32.8	14.9	67	2.1	107.2	7.7
April	35.6	19.2	68	1.5	321.8	7.8
May	33.9	20.1	78	0.4	253.1	5.3
June	33.9	22.3	83	0.1	556.4	3.7
July	34.3	22.5	83	0.1	529.6	3.5
August	35.2	23.1	84	0.0	369.6	5.5
September	34.7	22.8	84	0.1	297.2	5.4
October	33.5	22.0	85	0.01	169.2	5.4
November	31.4	18.8	84	0.0	100.4	6.0
December	27.8	12.1	82	0.7	0.0	6.7
DHENKANAL, ORISSA						
January	28.6	11.4	60	0.4	0.0	7.0
February	33.1	16.7	61	0.5	0.0	8.0
March	35.5	21.8	64	0.9	7.0	7.1
April	38.1	24.1	65	0.6	2.0	8.6
May	41.2	25.8	59	1.2	54.3	7.7
June	32.8	24.8	79	0.5	206.6	3.5
July	30.2	24.6	85	0.2	815.4	3.7
August	31.5	25.3	83	0.1	668.6	3.6
September	32.9	24.8	82	0.6	121.2	6.1
October	31.9	23.6	82	1.0	177.7	7.2
November	29.9	20.6	87	1.8	64.0	6.4
December	27.7	12.9	74	0.1	0.0	7.5

PUBLICATIONS

RESEARCH ARTICLES

Alam, B. and James, J. (2002). Over production of photosynthetic electrons is associated with chilling injury in green leaves. *Photosynthetica*, **40**(1): 91-95.

Annamalainathan, K., Krishnakumar, R. and Jacob, J. (2001). Tapping-induced changes in respiratory metbolism, ATP production and reactive oxygen species scavenging in *Hevea*. *Journal of Rubber Research*, **4**(4): 245-254.

Chaudhury, M., Sarma, A. C., Pal, T.K., Chakrabarty, S. K. and Dey, S. K. (2001). Available nutrient status of the rubber (*Hevea brasiliensis*) growing soils of Tripura. *Indian Journal of Natural Rubber Research*, **14**(1): 66- 70.

Chaudhury, M., Sarma, A.C., Pal, T.K., Chakraborty, S.K. and Dey, S.K. (2001). Available nutrient status of the rubber (*Hevea brasiliensis*) growing soils of Meghalaya, Mizoram, Manipur and Southern part of Assam. *National Seminar on Approaches for Increasing Agricultural Productivity in Hill and Mountain Ecosystem*. 18 - 20 October 2001, Umiam, Meghalaya, India, p.126.

Das, G., Alam, B., Raj, S., Dey, S. K., Sethuraj, M. R. and Mandi, S. S. (2002). Over-exploitation associated changes in free radicals and its scavengers in *Hevea brasiliensis*. *Journal of Rubber Research*, **5**(1): 28-40.

George, E. S., Nair, R. B., Maheepala, C., Leena, K. K. and Punnoose, K.I. (2001). Influence of soil inorganic phosphorus fractions on leaf phosphorus status in *Hevea brasiliensis*. *Indian Journal of Natural Rubber Research*, **14**(1): 75-78.

George, K. M., Rajamal, G., Peethambaran, N. R. and Mathew, N. M. (2001). Enzymatic deproteinization of natural rubber latex. *Indian Journal of Natural Rubber Research*, **14**(1): 7-13.

George, K. M., Varkey, K. J., Thomas, K. T. and Mathew, N. M. (2002). Epoxidised natural rubber as a reinforcement modifier for silica filled nitrile rubber. *Journal of Applied Polymer Science*, **85**: 292-306.

George, K. T. (2001). Economic reforms and its consequences on natural rubber sector in Kerala. *National Seminar on Globalisation and its Impact on Indian Economy*, 20-21 October 2001, Department of Economics, Fatima Matha National College, Kollam, India.

George, K. T. (2001). Natural rubber sector in India in the era of globalisation. *Round Table Meeting on Commodity Development in Asia*, 19-22 November 2001, Common Fund for Commodities, Kochi, India.

