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Cover

Inflorescence of a variant among wild *Hevea* germplasm showing red colour at floral base.

Cover design

Mr. K.P. Sreerenganathan

October, 2000

* With particulars of personnel as on 31.03.1997

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 nearest airport is at Cochin, 70 KM north. The capital of the State is Trivandrum, 160 km south where there is an international airport. The distance to New Delhi, the capital of the country, is 2950 km.

Functions

Undertaking, assisting and encouraging scientific, technological and economic research and dissemination of knowledge to the NR industry are the statutory functions of the RRII.

Organisation

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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THE RUBBER BOARD

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

Organisation

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 five departments under the Board, *viz.* Administration, Rubber Production, Processing & Product Development, Finance & Accounts and Training.

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DIRECTOR'S REVIEW

The increase in productivity of natural rubber (NR) has been quite impressive compared to other plantation crops in the country. This has been achieved mostly by the use of improved planting materials and adoption of new technologies and sustainable management measures. Besides its contributions to economic development, the positive environmental credentials of NR plantations are widely accepted. The potential biomass production of this crop is comparable to any fast growing tropical species and the estimated biomass produced by rubber plantations globally is around 200 t. This has enabled considerably to maintain, restore and improve the productive capacity of soils under rubber. However, concerted attention is still warranted to increase productivity, narrow down yield gap existing between the realized and potential yield of popular clones, reduce the cost of production and develop value-added products. The environmental hazards related to the extensive use of plant protection chemicals and the possible danger of pesticide resistance prompt us to look for alternative strategies in pest and disease management. The research projects of the Institute are being prioritized to achieve the above goals.

Nutritional management studies were continued to optimize fertilizer application for mature and immature rubber. The studies on soil and water conservation measures in plantations were continued and the accumulated run off soil in silt pits was estimated as 6 t/ha. The experiments to evolve model cropping systems with different components have been in progress.

Experiments on genetic improvement of the crop through hybridization and ortet selection were continued. The performance of clonal composites and the interaction of Genotype x Environment have been assessed. Six years' yield data reveal that PB 235 is the highest yielding clone in Tripura in the North East India. The conservation and evaluation of *Hevea* germplasm received maximum priority. The wild genotypes were evaluated for their tolerance to biotic and abiotic stresses. Crop improvement was attempted also through somatic embryogenesis and *Agrobacterium*-assisted genetic transformation system. Two RAPD markers associated with tapping panel dryness (TPD) were identified. The genomic stability of tissue culture plants was analysed.

The disease management studies focussed on testing of alternative fungicide formulations for checking *Phytophthora* leaf fall. Development of lighter low volume sprayers was attempted in collaboration with sprayer manufacturers. Several new fungicides including systemics, have been tested for their efficacy in controlling diseases. Severe *Corynespora* leaf infection has been noticed in the clone RRII 105, in the Dakshin Kannada district of Karnataka. A survey on the disease incidence was undertaken in Karnataka and bordering areas in Kerala. Field trials were initiated to identify effective chemical control measures against *Corynespora* disease. Incidence of minor pests like bark-feeding caterpillar, rainguard-damaging cricket, etc. have been reported and strategies for their control worked out.

Effluent from sheet processing was found to generate 10-15 per cent more biogas when biologically inert materials were added to it. The soil microbiological investigations

included use of microbes for phosphorus uptake by rubber and cover crop. Bee-keeping in rubber plantations was another important area of research as this has been identified as a source of additional income for the rubber holdings.

Physiological investigations related to water stress and photosynthesis under drought conditions, influence of atmospheric and soil drought on growth and yield of irrigated and rainfed trees, increased accumulation of amino acids, phenols, sugars, proteins and peroxidase in the bark during summer etc. have been in progress. Multiple stress tolerance studies have indicated that the combined effect of drought and high temperature was more damaging than any of the stresses alone. High peroxidase activity in the bark tissue and latex has been noticed in TPD-affected trees.

