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Corynespora leaf disease on rubber

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December, 2000

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The Rubber Research Institute of India (RRII), under the Rubber Board (Ministry of Commerce, 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. The capital of the State is Trivandrum, 160 km south where there is an international airport. The distance to New Delhi, the capital of the country is 2950 km.

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.

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ANNUAL REPORT
1997-98

RUBBER RESEARCH INSTITUTE OF INDIA
KOTTAYAM - 686 009, KERALA, INDIA

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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 first in 1954 and later in 1960. In 1982, the Act was again amended by the Rubber (Amendment) Act which is currently in force.

Organization

The Chairman is the principal executive officer and exercises control over all departments of the Board. The Rubber Research Institute of India 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 growth rate of natural rubber (NR) achieved in India has been remarkable. The industry has derived its strength through efficient, economic and environment-friendly crop management practices nurtured by the technological spill-over from research. Through research and development, the industry has been transformed to such an extent that NR is no longer regarded merely as an agricultural commodity but as an industrial raw material of biological origin.

It is a matter of pride that India ranks first in productivity of rubber, though some biotic and abiotic stresses hamper in achieving its much higher yield potential. The fungus *Corynespora* remains a potential threat to rubber plantations, for which effective management strategies are being developed. The scope for further extension of cultivation to non-traditional or marginal areas is dwindling due to many socio-ecological factors and paucity of clones adapted to such conditions. The increasing cost of production is also a matter of concern for the maintenance of a viable and sustainable plantation industry. The adoption of improved agronomic and horticultural practices, coupled with the use of advanced planting materials, is more relevant under the present situation for reducing the immaturity period. Plant breeders should have a pragmatic approach to consider rubber trees not only for latex, but also for timber. The growth of NR processing units has been phenomenal and efforts to improve the quality and consistency in processability of NR in line with the specific needs of consumers shall be continued. In the present context, research is to be geared towards the development of new applications for rubber.

The Rubber Research Institute of India has, therefore, taken up research programmes keeping in view of the national interests and future perspective. The technological sophistication and infrastructural excellence available in the Institute enable it to remain at the cutting edge of advancing frontiers of rubber science.

In the field of Agronomy/Soils, investigations on the economic management of nutrition in mature as well as immature phases of rubber were continued. The studies on weed management have revealed higher population of beneficial microorganisms in soil when the integrated approach of herbicide application and slashing was adopted. In cropping system studies, maintaining coffee as intercrop in mature rubber plantation was found possible. The growth of rubber plants in the cropping system model experiment with different intercrops continued to be superior compared to that in monoculture.

Under the crop improvement programmes, evaluation and selection of clones with yield and secondary characters better than RRII 105 were in progress. Breeding for powdery mildew disease resistance and drought tolerance has been given priority. Bark and wood anatomical studies related to tapping panel dryness (TPD) and ethrel application have been in progress. Efforts were continued for the conservation and evaluation of *Hevea* germplasm. The RAPD studies to establish the genetic relationship among wild *Hevea* germplasm have been initiated.

The experiments for refining the techniques of somatic embryogenesis have made good progress. The *Agrobacterium*-assisted genetic transformation system in *Hevea* has

been standardized. Identification of markers associated with TPD and the sequencing of the nucleotide bands were in progress.

In the field of crop protection, the studies to identify alternative fungicides for the control of *Phytophthora* leaf fall disease were continued. Testing of systemic fungicides against various diseases was in progress. Severe incidence of *Corynespora* was reported from South Karnataka. An exhaustive survey indicated that 62 per cent holdings in Sullia, 21 per cent in Puthur and 10 per cent in Belthangadi taluks were affected by the disease, where the intensity ranged from 10 to 70 per cent. Disease control studies proved that the dust formulation of hexaconazole and oil-based COC and mancozeb are effective against *Corynespora* in mature rubber. Microbiological studies included the use of microbes for improving P uptake and the investigations into the role of *Azotobacter, Azospirillum*, mycorrhizae and phosphobacteria on plant growth. Studies to manage minor pests like termites, crickets, nematodes, etc. were in progress. Biogas generated from ribbed smoked sheet (RSS) processing effluent was quantified and maximum production was noticed during March to May.

The photoinhibition and enzyme activity in leaves exposed to stress conditions were investigated. Severe photoinhibition of photosynthesis and decreased level of several scavenging enzymes were observed. A comparison of the canopy architecture and the growth and distribution was made in trees grown in drought-prone areas. A study was initiated to assess the impact of rubber cultivation on the ecosystem in comparison with other forest species. Studies on yield, yield components and growth of several popular clones were also continued.

The research activities in the area of processing and technology were focussed on the thrust areas of primary processing, chemical modification, rubber composites and development of new products. Epoxidized natural rubber (ENR) was identified as a reinforcement modifier in rubber-silica composites. A process has been developed for the reclamation of vulcanized scrap rubber. Attempts were also made to prepare modified bitumen using waste rubber powder from the retreading industry. Technology for the manufacture of on-line leak sealant rubber compound has been transferred for industrial application.

In agricultural economics, the commercial yield performance index of various clones was studied. Studies were also undertaken on the economic analysis of intercropping production and consumption of rubber wood and replanting, stockholding practices of smallholdings and prospects of the tyre industry in the backdrop of liberalization.

The World Bank-Assisted Rubber Project comprised seven major research projects and significant progress was achieved in all these projects. The Regional Research Stations in Kerala and other states concentrated on location-specific research with the primary aim of developing agrotechnology suited to each location.

The nature and character of research activities of RRII have undergone substantial changes in recent years. The research policies are formulated in such a way that maximum benefits are accrued and applied in all sectors of the industry.

AGRONOMY AND SOILS DIVISION

The Agronomy and Soils Division is engaged in the development of suitable agromanagement techniques for improving the productivity and sustainability of the rubber plantation system. The major research projects of the Division are on nutrient management in immature and mature rubber, density of planting, irrigation and water management, soil and water conservation and weed management. Cropping system model experiment integrating different annual and perennial crops with rubber and intercropping experiments with coffee are also being continued. To increase the fertilizer use efficiency, slow-release fertilizers and different forms and methods of fertilizer application are being tried. The Division continues to support the large estates by offering soil and leaf analyses-based discriminatory fertilizer recommendation. For further improving the discriminatory fertilizer recommendation, studies on Diagnosis and Recommendation Integrated System (DRIS) and standardization of analytical methods are being continued.

1. Nutritional studies (immature rubber)

The field experiment at Kodumon Estate started during 1989 to assess the NPK requirement in clone RRII 105 was continued. The girth (1998) and girth increment (1991-98) were analysed statistically and are presented in Table Ag.1. The NPK combination of 30:30:20 kg/ha continued to be the economical dosage in providing better growth. The trees were brought under tapping during this year (1997) and the experiment is being continued.

Table Ag.1. **Effect of fertilizer on girth and girth increment**

Treatment NPK (kg/ha)	Girth (cm)	Girth increment (cm)
0 0 0	52.77	44.61
30 30 20	58.60	48.73
30 30 40	56.31	46.84
30 60 20	58.51	49.34
30 60 40	55.15	46.32
60 30 20	54.84	45.89
60 30 40	60.11	50.61
60 60 20	55.91	46.68
60 60 40	58.98	49.59
90 30 20	56.32	46.60
90 30 40	56.02	46.92
90 60 20	56.06	46.58
90 60 40	54.97	46.18
SE	1.40	1.27
CD (P=0.05)	4.08	NS

2. Nutritional studies (mature rubber)

2.1 NPK fertilizer trial

The experiment on clone RRII 105 initiated during 1986, at Vaniampara Estate was continued. The fertilizer treatments tried did not affect the yield significantly.

2.2 Sequential skipping of fertilizers

The field experiment initiated during 1996 in mature rubber to compare the effect of periodic skipping of fertilizer with continuous regular application was in progress. Observations on growth and yield were recorded.

2.3 Clone-cum-fertilizer experiment

The experiment to study the clonal variations in fertilizer requirement is being continued. Clone RRIC 100 recorded the highest mean yield followed by PB 311 and

RRII 105, which were comparable (Table Ag.2). The highest mean girth was noticed for RRII 203 followed by RRIC 100. However, differential nutrient requirement for individual clone was not indicated.

Table Ag.2. **Clonal differences in girth and yield**

Clone	Girth (cm)	Yield (g/tree/tap)
RRII 5	64.66	27.83
RRII 105	62.25	34.79
RRII 203	70.39	31.00
RRII 208	57.56	24.73
RRII 300	60.63	21.02
RRII 308	61.61	18.90
PR 255	58.56	23.77
PR 261	60.16	31.91
PB 311	65.93	36.60
RRIC 100	67.73	42.56
SE	2.24	3.37
CD (P=0.05)	7.16	10.79

2.4 Potassium nutrition of mature rubber

The field experiment initiated during 1990 with graded levels of K_2O was concluded. Significant yield increase was recorded only during summer months indicating the positive influence of K in improving the water balance in the plant system. The optimum dose of K derived from the quadratic equation was 63.6 kg/ha and from the cubic equation was 78.4 kg/ha. Similarly, critical values of soil available K for Morgan K (4.52 mg/100 g soil) and ammonium acetate K (5.40 mg/100 g soil) and critical leaf K concentration (1.281 %) were also derived from the respective response models.

3. Density of planting

The experiment started in 1994 at CES, Chethackal to study the effect of density of planting on growth and yield of rubber under two fertilizer regimes continued. The growth of the plants did not register any significant difference with respect to either the planting density or fertilizer regime.

4. Irrigation and water requirement

During 1997-98, irrigation could not be done in the microirrigation trial due to the failure of the system. The data on girth (1997) and girth increment (1992-97) indicated positive effect of irrigation on growth of rubber (Table Ag.3). Tapping commenced in the experimental area during 1997.

Table Ag.3. **Influence of irrigation on girth and girth increment**

Irrigation	Girth (cm)	Girth increment (cm)
25% ET	46.40	39.73
50% ET	46.46	39.98
75% ET	46.58	40.45
100% ET	48.82	41.73
No irrigation	44.67	38.64
SE	0.65	0.62
CD (P=0.05)	2.02	1.91

5. Soil and water conservation

5.1 Effect of silt pits (conservation pits) on soil and moisture conservation

Field experiment on mature rubber initiated in 1994 to study the effect of silt pits taken at the rate of 100, 150 and 200 numbers per ha on soil and water conservation in the estate of the State Farming Corporation of Kerala Ltd., Punalur is in progress. Girth and yield of trees during 1997-98 and soil moisture content during summer months did not differ significantly between treatments.

A new trial was laid out in RBD with four replications having a gross plot size of 1 ha at Manickal Estate, Mundakayam during 1998 with the objective of studying the effect of pits on soil and moisture conservation. The treatments consisted of various frequencies (100, 150, 200 and 250 pits per ha and a no-pit control) of conservation pits of

120x45x75 cm size. Quantification of soil and nutrients loss by erosion and conservation by the pits under the various treatments is envisaged. Pre-treatment soil samples were collected for chemical analysis and girth of plants is being recorded. Yield data are being collected from estate records every month.

5.2 Coir pith manure for pit manuring and mulching in young rubber

The suitability of coir pith manure (CPM) for pit manuring and mulching was evaluated in comparison with the conventional farm yard manure (FYM) in a field experiment in young rubber initiated during 1994. The girth data recorded four years after treatment imposition indicated that CPM could be a substitute for FYM, which is commonly used for pit manuring.

6. Weed management

6.1 Weed control methods on planting strips

The experiment laid out in Shaliacary Estate, during 1995 to evaluate the different weed control methods in the planting strips of rubber was continued.

A study on the population of soil microflora revealed that weeding by scraping the entire platform reduced the number of beneficial bacteria, while an integrated approach of spraying the immediate plant basin with herbicide and slashing the remaining area maintained a higher population of beneficial bacteria (Table Ag.4).

Table Ag.4. **Population of beneficial bacteria (colonies/g of soil)**

Treatment	Bacteria	Phospho-bacteria
Scraping entire platform	15.50	1.25
Slashing entire platform	93.63	27.50
Spraying paraquat (Gramoxone) 2.25 L/ha + 2,4-D (Fernoxone) 1.25 kg/ha in entire platform	23.00	3.00
Spraying glyphosate (Round up) 2.0 L/ha in entire platform	39.50	12.50
Slashing interspaces and scraping plant basin	77.50	23.75
Slashing interspaces and applying paraquat 2.25 L/ha + 2,4-D 1.25 kg/ha in plant basin	48.50	10.25
Slashing interspaces and applying glyphosate 2.0 L/ha in plant basin	50.00	5.75
SE	3.15	1.57
CD (P=0.05)	9.06	4.53

6.2 Control of lemon grass

The trial was initiated in an area having heavy infestation of lemon grass (*Cymbopogan citratus*) to evolve an effective and economic control measure. The economics for the different schedules worked out for a period of nine months is given in Table Ag.5.

Application of two rounds of glyphosate at 2 L/ha gave satisfactory control of the grass at minimum expenditure.

6.3 Control of *Mucuna bracteata*

The trial was laid out during 1997 in a four-year-old rubber plantation with an objective to find out a herbicide application schedule for the control of *Mucuna bracteata* along the planting lines of rubber and to work out the economics of different treatments (Table Ag.6).

7. Cropping systems

7.1 Intercropping coffee in mature rubber

The experiment laid out at CES, Chethackal to study the possibilities of intercropping coffee in mature rubber plantations and its effect on growth and yield of rubber is being continued. The growth and yield of rubber were not influenced by intercropping.

Table Ag.5. **Economics of different treatments for lemon grass control**

Treatment	No. of rounds slashing/ spraying	No. of man-days/ ha/round	Total labour charges (Rs.)*	Cost of chemical (Rs.)	Total amount (Rs.)
Uprooting	2	33	4967.16	Nil	4967.16
Slashing	6	20	9031.20	Nil	9031.20
Glyphosate (Round up) 3 L/ha	2	6	903.12	1800	2703.12
Slashing followed by spraying glyphosate 3 L/ha	2	26	3913.52	1800	5713.52
Glyphosate 2 L/ha	2	6	903.12	1200	2103.12
Slashing followed by spraying glyphosate 2 L/ha	2	26	3913.52	1200	5113.52
Paraquat (Gramoxone) 2.25 L/ha	6	6	2709.36	2646	5355.36

* @ Rs.75.26/man-day; Round up : Rs.300/L; Gramoxone : Rs.196/L.

A block trial was laid out at Shaliacary Estate to further ascertain the effect of intercropping coffee in mature rubber. The growth of rubber trees inter-planted with single and double rows of coffee (var. cauvery) was on par with that of monoculture. The growth of coffee was comparable in both single and double row systems. Chemical analysis of soil samples collected from sites between rubber trees of the different treatments showed no significant difference in pH, organic carbon and available P, K and Mg.

7.2 Cropping system model

The cropping system model experiment initiated in 1993 at CES, Chethackal was continued. The different intercrops were banana for initial two years, pineapple up to fifth year, tuber crops during the fourth and

Table Ag.6. **Economics of different control methods for *Mucuna***

Treatment	No. of rounds slashing/ spraying	No. of man-days/ ha/round	Labour charges (Rs.)*	Cost of chemical (Rs.)	Total amount (Rs.)
Slashing	8	20	12041.6	Nil	12041.60
Glyphosate (Round up) 2 L/ha	6	6	2709.4	3600.0	6309.40
Glyphosate 1 L/ha	9	6	4064.0	2700.0	6764.00
Glyphosate 0.5 L/ha + urea 0.25 kg/ha	9	6	4064.0	1395.0	5459.00
Paraquat (Gramoxone) 2.25 L/ha + 2,4-D (Fernoxone) 1.25 L/ha	5	6	2257.8	3267.5	5525.30
Paraquat 2.25 L/ha	10	6	4515.6	4410.0	8925.60
2,4-D 1.25 kg/ha	5	6	2257.8	1062.5	3320.30
2,4-D 2.50 kg/ha	4	6	1806.2	1700.0	3506.30

* @Rs.75.26/man-day; Round up : Rs.300/L; Gramoxone : Rs.196/L; Fernoxone : Rs.170/kg.

fifth year in the space previously occupied by banana, pepper and coffee as permanent crops, cover crops in the narrow inter-row and grass and teak along the boundary. The stand per ha of rubber was 406.

The growth of rubber plants in the present system continued to be superior compared to that in monoculture. Coffee plants planted during 1996 started flowering and deflowering was carried out. A few pepper plants also started flowering. Tuber crops were planted for the second year consecutively after harvesting the previous year's crop. During the fourth year also pineapple gave satisfactory yield.

8. Integrated nutrient management

The field experiment started in immature rubber in 1994 at Shaliacary Estate to compare the effect of organic manures alone and in combination with chemical fertilizers is being continued. The girth data did not show significant difference between treatments.

9. Forms and methods of fertilizer application

9.1 Bowl sludge as a source of phosphorus

The field experiment to evaluate the effectiveness of bowl sludge as a P-fertilizer is being continued to the mature phase. The data on girth increment for the period from 1989 to 1997 and mean yield for 1997 are presented in Table Ag.7.

Table Ag.7. **Influence of bowl sludge on growth and yield**

Treatment	Girth increment (cm)	DRC (%)	Dry rubber yield (g/tree/tap)
Super phosphate	48.90	37.03	42.85
Mussoorie rock phosphate	47.42	37.12	43.11
Bowl sludge	49.07	36.83	45.45
Control (No P)	44.28	35.89	35.16
SE	1.18		2.36
CD (P=0.05)	3.55	NS	7.07

9.2 Effect of phosphorus on the growth of different cover crops

Two sets of pot culture experiments were conducted to study the effect of three levels of rock phosphates viz. 0, 30, 45 kg P_2O_5/ha on the nodulation and biomass production of three cover crops. Plants in one experiment were uprooted three months after sowing and in the second experiment those were uprooted six months after sowing. Dry weight of the shoot, root and root nodules from each pot was recorded. Powdered shoot and root samples were analysed for major nutrients and the uptake was calculated.

The dry matter production at three-month and six-month growth is given in Table Ag.8. After three months, for *Pueraria*, there was no difference between control and two levels of P. But after six months, P at 30 kg/ha was significantly superior in dry matter production. In the case of *Mucuna*, after three months, the first level of

Table Ag.8. **Effect of rock phosphate on dry matter production of cover crops**

Cover crop	Rock phosphate (kg/ha)	Dry matter (g/pot) after 3 months	Dry matter (g/pot) after 6 months
Pueraria	0	7.06	34.56
	30	9.58	42.97
	45	9.00	39.19
Mucuna	0	7.17	23.58
	30	12.23	26.39
	45	8.36	25.45
Calopogonium	0	6.02	20.50
	30	8.96	26.11
	45	13.57	27.29
CD (P=0.05)		3.07	3.69

P (30 kg/ha) was significantly superior to the other levels studied. After six months, the treatments were comparable. For *Calopogonium* the highest level of P (45 kg/ha) recorded the highest dry matter production at both the stages.

9.3 Use of slow-release fertilizers

Two field experiments on immature rubber, one at CES, Chethackal and another at Kuzhimattam to compare the relative efficiency of NPKMg pellets, nimin-coated urea and neem cake-mixed urea are being continued. The girth data from the two experiments give indication for reducing the dose as well as number of splits of application of fertilizers using controlled-release formulations (Tables Ag.9 and Ag.10).

Table Ag.9. **Effect of controlled-release fertilizers on girth, (CES, Chethackal)**

Treatment	% of full dose	Girth (cm)
Prilled urea	100	36.31
NPKMg pellets	100	38.74
NPKMg pellets	75	39.72
Nimin-coated urea	100	37.42
Nimin-coated urea	75	37.20
Neem cake-mixed urea	75	37.47
Control (no manure)		33.97
SE		0.96
CD (P=0.05)		2.96

Table Ag.10. **Effect of controlled-release fertilizers on girth (Kuzhimattom)**

Treatment	% of full dose	No. of application(s)	Girth (cm)
Prilled urea	100	Two	36.94
NPKMg pellets	75	Single	36.65
NPKMg pellets	75	Two	36.60
NPKMg pellets	50	Single	34.53
NPKMg pellets	50	Two	36.29
Nimin-coated urea	100	Two	34.90
Nimin-coated urea	75	Two	34.27
Neem cake-mixed urea	100	Two	35.49
Neem cake-mixed urea	75	Two	36.20
Control (no manure)			29.97
SE			1.23
CD (P=0.05)			3.50

9.4 Effect of N-inhibitors on the growth and yield of rubber

The field experiment to study the effect of nitrification inhibitor (neem cake), when mixed with urea, on the growth and yield of rubber is being continued. The data on girth and yield revealed no significant difference between treatments.

9.5 Comparison between Rajphos and Mussoorie rock phosphate

9.5.1 Young rubber

Two experiments, one at Malankara Estate and another at Boyce Estate, to compare the effect of Rajphos and Mussoorie rock phosphate initiated during 1997 on young rubber are in progress. Pre-treatment soil nutrient status and diameter of the plants were recorded.

9.5.2 Mature rubber

Two field experiments to compare two sources of rock phosphate applied at different levels are in progress. Pre-treatment soil and leaf samples were collected and analysed for major nutrients. Girth of the trees was also recorded. Yield recording on monthly basis was started from December 1997.

9.6 Different levels of P in mature rubber

A field experiment was laid out at Mooply Estate, Palappilly in 1997 to study the effect of different levels of P on growth and yield. Pre-treatment soil and leaf samples were collected and analysed for major nutrients. Girth of the trees before incorporating the treatments was recorded. Monthly yield recording was started from December 1997.

10. Physical and chemical properties of soils

Soil samples from various fields under rubber cultivation for different periods were collected to study the inter-relationship of organic matter, organic carbon and available nutrients from three regions in the traditional belt. The analyses of the soil samples are in progress.

11. Discriminatory fertilizer recommendation

11.1 Advisory service

Soil and leaf analyses-based discriminatory fertilizer recommendations were offered to 970 fields belonging to 32 large estates. A total of 1125 soil and 970 leaf samples were analysed during the year.

11.2 DRIS approach for fertilizer recommendation

The DRIS norms were tested through independent set of data on leaf nutrient values and the corresponding yield from four fertilizer experiments of the Division. Three experiments had 3^3 NPK factorial design with 0, 30 and 60 kg/ha of N, P_2O_5 and K_2O. The experiment four was a single factor experiment with seven levels of K_2O viz. 0, 15, 30, 45, 60, 75 and 90 kg/ha.

The study indicated that better diagnosis of the nutritional status of the trees is possible with DRIS system. In all the cases, assessment of the nutritional status through sufficiency range showed either sufficiency or excess and failed to predict the possibilities of plant response to applied fertilizer. Whereas, DRIS could indicate the deficiency or sufficiency of individual nutrient and the nutrient elements could be arranged in their order of importance. The yield response to fertilizer treatments could also be explained in a better way through DRIS approach. Thus the preliminary DRIS norms established were found to be highly useful for assessing the nutritional status of rubber similar to other crops.

12. Standardization of analytical values

The seasonal variations in leaf nutrient status of clone RRII 105 were analysed with respect to age of the leaf samples. In general, a negative correlation existed between leaf age and N, P, K and Mg and a positive correlation with Ca. The most ideal period for leaf sampling was found to be 220 to 310 days from the date of emergence. However, for practical purpose, assuming the leaf emergence in the first week of January, mid-August to mid-November can be recommended for leaf sampling.

BIOTECHNOLOGY DIVISION

The thrust areas of research of the Biotechnology Division are development of protocols for high frequency somatic embryogenesis, regeneration of plants from protoplast, shoot tip culture, genetic transformation, RAPD analysis and identification of molecular markers, pathogenesis-related proteins and analysis of genomic stability of *Hevea* plants propagated through different methods.

1. Somatic embryogenesis

Experiments were conducted to enhance the efficiency of somatic embryo induction and plantlet formation achieved earlier from immature inflorescence as the initial ex-

plant. The various nutritional as well as hormonal requirements were studied. As a result, a high frequency somatic embryogenesis and plantlet formation were obtained. At present, the time span required for the formation of plantlets from initial explants is approximately one and a half years. Experiments are going on to reduce the time span between initial explant inoculation and plantlet development through somatic embryogenesis.

2. Genetic transformation

The various factors controlling the genetic transformation of *Hevea* tissue through the natural vector system *Agrobacterium tumefaciens* were standardized using the gene coding for the enzyme β-glucuronidase as the marker gene and kanamycin resistance as the selectable gene. The details of the standardization are given in Table Bio. 1.

Table Bio. 1. **Optimization of different factors for maximum gene incorporation.**

Factors optimized	Result
Explant source	Immature inflorescence
Stage of target tissue	Two-month-old callus
Agrobacterium strain	EHA 101
Period of inoculation	20 min
Concentration of antibiotic in the pre-selection medium	500 mg/ml ceffatoxime
Concentration of antibiotics in the selection medium	350 mg/ml kanamycin 500 mg/ml ceffatoxime
Frequency of transformation achieved	3 %

After optimizing all the parameters for *Agrobacterium*-mediated gene transfer, *Hevea* cell lines were transformed with agronomically important genes. Initially four genes were identified for transformation of *Hevea* clone RRII 105 in order to contain TPD syndrome as well as to relieve from other abiotic stresses. The four genes selected are superoxide dismutase (SOD), isopentenyl transferase (IPT) for the biosynthesis of cytokinin, antisense for ACC synthase gene for blocking the over production of endogenous ethylene and sorbitol 6-phosphate dehydrogenase (S6-PDH) for the accumulation of sorbitol.

Since the transgenic cell lines have a different nutritional requirement compared with the normal cell lines for embryogenesis and plantlet formation, experiments were undertaken on this aspect. A pathway for high frequency somatic embryogenesis was developed for the cell lines transformed with S6-PDH. Mature embryos were obtained in large-scale from the S6-PDH transgenic lines. Transgenic cell lines were obtained with the three other genes are also in the proliferating callus stage.

3. Protoplast culture

The previous experiments on protoplast division and micro-colony formation indicate that a nurse culture is essential for active cell division and micro-colony formation leading to callus with embryogenic potential. Although embryogenic calli and plantlet formation have been obtained with *Lolium*-derived nurse culture, experiments are going on to achieve high frequency micro-colony formation and somatic embryo induction with nurse culture derived from different species.