George, K. T. and Joseph, T. (2002). The genesis of WTO and the aftermath. Rubber Research Institute of India, Kottayam, India, 54 p. (Monograph).

Gupta, C., George, E. S., Punnoose. K. I., Rao, K. N. and Edathil. T. T. (2001). Rubber (*Hevea brasiliensis*) plantations in Orissa; Some ecological considerations with reference to soil properties. *National Seminar on Plant Resource Management for Sustainable Development*, 25-26 March 2001, Bhubaneswar, India, pp 49-50.

Gupta, C., Rao, K. N., Edathil. T. T. and Saraswathyamma, C. K. (2001). Early performance of elite clones and polyclonal seedlings of rubber (*Hevea brasiliensis*) in lateritic soils of Orissa. *Seminar on Plant Resource Management for Sustainable Development*, 25-26 March 2001, Bhubaneswar, India, pp. 50-51.

Idicula, S. P., Rajalakshmy, V. K., Joseph, A., Manju, M. J., Prem, E. E. and Edathil, T. T. (2002). Management of root disease caused by *Phellinus noxius* and *Poria vincta* in rubber plantations. *National Symposium on Crop Protection and WTO : An Indian Perspective*, 22-25 January 2002, Central Plantation Crops Research Institute, Kasaragod, India.

Jayasree, P. K., Sunitha, S. S. and Thulaseedharan, A. (2001). Effect of cytokinins on *in vitro* germination of *Hevea* somatic embryos. *Symposium on Natural Rubber Research*, 2001, CIRAD, France.

Jayasree, P. K., Thomas, V., Saraswathyarnma, C. K. and Thulaseedharan, A. (2001). Optimization of parameters affecting somatic embryogenesis in *Hevea brasiliensis*. *Indian Journal of Natural Rubber Research*. **14**(1): 20-29.

Jose, M. and Korah, A. C. (2002). Directory of rubber and allied organizations. Rubber Research Institute of India, Kottayam, 54 p.

Jose, V. T., Joseph, T. and Veeraputhran, S. (2001). Problems and prospects of bee-keeping in rubber plantations in India. *Proceedings of the Sixth Asian Apicultural Association (AAA) International Conference and World Api Expo*, 24 February –1 March 2002, Bangalore, India.

Joseph, A. and Manju, M. L. (2002). Control of Coryenespora leaf disease in rubber nurseries. *National Symposium on Crop Protection and WTO : An Indian Perspective*, 22-25 January 2002, Central Plantation Crops Research Institute, Kasaragod, India.

Joseph, T. and George, K. T. (2002). Duty exemption and remission schemes: Case for review. *Economic and Political Weekly*, **37**(10): 909-910.

Joseph, T. and George, K. T. (2002). WTO and natural rubber sector in India. Rubber Research Institute of India, Kottayam, India, 111 p.

Karunaichamy, K., Vijayakumar, K.R., Thomas, K.U., Rajagopal, R. and Anilkumar, D. (2001). Response of rubber trees (*Hevea brasiliensis* Muell. Arg., Clone RRII 105) to low frequency tapping systems. *Indian Journal of Natural Rubber Research*, **14**(2):79-87.

Krishnakumar, R., Annamalainathan, K., Simon, S.P. and Jacob, J. (2001). Tapping panel dryness syndrome in *Hevea* increases dark respiration but not ATP status. *Indian Journal of Natural Rubber Research*, **14**(1): 14-19.

Krishnakumar, R., Annamalainathan, K., Simon, S. P. and Jacob, J. (2001). Oxidative stress leads to inhibition of mevalonate pathway in *Hevea brasiliensis*. *National Symposium on Metabolic Pathway Studies for Crop Improvement*, 13-15 December 2001, CPMB, TNAU, Coimbatore, India p. 68.

Krishnakumar, R., Kornish, K. and Jacob, J. (2001). Rubber biosynthesis in tapping panel dryness affected *Hevea* trees. *Journal of Rubber Research*, **4**(2): 131-139.

