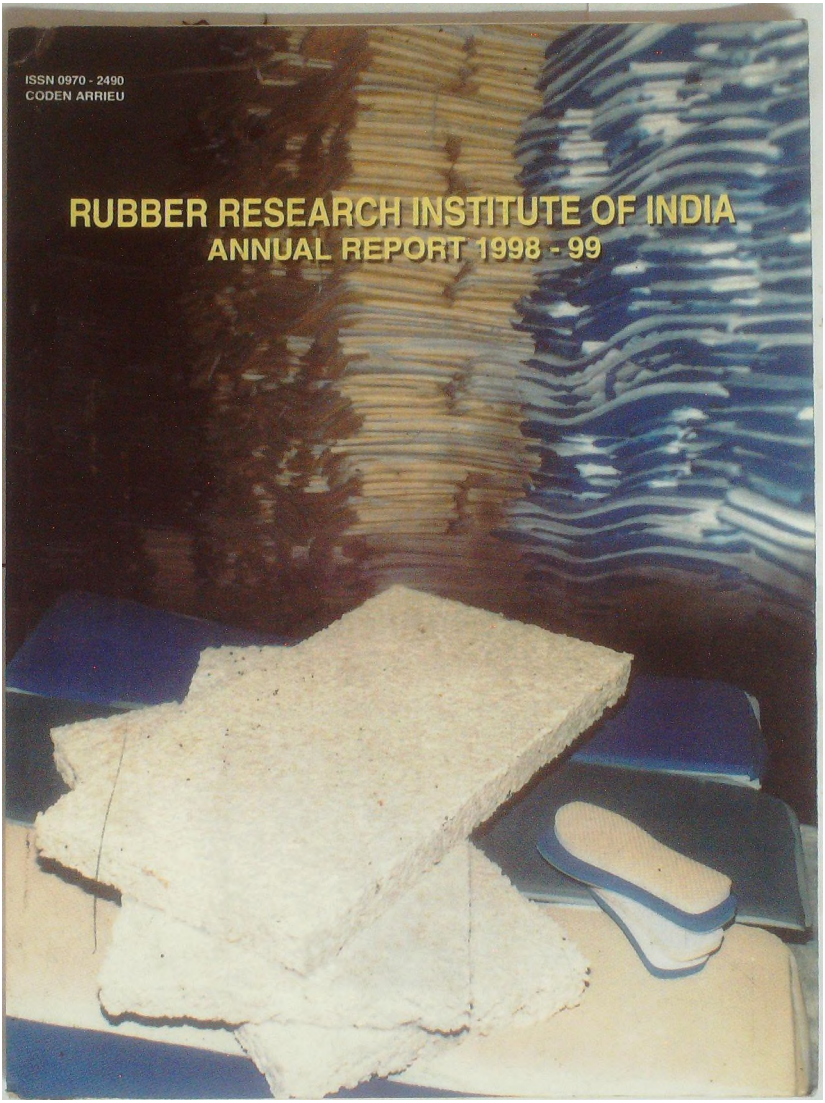
ISSN 0970 - 2490
CODEN ARRIEU

RUBBER RESEARCH INSTITUTE OF INDIA

ANNUAL REPORT 1998 - 99



Rubber Research Institute of India

Annual Report 1998-99*
ISSN 0970 2490
CODEN ARRIEU

Publisher

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Styrene-grafted natural rubber prepared by graft co-polymerization under gamma radiation

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February, 2001

*With particulars of personnel as on 31.03.1999

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 Thiruvananthapuram, 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
1998-99

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 in 1954, 1960, 1982 and in 1994. The Act was again amended by The Rubber (Amendment) Act, 1994 (Act 33 of 1994) which is now in force.

Organization

The Chairman is the principal executive officer and exercises control over all departments of the 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, Administration, Rubber Production, Processing & Product Development, Finance & Accounts, Training & Technical Consultancy and Licensing & Excise Duty.

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DIRECTOR'S REVIEW

The natural rubber (NR) sector in India, at the turn of the millennium, is at a critical juncture. The privileges, which the sector enjoyed so far, have been undergoing gradual changes since India has embarked on the path towards market integration with the introduction of liberalized economic policies since early 1990s. The changes, which the NR sector in India along with the economic and trade regimes all over the world have been witnessing, became more obvious with the signing of the GATT treaty and the subsequent emergence of the WTO. In the emerging context of globalization and market integration, the era of administered and support prices may not be sustainable and the strategies hitherto followed need appropriate changes. Research programmes on NR have to be fine-tuned taking into account of the changes in national policies.

Efforts in developing suitable agromanagement techniques for profitable and sustainable rubber cultivation were continued. The studies on nutritional requirements showed that NPK at the rate of 60:30:40a kg/ha recorded the highest yield in RRII 105. No significant difference was observed between bowl sludge and other sources of P with respect to girth increment and yield. Field experiments to compare the effect of continuous and periodic skipping of fertilizers and studies on soil and water conservation and cropping systems were continued.

In biotechnology experiments to enhance the frequency of somatic embryogenesis and plant regeneration using immature anther and inflorescence from RRII 105 were in progress. Experiments carried out to reduce the time span between explant inoculation and plant regeneration resulted in reduction of four to six months when explants were cultured in a liquid medium followed by a solid medium. Experiments on micropropagation through nodal culture, pollen protoplast culture and genetic transformation were continued. Experiments to develop molecular markers for tapping panel dryness were also in progress.

Research activities on crop improvement programmes were continued in the Botany Division. Ten of the new hybrid clones in the pipeline exhibited superiority in yield over RRII 105 during the fifth year of tapping in the preliminary evaluation trial. In a large-scale evaluation of clones, nine clones exhibited higher girth than RRII 105 during the fifth year of planting. In the mixed clone trial including RRII 105, during the ninth year of tapping, PR 255 has been identified as the highest yielder. Breeding experiments for combining drought tolerance and powdery mildew resistance and investigations on G x E interaction were continued.

The germplasm collection comprising of 125 Wickham clones and the wild Brazilian genotypes from the 1981 IRRDB collection has been maintained in five gardens and seven source bush nurseries. Preliminary evaluation trials of the 1981 IRRDB collection found a few genotypes of higher yield than RRII 105, and in a large-scale evaluation trial, out of the 80 genotypes evaluated, 41 recorded higher girth than the control. DNA extraction has been completed from leaf samples of 45 selected genotypes for establishing genetic relationship among the wild germplasm through RAPD studies.

Abnormal leaf fall disease was severe in all the traditional rubber growing areas and evaluation of new fungicide formulation for

control of the disease was continued. Rubber seed oil was tested as a partial replacement for spray oil used as diluent for copper oxychloride. Field experiments for the control of shoot rot, powdery mildew, pink and panel diseases were conducted. Experiments for the control of *Corynespora* leaf disease using dust formulation of systemic fungicides were carried out. Studies on the control of pests like rainguard-damaging crickets, termites, nematodes, slugs and snails etc. and those on vermiculture and beekeeping in rubber plantations were continued.

Studies on ecophysiology of *Hevea* and physiology of growth and yield were continued. An evaluation of *Hevea* clones has identified RRIM 600 and Haiken 1 as comparatively more tolerant to drought than RRII 105 and PB 260. A suitable protocol for isolation of PCR amplifiable DNA from *Hevea* bark samples has been standardized. It was found that occurrence of TPD in a new tapping panel was relatively fast and more in trees with a TPD history in the previous tapping panel.

In primary processing of NR, evaluation of sun drying of sheets in comparison with other modes of drying indicated that sheets exposed to sunlight for prolonged periods are more vulnerable to degradation. A protocol for the pilot plant-scale preparation of styrene-grafted NR using gamma radiation was standardized. Studies on deproteinization of NR revealed that a proteolytic enzyme preparation could significantly reduce the levels of protein in centrifuged latex. A reclamation process for vulcanized scrap rubber by mechanical shearing of the waste rubber in an open mill was evolved.

Studies on the economic aspects of NR cultivation, processing, marketing and end uses, ancillary sources of income and by-products were continued. An evaluation of the planting materials under commercial cultivation had identified RRII 105 as the highest yielder (1703 kg/ha). Availability of family labour, type of intercrops, the perception of profitability of intercropping and the sources of off-farm income were identified to be the major determinants of intercropping decisions. The monitoring of the by-products has been continued and the estimated availability of rubber wood was 1.35 million m^3. The production of rubber seed oil and rubber honey was estimated to be 2300 and 1750 t respectively.

Various research projects under the World Bank-Assisted Rubber Project were continued. Results of the rainguarding experiment showed 35 and 50 per cent yield reduction in the absence of rainguard under d/3 and d/2 system of tapping respectively. Various trials on nutritional requirements under different fertility status of the soil, evaluation of high yielding and cold/drought tolerant clones, disease and pest management, exploitation systems and evaluation of suitable agrotechnology undertaken at the regional research stations were continued.

The meteorological parameters at five locations representing different agroclimatic regions were recorded. Agroclimatic classification of rubber growing areas and studies on crop-weather relations were initiated. The Library and Documentation Centre continued its role of communicating and disseminating information on NR and allied subjects through information services and publications.

AGRONOMY AND SOILS DIVISION

The Division continued its research in developing suitable agromanagement techniques for profitable and sustainable rubber cultivation and also supported large estates through the advisory service by providing discriminatory fertilizer recommendation based on soil and leaf analyses.

1. Nutritional studies (immature rubber)

1.1 NPK requirement of clone RRII 105

The experiment started in 1989 to study the nutritional requirement of clone RRII 105 was continued. The girth (1999) and girth increment (1991-1999) did not indicate any significant difference between treatments.

Significant differences was observed for yield during 1998-99 (Table Ag. 1). The

Table Ag. 1. **Effect of fertilizer on yield**

NPK (kg/ha)	Yield (g/tree/tap)
0 0 0	46.08
30 30 20	55.21
30 30 40	59.32
30 60 20	55.95
30 60 40	49.58
60 30 20	46.91
60 30 40	74.36
60 60 20	48.45
60 60 40	64.46
90 30 20	47.83
90 30 40	51.96
90 60 20	56.12
90 60 40	44.29
SE	5.43
CD (P=0.05)	15.86

NPK at the rate of 60:30:40 kg/ha recorded the highest yield followed by 60:60:40 and 30:30:40 kg/ha.

2. Nutritional studies (mature rubber)

2.1 Clone-cum-fertilizer experiment

The experiment to study the clonal difference in nutrient requirement is being continued. Significant clonal differences were noticed in girth and yield. Highest mean girth was observed for clone RRII 203 followed by RRIC 100, which were comparable. The highest yield was for PB 311 followed by RRII 105, which were on par (Table Ag. 2). However, no clonal difference in nutrient requirement was indicated.

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

Clone	Girth (cm)	Yield (g/tree/tap)
RRII 5	67.86	39.83
RRII 105	65.21	41.72
RRII 203	72.87	35.72
RRII 208	59.00	26.21
RRII 300	63.17	28.34
RRII 308	64.36	24.76
PR 255	61.18	27.63
PR 261	62.06	32.51
PB 311	68.85	45.56
RRIC 100	71.52	40.63
SE	2.09	4.21
CD (P =0.05)	6.69	13.46

2.2 Sequential skipping of fertilizer

The field experiment to compare the effect of continuous avoidance of manures and periodical skipping of fertilizers with regular fertilizer application was continued. One round of treatment imposition was completed by 1998. Observations on growth and yield were recorded at periodic intervals.

3. Density of planting

The experiment on density of planting started in 1994 at CES, Chethackal with five different spacings as main plot and two regimes of fertilizers viz. fertilizer on per area basis and fertilizer on per plant basis, as sub-plot, is being continued. No significant differences were observed between treatments, with respect to girth, girth increment and soil nutrient status.

4. Soil and water conservation

4.1 Effect of silt pits (conservation pits)

Experiment on mature rubber to study the effect of silt pits on soil and water conservation is being continued. The soil deposited in the pits was quantified. The soil conserved in the pits ranged from 5.3 to 13.9 t/ha/year, when the number of pits was increased from 100 to 250 per ha (Table Ag. 3). But no beneficial effects of silt pits on yield and girth were indicated.

Table Ag. 3. **Soil conserved in silt pits (1998-99)**

Treatment (pits/ha)	Soil conserved (t/ha/year)
100	5.28
150	8.25
200	9.76
250	13.95
SE	5.21
CD (P=0.05)	1.69

4.2 Silt pits and fertilizer placement

A field experiment was initiated on mature rubber at TR&T Estate, Mundakayam during 1998 to study the influence of silt pits on the growth and yield of mature rubber and the effect of applying fertilizers in silt pits. The treatments included two frequencies (150 and 250 pits/ha) of conservation pits (125 x 45 x 75 cm) and two methods of fertilizer application (normal practice and fertilizer placement in pits) and a control (no pit and normal practice of fertilizer application). Growth and yield are being monitored periodically. Soil samples are being collected for chemical analysis and moisture estimation.

5. Weed management

5.1 Weed control on planting strips

The experiment at Shaliacary Estate, Punalur to evaluate different weed control methods in planting strips of rubber was continued. Observations on weed infestation by visual rating and weed density measurements (dry weight/m^2) indicated that scraping of the entire platform continued to be the best treatment for controlling weeds. Herbicide spraying in the entire platforms and the integrated approach of spraying in the plant basins and slash weeding the remaining area were found to be comparable with respect to weed dry matter production (Table Ag. 4).

Table Ag. 4. **Weed dry matter accumulation**

Treatment	Weed DMP (g/m^2)
Scraping entire platform	43.05
Slashing entire platform	113.90
Spraying paraquat (Gramoxone 2.25 L/ha) + 2,4-D (Fernoxone 1.25 kg/ha) in the entire platform	64.78
Spraying glyphoste (Round up 2 L/ha) in the entire platform	64.22
Slashing interspaces and scraping plant basin	72.85
Slashing interspaces and applying paraquat (2.25 L/ha) and 2,4-D (1.25 kg/ha) in plant basin	69.60
Slashing interspaces and applying glyphosate (2 L/ha) in plant basin	70.58
SE	7.90
CD (P=0.05)	23.46

5.2 Evaluation of herbicide applicators and the efficacy of Sulfosate (Touch down)

The experiment was initiated at TR&T Estate, Mundakayam to evaluate the efficacy of Controlled Droplet Application (CDA) sprayer and to study the effect of sulfosate (Touch down) on weed control. The treatments included;

Scraping

Application of paraquat (Gramoxone) 2.25 L/ha + 2,4-D (Fernoxone) 1.25 kg/ha

Application of glyphosate (Round up) 2 L/ha with knapsack sprayer

Application of glyphosate 2 L/ha with CDA sprayer

Application of glyphosate 1.5 L/ha with CDA sprayer

Application of sulfosate (Touch down) 2.0 L/ha with knapsack sprayer

Application of sulfosate 2.0 L/ha with CDA sprayer

Application of sulfosate 1.5 L/ha with CDA sprayer

Observations on growth and weed infestation by visual rating and weed density measurements are recorded at periodic intervals. Initial observations indicated weed control for a period of about two months irrespective of the herbicides, dosage and sprayers used.

5.3 Effect of herbicide rotation on weed management

The experiment was started during 1998 at TR&T Estate, Mundakayam to study the effect of herbicide rotation on the extent of weed control with the following treatments;

Scraping

Scraping followed by application of glyphosate (Round up) 2 L/ha

Scraping followed by application of sulfosate (Touch down) 2 L/ha

Glyphosate 2 L/ha followed by paraquat (Gramoxone) 2.25 L/ha + 2,4-D (Fernoxone) 1.25 kg/ha

Sulfosate 2 L/ha followed by paraquat 2.25 L/ha + 2,4-D 1.25 kg/ha.

The treatments were repeated at 50 and 75 per cent regeneration of weeds. Observations on growth and weed infestation by visual rating and weed density measurements are being recorded at periodic intervals.

5.4 Control of *Mucuna bracteata*

The trial initiated in 1997 to find out the number of rounds of herbicide application required to control *Mucuna bracteata* along the planting strips of rubber was continued. Results indicated that 2,4-D (Fernoxone) at 1.25 kg/ha gave the most effective and economic control of *Mucuna bracteata* in the planting strips (Table Ag. 5).

Table Ag. 5. **Economics of controlling *Mucuna bracteata***

Treatment	Number of rounds (slashing/ spraying)	Number of man-days/ha/ round	Total labour charges* (Rs)	Total cost of chemicals (Rs)	Total amount (Rs)
Slashing	11	20	16557.20	-	16557.20
Glyphosate 2 L/ha	8	6	3612.48	4800.00	8412.50
Glyphosate 1 L/ha	12	6	5418.70	3600.00	9018.72
Glyphosate 0.5 L/ha + urea 1.25 kg/ha	12	6	5418.72	1860.00	7278.72
Paraquat 2.25 L/ha + 2,4-D 1.25 kg/ha	7	6	3160.90	4574.50	7735.42
Paraquat 2.25 L/ha	13	6	5870.30	5733.00	11603.30
2,4-D 1.25 kg/ha	7	6	3160.90	1487.50	4648.42
2,4-D 2.50 kg/ha	6	6	2709.40	2550.00	5259.40

* @ Rs.75.26/man-day

Glyphosate (Round up) Rs.300/L; Paraquat (Gramoxone) Rs.196/L; 2,4-D (Fernoxone) Rs.170/kg.

6. Cropping systems

6.1 Intercropping in mature rubber

The experiment to study the possibilities of intercropping coffee in mature rubber at CES, Chethackal was continued. No significant difference in girth of rubber plants was observed (Table Ag. 6).

Table Ag. 6. **Girth of rubber**

Treatment	Girth (cm)
Rubber + coffee (robusta) single row 10'	70.85
Rubber + coffee (cauvery) single row 5'	78.44
Rubber + coffee (cauvery) double row 5 x 5	75.11
Rubber alone	72.58
SE	4.62

The block trial laid out at Shaliacary Estate, Punalur on intercropping coffee in mature rubber plantation was in progress. The growth of rubber inter-planted with single and double rows of coffee var. cauvery was comparable with that of rubber monoculture. A few coffee plants have started bearing in the third year of planting.

6.2 Cropping system model

The cropping system experiment initiated in 1993 at CES, Chethackal was in progress. The intercrops included banana for initial two years, pineapple and tuber crops during the fourth, fifth and sixth year in the space occupied by banana, pepper on *Erythrina* standards and coffee. Cover crop was established in the narrow inter-row areas. Grass and teak were planted along the boundary. The stand per ha of rubber was 406.

The growth of rubber plants continued to be superior in the cropping system compared to that in monoculture. Tuber crops gave satisfactory yield in the sixth year also. Yield of pineapple has started declining.

7. Integrated nutrient management in rubber

7.1 Organic and inorganic sources in young rubber

The experiment initiated in 1994 at Shaliacary Estate, Punalur was continued. No significant difference was noticed between the growth of plants applied with organic manure and without organic manure.

7.2 Comparison of different ecosystems with special reference to soil organic matter

This experiment has been initiated to assess the soil organic matter and its constituents. Sites have been selected in a virgin forest and nearby rubber and teak plantations. The forest and teak plantation systems are in the Kanamala range of Erumely Forest Division and the rubber system is in Travancore Rubber Estate, Mukkoottuthara. In the rubber plantation, leaf litter disintegration studies have been started in *Mucuna*- and *Pueraria*-grown areas.

8. Forms and methods of fertilizer application

8.1 Bowl sludge as a source of P

The experiment initiated in 1989 at TR&T Estate, Mundakayam was continued. Girth increment for the period 1989 to 1998 and the yield for 1998 are presented in Table Ag. 7.

Table Ag. 7. **Effect of bowl sludge application on girth increment and yield**

Treatment	Girth increment (cm)	Mean yield (g/tree/tap)
Super phosphate	51.28	40.54
Mussoorie rock phosphate	49.83	41.49
Bowl sludge	51.79	41.41
Control (no P)	47.06	29.36
SE	1.44	2.81
CD (P=0.05)	NS	8.42

No significant difference was noted between the treatments with respect to girth increment. All the sources viz. super phosphate, Mussoorie rock phosphate (MRP) and bowl sludge gave significantly higher yield over no P- control. Significant difference was not recorded between the three sources with respect to yield. Latex samples from the individual treatments were analysed for the nutrient concentration and was not influenced by the treatments (Table Ag. 8).

Table Ag. 8. **Influence of different P sources on nutrient concentration of latex (total solids)**

Treatment	Nutrient concentration (%)			
	N	P	K	Mg
Super phosphate	0.41	0.37	0.69	0.25
MRP	0.51	0.36	0.62	0.23
Bowl sludge	0.51	0.37	0.64	0.23
Control (no P)	0.41	0.31	0.66	0.20
SE	0.03	0.03	0.03	0.01

8.2 Use of controlled-release fertilizers

The field experiments at CES, Chethackal and Kuzhimattom on the use of controlled-release fertilizers for immature rubber were in progress. The girth data from the two experiments indicated possibility for reducing the dose and number of splits of fertilizer application using controlled-release formulations (Tables Ag. 9 and 10).

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

Treatment	Recommended dose (%)	Girth (cm)
Prilled urea	100	43.6
NPKMg pellets	100	47.03
NPKMg pellets	75	47.63
Nimin-coated urea	100	46.43
Nimin-coated urea	75	46.20
Neem cake-mixed urea	75	47.17
Control (no manure)		41.37
SE		1.06
CD (P=0.05)		3.27

8.3 Effect of N-inhibitors on the growth and yield

The experiment at Vembayam to study the efficiency of utilization of urea when mixed with the neem cake in mature rubber continued. The data on girth and cumulative yield (1996-99) did not exhibit any significant difference between treatments.

8.4 Effect of substitution of potassium by sodium on the growth

A pot culture experiment was conducted with six treatments and four replications to

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

Treatment	Recommended dose (%)	Number of application	Girth (cm)
Prilled urea	100	two	42.87
NPKMg pellets	75	single	42.65
NPKMg pellets	75	two	43.80
NPKMg pellets	50	single	41.00
NPKMg pellets	50	two	42.53
Nimin-coated urea	100	two	42.24
Nimin-coated urea	75	two	41.80
Neem cake-mixed urea	100	two	42.00
Neem cake-mixed urea	75	two	41.57
Control (no manure)			36.35
SE			1.22
CD (P=0.05)			3.62

study the effect of application of sodium chloride on the performance of young rubber plants. The treatments were the substitution of K_2O (applied as KCl) by Na_2O (applied as NaCl), to the extent of 0, 25, 50, 75 and 100 per cent. The data on dry matter production of plants as influenced by various combinations of K and Na are presented in Table Ag. 11.

Table Ag. 11. **Effect of different levels of K and Na on dry matter production**

Treatment	Mean dry matter production (g/pot)
K_2O 100%	556.35
K_2O 75% + Na_2O 25%	500.77
K_2O 50% + Na_2O 50%	504.86
K_2O 25% + Na_2O 75%	473.45
100% Na_2O	412.32
Control (No K and Na)	401.46
SE	29.83
CD (P=0.05)	88.63

The results indicated that sodium partially substituted the role of K in young plants and maintained the same level of dry matter production up to 50 per cent substitution. The total uptake of N, P, K, Na, Ca and Mg by the application of different levels of K and Na are given in Table Ag. 12.

The total uptake of potassium and sodium differed significantly. The treatments 0, 25 and 50 per cent substitution of K_2O by Na_2O gave higher K uptake than other treatments and no difference was noted between these treatments in K uptake. Total Na uptake also increased with increased level of Na_2O application. The uptake of N, P, Ca and Mg was not influenced by the differential application of K and Na.

The available K and Na in soil increased with increased application, while the other characteristics of soil such as pH and EC were not influenced. A field study was laid out on mature rubber at Malankara Estate, Thodupuzha, with 10 treatments and three replications to find out the effect of substitution of various levels of K by Na on yield of rubber as well as on soil properties.

8.5 Comparison between Rajphos and MRP

The experiments laid out in young rubber at Boyce Estate, Mundakayam and Malankara Estate, during 1997 for comparing the efficacy of Rajphos and MRP were in progress. Girth increment during the period 1997-99 did not indicate any significant difference between the two sources of rock phosphate. Uniform application of 40 kg N, 20 kg K_2O and 6 kg MgO was given in all plots.

8.6 Comparison of Rajphos and MRP at varying levels of application (mature rubber)

The experiments started during 1997 at two locations (Boyce Estate and Malankara

Table Ag. 12. **Effect of substitution of K by Na on uptake of nutrients**

Treatment	Uptake of nutrients (g)					
	N	P	K	Na	Ca	Mg
K_2O 100%	9.87	0.92	5.98	0.24	4.31	0.85
K_2O 75% + Na_2O 25%	10.52	0.88	5.98	0.38	4.55	0.77
K_2O 50% + Na_2O 50%	10.60	0.69	5.83	0.46	4.43	0.66
K_2O 25% + Na_2O 75%	9.90	0.89	4.39	0.60	4.37	0.73
100% Na_2O	9.87	0.75	4.22	0.69	4.71	0.72
Control (No K and Na)	10.62	0.65	3.60	0.21	3.91	0.73
SE	-	-	0.55	0.04	-	-
CD (P=0.05)	NS	NS	1.63	0.13	NS	NS

Estate) to study the effect of Rajphos and MRP at different levels on growth and yield of rubber were in progress. Yield was recorded monthly.

8.7 Evaluation of availability of Mg contained in Rajphos, MRP and IRP

A pot culture experiment was conducted to study the utilization pattern of Mg contained in three rock phosphates viz. Rajphos, MRP and imported rock phosphate (IRP). *Pueraria phaseoloides* was taken as a test crop. The crop was harvested after 90 days and the dry matter production (DMP) was recorded (Table Ag. 13). The dried plant material was analysed for Mg content and the Mg uptake was calculated. No significant difference was noted among the three rock phosphates with regard to dry matter production and Mg uptake.

Table Ag. 13. **Effect of rock phosphate on dry matter yield and magnesium uptake**

Treatment	DMP (g)	Mg (mg/pot)
Rajphos	14.98	54.43
MRP	15.04	59.68
MRP + $MgSO_4$	15.41	61.10
IRP	15.63	54.96
IRP + $MgSO_4$	16.82	62.57
$MgSO_4$	14.03	50.37
Control (No P and Mg)	12.69	40.47
SE	1.44	6.20
CD (P=0.05)	4.16	17.90

8.8 Incubation study on release pattern of Mg from Rajphos, MRP and IRP

An incubation experiment was conducted to study the Mg release pattern from three rock phosphates viz. Rajphos, MRP and IRP for 150 days. Soil samples drawn at 15-day interval up to 120 days and on 150th day were analysed for available Mg (Table Ag. 14). The results indicated that for Rajphos and MRP, Mg release was significant over IRP.

8.9 Studies on different levels of P in mature rubber

The field experiment was laid out at Mooply Estate, Palapilly during 1997 to study the effect of different levels of P on the growth and yield of rubber. Yield was recorded monthly. Girth increment during 1997-99 did not indicate any significant difference between the treatments.

9. Physical and chemical properties of soils under rubber

9.1 Inter-relationship of organic matter, organic carbon and available nutrients

Soil samples were collected from Mundakayam, Punalur and Thrissur regions. The samples are being analysed for the nutrient status.

9.2 Interaction of decomposition products of leaf litter with added fertilizers

An incubation experiment was started with the following 12 treatments;

Table Ag. 14. **Release pattern of magnesium* from three rock phosphates**

P sources	Time interval (days)									
	0	15	30	45	60	75	90	105	120	150
Rajphos	6.50	9.60	13.20	15.40	15.10	17.10	11.70	16.40	18.60	18.70
MRP	7.50	10.40	14.40	15.60	18.00	17.30	10.20	17.00	14.80	16.50
IRP	2.70	2.70	3.40	3.70	3.80	3.80	2.70	3.70	4.20	4.30
SE	0.26	0.58	0.61	0.64	1.57	0.57	0.36	1.19	0.96	0.90
CD (P=0.05)	0.78	1.73	1.81	1.89	4.66	1.71	1.08	3.53	2.85	2.68

* Available Mg (mg/100 g soil)

1. Soil
2. Soil + NPK fertilizer
3. Soil + rubber leaf litter
4. Soil + *Mucuna* leaf litter
5. Soil + *Pueraria* leaf litter
6. Soil + weed flora litter
7. Soil + litter (rubber + *Mucuna*)
8. Soil + litter (rubber + *Pueraria*)
9. Soil + litter (rubber + weed)
10. T7 + NPK
11. T8 + NPK
12. T9 + NPK

The soil samples were drawn after three months and six months of incubation periods. The samples are being analysed for the nutrient status.

9.3 Soil solution chemistry and nutrition of *Hevea*

A project to study the soil solution chemistry in relation to nutrition of *Hevea* was initiated. Centrifugal filters were fabricated for the experiment and the soil samples are to be collected after the pre-monsoon fertilizer application from Kodumon Estate.

9.4 Soil acidity and liming

9.4.1 Effect of liming on growth of seedlings in the nursery

To study the effect of liming on the growth of seedlings in the nursery, two nursery experiments were initiated at two locations during August 1998. Different levels of lime and fertilizer were incorporated as treatments. The diameter was recorded monthly from March.

9.4.2 Effect of liming on growth of immature rubber plants

A field experiment was initiated at Boyce Estate to study the influence of liming on the growth of young rubber plants. Treatments included different levels of lime and fertilizer.

10. Discriminatory fertilizer recommendation

10.1 Estate advisory service

Discriminatory fertilizer recommendation based on soil and leaf analyses were offered to 812 fields belonging to 31 large estates. A total of 580 soil and 863 leaf samples were analysed during the year.

10.2 Diagnosis and Recommendation Integrated System (DRIS) approach for fertilizer recommendation

Work on DRIS was continued to develop more theoretical basis for giving DRIS-based fertilizer recommendation.

11. Studies on wind damage

11.1 Survey on the occurrence of wind damage

A survey on wind damage was initiated during 1998. A proforma for collecting the details on wind damage was sent to 48 estates in South India. The details are being collected from different estates.

11.2 Studies on pit size and incidence of wind damage

This experiment was laid out in the 1996 RP of Rajagiri Estate for studying the influence of pit size on growth and wind damage on trees. Various dimensions of pits viz. 60 x 60 x 60 cm, 75 x 75 x 75 cm and 90 x 90 x 90 cm and no pit are the treatments. The girth recorded during February 1997 did not show significant difference between the treatments. The pit size, 90 x 90 x 90 cm recorded highest girth (22.5 cm).