4. Shoot tip culture

Several modifications were done in the protocol developed for the ongoing programme to generate *in vitro* plants through shoot tip culture. A protocol to induce a very efficient root system in the shoot tip culture-derived plantlets was developed. To develop a more efficient micro-propagation system through multiple shoots, nodal cultures

were initiated. In the preliminary investigation, axillary bud growth was successfully obtained from nodal cultures. Work is going on to enhance the rate of multiple shoot induction and development of rooted plants.

5. Isozyme studies

The use of isozyme profile for distinguishing embryogenic calli from the non-embryogenic calli was evaluated. Isozyme profiles were developed for various enzymes using *in vitro*-grown tissues at different developmental stages and mature leaves from field-grown plants. Clear isozyme markers were observed for four enzymes, viz. aryl esterase, peroxidase, shikimate dehydrogenase and superoxide dismutase in order to distinguish embryogenic calli from the non-embryogenic.

6. RAPD analysis and identification of molecular markers for TPD

The nucleotide sequencing of the 1.3 kb polymorphic band identified for tolerance to TPD was done. The sequence was compared with the sequence of the characterized genes available in the database. The structural analyses of the sequence were also done. A partial similarity was observed with one of the genes of *Arabidopsis thaliana*. Attempts are being made to isolate the full length gene and to study the function.

7. Pathogenesis-related proteins

Studies to identify pathogenesis-related (PR) proteins involved in the tolerance to *Phytophthora* infection were in progress. Extraction of acidic proteins from leaf samples of tolerant (RRII 105) and susceptible (RRIM 600) cultivars of *Hevea* after infection with *Phytophthora* and polyacrylamide gel electrophoresis were carried out to separate and identify PR proteins. Eleven new proteins were formed in the tolerant cultivar during the hypersensitive response. Immunological studies showed a strong similarity of two proteins with already established PR proteins. Work is in progress to characterize these proteins and to study the molecular mechanism conferring tolerance against *Phytophthora* infection.

BOTANY DIVISION

Botany Division continued research activities on genetic improvement programmes. Thrust areas are evaluation and selection of clones having more yield and better secondary characters than RRII 105. Investigations on propagation, anatomy and cytogenetics are also in progress.

1. Evolving high yielding clones for traditional area

1.1 Hybridization and clonal selection

The trees included in two small-scale trials (SST) of hybrid clones were opened for tapping. Monthly yield and annual girth are being monitored.

Monthly yield recording was carried out in the 1985 small-scale trial of hybrid clones. Out of 23 hybrid clones, 13 clones exhibited superiority for yield over RRII 105, the standard heterosis ranging from 4 to 52 per cent (Table Bot. 1) during the fourth year of tapping.

Among the 15 clones under evaluation in the SST 1988, test tapping at the fifth and sixth year after planting showed two clones

Table Bot. 1. **Standard heterosis for dry rubber yield in hybrid clones**

Clone	Standard heterosis (%) for yield (g/tree/tap)
82/3	48.27
82/4	44.16
82/7	52.29
82/10	9.74
82/14	48.82
82/17	14.28
82/21	18.55
82/22	31.03
82/25	6.88
82/26	3.60
82/27	6.56
82/29	42.04
82/30	29.67

Table Bot. 2. **Yield components pooled over the two years of study**

Clone	Test tap yield (g/tree/tap)		Volume of latex (ml/tree/tap)		DRC (%)	
RRII 105	169.30	bc	48.53	cd	27.73	ab
RRII 102	144.37	bc	39.60	cd	26.93	ab
GT 1	209.33	ab	74.87	b	26.83	ab
Tjir 1	169.87	bc	55.23	bcd	26.03	ab
Fx 516	156.97	bc	50.73	bcd	23.57	ab
Ch 31	120.63	c	59.20	bc	23.93	ab
31	170.03	bc	52.03	bcd	23.10	ab
35	158.00	bc	47.83	cd	26.13	ab
55	88.97	c	31.37	d	27.83	ab
99	145.97	bc	43.20	cd	29.67	a
32/6	249.40	a	74.03	b	25.10	ab
33/8	273.50	a	97.17	a	24.10	ab
34/3	135.23	bc	52.20	bcd	21.12	b
38/1	146.37	bc	45.67	cd	26.63	ab
39/1	119.20	c	41.07	cd	28.10	a
General mean	163.81		54.18		25.79	
Variance ratio	4.08*		4.92*		NS	

* Significant at P = 0.05

Values followed by the same letter do not differ significantly according to Duncan's Multiple Range Test.

viz. 32/6 and 33/8, which are the progenies of Tjir 1, to be significantly superior, giving 65.5 and 47.3 per cent higher yield respectively in comparison to RRII 105 (Table Bot. 2). The secondary attributes of the clones are given in Table Bot. 3.

Table Bot.3. **Secondary attributes of clones**

Clone	Wintering	Incidence of powdery mildew
RRII 105	Medium	Moderate
RRII 102	Medium	High
GT 1	Medium	High
Tjir 1	Medium	High
Fx 516	Late	Low
Ch 31	Medium	Moderate
31	Medium	High
35	Late	High
55	Medium	High
99	Medium	Moderate
32/6	Medium	High
33/8	Medium	High
34/3	Medium	High
38/1	Early	High
39/1	Medium	High

Wintering

Early : > 50% of leaves shed by January second week

Medium : 50% of leaves shed between the second and last week of January

Late : > 50% of leaves shed after February first week

Powdery mildew (recorded during February)

Low : < 25% of the leaves affected

Moderate : 25-50% of leaves affected

High : > 50% of leaves affected

Hybridization was carried out in 1997 incorporating nine selected genotypes from wild germplasm with RRII 105 and RRIM 600. The cross combinations attempted and the fruit set in such combinations are shown in Table Bot. 4.

1.2 Ortet selection

Among the 53 ortets under evaluation in small-scale trials at Cheruvally Estate, five

Table Bot. 4. **Fruit set of Wickham x Wild germplasm crosses**

Female parent		Male parent	Fruit set (%)
RRIM 600	X	MT 999	5.85
	X	MT 1021	15.15
	X	MT 1027	6.80
	X	MT 1014	4.74
	X	MT1005	8.33
	X	AC 495	7.33
	X	AC 498	4.53
	X	AC 817	7.80
	X	RO 380	16.43
RRII 105	X	MT 1014	4.57
	X	MT 999	7.82
	X	MT 1027	1.65
	X	MT 1005	14.45
	X	MT 1021	1.15

clones registered higher yield than RRII 105 during the first year of tapping ranging from 48.52 to 54.34 g/tree/tap whereas RRII 105 recorded a mean yield of 45.88 g/tree/tap. From the 43 ortets under evaluation at Mundakayam Estate in SST, two clones were found on par with RRII 105, in terms of initial yield. Trees were opened for tapping in SST of ortets at Koney Estate. Clones from 1992 SST showing higher yield than RRII 105 on test tapping at the age of 4.5 years were multiplied for further evaluation. Girth of ortet clones along with control clones was recorded both in mature and immature trials.

1.3 Special techniques in breeding

Annual girth recording was carried out in the clone trial of irradiated materials, laid out in 1985. Yield collection on all tapping days was done from the clones yielding more than RRII 105.

Girth data from the 1992 SST incorporating eight clones indicated higher girth for two clones than RRII 105.

2. Evaluation of clones

2.1 Large-scale evaluation

Trees in two multidisciplinary evaluation trials comprising of 13 clones each were opened for tapping. Monthly yield recording and girth measurements are being carried out.

Monthly recording of yield and periodical recording of secondary characters were undertaken from the trials on large-scale evaluation of clones.

2.2 Onfarm evaluation

Regular recording of yield and secondary characters was carried out in the onfarm trials. In the block trial at Mannarghat Estate, average yield over three years was the highest in PB 311 registering 1317 kg/ha/year followed by PR 261 (962 kg/ha). One block each of 14 clones under commercial evaluation in Chemoni Estate has been opened for tapping during the period under report. Annual girth recording of the block trial at Sasthamkotta revealed highest girth for the clone PB 314 followed by PB 255 and PB 311.

3. Performance of clonal composites

Scrutiny of girth data of the five different multiclonal combinations with monoclonal population at CES Chethackal and RRS Nagrakatta exhibited varying girthing pattern. A comparative girth performance in the two regions is given in Table Bot. 5. The trial at RRS, Nagrakatta exhibited comparatively better growth than that at CES, Chethackal.

4. Polycross progeny evaluation

Girth and incidence of pink disease were recorded from the clones in the two field trials established for the evaluation of progenies of prepotent clones. Girth ranged from a mean of 18.50 cm for the progeny of PB 5/76 to 23.54 cm and 23.13 cm for the progenies of

Table Bot. 5. **Comparative performance in girth of multiclonal combinations at CES and RRS, Nagrakatta**

Multiclonal combination/ monoclonal population	Mean girth during 4th year of planting (cm)	
	CES Chethackal	RRS Nagrakatta
Blend 1	18.28	29.15
Blend 2	19.27	27.71
Blend 3	19.19	26.66
Blend 4	19.00	25.99
Blend 5	18.09	19.25
Monoclone population of RRII 105	17.40	21.75
Mean	18.54	25.09
SD	0.739	3.792

Blend 1. Completely randomized planting of clones RRII 105 (40%); RRIM 600, GT 1, PB 235, PB 28/59, PB 217, RRIM 703 (48%); PR 255, PR 261, RRII 5, PB 260, PB 280, PB 311 (12%).

Blend 2. Clonewise planting of RRII 105 (40%); RRIM 600, GT 1, PB 235, PB 28/59, PB 217, RRIM 703 (48%); PR 255, PR 261, RRII 5, PB 260, PB 280, PB 311 (12%).

Blend 3. Completely randomized planting of clones RRII 105 (40%); RRIM 600, PB 28/59, PB 217 (48%); PR 255, RRII 5, PB 280 (12%).

Blend 4. Completely randomized planting of clones RRII 105 (40%); GT 1, PB 235, RRIM 703 (48%); PR 261, PB 261, PB 311 (12%).

Blend 5. Same as in Blend 1, except for the design – RBD with 35 replications.

PB 217 and RRII 105 respectively in Trial 1. In Trial 2, mean girth of progenies ranged from 22.37 cm (progeny of PB 242) to 32.75 cm (progeny of PB 252). Progeny of AVT 73 and RRII 105 recorded a mean girth of 28.32 cm and 28.20 cm respectively.

5. Breeding clones for combining compact canopy with good yield

The girth of trees recorded during 1998 in the observational trial at RRII experiment stations showed that the normal plants from the genetic variant recorded the highest girth (61.53 cm) followed by RRII 105 (57.01 cm). The trees were opened for tapping and monthly yield recording is being done.

6. Breeding for drought tolerance

Twenty four hybrid seedlings resultant of crosses between seven parent clones selected on the basis of drought tolerance parameters were cloned and established in a polybag nursery for laying out a SST.

Fifteen ortets selected based on their yield performance in the drought-prone tract of North Konkan were cloned and established in a polybag nursery for laying out a SST at CES. Simultaneously source bushes of the same clones have also been raised at RRS, Dapchari.

7. Breeding for powdery mildew resistance

In the trial on screening clones for tolerance to powdery mildew, the inoculum was not sufficient for uniform disease rating under field conditions. The trial is being maintained properly.

8. Investigations on Genotype x Environment interaction

Twelve clones were planted at five locations comprising both traditional and non-traditional rubber growing regions with a view to study the adaptability and stability of performance of these clones. Periodical recording of girth, plant height and number of whorls was continued. Marked variation in initial growth pattern of clones was observed.

9. Estimation of genetic parameters

Data on latex yield and five biochemical components of latex viz. total solid content, thiols, sucrose, inorganic phosphorus and magnesium of 11 clones, during the third

year of tapping were subjected to variability analysis. High estimates of variability, heritability and genetic advance (Table Bot. 6) for most of the characters favour good scope for selection.

Table Bot. 6. **Genetic parameters for latex yield and biochemical sub-components**

Character	Coefficient of variation		Heritability (%)	Genetic advance (%))
	GCV	PCV		
Latex yield	30.91	36.98	69.85	52.57
Total solid content	6.16	8.65	50.64	9.09
Thiols	22.65	30.67	54.51	34.75
Inorganic phosphorus	31.12	39.98	60.59	50.23
Magnesium	40.10	46.70	73.73	71.19
Sucrose	28.60	37.95	56.81	44.55

10. Cytogenetical investigations

Cytomorphological analysis of an induced tetraploid of clone RRII 116 had been done. The tetraploid showed wide variation in foliar and floral characters compared to its diploid counterpart (Table Bot. 7). The chromosome complement of the diploid was 2n=2x=36 and the tetraploid was 2n=4x=72. Meiosis was highly irregular in tetraploid showing univalents, bivalents, trivalents and tetravalents with a range of 2 to 4, 22 to 30, 2 to 4 and 2 to 6 respectively. Pollen stainability in the diploid and tetraploid was 96.45 and 74.03 per cent respectively. Pollen grains in the diploid were 3-zonocolporate. In addition to 3-zonocolporate grains, 4-zonocolporate as well as micropollen grains were present in the tetraploid.

Table Bot. 7. **The foliar and floral characters of diploid and tetraploid (RRII 116)**

Parameter	Diploid	Tetraploid
Leaf area (cm^2)	174.34 ± 19.36	461.42 ± 56.86
Leaf thickness (mm)	0.22 ± 0.004	0.26 ± 0.009
Male flower (mm)	5.2 x 2.8	6.3 x 3.2
Female flower (mm)	8.3 x 3.2	9.2 x 3.8
Petiole length (cm)	11.53 ± 1.06	17.8 ± 1.85
Sterile pollen (%)	3.55 ± 0.40	25.97 ± 2.27
Pollen size (mm)	42.44 x 33.88	48.93 x 38.37

11. Floral biology and fruit set

Insufficiency of pollen adherence on the stigmatic surface was observed in the samples studied for pollen tube growth at different intervals following hand pollination.

12. Anatomical investigations

12.1 Bark anatomical investigations

Removal of the dry unproductive bark of TPD-affected trees by successive tapping, leaving the residual bark undisturbed, was found to be a feasible approach to manage bark dryness in rubber. The regenerated bark from the affected area was found to be productive while the control trees have not recouped. A detailed study on this aspect was initiated at two locations with clones RRII 105 and RRIM 600. After six months, samples were collected to study cambial activity from four regions viz. unaffected area, TPD affected area on rest, regenerated bark from affected area and normal regenerated bark.

To study the effect of tapping on normal rhythm of cambial activity, samples of cambium and twigs were collected periodically from trees under different tapping intensity. Anatomical studies on cambium, bark and latex vessels are in progress.

To study the effect of ethrel on untapped trees, monthly application of five per cent ethrel on the bark is being continued. Twig samples of 58 seedlings from 1993 HP were collected to study intraxylary phloem, primary xylem group and thickness of phloem and xylem. Microscopic observations of the parameters selected are in progress.

12.2 Evaluation of clones for structural components

Virgin bark thickness and number of latex vessel rows at 24 years growth of nine clones from RRII 200 series along with PR 107 were recorded for the characterization of clones (Table Bot. 8).

Table Bot. 8. **Anatomical parameters of selections from RRII 200 series clones**

Clone	Bark thickness (cm) Mean ± SE	Number of latex vessels Mean ± SE
RRII 201	1.16 ± 0.068	34.29 ± 1.85
RRII 202	1.04 ± 0.068	36.40 ± 5.85
RRII 203	1.30 ± 0.447	38.67 ± 4.32
RRII 204	1.23 ± 0.132	34.00 ± 6.89
RRII 205	1.15 ± 0.104	30.75 ± 2.96
RRII 206	1.10 ± 0.07	43.25 ± 3.86
RRII 207	1.00 ± 0.063	29.60 ± 2.27
RRII 208	1.15 ± 0.92	40.00 ± 2.696
RRII 209	1.35 ± 0.96	33.75 ± 2.18
PR 107	1.28 ± 0.48	30.50 ± 0.058

13. Wood anatomical investigations

Monthly ethrel application is being continued in the trial on effect of ethrel stimulation on rubber wood quality.

A comparative study on xylem structure in relation to water translocation in *Hevea* clones was initiated. Three clones viz. RRIC 52, RRII 105 and PR 261 were selected for the study. Wood samples were collected from these clones grown under two agroclimates, Punalur representing the traditional region and Dapchari representing the non-traditional region, experiencing severe drought. Mean vessel lumen diameter including that of solitary vessels was recorded from macerated wood samples. The observations are given in Table Bot. 9.

14. Studies on propagation

A new trial to study the effect of long snag and nicking of snag buds on establishment of green-budded plants in bags was

Table Bot. 9. **Mean conduit dimensions (mm) in three clones from traditional (L1) and non-traditional (L2) region**

Character	Clone			Mean
	RRIC 52	RRII 105	PR 261	
Single vessel diameter				
L1	0.2175	0.2507	0.2151	0.2278 ^{NS}
L2	0.2363	0.2260	0.2275	0.2299
Mean^{NS}	0.2269	0.2383	0.2213	
Vessel lumen diameter				
L1	0.1658	0.1385	0.1305	0.1450 ^{NS}
L2	0.1622	0.1510	0.1347	0.1493
Mean^{*3}	0.1640	0.1448	0.1325	
Vessel element				
L1	0.6375	0.5887	0.6077	0.6113 ^{*3}
L2	0.6020	0.5940	0.5634	0.5865
Mean^{*2}	0.6197	0.5913	0.5855	

CD (P=0.05) : ^{1}0.018; ^{2}0.025; ^{3}0.020 * Significant at P< 0.05

initiated. No incidence of uprooting was observed in the trial on budding height and depth of planting. In the trial on comparative study of twin stocks and single stocks, bag plants produced by raising single stocks in bags followed by *in situ* budding recorded poor growth than the normal bag plants. Bench grafts opened after 40 days recorded better success than the normal nursery grafts. Growth of the bench-grafted plants was also on par with nursery grafts. Bench-grafted plants being grown in the field continued to show marginally better growth than the nursery grafts. Among the bag plants planted at different depths, those plants with bud union buried 10 cm deep continued to show better growth. Growth characters were recorded from the plants raised to assess the effect of delayed opening and pulling out on establishment of plants in bags.

15. Genetic basis of stock-scion relationship

In the trial to study the performance of certain modern clones on different root systems, RRII 203 on all stocks recorded more vigour (72.47 cm) and RRII 105 on assorted stock gave the maximum yield (66.20 g/tree/tap). In the 3 x 3 stock-scion combination trial also, RRII 203 showed the highest girth, the figures being 57.93 cm on RRII 203 stock, 53.78 cm on RRIM 600 stock and 52.45 cm on RRII 105 stock.

16. Studies on early evaluation

The plants under the trial on early evaluation of 10 clones of high, medium and low yield potential were subjected to test tapping at the age of 52 months. Measurement of girth was also taken. The clone PB 260 recorded the highest girth (32.6 cm) followed by PB 235 (31.2 cm). PB 235 registered the highest yield (17.9 g/tree/tap) and RRII 33 the lowest (2.09 g/tree/tap).

17. Morphological characterization of popular clones

Fifteen clones were morphologically characterized at the age of 10 months. Morphological parameters studied were nature of buds and leaf scars, shape of leaf storey and characteristics of leaves. The shape of leaf storey viz. hemispherical, bow-shaped, conical and truncate was observed to be clone-specific. The leaf storey of RRII 105 was bow-shaped, RRII 300 and RRII 208 truncate and RRIM 600 conical. The important distinguishing characters of the leaflets are colour, lusture, texture, size, shape, leaf margin, longitudinal and cross-sectional view, leaf apex and degree of separation.

GERMPLASM DIVISION

The Division's research activities centred around conservation, characterization and evaluation of germplasm. Both Wickham and IRRDB collections are being maintained. Attempts are also being made to establish genetic relationship among germplasm materials using molecular methods.

1. Introduction, collection and conservation of germplasm

1.1 Wickham collection from secondary centres

Five *ex situ* germplasm conservation gardens established at CES, Chethackal are being maintainead with a population of 125 Wickham clones. Monthly yield and annual

girth were recorded in Garden II and III.

Significant differences in girth were noted among the five IRCA clones of Garden IV in the sixth year after planting. The clones IRCA 109, IRCA 230 and IRCA 18 were found to be on par with control clone RRII 105, whereas IRCA 111 and IRCA 130 were superior with regard to the annual girth (Table Ger. 1).

Table Ger. 1. **Average annual girth of IRCA clones at sixth year**

Clone	Girth (cm)
IRCA 111	38.24
IRCA 130	36.89
IRCA 109	34.83
IRCA 230	31.79
IRCA 18	30.62
RRII 105	29.82
CD (P=0.05)	6.27

Twenty Wickham clones in the fourth year of planting exhibited no significant variation in girth. The average girth of the clones ranged from 14.31 cm for the clone SCATC 88-13 to 23.63 cm for RRIC 100, while RRII 105 had a girth of 16.06 cm (Table Ger. 2).

1.2 Wild Brazilian germplasm from 1981 IRRDB collection

Seven source bush nurseries comprising 3617 wild genotypes of the Brazilian germplasm established at CES, Chethackal are being maintained. These nurseries are used as a source of budwood for raising planting materials for various evaluation trials. One tree per genotype is maintained for floral biology studies and hand pollination programmes.

2. Evaluation of germplasm

2.1 Preliminary evaluation of 1981 IRRDB collection

There are seven ongoing preliminary evaluation trials comprising 445 wild *Hevea* germplasm. One hundred seventy five wild genotypes in the Evaluation Trial A planted in 2 x 2 m spacing, with a girth of 35 cm and above were opened for 1/2S d/2 tapping for comparison of genotypes. Ninety nine genotypes were selected for preliminary screening for drought tolerance. The average annual girth data of wild genotypes in Evaluation Trial B were recorded in the sixth year after planting. The minimum girth was recorded by the wild genotype MT 1029 (37.69 cm) whereas the control clone RRII 105 had an average girth of 28.05 cm. Detailed leaf and bark anatomical observations were completed and the data are being compiled.

Table Ger. 2. **Average annual girth of 20 clones in germplasm garden at fourth year of planting**

Clone	Girth (cm)
RRIC 36	18.63
RRIC 100	24.63
RRIC 102	22.77
RRII 12	20.12
RRII 15	17.25
RRII 20	18.86
RRII 22	23.24
RRII 23	21.25
RRII 27	15.93
RRII 105	16.06
RRII 108	22.53
RRII 168	18.97
RRII 178	23.47
RRIM 609	24.25
RRIM 618	18.84
SCATC 88-13	14.31
SCATC 93-114	19.02
PB 255	19.68
Haiken 1	19.81
PR 255	19.27
CV	25.27

Annual girth was recorded and test tapping was carried out on the 50 genotypes in the Evaluation Trial C for a preliminary screening. In general, though many ortets showed girth comparable to

RRII 105, the test tap yield of most accessions was very low. Bark samples were also collected and are being processed for anatomical traits.

In Evaluation Trial D, annual girth was recorded for 24 wild genotypes. Maximum girth of 26.16 cm was recorded for the genotype RO 867 and the minimum girth of 17.27 cm for MT 932, while RRII 105 had a girth of 22.08 cm.

Data collected from Evaluation Trial E on morphological traits during the first year of growth indicated significant overall differences for height, diameter at 5 cm height from the bud union, total number of flushes, total number of leaves and leaf number and area of the topmost mature flush. Several accessions were superior to the control, RRII 105, for height, diameter, leaf number and area of the topmost mature flush (Table Ger. 3). Girth recording, test tapping and bark sampling were carried out for comparison.

Analysis of data on girth in the fourth year of growth, of the nine wild ortets and control, RRII 105, planted in an RBD in Evaluation Trial G, showed that there was significant overall variation for this trait. Four clones had girth values comparable with that of the control.

2.2 Large-scale evaluation trial of 1981 IRRDB collection

Eighty wild genotypes found promising for various growth characters from the preliminary evaluation trials were selected for large-scale evaluation and the field trial was laid out at RRS, Padiyoor in 1995. The genotypes were planted in a simple lattice design with normal spacing with the objective of a detailed multidisciplinary evaluation. The growth of the clones was monitored in the third year by the annual girth recording. The girth values ranged from a minimum of 5.67 cm for AC 685 to a maximum of 11.86 cm for AC 650 with 7.96 cm girth for the control, RRII 105.

3. Multidisciplinary / general studies

3.1 Variation in the anatomical features related to stress, yield, diseases, etc.

The leaf samples and bark samples collected from 80 wild genotypes belonging to Evaluation Trial B were processed and subjected to microtomy and observations on anatomical parameters were recorded.

Table Ger. 3. **Variation in wild germplasm in the first year of growth in Evaluation Trial E**

Character	Range		Mean	Control (RRII 105)
	Maximum	Minimum		
Height (cm)	218.5 (AC 714)	131.3 (AC 634)	173.6	154.2
Diameter (mm)	25.0 (AC 458)	17.1 (RO 856)	21.9	19.4
Total number of flushes produced	5.54 (AC 438)	3.49 (AC 689)	4.46	5.47
Total number of leaves	61.5 (AC 438)	34.3 (AC 689)	48.3	52.7
Number of leaves in topmost mature flush	19.5 (AC 714)	11.8 (RO 856)	16.2	14.6
Leaf area of topmost mature flush (cm^2)	3183 (AC 961)	1137 (RO 856)	2037	1196

3.2 Maintenance of National Accession Register, herbarium and clone museum

The National Accession Register for wild *Hevea* germplasm was kept updated. Budwood of 12 clones and leaf samples of 11 clones from the clone museum were supplied to Botany, Physiology and Biotechnology Divisions for various experiments. Three hundred and sixty herbarium specimens of 120 accessions of wild *Hevea* germplasm were prepared during the flowering season of the reporting year.

3.3 Micromorphological, histological and histochemical characterization of the IRRDB germplasm

Processing and serial sectioning of the paraffin-embedded leaf samples collected from 100 wild genotypes from Evaluation Trial A are being continued.

3.4 Multivariate analysis

Data on morphological, anatomical and physiological parameters, along with yield, were recorded in the mature plants, while growth parameters in terms of girth at 15 cm height, number of flushes and leaves and height were recorded from the polybag plants.