Mandal, D., Singh, R.P., Chaudhuri, D, Sarma, A.C. and Deka, H.K. (2001). Influence of rubber cultivation on physico-chemical properties of soil: A case study. *Indian Journal of Natural Rubber Research*, **14**(1): 71-74.

Manju, M. J., Vinod, K. K., Idicula, S. P., Suryakumar, M. and Jacob, C. K. (2002). Occurrence of major leaf diseases of *Hevea* in rubber growing regions of Karnataka. *National Symposium on Crop Protection and WTO: An Indian Perspective*, 22-25 January 2002, CPCRI, Kasaragod, Kerala, India.

Mercykutty, V. C., Marattukalam, J. G., Saraswathyamma, C. K. and Meenakumari, T. (2002). Identificantion of *Hevea* clones: A manual. Rubber Research Institute of India, Kottayam, Kerala, India.

Mohanakumar, S. and George, K. T. (2001). Impact of economic reforms on tyre industry. *Economic and Political Weekly*, **36** (12): 1044-1050.

Nair, N. U., Sreelatha, S., Thomas, M., Simon, S. P. and Vijayakumar, K. R. (2001) Latex diagnosis for assessment of clonal performance in *Hevea*. *Indian Journal of Natural Rubber Research*, **14**(1): 63-65.

Philip, A., Punnose, K.I. and George, E.S. (2001). Effect of phosphorus on the growth and nutritional status of three leguminous cover in rubber plantations. *Indian Journal of Natural Rubber Research*, **14**(1): 43-47.

Philip, S., Joseph, A. and Jacob, C. K. (2001). Involvement of esterase isozyme in the surface attachment of conidia of *Corynespora cassiicola* on rubber (*Hevea brasiliensis*) leaves. *South Zone Meeting, Indian Phytopathological Society*, 10-12 December 2001, Calicut, India.

Philip, S., Jospeh, A., Kumar, A., Jacob, C. K. and Kothandaraman, R. (2001). Detection of β-1, 3-glucanase isoforms against Corynespora leaf disease of rubber (*Hevea brasiliensis*). *Indian Journal of Natural Rubber Research*, **14**(1): 1-6.

Priyadarshan, P. M., Sasikumar, S. and Goncalves, P. de S. (2001). Phenological changes in *Hevea brasiliensis* under differential geo-climates. *The Planter*, **77**(905): 444-459.

Rajagopal, R., Vijayakumar, K.R. and Thomas, K.U. (2000). Comparative effectiveness of different stimulation methods on yield performance of *Hevea brasiliensis*. *Proceedings of International Conference on Plantation Crops (PLACROSYM XIV)*, 2000, Hyderabad, India, pp. 420-423.

Ramesan, M. T., Kumar, T. K., Alex, R. and Kuriakose, B. (2002). Investigations on the addition of styrene butadiene rubber in natural rubber and dichlorocarbene modified styrene butadiene rubber blends. *Journal of Materials Science*, **37**: 109-116.

Ramesan, M. T., Mathew, M., Kuriakose, B. and Alex, R. (2001). Role of dichlorocarbene modified styrene butadiene rubber in compatibilization of styrene butadiene rubber and chloroprene rubber blends, *European Polymer Journal*, **37**: 719-728.

Reju, M. J., Thapliyal, A. P., Deka, H. K. and Varghese, Y.A. (2001). Growth performance of *Hevea* clones in sub-tropical Meghalaya. *Journal of Plantation Crops*, **29**(1): 22-26.

Roy, D., Das, G., Raj, S and Dey, S. K. (2002). Characterization of *Hevea* polyclonal seedling population under low temperature stress condition. *National Symposium on New Opportunities and Challenges of Improving Crop Productivity through Biotechnology*, 13-15 February 2002, CCS, Haryana Agricultural University, Hisar, India, p.112.

Roy, D., Das, G., Raj, S. and Dey, S. K. (2001). Temporal differences in wintering in *Hevea*: An indication of clonal responses to low temperature. *National Symposium on Plant Physiology and Biochemistry in Transgenic Era and Beyond*, 1-3 December 2001, Bose Institute, India, p. 46.