Another experiment was laid out in the 1998 RP of Rajagiri Estate with the same objective. Four sizes of pits viz. 60 x 60 x 90 cm, 75 x 75 x 75 cm, 60 x 60 x 60 cm and 75 x 75 x 105 cm are the treatments. Observations on girth are being recorded.

BIOTECHNOLOGY DIVISION

The Division continued research on micropropagation, genetic transformation, protoplast culture, etc. Attempts to develop cDNA libraries are also in progress.

1. Somatic embryogenesis and plant regeneration

Experiments were continued to enhance the frequency of somatic embryogenesis and plant regeneration using immature anther and flower buds from the clone RRII 105. The effect of different concentrations and combination of hormones, sucrose, salts, amino acids, light, the physical nature of the medium etc. was evaluated with immature anther as explants. Optimum callus induction was observed in modified Murashige & Skoog (MS) medium supplemented with 2.0 mg/L 2,4-dichlorophenoxyacetic acid (2,4-D) and 0.5 mg/L kinetin (Kn). Among four auxins tested, the synergistic effect of NAA with Kn was found suitable for embryogenesis (Table Biotech.1). Maximum number of somatic embryos was produced in a basal medium supplemented with 0.7 mg/L Kn and 0.2 mg/L α–naphthalene acetic acid (NAA) (Table Biotech. 2). Further development of embryos into plantlets was achieved on a hormone-free medium. Cytological analysis indicated all the tested plants to be diploid. Both L-glutamine and casein hydrolysate are found to promote embryogenic efficiency. Gibberellic acid (GA_3) had a stimulatory effect on both embryo induction and germination. Incorporation of GA_3 at 1-2 mg/L was found to be the most effective for embryogenesis and plant regeneration. *Hevea* explants and callus need dark incubation for acquisition of embryogenic competence and light for plantlet development. Sucrose at 234 mM concentration significantly influenced the rate of embryo induction and maturation from immature flower bud-derived calli. This pathway required about one and a half year to get plantlets after inoculation of initial explants. Experiments carried out to reduce time span between explant inoculation and plant regeneration resulted in reduction of four to six months when explants were cultured in a liquid medium followed by a solid medium.

Table Biotech.1. **Effect of different auxins in combination with kinetin on embryogenesis**

Growth regulators	Concentration (mg/L)	Nature of response		
		Callus browning	New calli proliferation	Embryo formation
2,4-D/Kn	0-0.4/0.5-1.0	less	70% FEC with fast growth	Sporadic development
IBA/Kn	0-0.4/0.5-1.0	abundant	20%FEC with slow growth	Sporadic formation
IAA/Kn	0-0.4/0.5-1.0	abundant	20% FEC with slow growth	Sporadic formation
NAA/Kn	0-0.4/0.5-1.0	moderate	40% FEC with slow growth	Frequent development

Observations were made 4-5 months after culture in embryo induction medium ;
EFC – Friable Embryogenic Calli

Table Biotech. 2. **Influence of NAA and kinetin on the number of somatic embryos formed**

NAA (mg/L)	Kn (mg/L)					
	0.5	0.6	0.7	0.8	0.9	1.0
0.0	00.00 ± 0.00	00.00 ± 0.00	00.00 ± 0.00	00.00 ± 0.00	00.00 ± 0.00	00.00 ± 0.00
0.1	0.40 ± 1.75	10.83 ± 1.33	15.33 ± 1.63	11.83 ± 1.72	5.67 ± 0.82	0.70 ± 0.82
0.2	10.00 ± 1.67	18.00 ± 2.37	23.83 ± 1.72	20.67 ± 2.58	10.30 ± 1.75	3.50 ± 2.74
0.3	2.83 ± 1.72	9.00 ± 1.79	14.17 ± 2.93	11.83 ± 1.72	4.67 ± 1.51	1.00 ± 0.89
0.4	0.50 ± 0.84	3.17 ± 1.47	6.00 ± 1.26	3.83 ± 1.47	1.33 ± 1.75	0.00 ± 0.00

F = 10.92** CD (P=0.05) = 1.95 ** Significant at P < 0.01

Mean number of embryos from pooled data after 4-5 months of culturing in embryo induction medium.

2. Nodal culture

Micropropagation system through nodal cultures using explants derived from field-grown and green house-raised plants was successfully established with sprouting of axillary buds and further elongation. The chemical, thidiazuron suppressed the apical dominance and induced profuse multiple shoot formation.

3. Pollen protoplast culture

A method for the isolation of aseptic pollen from mature male flowers and the release of protoplasts was standardized. Viable protoplasts with considerably higher yield could be obtained in the presence of proper osmoticum and other culture conditions. Further culturing of pollen protoplasts for their division and colony formation is in progress.

4. Genetic transformation of *Hevea*

Experiments for the induction of high frequency somatic embryogenesis and plant regeneration of RRII 105 calli transformed with the genes coding for superoxide dismutase (SOD), isopentenyl transferase (ipt), antisense gene for ACC synthase and sorbitol 6-phosphate dehydrogenase (S6-PDH) were continued. After extensive optimization, a low frequency plant regeneration was obtained from the callus transformed with the gene coding for S6-PDH in modified woody plant medium containing high sucrose, calcium and thidiazuron. Plant regeneration was also obtained from the callus transformed with gene coding for SOD using a modified medium. Somatic embryogenesis was obtained from callus transformed with isopentenyl transferase and antisense gene for ACC. Attempts are under way to induce high frequency plant regeneration from transformed embryos of all the four genes.

5. Molecular markers for tapping panel dryness

To construct cDNA libraries of the DNA markers associated with TPD tolerance, a simple and efficient protocol for obtaining good quality RNA was developed. RNA from both TPD tolerant and susceptible trees was isolated for differential screening. In Northern Blot analysis, the marker DNA hybridized with the RNA isolated from the bark of healthy trees but not from the affected trees.

6. Genomic stability of RRII 105 plants developed through somatic embryogenesis

Leaf DNA was isolated from 10 plantlets, obtained through somatic embryogenesis using immature buds derived from the clone RRII 105. All the plants showed similar RAPD profiles with 10-mer random primers.

BOTANY DIVISION

Botany Division continued research activities on genetic improvement programmes. The thrust area was on identification of clones having more yield and better secondary characters than RRII 105. Investigations on propagation, anatomy and cytogenetics were also in progress.

1. Evolving high yielding clones for traditional area

1.1 Hybridization and clonal selection

Sixteen promising hybrid clones from the 1993 hybridization programme were planted in RBD in a small-scale trial (SST) at CES, Chethackal along with their parents and RRII 105 as check. Ninety selected hybrid seedlings from the 1994 and 1995 hybridization programmes were cloned and established in a polybag nursery at CES for taking up field trials.

Annual girth was recorded from the trials on mature and immature plants. Trees in nine small-scale trials of hybrid clones were opened for tapping. Monthly yield and annual girth were monitored. Ten pipeline clones exhibited superiority for yield over RRII 105 during the fifth year of tapping, the standard heterosis ranged from 10 to 68 per cent. In the 1995 SST, three clones exhibited superior girth than the control, RRII 105, during the third year after planting.

In progenies of 1997 Wickham x Amazonian hybridization programme, highest girth recorded (Table Bot. 1) was for the progenies of RRII 105 x MT 1021 (9.32 cm) followed by RRIM 600 x AC 495 (9.15 cm) and RRIM 600 x MT 1027 (9.11 cm).

Table Bot. 1. **Growth characters of hybrid progenies of 1997 hand pollinations**

Cross combination	Height (cm)	CV (%)	Girth (cm)	CV (%)
RRII 105 x MT 1027	184.00	43.99	7.48	30.88
RRII 105 x MT 1005	217.32	17.31	8.20	20.36
RRII 105 x MT 999	158.25	34.84	5.78	24.50
RRII 105 x MT 1014	139.54	26.01	4.45	18.65
RRII 105 x MT 1021	266.60	9.35	9.32	18.45
RRIM 600 x MT 1027	257.20	16.80	9.11	12.40
RRIM 600 x MT 1005	223.25	20.15	7.74	22.59
RRIM 600 x MT 999	224.48	25.60	7.71	25.68
RRIM 600 x MT 1014	242.00	17.85	8.45	13.46
RRIM 600 x MT 1021	240.72	20.48	8.47	22.20
RRIM 600 x AC 495	239.15	19.66	9.15	21.42
RRIM 600 x AC 498	210.07	25.96	7.11	23.20
RRIM 600 x AC 817	234.39	12.86	8.87	14.77
RRIM 600 x RO 380	240.22	17.90	8.44	21.09

1.2 Ortet selection

Out of the 53 ortets planted in Cheruvally Estate, five clones continued to record higher yield over the control, RRII 105, in the third year of tapping. Yield ranged from 49.83 to 65.33 whereas RRII 105 recorded a yield of 47.89 g/tree/tap. Out of 43 ortet clones at Mundakayam Estate, six clones showed annual mean yield comparable to that of RRII 105 in the second year of tapping. At Koney Estate, out of 47 ortet clones, 11 clones exhibited superior performance for yield over RRII 105 during the first year of tapping. Clone 11 had highest girth at opening (58.56 cm) followed by clone 27 (57.73 cm) and clone 6 (57.47 cm). Highest yield was observed in clone 27 (67.30) followed by clone 25 (65.57) and clone 10 (54.91) whereas RRII 105 yielded 36 g/tree/tap. A SST of 12 ortets selected from Kaliyar Estate, Thodupuzha was laid out at CES, Chethackal.

2. Evaluation of clones

2.1 Large-scale evaluation

In the large-scale trial of hybrid clones at CES, Chethackal, girth during the fifth year

of planting revealed nine clones to be superior to RRII 105 (Table Bot. 2).

Table Bot. 2. **Girth of promising hybrid clones in the fifth year of planting**

Clone	Girth (cm)
82/2	34.75
82/3	26.24
82/7	30.02
82/1	31.56
82/14	35.10
82/17	33.81
82/22	35.95
82/27	32.46
82/29	31.21
82/30	41.16
RRII 105	27.71
General mean	32.72
SD	4.13

To study the growth pattern of *Hevea* in the traditional region, monthly recording of girth was carried out. Monthly yield and yield components were recorded in the 1989 trial on multidisciplinary evaluation of modern clones.

In the mixed clone trial at CES, Chethackal, yield during the ninth year of tapping indicated PR 255 as the highest yielding clone followed by PB 310, PR 261 and RRII 105 (Table Bot. 3).

Table Bot. 3. **Yield in the ninth year of tapping**

Clone	Yield (g/tree/tap)
RRII 44	52.27
RRII 45	40.98
RRII 105	50.11
PR 255	56.15
PR 265	52.35
PB 235	49.41
PB 260	38.56
PB 310	52.53
PB 311	42.74
RRIM 600	49.25
General mean	48.44

Data on growth, yield and meteorological variables were collected from the 1985 clone trial at RRS, Dapchari. Analysis of seasonal growth from the trial for the years 1989 and 1995 indicated clonal variation among the 15 clones (Table Bot. 4).

Table Bot. 4. **Clonal variation in absolute girth (cm) in May 1989 and 1995**

Clone	Girth (1989)	Wet season		Mid-season		Dry season		Annual		Girth (1995)
		MGIN	MRIR	MGIN	MRIR	MGIN	MRIR	MGIN	MRIR	
RRII 5	17.8	2.9	1.05	1.04	0.35	0.08	0.05	4.0	1.4	42.0
RRII 6	22.5	2.6	0.81	1.11	0.35	0.05	0.01	3.7	1.2	44.9
RRII 105	19.3	3.0	1.02	0.97	0.31	-0.03	0.01	4.0	1.3	43.1
RRII 208	22.1	3.0	0.91	1.49	0.43	0.02	0.02	4.6	1.4	49.3
RRII 308	17.0	3.1	1.12	0.79	0.29	0.00	0.03	3.9	1.4	40.1
PR 255	16.7	3.2	1.21	0.79	0.28	-0.11	-0.02	3.9	1.5	40.2
PR 261	14.3	3.2	1.30	0.93	0.36	0.01	0.03	4.2	1.7	39.3
PB 260	18.0	3.1	1.11	0.69	0.23	-0.02	0.01	3.8	1.3	40.7
PB 310	18.9	2.9	1.01	0.84	0.28	-0.04	0.00	3.7	1.3	40.9
PB 311	18.6	3.1	1.10	0.72	0.24	-0.12	-0.02	3.7	1.3	40.5
RRIC 52	17.2	3.6	1.23	0.99	0.33	0.10	0.06	4.7	1.6	45.3
RRIC 100	17.0	3.3	1.16	1.19	0.40	0.07	0.05	4.6	1.6	44.3
RRIC 102	19.3	3.1	1.03	1.02	0.32	0.04	0.03	4.1	1.4	44.0
RRIC 105	19.0	3.1	1.06	0.77	0.25	0.07	0.04	3.9	1.4	42.5
RRIM 605	19.8	2.7	0.95	0.75	0.24	0.12	0.05	3.6	1.2	41.4
SE	1.5	0.1	0.07	0.13	0.04	0.05	0.02	0.2	0.1	2.1

MGIN – Seasonal mean girth increment (cm/season)
MRIR – Seasonal mean relative increment rate (mm/cm/season)

All available yield data from 1982 clone trial and polyclonal blocks planted during 1983 and 1984 were processed to assess yield trend in North Konkan region.

2.2 Onfarm evaluation

Block yield data of eight clones over the first five years of tapping at Manickal Estate, Mundakayam revealed RRII 105 yielding high (1178 kg) followed by RRII 4 (1040 kg) and PB 310 (1014 kg). GT 1 recorded the lowest yield (687 kg).

At Sasthamkotta during 1994, PB 255 recorded the highest girth (33.68 cm) followed by PB 314 (32.45 cm) and PB 311 (32.09 cm) during the fourth year of planting. In the trial at Erumeli comprising six clones viz. RRII 50, RRII 51, RRII 203, RRII 105, PR 255 and PR 261, RRII 203 recorded the highest girth (38.57 cm) followed by PR 261 (33.90 cm) whereas RRII 105 had the lowest girth (31.42 cm) in the third year.

Intraclonal variation worked out for yield in four clones viz. RRII 105, RRII 203, RRIM 600 and GT 1 planted at CES, Chethackal gave a mean variability of 25.8 per cent (Table Bot. 5).

Table Bot. 5. **Intraclonal variability in clones**

Clone	Year of tapping	Coefficient of variation (%)
RRII 105	4	26.7
RRII 203	3	24.5
RRIM 600	2	26.4
GT 1	3	25.7
Mean	-	25.8

3. Performance of clonal composites

A new trial to evaluate the performance of various clones in different proportion and combinations of blends in comparison to monoclonal planting was laid out at RRS, Padiyoor. The clones selected were RRII 105, PR 255, PR 261, PB 260, PB 217 and PB 280 (Table Bot. 6). The design adopted was RBD with three replications and seven treatment combinations in different proportions.

Table Bot. 6. **Clone combinations and proportions**

Treatment	Group I (45%)	Group II (40%)	Group III (15%)
1	RRII 105	PR 255	PB 280
2	RRII 105	PR 261	PB 280
3	RRII 105	PB 217	PB 280
4	RRII 105	PB 217	PB 260
5	RRII 105	PB 260	PR 255
6	RRII 105	PB 260	PR 261
Control	Monoclonal parentage of RRII 105		

4. Polycross progeny evaluation

Girth was recorded in the two trials during the sixth year after planting. Open-pollinated seedlings of 10 promising clones of Indian, Malaysian and Chinese origin were planted in a nursery for seedling progeny analysis.

5. Breeding clones for combining compact canopy with good yield

Growth index of the four morphotypes of the genetic variant computed based on girth, bark thickness, petiole length and leaf area in the eighth year after planting showed highest index of 9.73 for normal plants followed by control (8.78) and intermediates (8.63). Normal and intermediate plant types appear to be promising (Table Bot. 7).

Table Bot. 7. **Morphological characters and growth index of morphotypes**

Treatment	Girth (cm)	Bark thickness (mm)	Petiole length (cm)	Leaf area (cm^2)	Growth index
Dwarf	26.17	5.11	8.46	141.21	6.01
Semi-dwarf	33.21	6.04	7.37	148.24	6.80
Intermediate	49.28	7.26	12.16	147.04	8.63
Normal	53.34	8.06	14.75	180.18	9.73
Control	48.35	7.35	12.62	182.42	8.78
GM	42.07	6.77	11.07	159.94	7.99
SE	4.57	0.47	1.29	15.56	
CD (P=0.05)	13.70	1.41	3.87	-	

6. Breeding for drought tolerance

A SST of 22 clones comprising 15 hybrids and their parents with clone RRII 105 as check was laid out in RBD with three replications at CES, Chethackal.

A SST of 15 ortets selected from RRS, Dapchari along with two check clones was also laid out in RBD at CES, Chethackal.

Sixty hybrid seedlings resultant of 1995 hand pollination among four clones in three cross combinations were selected on the basis of juvenile yield. The plants were cloned and established in polybags at CES for SST. One hundred and seven hybrid seedlings resultant of the crosses between RRII 105 and PB 280 and the reciprocals were test-tapped at the age of two years in the nursery.

7. Investigations on Genotype x Environment interaction

Girth data from the five locations revealed significant clonal differences except in Bhubaneswar. The clone 82/29 recorded the highest girth in Agartala region (16.50 cm) during the second year of planting.

8. Cytogenetical investigations

Chiasma frequency studies of two clones viz. PB 255 and PR 255 revealed that chiasma per cell in PR 255 is higher (29.43) than that of PB 255 (26.38). Somatic embryoids regenerated from immature anthers were diploids having 36 chromosomes in the somatic cells. Pollen germination studies in three clones revealed highest germination in RRII 208 followed by PB 280 and Haiken 1.

In the field trial on evaluation of selected clones resultant of mutation and polyploidy, three clones showed superior girth than that of RRII 105. From the 1985 trial of irradiated materials, four clones having higher yield than RRII 105 have been identified based on yield of four years of tapping. The clones were multiplied for laying out a large-scale trial.

9. Breeding for powdery mildew resistance

Screening for mildew resistance was carried out and the percentage disease index (PDI) was worked out. The disease was more in PB 235 followed by PB 5/51 during the first year of observation while in the second year PB 5/51 was seriously affected. Individual as well as pooled analysis of data revealed significant clonal difference. Lowest disease incidence was recorded in PB 86 (Table Bot. 8).

Table Bot. 8. **Powdery mildew incidence**

Clone	PDI		
	1997	1999	Pooled average
RRII 5	40.83	41.50	41.46
RRII 105	52.25	40.66	46.45
RRIC 52	33.33	27.33	30.33
RRIC 102	28.27	34.10	31.19
RRIM 600	47.50	52.00	44.75
RRIM 703	38.47	29.20	33.84
PB 260	50.37	47.80	49.08
PB 28/59	51.90	33.47	42.69
PB 86	21.27	20.43	20.85
PB 217	39.17	40.80	39.88
PB 235	76.57	45.91	61.24
PB 5/51	66.13	65.47	65.80
PB 311	63.73	59.87	61.80
PR 255	34.34	39.83	37.09
PR 261	34.20	32.23	33.22
GT 1	38.93	40.41	39.67
IAN 45-873	36.73	26.62	31.67
AC 709	38.90	29.51	34.20
AC 717	41.33	33.15	37.24
RO 2623	28.43	26.60	27.52
Variance ratio	10.55**	3.43**	7.74**
CD (P=0.05)	12.10	17.22	12.54

10. Estimation of genetic parameters

Data on yield and yield components of a hybrid population of the cross of RRII 105 x RRIC 100 over the first three years of tapping were subjected to analysis for estimating genetic parameters. Medium to high coefficients of variation followed by medium to high heritability and genetic advance for all the characters except those

Table Bot. 9. **Estimates of genetic parameters for yield and yield components**

Character	Coefficients of variation		Heritability (%)	Genetic advance
	GCV	PCV		
Annual mean dry rubber yield	33.73	39.54	72.72	58.66
Volume of latex	30.91	36.98	69.85	52.57
Rate of latex flow	27.17	30.48	79.46	49.59
DRC	7.02	9.96	49.71	10.05
Plugging index	20.94	25.73	66.23	34.94
Girth at opening	4.81	10.19	29.69	5.40
Girth increment rate	32.09	46.11	48.39	45.56
No. of latex vessel rows at opening	21.05	29.72	50.12	30.54
Bark thickness at opening	3.91	7.83	25.00	26.41

for girth at opening, bark thickness and DRC reveal better scope for selection based on these characters (Table Bot. 9).

11. Floral biology and fruit set

Pollinated flowers of selected clones were collected at different developmental stages to study the consequences of ovule development.

12. Anatomical investigations

12.1 Bark anatomical investigation

An attempt was made to control TPD by removing the unproductive dry bark by successive tapping leaving residual bark undisturbed. Tapping of the renewed bark after two years indicated that the bark was productive while the control trees did not recoup even after rest. Anatomical studies of the respective bark samples revealed 13 rows of latex vessels in the soft bark of the regenerated bark of the debarked tree while the TPD-affected bark on rest showed only six rows of latex vessels. The propagation of soft bark to hard bark was 1 : 3 and 1 : 13 respectively.

A study on the seasonal activity of cambium in clone RRII 105 indicated less number of cambial layers in May and higher number in the months of December and January (Table Bot. 10).

Table Bot. 10. **Seasonal activity of cambium and latex vessels**

Month	Twig	Bark	
	Cambial layers	Total latex vessels	Thickness of soft bark devoid of latex vessels (mm)
1997			
July	4.27	12.32	0.74
August	5.67	12.00	0.45
September	5.20	12.08	0.50
October	5.44	14.83	0.45
November	4.17	17.80	0.47
December	4.76	15.48	0.40
1998			
January	5.13	15.96	0.47
February	3.82	13.36	0.36
March	5.14	13.84	0.38
April	4.93	12.80	0.61
May	3.90	12.56	0.67
June	4.57	15.08	0.64
Mean	4.57	14.14	0.51

Anatomical characters viz. number of latex vessel rows, incidence of intraxylary phloem, primary xylem group and thickness of phloem and xylem were recorded from bark and twig samples of 20 ortets growing in the drought-prone North Konkan.

Monthly application of five per cent ethrel on the bark of untapped trees to study its effect on bark structure was continued.

12.2 Evaluation of clones for structural components

Bark samples of 1985 SST of hybrid clones were collected to study the anatomical parameters related to yield.

13. Wood anatomical investigations

Observtions on ray characteristics from three clones viz. RRIC 52, RRII 105 and PR 261 from the traditional region were made to identify the most promising xylem component in relation to water translocation in *Hevea* clones. Height and width of the ray cells and their frequency are summarized in Table Bot. 11.

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

14. Studies on propagation

In the trial on budding height and depth of planting, no uprooting was noticed. Fourth year girth data of plants from the trial on twin stock and single stock indicated that single stock plants raised in bags had better girth than the control (Table Bot. 12).

Table Bot. 12. **Girth under various treatments**

Treatment	Girth (cm)
Twin stock polybag plants	14.35
Single stock polybag plants	16.99
Twin stock seed-at-stake plants	11.61
Single stock seed-at-stake plants	10.12
Twin stock budded stumps	10.11
Single stock budded stumps	13.41
Polybag plants (control)	16.80

In the trial on bench-grafted plants, girth data in the second year of tapping showed a marginal increase for the bench-grafted plants (63.68 cm) than nursery-grafted plants (63.06 cm). In the trial on deep planting of two-whorled bag plants, buried plants in general showed better girth than normal plants (Table Bot. 13).

Table Bot. 13. **Girth of deep-planted two-whorled polybag plants**

Treatment	Girth (cm)
Bud union buried 5 cm	54.03
Bud union buried 10 cm	53.34
Bud union buried 15 cm	50.26
Normal planting (control)	49.91

In the study on the effect of long snag and nicking of snag buds on establishment of green-budded stumps in polybags, plants with long scion (30 cm) recorded less height. Among the plants with shorter snags, those subjected to nicking of snag buds were found superior in growth (Table Bot. 14).

Table Bot. 11. **Ray characteristics of selected *Hevea* clones from the traditional region**

Clone	Number/unit field	Height (µm)	Width (µm)
RRIC 52	20.45 ± 0.35	547.33 ± 13.16	50.29 ± 1.35
RRII 105	21.58 ± 0.97	580.40 ± 19.59	45.45 ± 1.38
PR 261	26.18 ± 1.03	559.77 ± 18.68	38.07 ± 1.72

Table Bot. 14. **Height of green-budded plants**

Treatment	Height (cm)
30 cm long snag + nicking of snag buds	70.45
20 cm long snag + nicking of snag buds	89.98
10 cm long snag + nicking of snag buds	91.96
30 cm long snag + no nicking	77.65
20 cm long snag + no nicking	84.37
10 cm long snag + no nicking	88.87

A new experiment to study the feasibility of young buddings on less than two-month-old seedlings in polybags was initiated. Observations after six months of growth indicated better growth characters in young-budded plants than the conventional green-budded plants.

15. Genetic basis of stock-scion interaction

In the trial to study the performance of certain modern clones on different root systems, RRII 203 scion recorded more girth than other scions on all the three types of stocks (61.2 cm). Clone RRII 105 ranked second with a girth of 49.15 cm. RRIM 600 having a mean girth of 45.10 cm was found to be the least vigorous among the three clones.

16. Studies on early evaluation

In this trial, PB 260 continued to be the vigorous clone with girth of 49.31 cm followed by PB 235 (48.42 cm) during the fifth year after planting.

GERMPLASM DIVISION

The Division concentrates primarily on introduction, collection and conservation of *Hevea* germplasm.

1. Introduction, collection and conservation of germplasm

1.1 Wickham collection from secondary centres

A total of 125 Wickham clones are being maintained at the Central Experiment Station, Chethackal, in five germplasm gardens. Monthly yield and annual girth were recorded from Garden II and III. Among the 16 Wickham clones in Garden III, RRII 118 showed the highest girth (113.83 cm) followed by RRII 203 (119.6 cm). In Garden IV, after seven years of growth, IRCA 111 and IRCA 130 were found superior to RRII 105, while the others were on par (Table Ger. 1). Among the 20 Wickham clones in Garden V, RRIC 100 had the highest girth of 32.35 cm and PR 255 the lowest (14.25 cm), while the control clone (RRII 105) recorded a girth of 22.31 cm.

Table Ger.1. **Mean girth of Garden IV clones in the seventh year**

Clone	Girth (cm)
IRCA 18	39.04
IRCA 109	41.63
IRCA 111	46.36
IRCA 130	45.59
IRCA 230	40.10
RRII 105	37.58
CD (P=0.05)	6.59

1.2 Wild Brazilian germplasm from the 1981 IRRDB collection

This collection is being maintained in seven source bush nurseries. Test tapping of one tree per accession in 1984 and 1985 nurseries has indicated that four accessions were relatively high yielding. An evaluation study in the 1989 nursery revealed a wide range of variability for plant height, crotch height, single leaflet area, girth, bark thickness, number of laticifer rows and test

Table Ger. 2. **Variation in morphological characters and yield in wild *Hevea* germplasm**

Character	Wild genotypes			Control (RRII 105)
	Minimum	Maximum	G. mean	
Plant height (m)	3.50 (RO 2890)	7.60 (AC 3013)	5.85	5.86
Crotch height (m)	0.72 (RO 2629)	6.50 (MT 2529)	2.07	0.86
Leaf area (cm^2)	46.37 (RO 2729)	152.48 (AC 2686)	88.22	65.51
Girth (cm)	14.34 (RO 2906)	27.70 (MT 2217)	19.26	21.54
Bark thickness (mm)	2.06 (RO 3032)	4.80 (RO 2629)	3.25	4.10
Laticifer rows	3.20 (RO 3032)	7.60 (MT 2217)	4.55	6.00
Test tap yield (g/tree/tap)	0.05 (RO 2856)	1.57 (RO 2629)	0.17	1.70

tap yield (Table Ger. 2). The yield of RO 2629 (1.57 g/tree/tap) was comparable with that of the control clone RRII 105 (1.7 g/tree/tap). MT 2217 had a higher number of latex vessel rows (7.6) compared to the control (6.0). In a study on plants in the 1991 nursery, maximum girth was recorded by RO 3623 (59 cm) while the control had a girth of 43.25 cm. Maximum test tap yield among the accessions was recorded by RO 3624 (11.3 g), which was 50 per cent less than the control (22.32 g). The range for bark thickness and number of latex vessel rows in the accessions was 2.0 – 5.5 and 2.8 – 11.0 mm respectively, while the corresponding values for the control were 5.0 and 8.6. Visual scoring for *Oidium* resistance was carried out in all the nurseries. Budwood was collected from these nurseries for raising planting materials for the Ortet Trial to be planted in 1999, and the small-scale evaluation trial at Nagrakatta.

2. Evaluation of germplasm

2.1 Preliminary Evaluation Trials (PET) of the 1981 IRRDB collection

In the PET being conducted at CES, Chethackal, 445 wild genotypes are under evaluation. Yield data from the 1990 PET with 182 wild genotypes, accessions MT 196 (16.12 g), AC 163 (14.91 g) and AC 716 (14.76 g) indicated to be higher yielding than the control clone RRII 105, with an increase of over 80 per cent. In general, Mato Grosso (MT) accessions had better average yield (Table Ger. 3). Twenty three genotypes had a higher bark thickness than the control RRII 105 (3.2 mm) with the accession MT 42 recording a bark thickness of 4.4 mm. Fifty genotypes had more than 100 per cent girth increment than the control.

Data from 1992 PET with 143 wild genotypes revealed significant genetic variation for various characters. Minimum

Table Ger. 3. **Growth and yield performance of wild genotypes**

Character	Genotype provenances									Control RRII 105
	Acre			Mato Grosso			Rondonia			
	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	
Girth (cm)	28.30 (AC 652)	51.00 (AC 633)	37.84	24.40 (MT 913)	50.80 (MT 904)	38.72	28.00 (RO 25)	48.70 (RO 22)	37.54	46.20
Yield (g/tree/tap) (Over 2 seasons)	0 (12 genotypes)	14.91 (AC 163)	1.07	0 (2 genotypes)	16.12 (MT 196)	1.71	0 (5 genotypes)	8.84 (RO 92)	0.86	26.32

Table Ger. 4. **Growth parameters of 80 wild genotypes**

Character	Range		G. mean	Control
	Minimum	Maximum		
Girth of the plant (cm)	4.72 (MT 929)	10.41 (RO 322)	7.38	5.96
Height of the plants (cm)	100.89 (MT 929)	322.99 (RO 395)	191.98	145.70
Number of leaf whorls/plant	4.90 (MT 906)	9.12 (RO 894)	6.73	6.78
Total number of leaves/plant	41.20 (MT 929)	119.80 (RO 322)	69.79	62.80
Inter-whorl distance (cm)	13.86 (RO 399)	28.46 (MT 901)	16.69	12.74
Length of the petiole (cm)	13.03 (MT 1064)	32.47 (RO 886)	21.60	14.60
Leaf area index	0.08 (MT 929)	0.46 (RO 322)	0.19	0.13

girth recorded was for MT 1029 (16.28 cm) and the maximum for MT 1025 (43.53 cm) while the control clone had a girth of 31.74 cm. Several genotypes were found to be very vigorous in growth.