3.5 Studies on drought tolerance in *Hevea* germplasm

Ninety nine wild genotypes were selected from Evaluation Trial A for studies on drought and leaf stresses by means of cellular membrane stability analysis. A wide variability among these genotypes was noticed as indicated by the variation obtained for injury to cell membrane (Table Ger. 4). The genotype AC 446, AC 652, AC 643 and MT 80 showed

Table Ger. 4. **Genotypic variation of cellular membrane injury**

Genotype	% injury	Genotype	% injury	Genotype	% injury	Genotype	% injury
AC 175	33.05	AC 710	69.96	MT 198	53.80	MT 194	58.87
AC 446	29.77	AC 749	53.85	MT 196	43.30	MT 191	55.49
AC 163	52.49	AC 633	70.06	MT 57	65.12	MT 55	44.23
AC 168	41.04	AC 708	60.25	MT 202	55.57	MT 76	51.29
AC 165	57.64	AC 713	77.16	MT 199	63.14	MT 43	53.96
AC 155	60.41	AC 728	80.43	MT 188	58.53	MT 41	50.65
AC 177	57.63	AC 775	69.84	MT 187	49.73	MT 78	53.99
AC 160	51.12	AC 795	78.97	MT 63	52.49	MT 86	46.26
AC 162	52.43	AC 635	62.45	MT 66	45.04	MT 80	29.96
AC 166	54.11	AC 723	70.27	MT 69	67.35	MT 38	52.76
AC 161	40.75	AC 756	68.90	MT 189	62.28	MT 64	38.50
AC 762	43.88	AC 621	69.51	MT 185	58.33	MT 40	39.59
AC 676	62.62	AC 761	71.45	MT 193	61.30	MT 45	35.11
AC 697	58.05	AC 760	65.55	MT 56	59.60	MT 945	46.45
AC 750	45.06	AC 650	75.93	MT 184	48.17	MT 927	77.05
AC 727	40.08	AC 688	50.23	MT 180	47.80	MT 58	80.29
AC 769	53.12	AC 700	58.62	MT 179	48.01	MT 938	56.34
AC 765	42.03	AC 648	40.34	MT 178	56.32	MT 924	47.58
AC 729	50.28	AC 1044	56.82	MT 181	46.50	MT 913	48.74
AC 643	33.03	AC 702	56.89	MT 182	35.68	MT 904	56.67
AC 716	49.41	AC 631	66.70	MT 67	48.69	MT 930	62.22
AC 661	40.37	AC 537	35.68	MT 142	49.75	MT 919	46.95
AC 788	40.43	AC 606	54.12	MT 44	43.26	MT 943	60.32
AC 640	45.67	AC 658	41.24	MT 186	53.69	MT 942	44.58
AC 652	29.86	MT 197	44.64	MT 73	59.58	RRII 105	53.94
						Tjir 1	74.40

higher tolerance to water and temperature stresses.

3.6 Floral biology and fruit set characterization

The flowers and fruits of the two variants detected earlier in the 1981 Brazilian collection were examined in detail. Differences, primarily in the nature of the inflorescence, colour of flowers, presence of basal disk in the male flowers and the shape of the fruits indicate the possibility of these deviants being interspecific hybrids.

3.7 Genome analysis of the wild *Hevea* germplasm

A project was initiated for establishment of genetic relationship among the wild *Hevea* germplasm through RAPD studies in collaboration with Genome Analysis Laboratory. Forty five genotypes were selected from the preliminary evaluation trials representing the three provenances of Acre, Rondonia and Mato Grosso, for comparing the growth characters like girth, bark thickness, number of latex vessel rows and dry rubber yield. One genotype each from the three provenances having poor performance compared to RRII 105 was also included for a better comparison at molecular level. Leaf sample collection of these genotypes was initiated and DNA extraction of these genotypes was completed during the year.

3.8 Hybridization of wild Brazilian germplasm with Wickham clones

Nine superior wild genotypes identified on the basis of data from evaluation trials were used as parents for hand pollination with two popular Wickham clones in 1997 in collaboration with Botany Division. The progenies resultant of this hand pollination are established in the seedling nursery for evaluation.

MYCOLOGY AND PLANT PATHOLOGY DIVISION

Mycology and Plant Pathology Division continued research on disease and pest management, causal agents, role of microbes in augmenting soil fertility, utilization of wastes and pollution control. Screening of germplasm materials for disease tolerance is also given importance.

1. Abnormal leaf fall disease

Severe incidence of abnormal leaf fall disease occurred in all the traditional rubber growing tracts due to prolonged southwest monsoon.

The new fungicide formulation containing 40% COC and 5% metalaxyl (Ridomil plus), which was found useful in the previous year, was field-tested in five locations in two clones. This chemical, sprayed at the rate of 5 kg/ha, was found to give higher leaf retention in four locations than COC-sprayed (8 kg/ha) plots. In one location, although the leaf retention was lower, it was comparable to COC-sprayed plots (Table Path.1).

Two dosages of this fungicide (3 kg/ha and 5 kg/ha) were field-tested in two clones

Table Path.1. **Percentage leaf retention in different locations**

Treatment	Malankara (GT 1)	Kanyakumari (GT 1)	Kumarankudy (RRIM 600)	Cheruvally (RRIM 600)	CES (RRIM 600)
Metalaxyl plus (5 kg/ha)	69.37	87.54	62.54	43.43	78.56
COC (8 kg/ha)	62.22	81.54	72.80	11.18	50.17

at CES, Chethackal. Although there was no appreciable difference between the dosages in leaf retention in the tolerant clone RRII 105, the difference was marked in susceptible clone RRIM 600 (Table Path.2).

Table Path.2. **Percentage leaf retention under different doses of metalaxyl plus**

Treatment	Dose (kg/ha)	RRIM 600	RRII 105
Metalaxyl plus	5	78.56	62.25
Metalaxyl plus	3	40.53	63.46
COC	8	50.17	73.29
Unsprayed		20.09	48.52

Two formulations of mancozeb (mancozeb alone and mancozeb + COC) were tested at two dosages. The effect of mancozeb spraying on leaf retention was not steady with respect to dosages and formulation. Although mancozeb-sprayed plots had much higher leaf retention (59.28 - 68.09%) than unsprayed plots (35.29%), it was inferior to COC-sprayed ones (75.21%).

In the experiment to study crop loss due to abnormal leaf fall, the percentage leaf retention in unsprayed plots of RRIM 600, RRII 105, GT 1 and RRII 118 were 20.09, 48.52, 28.54 and 54.43 compared to 50.17, 73.29, 75.21 and 84.39 per cent in sprayed ones. The crop loss followed the same trend as earlier with RRII 105 recording no loss. In another experiment to compare the effect of different dosages on leaf retention and yield, the mean percentages of leaf retention in RRII 105 sprayed with different dosages of COC were 47.35, 59.90, 74.24 and 53.27 for 2, 4, 6 and 8 kg/ha sprayed plots respectively.

2. High volume spraying

The effect of adding spray oil to 1% and 0.5% Bordeaux mixture in controlling abnormal leaf fall disease was compared with the conventional fungicides in the experiment conducted at Pudukkad Estate. Spraying of 1% Bordeaux mixture and COC in oil at recommended dose served as the check. The percentage leaf retention recorded in various treatments is furnished in Table Path.3. It indicated that 0.5% Bordeaux mixture with 1% spray oil is comparable with 1% Bordeaux mixture in controlling the disease.

Table Path.3. **Percentage leaf retention in various treatments using spray oil**

Treatment	Leaf retention (%)
1% Bordeaux mixture + 1% spray oil	81.0
0.5% Bordeaux mixture + 1% spray oil	76.0
1% Bordeaux mixture	69.0
COC in spray oil (1:5 proportion)	60.0

3. Powdery mildew disease

In mature rubber, a dusting experiment was undertaken to compare the efficacy of hexaconazole (Contaf) 2% dust at the rate of 8 kg/ha alone or in alternate rounds with sulphur (12 kg/ha). The efficacy of the new chemical is being evaluated.

In the nursery, six systemic fungicides were evaluated in comparison with wettable sulphur for the disease control. After four rounds of spraying, higher reduction in disease intensity was noticed with propiconazole (Tilt) 0.05%, hexaconazole (Contaf) 0.01%, penconazole (Topas) 0.05%and myclobutanil (Systhane) 0.04%.

4. Pink disease management by curative fungicide treatment

Field trial was undertaken at Manickal Estate, Mundakayam to evaluate the efficacy of two fungicides viz. hexaconazole (Contaf) and TMTD (Thiride) in different

carriers for controlling pink disease. The application of Bordeaux paste remained as control. Vinofan and Dipicol were found better carriers for both the fungicides. The recovery of trees in various treatments is given in Table Path.4.

Table Path.4. **Percentage recovery of pink disease-affected trees**

Treatment	Recovery of trees (%)
Hexaconazole in Rubberkote	60.0
Hexaconazole in Vinofan	80.0
Hexaconazole in Dipicol	70.0
TMTD in Rubberkote	60.0
TMTD in Vinofan	70.0
TMTD in Dipicol	70.0
Bordeaux paste	60.0

5. Control of shoot rot disease

The experiment to study the effect of adding stickers to Bordeaux mixture and phosphorous acid against shoot rot disease was continued. The disease incidence registered in various treatments did not indicate any marked difference (Table Path. 5).

Table Path.5. **Control of shoot rot disease**

Treatment	Disease index (%)
1% Bordeaux mixture + Sandovit	19.00
Bordeaux mixture + Vinofan	18.00
Bordeaux mixture + Delair wet	18.00
1% Bordeaux mixture alone	13.00
0.16% Phosphorous acid + Sandovit	17.00
0.16% Phosphorous acid + Vinofan	20.00
0.16% Phosphorous acid + Delair wet	15.00
Phosphorous acid alone	15.00

The amount of copper retained on the leaf, after adding stickers, between two sprayings is estimated using Atomic Absorption Spectrophotometer. The amount of copper retained on leaves in various treatments is furnished in Table Path.6.

Table Path.6. **Mean copper content in leaves**

Treatment	Mean copper content	
	I	II
1% Bordeaux + Sandovit	415.4	134.6
1% Bordeaux + Vinofan	421.5	161.3
1% Bordeaux + Delair wet	274.8	256.5
1% Bordeaux alone	274.6	119.6
0.16% Phosphorous acid + Sandovit	56.1	51.4
0.16% Phosphorous acid + Vinofan	104.5	70.06
0.16% Phosphorous acid + Delair wet	125.7	66.37
0.16% Phosphorous acid alone	123.6	62.0

* I - Sampling on same day after spraying
II - Sampling after 15 days, before next round spraying

6. Control of dry rot disease

The field experiment to control dry rot disease was continued. Hexaconazole (Contaf) 0.02% incorporated in rubberkote continued to give effective control of the disease irrespective of the stage of development of the disease at the time of treatment. Other fungicides found effective were tridemorph (Calixin) 1.00% propiconazole (Tilt) 0.2%, validacin (Validacin) 0.06% and penconazole (Topas) 0.04%.

7. Control of patch canker disease

Two field experiments were carried out in two locations one in clone RRII 105 and the other in PB 260 for the control of patch canker disease. Metalaxyl+mancozeb combination (Ridomil MZ) at the rate of 5 g/kg rubberkote gave better control in both locations comparable to Bordeaux paste. Phosphorous acid (Akomin 5 ml/kg) and mancozeb (Indofil M45 10 g/kg) were less

effective in one location each.

8. Panel diseases and their control

One of the difficulties by rubber estates which use mancozeb or phosphorous acid formulations for panel disease control was that the fungicide applied areas cannot easily be distinguished from untreated ones, posing difficulties in supervision. An attempt was made to overcome this problem by incorporating a cheap additive to provide a colour to applied panels. Preliminary trials indicated usefulness of China clay and synthetic dyes. An experiment was conducted to evaluate the effect of such addition on the disease control efficacy of these fungicides. Phosphorous acid (Akomin) and mancozeb (Indofil M45) were evaluated with China clay alone and China clay + dye as addition. The addition of these additives had no negative impact on disease control efficacy of the fungicides. Mancozeb with China clay (100 g/ha) is the most effective treatment in disease control. The applied panels could easily be distinguished by the white colour.

9. Studies on leaf spot diseases

9.1 *Gloeosporium* leaf disease

The field trial for evaluating the efficacy of different fungicides against *Gloeosporium* leaf disease at Manickal Estate was continued this year. The result of the trial indicated that all the fungicides tested were significantly better than unsprayed control. The efficacy of mancozeb (Indofil M45), carbendazim (Bavistin), their alternate use and combination was confirmed this year also (Table Path.7).

Table Path.7. **Efficacy of fungicides against *Gloeosporium* leaf disease**

Fungicide	Disease index (%)
Mancozeb 0.2%	27.22
Carbendazim 0.05%	26.75
Mancozeb (0.1%) + Carbendazim (0.025%)	29.86
Hexaconazole 0.02%	34.84
Metalaxyl MZ 0.1%	30.40
Metalaxyl MZ 0.2%	27.64
Mancozeb & carbendazim (alternate)	31.53
Bordeaux mixture 1%	34.00
Unsprayed control	50.49
CD (P=0.05)	5.90

9.2 *Corynespora* leaf disease

Severe incidence of *Corynespora* was reported from Dakshin Kannada district of Karnataka during January to June 1998. A survey was conducted with the assistance of Rubber Production Department of the Rubber Board in the rubber growing regions of the district. The disease was found to be widespread in the areas affecting up to 62% holdings in Sullia and Madikeri, 21% in Puthur and 10% in Belthengadi taluks. Intensity of the disease varied from 10-70% in individual holdings. A training was conducted for field officers of the Board on the diagnosis and control of the disease. A demonstration spraying campaign was conducted in 25 locations covering all the taluks.

Experiments were conducted for the evaluation of dust formulation and oil-based fungicides for the control of the disease in mature plantations at South Karnataka region. The results indicated that between the dust formulations, i.e. hexaconazole (Contaf) and carbendazim (Bavistin), the former was better and both oil-based COC and mancozeb were on par.

A field trial was carried out to evaluate the efficacy of different fungicides against *Corynespora* leaf disease in a polybag nursery of RRII 105 at Manickal Estate. All the fungicides tested were significantly superi-

or to unsprayed control. The lowest disease intensity was recorded with 0.05% carbendazim which was significantly superior to 1% Bordeaux mixture (Table Path.8).

Table Path.8. **Effect of fungicides on *Corynespora* leaf disease**

Fungicide	Disease intensity (%)
Metalaxyl MZ 0.2%	31.50
Carbendazim 0.02%	34.93
Carbendazim 0.05%	29.29
Mancozeb 0.2%	31.50
Mancozeb 0.1% + Carbendazim 0.025%	33.17
Hexaconazole 0.01%	36.53
Hexaconazole 0.05%	45.03
Tridemorph 0.1%	40.67
Phsophorous acid 0.08%	93.83
TMTD 0.2%	32.09
Bordeaux mixture 1%	39.94
COC WP 0.1%	41.06
Unsprayed control	66.55
CD(P=0.05)	8.75

The laboratory screening of eight fungicides using food poison technique was also proved the effectiveness of carbendazim (Table Path.9). Complete inhibition of growth of fungus was noticed even at 25 ppm.

10. Studies on physiology of disease resistance

Isolates of *Corynespora cassiicola* were collected during 1998 from rubber growing regions of South Karnataka and Kerala. The fungus could be isolated from alternative hosts like eupatorium and mango.

Studies on variabilities among isolates of *C. cassiicola* were initiated. Six isolates of *C. cassiicola* were inoculated on PDA medium and observations on rate of growth and mycelial characters were made. *In vitro* studies on the production of cellulase enzyme and toxin production by the isolates were also attempted.

The effect of temperature on the growth of *C. cassiicola* was also studied by keeping the inoculated plates at 22°, 28° and 35°C. The pathogen was found to grow more rapidly in the plates kept at 35°C.

11. Root diseases and their control

Observations on the experimental plants in the brown root disease control trial at Manickal Estate started in 1994 are being continued. The treated neighbouring plants around infected ones remain healthy.

High incidence of purple root disease was observed in Rajagiri Estate, near Konni, affecting the sprouting of the bud patch in nursery plants and also causing death of

Table Path.9. **Growth of *Corynespora cassiicola* in different concentrations of fungicide**

Fungicide	Per cent inhibition at different concentrations (ppm)				
	25	50	100	250	500
Carbendazim	100*	100*	100*	100*	100*
Hexaconazole	—	82.20	82.20	86.67	87.00
Tridemorph	—	88.89	88.89	92.22	94.44
Metalaxyl MZ	—	72.22	73.33	76.60	80.60
Phosphorous acid	—	57.77	58.20	59.33	82.20
Mancozeb	—	76.67	82.22	84.44	91.11
COC WP	—	39.10	62.20	68.20	82.20
TMTD	—	74.11	78.89	80.98	83.00

* Fungicidal

the plants. A trial was started to control the disease using fungicides such as tridemorph (3 ml/L), propiconazole (4 ml/L), hexaconazole (2 ml/L) and TMTD (10 g/L). The affected seedlings were uprooted, pruned and dipped in fungicide solution and planted in polybags. The soil in the polybag was also drenched with the respective fungicide solution. Untreated plants formed the control. The plants were observed every month for the recovery from the disease. Nursery beds infested by purple root disease and drenched with fungicides were planted with budded stumps and observations on infection by the pathogen are being made. A new trial for *Poria* root disease control was started at Kumbazha Estate using propiconazole (0.125%), tridemorph (1%, 0.5%), hexaconazole (0.05%) and TMTD (0.75%) and observations on disease progress are being made.

12. Evaluation of diseases of germplasm, HP and other clones

12.1 Evaluation of germplasm material

Observations on powdery mildew and shoot rot incidences in germplasm gardens were recorded. No tolerant genotype could be noticed.

12.2 Multidisciplinary evaluation of clones

The data on powdery mildew incidence during the years 1992, 1993, 1994 and 1995 were consolidated and statistically analysed. The results showed that RRIM 703 and PB 310 had low incidence of disease. The low susceptibility of the clone RRIM 703 could be attributed to its early wintering habit, but in the case of PB 310, the tolerance to disease indicated an inherent clonal character. Since the wintering pattern was not uniform, the study is to be continued to get conclusive results.

13. Crown budding for protection against abnormal leaf fall disease

The intensity of abnormal leaf fall and powdery mildew diseases in the experimental area was assessed. Powdery mildew disease was negligible in crown-budded and control (PB 311) plants. The incidence of abnormal leaf fall in different blocks is given in Table Path.10.

Table Path.10. **Percentage leaf retention**

Crown clone	Leaf retention (%)
Fx 516	71.0
RRII 33	75.0
Control (PB 311)	59.0

14. Studies on pollution due to plant protection chemicals

A detailed project entitled 'Impact of continuous application of copper fungicides on ecosystems of the major rubber growing tracts of Kerala and Tamil Nadu' was entrusted with Kerala Agricultural University with World Bank funding.

15. Investigations on non-symbiotic nitrogen fixing organisms

15.1 Survival of *Azotobacter*

The survival of five free living nitrogen fixing *Azotobacter* isolates in RRII soil was studied. The cultures were inoculated to soil in pots and periodic soil samples were taken for one year for *Azotobacter* estimation. Among these five cultures, maximum survival in soil was shown by the *Azotobacter* Isolate 4 followed by Isolate 2.

Different carrier materials like neem cake, humic acid, vermicompost, lignite, vermiculite, charcoal, coir dust, peat, rock phosphate with cow dung, cow dung alone and mushroom spent were tested. *Azoto-*

Table Path.11. **Microbial population after 6 months in inoculated soil**

Treatment	Bacteria	Fungi	Actinomycetes	Phosphobacteria	*Azotobacter*
Inoculated rhizosphere soil	$137x10^6$	$93x10^5$	$47x10^5$	$91x10^5$	$15x10^5$
Uninoculated rhizosphere soil	$71x10^6$	$13x10^5$	$16x10^5$	$59x10^5$	Nil
Inoculated soil	$120x10^6$	$68x10^5$	$81x10^5$	$74x10^4$	$16x10^5$
Uninoculated soil	$64x10^6$	$51x10^5$	$62x10^5$	$80x10^5$	Nil

bacter culture containing 10^6 cell/ml was mixed with unsterilized carriers along with 2% $CaCo_3$. Vermiculite and charcoal were found to be good carriers followed by lignite.

15.2 Inoculation studies with *Azotobacter*

Azotobacter sp. was found to establish more in the rhizosphere of rubber seedlings compared to non-rhizosphere soil upon inoculation. They also found to stimulate the population of other microorganisms in soil and rhizosphere (Table Path.11).

The experiment on the effect of *Azotobacter* inoculation on rubber seedlings at various levels of urea application at Central Nursery, Karikattoor was continued for the third year also. Rubber seedlings recorded better growth upon *Azotobacter* inoculation at reduced levels of nitrogenous fertilizer application (Table Path.12).

Table Path.12. **Effect of *Azotobacter* inoculation on growth of rubber seedlings at various levels of urea**

Treatment	1997-98	
	Girth (mm)	Height (cm)
25% Urea + *Azotobacter*	9.61	99.24
50% Urea + *Azotobacter*	10.05	101.65
75% Urea + *Azotobacter*	10.65	105.98
100% Urea alone	10.57	105.04
CD (P = 0.05)	0.80	9.92

15.3 Biochemical studies of *Azotobacter*

Five different isolates of *Azotobacter* isolated from different rubber growing soils were tested for polysaccharide production and indole acetic acid production. Among the isolates, Isolate 4 produced more water-soluble polysaccharides. All the isolates produced both alkali-stable and water-soluble polysaccharides. With respect to alkali-stable polysaccharides, Isolate 1 produced more ASP followed by Isolate 5.

The isolates when tested for indole acetic acid production, *Azotobacter* Isolate 4 produced more IAA (3.84 mg/100 ml broth) followed by Isolate 5. These *Azotobacter* cultures were found to solubilize rock phosphate in Pikovskaya's broth. Maximum phosphate solubilization was shown by Isolate 4 followed by Isolate 3.

15.4 Studies on *Azospirillum*

Two *Azospirillum* isolates were collected from rubber roots. Gas chromatographic studies showed nitrogenase activity by these cultures. A pot culture experiment was started to study the effect of these two *Azospirillum* cultures on the growth of rubber seedlings. Nitrogen was applied in two levels, 50 and 75% of the recommended level, with each isolate. Control plants were maintained with full dose of fertilizers. The plants were raised in pots and five replications were maintained for each treatment. Initial observations showed positive results in the growth of rubber seedlings upon

Azospirillum inoculation.

16. Effect of cover crops on growth of rubber

The experiment to assess the influence of cover crops, weeds and clean-weeded condition on the growth of rubber was continued. The rubber roots under *Mucuna* cover crop showed higher percentage of VAM colonization followed by *Pueraria*, weeds and clean-weeded area.

17. Improvement of phosphate uptake of rubber and cover crops through microorganisms

17.1 Influence of mycorrhiza on seedlings

Results of the initial studies on the effect of mycorrhizal inoculation in rubber seedlings under unsterile condition in polybags are given in Table Path.13.

Table Path.13. Effect of mycorrhizal inoculation on rubber seedlings at different levels of P application

Treatment	Height (cm)	Girth (mm)
Glomus fasciculatum	85.00	9.13
G. fasciculatum + 50% P	97.67	10.23
G. fasciculatum + 100% P	93.00	10.10
G. caledonicum	83.67	8.87
G. caledonicum + 50% P	95.00	9.50
G. caledonicum + 100% P	92.67	9.47
Glomus isolate	88.00	8.73
Glomus isolate + 50% P	96.33	9.70
Glomus isolate + 100% P	98.67	9.60
Uninoculated with 100% P	98.00	9.53
CD (P=0.05)	6.68	0.89

With all the three isolates tested, the girth and height of inoculated plants at 50% recommended level of P was comparable with 100% P application without mycorrhizal inoculation. Mycorrhizal inoculation without P application was not giving comparable results and at 100% P application, mycorrhizal inoculation was not stimulating the growth of rubber seedlings.

17.2 Studies on phosphobacteria

Survival of phosphobacteria in different carrier materials like lignite, unsterilized neem cake, humic acid, vermicompost, charcoal, coir dust peak, rock phosphate with cow dung, cow dung alone and mushroom spent was studied. Among these, coir dust and lignite were found to be good carriers for phosphobacteria under unsterile condition.

18. Mushroom culture

Four different wild mushrooms growing on rubber wood in the field were collected and studied for the growth on rubber wood saw dust. All of them grew profusely and produced sporocarps. When inoculated in the field, the cut surface of the rubber trees started producing this mushrooms. The possibility of utilizing these mushrooms is being explored.

19. Problems and prospects of waste generated from rubber industries

Ribbed smoked sheets' (RSS) effluent was fed to a 3 m^3 Deenbandhu biogas plant. The pH of the effluent was adjusted to 7.0 with lime (1 g/L). The flow rate was adjusted to 75 L/day in such a way that the HRT remains 40 days. The plant was initially seeded with the effluent from the gobar gas plant. The plant was run for 60 days to establish methanogenesis as evidenced by satisfactory biogas production with desired methane content in it (55%). The plant was further run for one year and its performance was monitored.

Biogas production data are expressed as m^3/day and presented in Table Path.14. The highest yield of biogas was observed during March to May. The methane content was found to be 55 to 65% and hydrogen sulphide was 3-7%. As hydrogen sulphide

Table Path.14. **Biogas production/day (averaged over the month)**

Month	Gas production (m^3)
August	1.50
September	1.66
October	1.72
November	1.75
December	1.72
January	1.82
February	2.21
March	2.44
April	2.51
May	2.55
June	2.32
July	2.20
Average	2.03

could become toxic when released in confined spaces, its removal using chemicals was attempted. Among the chemicals, calcium hydroxide and lead acetate were found good in removing hydrogen sulphide completely. But calcium hydroxide could be recommended as it is cheap and eco-friendly.