Saraswathyamma., C. K., Sankariammal, L. and Sebastian, T. (2002). Palynological studies in *Hevea brasiliensis*: A review. *Seminar on Palynological Studies in Kerala*, January 2002, RCC, Trivandrum, India.

Singh, R. P., Mandal, D., Darma, A. C. and Gohain, T. (2001). Nutritional requirement of *Hevea*: Effect of N, P and K on dry matter yield, nutrient content and uptake of nutrients by *Hevea* seedlings in Assam. *International Symposium on Importance of Potassium in Nutrient Management for Sustainable Crop Production in India*, 2001, India, pp. 411-413.

Sobha, S. and Sushamakumari, S., Rekha, K., Jayasree, R., Kala, R. G., Jayasree, P. K., Asokan, M. P., Sethuraj, M. R. and Thulaseedharan, A. (2001). Abiotic stress induced over-expression of superoxide dismutase enzyme in transgenic *Hevea brasiliensis*. *Symposium on Natural Rubber Research*, 2001, CIRAD, France.

Sobhana, P., Krishnakumar, R., Jacob, J. and Sethuraj, M. R. (2001). Effect of root stock-scion interaction on isozyme polymorphism in budgrafted plants of *Hevea brasiliensis*. *Journal of Plant Biology*, **28**(1): 49-54.

Thomas, K. K. (2001). Role of Clements Robert Markham in the introduction of *Hevea* rubber into the British India. *The Planter*, **77**(902): 287-292.

Thomas, K. K. (2002). Rubber Board: Organisation history. Rubber Board, Kottayam, 36 p. (Monograph).

Thomas, K. K. and Mathew, N. M. (2002). Rubber Research Institute of India: Organisational history. Rubber Research Institute of India, Kottayam, 31 p. (Monograph).

Thomas, K.U., Vijayakumar, K.R., Rajagopal R. and Karunaichamy, K. (2000). Performance of mini and reduced spiral tapping cuts in *Hevea brasiliensis*. *Proceedings of International Conference on Plantation Crops (PLACROSYM XIV)*, 2000, Hyderabad, India, pp. 126-130.

Thomas, M., Saha, T., Sobhana, P. and Jacob, J. (2000). Dissimilarities in the genetics between the root stock and scion and their relationship with the occurrence of tapping panel dryness syndrome in *Hevea*. *Proceedings of the National seminar on Recent Advances in Plant Biolog*, 2000, Central Plantation Crops Research Institute, Kasaragod, Kerala, India.

Thomas, M., Saha, T. and Jacob J. (2001). A note on isolation of DNA from bark tissues of mature rubber trees *(Hevea brasiliensis)*. *Indian Journal of Natural Rubber Research*, **4**(1): 60-62.

Varghese, S., Kuriakose, B. and Alex R. (2002). Effect of molecular weight of natural rubber, cure system and type of antioxidant on the processing and technological properties of natural rubber-isotactic polypropylene thermoplastic blends. *Proceedings of the Indian Rubber Conference*, RUBCON, 12-13 January 2002, Kharagpur, India, pp. 237-241.

Venkatachalam, P., Jayasree, R., Priya, P., Saraswathyamma, C. K. and Thulaseesharan, A. (2001). Identification of a DNA marker associated with dwarf trait in *Hevea brasiliensis* (Muell.) Arg. through random amplified polymorphic DNA analysis. *Symposium on Natural Rubber Research*, 2001, CIRAD, France.

Vijayakumar, K.R., Thomas, K.U., Rajagopal, R. and Karunaichamy, K. (2001). Low frequency tapping systems for reduction in cost of production of natural rubber. *Planters' Chronicle*, **97**(11):451-454.

Vimalakumari, T. G., Joseph, K., Jessy, M. D., Kothandaraman, R., Mathew, J. and Punnoose, K.I. (2001). Influence of intercropping on the rhizosphere microflora of *Hevea*. *Indian Journal of Natural Rubber Research*, **14**(1): 55-59.