In another study conducted on immature plants, genotype RO 322 was found to be the most vigorous clone with good girth, number of leaves per plant and leaf area index followed by RO 894 (Table Ger. 4).

In a study on test tap yield in young plants, MT 1057 recorded a higher yield of 4.27 g compared to 2.35 g/tree/tap for the control clone (Table Ger. 5).

Comparative evaluation of wild genotypes from three provenances indicated better growth in Rondonian genotypes (Table Ger. 6) while no specific pattern was noticed for leaf structural characters (Table Ger. 7).

In three experiments started in 1994, test tapping revealed high variability for yield, though none of the accessions was comparable with the control. Yield ranged from 0.08 g (AC 666) to 2.52 g (MT 1012) while that of the control was 6.3 g/tree/tap.

Analysis of girth data in a set of nine ortet clones in the fifth year of planting showed significant clonal variation. Five clones were

Table Ger. 5. **Bark structural characteristics and test tap yield of 80 wild genotypes**

Character	Range		G. mean	Control
	Minimum	Maximum		
Bark thickness (mm)	2.00 (RO 886)	4.00 (RO 395)	2.86	3.06
Soft bark thickness (mm)	0.87 (AC 986)	1.75 (RO 311)	1.19	1.16
Hard bark thickness (mm)	0.84 (AC 654)	2.53 (RO 395)	1.67	1.90
Number of LVR in soft bark	1.74 (AC 947)	8.01 (RO 399)	3.65	5.75
Number of LVR in hard bark	1.00 (AC 959)	5.01 (AC 733)	2.16	2.25
Total number of LVR	2.99 (MT 1021)	11.01 (RO 399)	3.65	8.00
LVR in soft bark (mm)	0.12 (AC 644)	0.75 (AC 647)	0.32	0.20
Frequency of phloic rays	2.50 (MT 935)	7.75 (AC 629)	3.78	4.00
Height of phloic rays (mm)	0.18 (MT 1024)	0.41 (AC 644)	0.30	0.21
Width of phloic rays (mm)	0.03 (RO 287)	0.08 (MT 947)	0.05	0.05
Height/width ratio	3.48 (MT 1008)	11.35 (RO 254)	5.86	4.12
Density of LV per row/mm circumference	11.50 (RO 299)	25.00 (RO 894)	17.15	23.76
Diameter of LV (mm)	13.44 (MT 906)	34.00 (MT 899)	21.46	16.3
Total CSA of LV(mm^2)	1.33 (MT 929)	17.77 (AC 1043)	6.96	7.14
Test tap yield (g/tree/tap)	0.05 (RO 257)	4.27 (MT 1057)	0.53	2.35

LVR – Latex vessel rows; CSA – Cross-sectional area

Table Ger. 6. **Growth performance of wild genotypes from three provenances**

Character	Provenances			Control
	Acre	Rondonia	Mato Grosso	
Girth of the plant (cm)	7.25	8.08	6.86	6.06
Height of the plants (cm)	173.93	220.78	181.98	145.69
Number of leaf whorls/plant	6.25	7.48	6.43	6.78
Total number of leaves/plant	64.96	81.01	63.53	62.83
Inter-whorl distance (cm)	18.85	20.28	20.13	12.74
Length of the petiole (cm)	22.98	23.33	18.94	14.59
Leaf area index	0.17	0.23	0.16	0.13

Table Ger. 7. **Leaf structural characteristics of wild genotypes from three provenances**

Character	Provenances			Control
	Acre	Rondonia	Mato Grosso	
Number of stomata/mm^2	439.50	424.76	434.38	525.30
Number of epidermal cells/mm^2	1617.82	1697.09	1790.23	2237.76
Single leaf area (cm^2)	100.65	105.50	81.73	60.83
Stomatal index	21.70	20.47	19.87	19.26
Thickness of lamina (mm)	0.14	0.14	0.14	0.15
Thickness of leaf midrib (mm)	0.84	0.74	0.79	0.70
Thickness of palisade layer (µm)	58.89	59.79	62.49	70.87
Thickness of spongy layer (µm)	64.85	60.13	62.49	70.87
Number of cells/unit distance of palisade layer	117.52	117.97	115.68	117.24
Number of cells/unit distance of spongy layer	278.36	273.95	271.50	232.24
Thickness of cuticle (µm)	2.62	2.43	2.63	3.67

found to be on par with the control.

2.2 Large-scale evaluation trial of 1981 IRRDB collection

Eighty wild genotypes are in the fourth year of evaluation at RRS, Padiyoor. Out of the 80 genotypes evaluated, forty one genotypes recorded higher girth than the control. Average girth ranged from 10.79 (AC 685) to 20.77 cm (MT 1674) in comparison to 16.44 cm for the control. Bark samples were collected for detailed anatomical investigations. Test tapping was done and the data are being analysed.

3. Multidisciplinary/general studies

3.1 Maintenance of National Accession Register, herbarium and clone museum

Computerization of the basic data in the National Accession Register had been completed. Computerization of the descriptor and database is also underway. During the flowering season of the reporting year, 96 herbarium specimens of 32 accessions were prepared.

3.2 Screening for *Oidium* resistance

Screening of wild genotypes for resistance to *Oidium* in all field trials was carried out.

3.3 Multivariate analysis

Morphological, physiological and biochemical parameters were recorded in the second year of the experiment from the mature trees of 25 clones. These parameters were also recorded from plants of some clones, being raised in polybags. Test tapping was also carried out in the polybag plants. Data are being analysed. Significant clonal differences were observed for girth and yield among the mature trees.

3.4 Screening for drought tolerance

A second set of accessions comprising 10 wild accessions and three standard clones were multiplied and raised in polybags for

a detailed investigation on drought tolerance under controlled conditions.

3.5 Genome analysis of the wild germplasm

For the establishment of genetic relationship among the wild *Hevea* germplasm through RAPD studies, DNA extraction from leaf samples of 45 selected genotypes has been completed in collaboration with Genome Analysis Laboratory. About 80 random primers have been screened so far, out of which 20 primers were found to be informative. Twelve of these primers have already been used for RAPD studies and the database prepared.

MYCOLOGY AND PLANT PATHOLOGY DIVISION

The Division continued to focus its research activities mainly on pest and disease management through the mycology, plant pathology and entomology units. Germplasm materials are being screened for disease tolerance. The microbiology unit involves in improving soil fertility using microbes and also in abating pollution from processing centres by biological methods.

1. Abnormal leaf fall disease

The incidence of abnormal leaf fall was severe in all the traditional rubber growing areas. The unprotected susceptible clones incurred heavy loss of canopy and subsequent yield loss.

The testing of new fungicide formulations for control of abnormal leaf fall disease was continued. The metalaxyl (Ridomil)-copper oxychloride (COC) combination although found effective in the previous year, could not be repeated for confirmation due to non-availability of the formulated product.

Two powder formulations and one liquid formulation of mancozeb were field-tested in a mature area planted with clone GT 1 at Malankara Estate. The powder formulation of mancozeb (75%) at 3 and 5 kg/ha was found to be superior to other formulations. However, COC-sprayed plot had a slightly higher leaf retention compared to mancozeb-sprayed plots (Table Path. 1).

Table Path. 1. **Effect of mancozeb formulations on control of abnormal leaf fall disease**

Treatment	Formulation	Dose	Leaf retention (%)
COC 15% + mancozeb 50%	Powder	3 kg/ha	26.46
COC 15% + mancozeb 50%	Powder	5 kg/ha	37.92
COC 10% + mancozeb 30%	Liquid	4 L/ha	24.01
COC 10% + mancozeb 30%	Liquid	6 L/ha	46.66
Mancozeb 75%	Powder	3 kg/ha	53.25
Mancozeb 75%	Powder	5 kg/ha	64.90
Copper oxychloride 56%	Powder	6 kg/ha	66.41
CD (P=0.05)			24.68

In another experiment, rubber seed oil was tested as an additive to replace spray oil for spraying copper oxychloride. Of the different proportions tried, spray oil and rubber seed oil at 2 : 1 was found to be useful. Higher level of rubber seed oil increases the viscosity of the spray fluid thereby clogging the nozzle of the sprayer. There was no apparent difference in the leaf retention in the areas sprayed with copper oxychloride using spray oil and spray oil-rubber seed oil combination.

Micronair atomizer assembly imported from M/s. Micronair, USA was field-tested by fixing it on micron sprayer. The discharge of the spray fluid to a greater height could be achieved with the new atomizer assembly. The spray fluid could be discharged to a height of approximately 30 m as against

22 m with micron atomizer. However, there was no apparent difference in the leaf retention in plots sprayed using sprayer fitted with either of the atomizer assembly.

In the experiment to evaluate crop loss due to abnormal leaf fall disease, the percentage leaf retention in unsprayed plots of RRIM 600, RRII 105, GT 1 and RRII 118 were 7.96, 39.14, 20.67 and 18.85 compared to 55.62, 72.44, 53.46 and 59.11 in sprayed plots. There was no change in the crop loss pattern with RRII 105 recording the least crop loss. The mean leaf retention in the clone RRII 105 sprayed with different dosages of COC was 23.06, 34.42, 38.48 and 51.14 per cent respectively in plots sprayed with 2, 4, 6 and 8 kg COC/ha.

2. High volume spraying

A field experiment was initiated at Pudukkad Estate in clone RRIM 600 to test the efficacy of various concentrations of Bordeaux mixture when mixed with rubber seed oil in controlling abnormal leaf fall disease. Rubber seed oil (1% concentration) was added to 1 and 0.5 per cent Bordeaux mixture and these were compared with recommended dosage of 1 per cent Bordeaux mixture. The maximum leaf retention was recorded where 1 per cent rubber seed oil was added to 1 per cent Bordeaux mixture (Table Path. 2).

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

Treatment	% leaf retention
1% Bordeaux mixture + 1% rubber seed oil	57.0
0.5% Bordeaux mixture + 1% rubber seed oil	49.0
1% Bordeaux mixture	51.0

3. Control of shoot rot disease

Two field experiments were conducted at Manickal Estate, Mundakayam for the control of shoot rot disease.

3.1 Use of rubber seed oil with fungicides

Rubber seed oil (1%) added to one and 0.5 per cent Bordeaux mixture was compared with conventional recommendations in checking shoot rot disease. The treatments included 1 per cent Bordeaux mixture + 1 per cent rubber seed oil, 0.5 per cent Bordeaux mixture + 1 per cent rubber seed oil, 1 per cent Bordeaux mixture alone, 0.5 per cent benomyl (Benlate) and unsprayed control. Fynol 40 was used as the emulsifier. The results indicated that the treatments with rubber seed oil are on par or better than 1 per cent Boardeaux mixture, which is used conventionally for controlling the disease. The systemic fungicide, benomyl (0.5%), was inferior to others.

Leaf samples were analysed for copper content and the copper content in various treatments was estimated.

3.2 Use of stickers in disease control

This experiment was aimed to compare the efficacy of adding sticker to one per cent Bordeaux mixture in controlling shoot rot disease. Vinofan was used as the sticker. Copper content on leaves was estimated at periodic intervals after spraying. The disease control in both the treatments was at par.

4. Powdery mildew disease

Powdery mildew disease control experiment was undertaken at Cheruvally Estate on susceptible clone PB 5/51. The treatments included hexaconazole (Contaf), hexaconazole + sulphur and sulphur dust. Maximum disease control was observed in plots where mixing of hexaconazole and sulphur was undertaken (Table Path. 3).

Table Path. 3. **Powdery mildew disease control**

Treatment	Dose (kg/ha)	Incidence of disease (%)
Hexaconazole	7	10.4
Hexaconazole + sulphur	3.5 + 6	8.7
Sulphur	12	16.0

5. Pink disease management

Field trials were undertaken at Manickal Estate for comparing the efficacy of few systemic fungicides in different carriers in controlling pink disease. The systemic fungicides, hexaconazole (Contaf) and thiophosphate (Kitazin) were compared with thiram (Thiride) and Bordeaux paste. The carriers used were rubberkote, Indtron and Vinofan. The results indicated that both Indtron and Vinofan were as good as rubberkote in controlling the disease.

Another experiment was carried out to assess the efficacy of spraying of fungicides on the disease affected regions. Hexaconazole, thiophosphate and thiram were sprayed to the loci of infection. The results revealed that spraying is much inferior to conventional pasting of fungicides.

6. Panel disease and their control

The experiment to evaluate addition of China clay to panel protectant fungicides to make applied panels distinguishable was continued for the second season. Mancozeb (Indofil M45) and phosphorous acid (Akomin) were evaluated with and without China clay. There was no negative effect of the additive on disease control during the second year also. Mancozeb with China clay 100 g/ha continued to be the most effective treatment. The applied panels could be distinguished by the white colour.

7. Patch canker

The field experiment was conducted to evaluate the fungicides for patch canker disease control. Among the fungicides incorporated in rubberkote, mancozeb (Indofil M 45, 10 g/kg) followed by metalaxyl (Ridomil MZ, 5g/kg) and thiophosphate (Kitazin 4 ml/kg) were found to be effective. Among the other fungicides tried, phosphorous acid (Akomin 5 ml/kg) and benomyl (Benlate 4 g/kg) were also superior to Bordeaux paste application. Thorough cleaning of wound is essential for good control.

8. Physiology of disease resistance

Reactions of some *Hevea* clones to *Corynespora* leaf disease which were known to be tolerant/susceptible to abnormal leaf fall and powdery mildew disease were studied. Detached leaves from 12 clones at light green stage were inoculated with spore suspensions of 16 different *Corynespora* isolates collected from Kerala and Karnataka. The lesion size, veinal necrosis and development of mycelium on both surfaces of leaves were considered for the level of resistance/susceptibility of these clones. Among the 12 clones, GT 1 showed resistant/tolerant reaction while clones RRII 105, RRII 208, BD 10 and RRIM 701 showed susceptible reaction to almost all the isolates tested.

9. Variation among isolates of *Corynespora*

Forty different isolates of *C. cassiicola* were collected during 1999 season from rubber growing areas of Karnataka and Kerala.

Studies on variability among different isolates of *C. cassiicola* are in progress. Sensitivity of 20 isolates collected during 1996-98 season to the fungicide benomyl was tested using poisoned-food technique. Pathogenecity tests of these 20 isolates in four different clones viz. RRII 105, GT 1, RRIM 600 and PB 86 are initiated. Preliminary results showed variation among the isolates in the degree of virulence, which indicates the presence of different strains of pathogen in the field. Studies on genetic variability showed presence of different strains among Kerala and Karnataka isolates.

10. Root diseases and their control

The brown root disease control trial carried out at Manickal Estate was completed. The results showed that the fungicides tridemorph (Calixin 80 EC) 0.05 and 1.0%, propiconazole (Tilt 25 EC) 0.1% and thiram

(Thiride 75 WP) 0.75% were on par with the methoxyethyl mercury chloride (0.15%) with regard to the effectiveness in disease control. MEMC, being banned, could be replaced by these fungicides.

Observations on nursery trial on purple root disease were continued. In the trial on *Poria* root disease, the disease status of infected and neighbouring plants is being observed.

11. *Corynespora* leaf disease and control

A detailed survey was conducted during the disease season to assess the damage in disease-prone areas in South Karnataka and North Kerala.

Experiment was conducted for the control of *Corynespora* leaf disease using dust formulation of systemic fungicides. The percentage reduction of disease was maximum with hexaconazole (Contaf) dust (Table Path. 4).

The efficacy of oil-based fungicides was also evaluated. Liquid formulation of mancozeb (30%) + COC (10%) gave the best protection for leaves from the disease (Table Path. 5).

Table Path 4. **Efficacy of dust formulations in *Corynespora* disease control**

Treatment	Dose	Disease incidence (%)		Disease reduction (%)
		Initial	Final	
Tridemorph (Calixin 1.5%)	7 kg/ha	52.0	27.3	47.50
Carbendazim (Bavistin 1.5%)	7 kg/ha	55.3	18.5	66.55
Hexaconazole (Contaf 2%)	7 kg/ha	57.8	11.5	80.10
Control		55.5	51.4	7.39

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

12.1 Screening of germplasm and other clones

Observations were made on powdery mildew and *Gloeosporium* diseases in the IRCA clones in the trial at CES, Chethackal. Evaluation of powdery mildew was also carried out in different clone evaluation trials and germplasm garden maintained at CES.

12.2 Multidisciplinary evaluation of clones

The susceptibility to *Phytophthora* leaf fall in the field was evaluated for the test clones in Trials 1 and 2 of Botany Division.

13. Crown budding for protection against abnormal leaf fall disease

The intensity of *Phytophthora* leaf fall and powdery mildew diseases was assessed in the experimental area at Malankara Estate. Powdery mildew incidence was mild in the three experimental blocks, whereas the abnormal leaf fall was less in crown-budded plants compared to control (Table Path. 6).

Table Path. 6. **Incidence of *Phytophthora* leaf fall in crown-budded plants**

Crown clone	Leaf retention (%)
Fx 516	75.00
RRII 33	70.00
PB 311	50.00
(Control)	

Table Path. 5. **Efficacy of oil-based fungicides in *Corynespora* disease control**

Treatment	Formulation	Dose	Disease incidence (%)		Disease reduction(%)
			Initial	Final	
Copper oxychloride (56%)	Powder	8 kg/ha	56.2	28.5	49.29
Mancozeb (30%) + COC (10%)	Liquid	6 L/ha	54.6	20.1	63.19
Mancozeb (75%)	Powder	5 kg/ha	51.6	23.0	55.34
Mancozeb (50%) + COC (15%)	Powder	5 kg/ha	57.3	34.3	40.14
Control			55.5	51.4	7.39

The yield data from the experimental blocks were recorded.

14. Improvement of rubber and cover crops through microbial inoculants

14.1 Investigations on non-symbiotic nitrogen fixing organisms

Diameter and height of rubber seedlings in pots inoculated with two isolates of *Azospirillum* at 50 per cent and 75 per cent recommended levels of nitrogenous fertilizer and control plants applied with full dose of nitrogen were recorded after seven months growth.

The height and diameter of rubber seedlings inoculated with *Azospirillum* isolates at lower levels of nitrogenous fertilizer were comparable with that of uninoculated plants applied with full dose of nitrogen (Table Path. 7).

Table Path. 7. Effect of *Azospirillum* inoculation on growth of seedlings

Treatment	Diameter (mm)	Height (mm)
Azospirillum isolate 1 + 50% N	8.20	130.2
Azospirillum isolate 1 + 75% N	9.00	135.4
Azospirillum isolate 2 + 50% N	8.20	140.6
Azospirillum isolate 2 + 75% N	9.00	142.2
Uninoculated control with 100% N	7.00	115.0
CD (P=0.05)	1.85	36.0

Rhizosphere soil samples were also collected from inoculated and uninoculated plants and the microbial population was estimated. Inoculated seedlings recorded higher counts of fungi, bacteria and *Azospirillum*.

Thin layer chromatographic (TLC) studies using different *Azotobacter* isolates had shown that these isolates are capable of producing indole acetic acid, gibberellin and cytokinin. They were also known to produce polysaccharides and siderophores.

Effect of different antibiotics (tetracycline, erythromycin and amoxyline, ampicilin), weedicides (glyphosate and diuron) and fungicides (Bavistin, Fytolan and Dithane M-45) at various concentrations on the survival, growth and nitrogenase activity of *Azotobacter* isolates was also studied. The isolates showed variation in tolerance at different concentrations of these chemicals.

Studies were also initiated to isolate nitrogen fixing *Beijerinckia* from different rubber growing areas.

14.2 Microbial activity in soils under cover crops

Soil samples were collected for analysing the microbial population and soil nitrogenase activity. Bacteria and actinomycetes counts were more in *Pueraria* plots while fungal count was more in *Mucuna* plots. *Azotobacter* population and nitrogenase activity were high in soil under *Mucuna* followed by *Pueraria*, weeds and plots without any weed or cover crop.

14.3 Improvement of phosphate uptake of rubber and cover crops through microorganisms

Soils under *Hevea* (collected from various rubber growing localities) were examined for mycorrhizal spore types and population. The spore population varied in different locations from 214 to 428 per 50 g soil (Table Path. 8). Majority of the VAM spores belonged to *Glomus* type. More than one type of *Glomus* were found in these locations.

Roots of rubber under various intercrops like pineapple, coleus, yam, sweet potato, *Pueraria*, fodder grass, coffee, pepper, arrow root, etc. were stained and per cent root infection by VAM was assessed. Mycorrhizal spore counts in this soil were also estimated. Results show that these intercrops have

Table Path. 8. **Mycorrhizal population in soil**

Location	Spore count	Per cent distribution				
		Glomus spp.	*Acaulospora* spp.	*Sclerocystis* spp.	*Gigaspora* spp.	Unidentified
Nagercoil	407	75	10	10	2	3
Thiruvananthapuram	374	72	13	8	1	6
Punalur	413	70	12	10	2	6
Kodumon	326	76	10	8	2	4
Chethackal	258	72	15	8	2	5
Kottayam	214	66	22	8	2	2
Mundakayam	369	79	12	7	1	1
Thodupuzha	344	68	20	8	2	2
Kalady	274	74	10	10	3	3
Puthukkad	314	70	14	12	1	3
Palakkad	428	82	10	4	2	2
Pullengode	230	76	10	11	1	2
Kinalur	318	79	11	7	1	2
Kalpetta	330	70	15	10	2	3
Iritty	296	77	12	6	3	2
Mangalore	262	74	13	7	2	4

some effect on VAM in rubber. The influence of these intercrops on rubber rhizosphere microorganisms like bacteria, fungi, actinomycetes and phosphobacteria was also studied.

15. Pollution studies

Biologically inert materials were used to increase the surface area for the microorganisms to act in the anaerobic digester. Addition of materials like broken stone, broken brick, plastic mesh and polyurethane foam has resulted 10.5 to 21.1 per cent increase in biogas production. Considerable reduction in the pollution parameters was also achieved due to the presence of these materials. Among the various materials, the reduction was more prominent with polyurethane foam. Polyurethane foam recorded BOD and COD removal efficiency of 88.0 and 85.5 per cent respectively. Total solids and suspended solids removal efficiency was also more with this treatment, while the gas production was also maximum. Field testing of this technology is being carried out.

16. Pests of rubber

16.1 Rainguard damaging crickets

Crickets, *Gryllacrys* sp. were found damaging the rainguard of the tapping rubber trees during March to November. Various insecticides as well as repellents have been tested against them. Application of used engine oil, cashew kernel oil and neem oil inside the polythene sheets was found reducing the damage (Table Path. 9.).

Table Path. 9. **Effect of insecticides/repellents on the crickets**

Treatment	Per cent attack of crickets on rainguard
Used engine oil	20.66
Cashew kernel oil	26.82
Neem oil	38.06
'Maroti oil'	42.21
Castor oil	42.63
Mineral turpentine	44.48
Phenyl	52.34
Kerosene	53.08
Control (untreated)	65.79

16.2 Termites

Termites, *Odontotermes obesus*, were found associated with rubber plants. The young plants and the external corky layer of the bark as well as the dried portion of the old trees are also found attacked by *O. obesus*. The efficacy of various doses of chlorpyriphos in controlling termite attack is being evaluated.

16.3 Nematodes

Studies on the inter-relationship of the population density and infestation of root-knot nematode, *Meloidogyne incognita* with seasons and soil temperature are in progress. Generally, the highest population density is recorded in the upper 10-20 cm soil depth and gradually the number declined in lower depths. There was significant differences in the nematode population among monthly samples collected from different soil depths. Moderate rainfall was found to be the most favourable condition for the plant parasitic nematodes. The incidence of root-knot infestation was also recorded from brown-budded eight-month-old rubber seedlings.

16.4 Slugs and snails

An *in vitro* study has been conducted to test the efficacy of different chemicals viz. lime, copper sulphate, Bordeaux mixture, metaldehyde, endosulfan, carbaryl and malathion in three formulations (spray, dust and bait) against slugs *Mariaella dussumieri* Grey attacking rubber seedlings. The percentage mortality of slugs at different time intervals, such as 24, 48, 72, 96, 120, 144 and 168 h was recorded. Maximum mortality (100%) was recorded within 24 h of treatment with the application of lime dust @ 5 g/pot, which was significantly superior to all the other treatments followed by that of lime spray 1% and metaldehyde 2.5% bait. The treatments with carbaryl 0.11 and malathion 0.05% spray were ineffective against the slugs (Table Path. 10).

Table Path. 10. **Effect of different chemicals on the per cent mortality of slugs**

Treatment	Per cent mortality at periodic intervals						
	24 h	48 h	72 h	96 h	120 h	144 h	168 h
Lime 1% spray	53.00 (46.92)	56.67 (48.84)	73.33 (59.00)	93.33 (81.44)	100.00 (90.00)	0.00 (1.28)	0.00 (1.28)
Lime dust	100.00 (90.00)	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)
Metaldehyde bait	33.33 (35.22)	53.33 (46.92)	73.33 (59.00)	86.67 (72.29)	100.00 (90.00)	0.00 (1.28)	0.00 (1.28)
Copper sulphate spray	30.00 (33.00)	43.33 (41.07)	53.33 (46.92)	76.67 (61.21)	80.00 (63.93)	90.00 (68.86)	93.33 (81.14)
Bordeaux mixture 1% spray	26.67 (31.00)	36.67 (36.93)	46.67 (43.00)	76.67 (61.21)	83.33 (66.14)	90.00 (71.57)	93.33 (77.71)
Endosulfan 0.05% spray	20.00 (26.07)	26.67 (30.29)	40.00 (39.15)	46.67 (43.07)	53.33 (46.92)	56.67 (48.84)	60.00 (50.85)
Carbaryl 1% spray	3.33 (7.00)	10.00 (18.43)	16.67 (23.86)	36.67 (37.22)	46.67 (43.08)	53.33 (46.92)	56.67 (48.84)
Malathion 0.05% spray	6.67 (12.72)	13.33 (21.14)	16.67 (23.86)	16.67 (23.86)	20.00 (26.57)	23.33 (28.78)	30.00 (33.00)
Control	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)
CD (P=0.05)	12.53	9.60	7.92	14.08	5.94	4.45	11.77

Figures in parentheses are transformed values

16.5 Scale insect and mealy bug

Application of chlorpyriphos 0.1% was found effective in controlling scale insect, *Saissetia nigra* and mealy bugs, *Ferrisiana virgata*, attack on rubber seedlings.

16.6 Borer beetles

There are several beetles enter in the woody tissue mostly as secondary invaders. The borers invade in partially dried rubber tissues due to disease, lightning and brown bast. Experiment was undertaken to manage the borer attack in rubber plantations using different insecticide formulations. Treatment with insecticides on the borer beetle-affected portion with lindane 0.32%, carbaryl 0.5% and chlorpyriphos 0.4% was found fairly effective for the control of the beetles (Table Path. 11).

Table Path. 11. **Control of borer beetles**

Treatment	Concentration (% a.i.)	Per cent control
Carbaryl 50 WP	0.50	51.24
Lindane 6.5 WP	0.32	55.43
Fanvalerate 6.5 WP	0.32	25.65
Malathion 50 EC	0.50	42.76
Chlorpyriphos 20 EC	0.40	48.26
Dichlorvos 80 EC	0.40	45.25
Monocrotophos 40 EC	0.40	38.56
Phosphomidon 100 EC	0.50	39.76
Quinalphos 25 EC	0.50	44.45
Control (untreated)	1.15	

16.7 Mooply beetles

Mooply beetle (*Lyprops corticollis*) is causing serious menace in the houses located near rubber growing areas. The beetles swarm into the buildings at dusk and aggregate on roof and walls. It produces bad odour and causes skin blisters when touched. The biology of mooply beetles was studied. The beetles remain quiescent during the monsoon. By December and January, they fly back to the rubber plantation and feed on the fallen semi-dried green leaves. They lay eggs, hatch and grow to adult in two months time. For control of the mooply beetle sheltered on the houses, the insecticides viz. fenvalarate 0.05%, chlorpyriphos 0.2% and carbaryl 0.2% were found effective.

16.8 Mites

Mite incidence was observed on *Mucuna bracteata* grown at HBSS Nettana, Karnataka during February to April. The mite was identified as *Brevipalpus obovatus* Dannadieu, Tenuipalpidae, Acari. The mites were cultured in the laboratory for biological studies.

17. Bee-keeping in rubber plantations

The attack of bee-hunting bird, *Merops orientalis* on *Apis mellifera* colonies was observed to be more. TSBV disease intensity in *Apis cerana indica* colonies was comparatively low during 1998-99 season. Further steps on multiplication of disease-free colonies and comparative studies on the performance of Indian honey bees in six and eight-frame hives are in progress.

18. Vermiculture

Mass culturing of *Eudrillus eugeniae* has been standardized. The nitrogen, phosphorus and potassium levels in vermicompost have been worked out. Microbial population of fungi, bacteria, phosphobacteria *Azotobacter* and actinomycetes was determined. Rubber wood sawdust was found as a good additive in the semi-decomposed agricultural wastes feed for the worms. Cellulolytic fungi were isolated from the vermicompost.

19. Etiology of tapping panel dryness

Chemical treatments for symptom remission in TPD-affected trees were conducted in two estates on PB 235 and RRII 105.

The treatments including tetracycline (10000 ppm), penicillin G (500 ppm), carbendazim (Bavistin 10000 ppm) and Flagyl (500 ppm) were imposed using specially designed pressure injection devices. Each tree was injected twice in a month. The chemicals selected were for testing their effects against specific pathogenic forms viz. tetracycline for phytoplasma, penicillin for bacteria/RLO, Flagyl against protozoa and carbendazim against fungi.