20. Isolation and characterization of rubber degrading bacteria

Rubber degrading microorganisms were isolated from soil collected from the area irrigated with rubber factory effluent. One species of fungus and one bacterial isolate were found to degrade rubber efficiently. Among the isolates, bacteria was found to degrade rubber more efficiently than fungus.

21. Rainguard-damaging crickets and their control

The cricket, *Gryllacrys* sp. damages the rainguard plastic by making semicircular cuts and making the cut ends to bend to form a comfortable nest. During the rainy season, water is leaked onto the tapping panel accelerating panel rotting. For preventing the attack of crickets on the rainguards, plastics of different colours viz. green, yellow, red, blue and white were used. The results indicated that blue-coloured plastic had least damage which was followed by red-coloured plastic.

22. Control of termites

Termites make mud gallery on the rubber plants and feed on the corky layer of bark. Due to the removal of corky layer of bark, the rubber plant suffers from sunscorch and subsequent drying. For the control of termite attack, insecticidal concentrations were tested by drenching at the base of plants. Chlorpyriphos 0.2% was the most effective. It gave 68.15% control of termite attack compared to the previous year attack. This was followed by chlorpyriphos 0.14%, 0.10% and endosulfan 0.175% giving 49.63%, 48.57% and 33.14% respectively (Table Path.15).

Table Path.15. **Control of termite infestation**

Treatment	Mean per cent control
Chlorpyriphos 0.06%	9.56
Chlorpyriphos 0.10%	48.57
Chlorpyriphos 0.14%	49.63
Chlorpyriphos 0.20%	68.15
Fenvalerate 0.02%	28.21
Fenvalerate 0.04%	27.03
Endosulfan 0.10%	18.48
Endosulfan 0.175%	33.14
Untreated control	9.83

23. Bee-keeping in rubber plantations

Reduction in the intensity of TSBV disease attack on the Indian bees has been observed. The European bees have found more acclimatized to the ecological conditions of the rubber estates in Kerala. During 1997 and 1998, *Apis*

Table Path.16. **Honey yield, cost and income of *A. cerana indica* and *A. mellifera***

	1997 January-March			1998 January-March		
	Mean honey yield/hive	Total cost/hive	Total income/hive	Mean honey yield/hive	Total cost/hive	Total income/hive
A. cerana indica	7	706	940	9	734	1098
A. mellifera	18	2483	2560	39	2501	4108

cerana indica F. yielded an average of 7 and 9 kg honey and *A. mellifera* L. yielded 18 and 39 kg honey per hive per annum (Table Path.16). The data showed that the net profit from *A. indica* being Rs.234/- and Rs.364/- while that of *A. mellifera* being Rs.77/- and Rs.1548 per hive per annum during 1997 and 1998 respectively.

24. Studies on vermiculture

The organic matter feeding worm, *Eudrillus euginiae* was found efficient in the production of vermicompost. Trials were conducted with different combinations of rubber wood sawdust and cow dung. This substrate was used for releasing worms and an equal quantity of the substrate left for natural decomposition without releasing the worm. The nutritive values of the vermicompost and compost were determined. The results showed that the organic carbon content was less in the vermicompost as compared to compost. The organic carbon was low when the rubber wood sawdust proportion brought down and cow dung proportion increased. The nitrogen content increased considerably after decomposition and the compost showed to have more nitrogen compared to vermicompost. The microbial contents indicated higher fungal, bacterial, phosphobacterial and actinomycetes counts in the vermicompost than the compost made without worms.

25. Studies on plant parasitic nematodes

The relative efficacy of nematicides such as carbofuran 3G, phorate 10G, aldicarb 10G and Sevidol 4:4G at 6, 10 and 15 kg per ha against root-knot nematode *Meloidogyne incognita* infesting rubber seedlings was evaluated. Carbofuran at 15 kg/ha recorded better plant growth followed by phorate and aldicarb at the same dosage. Carbofuran is also found to decrease the nematode infestation significantly compared to respective doses of other chemicals (Table Path.17).

Table Path.17. **Effect of treatments on nematode infestation**

Treatment		Galls/ plant	Population/g soil	Root-knot index
Carbofuran				
	6	41.2	37.8	2.8
	10	1.8	4.6	1.6
	15	0.0	0.0	1.0
Phorate				
	6	58.8	104.6	3.4
	10	51.4	97.0	2.6
	15	43.2	82.2	1.8
Aldicarb				
	6	72.0	99.8	2.4
	10	73.2	81.2	3.4
	15	54.2	69.4	3.6
Sevidol				
	6	94.6	146.4	3.6
	10	80.8	110.8	3.4
	15	69.4	100.6	2.5
Control		94.4	157.6	2.5
CD (P=0.05%)		16.21	25.73	0.9022

PLANT PHYSIOLOGY AND EXPLOITATION DIVISION

The Division has been involved in both applied and basic research in the various thrust areas such as ecophysiology, physiology of growth and yield, stock-scion interaction, tapping panel dryness, etc.

1. Ecophysiology of *Hevea*

1.1 Abiotic stress and oxidative damage in mature leaves

Trees grown in two agroclimatically distinct regions (one experiencing drought stress in summer and the other cold stress in winter, both concomitant with high PPFD) experienced severe photoinhibition of photosynthesis during the unfavourable seasons. The degree of photoinhibition was so large that the upper canopy leaves exposed to high PPFD fixed little carbon for most part of the day during the stress periods. Photosynthesis rates were higher in the shaded leaves in the lower canopy. Increased dark respiration contributed to decreased quantum yield for CO_2 assimilation in stressed leaves. The activities of several scavenging enzymes, particularly superoxide dismutase and peroxidase decreased in the leaves suggesting their increased vulnerability to oxidative damage under drought and cold stresses. The other scavenging enzymes (catalase, ascorbate peroxidase and polyphenol oxidase) did not show any consistent trend. The concentrations of total glutathione and phenols increased in the leaves in response to drought and cold stresses, possibly as a consequence of the damages already caused. Chlorophyll fluorescence measurements with pot-grown plants experiencing drought showed marked reductions in the maximum potential quantum yield (Fv/Fm in the dark adapted state) and the effective quantum yield (ΦPSII at PPFD=500 $\mu mol/m^2/s$) of PSII. Fv/Fm did not decrease, but ΦPSII was markedly reduced in the potted plants when exposed to one cold night. Reduction in ΦPSII was more in the drought - and cold - stressed than the control leaves which corroborates the high PPFD induced inhibition in leaf CO_2 uptake in the field.

1.2 Drought and canopy architecture

In this study a comparison of the canopy architecture and the growth and distribution of roots was made in 10-year-old trees grown in the severely drought-prone area of RRS, Dapchari. LAI and light interception increased significantly in the irrigated trees compared to the rainfed ones. The girth and height of the trees and width and height of the canopy were higher by 29, 19, 19 and 20 per cent respectively for the irrigated trees than the rainfed trees. The number of primary branches and their diameter was higher (22 and 26% respectively) for the irrigated trees than the others. The branches were inserted to the main trunk at an angle of 58.36 in the irrigated and 44.22 in rainfed trees. This led to more light penetration which altered the light distribution inside the rainfed canopy during summer and inhibit leaf photosynthesis particularly in the top canopy leaves.

In the rainfed trees, most of the growth occurred during the short favourable season immediately after the monsoon between June and October and no growth or even shrinking of the trunk was seen during summer. In the irrigated trees, a higher growth was seen throughout the year and summer had no adverse effect. Although there was some difference in the root distribution pattern, the total root density per unit soil volume did not vary between the irrigated and rainfed trees.

The influence of the canopy architecture on various micro-climatic parameters within the canopy are given in Table Phys.1.

Table Phys.1. **Micro-climatic conditions under irrigated and rainfed plantations during summer in comparison with open field**

Parameter	Irrigated plantation	Rainfed plantation	Open field
PPFD at soil surface ($\mu mol/m^2/s$)	185	944	1860
Soil surface temperature (°C)	35.37	38.65	40.67
Soil temperature at 10 cm depth (°C)	25.9	27.7	42.7
Soil moisture (%)			
0-30 cm depth	16.2	9.9	9.7
30-60 cm depth	18.2	14.6	17.5

Treatment means were significantly different at $P = 0.05$

1.3 Water and irrigation requirement in drought-prone areas

The amount of water mined by irrigated and rainfed trees at RRS, Dapchari was measured during summer and post-monsoon season using the sap flow technique. The average rate of uptake of water by irrigated trees during mid-day in peak summer was about 3.2 L/h and in the rainfed tree, this was only 0.84 L/h. During the post-monsoon season, the mean rate of water uptake at mid-day was 3 and 2.8 L/h in the irrigated and rainfed trees respectively. The cumulative water loss was about 35 L/tree/day in the irrigated and about 10 L/tree/day in the rainfed tree during summer. In the post-monsoon season, this was similar (a little less than 30 L/tree/day) in both the treatments. The difference in the rate of water loss during summer was largely because of their canopy size (LAI was 6.3 and 4.3 in irrigated and rainfed trees respectively) and trunk girth (58.02 and 44.2 cm in irrigated and rainfed trees respectively). A total shoot dry biomass of 211 kg/tree and 101 kg/tree was recorded in these two treatments which were significantly different. No statistical difference in biomass diverted for root growth was seen between these two treatments.

Considering that these trees are consuming more quantity of water required to sustain growth and productivity during summer (luxury consumption) because of adequate availability of water through irrigation, the irrigation was restricted to one-third of standard 1 ETc in such a way that there was a saving of labour and quantity of water by that proportion. During the 18 dry summer weeks, this restricted irrigation did not affect the yield and no detectable stress effects on the physiology of the trees were noticed. However, had the drought continued further, there could have been some adverse effects. But, the present results indicate the possibility of reducing the irrigation (both quantity and frequency) in a mature plantation. This may be related to the altered micro-climate within the canopy and improved soil properties.

1.4 Studies on cellular membrane stability

The role of light in drought-induced damage to *Hevea* leaf discs was experimentally evaluated in a plant growth chamber. Leaf discs of clone RRII 105 were incubated in 10, 20, 40, 60 and 80 per cent concentrations of PEG (water potentials -2.5, -5, -15, -40 and-60 bars, respectively) at 10°C for 24 h and light (250 $\mu mol/m^2/s$) was simultaneously applied from a flourescent lamp. Another set was incubated in PEG without light and served as control. As expected, with the increase in concentration of PEG the leakage of electrolytes increased from the leaf tissue. When incubated at 10°C for 24 h, light aggravated the membrane dam-

Table Phys. 2. **Effect of light on drought induced leakage of electrolytes (per cent injury)**

Treatment	Concentration of PEG (%)				
	10	20	40	60	80
Drought (PEG)	0	-1.11	20.88	45.34	63.88
SE	-	0.77	3.30	1.10	3.10
Drought and light (PEG + 250 µmol/m²/s)	0	0.60	23.44	51.82*	63.16
SE	-	1.40	3.80	2.10	3.80

* Significantly different at P=0.05

age only at 60 per cent PEG (Table Phys. 2). But there was a greater loss of membrane stability at a higher incubation temperature of 20°C and 60 per cent PEG (Table Phys. 3).

Table Phys. 3. **Effect of light and drought stress on cell membrane injury (per cent injury)**

Treatment	Incubation temperature	
	10°C	20°C
Drought (PEG 60%)	45.34*	51.00*
SE	1.10	1.50
Drought and light (PEG 60% + 250 µmol/m²/s)	51.81*	68.23*
SE	2.10	2.30

* Significantly different at P=0.05

Leaf photosynthetic oxygen evolution was estimated using a Hansatech oxygen electrode. The photosynthetic O_2 evolution declined in osmotically-stressed leaf discs (Table Phys. 4). Higher concentration of PEG further deteriorated the O_2 evolving mechanisms in leaf tissues. Dark-incubated samples had higher rate of O_2 evolution than the light-incubated leaf discs, but the difference was significant only at 10 and 60 per cent PEG. Thus, it appears that depending upon the PEG concentration, incubation and temperature and possibly the duration of incubation, light aggravated the damaging effects of PEG stress on membrane stability and photosynthetic apparatus.

Table Phys. 4. **Effect of PEG treatment in light- and dark-incubated leaf discs on photosynthetic O_2 evolution (relative units)**

PEG (%)	Light	SE	Dark	SE
0	3.70	0.17	3.90	0.10
10	2.70 *	0.13	3.10 *	0.12
20	2.00	0.20	2.29	0.21
40	1.25	0.18	1.60	0.10
60	0.30 *	0.10	0.70 *	0.29
80	0.00	-	0.00	-

* Significant at P=0.05

1.5 Plant ideotype

To identify an ideotype of rubber tree suitable for cultivation under drought-prone regions, a new study was initiated. Those polyclonal trees that are found to grow and yield very well at RRS, Dapchari are being subjected to thorough investigation ranging from phenotype to the gene to understand the mechanism of tolerance to severe drought. It is hypothesized here that the observed tolerance in the field has to be due to the combined effects of the genetic potential (to scavenge active oxygen species) as well as the phenotypic nature of the tree (canopy architecture).

1.6 Ecological impact of rubber cultivation

The study initiated during this year was on the impact of rubber cultivation on the

ecosystem in comparison with other forest species like teak, 'jarul' and native forest. In this study effect on soil physical characters, moisture and nutrient status, soil microfauna, macrofauna and flora and microclimate are being studied.

2. Physiology of growth and yield

2.1 Studies on yield and yield components

Studies on yield, yield components and growth of 17 clones were continued for the year 1997-98. Mean annual yield, Y (g/tree/tap), initial flow rate, IFR (ml/cm/min), dry rubber content (DRC), plugging index (PI) and girth are presented in Table Phys. 5. Mean latex yield was found higher in clone RRII 105. Clone RRIM 612 recorded the lowest yield of 18.6 g/tree/tap. The prominent high yielders are, RRII 105, PB 235, GT 1, RRIM 501, RRIM 600, RRII 118, LCB 1320 and PB 28/59 at the rate of 45.60 g/tree/tap. Clones Gl 1, RRIM 605, Tjir 1, PR 107 and RRII 300 yielded between 30-35 g/tree/tap, whereas BD 10, HP 20, RRIM 703 and RRIM 612 yielded below 24 g/tree/tap. Mean IFR was found high in clone RRII 105 (0.13 ml/cm/min) and low in RRIM 703 (0.06 ml/cm/min). The DRC ranged between 33-39 per cent. Among the low yielders RRIM 703 had low PI (5.0) and in high yielders LCB 1320 exhibited high PI (5.1). Maximum girth was attained by clones PB 235, LCB 1320, RRII 118, RRIM 612, RRIM 605 and PB 28/59 (in the range of 80-87 cm) and minimum by clones RRII 105 and Gl 1 (72 cm).

2.2 Mechanism of ethrel action

The experiment conducted with the aim of understanding the mechanism of ethrel-induced stability of lutoids showed that ethrel caused peroxidative damage and loss of semi-permeability of lutoid membrane. Ethrel altered the water relations of the latex in such a way that there was less osmotic flux of water from the cytosol into the lutoid lumen. This delayed the bursting of lutoids and reduced the plugging of latex vessels leading to more flow of latex and hence

Table Phys. 5 **Mean yield and yield components of 17 *Hevea* clones at CES, Chethackal (1997-98)**

Clone	Yield (g/tree/tap)	IFR (ml/cm/min)	DRC (%)	PI	Girth (cm)
BD 10	24.84	0.087	38.19	7.36	76.20
Gl 1	35.51	0.102	33.66	4.87	72.55
Tjir 1	33.08	0.115	38.93	7.41	75.64
GT 1	45.81	0.086	36.97	4.15	74.63
LCB 1320	42.80	0.113	39.36	5.14	85.18
PB 28/59	41.84	0.087	39.08	4.62	80.25
PB 235	51.58	0.088	37.42	3.63	86.95
PR 107	32.12	0.112	38.48	5.80	65.83
RRII 105	59.30	0.128	37.90	4.50	72.57
RRII 118	45.80	0.072	38.81	3.79	84.93
RRII 300	31.62	0.083	38.39	5.61	77.64
RRIM 501	45.52	0.089	35.99	3.59	63.90
RRIM 600	45.01	0.096	36.03	4.45	74.53
RRIM 605	35.22	0.113	37.43	6.45	82.31
RRIM 612	18.60	0.086	37.03	8.94	83.25
RRIM 703	23.74	0.064	35.12	5.04	68.98
HP 20	24.48	0.111	36.77	7.75	75.68

more rubber yield from trees applied with ethrel.

2.3 Ethrel-induced drain of resources in *Hevea*

Ethrel-induced drain of resources viz. sucrose, Pi, Mg^{++}, K^{+}, Cu^{++} in the latex were determined for the clone RRII 105. It is observed that the drain of carbohydrates and minerals through the latex is more in the trees applied with ethrel than control trees. The concentration of sucrose in the latex was less in ethrel-treated than control plants. Whereas the concentrations of Pi, Mg^{++}, K^{+} and Cu^{++} were more in the latex of ethrel-treated than control plants. When the total drain of these components per tree was computed for the entire experimental period, the loss of sucrose, Pi, Mg^{++}, K^{+} and Cu^{++} were respectively 21, 400, 186, 68 and 67 per cent more in ethrel-treated than control plants.

3. Stock-scion interaction studies

3.1 Performance of seedlings

An experiment was carried out to characterize the polyclonal and monoclonal seedlings for raising better root stocks. The growth performance of monoclonal and polyclonal seedlings was monitored. Monoclonal seeds of RRII 105, RRIM 600, PB 86, PB 28/59 and GT 1 and polyclonal seeds were used for the study. Seedling nursery was raised at Central Nursery, Karikattoor. Plant height, number of leaves, number of whorls, dry matter accumulation and leaf area were recorded. Seedlings raised from PB 86 showed better growth vigour. The study is being continued to see the isozyme variations between the mono- and polyclonal seedlings. They will be used as root stock for further study.

3.2 Effect of root stock on TPD

A new experiment has been initiated to study the effect of root stock on TPD and to examine if bud grafting from a TPD-affected tree increases the chances of TPD. About 30-year-old clonal trees from CES, Chethackal, both TPD affected and healthy, were selected and are being propagated through air layering. The own-rooted plants raised through air layering from these trees will be used as root stock for bud grafting in different combinations.

Significant influence of root stock on scion and *vice versa* has been observed confirming earlier reports. These effects ranged from root activity to photosynthesis and isozymes of scion leaves. A new study on root shoot communication has been proposed to understand any delayed physiological incompatibility between the root stock and scion.

4. Tapping panel dryness syndrome

4.1 Long-term field studies under the IRRDB programme

Yield and yield contributing factors like plugging index (PI), initial flow rate, total volume and DRC were recorded once in a week in the ongoing long-term experiment at Vennimala. Biochemical composition (sucrose, thiols, inorganic phosphorus) of latex and incidence of TPD percentage were determined at monthly intervals. Inorganic phosphorus and sucrose concentration were higher in the eleven affected (total so far) than the normal trees before the occurrence of TPD. This is in line with the findings so far that deficiency of carbohydrates is not a cause for TPD.

4.2 Cytokinin in the root stock and scion

This study was confined to the quantification of endogenous t-ZR in the bark tissues taken from the scion and stock portions of normal and TPD-affected *Hevea* plants. The t-ZR content in the bark was significantly less ($p<0.001$) in the scion tissues collected from TPD-affected than the

healthy trees. But, the t-ZR contents in the bark tissues from the stock regions of healthy and TPD-affected trees were not significantly different. This indicates that the reduced t-ZR level in the scion of the TPD-affected trees is not due to poor availability of t-ZR in the stock. The remarkable reduction in the endogenous t-ZR level in the TPD-affected bark must be, therefore, a local effect. The present results show that reduced content of t-ZR in the scion was related to TPD which fully inhibited rubber biosynthesis. It may also be concluded that the root stocks, which produce and translocate cytokinin to shoots, may not be responsible for the reduced t-ZR content in the scion of TPD-affected plants.

4.3 Studies on tissue respiration in relation with TPD

The present study was conducted in GT 1 and RRII 105 to examine the respiratory rates of the bark tissues from TPD-affected and normal trees and relate to the carbohydrate status of the tissues. Concomitant with an increase in the total sugars, sucrose and starch content in the bark, respiration rate also increased in TPD-affected compared to healthy bark from normal trees. In general, the bark tissues from the opposite side of the tapping panel of the two clones showed a decrease in the respiration, however, they did not show much variation in their carbohydrate contents in healthy trees. In trees of GT 1 partially affected by TPD, the sucrose and total sugar contents of the bark tissues from the latex yielding (wet) portion of the tapping panel showed a significant decrease compared to the dry portion of the same bark. But, respiration and starch contents did not change in this clone. Carbohydrate content and respiration of wet and dry portions of the panel from TPD trees did not vary in RRII 105. It would appear from the present study that increased availability of carbohydrates and increased respiratory activity in the bark must have led to increased biomass production at the cost of rubber biosynthesis in TPD-affected *Hevea* trees.

RUBBER CHEMISTRY, PHYSICS AND TECHNOLOGY DIVISION

Major research activities of the Division focussed mainly on studies on primary processing of natural rubber, chemical modification, reclamation, rubber blends, composites and product development.

1. Primary processing : Studies on drying of raw natural rubber

Efforts are being made to install two solar-cum-smoke driers of 900-sheet capacity at *Hevea* Breeding Sub-station, Nettana and Regional Research Station, Dapchari.

Evaluation of the solar-cum-smoke drier (96-sheet capacity) is being continued. Construction of a smoke house with access for partial sun drying of sheet rubber was completed at the RRII campus.

A study was initiated to assess the effect of sun drying on the properties of sheet rubber. Sheets, which predominate in Indian rubber market, are conventionally dried in smoke. However, owing to various constraints, many small growers resort to at least partial drying in open sun. The extent of degradation by different modes (Table Chem.1) of drying was compared with sun drying.

Higher Wallace plasticity and gel content and lower PRI were observed for sun-

Table Chem. 1. **Different modes of drying adopted for sheet rubber**

Treatment	Mode of drying
1	Smoke-dried for 5 days
2	Sun-dried for 40 h*
3	Excess smoke dried for 10 days
4	Slightly excess sun-dried for 60 h
5	Wet sheets exposed to 3 h UV radiation** and smoke-dried for 5 days
6	Wet sheets exposed to 3 h UV radiation and sun-dried for 40 h
7	Smoke-dried for 2 days and then dried in the sun for 20 h
8	Sun-dried for 20 h and then smoke-dried for 2 days
9	Smoke-dried sheets exposed to 3 h UV radiation

* For sun-drying, 5 h (10 am – 3 pm) were treated as an effective day

** Two UV lamps of 20 Watts kept at a distance of 25 cm from the sample

dried samples (Table Chem. 2). Excess exposure to sun deteriorates the quality and appearance of the sheet rubber.

2. Studies on different forms of NR

Processability of different forms of natural rubber such as RSS, EBC (DC), BC (FC), ISNR 20 (DC), ISNR 20 (FC) was studied using a torque rheometer. These different grades of NR were subjected to successive mastication cycles with time interval of 24 h and the changes in characteristic parameters were noted (Table Chem. 3). A methodology has been evolved to assess the degradation of the same.

Table Chem. 2. **Raw rubber properties**

Treatment	Parameter			
	Volatile matter (%)	P_o	Gel content	PRI (%)
1	0.56	46.60	9.75	82.0
2	0.45	50.60	21.42	69.8
3	0.58	44.80	10.64	80.8
4	0.49	42.20	19.50	53.6
5	0.64	47.20	11.30	80.8
6	0.48	48.80	18.60	68.4
7	0.56	47.67	19.62	59.3
8	0.65	48.67	17.21	77.6
9	0.52	46.00	9.75	85.8
VR	0.82^{NS}	14.93^{**}	8.84^{**}	36.8^{**}

3. Chemical modification of NR – epoxidized natural rubber (ENR)

Studies on storage behaviour of different grades of ENR viz. ENR 10, 25, 50 and 60 are in progress. Wallace plasticity (P_o), plasticity retention index (PRI), gel content and Mooney viscosity of the above grades of rubber showed an increasing tendency with storage period, while the epoxy content showed slight decrease.

ENR is reported to have better interaction with certain fillers. Blending of the former at a lower proportion with elastomers was found to improve the filler rein-

Table Chem. 3. **Difference in characteristic values during 1st and 2nd mastication**

Form of rubber	M_2 (Nm)	M_{15} (Nm)	T_F (°C)	$M_{2\text{-}15}$ (Nm)	ΔP_o	ΔT (°C)	$M_{2\text{-}15}$ (Nm-min)
RSS 4	51	29	27	22	6	27	444
EBC (FC)	38	10	18	28	6	10	265
EBC (DC)	31	5	7	26	3	7	138
ISNR 20 (FC)	36	17	16	19	3	16	190
ISNR 20(DC)	29	18	14	11	3	11	211

DC : Dry coagulum; FC : Fresh coagulum; M_2 : Torque at 2nd minute; M_{15} : Torque at 15th minute T_F : Temperature at the end of mastication; $M_{2\text{-}15}$: Reduction in torque; ΔT : Temperature rise during mastication; ΔP_o : Difference of P_o between 1st and 2nd mastication

forcement, especially in silica-filled elastomers. Hence a study on the reinforcement characteristics of the blends with silica-containing ENR was carried out by evaluating the technological properties and swelling behaviour. Studies on blends of NR, SBR and NBR with ENR were initiated.

4. Blends of NR with other elastomers and thermoplastics

Sulphur-vulcanized ternary blends of NR/ENR/PVC having varying concentrations of ENR were compared with conventional NBR/PVC blends. The ternary blends containing certain critical concentrations of ENR were comparable with NBR/PVC blends (Table Chem. 4).

5. Reclamation from product waste

A process has been developed for the reclamation of the vulcanized scrap rubber. The reclaimed rubber thus obtained can be cured with suitable curatives. The vulcanizate properties of the same were found to be superior to that of the conventionally reclaimed rubber.

6. Composites based on NR

Modified bitumen samples were prepared by incorporating rubber buffing powder obtained from tyre retreading units having different particle sizes. The same was observed to increase the viscosity and softening point of the bitumen and reduce the penetration characteristics. However, the ductility was adversely affected. It was observed that, lower the particle size of the buffing powder, better the properties of the resulting bitumen.