In a competitive market environment, both quality improvement and cost reduction of rubber and rubber products assume great importance. Hence these aspects have been given high priority in the area of rubber processing/technology. A 60:40 blend of centrifuged NR and creamed SBR latex has been found more suitable for the manufacture of latex foam.

A comprehensive database has been built up with the data collected in a survey to assess the operational efficiency of rubber plantations at different levels of management. The survey conducted among smallholdings indicated better adoption of the recommended cultural practices among members of Rubber Producers' Societies (RPS) compared to other growers. Attempts were made to assess the role of cooperative sector in marketing and in value addition to the smallholder's raw rubber. The NR price fluctuations in India were also analysed.

The research component of the World Bank-Assisted Rubber Project included seven research projects. The low frequency tapping trials laid out at different locations have yielded promising results. A new regional laboratory was set up for soil and leaf analyses and more infrastructure facilities were provided for the other laboratories. The studies on improving drying conditions of sheet rubber in smallholdings, break down behaviour of different forms of NR and modified forms of NR have also been in progress.

The overall excellence of rubber from *Hevea brasiliensis*, which is yet to be matched by any biological or man-made substitute, provides this crop an assured future. Considering this, the Institute will continue to strive for innovations for the improvement and further development of this industry.

AGRONOMY AND SOILS DIVISION

The Agronomy and Soils Division focuses research on nutrient requirement and fertilizer management of rubber at its various stages of growth. Other areas of research are intercropping and cropping systems, weed management, irrigation and moisture management and soil and water conservation. The relative efficiency of rock phosphates was studied in detail on cover crops and immature rubber. Research on Diagnosis and Recommendation Integrated System (DRIS) for refinement of fertilizer recommendation was continued. Discriminatory fertilizer recommendation on the basis of soil and leaf analyses was extended to large estates.

1. Nutritional studies (immature rubber)

1.1 NPK requirement of clone RRII 105

The field study on nutrient requirement of RRII 105 started during 1989 at Kodumon Estate is being continued. Different combinations of N, P and K were tried. The observations on girth (1997) and girth increment (1991-97) were recorded and analysed statistically (Table Ag.1).

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

Treatment NPK kg/ha	Girth (cm) 1997	Girth increment (cm) 1991-97
0 0 0	51.00	42.84
30 30 20	55.96	46.09
30 30 40	53.51	44.04
30 60 20	55.51	46.34
30 60 40	47.89	39.06
60 30 20	51.19	42.24
60 30 40	56.00	46.50
60 60 20	52.26	43.02
60 60 40	54.48	45.09
90 30 20	53.90	44.18
90 30 40	53.09	43.99
90 60 20	51.09	41.61
90 60 40	51.64	42.85
SE	1.36	1.31
CD (P=0.05)	3.98	3.84

The growth data indicated that combination of 30:30:20 NPK kg/ha is sufficient for achieving higher girth. The same trend was observed in previous years.

1.2 N-biofertilizers in seedling nursery

The experiment conducted in seedling nursery during 1995 was repeated during 1996. The treatments were *Azotobacter* and *Azospirillum* from three different sources and four levels of N as urea, *viz.* 0, 25, 50 and 100 per cent of the recommended dose. In both the experiments, biofertilizers did not influence the growth of seedlings.

1.3 P-biofertilizers in seedling nursery

The experiments to study the influence of P-biofertilizers (P-Symbion) on the growth of rubber seedlings were repeated during 1996 at two locations. The effect of P-Symbion alone and in combination with 0, 25, 50, 75 and 100 per cent of the recommended levels of P as Mussoorie rock phosphate was studied. The two years data on seedling diameter from both the experiments indicated that P-solubilizers did not improve the growth of seedlings.

1.4 Growth promoters in seedling nursery

The experiment started in 1995 to study the effect of growth promoters *viz.* Growbuck, Multiplex and Perfectose was repeated in 1996. No beneficial effect of these growth promoters was noticed on seedling growth.