The results of chemical treatment were similar between locations and different stages of TPD. At Vaniampara Estate in clone RRII 105, the treatments with tetracycline indicated recovery in three of the four plants in seventh and fourth year of tapping. At Malankara Estate (clone PB 235) also similar recovery was obtained at fifth and third year of tapping. At both the locations, there was an increase in disease percentage in plants treated with penicillin.

PLANT PHYSIOLOGY DIVISION

The Division has been working on both basic and applied research in the different priority areas such as environmental physiology, physiology of growth and yield, root stock-scion interactions, tapping panel dryness and ecological aspects of natural rubber cultivation.

1. Ecophysiology of *Hevea*

1.1 Evaluation for drought tolerance

A field study was conducted in RRII, Kottayam using five *Hevea* clones viz. RRII 105, SCATC 88-13, PB 260, RRIM 600 and Haiken 1. Treatments were imposed on one-year-old polybag plants kept in two separate blocks in February. Fifteen plants each were watered on alternate days and the other 15 per clone were not irrigated and allowed to attain water deficit in soil. Meteorological data and moisture content in soil revealed that soil drought and high atmospheric temperature prevailed during the period of study in the months of February and March (Tables Phys. 1 and 2).

Table Phys. 2. **Per cent moisture content in irrigated and water-stressed polybag soils**

Month	Soil depth (cm)	Moisture (%)	
		Irrigated soil	Unirrigated soil
February	00 – 15	19.06	10.71
	15 – 30	21.43	12.68
March	00 – 15	18.71	08.55
	15 – 30	20.54	10.91

Table Phys. 1. **Weather parameters of RRII, Kottayam**

Month (1998)	Temperature (°C)		Relative humidity (%)	Rainfall (mm)
	Maximum	Minimum		
January	33.3	22.4	85	33.6
February	34.5	23.8	88	-
March	36.1	24.3	89	38.4
April	35.8	25.3	90	115.3
May	34.2	25.6	91	150.9

Table Phys. 3. **Leaf characteristics in irrigated (C) and water-stressed (S) polybag-grown plants**

Clone		Leaf number	Leaf area (cm^2)	Wax (mg/cm^2)	Chlorophyll (mg/g fresh weight)	Chlorophyll a/b	CMS % injury
SCATC 88-13	C	39.8 ± 8.1	90.1 ± 3.2	39.9 ± 1.9	3.23 ± 0.07	3.76	60.5 ± 0.8
	S	29.3 ± 4.9	53.1 ± 2.8	77.2 ± 6.7	2.40 ± 0.05	3.43	44.2 ± 2.1
Haiken 1	C	45.1 ± 7.2	86.2 ± 7.4	34.2 ± 1.9	2.73 ± 0.06	3.79	37.0 ± 1.6
	S	22.2 ± 2.5	67.4 ± 5.7	84.5 ± 3.3	1.94 ± 0.06	3.52	23.7 ± 1.3
RRII 105	C	44.9 ± 7.4	97.6 ± 7.9	50.4 ± 5.4	3.63 ± 0.10	3.51	48.8 ± 0.5
	S	25.7 ± 3.0	53.1 ± 4.5	78.7 ± 5.5	2.57 ± 0.09	3.34	33.2 ± 0.9
PB 260	C	54.2 ± 5.6	107 ± 4.6	50.9 ± 2.8	2.97 ± 0.11	3.74	42.0 ± 1.3
	S	19.1 ± 3.8	59.6 ± 2.1	88.3 ± 3.5	2.05 ± 0.23	3.38	36.6 ± 1.8
RRIM 600	C	32.7 ± 2.4	69.5 ± 4.6	55.3 ± 3.4	3.27 ± 0.14	3.69	38.2 ± 2.7
	S	26.5 ± 3.8	55.9 ± 3.3	95.1 ± 3.3	2.76 ± 0.07	3.50	31.2 ± 2.2

Significant variations in leaf area, wax content and chlorophylls were observed in irrigated and water-stressed plants. At peak stress period (March), the number of green leaves per stand was low in RRII 105 and PB 260. Under stress conditions, 18 per cent reduction in leaf area was observed in clone RRIM 600 and it was maximum in clone PB 260 (64%). However, in normal irrigated conditions, clone PB 260 maintained higher leaf area per plant. Additional deposition of wax among stressed-plants was minimum in clone RRII 105 (28 mg/cm^2) and maximum in Haiken 1 (50 mg/cm^2). Total chlorophylls, chlorophyll a, b and a/b ratio decreased in water deficit plants. The per cent cell membrane injury (CMS) was higher in leaves of clone SCATC 88-13 followed by RRII 105. In plants experiencing water deficit stress, the injury was comparatively low in clone RRIM 600 and Haiken 1, indicating the presence of more stable membranes and their tolerance to drought (Table Phys. 3).

The physiological functioning of plants was monitored by measuring the leaf water potential Ψl and photosynthetic rates in February as well as in peak stress period of March (Tables Phys. 4 and 5). The irrigated plants maintained high leaf water status and it drastically declined in water deficit plants at the peak time of photosynthesis. In irrigated soils, the leaves of clone RRII 105 exhibited high water potentials and under stress conditions, the clones RRII 105 and

Table Phys. 4. **Physiological characteristics in irrigated (C) and water-stressed (S) polybag plants (February)**

		Ψl (-bar)	Mid-day Ψl (-bar)	A ($\mu mol/m^2/s$)	gs ($mol/m^2/s$)	E ($mmol/m^2/s$)
SCATC 88-13	C	10.1 ± 0.7	20.9 ± 0.9	11.72 ± 0.4	1.13 ± 0.09	34.04 ± 1.10
	S	18.9 ± 0.8	25.2 ± 1.0	5.11 ± 0.7	0.54 ± 0.04	25.35 ± 0.7
Haiken 1	C	12.3 ± 1.2	22.0 ± 0.8	3.93 ± 0.4	0.38 ± 0.03	23.96 ± 0.2
	S	17.4 ± 0.7	25.6 ± 1.1	1.71 ± 0.2	0.30 ± 0.01	20.38 ± 0.3
RRII 105	C	9.7 ± 0.6	21.9 ± 0.9	9.39 ± 0.6	0.91 ± 0.61	34.11 ± 0.9
	S	21.4 ± 0.6	28.4 ± 1.1	0.67 ± 0.1	0.26 ± 0.01	19.35 ± 0.3
PB 260	C	15.3 ± 1.0	23.4 ± 0.8	4.99 ± 0.2	0.42 ± 0.02	26.22 ± 0.2
	S	21.4 ± 0.6	29.7 ± 0.9	0.29 ± 0.2	0.27 ± 0.01	16.05 ± 0.2
RRIM 600	C	10.9 ± 0.5	21.8 ± 0.6	10.40 ± 0.5	0.86 ± 0.01	34.45 ± 0.2
	S	17.3 ± 0.6	24.9 ± 1.1	3.37 ± 0.2	0.33 ± 0.01	21.09 ± 0.4

Table Phys. 5. **Physiological characteristics in irrigated (C) and water-stressed (S) polybag plants (March)**

		Ψl (-bar)	Mid-day Ψl (-bar)	A (μmol/m²/s)	gs (mol/m²/s)	E (mmol/m²/s)
SCATC 88-13	C	11.8 ± 0.8	26.2 ± 0.5	9.86 ± 0.37	0.64 ± 0.04	26.94 ± 0.59
	S	22.8 ± 0.4	29.2 ± 0.5	0.61 ± 0.08	0.18 ± 0.01	17.30 ± 0.15
Haiken 1	C	14.3 ± 1.3	26.9 ± 1.1	3.40 ± 0.28	0.26 ± 0.01	19.88 ± 0.25
	S	21.7 ± 1.1	29.6 ± 1.1	0.71 ± 0.15	0.20 ± 0.01	18.75 ± 0.43
RRII 105	C	13.7 ± 0.8	28.1 ± 0.9	9.78 ± 0.55	0.71 ± 0.96	26.85 ± 0.96
	S	23.6 ± 0.8	33.4 ± 0.9	0.78 ± 0.10	0.17 ± 0.01	17.65 ± 0.21
PB 260	C	14.3 ± 1.3	28.9 ± 0.9	4.73 ± 0.26	0.25 ± 0.01	21.22 ± 0.27
	S	24.9 ± 0.9	32.0 ± 0.9	0.01 ± 0.01	0.01 ± .001	18.69 ± 0.19
RRIM 600	C	13.2 ± 1.5	25.9 ± 1.5	6.64 ± 0.15	0.36 ± 0.01	26.11 ± 0.27
	S	19.9 ± 0.9	27.9 ± 1.1	1.03 ± 0.07	0.20 ± .006	18.63 ± 0.28

PB 260 showed low leaf water status as indicated by more negative water potential values. Similarly, the mid-day values were found in water deficit plants of PB 260 and RRII 105. At peak stress period (March), the mid-day values were as low as -32 to -33 bars in clones PB 260 and RRII 105 indicating the acute water scarcity in leaves.

Clonal variations in net assimilation rate was evident in the amount of CO_2 fixed by various clones. The irrigated plants of SCATC 88-13 exhibited high photosynthetic rate and Haiken 1 the lowest (Table Phys. 4). The clones SCATC 88-13, RRIM 600 and Haiken 1 had comparatively stable net assimilation rates and highly inhibited in clones RRII 105 and PB 260. During severe stress periods, the net carbon assimilation (A) was almost nil or ceased to a minimum rate (Table Phys. 5). The stomatal conductance (gs) decreased by half and all drought-imposed plants exhibited low transpiration (E) rates.

The biochemical estimations of total sugars and starch contents in leaves of irrigated and water-stressed plants are shown in Table Phys. 6. Sugar content decreased in leaves as a result of water stress in plants. The variation was found less in clone RRIM 600 and it revealed that the carbohydrate synthesis was less affected in these plants. Contrastingly, the starch content in leaves increased due to imposition of water deficit stress. Maximum accumulation of starch in drought conditions was noticed in clones RRIM 600 and Haiken 1 probably playing a role in osmotic adjustment of drought-affected leaves.

The reduction in loss of leaves, leaf area, the increase in stability of cell membranes, accumulation of more cuticular waxes, min-

Table Phys. 6. **Total sugar and starch contents in leaves of irrigated and water-stressed polybag plants**

Clone	Sugar mg/g fresh weight		Starch mg/g fresh weight	
	Irrigated plants	Unirrigated plants	Irrigated plants	Unirrigated plants
SCATC 88-13	54.95 ± 2.10	45.16 ± 3.50	78.94 ± 3.90	93.30 ± 4.50
Haiken 1	60.02 ± 3.25	52.06 ± 2.37	74.15 ± 6.55	110.28 ± 5.16
RRII 105	59.02 ± 4.20	45.39 ± 1.60	79.76 ± 2.70	93.82 ± 6.90
PB 260	76.91 ± 4.30	64.11 ± 4.00	86.19 ± 4.40	94.68 ± 4.80
RRIM 600	56.51 ± 3.00	53.48 ± 1.60	91.97 ± 8.40	112.71 ± 5.50

imum loss of photosynthetic pigments, better leaf water status and maintenance of some level of photosynthetic activity under extreme water deficit conditions indicated that clones RRIM 600 and Haiken 1 were comparatively more tolerant to drought than RRII 105, SCATC 88-13 and PB 260.

1.2 Irrigation experiment (RRS, Dapchari)

An experiment was conducted in 10-year-old plants at RRS, Dapchari on RRIM 600. The trees were under 1.00 ETc irrigation during summer and one set of trees were left as unirrigated (control). During the summer season of 1998 onwards the schedule of irrigation was altered. The 1.00 ETc-irrigated plants were divided into two groups and one was being irrigated with 1.00 ETc and another with 1/3 of 1.00 ETc level. At the end of summer, the physiological changes were assessed in partially irrigated plants.

Total chlorophyll content in the leaves was significantly less in rainfed plants, but similar in full and partially irrigated plants (Table Phys. 7). The chlorophyll a/b ratio was more in unirrigated than irrigated plants. The unirrigated plants had less leaf soluble proteins and total proteins. Among the different levels of irrigated plants, there was no significant difference in protein levels.

The photosynthetic capacity of leaves was studied in full, partial and rainfed plants. There was no difference in the photosynthetic O_2 evolution rate between full and partially irrigated, but 37 per cent reduction was observed in rainfed trees compared to 1.00 ETc trees. The bark respiration rate measured in soft bark tissues also showed no significant difference between full and partially irrigated plants (Table Phys. 7).

1.3 Physio-biochemical comparison of drought tolerant and susceptible clones

Leaf and bark samples of trees representing high and low yield, high and low girth were collected from the polyclonal seedling area at RRS, Dapchari. Biochemical components (sugars, phenols, proteins, amino acids and glutathione) and activities of peroxidase, polyphenol oxidase, catalase, ascorbate peroxidase and superoxide dismutase were estimated (April and October 1998). The project was started in 1996 and the results of this study (three years data) are being analysed.

1.4 Molecular level responses to low tissue water status

As part of this experiment, a field study was conducted at RRS, Dapchari from 1996. The objective of the experiment was to examine the biochemical changes in various tissues of rubber plants associated with drought. A mature plantation of RRIM 600 was selected for the study. A part of the plantation is irrigated during summer and another part is left unirrigated. Biochemical

Table Phys. 7. **Chlorophyll and protein contents of leaves, photosynthetic O_2 evolution rate and bark respiration rate in unirrigated, full (1.00 ETc) and partially irrigated plants**

Irrigation	Total chlorophyll (mg/g fresh weight)	Chlorophyll a/b	Proteins (mg/g fresh weight)		Photosynthetic O_2 evolution (relative units)	Respiration (nmols O_2/ mg dry weight/min)
			Soluble	Total		
1.00 ETc	4.66 ± 0.08	1.84	39.40 ± 0.60	92.30 ± 1.40	4.2 ± 0.19	592 ± 40.4
Partial*	4.55 ± 0.05	1.94	35.70 ± 1.04	93.50 ± 1.40	4.3 ± 0.14	642 ± 36.2
Unirrigated	2.70 ± 0.06	3.1	26.70 ± 1.31	81.03 ± 1.60	2.7 ± 0.17	—

±SE n = 6-10 * 1/3 of 1.00 ETc

Table Phys. 8. **Biochemical composition (mg/g fresh weight of tissue) and activities of scavenging enzymes (relative units/mg fresh weight of tissue)**

Biochemical component	Summer		Post-monsoon	
	Irrigated	Rainfed	Irrigated	Rainfed
Soluble sugar	30.30 ± 0.60	24.50 ± 0.55	39.20 ± 1.30	40.50 ± 1.80
Protein	22.50 ± 1.00	23.80 ± 0.50	22.00 ± 0.85	22.20 ± 0.90
Free amino acids	3.10 ± 0.06	5.20 ± 0.10	3.60 ± 0.08	4.00 ± 0.10
Phenols	2.80 ± 0.06	3.90 ± 0.05	3.80 ± 0.06	4.00 ± 0.10
Glutathione	2.34 ± 0.09	3.38 ± 0.07	3.20 ± 0.07	3.30 ± 0.11
Polyphenol oxidase	0.919 ± 0.08	0.517 ± 0.07	1.054 ± 0.04	1.01 ± 0.06
Catalase	0.138 ± 0.01	0.191 ± 0.01	0.114 ± 0.02	0.188 ± 0.02
Peroxidase	5.24 ± 0.27	2.29 ± 0.14	7.79 ± 0.10	4.77 ± 0.22
Ascorbate peroxidase	0.742 ± 0.09	0.273 ± 0.02	0.318 ± 0.01	0.469 ± 0.04
Superoxide dismutase	2.92 ± 0.13	2.44 ± 0.14	5.86 ± 0.08	5.52 ± 0.22

Average values of two years data; n = 15

composition and certain scavenging enzymes in the leaves were analysed and the results are shown in Table Phys. 8.

The results show that the leaf protein content did not change with irrigation treatment either in summer or in the post-monsoon season. But the concentration of free amino acids was significantly more in the leaves of the unirrigated than the irrigated trees during summer. The concentration of soluble sugars was similar in the post-monsoon season, but less in the rainfed than the irrigated trees in the summer season. Total glutathione and phenol contents in the leaves did not change between the irrigated and rainfed trees during peak summer. The activities of polyphenol oxidase, peroxidase, ascorbate peroxidase and superoxide dismutase were significantly less, but that of catalase was more in the rainfed trees than the irrigated trees during summer.

1.5 Molecular level responses to low temperature stress

A field study was conducted at RRS, Agartala during January 1996 to examine the biochemical changes in leaf tissues associated with low temperature. Biochemical components and some scavenging enzymes were analysed and the results are shown in Table Phys. 9.

The results show that the concentration of soluble proteins decreased, but that of free amino acids did not change in the

Table Phys. 9. **Biochemical composition (mg/g fresh weight of tissue) and activities of scavenging enzymes (relative units/mg fresh weight of tissue)**

Biochemical component	RRII 105		RRIM 600	
	Winter	Post-monsoon	Winter	Post-monsoon
Soluble sugar	61.3 ± 0.82	41.3 ± 1.23	73.7 ± 1.05	32.9 ± 1.39
Protein	21.6 ± 0.27	32.3 ± 1.28	28.1 ± 0.28	32.1 ± 0.65
Free amino acids	3.0 ± 0.28	2.8 ± 0.11	3.2 ± 0.18	3.0 ± 0.18
Phenols	5.4 ± 0.10	3.8 ± 0.25	5.1 ± 0.10	3.7 ± 0.20
Total glutathione	4.7 ± 0.13	3.6 ± 0.09	5.2 ± 0.05	2.4 ± 0.11
Polyphenol oxidase	1.75 ± 0.08	1.25 ± 0.08	0.884 ± 0.07	0.775 ± 0.08
Catalase	0.238 ± 0.02	0.192 ± 0.016	0.134 ± 0.01	0.614 ± 0.06
Ascorbate peroxidase	0.578 ± 0.01	2.45 ± 0.30	0.53 ± 0.01	1.97 ± 0.15
Superoxide dismutase	3.13 ± 0.19	6.43 ± 0.08	2.12 ± 0.15	5.19 ± 0.08
Peroxidase	6.49 ± 0.28	8.2 ± 0.45	4.81 ± 0.23	6.87 ± 0.45

Average values of two years data; n = 15

imum loss of photosynthetic pigments, better leaf water status and maintenance of some level of photosynthetic activity under extreme water deficit conditions indicated that clones RRIM 600 and Haiken 1 were comparatively more tolerant to drought than RRII 105, SCATC 88-13 and PB 260.

1.2 Irrigation experiment (RRS, Dapchari)

An experiment was conducted in 10-year-old plants at RRS, Dapchari on RRIM 600. The trees were under 1.00 ETc irrigation during summer and one set of trees were left as unirrigated (control). During the summer season of 1998 onwards the schedule of irrigation was altered. The 1.00 ETc-irrigated plants were divided into two groups and one was being irrigated with 1.00 ETc and another with 1/3 of 1.00 ETc level. At the end of summer, the physiological changes were assessed in partially irrigated plants.

Total chlorophyll content in the leaves was significantly less in rainfed plants, but similar in full and partially irrigated plants (Table Phys. 7). The chlorophyll a/b ratio was more in unirrigated than irrigated plants. The unirrigated plants had less leaf soluble proteins and total proteins. Among the different levels of irrigated plants, there was no significant difference in protein levels.

The photosynthetic capacity of leaves was studied in full, partial and rainfed plants. There was no difference in the photosynthetic O_2 evolution rate between full and partially irrigated, but 37 per cent reduction was observed in rainfed trees compared to 1.00 ETc trees. The bark respiration rate measured in soft bark tissues also showed no significant difference between full and partially irrigated plants (Table Phys. 7).

1.3 Physio-biochemical comparison of drought tolerant and susceptible clones

Leaf and bark samples of trees representing high and low yield, high and low girth were collected from the polyclonal seedling area at RRS, Dapchari. Biochemical components (sugars, phenols, proteins, amino acids and glutathione) and activities of peroxidase, polyphenol oxidase, catalase, ascorbate peroxidase and superoxide dismutase were estimated (April and October 1998). The project was started in 1996 and the results of this study (three years data) are being analysed.

1.4 Molecular level responses to low tissue water status

As part of this experiment, a field study was conducted at RRS, Dapchari from 1996. The objective of the experiment was to examine the biochemical changes in various tissues of rubber plants associated with drought. A mature plantation of RRIM 600 was selected for the study. A part of the plantation is irrigated during summer and another part is left unirrigated. Biochemical

Table Phys. 7. **Chlorophyll and protein contents of leaves, photosynthetic O_2 evolution rate and bark respiration rate in unirrigated, full (1.00 ETc) and partially irrigated plants**

Irrigation	Total chlorophyll (mg/g fresh weight)	Chlorophyll a/b	Proteins (mg/g fresh weight)		Photosynthetic O_2 evolution (relative units)	Respiration (nmols O_2/ mg dry weight/min)
			Soluble	Total		
1.00 ETc	4.66 ± 0.08	1.84	39.40 ± 0.60	92.30 ± 1.40	4.2 ± 0.19	592 ± 40.4
Partial*	4.55 ± 0.05	1.94	35.70 ± 1.04	93.50 ± 1.40	4.3 ± 0.14	642 ± 36.2
Unirrigated	2.70 ± 0.06	3.1	26.70 ± 1.31	81.03 ± 1.60	2.7 ± 0.17	—

±SE n = 6-10 * 1/3 of 1.00 ETc

Table Phys. 8. **Biochemical composition (mg/g fresh weight of tissue) and activities of scavenging enzymes (relative units/mg fresh weight of tissue)**

Biochemical component	Summer		Post-monsoon	
	Irrigated	Rainfed	Irrigated	Rainfed
Soluble sugar	30.30 ± 0.60	24.50 ± 0.55	39.20 ± 1.30	40.50 ± 1.80
Protein	22.50 ± 1.00	23.80 ± 0.50	22.00 ± 0.85	22.20 ± 0.90
Free amino acids	3.10 ± 0.06	5.20 ± 0.10	3.60 ± 0.08	4.00 ± 0.10
Phenols	2.80 ± 0.06	3.90 ± 0.05	3.80 ± 0.06	4.00 ± 0.10
Glutathione	2.34 ± 0.09	3.38 ± 0.07	3.20 ± 0.07	3.30 ± 0.11
Polyphenol oxidase	0.919 ± 0.08	0.517 ± 0.07	1.054 ± 0.04	1.01 ± 0.06
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	Winter	Post-monsoon	Winter	Post-monsoon
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Free amino acids	3.0 ± 0.28	2.8 ± 0.11	3.2 ± 0.18	3.0 ± 0.18
Phenols	5.4 ± 0.10	3.8 ± 0.25	5.1 ± 0.10	3.7 ± 0.20
Total glutathione	4.7 ± 0.13	3.6 ± 0.09	5.2 ± 0.05	2.4 ± 0.11
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Ascorbate peroxidase	0.578 ± 0.01	2.45 ± 0.30	0.53 ± 0.01	1.97 ± 0.15
Superoxide dismutase	3.13 ± 0.19	6.43 ± 0.08	2.12 ± 0.15	5.19 ± 0.08
Peroxidase	6.49 ± 0.28	8.2 ± 0.45	4.81 ± 0.23	6.87 ± 0.45

Average values of two years data; n = 15

Table Phys. 10. **Mean yield and yield components in 12 clones at CES, Chethackal**

Clone	Yield (g/tree/tap)	IFR (ml/cm/min)	DRC (%)	PI	Girth (cm)
RRII 105	53.48	0.110	37.39	4.15	77.23
RRII 118	48.41	0.075	36.95	3.41	88.65
RRII 300	33.79	0.078	36.77	4.85	80.42
GT 1	49.98	0.083	34.38	3.13	77.26
PR 107	32.44	0.111	36.08	5.54	67.51
Tjir 1	33.53	0.107	36.41	6.42	77.48
GI 1	28.53	0.085	31.93	4.76	74.46
PB 235	47.15	0.070	35.13	3.36	89.82
RRIM 501	45.87	0.075	34.37	2.89	65.12
RRIM 600	46.62	0.095	33.35	3.73	77.00
RRIM 612	27.45	0.090	35.28	6.64	85.00
RRIM 703	25.88	0.048	34.30	3.67	70.67

leaves during winter compared to post-monsoon season in the two clones studied. The concentrations of soluble sugars, total glutathione and phenols increased in winter. The activities of catalase and polyphenol oxidase increased, but that of peroxidase and superoxide dismutase decreased during winter in both clones.

1.6 Identification of molecular basis for drought tolerance

The plasmid DNA corresponding to the genes HaDhn1 and HaDhn2, coding for the protein dehydrin, which is reported to be responsible for drought tolerance in *Helianthus annuus* was transformed into the *E.coli* strain DH5µ. Extracted the plasmid DNA from the transformed DH5µ and confirmed the presence of the gene by digestion with restriction enzyme EcoR1 and gel electrophoresis. The strains were preserved at –70 °C. The genes will be isolated from the strain and will be used as probe for Southern/ Northern Hybridization Analysis of drought tolerant/ susceptible genotypes of *Hevea*.

A suitable protocol for the isolation of PCR amplifiable DNA from *Hevea* bark samples has been standardized.

2. Physiology of growth and yield

2.1 Studies on yield and yield components

The yield and yield components of 12 clones were recorded for the year 1998-99. Mean annual yield Y (g/tree/tap), initial flow rate IFR (ml/cm/min), DRC (%), plugging index (PI) and girth (cm) are shown in Table Phys. 10. Clone RRII 105 continues to be a top yielder. RRIM 703 recorded the lowest yield of 25.88 g/tap. Clones like GT 1, RRII 118, PB 235, RRIM 600 and RRIM 501 yielded between 45-50 and all other clones between 25-34 g/tree/tap. Mean IFR was found higher in clones RRII 105, Tjir 1 and PR 107 and low in RRIM 703. DRC ranged between 32-37 per cent. Plugging index varied with clones and RRIM 612 recorded maximum values of PI (6.6). The mean girth of these clones was in the range of 65.12 (RRIM 501) to 89.82 cm (PB 235).

2.2 Investigations on the mechanisms of tapping-induced loss of biomass at HBSS, Nettana

The project was started in October 1997 with five clones in a 1987 plantation at HBSS, Nettana to find out the mechanism of loss in biomass of a rubber tree subjected to regular tapping.

The trees were opened for tapping during November 1997 and one set left untapped as control. The annual mean girth increment in d/2 tapped and untapped control trees is shown in Table Phys. 11. The girth increment during the first year of tapping in tapped trees was lesser than

Table Phys. 11. **Difference in annual girth increment between tapped and untapped trees**

Clone	Girth increment (cm)	
	Untapped	Tapped
RRII 300	3.97 ± 0.99	2.37 ± 0.26 (40.30)
RRII 105	3.91 ± 0.30	2.10 ± 0.49 (46.30)
PB 235	5.19 ± 0.61	3.80 ± 0.17 (26.77)
PB 260	4.23 ± 0.49	3.01 ± 0.16 (28.90)
PB 311	4.05 ± 0.47	2.42 ± 0.16 (40.25)

Figures in parentheses indicate percentage of reduction in annual girth increment of tapped trees compared to respective untapped trees

untapped trees in all the five clones indicating tapping induced more partitioning of assimilates to rubber biosynthesis. The reduction of biomass allocation to girth may also be due to tapping-induced maintenance respiration. The reduction in tapping-induced girth increment was more in RRII 105 and less in PB 235.

The dark respiration-mediated oxygen evolution rate was measured in tapping panel area of the d/2 tapped trees and from the corresponding point in the untapped trees during May and November 1998 covering two different seasons representing summer and post-monsoon respectively. The tapping panel respiration rate was significantly higher than respective untapped control trees. The high rate of respiration recorded in the tapping panel area could be due to the increased rate of metabolism for biosynthesis of rubber molecules as well as possible wound-induced maintenance respiration. There was seasonal changes in respiration rates recorded in tapped trees. The rate measured during stress-free November was higher than summer respiration in all the clones. Among the tapped trees, RRII 105 recorded maximum respiration and PB 260 recorded minimum respiration in both the seasons (Table Phys. 12).

The total sugars content in tapping panel area was higher than untapped trees in all the clones. It could be attributed that sugar content in the tapping panel area had a direct role in energy producing respiratory metabolism. There was no difference between tapped and control trees in starch content (Table Phys. 13).

Table Phys. 12. **Dark respiration rate of soft bark tissues**

Clone	Respiration rate (nmols O_2/g dry weight/min)			
	Summer		Post-monsoon	
	Untapped	Tapped	Untapped	Tapped
RRII 300	215.0 ± 13.7	552.6 ± 21.9	222.0 ± 19.5	615.0 ± 28.5
RRII 105	265.6 ± 23.7	687.1 ± 32	306.5 ± 9.2	763.9 ± 25.2
PB 235	218.6 ± 11.7	484.6 ± 35.6	237.5 ± 26.5	643.6 ± 32.6
PB 260	267.6 ± 19.9	466.5 ± 22	220.3 ± 12.7	582.5 ± 33.6
PB 311	201.0 ± 11.4	539.1 ± 37.5	241.2 ± 19.6	728.8 ± 36.6

Table Phys. 13. **The total sugars and starch composition of laticiferous soft bark tissues**

Clone	Sugars (mg/g fresh weight)				Starch (mg/g fresh weight)			
	Summer		Post-monsoon		Summer		Post-monsoon	
	Untapped	Tapped	Untapped	Tapped	Untapped	Tapped	Untapped	Tapped
RRII 300	40.8±0.5	46.7±2.9	39.8±2.8	42.6±1.3	56.0±7.3	62.5±3.6	48.7±0.8	58.6±5.7
RRII 105	36.8±1.1	47.7±1.7	31.3±1.0	45.4±1.4	60.0±3.1	68.9±2.1	49.4±1.0	52.0±3.9
PB 235	49.0±1.7	52.6±1.6	39.5±2.0	45.6±1.2	50.8±7.1	74.6±1.5	63.9±1.4	61.5±1.4
PB 260	33.5±1.20	35.8±0.6	29.6±1.1	39.6±2.7	54.9±2.4	78.9±6.7	64.0±3.3	77.6±2.9
PB 311	39.8±1.1	44.7±2.6	27.9±1.1	36.9±1.1	83.3±5.1	84.4±3.8	53.3±4.7	56.1±1.6

Table Phys. 14. **Tapping-induced changes in respiration rate, reactive oxygen quenching enzymes activities in RRII 105.**

Parameter	Untapped	Before tapping	After tapping	Resting day 1	Resting day 2
Respiration*	487 ± 34	784 ± 34	968 ± 41	833 ± 27	694.6 ± 52
SOD**	2.64 ± 0.34	3.15 ± 0.34	3.4 ± 0.04	3.8 ± 0.05	3.26 ± 0.05
Catalase**	0.027 ± 0.004	0.027 ± 0,004	0.038 ± 0.004	0.033 ± 0.0031	0.032 ± 0.006
Peroxidase**	0.09 ± 0.01	0.096 ± 0.0046	0.13 ± 0.005	0.11 ± 0.01	0.11 ± 0.012

* nmols O_2/mg dry weight tissue/min ** relative units/min/mg protein

2.3 Tapping induced changes in respiration rate and reactive oxygen scavenging systems in bark tissues

The tapping induced changes in the dark respiration rate was studied in soft bark tissues of the clone RRII 105 undergoing tapping by 1/2S d/3 system. Respiration rate was measured just before tapping in the early morning (0630 IST), just after the collection of latex (1000 IST) and following resting days during morning hours (1000 IST). Similarly the activities of reactive oxygen species (ROS) quenching enzymes such as superoxide dismutase (SOD), catalase and peroxidase were studied in bark samples. The respiration rate was higher in after tapping samples than before tapping and resting days (Table Phys. 14). There was no significant difference in the activities of ROS quenching enzymes such as SOD, catalase and peroxidase in both before and after tapping samples.