7. Development of rubber products and transfer of technology

Rubber compound for on-line sealant, which prevents the leakage of fluids through pipelines has been developed and the technology has been transferred to M/s. Usha Martin, New Delhi.

Table Chem. 4. **Properties of ternary blends with varying concentrations of ENR**

Blend ratio	Modulus 300% (N/mm^2)	Tensile strength (N/mm^2)	Properties Elongation at break (%)	Tear strength (N/mm^2)	Compression set (%)
NBR/PVC (70/30)	4.0	15.0	600	36.0	42
NR/PVC (70/30)	2.5	10.8	600	24.0	43
NR/ENR/PVC (65/5/30)	4.8	16.1	550	35.5	41
NR/ENR/PVC (60/10/30)	4.9	17.0	550	38.0	40
NR/ENR/PVC (55/15/30)	5.0	17.0	550	39.0	40
NR/ENR/PVC (50/20/30)	5.0	16.5	550	38.0	40

AGRICULTURAL ECONOMICS DIVISION

The Agricultural Economics Division is concentrating on the studies relating to economic aspects of natural rubber cultivation, processing, marketing, end uses, ancillary sources of income and by-products. Inter-divisional collaborative projects are also undertaken to analyse the economic viability of the experimental findings.

1. Commercial yield evaluation of planting materials

This is a continuous study since 1974 to generate information on the commercial yield of prominent planting materials. The al-

ready constructed massive database covering fieldwise yield and related information on a monthly basis has been updated using the data collected during the period under review. An alternative approach for evaluating the commercial yield performance of the planting materials has been formulated through developing a commercial yield performance index (CYPI) incorporating variables viz. extent of immature phase, composition of yield, tapping intensity and stand per ha. An analysis with 10-year-yield data covering 19 clones showed that except in three cases, the relative position in ranking order of yield got shifted when ranked according to CYPI. The first three ranks with regard to yield were claimed by RRII 105, PB 260 and PB 28/59 respectively while PB 260, RRII 105 and PB 235 attained the first three positions when ranked according to CYPI.

2. Monitoring of ancillary products from rubber plantations

The studies on the production and consumption of ancillary products viz. rubber wood, rubber seed and rubber honey are continuous in nature.

2.1 Annual estimates (1997-98)

During 1997-98, the estimated production of rubber wood was 1.27 million m^3 and that of rubber seed oil and cake were 2890 t and 4710 t respectively. The estimated production of rubber honey was 1500 t (Table Age. 1).

Table Age.1. **Production of ancillary products**

Production	Quantity
Rubber wood	1.27 million m^3
Rubber seed oil	2890 t
Rubber seed cake	4710 t
Rubber honey	1500 t

The end use pattern of stem rubber wood (Table Age. 2) showed that 58.5 per cent is consumed by the packing case industry.

Table Age. 2. **Consumption pattern of stem rubber wood**

Consuming sector	Consumption (%)
Packing case	58.50
Safety matches	3.00
Plywood	24.50
Processed wood*	12.00
Others	2.00

* Inclusive of 4% diffusion treated wood

2.2 Status report on processed wood sector

The study examined the performance of the secondary processing sector in terms of scale of operation, procurement, processing and downstream manufacturing, capacity utilization and market orientation covering 42 rubber wood secondary processing units located in Kerala (72%), Tamil Nadu (18%) and Karnataka (10%). There was a tremendous growth in the number of the processing units in the early 1990s mainly on account of the looming importance of rubber wood as an eco-friendly timber. Most of the units used indigenous technology and the average annual installed capacity for chemical impregnation and kiln seasoning was estimated to be 1115 m^3. The mostly preferred chemical treatment was Copper Chrome Boric (CCB). The sawing and seasoning rejections were higher because of poor quality of the raw material. Only 43 per cent of the units have downstream manufacturing facilities producing low value-added items mainly catering the internal market. The operational level constraints faced by the industry at procurement, processing, downstream manufacturing and marketing were reflected in lower levels of capacity utilization at 51 per cent. Certain policy options related to technology, marketing and institutional intervention that are necessary to attain the maximum commercial potential of the eco-friendly by-product of rubber plantations were also listed.

2.3 Status report on rubber seed sector

The study was based on a primary survey covering 29 dealers and 14 processing units. Most of the units do processing as a part-time activity and use rotaries, since cake obtained from expeller is of inferior quality. The processing cost of seed oil and cake was estimated to be Rs.19.80 and Rs.3.40 while the price rates are Rs.21 and Rs.6 per kg respectively. The price of oil has been almost stagnant at Rs.13.50 per kg mainly due to the competition from acid oils (waste of oil refinery mills). Rubber seed oil is extensively used in inferior quality soaps for the manufacturing industry. The major selling points are Chennai, Coimbatore and Nagercoil in Tamil Nadu, Kollam and Thrissur in Kerala and Mysore and Bangalore in Karnataka.

3. Operational efficiency of rubber plantations under different levels of management

The data analysis of the reconnaissance and main survey have been completed and the preparation of draft report is in progress.

4. Analysis of NR prices

4.1 Price stability and its impact on production, yield and area expansion : A comparative analysis with respect to NR cultivation in Kerala.

The study was initiated with the objective to analyse and compare the variability in price of six important crops viz. paddy, tapioca, coconut, tea, rubber and cardamom to examine the relationship, if any, between growth in area, production and price stability and to explore and identify the major sources of area expansion in the case of rubber. Data analysis has been completed and draft report is prepared.

4.2 Disaggregate level analysis of NR price

Computerized the monthly data on domestic price (RSS 4 and ungraded sheet), production, consumption, stock, import and world price (RSS 3 at Kuala Lumpur) of NR from 1968-69. Data analysis is in progress.

5. Intercropping in smallholdings

The study was focussed on the determinants of intercropping decisions and estimation of costs and returns of various intercrops. Primary data were collected from 240 growers from three regions viz. Punalur in southern, Thodupuzha in central and Thaliparamba in northern Kerala. A multiobjective land use planning model was developed based on the costs and returns. A draft paper on the determinants was prepared.

6. Analysis of replanting in smallholdings

The study was focussed on the factors influencing replanting decisions and to derive the optimum age of replanting. Initiated primary data collection from the central Travancore region.

7. Regional agricultural planning in rubber-based farming systems : A mathematical programming model

The study was initiated with the objective of identifying the existing resource use pattern and to develop an optimum regional agriculture plan through mathematical programming techniques. Primary data collection from Palakkad district was completed.

8. Stockholding practices of small growers in Kerala

The study was intended to inquire the extent of stockholding practices among the smallholders, to list out the prime factors determining the stockholding capacity and to analyse the difference in stockholding capacity of growers at different asset levels and growers with and without alternative sources of income. The samples for the study were randomly selected from the

Rubber Production Department registers for the years 1982 and 1983 from five Regional Offices. The field survey covering five traditional regions and 250 small growers was completed.

9. Economic liberalization and Indian tyre industry

The prospects of the tyre industry in the domestic as well as export market were examined in the backdrop of the ongoing process of liberalization in India. The analysis encompasses a period from 1965-66 to 1993-94 confining to truck and bus and lorry tyres which account for more than 85 per cent in the total export value of tyres.

10. Region and sizewise utilization of hired labour in smallholdings

The study entails a socio-economic survey of the tapping labourers in various regions of Kerala. Accordingly, survey has been completed in northern and central regions.

WORLD BANK-ASSISTED RUBBER PROJECT RESEARCH COMPONENT

1. Exploitation studies

Twelve field experiments on low frequency tapping systems, laid out in five estates and four medium holdings, were maintained. Stimulation treatments as per the schedule were imposed in all the trial areas and monitoring of yield, DRC and scrap per cent was continued.

Results obtained so far gave further promise for recommending low frequency tapping systems with stimulation. Under d/4 frequency, clone RRII 105 in Ambanad Estate showed considerable yield increase, recording 1800 kg/400 trees. The yield is quite reasonable compared to third year tapping of the clone under d/3 frequency. At Vennimala, second year tapping for 11 months, yielded 1608 kg/400 trees compared to the previous year yield of 1805 kg/400 trees (12 months). The yield was only 28 kg less than what was obtained from trees under d/3 frequency. In clone RRIM 600 under d/4 frequency (New Ambady Estate), yield was comparable to that obtained from d/3 frequency. However, third year yield did not show much improvement over the previous year. In clone PB 217 under d/4 frequency (Koney Estate) yield for 11 months showed slight increase over the previous year (12 months). In clone GT 1, under d/4 frequency (Ambanad Estate) yield for the first 11 months was more than what was obtained in the previous year.

Field experiments at the RIT campus were continued. Recommendation on Controlled Upward Tapping (CUT) was modified and the approach is to tap short cuts like 1/4S or even minicuts with sufficient number of stimulations (in fortnightly frequencies to adjust the crop reduction).

2. Latex diagnosis

The four experiments were continued in large estates for fixing the values of latex diagnosis parameters for clone RRII 105 under d/2 and d/3 system of tapping. Data from April 1997 to February 1998 were analysed.

Latex diagnosis studies conducted in the low frequency tapping trial laid out at Vengathanam Estate in clone RRII 105 under d/3 system indicate that the yield

increase obtained in the stimulated treatments does not exceed the physiological limit of optimum yield as indicated by the level of latex diagnosis parameters. Results suggest the possibility of utilizing latex diagnosis technique for fixing the optimum stimulation schedule in low intensity tapping experiments. The above studies were extended to smallholdings.

3. Clone evaluation

Various field experiments under this project were maintained. Regular recording of growth data was continued. In the clone evaluation trials at Keeriparai, in Kanyakumari region in Tamil Nadu, highest girth was recorded by IRCA 111 and in the trial at Padiyoor in Malabar region, IRCA 230 showed highest girth. In the 1994 onfarm trial at Keeriparai, among the 13 clones, PB 235 had the highest girth (28.50 cm) and PR 260 had the lowest girth (16.30 cm).

At Tamarakulam, two pipeline clones 82/22 and 82/14 along with RRII 105 as control were planted and maintained. The trial for identification of clonal composites laid out at Keeriparai was maintained.

At RRS, Agartala, the clone evaluation studies in immature phase with four clones viz. RRIM 600, RRII 105, PB 235 and GT 1 indicated highest girth for RRIM 600 while PB 235 recorded poor growth. In mature phase, the evaluation was made in clones RRIM 600, RRII 105 and GT 1.

4. Biotechnology

4.1 *In vitro* plant regeneration

Experiments were conducted to enhance the rooting efficiency using different combinations of auxins with or without cytokinins at different concentrations. The different combinations of growth hormones and nutrients effected axillary bud germination and its further elongation. Attempts were also made to induce multiple shoots on axillary buds.

4.2 Somatic embryogenesis and transgenic plant synthesis

As part of the collaborative research programme with the University of California, 14 tubes containing transgenic embryos and embryogenic calli incorporated with sorbitol-6-phosphate dehydrogenase and a tube containing embryogenic callus transformed with superoxide dismutase gene were brought to Biotechnology Division. These embryos and embryogenic calli were subcultured onto different media and high frequency secondary embryos were obtained. These embryos were subcultured on to maturation medium, for further development into plantlets.

At RRII, large-scale production of transgenic calli was obtained. After optimising all the essential parameters, genes encoding sorbitol-6-phosphate dehydrogenase, superoxide dismutase and isopentenyl transferase were incorporated into fresh calli of clone RRII 105. These calli were under different stages of development.

5. Germplasm / Genome analysis

5.1 Screening of *Hevea* germplasm for drought / cold tolerance

Selected genotypes of Brazilian germplasm together with a few modern clones were planted in polybag nursery for various studies. The 'Hot Spot' trial at Regional Research Station, Sukma, Madhya Pradesh was maintained. At 20-month stage, after field planting, highest girth increment was recorded for genotype RO 2629 (1.54 cm) followed by RO 5554 (1.36 cm). Among the control clones, GT 1 and RRII 118 had higher and comparable girth increment (1.43 cm).

5.2 Genome analysis

Most of the essential equipment, for Genome Analysis Laboratory were procured

and installed and the laboratory has started functioning since August 1997. Current research focuses on (1) the establishment of genetic relationship among the wild *Hevea* germplasm accessions, and (2) the development of random amplified polymorphic DNA marker(s) closely linked to the locus conferring resistance to *Phytophthora* in *Hevea*. Besides, a prepotency study using RAPD markers, in collaboration with the Botany Division, was also initiated.

6. DRIS fertilization

Field experiments were laid out at four locations to compare General Fertilizer Recommendation (GFR), Discriminatory Fertilizer Recommendation (DFR) and Diagnosis and Recommendation Integrated System (DRIS). From one year data, no significant difference could be noticed among the treatments.

A total of 10919 soil samples, 1631 leaf samples and 1512 latex samples were analysed in the central, regional and satellite laboratories and fertilizer recommendations were offered for all the samples analysed. Mobile soil testing camps were held in different regions.

The study to evaluate any progress in the number of soil samples analysed due to the implementation of World Bank Scheme indicated an increase in number of soil samples in eight out of nine laboratories. In all these laboratories, facilities for DRC estimation and leaf analysis were also provided.

7. Rubber-based sustainable farming system

Three experiments following three different models were laid out during 1996-1997 at the farm at Taranagar, RRS Agartala.

Model I : Rubber with banana and pineapple as intercrops supplemented by paddy and fishery-piggery integrated system.

Model II : Rubber with banana and pineapple as intercrops

Model III : Rubber with tea as intercrop

Average girth of rubber recorded were 7.08 cm and 6.14 cm in Model I and II respectively.

Among the intercrops, growth of banana was not satisfactory. Pineapple yield during the first year was lower than expected. The summer season paddy yielded only 60 kg whereas the kharif season yielded 418 kg.

In fishery-piggery system, 56 kg of fish was harvested during February 1998.

8. R&D activities on NR processing

8.1 Solar drying

The evaluation of the efficiency of the ready-made smoke house converted as a solar-cum-smoke dryer was continued. The efficiency of solar-cum-smoke dryer in comparison to a smoke house without solar drying facility is being worked out.

8.2 Comparative evaluation of dryers used in the production of technically specified rubber (TSR)

A systematic study was conducted to compare the performance of electrical and diesel dryers used in the production of TSR. In terms of efficiency and temperature control, the electrical dryers performed better. But the unit cost of drying was lesser for diesel dryers. The initial plasticity (P_o) of the samples dried in diesel dryers was found to be slightly higher compared to the electrical dryers. Volatile matter per cent is almost same. Batch to batch variation for the same raw material is higher for diesel drier. The rate of breakdown is higher during the initial period in the case of samples dried in the electrical dryers. However, as the mastication proceeds, the nature of breakdown becomes similar in both cases. The vulcanizate properties of samples dried in both types of dryers were observed

to be almost similar.

8.3 Modified forms of natural rubber

8.3.1 Storage behaviour of ENR

The effect of storage on the raw rubber and vulcanizate properties of different grades of ENR was evaluated periodically. The epoxy content of respective grades were observed to decrease during storage. The Wallace plasticity and gel content was observed to increase during storage in all the grades. However, vulcanizate properties were not observed to vary much due to the storage of the raw ENR.

8.3.2 ENR as a compatabilizer in polymer blends

The effect of ENR as a compatabilizer in NR/PVC blends was studied. At an optimum concentration of 15 phr of ENR, the technical properties of the NR/PVC blends were found superior. The ozone resistance was also improved by the addition of ENR.

9. UPASI component

The World Bank-aided project on Diagnostic Nutrient Recommendation facility by the UPASI R&D Centre, Kottayam, started in 1995 with the objective of augmenting the diagnostic nutrient facilities of the Rubber Board has ended by 31 March 1998.

The target of sample analysis was 2500 for the period 1997-98, out of which 2095 samples (1365 soil and 730 leaf) were collected and analysed. The number of samples for which fertilizer recommendations given was 1920, benefiting 1048 farmers.

10. Consultancy services

10.1 Impact of continuous application of copper fungicides on ecosystems of the major rubber growing tracts of Kerala and Tamil Nadu.

Eight locations covering plantations of five age groups viz. 5, 10, 20, 30 and above 30 years have been sampled for the study. The study covered chemical analysis for total copper, DTPA copper, clay content, organic carbon, pH, CEC, copper in leaf, latex and water. The impact on soil microflora and fauna was also studied.

Total copper content registered higher values in samples collected from plantations of known history of continuous copper fungicide spraying when compared to unsprayed plantations of the same age group. This variation was pronounced both in the vertical and horizontal distribution of total copper in almost all the samples studied. Among the locations, the lowest values for total copper was reported from HBSS, Paraliar followed by TR&T, Mundakayam, CES, Chethackal and RRII, Kottayam in the increasing order of copper content. More or less the same trend was found true for DTPA copper also. Unsprayed plantations and virgin lands recorded substantially lower values for DTPA copper and latex copper also, compared to sprayed plantations. Profile samples showed a clear depthwise decrease in DTPA copper in all the profiles studied.

Leaf copper registered higher values for sprayed plantations. Among sprayed plantations, samples collected from RRII Kottayam and CES Chethackal recorded higher values. Latex copper content varied from trace to 5 ppm in many of the samples studied. The variation in latex copper was minimum between samples taken from sprayed and unsprayed plantations. Copper was not detected in any of the water samples collected from plantations and adjoining areas. All samples including well water and river water did not show traces of copper.

Population of soil organisms such as earthworms, millipedes, centipedes, bee-

tles, ants, pseudoscorpion, symphylla, japyx, collembola, mites, spiders and protozoa was estimated. The number of soil organisms in plantations of all age groups, except five - year - group were higher in unsprayed plantations than in sprayed and virgin lands, the highest being in 30 - year - group. The population of nematodes also showed a similar trend. In all the age groups, the population of fungi was higher in unsprayed plantations. Population of actinomycetes was also higher in unsprayed plantations except in the case of 10-year group. Bacterial population, however, did not show any general trend.

10.2 Resource soil survey and mapping of rubber growing soils of Kerala and Tamil Nadu

A survey of the rubber-growing areas of Kerala and Tamil Nadu was undertaken in August 1997 to know the extent of rubber cultivation and to delineate the areas on 1:50000 scale. The base maps for field work were prepared by interpretation of remotely-sensed data/toposheets.

Field work was initiated in toposheets of central and southern Kerala, being the major rubber growing areas.

The field work involved : (a) checking and correction of physiography map, (b) study of profiles in transects, (c) study of grids at 1 km interval, (d) study of deeper grids at 5 km interval, (e) review by field review team and soil correlation, and (f) finalisation of soil map. The soils studied were grouped and seven soil series were established.

Laboratory analyses of particle size, cation exchange capacity, exchangeable Na, K, Ca, Mg, organic carbon, etc. are being carried out at the regional centres of the National Bureau of Soil Survey and Land Use Planning.

11. Training programme

11.1 Computer training

In the second batch of short-term computer training 59 staff members completed training at four centres.

11.2 Visit / Training abroad

11.2.1 Long-term attachment

Dr. N. Usha Nair, Senior Scientist (Biochemistry) and Dr. Kavitha K. Mydin, Scientist S3 (Plant Breeding) were deputed to the Department of Pomology, University of California, Davis, for three months for advanced training in construction of a cDNA library and in molecular marker-assisted breeding.

Dr. K.U. Thomas, Scientist S3 was deputed to the Indonesian Rubber Research Institute for a training in modern methods of exploitation, for 28 days and Smt. Rajeswari Meenattoor, Scientist S3 (Plant Breeding) was deputed to the International Agriculture Centre (IAC), Wageningen, the Netherlands for four months, for a training in applied plant breeding and molecular techniques.

11.2.2 Short visits

Dr. M.A. Nazeer, Joint Director (PM) was deputed to RRIM, Malaysia from 12 to 16 May on a short mission to familiarize with the latest developments on the research activities of RRIM.

Dr. P.J. George, Deputy Director (Germplasm) was deputed to IPGRI, Rome, Italy for eight days from 30 May 1997 to familiarize with the latest techniques of screening and conservation of germplasm and utilization of genetic resources.

CENTRAL EXPERIMENT STATION, CHETHACKAL, KERALA

The Central Experiment Station of the Rubber Research Institute of India covers an area of 255 ha. Experimental projects of the different divisions of the RRII are conducted at the Station. The current projects include clone evaluation, exploitation studies, screening of Brazilian germplasm, intercropping studies, density trial, weed management studies, yield loss assessment due to *Phytophthora* leaf fall, etc.

During the period under report, the total crop realised from the station was 141655 kg. A total of 302 tapping days were possible in the year with 19613 man-days. There are 209 permanent workers and 167 casual workers in the rolls during the period. The total mandays involved during the period for different operations were 67200.

The medical unit functioning in the station catered to the needs of 9752 patients during the period under report.

REGIONAL RESEARCH STATION, GUWAHATI, ASSAM

The Regional Research Station, Guwahati carries out research mainly on evaluation of clones, polyclonal seedlings and wild germplasm, nutritional requirement, diseases and pest management.

1. Evaluation of clones

1.1 Clone trial (1985)

Girth of 10 *Hevea* clones (RRII 105, RRII 118, RRII 203, RRIM 600, RRIM 605, PB 235, PB 86, PB 5/51, GT 1 and Gl 1) was recorded at monthly intervals. Highest girth over 12 years was noticed in RRIM 600 (65.11 cm) followed by RRII 118 (63.3 cm), PB 86 (62.9 cm) and the minimum girth was recorded in PB 5/51 (47.68 cm). RRIM 600 had the highest average yield (34.76 g/tree/tap) followed by PB 235 (27.92 g), RRII 105 (26.48 g), whereas PB 5/51 (20.38 g) had the minimum over four years of tapping.

1.2 Clone trial (1986)

Girth of eight *Hevea* clones (RRIC 102, RRII 105, RRII 208, RRII 5, PB 260, PB 310, PB 311 and PR 255) was recorded at monthly intervals. Maximum girth over 11 years was noticed in RRIC 102 (67.3 cm) followed by PR 255 (62.3 cm) and minimum in RRII 5 (57.25 cm). The maximum average yield over three years was recorded in PB 311 (25.09 g/tree/tap) followed by PB 310 (23.47 g) and minimum in PR 255 (16.95 g).

2. Nutritional studies (mature phase)

The experiment laid out at Nayekgaon, Kokrajhar, in1987 as an onfarm trial with clone RRII 105 was continued. Observations on monthly yield and half-yearly girth were recorded. The effect of nitrogen (40 kg/ha) on average yield was found highly significant over control. The interaction of the three nutrients on yield was also significant. However, the effect of fertilizers on girth was non-significant (Table Nea.1).

3. Interaction between K and Mg

3.1 Immature phase

The trial at Sorutari, which was initiated in 1987 with clone RRII 105, is being continued. Observations on growth revealed that a combination of the highest dose of potassium and higher doses of magnesium gave maximum average girth compared to other treatment combinations (Table Nea.2) though the effect of treatment on growth was non-

Table Nea.1. **Effect of NPK on girth and yield**

Level of nutrient (kg/ha)	Girth (cm)	Yield (g/tree/tap)	DRC (%)
Nitrogen (N)			
0	46.96	32.24	28.71
20	50.12	35.35	30.57
40	51.64	40.29	31.21
60	51.92	36.28	30.71
CD (P=0.05)	NS	2.88	1.23
Phosphorus (P_2O_5)			
0	50.21	40.67	30.03
20	49.28	33.39	30.23
40	51.00	33.34	30.64
CD (P=0.05)	NS	2.49	NS
Potassium (K_2O)			
0	49.26	33.97	30.82
20	50.33	35.97	30.53
40	50.90	38.19	30.05
CD (P=0.05)	NS	2.49	NS

significant. The interaction between K and Mg on yield was significant.

3.2 Mature phase

The experimental trees at Nayekgaon were opened for tapping and yield recording was carried out. The data showed (Table Nea.2) that effect of treatments on growth was non-significant. Highest doses of magnesium effected significant yield difference though the effect of potassium on yield was not found significant.

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

The two trials which were laid out in two locations, viz. Sorutari and Nayekgaon, to study the effect of different sources and combinations of phosphatic fertilizer on the growth and yield were continued. The data from Sorutari revealed that effect of treatments on girth and mean yield was non-significant. The plants receiving water insoluble phosphorus recorded the highest mean yield. In Nayekgaon, treatments on yield were found significant and water soluble phosphorus at 40 kg/ha gave highest mean yield compared to other treatments. However, their effect on girth was found non-significant (Table Nea.3).

5. Survey of diseases and pests

Pest and disease survey was carried out in 34 locations covering 15 rubber growing tracts in Assam, Meghalaya, Arunachal Pradesh and eastern West Bengal.

Powdery mildew disease caused by *Oidium heveae* was severe in most of the

Table Nea.2. **Effect of Mg and K on growth and yield**

Level of nutrient (kg/ha)	Girth (cm)		Yield (g/tree/tap)	
	Sorutari	Nayekgaon	Sorutari*	Nayekgaon
Magnesium (MgO)				
0	51.43	50.81	-	30.00
7.5	51.48	51.47	-	33.24
15.0	50.28	51.90	-	39.86
CD (P=0.05)	NS	NS	-	2.46
Potassium (K_2O)				
0	51.35	51.59	-	30.12
20	49.78	50.96	-	35.34
40	52.06	51.62	-	37.64

* Tapping has been started from May 1998.

Table Nea.3. **Effect of phosphorus on growth and yield**

Treatment	Girth (cm)	Yield (g/tree/tap)
Sorutari*		
Water insoluble P	61.69	43.00
50% water soluble and 50% water insoluble P	61.58	40.01
Water soluble P	61.06	39.51
Control	58.90	35.47
	NS	NS
Nayekgaon		
20 kg water soluble P	52.38	33.93
20 kg water insoluble P	53.65	32.35
40 kg water soluble P	52.93	41.52
40 kg water insoluble P	53.38	32.00
60 kg water soluble P	54.73	32.94
60 kg water insoluble P	51.88	40.14
Control	53.14	33.08
CD (P=0.05)	NS	5.44

* Recommended dose of P_2O_5@ 35 kg/ha

locations surveyed. High intensity of the disease was noticed in some locations like Beganabari, Jengichegre and Nagrakatta causing repeated premature defoliation and die-back of the twigs and branches.