Vinod, K. K. (2001). Studies on divergence of *Hevea brasiliensis* clones for yield and related traits during peak yielding seasons in Tripura. *Indian Journal of Natural Rubber Research*, **14**(1): 36-42.

Vinod, K. K. (2002). Genetic improvement in para rubber *Hevea brasiliensis (Willd.) Muell. Arg*. *Plant Breeding Approaches for Quality Improvement in Crops*, Centre for Advanced Studies in Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore, 28 January-February 2002, pp. 378-385.

Vinod, V. S., Varghese, S., Alex, R. and Kuriakose, B. (2001). Effect of aluminum powder on filled natural rubber composites. *Rubber Chemistry and Technology*, **74**(2): 236-248.

Vinod, V. S., Varghese, S.and Kuriakose, B. (2002). Degradation behaviour of natural rubber - aluminium powder composites: Effect of heat, zone and high energy radiation. *Polymer Degradation and Stability*, **75**: 405-412.

Viswanathan, P. K., Joseph, T. and George, K. T. (2001). Unorganised labour in small holder cash crop production. The case of rubber tappers in Kerala, *Indian Journal of Labour Economics*, **44**(4): 665-666.

POPULAR ARTICLES

Chakraborthy, S. K and Dey, S. K. (2001). Rubberized roads, saving with safety. *Dainik Sambad*, 29 July 2001 (Bengali).

Dey, S. K. (2001). Story of weeping wood. *Kisan World*, 5: 9-12 (Hindi).

Edathil, T. T. (2001). Be careful about rubber diseases of the rainy season. *Rubber*, **423**: 8-10, **424**: 19-22 (Malayalam).

Jacob, C. K. (2001). Spraying in plantations: Some methods for cost reduction. *Rubber*, **422**: 6-7 (Malayalam).

Jessy, M. D. (2001). Right time for planting. *Rubber*, **423**: 11-13 (Malayalam).

Joseph, A. (2001). Root diseases. *Rubber*, **428**: 14-15 (Malayalam).

Joseph, J. (2001). Rubber wood treatment factory in Tripura. *Rubber*, **423**: 32. (Malayalam).

Joseph, T. and George, K. T. (2001). WTO agreement and the rubber sector. *Deepika*, 23 December, 2001 (Malayalam).

Joseph, T. and George, K. T. (2001). Rubber product exports in major natural rubber producing countries. *Rubber Mithram*, **1**: 54-60 (Malayalam).

Joseph, T. and George, K.T. (2002). WTO and natural rubber sector. *Rubber*, **431**: 10-12 (Malayalam).

Karthikakuttyamma, M. and Meena, S (2001). Classification of rubber soils. *Rubber*, **423**: 23 (Malayalam).

Mathew, N. M. (2001). For enhancing the consumption of natural rubber. *Rubber*, **421**: 5-7 (Malayalam).

Mondal, G. C. (2001). Powdery mildew desease of rubber and its control. *Rubber Sangbad* (October-December), 9 (Assamese).

Mondal, G. C. (2002). Pink disease of rubber and its control. *Rubber Sangbad* (January-March): 2 (Assamese).

Punnoose, K. I. (2001). Intercropping. *Rubber*, **426**: 19-22 (Malayalam).

Reghu, C. P. (2002). Rubber yielding plants. *Rubber*, **430**: 5-6 (Malayalam).

Reghu, C. P. (2002). Rubber yielding plants: 2. *Rubber*, **431**: 13-16 (Malayalam).

Reghu, C. P. (2002). Rubber yielding plants. 3. *Manibot glaziovi*, *Rubber*. **432**: 21-23 (Malayalam).

Saraswathyamma, C. K. (2001). Five new clones. *Rubber*, **426**: 4-5 (Malayalam).

Saraswathyamma, C. K. (2001). Five new rubber clones. *Rubber*, **426**: 4-5 (Malayalam).