3. Studies on tapping panel dryness

A survey was made in GT 1 regarding the occurrence of TPD in a new tapping panel in relation with the TPD history in the previous tapping panel. The trees were regularly monitored and the percentage of TPD incidence in individual trees was recorded every week for a period of three years. The data indicated that the occurrence of TPD was relatively fast and more in trees which had TPD history in the previous tapping panel. In normal trees, the percentage of TPD incidence was very low and the occurrence of TPD was comparatively slow.

Soft bark tissues of normal and TPD trees from GT 1 and RRIM 600 were used for the biochemical analysis of proteins, sugars, phenols, thiols, glutathione and certain free radical scavenging enzyme systems like ascorbate peroxidase, superoxide dismutase etc. The trees that had gone fully dry had higher concentrations of total sugars and starch in bark tissues of both the clones. However, the reducing sugars in GT 1 did not show any significant change in the TPD trees. On the contrary to this, the C serum proteins were low in TPD trees. There was relatively high peroxidase activity in the TPD trees of both the clones. Analysis of the other biochemical components related to the free radical production in RRIM 600 is in progress. The data indicate that the stress-induced free radical system is very active in these clones during the onset of TPD.

The studies conducted in GT 1 and RRII 105, to examine the respiratory rates of the bark tissues from TPD-affected and normal trees and the carbohydrate status of the tissues revealed an increase in the total sugars, sucrose and starch contents in the bark, along with respiration in TPD trees. The bark tissues from the opposite side of the tapping panel of the two clones showed decreased respiration.

4. Stock-scion interaction studies

4.1 Studies on genetic variability

This experiment was carried out to test a hypothesis that a greater genetic distance between root stock and scion may interfere with the physiology of the scion, eventually leading to symptoms of delayed incompatibility between them culminating in a physiological disorder like TPD syndrome. Bark samples from the scion and root stock portions of healthy and TPD-affected trees of the clone GT 1 were subjected to isozyme and RAPD analysis. The isozyme profile of the enzyme peroxidase showed polymorphism both in the scion and the root stocks. The polymophism observed in the genetically homogeneous scion tissues can be attributed to the influence of the heterogeneous root stocks. The RAPD analysis showed genetic homogeneity between scion tissues (genetic distance=0) while the genetic distance among the root stock tissues ranged from 7 to 39 per cent. The genetic distance between root stock and scion tissues was greater in TPD-affected than in healthy trees.

4.2 Upward tapping

An experiment on upward (high panel) and normal tapping of healthy and TPD affected trees was started in the clone RRII 105 at CES, Chethackal. This study was initiated to find out whether translocated type of incompatibility exists in TPD-affected trees.

4.3 Isozyme polymorphism in the bud-grafted plants

Isozyme polymorphism was observed in three enzymes viz. peroxidase, catalase and esterase in the scion tissues of different clones and plants of a clone. Leaf samples from the same plant were subjected to isozyme analysis of the above enzymes to find out whether variations exist in the isozyme profile of these enzymes in the samples. There is no variation in the isozyme profile of these enzymes in sample of the same plant. This indicates that enzyme polymorphism observed in the scion tissues of different plants of a clone may be due to the influence of root stock/root stock-scion interaction.

RUBBER CHEMISTRY, PHYSICS AND TECHNOLOGY DIVISION

The Division continued studies pertaining to natural rubber mainly on primary processing, chemical modification, reclamation, rubber blends and composites.

1. Primary processing

1.1 Effect of exposure of sheet rubber to sunlight

The evaluation of sheets exposed to open sun for drying in comparison with other modes of drying was continued. The sheets dried in open sunlight for excess period than the required for optimum drying showed comparatively lower molecular weight and polydispersity (Table Chem. 1).

Breakdown characteristics of the samples were evaluated using a torque-rheometer. The heat generated during mastication for a fixed period was found to be lower for

Table Chem. 1. **Molecular characteristics of dry sheets**

Treatment	Mn (Dalton)	Mw (Dalton)	Polydispersity
Smoke-dried for 5 days	2.31×10^5	7.31×10^5	3.17
Sun-dried for 40 h	2.28×10^5	7.62×10^5	3.34
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Excess sun-dried for 60 h	2.01×10^5	6.21×10^5	3.09

sheets exposed to sunlight for prolonged period, indicating a higher extent of degradation. The technological properties of the filled vulcanizates were comparable to those prepared by other modes of drying except for ageing resistance.

1.2 Factors affecting coagulation of fresh natural rubber latex

Fresh natural rubber (NR) latex treated with fatty acids coagulates instantaneously on addition of acids. The volume of the acid required for coagulation depends on many factors viz. the quantity of the soap added, dry rubber content (DRC) and also on the presence of metal ions. Hence the volume of the acid required for coagulation of the latex could be related to the DRC. A methodology was suggested to determine the DRC of the field latex by finding out the volume of the acid required for instantaneous coagulation of the same. Trials are being carried out to reduce the error range of observed DRC values.

2. Chemical modification of NR

2.1 Graft copolymerization of vinyl monomers on to NR

A protocol for the pilot plant-scale preparation of styrene-grafted NR using gamma radiation was standardized. Samples were supplied to different rubber foot wear manufacturing units for evaluation of the material as a stiffening agent in microcellular soles. The same was reported to have comparable properties with other conventional high styrene resins being used in the industry. Efforts are being made to prepare larger quantities of the co-polymer, using the facilities at RVNRL pilot plant.

Prepared methyl methacrylate-grafted NR latex using gamma irradiation technique and the material was evaluated for adhesive formulations.

2.2 Epoxidized NR

Epoxidized natural rubber (ENR) was tried as a reinforcement modifier for NR-silica composites. ENR modified compounds showed lower mixing energy, faster cure and better technological properties and ageing resistance over the unmodified. Modified systems are being compared with rubber-silica mixes containing silane coupling agents and also with carbon black-filled mixes. Scanning electron microscopic studies revealed that the presence of ENR in NR-silica composites improved the silica dispersion of the latter.

In the case of nitrile rubber-silica composites, ENR was found to have improved the cure characteristics and technological properties.

3. Enzymatic deproteinization of NR latex

The residual soluble proteins in NR latex products could cause allergic responses in sensitized individuals. This has necessitated the production of latex products with very low extractable protein (EP) content. It was found that centrifuged latex with lower levels of protein could be prepared using Anilozyme P10, a proteolytic enzyme, in a single centrifuging process. The extent of deproteinization using the enzyme in a single stage centrifuging process was comparable to the double centrifuging of the preserved field latex.

4. Storage of NR

A study was initiated to evaluate the effect of the period and environmental conditions of storage of different forms of NR on the properties of the same. This was proposed in the context of longer storage periods anticipated especially for sheet rubber at the level of farmer/dealer/other government agencies involved in the process of procurement. The raw rubber properties and the properties of the vulcanizates prepared from the above samples were evaluated in a time interval of three months. The parameters regarding the conditions of storage such as temperature, humidity etc. were also monitored.

ISNR 20, the major form of technically specified rubber (TSR) produced in India, is being processed from field coagulum. The practices followed in handling and storage of field coagulum especially in the small grower sector is quite unsatisfactory, resulting in inconsistent and inferior quality rubber. A study has also been initiated to identify factors contributing to degradation of field coagulum prior to processing. Field coagulum samples were stored in different periods and subsequently processed as TSR. The effect of storage on the properties of the rubber was studied.

5. Characterization of molecular parameters of lattices of different clones

The study is being carried out in collaboration with the Botany Division. The lattices of the clones included in the study were evaluated periodically for pH, DRC, non-rubber constituents, Wallace plasticity, plasticity retention index, Mooney viscosity, gel content, acetone extractables, ash content and nitrogen content. Determination of molecular weight and molecular weight distribution (MWD) of the samples were also being carried out.

6. Natural rubber technology

6.1 Reclamation of vulcanized scrap rubber

The process developed earlier, for reclamation of vulcanized scrap rubber was refined. Reclamation was carried out by mechanical shearing of the waste rubber in an open two-roll mill. A lower proportion of premasticated NR was incorporated with the above regenerated rubber. The properties of former were found to be superior to the conventional reclaim rubber (Table Chem. 2).

6.2 Upgradation of the quality of radiation vulcanized NR latex

The pungent odour of the residual monomer viz. n-butyl acrylate being used as a sensitizer in the production of radiation vulcanized NR latex (RVNRL), is a constraint in handling the same. Hence attempts were made to substitute the monomer (n-butyl acrylate) by its oligomer. The oligomers were prepared by the radiation process. Though oligomers were less reactive compared to the monomer, the molecular weight of the oligomer was controlled to get maximum tensile strength for the latex films. Sodium dodecyl sulphate (SDS) was tried as a stabilizer for the oligomer emulsion. However, the vulcanizate properties of the latex films prepared using the above method were observed to be inconsistent. This was identified to be mainly due to the variability of the latex with regard to clone, Mg content and preservation system.

Table Chem. 2. **Processing and technological properties of regenerated and reclaim rubber**

Property	Regenerated rubber	Conventional reclaim rubber
Mooney viscosity, ML(1+4) at 100°C	51.4	87.3
Cure time, 150°C (min.)	14.4	8.5
Scorch time, t2, 150°C (min.)	5.5	1.5
Hardness (Shore A)	60.0	65.0
Modulus 300% (MPa)	7.9	12.3
Tensile strength (MPa)	23.8	16.5
Elongation at break (%)	630.0	355.0
Tear strength (kN/m)	103.6	35.5
Rebound resilience (%)	46.6	60.4
Compression set (%)	39.9	48.6
Heat build up (ΔT°C)	41.0	21.0

AGRICULTURAL ECONOMICS DIVISION

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

1. Evaluation of planting materials under commercial cultivation

A report has been prepared on yield and related aspects of 19 *Hevea* clones under commercial cultivation during the 1-10 phase (Table Age. 1). The clone RRII 105 recorded the highest commercial yield with 1703 kg/ha and the lowest yielding clone was LCB 1320 with 953 kg/ha and the phase mean was 1334 kg/ha. Other high yielding varieties were PB 260, PB 28/59 and PB 217. The clones such as PB 5/63, PB 86, Gl 1 and RRIM varieties other than RRIM 600 were found to be low yielding. The yield per tree ranged from 3.16 (RRIM 623) to 4.89 kg (PB 217) with a phase mean of 4.02 kg and altogether 10 clones had reported yield per tree above 4 kg. The share of field coagulum (FC) ranged from 20.1 (PB 217) to 37.9 per cent (RRIM 628) with a phase mean of 27.7 per cent. Other clones with lower FC content were PB 6/9, PB 5/139 and RRII 105. The tappable stand per ha extended from 259 (PB 5/63) to 391 (PB 5/139) with a phase mean of 329. The phase mean of tapping intensity was 82 per cent showing a combination of tapping systems such as 1/2 S d/3 (67%), 1/2 S d/7 (86%) and 1/2 S d/2 (100%).

Table Age. 1. **Commercial yield and related aspects during 1-10 phase**

Clone	Yield (kg/ha)	Yield (kg/tree)	Share of FC (%)	Tappable stand (no. per ha)	Tapping intensity (%)
RRII 105	1703	4.71	23.5	361	70
GT 1	1351	4.25	24.9	318	82
LCB 1320	953	3.17	31.1	301	89
Gl 1	1109	3.31	30.9	336	86
PB 217	1510	4.89	20.1	309	84
PB 235	1426	4.47	28.2	319	77
PB 252	1386	4.68	37.8	296	86
PB 260	1607	4.79	28.6	235	77
PB 28/59	1522	4.58	29.0	333	75
PB 5/139	1306	3.34	23.3	391	92
PB 5/51	1336	4.28	27.6	312	82
PB 5/63	1088	4.20	37.1	259	77
PB 6/9	1216	3.27	20.6	372	67
PB 86	1105	3.34	25.9	331	84
RRIM 600	1337	4.28	28.3	312	84
RRIM 605	1144	3.59	30.0	319	84
RRIM 623	1106	3.16	30.4	320	85
RRIM 628	1093	3.84	37.9	285	70
RRIM 701	1186	3.95	35.6	300	85
Mean	1333	4.02	27.7	329	82

2. Adoption of intercropping in rubber smallholdings in Kerala

A Tobit Model was used to analyse the determinants of the intercropping decisions in three regions viz. Punalur, Thodupuzha and Thaliparamba in South, Central and North Kerala respectively. The share of intercropped area in total rubber area was 61.25, 66.10 and 58.23 per cent in Punalur, Thodupuzha and Thaliparamba regions respectively. The family labour availability and the type of intercrops in all the three regions, the perception of profitability of intercropping in Thaliparamba and the sources of off-farm income in Thodupuzha region were found significant in explaining the intercropping decisions. Suitable extension policies designed to change the perception of farmers about the lack of profitability of intercropping can enhance the pace of adoption of intercropping practices in rubber smallholdings in Thaliparamba region.

3. Land use planning model for intercropping in rubber smallholdings

This study was conducted in the Thaliparamba region of North Kerala. A multiobjective land use planning model for a 1 ha farm was developed using the Compromise Programming Approach. Maximization of gross margin, family labour employment and minimization of hired labour and capital borrowing were the objectives set and activity included was intercropping of banana, tapioca, yam, colocasia, turmeric, ginger and cow pea. The compromise set of plants produced a set of farm plans with gross margin ranging from Rs.15671 to Rs.21250 per ha for different weights assigned to the objectives. An increase of 16 to 20 per cent in gross margin compared to the existing land use plans was shown in the compromise set of plans with a uniform weight for all the objectives.

4. Monitoring of the by-products sector

The monitoring of the by-products sector has been continued. The potential availability of rubber wood was estimated to be 1.35 million m^3 during 1998-99. But due to the very low price of logs and uncertainties in the natural rubber market, the actual production was lower by around 40 per cent. The consumption pattern of stem wood is given in Table Age. 2.

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

Consuming sector	% share of consumption
Packing cases	64.5
Plywood	18.5
Safety matches	3.0
Secondary processing	12.0
Others	2.0

The price of logs suitable for packing cases ranged from Rs.1250 to Rs.1500 per t while that of logs suitable for plywood and secondary processing ranged from Rs.1800 to Rs.2200. The production of rubber seed oil and cake was estimated to be 2300 and 3700 t respectively. The average price of rubber seed oil declined from Rs.22 to Rs.20 per kg while that of rubber seed cake increased from Rs.10 to Rs.12 per kg. The production of rubber honey increased from Rs.1500 to 1750 t.

Other studies such as operational efficiency of rubber plantations at the different levels of management, desegregate level analysis of natural rubber price in India, stock holding practices of small rubber growers, Indian tyre industry in the context of economic liberalization, utilization of hired labour in rubber smallholdings etc. are at different stages of completion.

WORLD BANK-ASSISTED RUBBER PROJECT RESEARCH COMPONENT

The research component of the World Bank-assisted rubber project has been implmented by RRII and it aims for long-term development of the rubber plantation industry.

1. Exploitation studies

In estates and medium holdings, stimulation treatments in low frequency tapping trials on RRII 105 under d/3 system continued to give better yield and recorded an average yield increase of 31.40 per cent over the unstimulated control. In Cheruvally Estate, stimulation treatments in PB 217 under d/3 system gave 20 per cent yield increase over the control. In New Ambady Estate, stimulation at the highest level in RRIM 600 (d/3 system) recorded an yield increase of 46.40 per cent over the unstimulated control.

As in the previous year (1997-98), differences among treatments were not significant under d/4 system particularly in RRII 105, confirming that lower stimulation level would suffice to achieve satisfactory yield improvement. In Koney Estate, highest level of stimulation in PB 217 under d/4 system resulted in 13.04 per cent yield increase over the control blocks. In a similar trial at Vennimala, stimulated d/4 blocks gave 13.86 per cent increase over d/3 blocks. In general, d/4 frequency of tapping gave good results.

Three new experiments on low frequency tapping were laid out at RRS, Dapchari, Maharashtra. Additional two locations in Maharashtra and one in Palakkad in Kerala were identified for conducting onfarm trials.

In the experiments at Rajiv Gandhi Institute of Technology (RIT), Kottayam, low frequency tapping with stimulation gave promising results except in the case of weekly tapping. In panel BO-1 and BO-2, yield from plots under d/3 frequency of tapping with stimulation was comparable to that of alternate daily tapping without stimulation. In d/4 tapping system, a decrease of about five per cent yield was noticed compared to d/3 tapping with mild stimulation. Results of the rain guarding experiment, showed 35-50 per cent yield reduction in the absence of rain guard under d/3 and d/2 frequency of tapping respectively. Stimulation could recover only 10 per cent of the yield loss under d/2 and 19 per cent under d/3. In GT 1, CUT of 1/4S cut during pre- and post-monsoon periods resulted in 24 per cent yield increase over the control under d/2 system of tapping.

2. Latex diagnosis studies

Latex diagnosis (LD) studies conducted in 36 smallholdings under Edakunnam RPS in Kanjirappally region showed that the values of LD parameters in d/2 and d/3 system of tapping were comparable during the period of observation. The results indicated that the base values fixed for clone RRII 105 could well be used as indices for advisory purposes on exploitation during August to November.

Latex diagnosis parameters (thiols, sucrose, inorganic phosphorus and DRC) obtained from an experiment at RIT indicated signs of over-exploitation. Results revealed that latex diagnosis parameters could be used as indicators for fixing optimum stimulation schedule.

3. Clone evaluation

In the 1994 Trial at Arasu Rubber Corporation, Keeriparai, Tamil Nadu, RRIM 703, RRII 105 and IRCA 111 continued to exhibit

better growth whereas PB 314 recorded the lowest girth (Table Wb. 1).

Table Wb. 1. **Clone evaluation**

Clone	Girth (cm)
RRII 105	38.02
IRCA 18	35.08
IRCA 109	35.19
IRCA 111	37.01
IRCA 130	32.40
IRCA 230	34.54
PB 28/59	35.24
PB 255	36.53
PB 314	31.28
PB 330	32.55
RRIM 703	39.90
Mean	27.65

Data on sun scorch incidence from the 1994 Trial at Arasu Rubber Corporation indicated three groupings (Table Wb.2). PB 217 and PB 311 showed better tolerance to sun scorch.

Table Wb.2. **Incidence of sun scorch**

Incidence	Clone
Low	PB 217
	PB 311
Medium	RRII 5
	RRII 50
	RRII 105
	RRII 176
	PR 255
	PR 261
	PB 260
	PB 235
	RRIC 102
High	PB 28/59

The onfarm blocks at Pullengode Estate, Thirumbadi Estate, Manappally, Suranadu, Vallikunnam and Thamarakkulam were maintained. At RRS Agartala, girth and yield recordings of the selected clones were continued.

4. Biotechnology

4.1 *In vitro* plant generation

The effect of explant stage and methods of sterilization were standardized for explants derived from field-grown plants. From field-grown mature trees, the ideal time for explant collection is December to January when new flushes emerge after wintering. A high concentration of sucrose and cytokinin in the initial inoculation medium was found to be essential for normal growth of explants. Shoot elongation and maturation could be obtained on subculture to a medium containing low level of cytokinin and gibberellic acid. Sprouting of multiple shoots from the base was obtained after removal of the shoot apex.

The effect of thidiazuron on the induction of multiple shoots in the nodal culture as well as shoot tip cultures was observed. This chemical suppressed the apical dominance and induced profuse multiple shoot production. However, the growth of multiple shoots was not satisfactory.

4.2 Somatic embryogenesis and transgenic plant synthesis

Experiments were conducted to enhance the efficiency of somatic embryo induction and plantlet formation achieved earlier from immature inflorescence (flower buds) and immature anther as the initial explants. Studies on various nutritional as well as hormonal requirements resulted in a high frequency somatic embryogenesis and plantlet formation from immature anther and flower buds. Time span required for the formation of mature embryos from initial explants is approximately one and a half years. Parallel experiments carried out to reduce the time span between initial explant inoculation and mature embryo formation resulted in the reduction of time span to three months.

In order to overcome the problem of the development of transgenic plantlets, exper-

iments were carried out with the transgenic embryos and embryogenic calli transformed with the gene coding for sorbitol 6-phosphate dehydrogenase brought from the University of California, USA. It resulted in the large-scale production of mature embryos transformed with the gene coding for sorbitol 6-phosphate dehydrogenase. Plantlets were produced up to the second leaf stage. Further experiments are in progress on the hardening process.

Experiments were carried out to enhance the transformation frequency and the frequency has been enhanced from 1 to 3 per cent . Fresh *Hevea* calli were transformed with the other genes coding for isopentenyl transferase, superoxide dismutase and the antisense sequence for ACC synthase brought from the University of California. Nearly 50 embryos transformed with antisense ACC gene and more than 1000 embryos each transformed with genes coding for isopentenyl transferase and superoxide dismutase were developed.

5. Germplasm evaluation/Genome analaysis

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

In the hot spot trial at the RRS, Sukma, Madhya Pradesh, Brazilian clones such as RO 5363 and RO 2629 were performing better, however poor growth was observed for AC 685. Among control clones, good growth was observed for clones RRII 118 and GT 1. Selected clones from this hot spot trial were multiplied and field-planted at the RRS, Nagrakatta, West Bengal for cold tolerance evaluation during 1998. During winter months, 10 Brazilian clones showed symptoms of cold injury like wilting followed by die-back with black discolouration of green bark.

5.2 Genome analysis

Independent screening for polymorphic/informative primers was carried out for wild and cultivated clones as they showed differential response in terms of PCR amplification. So far, 200 primers (20 random primers from each OPA and OPJ series) were screened with popular clones and 80 primers (8 primers from each series) with wild genotypes. RAPD profiles of 48 wild genotypes have been studied using 12 screened informative primers and database of the above RAPD profiles are being constructed simultaneously for relationship studies. Screening for RAPD marker for *Phytophthora* disease resistance in popular clones and wild germplasm of *Hevea* is being continued. The random primers which have been identified for polymorphism in tolerant clones are being subjected to tests for the consistent pattern for disease resistance in 15 genotypes.

6. DRIS fertilization

Experiments to compare two types of fertilizer recommendation viz. Discriminatory Fertilizer Recommendation (DFR) and Diagnosis and Recommendation Integrated System (DRIS) are in progress. Treatment incorporation and collection of yield data were undertaken during the period under report.

In the soil, tissue and latex testing laboratories at Nedumangad, Adoor, Kottayam, Pala, Kanjirappally, Muvattupuzha, Thrissur, Kozhikode, Thaliparamba and Mangalore, a total of 20577 soil and 867 leaf samples were analysed.

A survey was conducted among the smallholders of Kerala to study the impact of discriminatory fertilizer application among smallholders. The study revealed a saving of Rs.400/ha in fertilizer cost and an increase in rubber yield up to 132 kg/ha by adopting discriminatory fertilizer application.

7. Rubber-based sustainable farming system

Three experiments following three different models (Model I, II and III) laid out

during 1996 to 1997 at the Regional Research Farm, Taranagar, Agartala were continued.

Average girth of rubber trees in Model I and II was 13.36 and 10.8 cm respectively. A total of 207 kg of paddy and 115 kg of tapioca were harvested. Growth data recorded show that in Model I, the juvenile growth of clone RRIM 600 is the highest among the three clones followed by PB 235 and GT 1, whereas in Model II, PB 235 registered slightly better growth than GT 1 and RRIM 600.

8. R&D activities on NR processing

8.1 Improvement of drying conditions of sheet rubber in smallholdings

8.1.1 Solar drying

Civil work was started at the HBSS, Nettana to install solar-cum-smoke dryer of 600 kg capacity.

8.1.2 Sun-cum-smoke drying

Construction of a new smoke house was completed at RRII campus. This smoke house envisages a system, where sheets can be loaded on trolleys and rolled out of smoke house for partial drying in sunlight. Based on the results from the initial trials, the furnace and trolley were modified. Insulation of the metallic door of the smoke house had been done to avoid the loss of heat. Evaluation of the modified sun-cum-smoke dryer is in progress. Compared to the firewood consumption of 1.0 to 1.2 kg in smoke drying alone, sun-cum-smoke drying consumed only 0.7 kg firewood/kg of dried rubber. Every day, 7 kg of firewood is being used. The drying time of sheets varied between four and five days.

A new trolley has been designed for effecting maximum drying of sheets in open sun. In the new design, rubber sheets in the four bottom layers can be fully exposed to sun light by drawing the layers in four directions and can be fixed there horizontally for fast and uniform drying of wet sheets. Fabrication of the trolley with the above specifications was completed and the trials with this new trolley was taken up.

8.1.3 Low cost smoking devices

Evaluation of 96-sheet capacity solar-cum-smoke dryer was carried out with solar heat collectors attached to it. Total quantity of sheets dried was 6583 kg and the consumption of firewood was about 0.95 kg for every kg of dried sheet rubber. The firewood consumption without solar panel amounts to 1.4 kg for every kg of dried rubber and is higher than the conventional smoke house which requires 1-1.2 kg of firewood. Contribution of the solar panel was found to reduce the firewood requirement by 0.4 kg.

8.1.4 Upgradation of low quality sheet

A major portion of smallholders' sheet rubber is of very poor quality, due to reasons such as incomplete drying, mould growth and surface contamination. In order to upgrade the quality of these sheets a mechanical cleaning device was designed, fabricated and installed. This machine can clean both surfaces of the sheet in two to three seconds. Further trials are in progress.

8.2 Modified forms of NR

8.2.1 Storage studies of epoxidized natural rubber (ENR)

Four sets of ENR (ENR 10, ENR 25, ENR 50 and ENR 60) with and without calcium stearate were tested at pre-determined intervals for changes in properties on storage such as plasticity, gel content, Mooney viscosity, plasticity retention index, accelerated storage hardening and epoxy content. Vulcanizates of the compounds made from these rubbers are weakly acidic in nature. Minor decrease in epoxy content with storage time and a steady increase in plasticity, Mooney viscosity and gel content on storage were observed. The rate of increase was

higher for ENR with high epoxy content. Addition of calcium stearate appeared to have improved the processibility (i.e. lower plasticity, gel content and Mooney viscosity of the rubber with low epoxy content). However, overall vulcanization properties did not get much affected on storage.

8.2.2 Thermoplastic natural rubber (TPNR)

Two different grades (film grade and injection moulding grade) of PP and HDPE were collected and these were used for melt blending with natural rubber having two different levels of molecular weight. The blend ratio used was 60 : 40 (NR : thermoplastics). It was found that, for the uncross-linked blends, the tensile strength and elongation at break are less affected by the type of PP. However, the masticated rubber incorporated blends showed high MFI values indicating good processibility. Dynamically vulcanized blends were prepared with sulphur and peroxide as cross-linking agents. Vulcanized blends had inferior properties compared to the uncross-linked blend, suggesting the need for refinement of formulation/process. Formulations with a new activator-cum-antioxidant was designed and their properties were studied.

9. UPASI Component

In this project, being implemented through the UPASI, 2152 soil samples and 352 leaf samples from 1350 growers were analysed and discriminatory fertilizer recommendation was provided. Training classes on soil collection, campaign classes, exhibitions etc. for popularizing the discriminatory fertilizer use among planters were conducted.

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

This project has been entrusted with Kerala Agricultural University. Soil profile samples, leaf, latex and water samples were collected from rubber plantations of five age groups viz. 5, 10, 20, 30 and above 30 years from 10 locations covering sprayed, unsprayed and virgin lands. The samples were processed and estimation of parameters like organic carbon, clay percentage, CEC and pH, total copper, DTPA copper, leaf copper, latex copper and copper in water was carried out.

Total copper registered higher values in samples collected from plantations receiving copper fungicide spraying compared to unsprayed plantations of the same age group. A drastic decrease in the copper content was observed with soil depth. Among locations, lower values of the total copper were reported from HBSS Paraliar followed by Pantha, Kulasekharam, Kozhikkode, CES Chethackal and RRII, Kottayam in the increasing order of copper content. Plantations with 20 and 30 years of continuous copper fungicide spraying registered higher values compared to other age groups. Samples collected from the virgin land without spraying for the past 25 years recorded very low values.

Unsprayed plantations and virgin lands recorded substantially lower values for DTPA copper compared to sprayed plantations. Among the different locations studied, the highest values of DTPA copper was observed in the TR&T Estate, Mundakayam followed by samples from Kozhikode, RRII Kottayam, CES Chethackal, Kulasekharam, HBSS Paraliar and Pantha. Profile samples showed a clear depthwise decrease in DTPA copper in all the profiles studied from different locations. Profile samples from unsprayed and virgin lands registered invariably lower values than sprayed plantations especially for the first two depths.

Leaf copper content registered higher levels of copper in continuously sprayed plantations. In the case of copper in latex, not much variation was observed between sprayed and

unsprayed plantations from samples collected in the second year. Copper content in the latex varied from traces to 4.19 ppm.

Copper was not detected in any of the water samples showing that the copper deposited in the soil and foliage from spray drifts is washed away by subsequent rains and lost from the soil water system within a short period. Since this collection was done eight months after spraying, even traces of copper could not be detected in water samples.