Minor incidence of secondary leaf fall (SLF) disease on tender leaves caused by *Colletotrichum gloeosporioides* was noticed in nursery plants and also in field plantations during July to September in most of the locations surveyed. Collar rot disease caused by *Fusarium solani* was noticed in seedling nursery only at Jengichegre in Meghalaya during June-July with characteristic wilting symptoms of the disease.

High incidence of *Periconia* leaf blight disease caused by *Periconia heveae* was noticed on tender leaves in nursery plants during November to March which caused repeated premature defoliation and die-back of shoots in some locations in Assam, Meghalaya and Arunachal Pradesh. Minor incidence of brown root disease caused by *Phellinus noxius* was noticed in rubber plantations at Begenabari and Sorutari farm in Assam. Mild infestation of scale insects, termites, slugs and snails was also noticed in Assam and Meghalaya.

6. Isolation, identification and maintenance of pathogens

Routine isolation of fungal pathogens was made from diseased samples of rubber collected from different locations of North East during the survey. Fungal pathogens viz. *Periconia heveae, Colletotrichum gloeosporioides, Fusarium solani* and *Phellinus noxius* were isolated and studied the cultural characteristics.

7. Control of powdery mildew disease

The trial to evaluate the economic efficacy of powdery mildew disease control using agricultural grade sulphur was continued in mature rubber (RRIM 600) at RRS Sorutari farm. High incidence of powdery mildew disease was noticed in untreated control which resulted in repeated premature defoliation and die-back of twigs and branches. The dusting of three rounds of sulphur (25 kg/ha/round) effectively controlled the powdery mildew disease.

8. Evaluation of polyclonal materials

Out of 285 polyclonal seedlings, 143 trees were tapped (1/25 d/2) and the yield was recorded from June to December. Girth was also recorded twice a year. Preliminary selections were made based on yield over two years for further multiplication and evaluation.

9. Evaluation of wild germplasm

Selected genotypes were multiplied and established in polybag nursery for screening for cold and *Oidium* resistance in the early stages of establishment.

10. Potassium dynamics in the rubber growing soils of Assam

The project was initiated in 1997 with the following objectives :

i) To make a survey on K-status of potential rubber growing soils of Assam.

ii) To study the quantity-intensity (Q/I) relationships of soil K.

iii) To evaluate the crop response to K in soils differing in thermodynamic parameters. Soil samples at the depth of 0-30 and 30-60 cm were collected from lower Brahmaputra valley and different physico-chemical properties are being analysed.

REGIONAL RESEARCH STATION, AGARTALA, TRIPURA

The Regional Research Station, Agartala continued research activities on Agronomy/Soils, Plant Breeding, Plant Physiology/Biochemistry, Biotechnology and Rubber Processing. The Station has a mobile soil and tissue testing laboratory which caters to the needs of rubber growers in the entire north-eastern region.

1. Nutritional trials

1.1 NPK requirement in mature phase

This trial was started with a 3^3 factorial layout where three levels of N (0, 30, 60 kg/ha), P (0, 30, 60 kg/ha) and K (0, 30, 60 kg/ha) were imposed. Monthly yield and half-yearly girth were recorded.

Data showed that 60 kg N and 60 kg P resulted in higher yield over other treatments. Increasing levels of potassium increased the yield but it was not significant (Table Net.1). The effect of different levels of nutrients on annual girth increment was also not significant.

Table Net.1. **Yield (g/tree/tap) of RRIM 600 at different levels of nutrients**

Nutrient	Nutrient level (kg/ha)		
	0	30	60
N	36.83	38.45	40.61
P	35.72	38.83	41.34
K	38.09	38.49	39.31

1.2 Effect of higher levels of nutrients

Observations on half-yearly girth and monthly yield were recorded from this experiment on the response of *Hevea* to higher doses of nutrients and different sources of phosphatic fertilizers. The data revealed that treatment 60:60:60 (NPK kg/ha) recorded highest yield and girth increment (Table Net.2).

Table Net.2. **Effect of different nutrient levels on average yield and girth increment in the clone RRIM 600**

Treatment (NPK kg/ha)	Yield (g/tree/tap)	Girth increment (cm)
30:30:30	50.57	1.51
30:30(15):30	44.50	2.10
60:60:60	56.76	2.35
60:60(30):60	47.41	1.81
90:90:90	46.28	1.20
90:90(45):90	47.46	1.54

(Figures in parentheses indicate water soluble P)

2. Density-cum-nutritional trial

The trial was laid out at Taranagar farm in 1987 in split-split-plot design. Three planting densities viz. D1 – 420, D2 – 606 and D3 – 824 trees/ha were the main treatments. The sub-plot treatments consisted of three NPK fertilizer combinations (M1 - 40:40:20; M2 - 60:60:30; M3 - 80:80:40 kg/ha) and the two clones RRII 105 (C1) and RRII 118 (C2) were the sub-sub-plot treatments.

Highest yield was recorded in D1 which also showed significantly higher girth than D2 and D3. Among the fertilizer combinations M2 recorded the highest yield and girth.

3. Embryo culture

A project has been initiated for the rescue of immature embryos from desired cross-combination where fruit set is very low due to embryo abortion. The standardization of methods are in progress and early results showed formation of multiple shoots.

4. Evaluation of clones

4.1 Clone trial (1979)

The data on girth increment (Table Net.3) over one year (February 1997 - February 1998) revealed that RRII 203 recorded the highest increment (2.7 cm). The increment in girth was more during May to November.

Table Net.3. **Clonal difference in girth, girth increment and yield**

Clone	Girth (cm)	Girth increment (cm)	Mean yield (g/tree/tap)
RRII 5	69.3	1.9	33.04
RRII 105	74.0	1.6	38.41
RRII 118	85.8	2.5	58.14
RRII 203	82.5	2.7	60.51
RRIM 600	76.1	1.1	42.73
RRIM 605	76.0	1.2	33.44
RRIM 703	69.7	2.1	47.62
PB 5/51	66.1	1.2	30.46
PB 86	72.5	0.8	34.62
PB 235	80.2	0.7	63.24
RRIC 52	90.8	1.8	35.92
RRIC 105	85.8	1.2	37.97
GT 1	69.9	1.5	33.40
Gl 1	60.6	0.3	15.79
Harbel 1	66.2	0.0	25.07

The data on absolute girth of different clones over 18 years (1979-1997) revealed that RRIC 52 is having the highest girth (90.8 cm).

The data on mean yield of different clones indicated the highest yield for PB 235 followed by RRII 203 and RRII 118.

4.2 Evaluation of clones for stress tolerance

Analysis of girth data from 1987 trial revealed that the clone RRII 208 showed better growth during winter followed by Haiken 1 and SCATC 93-114. Wind damage assessment showed PB 5/51 and PR 107 to be wind tolerant. Of the six clones assessed for yield (RRII 208, RRIM 600, PR 107, SCATC 88-13, SCATC 93-114 and Haiken 1), RRII 208 yielded the highest with greater stability over high and low yielding regimes.

4.3 Evaluation of clones in the presence of windbreak (1995)

Ten oriental clones RRII 105, RRIM 600, RRIM 612, PB 217, PB 235, PB 260, PB 311, SCATC 88-13, SCATC 93-114 and Haiken 1 were laid in RBD with three replications and a gross plot size of 25 trees. A three-tier high density windbreak with social forestry trees was brought up in the periphery of the plantation to study the influence of windbreak on growth. Data on girth was collected at quarterly intervals. Initial observations revealed better girth for SCATC 93-114, PB 260 and PB 311.

5. Breeding and selection

5.1 Full-sib progeny evaluation

Data on morphological characters were recorded at quarterly intervals.

5.2 Half-sib progeny evaluation

The trial was started in 1994 with the objective of identifying useful recombinants (half-sibs) from five selected female parents (RRII 203, RRIM 600, GT 1, PB 5/51 and PB 86) out of a total of 15 clones planted in completely randomized design. A total of 49 half-sibs along with their female parents and probable male parents

were included following 8 x 8 simple lattice design with two replications. Data relating to growth were recorded at fixed intervals. Growth data revealed that progenies of PB 5/51 attained the highest annual mean girth (24.66 cm) followed by GT 1 (25.04) and RRIM 600 (24.59) in comparison to the parent values of 20.8, 22.62 and 23.33 cm respectively. Test tapping on the experimental plants was initiated.

6. Evaluation of polyclonal seedlings

Out of the 591 polyclonal seedling population planted in 1987 in completely randomized design, 409 trees are currently under tapping by 1/2S d/2 system. Data on growth, monthly yield and secondary characters were recorded. The dry rubber yield during the third year of tapping recorded a mean of 21.80 g/tree/tap. However, the yield of individual seedlings ranged from 2.62 to 71.48 g/tree/tap over three years. The seedling population attained a mean girth of 63.7 cm over 10 years. Based on three year's yield performance of individual seedling trees, 10 high yielding trees were selected for further multiplication and evaluation.

7. Investigations on Genotype x Environment interaction

This experiment, a part of a multilocational trial to study the G x E interaction pattern consisting of a total of 13 clones viz. RRII 51, RRII 105, RRII 176, RRII 203, RRIM 600, RRIC 100, PB 217, PB 235, PB 82/14, 82/17, 82/22, 82/29 and 82/30 was laid out in 1996 employing randomized block design with three replications and a plot size (net) of 36 trees. Early growth characters were recorded at periodic intervals. Mean girth at the age of 16 months of field planting was the highest in clone 82/29 (8.52 cm) followed by 82/30 (8.02 cm) in comparison to the values of 7.28 cm for RRIM 600 and 6.70 cm for RRII 105.

8. Germplasm conservation and evaluation

This Station maintains 256 wild Brazilian germplasm accessions planted during 1989. Out of these, 24 and 63 genotypes were field-planted in 1993 and 1994 respectively along with RRIM 600 as control following a simple lattice design. Another 80 genotypes have been multiplied and planted in polybag nursery during the current year for evaluation at juvenile phase. In the first trial, the girth of different genotypes varied from 7.7 to 12.4 cm, where mean girth of the population was 9.1 cm. In the second trial, girth ranged from 5.5 to 12.3 cm with a mean of 8.1 cm.

9. Exploitation studies

9.1 Effect of different tapping systems in combination with tapping rest during winter

The study on the effect of winter rest (20-20°C, 15-15°C and 10-10°C) in combination with different tapping systems (d/1, d/2 and d/3) showed that there is considerable reduction in yield of rubber when temperature goes down below 10°C. Incidence of TPD was more in d/1 system, though the yield was higher. Between the d/2 and d/3 systems, d/2 recorded better yield than d/3. However, a seasonal variation in the yielding pattern of the two systems was also observed. The sequential scoring of TPD for d/2 and d/3 tapping systems is in progress.

Based on the preliminary information from this experiment, an onfarm trial has been initiated incorporating 15-15°C, 12-12°C and 10-10°C regimes for tapping rests and d/2 system of tapping, in the clone RRII 105.

9.2 Effect of stimulation and intensive tapping on TPD

Physio-biochemical aspects of TPD have been studied in virgin bark of plants tapped for six months. Three treatments viz. alternate daily tapping (1/2S d/2), alternate daily tapping with the application of ethephon once in a month (1/2S d/2) and twice daily tapping (1/2S d/0.5) were imposed to develop the TPD syndrome. The result indicated an increase in the accumulation of free radical (measured by electron paramagnetic resonance spectrometer) in over-exploited plants than that of normal ones. During winter period, the yield showed significant negative correlation with sugar and thiol contents of latex irrespective of the treatments. The amount of thiol was found less in over-exploited plants than that in the control. The study of the isozyme polymorphism of superoxide dismutase, a free radical scavenging enzyme, also showed a reduction in the number as well as the intensity of the bands. High incidence of TPD was observed in trees with d/0.5 tapping. Moreover, the extent of TPD was more in d/0.5 than that of the stimulated ones. It appears that there is a balance between the accumulation of free radical and the efficiency of the active oxygen scavenging system (AOSS) that determines the occurrence of TPD.

10. Effect of soil moisture and agroclimatic parameters on yield

The experiment was initiated during October 1996 with five clones viz. GT 1, RRII 105, RRII 118, PB 235 and RRIM 600 planted in 1987 at RRS farm, Taranagar in completely randomized design. Apparent seasonal variability of the soil moisture (volumetric) was observed at 30 cm depth. Moisture content was recorded to be low during October to March and comparatively higher during April to September. The yield showed distinguished peak and lean periods. The consistent broad peak yielding period was October to November followed by a decreasing trend from mid-December till February. The yield (g/tree/tap) was high in PB 235 and low in RRII 118. Differential responses in total solid content (TSC) and the mineral elements (viz. Ca, Mg, K and Cu) with yield were also noticed. The data obtained on biochemical parameters viz. sugar, thiol and inorganic phosphate determined from latex indicated apparent variability not only within the clones but with respect to the season also. The thiol content in latex showed a significant increasing trend from December till mid-February. However, contents of thiol and inorganic phosphate in latex were comparatively low during the peak yielding period. Agroclimatic data and their interactions with yield along with other parameters studied are being analysed.

11. Prediction of yield by antecedent atmospheric parameters

Computational procedures were finalized for the selection of the most appropriate parameters from a continuous data set by a stepwise procedure. Preliminary results showed that temperature regimes of 20-25°C was found to contain the highest yield for all clones throughout the year. Consistent soil moisture deficit was observed in between the period of second week of November to the second week of February. Stepwise multiple regression equation revealed that vapour pressure deficit of the previous day afternoon showed a close relation with soil temperatures and played a significant role in the next day's yield.

Mean monthly agrometeorological data from six stations viz. Agartala, Guwahati,

Tura, Nagrakatta, Kolasib and Dhenkanal for the year 1997 were collected and tabulated.

12. Raw rubber processing

The factors affecting the quality of sheets in the north-east region were studied. Atmospheric oxidation is responsible for blackening of sheets in this region. High humidity in these regions favours the mould growth in the stored sheets. Bamboo reapers, commonly used in these regions are found to cause a high percentage of marks on the sheets than wooden reapers, if it is not cleaned regularly. Blisters and bubbles affect the quality of sheets in Guwahati region. In addition to the above, white pecks and irregular bubbles are found in sheets in this region due to pre-coagulation of the latex.

13. Advisory service

The Regional Research Station, Agartala is catering to the needs of rubber growers in the entire north-eastern region by undertaking soil and leaf samples analyses for giving site and situation-specific discriminatory fertilizer recommendation. During the year 1997-98, analyses of 1649 soil samples and 173 leaf samples were carried out and 231 individual recommendations were offered to the growers. The Mobile Soil and Tissue Testing Laboratory attached to this Station collected samples from different parts of Tripura, Assam, Meghalaya and Manipur.

REGIONAL RESEARCH STATION, TURA, MEGHALAYA

The Regional Research Station, Tura concentrated on studies related to evaluation of high yielding, disease resistant and cold tolerant clones and also on selection of high yielding mother plants from Garo Hills.

1. Field experiments at Ganolgre

1.1 Evaluation of clones

Girth recording from 10 clones in the 1985 trial indicated maximum girth for PB 235 (67.20 cm) followed by RRII 118 (66.35 cm), RRIM 600 (66.13 cm), RRII 203 (66.03 cm), PB 86 (63.20 cm), GT 1 (61.12 cm), RRIM 605 (60.15 cm), RRII 105 (58.60 cm), Gl 1 (55.14 cm) and PB 5/51 (53.51 cm). In 1986 clone trial, RRIC 105 (69.10 cm) and PB 311 (65.41 cm) have attained the maximum girth followed by RRII 208 (63.45 cm), RRII 118 (63.03 cm), PB 310 (63.0 cm), RRIC 102 (60.81 cm), RRII 105 (58.83 cm), PB 260 (55.95 cm), RRII 5 (52.94 cm) and PR 255 (49.63 cm).

1.2 Performance of polyclonal seedlings

The polyclonal seedlings planted in 1990 recorded an average girth of 36.41 cm.

1.3 Rubber-based cropping system

This trial has tea, orange and rubber (RRIM 600) planted in separate blocks (0.25 ha each) in 1987. The growth of rubber and tea plants was better, while that of orange was not satisfactory. Tea leaves weighing 491 kg were harvested at different time intervals during the year. Seventy per cent of rubber plants attained tappable girth.

1.4 Ortet selection

On the basis of growth, bark thickness, disease resistance, TPD incidence and yield, 10 and 15 mother trees were selected from an area of 2 ha plantations at Thebronggre (1974 planting, 620 m above msl) and Baghmara (1967 planting, 400 m above msl) respectively. The data on above parameters were collected at different time intervals from both the locations and finally eight and

ten mother trees are selected from Thebronggre and Baghmara regions respectively for further study.

1.5 Optimum season for budding

An experiment was initiated to find out the suitable season for budding under the agroclimatic conditions of Garo Hills (Meghalaya). Budding was carried out every week from July to December and percentage success was recorded. Maximum budding success was observed during August (90.3%) followed by July (88%) and September (82.8%) while the success was minimum in December (25.6%).

1.6 Evaluation of germplasm

Germplasm materials numbering 151 were planted in polybags during October and growth parameters such as sprouting percentage, height, leaf and whorl number and disease incidence were recorded at different time intervals. Due to prolonged winter, 50 per cent budded stumps were dried.

2. Field experiment at Darechikgre

2.1 Evaluation of clones

Among the 10 different clones (50 of each clone) planted in an area of 1.25 ha at 1100 m elevation, only 35 plants survived out of 500 plants due to low temperature. The growth of these plants was very poor. The results indicated that at 1100 m elevation rubber cultivation is not advisable under the Garo Hills condition.

2.2 Intercropping with perennial crops

Under this trial, tea, orange and polyclonal seedlings were maintained at 1100 m elevation. Due to high elevation effect and prolonged winter period, all polyclonal seedlings were perished and orange growth was retarded. The growth of tea was satisfactory.

3. Studies in plant pathology

3.1 Survey of rubber diseases

In general, no serious disease was noticed. The *Gloeosporium* leaf disease incidence was prevalent in mild form in all seasons (Table Nem.1).

Table Nem.1. **The incidence of *Gloeosporium* leaf disease**

Clone	Percentage disease index		
	Summer	Rainy	Winter
RRII 203	3.56	2.01	0.17
RRII 118	2.70	2.55	0.67
RRII 105	2.92	2.45	0.53
RRIM 600	3.45	2.42	0.35
RRIM 605	3.91	2.31	0.17
PB 235	3.23	2.55	0.42
PB 5/51	3.66	1.82	0.42
PB 86	3.65	1.82	0.42
GT 1	3.43	1.94	0.17
Gl 1	4.38	3.20	0.67

Sulphur dusting (22 kg/ha/round) was undertaken against powdery mildew. However, in unprotected areas moderate infection with defoliation could be noticed.

3.2 Microbiological studies

A comparative assessment was made on seasonal basis for the microbial population from native forest and rubber plantation. In general, the populations of bacteria and actinomycetes were higher in the rubber plantations. However, the number of fungal counts was comparable in both the soils. Among the fungi, *Aspergillus, Penicillium, Cladosporium, Cephalosporium* and filamentous yeasts were the dominant groups.

4. Physiological investigations

4.1 Effect of low temperature on growth

During winter period (December to February) average minimum air temperature of 10°C was recorded for three months which adversely affected the growth of all clones at 600 m elevation. During these months, average girth increment was 0.011 cm to 0.01 cm. Due to low temperature, defoliation started in the second week of January and all clones shed their leaves in first week

of February. Refoliation started in the first week of February or first week of March.

4.2 Effect of different aspect of slopes

In the experiment laid out in 1992, the growth of RRIM 600 plants, planted at west-south west (W-SW) and north-north east (N-NE) aspect of slopes was assessed. Plants in W-SW aspect of slope recorded better growth than those of N-NE. Between lower and upper part of the slope, better growth was observed in the former.

4.3 Evaluation of yield

Studies on yield and yield components of 10 and 12 clones from 1985 and 1986 trial respectively have indicated that rubber yield (g/tree/tap) was minimum during January to April in all the clones. The yield gradually increased from May recording maximum in November.

Maximum rubber yield from 1985 trial was observed in RRII 118 (18.46 g) followed by RRII 203 (17.47 g), RRIM 600 (16.73 g), RRII 105 (14.73 g), PB 5/51 (12.91 g), PB 86 (11.94 g), PB 235 (10.66 g), RRIM 605 (10.61 g) and Gl 1 (8.20 g). In the 1986 clone trial, the rubber yield of RRII 118 and RRIC 102 was 9.39 and 8.26 g/tree/tap respectively.

All the clones showed minimum DRC during the month of January and February while maximum in June. Generally, DRC ranged from 31 to 35 per cent in all clones except Gl 1 (27.3%). Minimum plugging index was recorded during November while maximum in April and July. Among the clones from 1985 trial, maximum plugging index was noticed in PB 5/51 (4.25), followed by PB 235 (4.24), RRIM 605 (3.78), RRII 105 (3.73), RRIM 600 (3.39), PB 86 (3.32), GT 1 (3.04), RRII 118 (2.8) and RRII 203 (2.13) while in 1986 trial, the plugging index of RRIC 102 and RRII 118 was 5.6 and 4.6 respectively.

5. Block plantation at DDC, Jengitchakgre

The girth recorded from RRII 105 plants indicated that 70 per cent of the total plants have attained tappable girth with an average girth of 51.0 cm.

REGIONAL RESEARCH STATION, KOLASIB, MIZORAM

The RRS, Kolasib conducts studies mainly in clone evaluation and nutritional aspects to develop an agro-technology for rubber cultivation suited to this region.

1. Multidisciplinary evaluation of clones

The study was initiated in 1985 with 10 clones to identify those suitable for Mizoram conditions. The growth data indicate that the clone RRII 118 recorded maximum girth followed by PB 86 (Table Nez.1). However, girth increment from April 1997 to February 1998 was high in RRIM 605 and low in Gl 1. Recording of

Table Nez.1. **Growth of different clones**

Clone	Girth* (cm)	Girth increment** (cm)
RRII 105	65.0	4.4
RRII 118	73.9	4.4
RRII 203	68.5	3.5
RRIM 600	64.0	3.0
RRIM 605	64.4	5.8
PB 86	69.0	3.7
PB 235	68.0	3.8
PB 5/51	65.4	5.8
Gl 1	56.1	1.9
GT 1	60.7	4.1

* as on February 1998
** for 1997-98 period

yield data by cup coagulation method is also in progress.

2. Polyclonal seed garden

The girth data of plants grown in foot hill, mid-hill and hill top showed that PB 235 (64.77 cm) has recorded better growth in foot hill followed by SCATC 93-114 (61.57 cm) and RRII 118 (60.84 cm). In mid-hill and hill top, growth of SCATC 93-114 was good and recorded the highest girth of 62.89 and 66.38 cm respectively (Table Nez.2).

Table Nez.2. **Girth and girth increment under different slopes**

Clone	Girth (cm)		
	Foot hill	Mid-hill	Hill top
RRII 105	57.7 (4.3)*	52.0 (0.2)	50.9 (2.6)
RRIM 600	47.2 (3.2)	50.5 (5.6)	58.5 (5.9)
SCATC 93-114	61.5 (0.9)	62.8 (1.8)	66.3 (4.9)
RRII 300	60.6 (5.5)	59.6 (4.1)	64.6 (7.0)
RRII 118	60.8 (1.3)	59.8 (2.7)	59.3 (6.0)
GT 1	59.2 (5.3)	61.0 (3.8)	60.5 (7.3)
PB 235	64.7 (6.0)	60.0 (2.9)	59.1 (3.4)

* Figures in parentheses indicate girth increment during 1997-98.

3. Influence of physiographic features on growth

The experiment started during 1987 to study the influence of physiographic features on growth of *Hevea* (clone RRII 105) was continued. The girth of plants grown in different aspects of slope as on February 1998 and girth increment from April 1997 to February 1998 are given in Table Nez. 3.

Table Nez.3. **Influence of aspect of slope on growth**

Aspect	Girth (cm)	Annual girth increment (cm)
North	43.8	9.9
South	49.4	3.9
East	52.4	4.9
West	52.4	6.1

Growth of plants in the eastern and western slopes was comparable. The girth increment was the highest among the trees planted in northern aspect.

4. Soil studies

The soils representing 21 rubber plantations at different altitudes and physiography in North Mizoram were studied for the fertility status. The soils in general were high in finer fractions up to 400 m above msl, acidic, high in organic matter and low in cation exchange capacity. Soils of low altitude were medium in fertility level. The study also revealed that foot hills with elevation up to 400 m above msl, which run North to South along the western belt having humid subtropical climate in Mizoram is fairly suitable for rubber cultivation from fertility point of view.

5. Nutritional trial

The girth data showed that fertilizer applied in two splits (April and August) at the rate 75:75:37.5 kg NPK per ha recorded the maximum girth (38.8 cm) followed by 50:50:25 kg per ha in two splits. However, there was no significant difference among treatments. The girth increment over the period from April 1997 to February 1998 was higher (6.7 cm) in four splits at 50:50:25 kg NPK per ha (Table Nez.4).

Table Nez.4. **Effect of split application of fertilizer on the growth of immature *Hevea***

Treatment (NPK kg/ha)	Girth (cm)	Annual girth increment (cm)
50:50:25 in 2 splits	38.7	5.9
50:50:25 in 4 splits	37.3	6.7
75:75:37.5 in 2 splits	38.8	6.0
75:75:37.5 in 4 splits	34.4	6.5
100:100:50 in 2 splits	34.8	5.8
100:100:50 in 4 splits	38.0	5.8

REGIONAL RESEARCH STATION, NAGRAKATTA, WEST BENGAL

Clone evaluation and nutritional studies are the thrust areas of research in this station. Out of the ten on-going trials, four are on clone evaluation, two on nutritional studies and one each on clone blending, Genotype x Environment interaction and exploitation system.

1. Nutritional studies

1.1 Nutritional requirement with reference to Terai soils of West Bengal

Significant response to nitrogen application and no response to phosphorus and potassium and their interaction were observed (Table Nag. 1). Different levels of nitrogen (20, 40 and 60 kg/ha) recorded significantly higher girth over no nitrogen but no significant difference was observed between the nitrogen levels. Trees in all the plots have attained tappable girth.