Thomas, K. K. (2001). Henry Wickham: 1. An introduction. *Rubber Mithram*, **2**(11): 47-49 (Malayalam).

Thomas, K. K. (2001). Henry Wickham: 2. Voyage in search of natural rubber. *Rubber Mithram*, **2**(12): 44-46 (Malayalam).

Thomas, K. K. (2001). Henry Wickham: 3. An unusual book. *Rubber Mithram*, 3(1): 30-32 (Malayalam).

Thomas, K. K. (2001). Henry Wickham: 4. The failed tubacco cultivation. *Rubber Mithram*, 3(2): 57-59 (Malayalam).

Thomas, K. K. (2002). Henry Wickham: 5. Experiments in British Honduras. *Rubber Mithram*, 3(7): 56-58 (Malayalam).

Thomas, K. K. (2002). Henry Wickham: 6. Again into misfortunes. *Rubber Mithram*, 3(8): 46-48 (Malayalam).

Thomas, K. K. (2002). Henry Wickham: 7. Again into the world of rubber. *Rubber Mithram*, 3(9): 50-53 (Malayalam).

Thomas, K. K. (2002). Hundred years of Indian rubber plantations industry. *Rubber*, **431**: 4-7 (Malayalam).

Thomas, K. K. (2002). Hundred years of Indian rubber plantations industry: 2, Fiftyfive years of the Rubber Board. *Rubber*, 432: 3-6 (Malayalam).

Thomas, K. U. (2001). Rain-guarding. *Rubber*, **422**: 3-5 (Malayalam).

Vijayakumar K.R. (2001). Rubber: Once in a week tapping to reduce cost of production. Malayala Manorama, 2 July 201 (Malayalam).

Vijayakumar, K. R, Thomas, K. U, Rajagopal, R and Karunaichammy, K. (2001). Weekly tapping towards reduction in cost of production, *Rubber*, **425**: 3-4 (Malayalam).

ANNUAL EXPENDITURE

Expenditure at a glance (2001-02)

Head of Account	Expenditure (Rs. in lakhs)
Non-plan	
General charges	428.04
Schemes	0.00
Projects (CES)	157.04
Total	**585.08**
Plan	
General charges	194.08
Schemes	387.54
NERDS Research Component	279.38
Total	**861.00**
Grand Total	**1446.08**

SCIENTIFIC AND SENIOR SUPPORTING PERSONNEL

Director of Research
N.M. Mathew, M.Sc, Ph.D.

Joint Director (Research)
Vacant

Agronomy and Soils Division

K.I. Punnoose, M.Sc.(Ag.), Ph.D.	Deputy Director
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Mercykutty Joseph, M.Sc.(Ag.), Ph.D.	Soil Chemist
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K.S. Sivasankaran Nair	Assistant Farm Superintendent

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C.T. Joseph	Assistant Farm Superintendent

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R. Krishnakumar, M.Sc., Ph.D.	Scientist S3
S. Sreelatha, M.Sc.	Scientist S3
Badre Alam, M.Sc., M.Tech., Ph.D.	Environmental Physiologist
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Jayasree Gopalakrishnan, M.Sc., M.Phil.	Scientist S2
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Leelamma Varghese, M.Sc., PGDHRM	Scientist S3
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Siby Varghese, M.Sc., Ph.D.	Scientist (Rubber Technology)
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Benny George, M.Sc.	Scientist S3
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C. Madheswaran, B.A.	Technical Assistant (Glass Blowing)

Agricultural Economics Division

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Toms Joseph, M.A.	Economist
Binni Chandy, M.A., B.Ed.	Scientist S2
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.	Scientist S2
S. Lakshmi, M.Sc.(Ag.)	Scientist S2 (on EOL from 01.03.2002)