In general, the arthropod population was significantly higher in unsprayed plantations of all age groups, except in the case of five-year plantations. The percentage reduction in arthropod population consequent to continuous application of copper fungicides in 10, 20 and 30-year plantations were 34, 60 and 61 per cent over unsprayed plantations.

The nematode population consisted of plant parasites viz. *Meloidogyne* sp., *Helicotylenchus* sp., *Hoplolaimus* sp., *Rotylenchulus* sp., *Tylenchorhynchus* sp. and *Criconemoides* sp., saprophytes and predators in varying levels in different plantations. The overall reduction of the nematodes in the sprayed, in comparison to unsprayed plantations is to the tune of 74.5 per cent.

In the case of microbial population, there was no definite trend in the plantations of different age groups. Among the unsprayed plantations, 30-year and 10-year plantations were having the maximum mean population.

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

Draft final report has been submitted by NBSS & LUP incorporating the comments of experts along with 10 copies of the soil atlas. The report is under review.

11. Training programme

11.1 Long-term attachment

Smt. Rajeswari Meenattoor, Scientist has completed her training at the International Agriculture Centre (IAC), Wageningen, the Netherlands in Applied Plant Breeding and Molecular Techniques. Dr. Rosamma Alex, Rubber Technologist completed her training at the School of Polymer Technology, University of North London, U.K. in Dynamic Mechanical Analysis and Dr. J. Licy, Plant Breeder was deputed for an advanced training in molecular aspects of stress tolerance at the University of Nottingham, U.K. for four months.

11.2 Short-term training

Computer training programmes were arranged for scientists and technical staff of RRII, Regional Laboratories and RRS, Guwahati.

CENTRAL EXPERIMENT STATION, CHETHACKAL, KERALA

The Rubber Research Institute (RRII) of India established the Central Experiment Station at Chethackal, Ranni in 1966. The Station is situated at about 50 km from the RRII, Kottayam and has a total area of 254.79 ha. The Station caters to the needs of the different divisions of the RRII. Presently the major areas of experimentation are clone evaluation, progeny, exploitation, intercropping, density etc. A germplasm collection of over 4000 genotypes is maintained and systematic screening of the same is being undertaken. Integration of chemical and manual weed control methods for implementation in the plantations is also being worked out. Hand-pollinated progenies of elite clones are being evaluated in systematic field trials. In addition to the above, routine fertilizer trials, exploitation trials etc. are being conducted.

During the reporting year, the total number of permanent workers engaged

was 209 and that of total casual workers was 167. The total man-days engaged during the year for different operations was 64338. A total of 303 tapping days was possible in the year and the total man-days engaged for tapping was 19535. A dispensary caters to the needs of the workers.

REGIONAL RESEARCH STATION, GUWAHATI, ASSAM

The thrust areas of research are assessment of nutritional requirement under different fertility status of soil, evaluation of clones and disease and pest management.

1. Evaluation of clones

1.1 Clone trial (1985)

The girth recorded (Table Nea. 1) indicated maximum girth for RRIM 600 (66.11 cm)and minimum for PB 5/51 (48.48 cm). The annual mean yield (g/tree/tap) was the highest for RRIM 600 (28.57) and minimum for PB 5/51 (20.22).

Table Nea. 1. **Growth and yield of clones**

Clone	Girth (cm)	Yield (g/tree/tap)	DRC (%)
RRII 105	58.16	26.05	31.42
RRII 118	65.32	24.95	33.82
RRII 203	64.78	21.80	29.77
GT 1	62.14	25.19	32.21
PB 86	65.08	26.40	29.73
PB 235	62.98	27.58	32.14
PB 5/51	48.48	20.22	29.72
Gl 1	53.09	22.26	29.77
RRIM 600	66.11	28.57	32.58
RRIM 605	61.14	23.13	31.77
SE	1.40	2.78	1.19
CD (P=0.05)	3.89	7.94	NS

1.2. Clone trial (1986)

Maximum girth (Table Nea. 2) was recorded in RRIC 102 (69.47 cm) and minimum in RRII 5 (59.34 cm). The annual mean yield (g/tree/tap) was the highest in PB 311 (31.99 g) and lowest in PB 260 (18.74 g).

2. Nutritional studies (mature phase)

2.1 Nutritional trial (1987)

The nutritional trial at Nayekgaon in Kokrajhar, which was started in 1987 as an onfarm trial with clone RRII 105, is being continued. Observations on monthly yield and half-yearly girth were recorded. It has been observed that highest girth is attained at 60 kg N/ha though 40 kg/ha was on par.

Table Nea. 2. **Growth and yield of clones**

Clone	Girth (cm)	Yield (g/tree/tap)	DRC (%)
RRII 5	59.34	23.23	32.51
RRII 105	61.45	20.80	28.34
RRII 208	62.33	25.33	30.70
PR 255	62.65	20.02	30.08
PB 260	60.75	18.74	30.67
PB 310	63.90	26.87	32.19
PB 311	61.27	31.99	30.60
RRIC 102	69.47	20.24	31.02
SE	2.74	2.85	1.17
CD (P=0.05)	7.6	8.13	NS

2.2 Nutritional trial (1998)

A field trial has been initiated at RRS, Tura, Meghalaya during the year 1998-99 to find out the effect of NPK doses on the growth and yield of *Hevea* at the high altitude (600 m above msl) region.

Treatment details are :

Clone	RRII 105
Design	RBD
Replication	4
Net plot	16 plants
Gross plot	36 plants
Treatments	35:35:35 (NPK)
	60:35:35
	75:45:45
	90:45:45
	Control

3. Interaction between K and Mg

Two trials, which were laid out in two locations (Sorutari and Nayekgaon) in 1987 are being continued. The results showed that the application of Mg and K was found non-significant on girth. Maximum yield (g/tree/tap) was recorded at the highest levels of Mg and K at Sorutari and Nayekgaon and their interaction was also found significant.

4. Rock phosphate and super phosphate as source of P

Two trials, which were laid out in two different locations (Sorutari and Nayekgaon) on mature rubber are being continued. The data revealed that effect of treatments on girth is non-significant (Table Nea. 3). However, the effect of treatments on mean yield (g/tree/tap) is highly significant and the application of rock phosphate gave the highest yield. Similar trend is also observed in Nayekgaon.

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

Treatment	Girth (cm)	Yield (g/tree/tap)
Sorutari*		
Water insoluble P	64.32	57.03
50% water soluble and 50% water insoluble P	64.09	52.26
Water soluble P	62.39	50.83
Control	62.29	45.50
SE	1.652	2.39
CD (P=0.05)	NS	7.36
Nayekgaon*		
20 kg water soluble P	54.76	52.39
20 kg water insoluble P	55.68	55.58
40 kg water soluble P	54.73	53.78
40 kg water insoluble P	54.72	59.78
60 kg water soluble P	55.88	55.92
60 kg water insoluble P	53.80	65.90
Control	55.20	45.89
SE	1.169	1.281
CD (P=0.05)	NS	3.81

* Recommended dose of P_2O_5 @ 35 kg/ha

5. Survey on diseases and pests

Pest and disease survey was carried out in 20 locations in Assam, Meghalaya, Tripura and northern part of West Bengal. High incidence of powdery mildew disease caused by *Oidium heveae* was noticed in most of the locations surveyed. Repeated defoliation of tender leaves due to this was noticed in Rongthelu Estate (Assam), Jengitchekgri and Umling Estate (Meghalaya), Rani and Anandanagar (Tripura) and Nagrakatta (West Bengal). Secondary leaf fall (SLF) disease caused by *Colletotrichum gloeosporioides* was also noticed in some plantations in Assam and Tripura during June to September.

Occurrence of thread blight disease caused by *Pellicularia filamentosa* was noticed in 16-year-old plants at Umling Estate, Meghalaya during September for the first time in N.E. region. Occurrence of leaf blight disease caused by *Periconia heveae* was noticed in nursery plants during November to March in Assam and Meghalaya. Incidence of brown root rot disease caused by *Phellinus noxius* was noticed in plantations at Rani and Purba-Mirza in Tripura and also in Assam.

Mild attack of termites, slugs and snails was noticed in most of the plantations surveyed. Scale insect infestation was noticed by the end of April in nursery plants. However, the scale insect population was controlled by the activity of an entomogenous fungus (*Hyprocrelia reineckiana*).

6. Isolation, identification and maintenance of fungal pathogens

Routine isolation of fungal pathogens was made from various diseased samples collected from different locations and iden-

tified. Fungal pathogens viz. *Phellinus noxius, Colletotrichum gloeosporioides, Pellicularia filamentosa, Fusarium solani* and *Periconia heveae* were maintained as stock cultures at laboratory for further mycological studies.

7. Control of powdery mildew disease

The trial on dusting of agricultural grade sulphur was continued in a block of RRIM 600. Pre-treatment girth and yield data were recorded both from treated and untreated blocks. Treatment was imposed during February 1999 by dusting of sulphur. Average girth of 60.01 and 58.4 cm was recorded in treated and untreated blocks respectively while yield (g/tree/tap) was 30.5 and 27.5 g respectively. High incidence of powdery mildew disease was noticed in both the blocks but the severity was comparatively high in the untreated.

8. Evaluation of polyclonal population

Out of 281 polyclonal trees, 167 were tapped (1/2S d/2) and yield (g/tree/tap) was recorded in normal tapping days from May to December. Girth was also recorded at an interval of three months. Performance of 10 polyclonal populations in terms of yield was found to be promising (Table Nea. 4).

9. Evaluation of wild germplasm

One hundred genotypes of wild germplasm were multiplied and planted in polybag nursery for screening against cold and *Oidium* resistance. Out of the 100 genotypes, high incidence of *Oidium* disease was noticed in 21 genotypes and 32 genotypes were free from infection.

10. Potassium dynamics on the rubber growing soils of Assam

The objective of this trial is to assess the K-status of soil in the potential rubber growing areas in Assam. As such, four important rubber-growing areas were identified and 96 soil samples were collected at two depths. The soils were processed, dried and physico-chemical properties were analysed.

11. Ecological impact of rubber cultivation

The work was initiated in the year 1997 to study the impact of rubber cultivation on the physico-chemical properties of soil, nutrient enrichment and biomass recycling in comparison to teak, 'jerul' and natural forest. Four (1x1 m) quadrats were kept randomly under each vegetation, from where litter samples were collected, fresh and dry

Table Nea. 4. **Growth and yield performance of polyclonal population**

Selection (Code No.)	Girth (cm)	Girth increment (cm)	Yield (g/tree/tap)	Length of tapping cut (cm)	Yield potential (g/cm)
S1	70.7	3.9	67.35	43.0	1.56
S2	66.0	5.7	70.05	50.0	1.40
S3	66.7	4.2	53.23	42.0	1.26
S4	53.4	2.3	38.18	31.5	1.21
S5	73.8	5.6	56.46	47.0	1.20
S6	77.9	4.1	54.81	46.5	1.17
S7	67.8	3.3	50.27	44.0	1.14
S8	56.6	1.5	36.16	33.0	1.09
S9	62.0	1.9	35.94	33.5	1.07
S10	74.2	1.2	46.89	46.0	1.01
General mean	59.68	3.35	18.75	38.3	0.48

Table Nea. 5. **Biomass and nutrient contents of accumulated litter under different vegetation**

Vegetation	Litter (kg/ha)	Nutrient content (kg/ha)					Total accumulation (kg/ha)
		N	P	K	Ca	Mg	
Rubber plantation	5959	39.90	8.09	12.01	22.12	19.30	101.42
Natural forest	5655	45.14	4.78	11.71	16.29	26.16	104.08
'Jerul' forest	4945	35.90	6.98	16.01	19.72	21.78	100.39
Teak forest	3838	27.14	7.38	13.21	19.98	16.26	83.97
SE		2.47	0.56	0.95	1.67	1.67	4.39
CD (P=0.05)	NS	7.41	NS	NS	5.01	NS	NS

weights were also taken. Based on dry weight, amount of litter accumulation under different vegetation was calculated. It has been observed that the litter accumulation was more in rubber plantations (5959 kg/ha) followed by natural forest (5655 kg/ha), 'jerul' (4945 kg/ha) and teak (3838 kg/ha).

The litter samples analysed for nutritent content (N, P, K, Ca and Mg) revealed that accumulation of phosphorus and calcium is more under natural rubber whereas N and Mg content is more in natural forest. Potassium content is found to be more in 'jerul' followed by the natural forest. Total nutrient cycle under different vegetations was more in natural forest followed by rubber plantation, 'jerul' forest and teak forest (Table Nea. 5).

12. Effect of sulphur on growth

The objective of this trial is to find out the effect of sulphur (S) and its different doses on growth and development of rubber during immature phase and also to find out the S-status of soil in the north-eastern region. The trial of S incubation study has been started at Sorutari farm in 1998 and rain water was also collected at different months during 1998 to find out the S content. Pot culture experiment on S has been started at Sorutari farm during the year under report.

REGIONAL RESEARCH STATION, AGARTALA, TRIPURA

The Regional Research Station, Agartala, Tripura 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 north-eastern region.

1. Density-cum-fertilizer trial

This trial was started in 1987 in the farm of RRS, Agartala. Three densities, D1 (420), D2 (620) and D3 (824 trees/ha), were imposed as main treatments. The sub-plot treatments consisted of three NPK fertilizer combinations 40:40:20 (M1), 60:60:30 (M2) and 80:80:40 kg/ha (M3). Two clones RRII 105 (C1) and RRII 118 (C2) were used as sub-sub-plot treatments. The trees were tapped under 1/2S d/3 system of tapping and the number of tapping days was 62 during this year.

Among the three densities, D1 recorded significantly higher yield as well as girth. Among the fertilizer combinations, M2 recorded higher yield and girth than the other two combinations and between the two

clones, RRII 118 recorded significantly higher girth (Table Net. 1).

Table Net.1. **Effect of densities and fertilizer combinations**

Treatment	Yield (g/tree/tap)	Girth (cm)
D1	37.56	62.83
D2	33.37	58.53
D3	29.03	54.62
CD (P= 0.05)	2.14	1.41
M1	31.83	58.12
M2	34.32	59.25
M3	33.81	58.60
CD (P=0.05)	NS	NS
C1	38.71	55.97
C2	27.93	61.35
CD (P= 0.05)	2.46	1.26

2. Nutritional studies

This trial in clone RRIM 600 started in 1980 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, 20, 40 kg/ha) was continued. Monthly yield and half-yearly girth were recorded. Data showed that 60 kg P resulted higher yield (53.68 g/tree/tap) over other treatments (Table Net. 2).

Table Net. 2. **Average yield at different nutrient levels**

Nutrient	Average yield (g/tree/tap)*		
	Nutrient level 0	Nutrient level 1	Nutrient level 2
N	47.10	49.48	50.74
P	45.97	47.68	53.68
K	48.44	48.71	50.18
CD (P= 0.05)	-	3.64	-

* Under 1/2S d/3 system of tapping

3. Embryo culture

Protocol for obtaining multiple shoots from 2 to 15-week-old immature embryos was standardized. It was observed that maximum number of shoots was obtained from 8-12-week-old embryos (average 5-8 shoots/explant). Addition of GA_3 enhanced number of shoots/explants and healthy plantlets were also obtained by culturing isolated shoots on zeatin-containing medium. Formation of normal root system was initiated by transferring the plantlets on hormone-free medium.

Calli were developed by culturing immature fruit integuments and subsequently used as source materials for suspension culture. Single cell culture was established using enzymes and cell colonies were established by culturing single cells on solid medium. These calli were subjected to regeneration and shoot bud formation obtained on the medium containing 2iP, IBA and GA_3.

4. Evaluation of clones

4.1 Clone trial (1979)

This trial consists of 15 clones (RRII 5, RRII 105, RRII 118, RRII 203, RRIM 600, RRIM 605, RRIM 703, PB 5/51, PB 86, PB 235, RRIC 52, RRIC 105, GT 1, Gl 1 and Harbel 1). The main objective of this trial is to identify the suitable high yielding, disease resistant and stress tolerant clones for the region. Quarterly girth data and fortnightly yield data are being collected.

Data on girth revealed that RRII 118 attained highest annual girth increment followed by RRIC 52, RRII 5, PB 235, GT 1 and PB 86. The highest mean dry rubber yield was recorded by PB 235 followed by RRII 203, RRIM 703, RRIM 600, RRII 118 and RRII 105 (Table Net. 3). A covariance analysis of yield data through bifurcating into lean and peak yielding periods revealed RRII 5, RRIM 703, PB 5/51 and PB 235 as the consistent clones over different periods. This result gives a clear inference that when both consistency and average yield are considered PB 235 and RRIM 703 deserve to be evaluated under onfarm trials.

Table Net. 3. **Mean yield of 15 clones**

Clone	Yield (g/tree/tap)* (June '98 – January '99)
RRII 5	51.64
RRII 105	55.91
RRII 118	57.04
RRII 203	80.15
GT 1	51.98
Harbel 1	38.16
Gl 1	27.07
PB 5/51	42.66
PB 86	51.88
PB 235	81.32
RRIM 600	64.30
RRIM 605	42.57
RRIM 703	64.42
RRIC 52	48.88
RRIC 105	48.59

* 1/2 S d/2 system of tapping

4.2 Evaluation of clones for stress tolerance

Data on girth and yield were collected from six out of 12 clones of 1987 trial. Yield data from1996-98 revealed that SCATC 93-114, PR 107 and RRII 208 are the stable clones. While RRII 208 gave significantly higher mean yield than other stable clones and the popular clone RRIM 600, the calculation of yield per cm also placed it in the top position followed by SCATC 88-13 and Haiken 1. The mean values of yield for Haiken 1, RRIM 600 and SCATC 88-13 were found to be on par (Table Net. 4). The potential clones are included in the commercial evaluation trial in the planters' field.

Table Net. 4. **Yield and stability of clones**

Clone	Mean yield (g/tree/tap)	Unit yield (g/cm)	Regression coefficient
SCATC 88-13	23.50	0.81	1.153
SCATC 93-114	10.58	0.38	0.567
Haiken 1	27.29	0.80	1.360
RRII 208	36.79	1.25	0.937
PR 107	10.84	0.38	0.629
RRIM 600	26.18	0.62	1.353
CD (P=0.05)	7.43	-	-

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

This trial is comprised of 10 clones including RRII 105, RRIM 600, RRIM 612, PB 217, PB 235, PB 260, PB 311, SCATC 88-13, SCATC 93-114 and Haiken 1. The clones PB 260 and PB 235 showed higher girth increment. Highest girth increment during winter period was observed in the clone PB 311.

4.4 Onfarm evaluation of clones (1998)

Block trials were undertaken in planters' field at three locations using clones already selected in the preliminary evaluation trials. These clones included RRII 105, RRII 203, RRII 208, PB 235, PB 260, SCATC 88-13, Haiken 1 and RRIM 600.

5. Breeding and selection

5.1 Full-sib progeny evaluation

Of the 26 recombinants being evaluated with their parents, the progeny of PB 86 x Gl 1, Gl 1 x RRIM 600 and PB 86 x RRII 105 recorded maximum girth attainment.

5.1.1 Hybridization programme

A total of eight cross combinations were attempted during the main flowering season of 1998 through 747 hand pollinations. The Wickham x Amazonian crosses gave higher fruit set as well as germination percentage in comparison to the W x W crosses. Hybrid seedlings are being maintained in the seedling nursery. During the main flowering season of 1999, 15 cross combinations were tried through 2338 pollinations.

5.2 Half-sib progeny evaluation (1994)

A total of 49 half-sibs along with their female parents and possible male parents were included in this trial following 8 x 8

simple lattice design with two replications. Girth recorded at a height of 150 cm from the bud union during the year revealed that progeny of PB 5/51 attained the highest girth followed by GT 1 and RRIM 600 in comparison to their respective parent values (Table Net. 5). The trees were opened for test-tapping and monthly dry rubber yield is being recorded.

Table Net. 5. **Girth of female parents and their half-sib progeny**

Female parent	Girth (cm)	
	Parent	Progeny
GT 1	29.58	34.09 (15.24)
RRII 203	30.76	31.50 (2.41)
PB 5/51	24.00	31.66 (31.92)
PB 86	29.27	29.55 (0.96)
RRIM 600	27.94	30.16 (7.94)

Percentage increase over parent is given in parentheses

5.3 Evaluation of polyclonal seedlings

Data on growth, yield and secondary characters of seedling population were recorded. The dry rubber yield during the fourth year of tapping revealed population mean value of 23.50 g/tree/tap. However, the yield of individual trees ranged from 2.86 to 78.35 g/tree/tap over the years. The seedling population attained a mean girth of 70.4 cm. Based on the yield performance of individual trees for four years, 10 high yielding elite trees were selected and multiplied for evaluation in small-scale trial.

5.4 Investigations on Genotype x Environment interactions (1996)

This trial was started in 1996 with 13 clones including five pipeline clones and their parents. The mean girth recorded at the age of 34 months after field planting revealed that among the 13 clones, the hybrid pipeline clone 82/29 attained the highest girth of 16.54 cm at a height of 150 cm from the bud union (Table Net. 6). Clone RRIC 100 was found susceptible to low temperature and the incidence of *Corynespora* leaf disease was also noticed.

Table Net. 6. **Girth of the clones**

Clone	Girth (cm)
RRII 5	13.21
RRII 105	12.42
RRII 176	12.72
RRII 203	14.19
82/14	12.12
82/17	12.41
82/22	12.35
82/29	16.54
82/30	14.41
PB 217	13.66
PB 235	12.57
RRIM 600	12.97
RRIC 100	10.39
CD (P=0.05)	1.71

6. Conservation and evaluation of germplasm

Two germplasm evaluation trials were initiated during 1993 and 1994. The first trial consists of 24 wild Brazilian genotypes in three replicates and the second trial consists of 63 wild genotypes in two replications with RRIM 600 as control. These germplasm materials are being evaluated for their performance regarding growth and disease resistance.

Data on girth are being recorded at quarterly intervals. In the first trial, the girth ranged from 11.5 to 18.8 cm in different genotypes, where population mean girth being 14.9 cm over five years and in the second trial, it ranged from 8.9 to 19.7 cm with a population mean of 13.4 cm.

7. Physiological and exploitation studies

7.1 Effect of different tapping systems in combination with tapping rests during winter

The study in RRIM 600 on effect of different tapping systems viz. 1/2S d/1, 1/2S d/2 and 1/2S d/3 in combination with low temperature rests during winter based on minimum temperatures of 20 – 20°C, 15 – 15°C, 10–10°C regimes and control (without annual rest) revealed that though the 1/2S d/1 system for all the combinations showed a high annual yield, the occurrence of TPD was found relatively high. Analysis of yield data showed a high significant relation between the sub-plot treatments of the temperature regimes. The average yield (g/tree/tap) was high for the continuous system of 1/2S d/3 tapping and also in 20 - 20°C rest. But, high annual yield was observed in 1/2S d/2 system of tapping with 15 – 15°C temperature rest and with a low incidence of partial TPD. However, 1/2S d/3 system of tapping performed better than 1/2S d/2 system, when minimum temperature is below 10°C during January. Occurrence of TPD was also more during cold period compared to other seasons and TPD incidence was the least in 1/2S d/3 system. It appears that low frequency tapping is favourable during low temperature period.

The one year data of the onfarm trial in clone RRII 105 with 1/2S d/2 system of tapping in combination with low temperature rests of 15 – 15°C, 12 – 12°C and 10 – 10°C with annual rest showed that the 1/2S d/2 system with 12– 12°C regime of temperature rest is performing better than that of the other combinations with very low incidence of TPD.

7.2 Effect of stimulation and intensive tapping towards occurrence of TPD

The normal plants were subjected to frequent tapping and stimulation treatment to accelerate the occurrence of TPD syndrome. The Electron Paramagnetic Resonance (EPR) response of free radical (FR) showed that with progression of exploitation, the amount of quinolic-FR increased. An initial increase in the activity of superoxide dismutase (SOD) was also observed with tapping and declined subsequently with time. The study also revealed that in frequently tapped plants (on excessive wounding), the amount of FR is lesser than that of the stimulated plants though the extent of decrease in scavenging enzyme viz. SOD is more in the frequently tapped trees. While considering the consequence of such disorder in terms of occurrence of TPD, it was observed that the percentage of TPD is more in the frequently tapped trees than that of the stimulated one; however, the normal plants showed negligible TPD syndrome. The yield showed negative correlation with total sugar and thiol content of latex in all the treatments during winter. There was a drop of yield by 40 to 50 per cent with a low DRC of 22 to 20 per cent when the minimum temperature went below 12–10°C.

7.3 Effect of soil moisture and agroclimatic parameters on yield

The experiment was continued from October 1996 with five clones viz. GT 1, RRII 105, RRII 118, PB 235 and RRIM 600 of 1987 planting in completely randomized design. Seasonal variability of soil moisture (volumetric) was observed at 0 - 30 cm. However, soil moisture may not be directly influencing the yield as the moisture content did not go below wilting point.

A decreasing trend in yield was observed from December along with the decline in minimum temperature showing a positive relation between each other. The yield (g/tree/tap) among five clones showed that the yield during 1998-99 was higher than the previous years. Variability in total solid content (TSC) and its mineral contents viz.

Ca, Mg, K and Cu were also observed. TSC showed a positive relation with yield, maximum and minimum temperature, with a decreasing trend in cold period. Analysis of biochemical parameters viz. sugar, thiol and inorganic phosphate from latex depicted seasonal and clonal variability. Consistent increase of thiol was observed with the decline of minimum temperature during the onset of cold period coupled with the decrease in yield showing its significant negative relations with yield and low temperature.

7.4 Physiological and biochemical studies for cold tolerance

The experiment was initiated during October 1998 with five clones viz. RRIM 600, PB 235, RRII 105, RRIC 100 and Haiken 1 in polybags in completely randomized design. Carbon dioxide exchange rate (CER) has shown significant reduction during January and February in comparison to the rate obtained in November and March indicating low CO_2 assimilation during cold period. Average of CER in January and February was higher in the clones PB 235, Haiken 1 and RRIM 600 than others. Differential response in soluble protein content of leaf has been noted with fairly increasing trend during winter. The initial reading in electrical conductivity in cell leachate of sampled leaf discs has not revealed any significant change in pre-winter and winter period. Two types of partial shades viz. transparent polythene sheet allowing about 50 per cent and cora cloth allowing 25 per cent of incident light were imposed in mid-December with a parallel control having no shade. Overall growth was better under 50 per cent shade.

7.5 Effect of cold on yield components

The experiment has been initiated during July 1998 in clone RRIM 600 of 1986 planting to study the effect of cold on major yield contributing factors under the Tripura conditions. Girth, initial flow rate, plugging index and dry rubber content (DRC) has been recorded at monthly intervals from selected 35 trees with periodical recording of block yield. Plugging index and DRC have shown a decreasing trend during the winter period.

8. Prediction of yield by antecedent atmospheric parameters

Evapotranspiration has been estimated for Agartala from 1994-98. Programmes for running large yield matrices for daily yield have been developed. In order to ascertain the predictive potential of yield on a weekly basis, a Markov Chain Model has been fitted to study the yield consistencies over a two-year period. The water balance parameters have been worked out over this period and parameters of relative rainfall and relative evapotranspiration have also been worked out and correlated with that of the yield probabilities. The probability estimate also gives a picture of a stable forecast of yield in different weeks of a year.

The period between the last week of December and the fourth week of February showed high yield potential with a variation of 6 to 17 per cent for all systems of tapping (1/2S d/1, 1/2S d/2, 1/2S d/3). The probabilities for yield at respective weeks showed a negative correlation with that of minimum and maximum temperatures. From the water balance estimates taken over two years, the excess water (P-PE) during the rainy months had showed a negative impact on yield while a positive impact is seen with periods of water deficit. This is also attributed to the direct effect caused due to low sunshine hours during the period. This period coincides with low minimum temperatures occurring during the winter season. Mean monthly agrometeorological data from six stations viz. Agartala, Guwahati, Tura, Kolasib, Nagrakatta and Dhenkanal for the year 1998 are furnished in Table Net. 7.