1.2 Nutrient use efficiency under Dooars area of West Bengal

Girth and annual girth increment were not significantly influenced by split fertilizer application during fourth year (Table Nag. 2). However, two split applications recorded higher girth compared to no fertilizer.

2. Evaluation of clones

2.1 Clone trial (1990a)

Significant difference in girth was observed among the 11 clones (Table Nag. 3). RRII 203, RRIM 703 and PB 235 recorded significantly higher girth over PB 5/51.

Table Nag. 2. **Effect of fertilizer split application on growth**

Treatment	Girth (cm)	Annual girth increment (cm)
Single split	29.2	9.0
Two splits	29.5	7.9
Three splits	29.0	8.5
Four splits	28.6	8.3
No fertilizer	26.6	8.0
SE	1.16	0.5
	NS	NS

Table Nag. 3. **Growth performance of various clones during seventh year**

Clone	Girth (cm)	Annual girth increment (cm)
Haiken 1	52.7	4.6
SCATC 88-13	51.8	4.6
SCATC 93-114	52.2	4.8
GT 1	49.2	2.6
PB 5/51	43.7	2.0
PB 235	53.3	3.9
PB 311	50.7	4.1
RRIM 703	54.3	4.0
RRII 118	51.4	3.2
RRII 203	54.5	4.2
RRII 300	47.6	2.4
SE	2.5	1.4
CD (P=0.05)	5.3	NS

Table Nag.1. **Girth as influenced by different levels of NPK**

Nutrient level	0 P				20 P				40 P				Mean N
	0K	20K	40K	Mean	0K	20 K	40 K	Mean	0K	20 K	40 K	Mean	
0 N	46.5	48.0	47.4	47.3	43.6	48.7	47.3	46.5	46.9	49.8	48.0	48.2	47.3
20 N	47.9	50.8	48.0	48.9	49.7	49.5	47.9	49.0	48.5	48.6	51.7	49.6	49.2
40 N	47.7	51.1	49.9	49.6	48.5	48.8	50.5	49.3	51.6	50.9	49.3	50.6	49.8
60 N	48.2	50.6	51.2	50.0	49.7	48.4	49.2	49.1	50.1	49.2	50.0	49.8	49.6
Mean	47.6	50.1	49.1	48.9	47.9	48.9	48.7	48.5	49.3	49.6	49.8	49.5	49.0
		N	P	K	NP	NK	PK	NPK					
SE		0.7	0.6	0.6	1.2	1.2	1.1	2.1					
CD (P=0.05)		1.4	NS	NS	NS	NS	NS	NS					

Variation in annual girth increment was found non-significant.

2.2 Clone trial (1990b)

Variation in girth among the seven clones was found significant (Table Nag. 4). RRIM 605 and RRIM 612 recorded significantly higher girth over Gl 1 and PR 107. Annual girth increment among the clones was found non-significant.

Table Nag. 4. **Growth performance of various clones during seventh year**

Clone	Girth (cm)	Annual girth increment (cm)
RRII 105	51.0	4.3
RRII 208	51.4	4.6
Gl 1	48.8	4.4
PR 107	47.7	7.3
PB 86	50.4	6.3
RRIM 605	52.5	4.3
RRIM 612	53.5	7.1
SE	1.3	1.3
CD (P=0.05)	2.9	NS

2.3 Clone trial (1991)

Variation in girth and annual girth increment showed significant difference among the clones (Table Nag. 5). RRIC 102, Haiken 1 and PB 235 recorded significantly higher girth over PR 107 and RRII 208. With respect to annual girth increment PB 235, RRIC 102, PB 86 and Haiken 1 recorded higher girth increment compared to RRIM 612, RRII 208 and PR 107.

Table Nag. 5. **Growth performance of various clones during sixth year**

Clone	Girth (cm)	Annual girth increment (cm)
Haiken 1	44.1	6.4
SCATC 93-114	42.9	5.7
PR 107	36.9	3.9
PB 86	43.1	6.6
PB 235	44.2	7.5
PB 260	41.5	6.0
PB 310	41.5	3.9
RRIM 600	42.8	5.3
RRIM 612	40.2	3.8
RRII 208	39.3	3.8
RRIC 102	45.4	7.5
SE	2.0	1.3
CD (P=0.05)	4.2	2.6

2.4 Clone trial (1993)

Girth and annual girth increment showed significant variation among 11 clones. RRIM 600, RRII 205, RRII 105 and RRII 300 recorded significantly higher girth over RRIC 104 and RRII 308 (Table Nag. 6).

Table Nag. 6. **Growth performance of various clones during fourth year**

Clone	Girth (cm)	Annual girth increment (cm)
Haiken 1	25.9	8.7
SCATC 93-114	27.4	9.3
PR 261	24.9	10.5
PB 235	25.0	8.3
PB 280	23.2	9.0
RRIM 600	31.6	10.4
RRII 105	29.1	9.7
RRII 205	29.2	8.4
RRII 300	27.2	9.5
RRII 308	20.6	5.8
RRIC 104	19.2	6.5
SE	2.1	1.2
CD (P=0.05)	4.5	2.5

The girth increment was more in PR 261 followed by RRIM 600, RRII 105 and RRII 300.

2.5 Investigation on Genotype x Environment interaction

Significant difference in girth and number of branches per plant was observed among the 12 different clones. RRII 203, 82/17, 82/29, 82/30, PB 217 and RRIM 600 recorded significantly higher girth over 82/22 and RRII 176. Regarding number of branches per plant RRII 176, 82/29, RRII 51 and RRII 203 recorded more branches compared to

RRIC 100, 82/17, 82/22 and 82/30 (Table Nag. 7).

3. Clone blend

Studies on performance of multimodal clone blends to monoclonal population are in progress. Treatments imposed in completely randomized design include 13 clones blended in different proportion and patterns. Girth of the plants is being recorded periodically.

4. Exploitation system

Trees under this trial are expected to open for tapping during 1998. Exploitation treatments are to be imposed at the tapping stage.

Table Nag. 7. **Growth performance of various clones during fourth year**

Clone	Girth (cm)	Number of branches/plant
PB 217	10.8	3.6
RRIM 600	10.4	3.1
RRII 51	9.7	4.5
RRII 105	10.2	3.6
RRII 176	9.4	5.5
RRII 203	12.1	4.3
82/14	10.1	2.9
82/17	11.5	2.2
82/22	9.3	2.5
82/29	11.3	4.7
82/30	10.8	2.9
RRIC 100	8.4	2.2
SE	0.6	0.9
CD (P=0.05)	1.3	1.8

REGIONAL RESEARCH STATION, DAPCHARI, MAHARASHTRA

The Regional Research Station, located at Dapchari, in Thane district of Maharashtra concentrated its research activities on irrigation, plant physiology, clone evaluation and also on evaluation of suitable agrotechnology for the North Konkan region.

1. Irrigation systems

This trial was started in 1987 with ETc-based drip and basin irrigation treatments in clone RRII 105. The basin-irrigated trees recorded higher mean girth than the control and drip-irrigated trees (Table Dap. 1). However, the mean annual girth increment was found to be lower in irrigation treatments (trees under tapping) than the control and 0.25 ETc level of irrigation which indicated that exploitation had profound impact on growth of plants. The basin-irrigated trees recorded higher dry rubber

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

Treatment	Girth (cm)	Girth* increment (cm)	Dry rubber yield (g/tree/tap)
Control (No irrigation)	49.29	3.13	Newly opened
1.00 ETc basin	59.66	1.57	59.19
0.75 ETc basin	59.87	1.66	56.72
0.50 ETc basin	57.45	1.32	47.52
0.75 ETc drip	57.60	1.68	48.33
0.50 ETc drip	56.87	1.34	47.70
0.25 ETc drip	56.12	2.27	39.73
SE	1.41	0.31	
CD (P = 0.05)	3.07	0.67	

* April 97 - March 98

Variation in annual girth increment was found non-significant.

2.2 Clone trial (1990b)

Variation in girth among the seven clones was found significant (Table Nag. 4). RRIM 605 and RRIM 612 recorded significantly higher girth over GI 1 and PR 107. Annual girth increment among the clones was found non-significant.

Table Nag. 4. **Growth performance of various clones during seventh year**

Clone	Girth (cm)	Annual girth increment (cm)
RRII 105	51.0	4.3
RRII 208	51.4	4.6
GI 1	48.8	4.4
PR 107	47.7	7.3
PB 86	50.4	6.3
RRIM 605	52.5	4.3
RRIM 612	53.5	7.1
SE	1.3	1.3
CD (P=0.05)	2.9	NS

2.3 Clone trial (1991)

Variation in girth and annual girth increment showed significant difference among the clones (Table Nag. 5). RRIC 102, Haiken 1 and PB 235 recorded significantly higher girth over PR 107 and RRII 208. With respect to annual girth increment PB 235, RRIC 102, PB 86 and Haiken 1 recorded higher girth increment compared to RRIM 612, RRII 208 and PR 107.

Table Nag. 5. **Growth performance of various clones during sixth year**

Clone	Girth (cm)	Annual girth increment (cm)
Haiken 1	44.1	6.4
SCATC 93-114	42.9	5.7
PR 107	36.9	3.9
PB 86	43.1	6.6
PB 235	44.2	7.5
PB 260	41.5	6.0
PB 310	41.5	3.9
RRIM 600	42.8	5.3
RRIM 612	40.2	3.8
RRII 208	39.3	3.8
RRIC 102	45.4	7.5
SE	2.0	1.3
CD (P=0.05)	4.2	2.6

2.4 Clone trial (1993)

Girth and annual girth increment showed significant variation among 11 clones. RRIM 600, RRII 205, RRII 105 and RRII 300 recorded significantly higher girth over RRIC 104 and RRII 308 (Table Nag. 6).

Table Nag. 6. **Growth performance of various clones during fourth year**

Clone	Girth (cm)	Annual girth increment (cm)
Haiken 1	25.9	8.7
SCATC 93-114	27.4	9.3
PR 261	24.9	10.5
PB 235	25.0	8.3
PB 280	23.2	9.0
RRIM 600	31.6	10.4
RRII 105	29.1	9.7
RRII 205	29.2	8.4
RRII 300	27.2	9.5
RRII 308	20.6	5.8
RRIC 104	19.2	6.5
SE	2.1	1.2
CD (P=0.05)	4.5	2.5

The girth increment was more in PR 261 followed by RRIM 600, RRII 105 and RRII 300.

2.5 Investigation on Genotype x Environment interaction

Significant difference in girth and number of branches per plant was observed among the 12 different clones. RRII 203, 82/17, 82/29, 82/30, PB 217 and RRIM 600 recorded significantly higher girth over 82/22 and RRII 176. Regarding number of branches per plant RRII 176, 82/29, RRII 51 and RRII 203 recorded more branches compared to

RRIC 100, 82/17, 82/22 and 82/30 (Table Nag. 7).

3. Clone blend

Studies on performance of multimodal clone blends to monoclonal population are in progress. Treatments imposed in completely randomized design include 13 clones blended in different proportion and patterns. Girth of the plants is being recorded periodically.

4. Exploitation system

Trees under this trial are expected to open for tapping during 1998. Exploitation treatments are to be imposed at the tapping stage.

Table Nag. 7. **Growth performance of various clones during fourth year**

Clone	Girth (cm)	Number of branches/plant
PB 217	10.8	3.6
RRIM 600	10.4	3.1
RRII 51	9.7	4.5
RRII 105	10.2	3.6
RRII 176	9.4	5.5
RRII 203	12.1	4.3
82/14	10.1	2.9
82/17	11.5	2.2
82/22	9.3	2.5
82/29	11.3	4.7
82/30	10.8	2.9
RRIC 100	8.4	2.2
SE	0.6	0.9
CD (P=0.05)	1.3	1.8

REGIONAL RESEARCH STATION, DAPCHARI, MAHARASHTRA

The Regional Research Station, located at Dapchari, in Thane district of Maharashtra concentrated its research activities on irrigation, plant physiology, clone evaluation and also on evaluation of suitable agrotechnology for the North Konkan region.

1. Irrigation systems

This trial was started in 1987 with ETc-based drip and basin irrigation treatments in clone RRII 105. The basin-irrigated trees recorded higher mean girth than the control and drip-irrigated trees (Table Dap. 1). However, the mean annual girth increment was found to be lower in irrigation treatments (trees under tapping) than the control and 0.25 ETc level of irrigation which indicated that exploitation had profound impact on growth of plants. The basin-irrigated trees recorded higher dry rubber

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

Treatment	Girth (cm)	Girth* increment (cm)	Dry rubber yield (g/tree/tap)
Control (No irrigation)	49.29	3.13	Newly opened
1.00 ETc basin	59.66	1.57	59.19
0.75 ETc basin	59.87	1.66	56.72
0.50 ETc basin	57.45	1.32	47.52
0.75 ETc drip	57.60	1.68	48.33
0.50 ETc drip	56.87	1.34	47.70
0.25 ETc drip	56.12	2.27	39.73
SE	1.41	0.31	
CD (P = 0.05)	3.07	0.67	

* April 97 - March 98

yield than the drip-irrigated trees. The control trees were opened this year only (11th year of planting) indicating the delay in attaining maturity by 3-4 years where irrigation could not be provided.

2. Effect of irrigation on yield and yield components

The trial was laid out in 1983 to study the effect of irrigation on yield and yield components among two clones RRII 105 and RRII 118. Between the two clones, RRII 118 was vigorous in growth whereas RRII 105 performed better in respect of yield potential (Table Dap. 2). The irrigation treatment showed non-significant effect on growth and yield parameters.

3. Clone trial

Among the 15 clones, RRII 208, RRII 6 and RRIC 52 are performing better in respect of growth whereas RRII 105 recorded the highest dry rubber yield (Table Dap. 3).

Table Dap. 3. **Mean girth of *Hevea* clones**

Clone	Girth (cm)	Dry rubber yield (g/tree/tap)
RRII 5	49.12	18.27
RRII 6	53.07	23.35
RRII 105	49.70	34.59
RRII 208	56.84	22.06
RRII 308	46.90	22.75
RRIM 605	47.97	21.08
PB 260	48.21	23.85
PB 310	48.59	19.45
PB 311	48.35	20.48
RRIC 52	54.52	12.29
RRIC 100	52.28	19.84
RRIC 102	52.47	19.32
RRIC 105	49.12	13.47
PR 255	48.12	29.49
PR 261	47.20	24.89
SE	2.90	2.01
CD (P = 0.05)	5.93	4.13

4. Effect of silt pits on soil and water conservation

Various frequencies of silt pits (100, 150 and 200 pits/ha) with or without sawdust (10 kg sawdust/pit) were maintained in polyclonal seedling area since June 1995. Soil moisture and girth increment of seedlings were recorded at monthly interval. Significant treatment effect on soil moisture was observed at 30-60 cm depth. However, the effect was non-significant at 0-30 cm. This increased soil moisture retention showed its effect on girth increment during post-monsoon period. The treatments 150 pits/ha and 150 pits/ha + 10 kg sawdust/pit were found to be effective in soil and moisture retention.

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

Treatment	Girth (cm)		Dry rubber yield (g/tree/tap)	
	RRII 105	RRII 118	RRII 105	RRII 118
1.00 ETc	61.46	72.12	45.55	30.09
0.75 ETc	60.73	74.15	39.61	32.45
0.50 ETc	57.56	64.75	49.14	26.62
Control (No irrigation)	52.03	57.51	35.12	24.43
For irrigation				
SE	3.66		3.14	
CD (P = 0.05)	8.95		7.68	
For clones				
SE	1.21		1.70	
CD (P = 0.05)	2.79		3.92	

5. Cost evaluation trial

This trial was laid out in 1987 with an objective to estimate the cost of cultivation of RRIM 600 under irrigated and unirrigated conditions. Tapping was started in irrigated trees since May 1994 whereas unirrigated trees could open for tapping from November 1997 only. Expenses incurred on various inputs, farm practices and irrigation were recorded.

In the existing trial, the irrigation treatments were altered from January 1998 with limited irrigation to save water and cost. However, no significant reduction in the block yield was noticed.

6. Polyclonal seedlings for selection

Promising polyclonal trees with more girth and high yield were selected for multiplication and further studies. A source bush nursery is being established from the selected ones.

REGIONAL RESEARCH STATION, DHENKANAL, ORISSA

The Regional Research Station located at Kadalipal (Dhenkanal), Orissa concentrated on research in agro-management techniques and evaluation of clones for specific drought-prone areas in the central Orissa.

1. Evaluation of clones

1.1 Clone trial (1987)

Maximum girth was recorded in clone RRIM 600 (47.52 cm) followed by GT 1 (46.11 cm) and RRII 105 (43.02 cm) in the 1987 clone trial (Table Ori. 1).

Table Ori. 1. **Clonal difference in girth and girth increment**

Clone	Girth (cm)	Girth increment (cm)
RRII 105	43.02	10.52
RRIM 600	47.52	8.04
GT 1	46.11	6.83

1.2 Clone trial (1990)

Among the 10 clones, RRIM 600 (41.7 cm), PR 255 (41.6 cm), SCATC 93-114 (41.4 cm), RRII 208 (41.1 cm) and RRII 5 (40.2 cm) have attained maximum girth while SCATC 88-13 (31.8 cm) and RRIM 701 (35.1 cm) showed the minimum girth (Table Ori. 2).

Table Ori. 2. **Clonal difference on growth**

Clone	Girth (cm)
RRII 5	40.2
RRII 208	41.1
RRII 300	39.5
RRIM 600	41.7
RRIM 701	35.1
PB 310	38.8
PR 255	41.6
SCATC 88-13	31.8
SCATC 93-114	41.4
Haiken 1	36.7

1.3 Clone trial (1991)

The clones GT 1, RRII 300 and the polyclonal seedlings performed better, showing drought tolerance. The lowest girth was noticed in PR 255 (23.7 cm) and PR 261 (25.7 cm). Life-saving irrigation was given during the summer months.

2. Polyclonal seedlings (1989)

A total of 431 seedlings having more than 55 cm girth at 50 cm height were identified and marked for yield evaluation. The growth and yield data are being monitored regularly for identifying stable high yielders for further selection.

3. Nutrient management

Nursery experiment with N and P-biofertilizers was initiated during 1997-98. The treatments included *Azospirillum* and phosphorus solubilizing microorganisms (PSM) alone and in combination with FYM and two levels of N, P and K viz. 25 and 100 per cent of the recommended doses of N as urea, P as MRP and K as MOP fertilizers. The experiment was laid out in RBD with 27 treatments and three replications. Growth parameters of seedlings were recorded monthly and soil samples were collected for chemical properties and microbial studies.

4. Investigation on Genotype x Environment interaction

This trial was started as an onfarm trial at Regional Research Laboratory, Bhubaneswar. Twelve clones were planted during 1996. Growth parameters recorded periodically showed no significant difference.

5. Budwood nursery

The budwood nursery having 20 genotypes with a total of 440 plants is maintained. Seasonal cultural practices like mulching, life-saving irrigation, etc. were undertaken to combat adverse conditions.

REGIONAL RESEARCH STATION, SUKMA, MADHYA PRADESH

The Regional Research Station, Sukma located in Bastar district in Madhya Pradesh concentrated research activities on screening of *Hevea* germplasm for drought tolerance and on growth of few *Hevea* clones in this region.

1. Multidisciplinary clone evaluation

The trial started in 1990 included two clones, RRII 105 and RRIM 600. The girth of 50 cm and 44 cm was recorded for RRIM 600 and RRII 105 respectively.

2. Screening of germplasm for drought tolerance

The genotypes of Brazilian germplasm together with a few modern clones were planted in field to screen for drought tolerance. Genotypes RO 5363, RO 2629 and RO 5554 were found to be superior in growth compared to AC 685.

3. Evaluation of polyclonal seedlings

Polyclonal seedlings planted in September 1996 are being maintained and the plants are showing satisfactory growth.

4. Investigation on phenology and architecture of *Hevea* germplasm

The variations in branching and form of plants have been recorded.

REGIONAL RESEARCH STATION, PADIYOOR, KERALA

The Regional Research Station at Padiyoor in Kannur district covers an area of 40 ha of which 24 ha has been planted with rubber. An area of 16 ha is proposed to be cleared for further experimental planting.

Long-term field experiments listed below have been laid out in the station by the various divisions of RRII.

1. Evaluation of Brazilian genotypes
2. Investigation of G x E interaction in *Hevea* clones
3. Multi-locational clone evaluation trial
4. Large-scale testing of hybrid clones
5. Multiclone blend trial
6. Disease evaluation trial

An agrometeorological observatory and a budwood nursery are being maintained.

HEVEA BREEDING SUB-STATION, NETTANA, KARNATAKA

This Station has an experimental farm of 50 ha area. Various field trials on clone evaluation and other breeding programmes are being conducted here. The agrometeorological observatory and budwood nursery are being maintained for research purpose.

1. Trials on growth, yield and exploitation systems

The two field trials, commenced in 1987 and 1988, were aimed to evaluate the response of clones for various tapping systems towards yield as well as their growth. Each of the trials has five clones planted in split plot design. The former was opened for tapping during July-August of the year under report. Clone PB 235 (66.35 cm) continued to be superior in growth followed by PB 260 (61.93 cm). The percentage of growth contribution towards the annual growth was more during the quarter from April-June (34.23%) and it gradually reduced as tapping progressed. In the second trial, RRII 118 showed highest average growth (62.29 cm) and lowest is PR 255 (46.82 cm). In this trial also the highest growth contribution recorded during April-June (46.91%) and lowest during January-March (12.65%).

Initial yield data indicated PB 235 yielding high (129.4 ml/tree/tap) and RRII 300 yielding the lowest (70.9 ml/tree/tap). Of the different systems under evaluation, 1/2 S d/4 recorded the highest mean yield of 116.2 ml/tree/tap. The maximum latex yield occurred during November to January. The damage caused by *Corynespora cassiicola* was severe in both the trials. In the first trial, the clone RRII 105 and in the latter PR 255 and PR 261 were severely affected.

2. Evaluation of ortet clone

Out of the three trials, all planted in 1988, two consisted of 17 clones and the third had 14 clones. All the experiments have three

Table Kar. 1. **Performance of 10 clones in 1987 and 1988 evaluation trials**

Clone	Mean girth (cm)	Quarterly girth increment in percentage				Mean yield (ml/tree/tap)
		April-June	July-September	October-December	January-March	
1987 Experiment						
PB 235	66.35 a*	3.64	2.38	1.78	2.32	129.4 a*
PB 260	61.93 b	2.96	2.15	1.67	1.22	113.3 c
PB 311	59.60 c	3.80	1.99	1.41	1.51	121.3 b
RRII 105	58.06 c	3.19	2.06	1.63	1.14	108.4 c
RRII 300	54.05 d	3.26	1.99	1.61	1.27	70.9 d
Mean	60.00	3.37	2.11	1.62	1.49	108.2
Average annual contribution (%)		39.23	24.56	18.86	17.35	
1988 Experiment						
RRII 118	62.29 a*	4.42	2.88	2.50	1.25	-
RRIC 36	49.87 bc	4.85	1.36	2.85	1.71	-
RRIC 45	50.04 bc	4.74	0.99	1.68	1.11	-
PR 255	46.82 c	5.37	0.94	2.85	1.36	-
PR 261	53.06 b	3.42	1.97	2.61	0.71	-
Mean	54.42	4.56	1.43	2.50	1.23	-
Average annual contribution (%)	-	46.91	14.71	25.72	12.65	-

* Clones followed by same letters are not significantly different at 5% level by LSD test

common standards viz. RRII 105, RRIM 600 and GT 1. Among the standards, GT 1 showed better girth followed by RRII 105. Three clones in the trial 1 viz. O47, C70 and T2 showed better girth increment than all three control clones. Similarly, one clone C9 showed superiority in trial 2 and three clones (O26, O47 and O56) in trial 3, over all three standard clones. The infection caused by the *Corynespora cassiicola* was very severe and many clones exhibited differential reaction to the disease under the same load. Clones found highly susceptible were O11, O46, O49, C 3/10, O14, O16, O38, C151 and RRII 105, while clones O9, O40, T1, C150, P0 and GT 1 showed tolerance.

3. Large-scale clone trial

Two trials evaluating 14 and 15 clones planted in 1989 and 1990 respectively were continued.

RRII 203 continued to show better growth in terms of girth (60.9 cm) while Haiken 1 continued to be the lowest (39.02 cm). In the 1990 trial, PB 235 recorded the maximum average girth of 51.29 cm as against the lowest of 37.79 cm for Gl 1 (Table Kar. 2).

Table Kar. 2. **Performance of clones in large-scale trials**

1989 trial		1990 trial	
Clone	Girth (cm)	Clone	Girth (cm)
RRII 105	49.69	RRII 105	43.79
RRII 203	60.90	HP 185	43.13
RRII 300	52.33	HP 187	41.43
RRII 308	51.05	HP 204	41.31
RRIM 600	48.69	HP 223	45.44
PB 255	52.21	HP 372	43.52
PR 255	43.24	PB 217	47.42
PR 261	50.63	PB 235	51.29
KRS 25	50.85	PB 260	48.15
KRS 128	55.21	PB 311	44.69
KRS 163	52.83	Hil 28	41.14
SCATC 88-13	45.00	Mil 3/2	43.58
SCATC 93-114	43.83	GT 1	46.85
Haiken 1	39.02	Tjir 1	40.90
		Gl 1	37.79
SE	1.697		2.104

The *Corynespora* disease incidence in these trials was relative less except for RRII 105.

4. Composite clone trial

The three small-scale clone evaluation trials consisted of 36 clones in the first and 13 each in the second and third trials. The clone GT 1, RRII 105 and RRIM 600 were used as control in all three trials. The average girth ranged between 30.29 cm (Haiken 1) to 45.76 cm (PB 235) in the first trial, 35.16 (PB 5/139) to 40.78 cm (Ch 3) in the second and 33.39 cm (AVROS 49) to 44.27 cm (HP 83/224) in the third. GT 1 recorded 39.09 cm, 38.67 cm and 36.01 cm girth respectively in the first, second and third trials. No serious disease incidence was noticed in these trials.