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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., B.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
Maintenance	
K.P. Sajeev, B.E.	Estate Officer
E.R. Subramanian	Assistant Estate Officer
Administration	
T.R. Mohankumar	Deputy Secretary
E.K. Thankamma	Assistant Secretary
T.M. George	Assistant Secretary
Annamma Joseph	Section Officer
N. Sunderasan	Section Officer
Accounts	
P.V. George	Dy. Director (Finance)
K. Vijayamma	Assistant Director (Finance)
R. Muraleedharan Pillai	Accounts Officer
Aleyamma Chacko	Section Officer
Experiment Station at RRII	
T.V. Kurian	Assistant Estate Superintendent
Mary Mathew	Sr. Pharmacist

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

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
Zacharia Kurian, M.Com., A.C.A.	Accounts Officer
N. Bhargavan	Farm Superintendent
M.D. Isaac	Assistant Estate Superintendent
K.S. Thomas	Assistant Section Officer
Annamma Andrews, H.S.C.	Nurse (HG)
T.T. Varghese	Assistant Farm Superintendent
M.J. Augustin	Assistant Farm Superintendent
M.T. Varghese	Assistant Security Officer
O.V. Mathew	Assistant Farm Superintendent
K.K. Kunjachan	Assistant Farm Superintendent

Regional Research Station, Padiyoor, Kerala

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

Regional Research Station, Guwahati, Assam

D. Chaudhuri, M.Sc.(Ag.)	Deputy Director
G.C. Mondal, M.Sc., Ph.D.	Plant Pathologist
R.P. Singh, M.Sc.(Ag.), Ph.D.	Scientist S2
D. Mandal, M.Sc.	Scientist S2
T. Gohain, M.Sc.(Ag.), Ph.D.	Junior Scientist (from 08.01.01)
A.K. Hazarika, M.Com., ICWAI	Assistant Accounts Officer

Regional Research Station, Agartala, Tripura

Sushil Kumar Dey, M.Sc., Ph.D.	Deputy Director
P. M. Priyadarshan, M.Sc., Ph.D.	Plant Breeder
Gitali Das, M.Sc, Ph.D.	Plant Physiologist
Shammi Raj, M.Sc., Ph.D	Agrometeorologist
Krishna Das, M.Sc., Ph.D.	Scientist S2
S. Sasikumar, M.Sc.	Junior Scientist (resigned w.e.f. 24.10.2001)
Santhanu Roy, M.Sc.(Ag.)	Junior Scientist
Mrinal Choudhury, M.Sc.(Ag.)	Junior Scientist
Debabrata Ray, M.Sc.(Ag.)	Junior Scientist
Joy Joseph, M.Sc.	Assistant Rubber Processing Technologist
Jiban Chakraborty, B.Com.	Accounts Officer
Haradhan Bhowmik	Assistant Farm Superintendent
M.J. Augustine	Assistant Farm Superintendent
N.K. Balasubramaniyam	Assistant Section Officer

Regional Research Station, Kolasib, Mizoram	
Rama Shankar Singh, M.Sc.(Ag.)	Junior Scientist
Regional Research Station, Tura, Meghalaya	
A.P. Thapliyal, M.Sc., Ph.D.	Deputy Director
H.K. Deka, M.Sc., Ph.D.	Scientist S3
M.J. Reju, M.Sc.	Scientist S2
T. Parimelazhagan, M.Sc., Ph.D.	Junior Scientist
Regional Experiment Station, Nagrakatta, West Bengal	
K.G. Vijayan	Assistant Farm Superintendent
Regional Research Station, Dapchari, Maharashtra	
Meena Singh, M.Sc.(Ag.), Ph.D.	Plant Physiologist
Gawai Prakash Pandharinath, M.Sc.(Ag.)	Scientist S2
P.N. Devarajan	Section Officer
P.A. Joykutty	Assistant Farm Superintendent
Regional Research Station, Dhenkanal, Orissa	
Chandra Gupta, M.Sc.(Ag.), Ph.D.	Agronomist
Katuri Nageswara Rao, M.Sc.(Ag.)	Junior Scientist
T.M. Mathew	Assistant Section Officer
P.J. George	Assistant Farm Superintendent
Regional Research Station, Sukma, Chattisgarh	
Bal Krishan, M.Sc., Ph.D.	Scientist (Germplasm Evaluation)
Hevea Breeding Sub-station, Nettana, Karnataka	
K.K. Vinod, M.Sc.(Ag.)	Plant Breeder
M.J. Manju, M.Sc (Ag)	Junior Scientist
M. Suryakumar, M.Sc (Ag)	Junior Scientist
C.K. Thomas	Assistant Farm Superintendent
Hevea Breeding Sub-station, Paraliar, Tamil Nadu	
T.A. Soman, M.Sc., M.Phil., Ph.D.	Scientist S3
P.V. John	Assistant Farm Superintendent
Regional Soil Testing Laboratory, Adoor, Kerala	
Thomas Eappen, M.Sc.	Junior Scientist
K.C. Jayasree	Senior Scientific Assistant
Regional Soil Testing Laboratory, Muvattupuzha, Kerala	
C.P. Mary, M.Sc.	Assistant Technical Officer
Regional Soil Testing Laboratory, Calicut, Kerala	
Joyce Cyriac, M.Sc.	Scientist S2
P.K. Madhusooddhanan, B.Sc.	Senior Scientific Assistant
Regional Soil Testing Laboratory, Nedumangad, Kerala	
S. Sheela, B.Sc.	Senior Scientific Assistant