Table Net. 7. **Agrometeorological data (1998) of different stations in non-traditional and NE regions**

Month	Temperature		Relative humidity		Wind speed	Sun-shine	Evaporation	Rainfall
	Maximum (°C)	Minimum (°C)	AM (%)	PM (%)	(km/h)	(h)	(mm)	(mm)
Agartala								
January	22.4	11.5	94	59	1.5	6.3	2.2	000.0
February	27.5	14.5	89	42	2.4	7.3	2.1	009.4
March	29.9	22.0	91	43	3.3	8.1	3.0	131.6
April	31.4	22.1	91	61	3.9	6.5	2.8	221.4
May	32.2	24.5	90	69	3.8	5.6	2.9	406.5
June	33.3	26.2	89	70	7.4	5.1	2.8	136.6
July	30.7	25.6	92	83	7.1	2.6	1.9	527.0
August	31.4	25.8	92	81	5.9	3.3	2.2	165.2
September	32.4	25.6	92	77	2.6	5.2	1.9	231.3
October	32.4	24.4	91	73	1.7	6.4	2.3	058.4
November	30.2	19.5	93	62	1.4	7.4	1.9	013.9
December	27.9	13.6	93	51	0.9	8.9	1.3	000.0
Tura								
January	23.0	08.1	86	53	1.6	7.0	2.2	000.0
February	25.6	10.0	84	57	2.1	6.4	2.9	015.0
March	27.2	11.2	83	51	3.0	7.7	3.4	020.0
April	30.1	16.1	79	61	2.6	8.2	2.7	129.7
May	30.9	20.6	85	70	3.4	6.7	3.5	023.2
June	31.7	21.5	89	80	3.2	4.5	3.3	194.6
July	30.2	22.8	91	84	2.2	3.7	2.7	541.8
August	30.1	22.8	87	89	1.8	2.9	2.7	332.6
September	29.2	20.7	93	84	1.8	4.3	2.6	336.0
October	30.3	19.6	89	80	2.0	5.9	2.6	248.0
November	30.0	15.1	79	64	1.6	7.1	2.4	000.0
December	27.4	11.3	87	67	2.4	7.4	2.8	000.0
Guwahati								
January	24.5	10.7	91	60	—	5.7	1.5	000.0
February	27.2	11.4	85	46	—	7.5	2.2	018.0
March	27.2	13.8	87	47	—	6.9	2.5	104.3
April	30.8	19.1	91	68	3.1	7.2	2.3	111.8
May	33.8	23.2	91	64	2.4	6.8	1.9	058.8
June	26.7	24.8	93	77	1.5	3.0	1.8	355.0
July	33.1	24.6	95	81	1.2	3.3	1.9	284.8
August	31.7	24.4	95	81	1.5	2.9	1.9	354.8
September	31.5	23.5	95	88	1.4	4.0	1.2	098.0
October	30.8	21.8	94	78	2.0	5.0	2.1	199.7
November	28.8	19.4	93	71	2.2	6.9	2.2	004.0
December	26.2	14.5	91	70	1.8	7.2	1.5	000.0
Nagrakatta								
January	22.9	06.9	96	90	4.8	4.6	—	0000.0
February	29.6	10.1	96	86	1.2	7.1	—	0014.2
March	28.2	12.7	94	54	1.0	5.3	2.5	0115.6
April	31.0	18.8	94	67	0.9	6.8	3.0	0200.4
May	32.4	22.0	93	77	0.8	6.4	2.8	0008.8

Month	Temperature Maximum (°C)	Relative humidity Minimum (°C)	Wind AM (%)	Wind PM (%)	Sun-shine (h)	Evaporation (mm)	Rainfall (mm)	
					speed (km/h)			
June	31.0	24.4	95	80	0.9	1.9	1.3	1737.8
July	31.3	25.3	94	84	0.3	1.3	1.0	1154.3
August	31.0	23.5	96	84	0.0	1.9	0.8	1351.6
September	31.1	24.1	94	80	0.8	4.5	2.4	0426.9
October	31.4	22.6	91	75	0.3	6.9	2.0	0215.0
November	29.7	14.9	93	64	0.4	7.2	2.3	0007.4
December	27.9	08.7	93	51	1.2	8.0	3.3	0000.0
Kolasib								
January	26.5	11.6	89	67	—	4.7	1.6	013.0
February	28.6	13.9	90	56	—	6.0	1.8	040.4
March	31.6	14.9	89	57	—	8.1	2.1	165.0
April	33.0	19.9	91	68	—	5.9	2.5	160.4
May	33.3	23.0	92	74	—	2.8	3.0	223.1
June	34.2	23.4	93	80	—	2.3	1.9	406.9
July	33.7	24.0	93	76	—	2.9	1.2	285.5
August	33.4	24.3	93	76	—	1.1	3.9	475.4
September	34.2	24.2	92	69	—	—	2.0	174.4
October	32.2	22.8	92	81	—	—	2.0	060.3
November	31.5	19.9	94	85	—	5.8	2.7	052.6
December	29.3	12.9	90	84	—	7.9	2.5	000.0
Dhenkanal								
January	26.5	15.6	86	74	—	4.5	2.1	000.0
February	29.4	17.7	92	61	—	7.5	3.5	006.3
March	32.8	21.1	92	63	—	8.5	5.1	071.8
April	37.0	23.6	90	58	—	8.7	5.8	094.2
May	39.6	26.9	76	—	—	10.2	7.4	040.3
June	35.5	27.1	85	69	—	5.3	5.2	249.7
July	32.1	23.3	86	75	4.0	4.4	4.0	399.3
August	32.0	24.1	88	70	2.0	3.7	3.5	185.2
September	31.3	24.0	92	74	2.0	5.6	3.4	160.2
October	30.5	23.8	94	83	—	7.3	3.1	055.4
November	29.4	19.1	88	72	—	8.0	3.9	010.0
December	28.3	10.1	90	56	—	8.5	3.2	000.0

9. Processing technology

A study on the collection and processing of the scrap rubber was conducted at places like Agartala, Kolasib, Nagrakatta, etc. The study reveals that the scrap is not properly collected in many places due to the lack of processing facilities and low price return. The entire scrap has to be sold as such without any further processing.

A study was also conducted on the processability of latex into air-dried sheets (ADS). It was found that Nagrakatta is not suitable for air drying due to high rain but in other places air drying is possible. It was also observed that marketing facility for ADS is limited compared to smoked sheets. It was also found that since there is no creosotic protection to ADS from the smoke, alternative measures are to be taken to protect the sheets from mould growth.

10. Advisory service

The Regional Research Station, Agartala caters to the needs of all categories of rubber growers in the north-eastern region by site and situation-specific discriminatory fertilizer recommendation, based on soil and leaf analyses. During the reporting period, a total of 1272 soil samples and 385 leaf samples were analysed and 325 individual recommendations offered. The recommendations were offered to the growers of North Tripura, Silchar and Karimgang of Assam and some parts of Mizoram after collection of samples by the Mobile Soil and Tissue Testing Laboratory attached to this station. Advisory services have also been extended to 26 units on processing and product manufacturing during the reporting period.

REGIONAL RESEARCH STATION, TURA, MEGHALAYA

Various trials are in progress for the evaluation of high yielding and cold tolerant clones, low temperature effect on growth, yield and its components, suitable exploitation systems and selection of high yielding mother trees for Meghalaya region.

1. Field experiments at Ganolgre

1.1 Evaluation of clones

On the basis of girth recorded for 10 clones from the 1985 trial, RRIM 600 (71.88 cm) attained the highest girth followed by PB 235 (70.05 cm) and RRII 118 (69.82 cm) while least girth was recorded for PB 5/51 (58.15 cm). Similarly in the 1986 clone trial, the highest girth was recorded for RRIC 105 (72.86 cm) and PB 311 (69.37 cm) and the lowest for PR 255 (56.04 cm). In all the clones, girth increment was very low during January to March. During these months minimum average temperature was below 10°C which adversely affected the growth of all clones.

1.2 Performance of polyclonal population

It has been observed that polyclonal population has attained an average girth of 44.52 cm and among the population, 11 seedlings showed vigorous growth (above 50 cm girth) and are ready for tapping.

1.3 Rubber-based cropping system

Under this trial, rubber (RRIM 600), tea and orange have been planted in 1987 and the rubber plants were opened for tapping under 1/2S d/2 system. Maximum yield was recorded from September to November while minimum from December to March which may be due to wintering effect. A total of 497 kg green tea leaves were harvested from 0.25 ha which fetched a net income of Rs.2773. The growth of orange plants was very poor.

1.4 Ortet selection

On the basis of growth, bark thickness, disease resistance, TPD incidence and yield performance, mother trees were selected from different locations of Garo Hills for budwood collection and further multiplication.

1.5 Optimum season for budding

The experiment to find out the suitable season for budding under the agroclimatic conditions of Garo Hills has been repeated and the results indicated that July, August and September are suitable for budgrafting, due to favourable temperature and soil moisture.

1.6 Evaluation of germplasm

Under this trial, 151 germplasm genotypes were planted in the polybag at Ganolgre farm for screening for resistance to cold and *Oidium* disease.

2. Field experiments at Darechikgre

In the clone evaluation trial, it has been noticed that due to high altitude (1100 m above msl) and low temperature, among the 500 plants, only 30 plants have survived and

growth of these plants is found retarded showing an average girth of 18 cm at the end of the 13th year. The rubber cultivation at this elevation is not advisable under Garo Hills conditions.

3. Pathological studies

A disease survey was conducted at various locations. Severe outbreak of powdery mildew was observed in the Garo Hills region of Meghalaya. At Ganolgre farm and District Development Centre, Jenggitchakgre farm, nearly 80 per cent of the total plants were infected by *Oidium* disease and defoliation of the young tender leaves was observed during March to April. Sulphur powder was dusted (22 kg/ha) at different time intervals to bring the disease under control.

4. Physiological investigations

4.1 Effect of cold on growth, yield and yield components

An experiment has been initiated to find out the effect of low temperature on growth, yield and yield components of *Hevea* at 600 m altitude. Under this trial, one block of 300 plants (RRIM 600) was selected for girth recording and 35 plants for plugging index, DRC and dry rubber yield at monthly interval. Results indicated that RRIM 600 has attained an average girth of 59.8 cm but when temperature drops below 10°C for three months, there was a complete retardation of growth. Maximum yield was recorded from September to November (21.0 g/tree/tap) while yield decreased from December till March when minimum temperature dropped below 10°C causing defoliation. As temperature increased, all plants refoliated and yield increased simultaneously.

4.2 Effect of different tapping systems in combination with tapping rests during winter

The effect of different exploitation systems in combination with tapping rests at different temperature regimes during winter was assessed in clone RRIM 600 to formulate suitable exploitation systems for this region. Initial results showed that when temperature falls below 10°C there is a drop in yield of rubber in 1/2S d/1, 1/2S d/2 and 1/2S d/3 tapping systems which may be due to wintering stress. Increase in yield has been noticed with increase of temperature in all the tapping systems.

REGIONAL RESEARCH STATION, KOLASIB, MIZORAM

The Regional Research Station, Kolasib conducted experiments mainly to identify the suitable clones under Mizoram conditions. The Station also engaged in studies on soil fertility, nutritional requirements of rubber and identification of suitable exploitation systems.

1. Nutritional trial (1998)

The field experiment was initiated during 1998 to assess the NPK requirement of clone RRIM 600 for foot hill region of Mizoram. The data on girth (1998) and girth increment from December 1998 to February 1999 are presented in Table Nez. 1.

The results indicate that the growth of RRIM 600 was better by application of 35:35:35 NPK in foot hill.

Table Nez. 1. Effect of different doses of fertilizers on girth and girth increment

Nutrient (NPK)	Girth (cm)	Girth increment (cm) Dec '98 to Feb '99
00:00:00	38.30	0.25
20:20:20	38.80	0.14
35:35:35	40.00	0.21
50:50:50	38.40	0.20

Table Nez. 2. **Clonal difference in girth and girth increment at different landforms**

Clone	Mean girth (cm) as on February 1999		
	Foot hill	Mid-hill	Hill top
SCATC 93-114	65.81 (4.24)	71.82 (8.93)	73.16 (6.78)
RRII 105	62.60 (4.90)	57.47 (5.41)	56.64 (5.71)
RRII 118	65.56 (4.72)	65.66 (5.81)	61.15 (1.79)
RRII 300	65.25 (4.57)	64.62 (4.94)	60.03 (4.57)
GT 1	63.33 (4.13)	66.22 (5.14)	70.58 (10.05)
PB 235	70.90 (6.13)	70.40 (10.35)	64.00 (4.90)
RRIM 600	50.00 (2.72)	55.80 (5.23)	58.88 (0.30)
Mean	63.35	64.57	63.49

Figures in parentheses are the annual girth increment

2. Evaluation of clones (1988)

The main objective of this study is to identify the clones suitable for the region. The performance of seven clones at foot hill, mid-hill and hill top has been studied in terms of growth and yield.

The data in Table Nez. 2 indicate the highest girth for PB 235 in foot hill followed by SCATC 93-114 and RRII 118. In mid-hill and hill top, growth of SCATC 93-114 was better. The yield of the clones was considerably high in foot hill as compared to mid-hill and hill top (Table Nez. 3).

Table Nez. 3. **Yield at different land forms**

Clone	Yield (g/tree/tap)*		
	Foot hill	Mid-hill	Hill top
SCATC 93-114	38.29	37.13	23.72
RRII 105	28.87	28.12	22.50
RRII 118	30.82	31.81	23.28
RRII 300	32.00	29.11	28.68
GT 1	29.67	28.48	24.77
PB 235	32.70	29.73	18.75
RRIM 600	30.66	27.92	20.19
Mean	31.85	30.32	23.12

* 1/2S d/2 system of tapping

3. Effect of tapping systems on yield

The study was initiated during 1998 with the objective to identify the suitable tapping system for blended clones of *Hevea*, specific to the Mizoram conditions. The clones include RRII 105 (15%), RRIM 600 (13%), SCATC 93-114 (16%), RRII 300 (15%), RRII 118 (13%), GT 1 (16%) and PB 235 (12%). The block yield for seven months under different tapping systems is being recorded.

4. Awareness and adoption of rubber cultivation practices : An analytical study of small growers in Mizoram

The study was undertaken to analyse the awareness and differential adoption behaviour, besides enumerating reasons for non-adoption of rubber cultivation practices for economic returns. The study also aims to provide information source utilization behaviour of Mizo-farmers, information dissemination behaviour, constraints faced in rubber cultivation and suggestions to overcome such constraints. About seven rubber growing villages and 75 respondents were selected using proportionate random sampling technique.

5. Soil studies

The morphology, physico-chemical properties and exchange characteristics of five representative pedons of rubber growing soils occurring at different altitudes in Mizoram were studied and classified as per soil taxonomy. The soils of pedon at altitudes 150, 280 and 750 m above msl were classified as Topic Hapludusts whereas soils at 400 and 550 m above msl were Umbric Dystrochrepts. Measures involving proper soil-water and nutrient management are important to increase use efficiency and optimizing land use on sustainable basis.

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REGIONAL RESEARCH STATION, NAGRAKATTA, WEST BENGAL

The Regional Research Station, Nagrakatta located in the northern part of West Bengal is spread over an area of 47.6 ha and the total planted area is 30 ha. During 1998-99, 7 ha was brought under tapping. The research activities are concentrated mainly on clone evaluation, nutritional trial and clone blend.

1. Nutritional studies

1.1 Nutritional requirement of *Hevea* with reference to Terai soils of West Bengal

The field trial started in 1989 on nutritional requirement of *Hevea* with reference to Terai soils of West Bengal was continued. Application of 40 kg N per ha showed significant effect on girth over 0 and 20 kg per ha but was on par with 60 kg N per ha (Table Nag. 1). Application of P and K and their interaction did not show any effect.

Preliminary yield recorded in November 1998 (Table Nag. 2) showed significant interaction effect of P and K on rubber yield (g/tree/tap). At 0 and 20 kg P levels, 40 kg K application showed depressing effect on rubber yield compared to 0 and 20 kg K. However, at 40 kg P levels, higher levels of K (40 kg/ha) showed positive effect but on par with other levels. Trees attained maturity and tapping was started in 1998. Considering the growth response to nutrient application during immaturity period, N levels have been changed from 0, 40 and 60 kg per ha to 0, 15, 30 and 45 kg per ha during maturity period from 1998. Levels of

Table Nag. 1. **Effect of N, P and K on girth (cm) during ninth year**

Nitrogen	0P				20P				40P				Mean of N
	0K	20K	40K	Mean	0K	20K	40K	Mean	0K	20K	40K	Mean	
0N	50.5	50.7	52.6	51.3	46.9	52.4	50.7	50.0	51.3	53.9	50.5	51.9	51.1
20N	51.2	53.8	51.3	52.6	52.6	52.0	52.9	52.5	51.7	51.3	54.4	52.5	52.3
40N	51.5	54.3	53.6	53.1	51.3	53.4	54.2	53.0	54.4	53.5	51.2	53.1	53.1
60N	52.2	53.6	56.3	54.0	52.0	52.2	51.1	51.8	53.9	53.8	52.5	53.4	53.1
Mean	51.4	53.1	53.4	52.6	50.7	52.5	52.2	51.8	52.8	53.1	52.2	52.7	52.4
	N	P	K	NP	NK	PK	NPK						
SE	0.46	0.4	0.4	0.8	0.8	0.7	1.4						
CD (P=0.05)	0.5	NS	NS	NS	NS	NS	NS						

Table Nag. 2. **Effect of N, P and K on yield (g/tree/tap) during ninth year**

Nitrogen	0P				20P				40P				Mean of N
	0K	20K	40K	Mean	0K	20K	40K	Mean	0K	20K	40K	Mean	
0N	24.2	19.5	15.3	19.6	19.9	25.7	14.3	19.9	12.4	21.3	21.4	18.3	19.7
20N	18.8	22.3	16.5	19.2	18.3	21.8	18.7	19.6	19.5	19.4	21.9	20.3	19.7
40N	17.1	20.5	15.2	17.6	19.1	20.1	11.3	16.8	18.1	14.9	21.0	18.0	17.4
60N	18.5	17.9	16.3	17.5	16.7	18.6	14.4	16.6	19.7	20.2	20.7	20.2	18.1
Mean	19.6	20.0	15.8	18.5	18.5	21.5	14.6	18.2	17.4	18.9	21.2	19.2	18.6
	N	P	K	NP	NK	PK	NPK						
SE	0.97	0.91	1.68	0.84	1.68	1.45	2.91						

P and K (0, 20 and 40 kg/ha) were not changed.

1.2 Nutrient use efficiency of rubber under Dooars area of West Bengal

The trial started in 1993 to evaluate the effect of fertilizer split application on *Hevea* growth under the agroclimatic conditions of the northern part of West Bengal was continued. Unlike previous years, the effect of fertilizer split application on girth and girth increment during fifth year subsided and did not show any significant effect.

2. Evaluation of clones

2.1 Clone trial (1990a)

Clone evaluation trial started in 1990 with 11 different clones was continued. Trees were opened for tapping in 1998. Observations on girth, girth increment and mean rubber yield (g/tree/tap) were recorded and presented in Table Nag. 3. Girth varied significantly among the clones. RRIM 703, SCATC 93-114, RRII 118, RRII 203 and Haiken 1 recorded significantly higher girth over PB 5/51 and RRII 300. Annual girth increment after commencement of tapping did not vary significantly among the clones. SCATC 88-13, PB 311 and PB 235 recorded more yield compared to SCATC 93-114, RRIM 703 and Haiken 1.

Table Nag. 3. **Clonewise girth, girth increment and mean rubber yield during first year of tapping**

Clone	Girth (cm)	Annual girth increment (cm)	Mean yield (g/tree/tap)
SCATC 88-13	55.3	2.7	45.6
SCATC 93-114	56.2	2.8	9.1
RRII 118	56.1	2.7	27.9
RRII 203	56.1	1.5	26.5
RRII 300	51.2	4.1	26.3
GT 1	52.4	2.7	23.6
Haiken 1	55.9	3.0	21.9
PB 235	55.3	1.2	31.0
PB 311	52.8	1.5	39.4
PB 5/51	49.0	2.4	25.1
RRIM 703	56.7	1.9	21.7
SE	1.5	0.6	—
CD (P=0.05)	4.5	NS	—

2.2 Clone trial (1990b)

Clone evaluation trial laid out in 1990 with seven different clones was continued. Trees were opened for tapping in 1998. Observations on girth, girth increment and mean yield (g/tree/tap) were recorded and presented in Table Nag. 4. Girth and girth increment varied significantly among the clones. RRIM 612 recorded significantly higher girth and girth increment compared to other clones. RRII 105, RRIM 605 and Gl 1 recorded higher yield compared to RRIM 612.

Table Nag. 4. **Clonewise girth, annual girth increment and rubber yield during first year of tapping**

Clone	Girth (cm)	Annual girth increment (cm)	Mean yield (g/tree/tap)
RRII 105	54.0	3.0	34.9
RRII 208	55.2	3.2	26.5
PR 107	50.9	3.2	23.5
Gl 1	52.1	3.4	27.1
PB 86	55.0	4.6	22.9
RRIM 605	57.1	3.9	27.4
RRIM 612	58.1	5.2	13.3
SE	0.9	0.4	—
CD (P=0.05)	2.8	1.3	—

2.3 Clone trial (1991)

Clone evaluation trial planted in 1991 involving 11 clones was continued. Girth and annual girth increment did not vary significantly among the clones. However, RRIM 612, RRIC 102, SCATC 93-114 and Haiken 1 showed better girth and girth increment.

2.4 Clone trial (1993)

Clone evaluation trial planted in 1993 involving 11 clones was continued. Girth

Table Nag. 5. **Clonewise girth and annual girth increment during eighth year**

Clone	Girth (cm)	Annual girth increment (cm)
SCATC 93-114	35.9	7.8
Haiken 1	32.7	7.3
RRII 105	36.2	6.5
RRII 205	36.1	6.7
RRII 300	34.3	6.7
RRII 308	25.9	5.0
PR 261	32.1	6.6
PB 235	32.2	6.7
PB 280	28.0	7.7
RRIM 600	38.4	6.3
RRIC 104	26.5	5.5
S.E	1.9	0.4
CD (P=0.05)	5.5	1.2

and annual girth increment varied significantly among the clones (Table Nag.5). RRIC 104 and RRII 308 recorded significantly low girth and girth increment over all other clones. Significantly higher girth (38.4 cm) was recorded by RRIM 600 and annual girth increment (7.8 cm) by SCATC 93-114.

2.5 Genotype x Environment interaction studies

Multilocational trial planted in 1996 was continued to study the Genotype x Environment interaction in 12 different clones. The clone 82/29 recorded significantly higher girth over all other clones except RRII 176, PB 217 and RRII 105. Lowest girth was recorded by RRIC 100 and 82/22 which also showed susceptibility to cold injury during winter (Table Nag.6).

3. Clone blend

A multilocational trial planted in 1992 to evaluate the performance of different clone blends in comparison to monoclonal population of RRII 105 has been continued. Data on girth were recorded and performance of clone blends shall be evaluated at maturity.

Table Nag. 6. **Clonewise girth during third year**

Clone	Girth (cm)
82/14	16.6
82/17	16.3
82/22	14.7
82/29	19.4
82/30	16.6
RRII 105	17.7
RRII 176	19.0
RRII 203	17.1
PB 217	17.8
RRIM 51	16.3
RRIM 600	17.4
RRIC 100	11.2
SE	0.93
CD (P=0.05)	1.93

4. Exploitation systems

An experiment on the effect of combination of tapping systems (1/2S d/1, 1/2S d/2, 1/2S d/3) with tapping rest based on temperature regime (18-18°C, 15-15°C and 12-12°C) and control without rest has been planned. Treatments will be imposed in a RRIM 600 block during October 1999. Experimental design is split-plot design with tapping system as main plot and temperature rest as sub-plot treatment.

5. Evaluation of germplasm for cold tolerance

A hot spot trial to evaluate germplasm (4 Wickham, 4 Mato Grosso, 6 Acre and 11 Rondonia collection) for cold tolerance was initiated in 1998 in simple lattice design with two replications to study the morphological, physiological, biochemical and anatomical characters of genotypes which enable to adapt to cold conditions. During first year, RO 2635 recorded significantly higher girth over AC 607, AC 623, MT 2594, RO 6139 and RO 5408 but on par with other germplasm materials (Table Nag. 7). Significant clonal variation was observed in sustaining cold stress. Among the 11 clones which showed cold injury, the

Table Nag. 7. Girth and cold injury during first year

Germplasm	Girth (cm)	Number of plants injured
RRII 105	4.9	2
GT 1	6.2	0
Gl 1	5.7	0
PB 260	5.6	0
AC 68	6.4	0
AC 607	2.3	9
AC 619	4.9	1
AC 623	4.6	2
AC 763	5.0	5
AC 1950	4.8	0
MT 44	6.0	1
MT 196	5.4	0
MT 2229	6.2	0
MT 2594	2.0	13
RO 2629	5.5	0
RO 2635	6.9	0
RO 2890	5.3	1
RO 3172	5.0	1
RO 5329	5.3	0
RO 5348	5.2	0
RO 5363	6.1	0
RO 5408	4.7	0
RO 5430	6.2	1
RO 5557	5.2	2
RO 6139	4.6	0
SE	0.32	—
CD (P=0.05)	2.1	—

injury was severe for MT 2594, AC 763 and AC 607.

6. Feasibility study on intercropping of rubber with tea in northern part of West Bengal

A feasibility study on the possibility of intercropping rubber with tea has been initiated and field preparation and planting is to be done in June/July 1999. Four different spacings (10 x 2.5 m, 10 x 5 m, 12 x 2.5 m, 3 x 3 x 18 m) for rubber will be tried and in the inter-rows, tea will be planted at normal spacing leaving 2.5 m space on either side of rubber line.

7. Role of zinc in the control of powdery mildew disease

An experiment on control of powdery mildew disease using zinc has been initiated in split-plot design with zinc level as main plot and sulphur dusting as sub-plot treatment. Main plot treatments include 5 ml chelazin per L as foliar application, 7.5 ml per L as soil application and zinc sulphate having a concentration of 2 g per L as foliar application, 3 g per L as soil application. With and without sulphur dusting as sub-plot treatments will be tried to compare effectiveness of zinc in controlling powdery mildew.

REGIONAL RESEARCH STATION, DAPCHARI, MAHARASHTRA

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

The RRS covers an area of 50 ha (planted area 36 ha) and total crop production during the period (April 1998 to March 1999) was 18093.19 kg from 18 blocks.

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 girth increment was higher in plants under control and basin irrigation (1.00 ETc and 0.75 ETc) than other lower levels of irrigation under basin (0.50 ETc) and drip, due to less exploitation of the control trees (newly opened) and compensation of soil moisture deficit under saturated irrigation levels. The dry rubber yield of all the irrigation levels is comparable except the control and 0.25 ETc drip due to severe soil moisture deficit during summer.

Table Dap. 1. **Effect of irrigation on growth and yield (April 1998 to March 1999)**

Treatment	Girth (cm)	Mean girth increment (cm)	Mean dry rubber yield (g/tree/tap)
1.00 ETc basin	61.82	2.16	50.50
0.75 ETc basin	62.33	2.46	52.22
0.50 ETc basin	58.94	1.48	52.40
0.75 ETc drip	59.16	1.56	51.25
0.50 ETc drip	59.39	1.38	53.57
0.25 ETc drip	56.67	1.55	46.91
Control (No irrigation)	52.77	2.79	44.28
SE	1.05	0.31	2.60
CD (P=0.05)	2.28	0.68	5.67

2. Effect of irrigation on yield and yield components

The trial was laid out in 1983 to study the effect of irrigation (1.00, 0.75 and 0.50 ETc) on yield and yield components of two clones, RRII 105 and RRII 118. The clone RRII 118 recorded better growth than RRII 105 in all irrigation treatments. On the contrary, RRII 105 recorded better yield and yield component characters in all the treatments. The irrigation treatments showed non-significant effect on growth and yield parameters (Table Dap. 2).

3. Clone trial

Among the 15 clones, RRII 208 is continuing to perform better in respect of growth, whereas RRII 105 is better in terms of yield than the others. The clones RRII 308 and RRIC 105 are poor in terms of growth and yield (Table Dap. 3).

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

Clone	Girth (cm)	Mean dry rubber yield (g/tree/tap)
RRII 5	51.62	22.58
RRII 6	55.68	25.78
RRII 105	51.77	33.09
RRII 208	59.16	26.81
RRII 308	49.32	23.30
PR 255	50.38	21.94
PR 261	49.81	23.31
PB 260	51.26	25.83
PB 310	51.50	20.49
PB 311	50.48	24.02
RRIM 605	50.34	25.12
RRIC 52	57.18	16.08
RRIC 100	53.56	25.99
RRIC 102	54.74	21.53
RRIC 105	51.35	15.97
SE	2.68	3.05
CD (P=0.05)	5.48	6.24

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	63.38	75.23	41.59	31.64
0.75 ETc	62.74	76.83	39.03	37.18
0.50 ETc	59.88	68.13	47.30	30.69
Control (No irrigation)	54.12	60.41	37.29	29.17
For irrigation				
SE		3.41		3.27
CD (P=0.05)		8.34		8.01
For clones				
SE		1.37		1.75
CD (P=0.05)		3.16		4.04

4. Silt pits for soil and water conservation

Various frequency of silt pits (100, 150 and 200 pits/ha) with or without sawdust (10 kg sawdust/pit) are maintained in polyclonal seedling area since June 1995. Soil moisture retention during the post-monsoon period is found to be higher in 150 pits per ha and 150 pits per ha + 10 kg sawdust treatments at 30-60 cm soil depth level.

5. Cost evaluation trial

Expenses incurred towards various inputs, farm practices and irrigation are being monitored since 1987 in irrigated and unirrigated RRIM 600 trees. No significant reduction in block yield and growth was observed in mature trees under tapping even after reducing the irrigation level to 50 per cent of that under immature phase.

6. Polyclonal seedlings for selection

Promising polyclonal trees with high girth and high yield were selected for multiplication and study. Multiplication of these trees was done by budding for laying out a field trial.

REGIONAL RESEARCH STATION, DHENKANAL, ORISSA

The Regional Research Station, Orissa situated in Dhenkanal district, is concentrating research on agromanagement techniques, water conservation and clone evaluation for specific drought-prone areas of this region. This Station has a research farm at Kadalipal covering an area of 30.8 ha.

1. Clone evaluation

1.1 Clone trial (1987)

This trial comprised of three elite clones (RRIM 600, GT 1, RRII 105). Maximum girth was recorded in GT 1 (49.0 cm) followed by RRIM 600 (48.4 cm) and RRII 105 (44.0 cm) (Table Ori. 1).

Table Ori. 1. **Mean girth of three clones**

Clone	Girth (cm)
RRII 105	44.0
GT 1	49.0
RRIM 600	48.4

1.2 Polyclonal seedlings (1989)

Observations indicated high girth variation within the population. A total of 536 trees having girth of 50 cm or above have been identified for evaluating the yield and stability in this drought-prone area for further selection.

1.3 Clone evaluation (1990)

Growth recorded in 10 clones from 1990 trial revealed maximum girth for SCATC 93-114 (47.3 cm) and minimum for SCATC 88-13 (36.8 cm) (Table Ori. 2).

Table Ori. 2. **Growth of different clones**

Clone	Girth (cm)
SCATC 88-13	36.8
SCATC 93-114	47.3
Haiken 1	40.7
RRII 5	45.5
RRII 208	47.1
RRII 300	42.8
PR 255	46.6
PB 301	44.4
RRIM 600	46.2
RRIM 701	38.8

1.4 Clone trial (1991)

In the clone trial 1991, the clone RRIC 102, RRII 300, GT 1, RRII 208, RRII 105 and the polyclonal seedlings exhibited better drought tolerance in this region (Table Ori. 3). Maximum girth 45.1 cm was noticed in polyclonal seedlings and the lowest girth in PR 255 (29.8 cm).

2. Nutrient management

The experiment was laid out in 1997-98 in seedling nursery with N and P biofertilizers alone and in combinations with FYM and N, P and K at three levels (0, 25 and

Table Ori. 3. **Growth of different clones**

Clone	Girth (cm)
RRII 5	35.7
RRII 105	36.9
RRII 208	40.9
RRII 300	42.9
GT 1	42.8
PR 255	29.8
PR 261	32.6
RRIM 600	35.2
RRIC 102	43.2
Polyclonal	45.1

100%) of the recommended dose. The growth parameters were recorded during the period and soil and leaf samples have been collected for microbial and chemical analysis.