5. Estimation of genetic parameters

Evaluation of 12 clones and their half sib progenies was undertaken for estimating the genetic parameters. The growth data of both the parents and progenies are being collected at quarterly intervals. Among the parents, PB 235 (66.38 cm) showed better growth, while IAN 893 (34.73 cm) exhibited poor performance. The progenies of the clone PB 235 recorded better growth (66.38 cm) as against the lowest for the progenies of RRIM 600 (57.06 cm). The performance of the progenies in general had little variation than that of the parents.

6. Poly-cross garden

Nine prepotent clones included in the poly-cross garden are being maintained well.

7. Agroclimate

During the calendar year of 1997, the station received a total rainfall of 5162.1 mm distributed in 10 months with a total of 137 rainy days. The maximum rainfall was recorded during July totaling 1656.5 mm. The highest maximum temperature recorded was 39°C during May and the lowest minimum was 10°C during January.

HEVEA BREEDING SUB-STATION, PARALIYAR, TAMIL NADU

The priority areas of research are to evaluate the hybrid seedlings in the nursery and to carry out hybridization programme incorporating selected parents. Investigations on floral biology and fruit set are also being undertaken.

The Station has established two modern breeding orchards consisting of 51 clones. Cross-pollination with different parental combinations and evaluation of the resultant hybrid progeny were also given importance during the year under report.

1. Evolving high yielding clones

The hybrid progenies of 1994-95, 1995-96 hand pollination were test-tapped. Yield and secondary characters were studied. The 22 hybrid seedlings showing promising yield were selected and multiplied for further evaluation. Hybridization programme was continued incorporating selected parental combinations.

2. Clone evaluation

In the clone trial laid out during 1990 (G x E interaction of clones), PB 260 continued to exhibit maximum growth followed by RRIC 105.

3. Floral biology and fruit set

Under the combined effect of various summer stresses, up to 28 per cent flowers were found drying in exposed panicles. An overhead partial shade significantly reduced premature shedding of flowers and improvement was noticed in the initial fruit set also (Table Par. 1).

The beneficial effect could mainly be due to the protection of young flowers and fruits from harmful solar radiations.

4. Control of sunscorch in rubber

A trial was conducted in order to find alternatives to the conventional method of mulching and lime washing.

Covering the plant base with coir pith and providing shade with plastic sac is as effective against sunscorch as the conventional method of mulching and lime washing (Table Par. 2).

Table Par. 2. **Percentage of plants affected by sunscorch**

Treatment	Sunscorch affected plants (%)
Control (no summer protective measure)	39.58 (38.94)
Lime washing alone	27.08 (31.33)
Mulching with dry leaves	22.92 (28.55)
Conventional method of mulching together with lime washing	6.17 (11.65)
Shading with plastic sac	25.00 (30.00)
Covering the plant base with coir pith and shading with plastic sac	6.25 (14.48)
CD (P = 0.05)	8.37

Figures in parentheses are the arc sine transformed value.

Table Par. 1. **Flower retention and fruit set**

	No. of young flowers observed	No. of flowers survived	Initial fruit set	Final fruit set
Exposed	1807	1301 (72%)	874 (67.2%)	27 (2.07%)
Under shade	2035	1722**(84.6%)	1314**(76.3%)	46 (2.67%)

** Significant at P <0.01 by χ^2 analysis

AGROMETEOROLOGY UNIT

1. Weather at various stations

The weather parameters recorded at five locations representing different agroclimatic regions show that Nettana recorded the highest rainfall of the year (5153 mm) and lowest at Dapchari (1920 mm). Highest maximum temperature was observed at Dapchari and lowest maximum at Kottayam. Diurnal variation of temperature was observed maximum at Dapchari, followed by Nettana and minimum at Kottayam. Highest maximum temperature of 41°C was observed on two days (i.e. 25 April and 17 May) at Dapchari, whereas the lowest minimum of 8.5°C was also recorded at the same place on 21 January.

2. Rainfall climatology of rubber growing areas

Expected length of dry and wet spells during the year can be used to plan agricultural operations during the various phases of the crop growth. A case study has been attempted for rubber at RRII for Kottayam region.

3. Studies on crop-weather relationship

A path analysis was employed to elucidate the relationship among meteorological parameters, yield components and yield in different clones. Results indicate that temperature is the most important single factor influencing the day-to-day variation in yield. Indirect influence through yield components is more for soil temperature (morning) and wind speed (previous day). A longer period of sunshine and adequate amount of summer rainfall have moderate positive effect on yield. Among the new clones studied, 14/82, 17/82 and 22/82 are sensitive to weather parameters in general and to temperature in particular. In clones 27/82 and 30/82, response to environmental parameter is rather poor.

LIBRARY AND DOCUMENTATION CENTRE

The Centre continued its important role of communicating and disseminating information on natural rubber through its library and information services and publications.

During the year 1997-98, 255 books were added to the stock of the library making a total collection of 21673. The library subscribed to 133 journals and 9 dailies. About 67 other journals were also received as gift/exchange.

Four issues of Documentation List, four numbers of Rubber Alert, one issue of List of New Additions and one issue of Bibliography of Rubber Chemistry and Technology Reviews (1963-1996) were compiled and distributed.

'RRII Library Holdings : Serials', a list of holdings of bound volumes of journals in the library up to 1995 was published during this year.

As part of database development, two databases for books and journals developed in the library were transferred to research divisions through LAN and also imparted training to staff of RRII for retrieving information from the database.

The library is participating in the sales promotion and distribution of publications viz. 'Indian Journal of Natural Rubber Research', 'Rubber Wood : Production and Utilization', 'Plant and Soil Analysis' and 'RRII Annual Report'. About 113400 photocopies of information materials were made by repographic section.

ANNUAL EXPENDITURE

Expenditure at a glance 1997-98

Head of account	Expenditure (Rs. in lakhs)
Non-plan	
General charges	359.58
Schemes	29.39
Projects (CES)	104.63
Total	**493.60**
Plan	
General charges	84.76
Schemes	154.38
NERDS Research Component	116.17
Total	**355.31**
World Bank Project	147.36
Grand Total	**996.27**

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Chandrashekar, T.R., Marattukalam, J.G. and Nazeer, M.A. (1996*). Growth reaction of *Hevea brasiliensis* to heat and drought stress under dry sub humid climatic conditions. *Indian Journal of Natural Rubber Research*, **9**(1) : 1-5.

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SCIENTIFIC AND SENIOR SUPPORTING PERSONNEL

Director of Research

M.R. Sethuraj, M.Sc.(Ag.), Ph.D. (up to 30.06.1997)

N.M. Mathew, M.Sc, Ph.D. (from 24.07.1997)

Joint Director (Research)

K. Jayarathnam, M.Sc.(Ag.), Ph.D.

Agronomy and Soils Division

K.I. Punnoose, M.Sc.(Ag.), Ph.D.	Deputy Director
*M. Karthikakuttyamma,M.Sc.(Ag.), Ph.D.	Senior Scientist (AC)
A.N. Sasidharan Nair, M.Sc.	Soil Chemist
Elsie S. George, M.Sc.	Soil Chemist
Mercykutty Joseph, M.Sc.(Ag.), Ph.D.	Soil Chemist
*P.M. Mathews, M.Sc.(Ag.), Ph.D.	Scientist (AC)
Varghese Philip, M.Sc.(Ag)	Scientist S2
V.K. Shyamala, M.Sc.	Scientist S2
Joshua Abraham, M.Sc.	Scientist S2
D.V.K.Nageswara Rao, M.Sc.(Ag.)	Scientist S2
Sherin George, M.Sc.(Ag.)	Scientist S2
M.D. Jessy, M.Sc.(Ag.)	Scientist S2
Annie Philip, M.Sc.	Junior Scientist
Mathew Joseph, M.Sc.(Ag.)	Junior Scientist
Mary Varghese, M.Sc.(Ag.)	Junior Scientist
**P. Prasannakumari, M.Sc., Ph.D.	Junior Scientist
**Thomas Eappen, M.Sc.	Junior Scientist
Jacob John, M.Sc.(Ag.), Ph.D.	Junior Scientist
Aleyamma Augusthy, B.Sc., Dip.N.R.P.	Assistant Technical Officer
**C.K. Chacko, B.Sc.	Assistant Technical Officer
M.J. Thomas, B.Sc.	Assistant Technical Officer
Molly Pothen, B.Sc.	Senior Scientific Assistant
K.S. Krishnakumari, B.Sc.	Senior Scientific Assistant
M.D. Chacko	Assistant Farm Superintendent
*M.J. Augustine	Assistant Farm Superintendent

Biotechnology Division

*M.P. Asokan, M.Sc., Ph.D.	Joint Director
A. Thulaseedharan, M.Sc., Ph.D.	Deputy Director (from October 1997)

S. Sushamakumari, M.Sc., Ph.D.	Scientist (B)
*P. Kumari Jayasree, M.Sc.	Scientist
R.G. Kala, M.Sc.	Junior Scientist
R. Jayasree, M.Sc.	Junior Scientist
K. Narasimhan, M.Sc.	Junior Scientist
R. Rekha, M.Sc.(Ag.)	Junior Scientist
S. Sobha, M.Sc., L.L.B.	Senior Scientific Assistant
*V. Vijayan	Assistant Farm Superintendent

Botany Division

C.K. Saraswathyamma, M.Sc., Ph.D.	Deputy Director
*D. Premakumari, M.Sc., Ph.D.	Senior Scientist (CE)
Joseph G. Marattukalam, M.Sc.	Botanist
J. Licy, M.Sc.	Plant Breeder
**T.R. Chandrashekar, M.Sc., M.Tech.	Botanist
Kavitha K. Mydin, M.Sc.(Ag.), Ph.D.	Scientist S3
J. Rajeswari Meenattoor, M.Sc.(Ag.)	Scientist S3
V.C. Mercykutty, M.Sc., Ph.D.	Scientist S2
L. Sankariammal, M.Sc., Ph.D.	Assistant Cytogeneticist
Vinoth Thomas, M.Sc., Ph.D.	Assistant Anatomist
Alice John, M.Sc.(Ag.)	Junior Scientist
Meenakumari, M.Sc., Ph.D.	Junior Scientist
*K. Kunhunni	Assistant Farm Superintendent
*T.T. Varghese	Assistant Farm Superintendent

Germplasm Division

P.J. George, M.Sc., Ph.D.	Deputy Director
C.P. Reghu, M.Sc., Ph.D.	Botanist
G. Prabhakar Rao, M.Sc.(Ag.)	Botanist
*Thakurdas Saha, M.Sc.(Ag.), Ph.D.	Scientist (GA)
Saji T. Abraham, M.Sc.(Ag.)	Scientist S2
Jayasree Madhavan, M.Sc.(Ag.)	Scientist S2
M.A. Mercy, M.Sc.(Ag.)	Scientist S2
K.P. Leelamma, B.Sc., Dip. N.R.P.	Assistant Technical Officer

Mycology and Plant Pathology Division

R. Kothandaraman, M.Sc.(Ag.), Ph.D.	Deputy Director
V.K. Rajalakshmi, M.Sc.	Mycologist
C. Kuruvilla Jacob, M.Sc.(Ag.), Ph.D.	Plant Pathologist
S. Thankamony, M.Sc.	Entomologist
Sabu P. Idicula, M.Sc.(Ag.)	Scientist S3
Jacob Mathew, M.Sc., Ph.D.	Scientist S3

Annakutty Joseph, M.Sc.	Scientist S3
Kochuthresiamma Joseph, M.Sc.	Scientist S3
V.T. Jose, M.Sc.(Ag.), Ph.D.	Scientist S3
T. Sailajadevi, M.Sc.	Agrometeorologist
K.B. Vrinda, M.Sc., Ph.D	Assistant Mycologist
M.J. Manju, M.Sc.(Ag.)	Junior Scientist
T.G. Vimalakumari, M.Sc.(Ag.)	Junior Scientist
M. Jayadevi, B.Sc., Dip. N.R.P.	Assistant Technical Officer
P.M. Levy Joseph, B.Sc., Dip. N.R.P.	Assistant Technical Officer
T.V. Kurian	Assistant Farm Superintendent
T.R. Divakaran	Assistant Farm Superintendent

Plant Physiology and Exploitation Division

*K.R. Vijayakumar, M.Sc.(Ag.), Ph.D.	Joint Director
James Jacob, M.Sc.(Ag.), Ph.D., DIC, Ph.D.	Deputy Director
*N. Usha Nair, M.Sc.(Ag.), Ph.D.	Senior Scientist (BC)
P. Sobhana, M.Sc.	Plant Physiologist
Molly Thomas, M.Sc., Ph.D.	Scientist S3
**K.U. Thomas, M.Sc., Ph.D.	Scientist S3
R. Krishnakumar, M.Sc., Ph.D.	Scientist S3
*Bhaskar Charan Behra, M.Sc., Ph.D	Scientist (ES) (up to 1.10.1997)
**R. Rajagopal, M.Sc., M.Phil., Ph.D, Dip. Stat.	Plant Physiologist
K. Annamalainathan, M.Sc., M.Phil, Ph.D.	Plant Physiologist
A.S. Devakumar, M.Sc.(Ag.), Ph.D.	Environmental Physiologist
D. Bhuvanendran Nair, M.Sc., Ph.D.	Scientist S2
S. Sreelatha, M.Sc.	Scientist S2
M.B. Mohammed Sathik, M.Sc., M.Phil.	Scientist S2
**Jayasree Gopalakrishnan, M.Sc., M.Phil.	Junior Scientist
N. Nataraj Karaba, M.Sc.(Ag.), Ph.D	Junior Scientist
S. Visalakshy Ammal, B.Sc.	Senior Scientific Assistant
S. George	Assistant Farm Superintendent (up to 10.7.1997)
*C.G. Varghese	Assistant Farm Superintendent

Rubber Chemistry, Physics and Technology Division

Baby Kuriakose, M.Sc., LPRI, Ph.D., PGDPM	Deputy Director (on leave)
K.T. Thomas, M.Sc., LPRI, M.Tech., Ph.D	Deputy Director (from 17.9.1997)
N.M. Claramma, M.Sc.	Rubber Chemist
Mariamma George, M.Sc.	Scientist S3
N. Radhakrishnan Nair, M.Sc., M.Tech.	Scientist S3
Jacob K. Varkey, M.Sc., M.Tech.	Scientist S3
Leelamma Varghese, M.Sc.	Scientist S3

Rosamma Alex, M.Sc., LPRI, M.Tech, Ph.D.	Rubber Technologist
*Siby Varghese, M.Sc., Ph.D.	Scientist (Rubber Technology) (on leave)
K.N. Madhusoodanan, M.Sc.	Rubber Chemist
Benny George, M.Sc.	Scientist S2
C.K. Premalatha, B.Sc., LPRI, Dip. NRP	Assistant Technical Officer
Agricultural Economics Division	
K. Tharian George, M.A., Ph.D.	Deputy Director
P. Rajasekharan, M.Sc.(Ag.), Ph.D.	Economist
Toms Joseph, M.A.	Economist
Binni Chandy, M.A.	Junior Scientist
S. Mohanakumar, M.A., M.Phil.	Junior Scientist
S. Veeraputhran, M.A.	Junior Scientist (on study leave)
P.K. Viswanathan, M.A.	Junior Scientist
S. Lakshmi, M.Sc.(Ag.)	Junior Scientist
World Bank Scheme	
*M.A. Nazeer, M.Sc., Ph.D.	Joint Director (PM)
Regional Research Stations	
Thomson T. Edathil, M.Sc., Ph.D.	Deputy Director
Statistics Section	
*P.V. Mathew, M.C.A., M.C.S.E.	Programme Analyst
Ramesh B. Nair, M.Sc.(Ag. St.)	Assistant Statistician
*B. Biju	Computer Assistant
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 Section	
S. Najmul Hussain, M.Tech., AMIETE	Instrumentation Officer
Thomas Baby, M.Sc., M.Phil, Ph.D.	Assistant Instrumentation Officer
Art/Photography Section	
K.P. Sreeranganathan	Senior Artist/Photographer
Maintenance Wing	
K.T. Davis	Engineering Supervisor (HG)
E.R. Subramanian	Assistant Estate Officer
Administration Section	
*Josy D'Cruz	Deputy Secretary
T.R. Mohankumar	Deputy Secretary (from 12.11.1997)

P.C. Joseph	Assistant Secretary
E.K. Thankamma	Administrative Officer
V. Mary Philipose, B.Sc.	Assistant Section Officer
Annamma Joseph	Assistant Section Officer
O.V. Mathew	Assistant Farm Superintendent

Accounts Section

*G. Rajasekharan Nair	Dy. Director (Finance)
P.J. Franklin Raphy	Assistant Director (Finance)
R. Muraleedharan Pillai	Assistant Accounts Officer
Annamma Kurian	Assistant Section Officer

Experiment Station at RRII

K.I. Thomas	Assistant Farm Superintendent

Security Wing

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
Mary Varghese, M.Sc.(Ag.)	Junior Scientist
P.J. Joseph	Farm Superintendent (up to 30.11.1997)
N. Bhargavan	Assistant Estate Superintendent
M.D. Isaac	Assistant Estate Superintendent
T. Hannef Rawther	Assistant Farm Superintendent (up to 31.1.1998)
N.D. Santhakumari	Assistant Section Officer (up to 30.12.1997)
K.S. Thomas	Assistant Section Officer (from 22.12.1997)
Annamma Andrews, H.S.C.	Nurse (HG)

Regional Research Station, Padiyoor, Kerala

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

Regional Research Station, Guwahati, Assam

Dhurjati Chaudhuri, M.Sc.(Ag.)	Deputy Director
Gopal Chandra Mondal, M.Sc., Ph.D.	Plant Pathologist
Ram Phool Singh, M.Sc.(Ag.), Ph.D.	Scientist S2
D. Mandal, M.Sc.	Junior Scientist
T. Gohain, M.Sc.(Ag.)	Junior Scientist (from 9.7.1997)
A.K. Hazarika, M.Com.	Assistant Accounts Officer
K.T. Joseph	Assistant Section Officer

Regional Research Station, Agartala, Tripura

Y. Annamma Varghese, M.Sc., Dr.Sc.(Ag.)	Project Co-ordinator
Sushil Kumar Dey, M.Sc., Ph.D.	Deputy Director
P. M. Priyadarshan, M.Sc., Ph.D.	Plant Breeder
*M.K. Sudha Soumyalatha, M.Sc., Ph.D.	Scientist (CE)
Gitali Das, M.Sc., Ph.D.	Plant Physiologist
Shammi Raj, M.Sc., Ph.D.	Assistant Agrometeorologist
Krishna Das, M.Sc., Ph.D.	Scientist S2
S. Sasikumar, M.Sc.	Junior Scientist
*Santhanu Roy, M.Sc.(Ag.)	Junior Scientist
Badre Alam, M.Sc., M.Tech, Ph.D	Junior Scientist
Mrinal Chaudhuri, M.Sc.(Ag.)	Junior Scientist
Joy Joseph, M.Sc.	Assistant Rubber Processing Technologist
Jiban Chakraborty, B.Com.	Accounts Officer
M.K. Idicula	Assistant Section Officer
*K. Kunjachan	Assistant Farm Superintendent

Regional Research Station, Kolasib, Mizoram

G.C. Satisha, M.Sc.(Ag.)	Soil Chemist

Regional Research Station, Tura, Meghalaya

A.P. Thapliyal, M.Sc., Ph.D.	Deputy Director
H.K. Deka, M.Sc., Ph.D.	Scientist S2
M.J. Reju, M.Sc.	Junior Scientist
K. Arunkumar, M.Sc., M.Phil	Junior Scientist (from 3.11.1997)

Regional Research Station, Nagrakatta, West Bengal

Sankar Meti, M.Sc.(Ag.)	Junior Scientist

Regional Research Station, Dapchari, Maharashtra

Gawai Prakash Pandharinath, M.Sc.(Ag.)	Junior Scientist
T.M. George, B.Sc.	Assistant Section Officer (up to 1.8.1997)
K.N. Vijayachandran Nair	Assistant Section Officer (from 22.8.1997)
C.C. Joseph	Assistant Farm Superintendent

Regional Research Station, Dhenkanal, Orissa

Chandra Gupta, M.Sc.(Ag.), Ph.D.	Agronomist
T.S. Sukumaran Nair	Assistant Section Officer
K.S. Sivasankaran Nair	Assistant Farm Superintendent

Regional Research Station, Sukma, Madhya Pradesh

*Bal Krishnan, M.Sc., Ph.D.	Scientist (GE)
K. Nageswara Rao, M.Sc.(Ag.)	Junior Scientist

Hevea Breeding Sub-station, Nettana, Karnataka

K.K. Vinod, M.Sc.(Ag.) — Plant Breeder
C.K. Thomas — Assistant Farm Superintendent

Hevea Breeding Sub-station, Paraliar, Tamil Nadu

T.A. Soman, M.Sc., M.Phil. — Scientist S2
S. George — Assistant Farm Superintendent

Regional Soil Testing Laboratory, Adoor, Kerala

A. Ulaganathan, M.Sc. — Junior Scientist

Regional Soil Testing Laboratory, Muvattupuzha, Kerala

K.K. Ambily, M.Sc. — Junior Scientist
C.P. Mary, M.Sc. — Assistant Technical Officer

Regional Soil Testing Laboratory, Kozhikode, Kerala

Joyce Cyriac, M.Sc. — Junior Scientist
P.K. Madhusooddhanan, B.Sc. — Senior Scientific Assistant

* Under World Bank Scheme
** Under World Bank Scheme on working arrangement

RESEARCH ESTABLISHMENTS

RUBBER RESEARCH INSTITUTE OF INDIA

Rubber Board, Kottayam – 686 009
Phone : 578311 (6 lines), 570318 Fax : 91 481 578317 E-mail : rrii@vsnl.com

REGIONAL RESEARCH STATIONS

Central Experiment Station
RRII, Rubber Board, Chethackal
Thompikandom P.O., Ranni
Pathanamthitta - 689 676, Kerala.
Phone : 91 473 526130

Regional Research Station
RRII, Rubber Board, Bhalukia Tilla
Kunjaban P.O.
Agartala – 799 006, Tripura.
Phone : 91 381 325287
Fax : 91 381 323149
E-mail: agtrrs@dte.vsnl.net.in

Regional Research Station
RRII, Rubber Board
Padiyoor P.O.
Kannur – 670 703, Kerala.
Phone : 91 498 273003

Regional Research Station
RRII, Rubber Board
R.G. Baruah Road
Guwahati – 781 024
Assam.
Phone : 91 361 452479
E-mail: dydirect@gw1.dot.net.in

Regional Research Station
RRII, Rubber Board
Dapchari – 401 610
Thane District, Maharashtra.
Phone : 91 2521 20071

***Hevea* Breeding Sub-station**
RRII, Rubber Board
College Road, Kadaba – 574 221
D.K. District, Karnataka.
Phone : 91 8251 60336

***Hevea* Breeding Sub-station**
RRII, Rubber Board
Thadikarankonam P.O.
Kanyakumari – 629 851
Tamil Nadu.
Phone : 91 4652 89116

Regional Research Station
RRII, Rubber Board
Dhenkanal – 759 001
Orissa.
Phone : 91 6762 34946

Regional Research Station
RRII, Rubber Board,
Sukma – 494 111
Bastar, Madhya Pradesh.
Phone : 91 778284 2301

Regional Research Station
RRII, Rubber Board
Tura – 794 001, Meghalaya.
Phone : 91 3651 23965

Regional Research Station
RRII. Rubber Board
Grassmore
Nagrakatta, Jalpaiguri – 735 225
West Bengal.
Phone : 91 3565 72316

Regional Research Station
RRII, Rubber Board
Kolasib – 796 081, Mizoram.
Phone : 91 3837 20357

Regional Soil Testing Laboratories

Rubber Board, II Floor
Kumudavathy Buildings, Balmatta
Mangalore – 575 001, Karnataka.

Rubber Board Regional Office
Thaliparamba – 670 141
Kerala.

Rubber Board, East Nadakkavu
Kozhikode – 673 011.
Kerala.

Rubber Board, East Bazar
Thrissur – 680 001
Kerala.

Rubber Board
P.O. Junction, Muvattupuzha – 686 661
Kerala.

Rubber Board, T.B. Road
Pala – 686 575
Kerala.

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

Rubber Board, Parvathy Mandiram
K.P. Road, Adoor – 691 523
Kerala.

Rubber Board, M.S. Road
Vettoornimadam, Nagercoil – 729 003
Tamil Nadu.

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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 and Exploitation; Rubber Chemistry; Physics and Technology and Agricultural Economics.

The thrust areas of research of the 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 and Exploitation Division conducts studies on identification of characteristics related to yield, physiology of latex flow and yield stimulation. 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 and Art/Photography. There is also a small experimental farm of 33 ha at the headquarters of the 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

The 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 (Madhya Pradesh), Paraliar (Tamil Nadu), Nettana (Karnataka) and Padiyoor (Kerala).

Regional soil testing laboratories have been established at Mangalore, Thaliparamba, Kozhikode, Thrissur, Muvattupuzha, Pala, Kanjirappally, Adoor and Nagercoil. Mobile units for soil and leaf analyses are available at the Kozhikode, Muvattupuzha and Nagercoil laboratories, apart from that at the headquarters.

National/International collaboration

The 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. The Rubber Board is a member of the Association of Natural Rubber Producing Countries (ANRPC) and the International Rubber Study Group (IRSG).

The RRII has research/academic linkages with the Banaras Hindu University (Varanasi), Kerala Agricultural University (Thrissur), Kerala University (Thiruvananthapuram), Mahatma Gandhi University (Kottayam), Cochin University of Science and Technology (Kochi), Indian Institute of Technology (Kharagpur), National Chemical Laboratory (Pune), Indian Institute of Sciences (Bangalore), University of Agricultural Sciences (Bangalore) and University of Goa (Goa).

Publications

Books

Handbook of Natural Rubber Production in India
Rubber Wood : Production and Utilization
Plant and Soil Analysis

Serials

Indian Journal of Natural Rubber Research
RRII Annual Report

Correspondence

The Director
Rubber Research Institute of India
Kottayam - 686 009, Kerala, India.
Phone : 91 481 578311 (6 lines)
Telex : 0888 285 RRII IN
Fax : 91 481 578317
E-mail : rrii@vsnl.com