RESEARCH ESTABLISHMENTS

RUBBER RESEARCH INSTITUTE OF INDIA

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REGIONAL RESEARCH STATIONS

Central Experiment Station
RRII, Rubber Board, Chethackal
Thompikandom P.O.
Pathanamthitta, Ranni - 689 676
Kerala.
Phone : 91 4735 226130, 261176

Regional Research Station
RRII, Rubber Board
Padiyoor P.O.
Kannur – 670 703, Kerala.
Phone : 91 4982 273003

Hevea Breeding Sub-station
RRII, Rubber Board
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Phone : 91 4652 89119

Hevea Breeding Sub-station
RRII, Rubber Board
College Road, Kadaba – 574 221
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Dhenkanal – 759 001, Orissa.
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Regional Research Station
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Phone : 91 3837 220357

Regional Research Station
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Kunjaban P.O.
Agartala – 799 006, Tripura.
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Regional Research Station
P.B. No. 26, RRII, Rubber Board,
Tura – 794 001, Meghalaya.
Phone : 91 3651 232413

REGIONAL SOIL TESTING LABORATORIES

Regional Soil Testing Laboratory
Rubber Board Regional Office
Taliparamba – 670 141, Kerala.
Phone : 91 498 203037, 203445

Regional Soil Testing Laboratory
Rubber Board, East Nadakkavu
Kozhikode – 673 011
Kerala.

Regional Soil Testing Laboratory
Rubber Board, Peramangalam P.O.
Manappady
Thrissur – 680 545,
Kerala.

Regional Soil Testing Laboratory
Rubber Board
P.O. Junction
Muvattupuzha – 686 661
Kerala.

Regional Soil Testing Laboratory
Rubber Board
T.B. Road, Pala – 686 575
Kerala.

Regional Soil Testing Laboratory
Rubber Board
Ann's Buildings, Old Church Junction
Kanjirappally – 686 507
Kerala.

Regional Soil Testing Laboratory
Rubber Board
Parvathy Mandiram
K.P. Road, Adoor – 691 523
Kerala.

Regional Soil Testing Laboratory
Rubber Board, East Bunglow
Nedumangad – 695 541
Kerala.

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Research divisions and functions

The major research divisions are Agronomy and Soils; Biotechnology; Botany; Germplasm; Mycology and Plant Pathology; Plant Physiology; Rubber Chemistry, Physics and Technology and Agricultural Economics. Studies on Exploitation Technology, 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 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).

Publications

Books

Natural Rubber : Agromanagement and Crop Processing
Idetification of *Hevea* clones
The Genesis of WTO and the Aftermath
WTO and Natural Rubber Sector in India
Rubber Wood : Production and Utilization
Plant and Soil Analysis

Serials

Indian Journal of Natural Rubber Research
RRII Annual Report

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