3. Genotype x Environment interaction

This onfarm trial at Regional Research Laboratory, Bhubaneswar included twelve clones planted during 1996. After three years of planting, maximum girth was recorded in PB 217 (19.4 cm) followed by 82/30 (19.3 cm), RRIC 100 (19.2 cm), RRII 203 (19.0 cm) and 82/17 (18.8 cm) while 82/14 and RRII 176 showed the lowest girth of 16.4 and 16.7 cm respectively (Table Ori. 4).

4. Agrometeorological observatory

The general weather parameters recorded during the year 1998 at RRS Kadalipal (Dhenkanal), Orissa indicated total rainfall of 1272.4 mm with only 76 rainy days. The highest mean maximum temperature of 39.6°C was recorded during the month of May 1998. The highest mean minimum temperature of 27.1°C was observed in June 1998 against the lowest minimum of 10.1°C in December 1998. Lowest relative humidity was observed during the months of April and May, especially during the afternoon hours.

Table Ori. 4. **Growth of different clones**

Clone	Girth (cm)
82/14	16.4
82/17	18.8
82/22	17.3
82/29	18.3
82/30	19.3
RRII 5	17.2
RRII 105	17.0
RRII 176	16.7
RRII 203	19.0
PB 217	19.4
RRIM 600	18.1
RRIC 100	19.2

5. Nursery

In the budwood nursery, a total of 22 genotypes having 412 points are maintained. In the seedling nursery, polyclonal and assorted seedlings were established during the period for generating planting materials for laying out new experiments at the research farm. Approximately 3560 budded stumps of RRIM 600, RRII 105 and GT 1 were raised as planting materials and 2500 polyclonal materials were maintained.

REGIONAL RESEARCH STATION, SUKMA, MADHYA PRADESH

The RRS, Sukma in Bastar district, Madhya Pradesh continued research activities on screening of *Hevea* germplasm for drought/cold tolerance, evaluation of polyclonal and modern clones and niche analysis concept in Madhya Pradesh.

1. Multidisciplinary evaluation of clones

In the clone trial started in 1990, RRII 105 and RRIM 600 have recorded 51.5 and 46 cm girth respectively.

2. Sreening of *Hevea* germplasm for drought tolerance

Selected genotypes of Brazilian germplasm together with a few modern clones were planted in field during July 1996, to indentify genotypes suitable for drought-prone conditions. Growth of clones differed significantly. Clones RO 5363, RO 2635,

RO 3172, RO 5463, RO 5554, RRII 118 and GT 1 showed higher girth while AC 685 and AC 623 exhibited poor growth.

3. Screening of *Hevea* germplasm for cold tolerance

The budded stumps of *Hevea* germplasm for cold tolerance were generated at RRS Sukma and sent to RRS, Nagrakatta. Field planting was undertaken in July 1998 with 25 Brazilian germplasm clones at RRS Nagrakatta, which experiences low temperature during winter season.

4. Evaluation of polyclonal seedlings

The growth of polyclonal plants, planted in 1997, is being monitored. The growth of plants is satisfactory with a mean girth of 7.5 cm.

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

Significant variation in pattern of growth has been observed among the clones. Branching height and number of branches (originated from main stem) also varied significantly. The lowest number of primary branches was observed in AC 707 and highest in RO 5369 and MT 196.

REGIONAL RESEARCH STATION, PADIYOOR, KERALA

The Regional Research Station at Padiyoor covers an area of 40 ha. Long-term trials laid out in 24 ha include evaluation of Brazilian germplasm (1981 IRRDB collection), investigations on Genotype x Environment interaction, clone evaluation (World Bank project), large-scale testing of potential hybrid clones, multiclone blend trial and disease evaluation in various clones.

1. Physico-chemical characterization of soil

Experiment to generate a database on soil physico-chemical properties has been initiated in 1998. Preparation of a slope map of the area under study is in progress.

2. Water requirement in seedling nursery

The experiment to study the water requirement in seedling nursery was initiated in 1998. Five irrigation regimes viz. irrigation at 0, 10, 25, 50 and 75 per cent depletion of available soil moisture were imposed along with an unirrigated control. Growth observation and soil moisture determination were carried out at periodic intervals.

3. Weather

July recorded the maximum total rainfall of 1153.2 mm with 30 rainy days. The summer months (January, February and March) received no rain. The highest maximum temperature recorded was 40°C in April 1998 while the lowest minimum temperature was 15°C in January 1999.

HEVEA BREEDING SUB-STATION, NETTANA, KARNATAKA

The experimental farm of the Station comprises an area of 47.6 ha. Different trials on clone evaluation, breeding and pathology are under progress.

1. Evaluation of growth, yield and exploitation systems

This trial constitutes two experiments, one planted in 1987 and the other in 1988 aiming at evaluating the effectiveness of different tapping systems in terms of yield and growth of the clones. Each experiment comprises of five clones planted in a split-plot design. In the first experiment, clone PB 235 (71.89 cm) continued to be superior in growth while RRII 300 (58.10 cm) was poor in growth (Table Kar.1). This trial is in the

Table Kar. 1. **Performance of different clones in 1987 and 1988 experiments**

Clone	Girth (cm)	Percentage girth increment			
		Apr-Jun	Jul-Sep	Oct-Dec	Jan-Mar
1987 experiment					
RRII 105	61.83d	1.15	0.64	0.58	1.00
RRII 300	58.10c	1.46	1.00	1.12	1.39
PB 235	71.89a	1.15	0.43	0.66	1.80
PB 260	66.13b	1.05	0.71	0.84	1.16
PB 311	63.70c	1.39	0.39	0.55	1.07
Mean	64.33	1.24	0.64	0.75	1.28
1988 experiment					
RRII 118	68.90a	1.55	2.84	1.60	1.42
PR 255	50.85d	1.77	0.61	1.38	1.45
PR 261	57.57b	1.26	1.61	1.73	1.07
RRIC 36	54.52c	1.68	1.46	1.50	1.50
RRIC 45	54.05c	1.32	1.81	1.55	1.21
Mean	57.18	1.52	1.67	1.55	1.33

Clones followed by same letters are not significantly different by LSD test at P=0.05.

second year of tapping and data on latex yield are being recorded for every tap. Considering the yield of the clones, PB 235 recorded the highest (134.6 ml/tree/tap) while RRII 300 showed the lowest (66.3 ml).

Under the different tapping systems employed, 1/2S d/3 recorded the highest average yield of 111.7 ml/tree/tap. The highest yield was recorded during November and December. In the second experiment, clone RRII 118 showed better growth in terms of girth (68.90 cm) while that of PR 255 was poor (50.85 cm).

In the trials, the leaf disease caused by *Corynespora* was observed during this year also. The clones PR 255, PR 261 and RRII 105 were found severely infected.

2. Evaluation of ortet clones

This trial comprises of three experiments each having the common control clones RRII 105, RRIM 600 and GT 1. The first two experiments have 17 constituent clones each, while the third experiment consists of 14 clones. Among the control clones, GT 1 showed better growth followed by RRII 105. Seven clones viz. O 15, O 46, O 47, C 1/2, C 7/2, C 70 and T 2 in Experiment 1 registered better girth increment over all the three control clones. Similarly, two clones (O 53 and C 9) in Experiment 2 and six clones (O 26, O 39A, O 51, O 55, O 56 and O 64) in Experiment 3 recorded higher girth increment over all the three control clones.

3. Large-scale clone trial

Two experiments, first with 14 clones planted during 1989 and second with 15 clones planted during 1990 constitute this trial. In the 1989 experiment, clone RRII 203 (67.18 cm) continued to be better in growth while Haiken 1 (43.54 cm) continued to exhibit poor growth (Table Kar. 2). In the 1990 experiment, clone PB 235 (54.59 cm) continued to record the highest growth in terms of girth while Gl 1 (45.24 cm) registered the lowest growth.

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

Clone	Girth (cm)*
1989 Experiment	
SCATC 88-13	49.76 de
SCATC 93-114	48.17 ef
Haiken 1	43.54 f
RRII 105	55.98 bc
RRII 203	67.18 a
RRII 300	56.28 bc
RRII 308	57.22 bc
PR 255	47.72 ef
PR 261	55.11 c
PB 255	56.96 bc
RRIM 600	53.45 cd
KRS 25	57.40 bc
KRS 128	60.85 b
KRS 163	58.45 bc
1990 Experiment	
HP 185	49.65 bcde
HP 187	47.90 def
HP 204	47.21 ef
HP 223	52.98 ab
HP 372	52.19 abc
RRII 105	59.79 bcd
GT 1	52.75 abc
Tjir 1	46.13 f
GI 1	45.24 f
PB 217	50.32 bcde
PB 235	54.59 a
PB 260	54.42 a
PB 311	50.75 bcd
Hil 28	49.16 cdef
Mil 3/2	50.83 bcd

Clones followed by same letters are not significantly different by DMRT at 0.05

4. Estimation of genetic parameters

This trial consists of 12 clones and their half-sib progenies planted during 1990 with the objective of estimating genetic parameters. The girth data for both parents and their progenies are being recorded at quarterly intervals. Among the parental clones, PB 235 (75.77 cm) recorded the highest growth in terms of average girth followed by RRII 118 (74.72 cm) while Tjir 1 (64.69 cm) showed poor growth. The progenies of clone PB 235 registered the highest average girth of 61.20 cm followed by those of clone RRII 203 (58.34 cm). The progenies of the clone IAN 873 (40.40 cm) recorded the lowest average girth.

5. Polycross garden

This consists of evaluation of nine prepotent clones planted in a polycross fashion during 1995.

6. Composite clone trials

Under this, three clone evaluation experiments commenced during 1991 have been included. The first experiment comprises of 36 clones, while there are 13 clones each in the other two experiments. GT 1 serves as the common control. Besides, clones RRII 105 and RRIM 600 have also been included in all the experiments. The control clone GT 1 recorded an average girth of 46.54, 45.69 and 42.58 cm respectively in the three experiments. The average girth in the first experiment ranged between 33.62 (Haiken 1) and 53.39 cm (RRII 203). In the second experiment, the average girth ranged between 41.51 (PB 5/139) and 48.81 cm (RRII 118) while it ranged between 39.03 (AVROS 49) and 52.57 cm (HP 83/224) in the third experiment.

7. Disease survey

Outbreak of leaf disease caused by *Corynespora cassiicola* was observed during 1999 season. A survey on the disease spread was carried out in South Canara, Udupi and Coorg districts of Karnataka and Kasaragod district of Kerala. The survey indicated that the disease was comparatively severe (5-50%) in Sullia, Guthigar, Subramanya, Shirady, Puttur and Kadaba regions of South Canara district. Almost similar intensity (5-60%) was observed in adjoining areas of Adoor, Delampady, Bandadka, Pody and Mulleria of Kasaragod district of Kerala. It was observed that the disease was more prevalent in clone RRII 105, which is widely planted in this region.

Experiments were conducted to evolve chemical control of *Corynespora* leaf disease. Water dispersible, oil dispersible and dust formulations of fungicides were tested

at Barya and Kumaradhara rubber plantations of the Karnataka Forest Development Corporation. Among the water dispersible fungicides with high volume sprayer, mancozeb (0.2%) was found superior to carbendazim (0.02%), copper oxychloride (COC 0.125%) and Bordeaux mixture (1%). Among oil-dispersible fungicides with micron sprayer, mancozeb (powder formulation) gave better control, followed by mancozeb (liquid formulation), COC and COC + mancozeb (mixed). Systemic dust fungicide, hexaconazole (2.0%) dust, gave adequate control over the *Corynespora* leaf disease, as compared to carbendazim (1.5%) and tridemorph (1.5%) dust.

HEVEA BREEDING SUB-STATION, PARALIYAR, TAMIL NADU

Research programmes on floral biology, hybridization, root trainer and clone evaluation were continued. Systematic pruning and pollarding of branches were also done for the proper maintenance of plants in breeding orchards.

1. Evolving high yielding clones

The hybrid progenies obtained by hand pollination during 1996-97 were test-tapped and 19 potential high yielders were screened for further evaluation. The hybrid seeds of 1997-98 hand pollination programme were raised in a seedling nursery for preliminary evaluation. Hand pollinations incorporating different parental combinations were continued during the flowering season in 1998-99 also.

2. Clone evaluation

In the clone trial, PB 260 continued to exhibit maximum girth followed by RRIC 105. Twelve clones of this trial have attained tappable girth at the age of seven years and the remaining three reached tappable girth at the end of eighth year only.

The experimental trees in large-scale clone trial (Keeriparai – 1994) were subjected to test-tapping. The clones PB 314, IRCA 111 and IRCA 109 recorded more yield than RRII 105.

3. Floral biology and fruit set

Wintering pattern, floral biology and anthesis of 25 clones in Breeding Orchard II were studied during the flowering season in 1999. Wide variations were observed in floral biology and anthesis of different clones.

4. Root trainer nursery for *Hevea*

Coiling of tap root is a serious handicap of the conventional polybag plants. The heavy and bulky polybags are inconvenient for transport and field planting. In order to overcome this, *Hevea* planting materials were raised in specially designed containers made of polypropylene.

Root trainer containers have 26-30 cm height with tapering shape provided with a drainage hole at the bottom. The tap root undergoes aerial pruning near the hole at the bottom and which helps to avoid coiling of tap root. The inside wall of the containers are provided with vertical ridges which direct the lateral roots downwards and avoid circular growth within the container. The compact containers reduce labour required for the nursery and field planting.

A field trial has been initiated to study the field performance of root trainer-derived plants in comparison to the conventional polybag plants. The aerially-pruned roots were noticed to grow much quickly and vigorously on transplanting to the field. Initial observations have also indicated that the root trainer plants were quicker to resume growth in the field than polybag plants.

LIBRARY AND DOCUMENTATION CENTRE

The library continued its important role of communicating and disseminating information on natural rubber and allied subjects through its library collection, information services and publications.

1. Library resources development

During the year, 176 books were added to the stock of the library making the total collection to 21849. The library subscribed to 74 foreign journals and 60 Indian journals. About 60 other journals were also received as gift/exchange.

2. Documentation services

Four issues of Documentation List, four numbers of Rubber Alert and one issue of List of New Additions were compiled and distributed. As part of selective dissemination of information, photocopies of relevant articles related to rubber research and industry were taken and distributed to the officials of the Board and RRII and 60 numbers of SDI Bulletins were issued.

3. Information services

Sixty articles were sent to various libraries/institutes as per request and also procured 20 numbers of photocopies/reprints of articles by inter-library loan services.

The bibliography holdings of 147 scientific serials were sent to Indian National Scientific Documentation Centre (INSDOC), New Delhi for incorporation into the revised edition of National Union Catalogue of Scientific Serials of India (NUCSSI), 1998 edition.

4. Computerization activities

As part of the computerization activities in the RLIND and RLCAT Databases, articles from journals, seminar papers, conference proceedings, etc. and details of books purchased were added and updated. Information on rubber and allied subjects was retrieved from the above database.

The Centre also engaged in the sales promotion of 'Indian Journal of Natural Rubber Research', 'Rubber Wood : Production and Utilization' and ' Plant and Soil Analysis'.

The library facility were also extended to the manufacturers and others related to natural rubber industry. Research scholars and students from universities and colleges were also allowed to utilize the library facilities.

AGROMETEOROLOGY UNIT

1. Weather at various stations

The meteorological parameters recorded at five locations representing different agro-climatic regions are summarized in Table Agmet.1.

Normal rainfall was received at all the five locations during the year 1998. Though the amount of rainfall received was normal, the distribution was different during the year. Above normal rainfall was recorded in almost all the locations during September. Dapchari recorded the highest of 906 mm. Same trend was observed in October too. Except for Paraliyar, where northeast monsoon is more active, other locations also

Table Agmet. 1. **Meteorological data from different stations**

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total annual rainfall
Rainfall (mm)													
Dapchari	0.0	0.0	0.0	0.0	0.0	405.4	746.4	428.6	906.2	192.8	3.0	0.0	2682.4
Nettana	0.0	0.0	2.2	52.2	93.4	772.8	1492.0	1157.6	780.3	421.0	182.8	17.3	4971.4
Kottayam	33.6	0.0	38.4	115.3	150.9	733.2	511.3	402.7	572.7	390.9	67.4	91.1	3107.5
CES, Chethackal	67.6	19.6	64.0	237.8	211.7	593.5	673.7	451.5	664.6	622.8	170.0	99.1	3883.9
Paraliyar	5.4	3.3	0.0	138.8	160.1	249.3	128.9	74.5	308.5	602.6	391.2	218.3	2281.4
Maximum temperature (°C)													
Dapchari	30.4	31.4	35.0	36.9	37.4	34.0	29.5	29.0	29.5	32.0	32.0	31.8	
Nettana	34.4	35.0	36.6	37.5	35.7	31.2	29.0	24.5	29.8	30.8	31.8	33.5	
Kottayam	33.3	34.5	36.1	35.8	34.2	30.8	30.0	30.2	29.8	30.1	31.4	32.0	
CES, Chethackal	34.5	35.6	37.3	36.0	34.3	31.5	30.2	30.5	29.8	30.6	32.3	32.4	
Paraliyar	33.2	35.0	37.0	36.3	34.0	31.4	30.5	31.2	30.3	30.5	30.6	30.0	
Minimum temperature (°C)													
Dapchari	14.9	15.6	18.4	23.7	27.0	26.0	25.3	25.0	24.1	22.7	18.7	14.5	
Nettana	18.1	17.8	20.3	24.4	24.7	23.3	22.9	23.5	22.9	22.5	21.1	18.2	
Kottayam	22.7	23.8	24.3	25.3	25.6	24.3	23.3	23.7	23.3	23.2	23.2	22.7	
CES, Chethackal	21.6	22.5	23.0	-	-	-	-	-	-	-	-	21.1	
Paraliyar	23.1	23.4	22.9	25.1	25.4	25.3	24.4	23.8	23.8	23.0	22.4	22.4	
Relative humidity (%)													
Dapchari	-	-	-	-	-	-	-	-	-	-	-	-	
Nettana	69	65	63	66	73	87	91	87	87	81	77	68	
Kottayam	68	69	69	74	78	88	86	87	88	86	82	79	
CES, Chethackal	68	71	71	76	79	85	85	87	85	83	79	80	
Paraliyar	68	67	66	72	82	83	81	83	85	85	86	84	
Bright sunshine hours													
Dapchari	278.6	270.1	315.3	317.0	328.7	204.6	48.0	90.1	95.0	230.4	249.0	267.3	
Nettana	280.5	261.5	299.0	268.4	226.8	70.6	68.3	66.0	98.3	143.5	171.5	207.0	
Kottayam	248.8	261.2	282.7	260.6	200.7	98.3	117.5	120.6	110.0	134.9	178.6	160.4	
CES, Chethackal	233.1	243.8	285.6	253.4	225.5	107.2	126.2	110.0	101.0	130.9	173.4	151.1	
Paraliyar	252.8	236.5	262.9	218.8	208.4	130.9	155.8	166.4	129.5	164.4	174.2	132.1	

rainfall

received fair amount of rainfall in November and December, which is not expected.

Another interesting feature observed during the year was the prevalence of high maximum and minimum temperatures. At RRII, maximum temperature observed was 37°C or above for more than 10 days during summer which is not usual. Highest maximum temperature (38.5°C) so far recorded in the station was on 6 April 1998.

Decennial analysis of maximum temperature at the station showed that 1971-80 recorded a mean maximum temperature of 33.9°C during March, whereas it was 34.2°C during the next decade and 34.4°C from 1991 to 1997. So over the years, a gradual increase in summer temperatures is observed.

2. Studies on crop-weather relations

2.1 Epidemiological studies on *Oidium heveae*

In order to find out influence of meteorological parameters on powdery mildew, data were collected from a laid out clone trial with RBD design, for four years (1992

to 1995, both inclusive). The clones selected were PB 217, PB 235, PB 255, PB 260, PB 280, PB 310, PB 311, PB 312, PB 314, KRS 25, KRS 128, KRS 163 and RRII 105.

The percentage of disease index (PDI) for each year is correlated with the meteorological parameters and the correlation is given below:

PDI vs X1 0.53* where X1 is the total rainfall during January and February

PDI vs X2 0.48* where X2 is the maximum of the monthly averages of RH during January and February

PDI vs X3 0.62** where X3 is the maximum of the monthly averages of minimum temperature

PDI vs X4 0.67** where X4 is the total number of days with sunshine hours less than five during January and February.

2.2 Latitudinal and altitudinal effect of the biotic events of *Hevea*

Wintering habit of *Hevea* from Nagercoil to Nettana covering the traditional region were observed for selected clones to find out the latitudinal and altitudinal influence as described by Hopkins Bioclimatic Law.

3. Agroclimatic classification of rubber growing areas

Long-term weather data of different IMD stations covering the state has been collected and tabulated to develop agroclimatic indices like effective rainfall, PET, water deficit, water surplus etc. which finally form the basis for identifying different agroclimatic regions.

ANNUAL EXPENDITURE

Expenditure at a glance 1998-99

Head of Account	Expenditure (Rs. in lakhs)
Non-plan	
General charges	376.83
Schemes	17.62
Projects (CES)	109.05
Total	**503.50**
Plan	
General charges	98.31
Schemes	138.93
NERDS Research Component	114.62
Total	**351.86**
World Bank Project	**167.04**
Grand Total	**1022.40**

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* Published during 1998-99.

SCIENTIFIC AND SENIOR SUPPORTING PERSONNEL

Director of Research

N.M. Mathew, M.Sc, Ph.D.

Joint Director (Research)

K. Jayarathnam, M.Sc.(Ag.), Ph.D.(up to 27.5.1998)

P.J. George, M.Sc, Ph.D. (from 2.7.1998)

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)
Joshua Abraham, M.Sc., Ph.D.	Scientist S3
V.K. Syamala, 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.	Scientist S2
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
K.K. Ambily, M.Sc.	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
K.S. Sivasankaran Nair	Assistant Farm Superintendent

Biotechnology Division

*M.P. Asokan, M.Sc., Ph.D.	Joint Director (on leave)
A. Thulaseedharan, M.Sc., Ph.D.	Deputy Director
S. Sushamakumari, M.Sc., Ph.D.	Scientist (Biotechnology)
*P. Kumari Jayasree, M.Sc.	Scientist (Biotechnology)
P. Venkatachalam, M.Sc., Ph.D.	Assistant Molecular Biologist
R.G. Kala, M.Sc.	Junior Scientist
R. Jayasree, M.Sc.	Junior Scientist
K. Narasimhan, M.Sc.	Junior Scientist
K. Rekha, M.Sc.(Ag.)	Junior Scientist
S. Sobha, M.Sc., L.L.B.	Junior Scientist

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 S3
L. Sankariammal, M.Sc., Ph.D.	Cytogeneticist
Vinoth Thomas, M.Sc., Ph.D.	Assistant Anatomist
Alice John, M.Sc.(Ag.)	Junior Scientist
Meenakumari, M.Sc., Ph.D.	Junior Scientist
T. Girish, M.Sc.	Junior Scientist
Sobhana Sankar	Senior Scientific Assistant
O.V. Mathew	Assistant Farm Superintendent
C.T. Joseph	Assistant Farm Superintendent
*K. Kunhunni	Assistant Farm Superintendent

Germplasm Division

Y. Annamma Varghese, M.Sc., Dr.Sc.(Ag)	Deputy Director (from 31.12.1998)
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
Arun Kumar, MSc.(Ag.), Ph.D.	Assistant Mycologist
Shaji Philip M.Sc., Ph.D.	Assistant Molecular Plant Pathologist (from 7.7.1998)
M.J. Manju, M.Sc.(Ag)	Junior Scientist (from 9.12.1998)
T.G. Vimalakumari, M.Sc.(Ag.)	Junior Scientist
E. Edwin Prem, M.Sc.(Ag.)	Junior Scientist (from 7.7.1998)
Sadanand K. Mushrif, M.Sc.(Ag.)	Junior Scientist (from 13.1.1999)
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

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
**R. Rajagopal, M.Sc., M.Phil., Ph.D, Dip. Stat.	Plant Physiologist
K. Annamalainathan, M.Sc., M.Phil, Ph.D.	Plant Physiologist
D. Bhuvanendran Nair, M.Sc., Ph.D.	Scientist S3
S. Sreelatha, M.Sc.	Scientist S3
M.B. Mohammed Sathik, M.Sc., M.Phil.	Scientist S2
**Jayasree Gopalakrishnan, M.Sc., M.Phil.	Scientist S2
N. Geetha, M.Sc., Ph.D.	Junior Scientist
S. Visalakshy Ammal, B.Sc.	Assistant Technical Officer
C.C. Joseph	Assistant Farm Superintendent
*C.G. Varghese	Assistant Farm Superintendent

Rubber Chemistry, Physics and Technology Division

Baby Kuriakose, M.Sc., LPRI, Ph.D., PGDPM	Joint Director (Rubber Technology)
K.T. Thomas, M.Sc., LPRI, M.Tech., Ph.D.	Deputy Director
N.M. Claramma, M.Sc.	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)
K.N. Madhusoodanan, M.Sc.	Rubber Chemist
Benny George, M.Sc.	Scientist S2
C.K. Premalatha, B.Sc., LPRI, Dip. NRP	Assistant Technical Officer
C. Madheswaran, B.A.	Technical Assistant (Glass Blowing)

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., B.Ed.	Scientist S2
S. Mohanakumar, M.A., M.Phil.	Junior Scientist
S. Veeraputhran, M.A.	Junior Scientist
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, M.Sc., PGDCA	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 Engineer
Thomas Baby, M.Sc., M.Phil., Ph.D.	Instrumentation Officer (from 23.7.1998)
R. Rejikumar, M.Sc., M.Tech.	Assistant Instrumentation Officer (from 23.7.1998)

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

T.R. Mohankumar	Deputy Secretary (up to 14.12.1999)
B. Lakshmanan	Assistant Secretary
E.K. Thankamma	Administrative Officer
V. Mary Philipose	Assistant Section Officer
Annamma Joseph	Assistant Section Officer

Accounts Section

*G. Rajasekharan Nair	Deputy 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
N. Bhargavan	Farm Superintendent
M.D. Issac	Assistant Estate Superintendent
K.S. Thomas	Assistant Section Officer (from 22.12.1997)
Annamma Andrews, H.S.C.	Nurse (HG)
T.T. Varghese	Assistant Farm Superintendent
T.R. Divakaran	Assistant Farm Superintendent
M.T. Varghese	Assistant Security Officer

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
A.K. Hazarika, M.Com.	Assistant Accounts Officer

Regional Research Station, Agartala, Tripura

Sushil Kumar Dey, M.Sc., Ph.D.	Deputy Director
P. M. Priyadarshan, M.Sc., Ph.D.	Plant Breeder
*M.K. Sudhasoumyalatha, M.Sc., Ph.D.	Scientist (CE)
Gitali Das, M.Sc, Ph.D.	Plant Physiologist
Krishna Das, M.Sc., Ph.D.	Scientist S2
Shammi Raj, M.Sc., Ph.D	Assistant Agrometeorologist
S. Sasikumar, M.Sc.	Junior Scientist
Badre Alam, M.Sc., M.Tech., Ph.D.	Junior Scientist
*Santhanu Roy, M.Sc.(Ag.)	Junior Scientist
Mrinal Chaudhuri, M.Sc.(Ag.)	Junior Scientist
Joy Joseph, M.Sc.	Assistant Rubber Processing Technologist
Jiban Chakraborty, B.Com.	Accounts Officer
N.K. Balasubramaniyam	Assistant Section Officer
*K.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

Regional Research Station, Nagrakatta, West Bengal

Sankar Meti, M.Sc.(Ag.)	Junior Scientist
Haradhan Bhowmik	Assistant Farm Superintendent

Regional Research Station, Dapchari, Maharashtra

Gawai Prakash Pandharinath, M.Sc.(Ag.)	Junior Scientist
K.N. Vijayachandran Nair	Assistant Section Officer
C.C. Joseph	Assistant Farm Superintendent (up to 19.6.1998)
V.J. George	Assistant Farm Superintendent (from 1.7.1998)

Regional Research Station, Dhenkanal, Orissa

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

Regional Research Station, Sukma, Madhya Pradesh

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

***Hevea* Breeding Sub-station, Nettana, Karnataka**

K.K. Vinod, M.Sc.(Ag.)	Plant Breeder
M. Sasikumar, M.Sc (Ag)	Junior Scientist (from 15.6.1998)
C.K. Thomas	Assistant Farm Superintendent

***Hevea* Breeding Sub-station, Paraliyar, Tamil Nadu**

T.A. Soman, M.Sc., M.Phil., Ph.D.	Scientist S2
V. Vijayan	Assistant Farm Superintendent

Regional Soil Testing Laboratory, Adoor, Kerala

A. Ulaganathan, M.Sc.	Junior Scientist

Regional Soil Testing Laboratory, Muvattupuzha, Kerala

C.P. Mary, M.Sc.	Assistant Technical Officer

Regional Soil Testing Laboratory, Kozhikode, Kerala

Joyce Cyriac, M.Sc.	Junior Scientist
P.K. Madhusoodhanan, 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
R.G. Baruah Road
Guwahati – 781 024
Assam.
Phone : 91 361 452479

Regional Research Station
RRII, Rubber Board, Bhalukia Tilla
Kunjaban P.O., Agartala – 799 006
Tripura.
Phone : 91 381 225287
Fax : 91 381 323149

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

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

Regional Research Station
RRII. Rubber Board
Grassmore, Nagrakatta
Jalpaiguri – 735 225
West Bengal.
Phone : 91 3563 72316

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

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
Padiyoor P.O.
Kannur – 670 703
Phone : 91 498 273003

***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 SOIL TESTING LABORATORIES

Regional Soil Testing Laboratory
Rubber Board, II Floor
Kumudavathy Buildings, Balmatta,
Mangalore – 575 001, Karnataka.

Regional Soil Testing Laboratory
Rubber Board Regional Office
Thaliparamba – 670 141
Kerala.

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

Regional Soil Testing Laboratory
Rubber Board, East Bazar
Thrissur – 680 001, Kerala.

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

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

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

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

Regional Soil Testing Laboratory
Rubber Board, 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, Computer 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), Paraliyar (Tamil Nadu), Nettana (Karnataka) and Padiyoor (Kerala).

Regional soil testing laboratories have been established at Mangalore, Thaliparambu, Kozhikode, Thrissur, Muvattupuzha, Pala, Kanjirapally, Adoor and Nagercoil. Mobile units for soil and leaf analysis 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 Agricultural Research Institute (New Delhi), Indian Institute of Sciences (Bangalore), Indian Institute of Technology (Kharagpur), National Chemical Laboratory (Pune), 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

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