1.5 Modelling Mg uptake in young rubber

The plants grown in glass house were uprooted and dry matter weight recorded. The analysis of the root, shoot and leaf Mg is in progress.

2. Nutritional studies (mature rubber)

2.1 NPK fertilizer trial

The fertilizer experiment on RRII 105, laid out at Vaniyampara Estate during 1986 was continued. Yield was not significantly influenced by the nutrients (N, P or K).

2.2 Clone-cum-fertilizer experiment

The experiment to study the clonal variation in nutrient requirement was continued. The trial was commenced in 1988 and trees were opened for tapping during October 1995. Significant difference between clones in girth and yield was observed (Table Ag.2). Clone RRIC 100 showed the highest girth and yield. Differential nutrient requirement for individual clones was not exhibited for growth or yield.

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

Clone	Girth (cm) January 1997	Yield (g/tree/tap) 1996-97
RRII 5	57.1	19.0
RRII 105	56.9	23.1
RRII 203	62.8	20.2
RRII 208	54.8	14.7
RRII 300	53.5	18.0
RRII 308	53.3	13.8
PR 255	51.9	15.5
PR 261	53.9	19.8
PB 311	58.8	21.8
RRIC 100	64.0	24.4
CD (P=0.05)	5.8	5.8

2.3 Sequential skipping of fertilizers

A field experiment was initiated during 1996 for comparing periodic skipping of fertilizers with continuous regular application. Yield is being recorded from June 1996.

2.4 Potassium nutrition of mature rubber

The yield recording from the field experiment is temporarily discontinued but the trial is being continued to assess the long-term effect. The soil samples collected during 1995 were subjected to detailed analysis for total K and different forms of K. The total K status was found to be very low. In the control and plots with low levels of K application, the total K was depleted indicating its utilization from the reserve pools and subsequent decline in K status.

3. Density of planting

The experiment was laid out in 1994 at CES, Chethackal, to elucidate the effect of planting density on the growth and nutrient requirement of rubber. The fertilizer treatments were imposed and growth measurements recorded. The girth data recorded during 1997 did not register any significant difference with respect to either planting density or manurial doses.

4. Irrigation and water requirement

The field experiment on young rubber, commenced in 1991 at Shaliacary Estate, is being continued. The treatment imposition with different levels of irrigation was continued during summer months and growth measurements were recorded (Table Ag.3).

Table Ag.3. **Effect of irrigation on growth**

Irrigation	Girth (cm) 1996	Girth increment (cm) 1992-96
25 % of ET	40.94	34.27
50 % of ET	41.34	34.36
75 % of ET	41.26	35.26
100 % of ET	42.71	35.66
No irrigation	37.51	31.48
SE	0.96	0.79
CD (P=0.05)	2.97	2.44

Irrigation significantly improved the growth of rubber as evidenced by the difference in girth and girth increment between control and irrigated plants. However, no significant difference was noticed between the different levels of irrigation.

5. Soil and water conservation

5.1 Effect of silt pits

Field experiment laid out in a mature plantation in the estate of the State Farming Corporation of Kerala, Punalur, during 1994 is in progress. Silt pits accumulated run off soil in the range of 5 to 6 t per tapping block.

5.2 Effect of coir pith manure in pit manuring and mulching for young rubber

Suitability of decomposed coir pith - coir pith manure - as pit manure during the time of planting and as mulch material is being studied since 1994. There was no significant improvement in the growth of rubber by the use of this material.

6. Weed management

6.1 Evaluation of weed control methods

Lowest weed infestation during the entire year was observed with scraping of entire platform. Herbicide spray in the entire strips and combination with slashing were observed to be on par in checking weed growth (Table Ag.4).

Table Ag.4. **Weed infestation in various weed control treatments**

Treatment	Mean weed infestation (%)
Scraping entire platform	26.49*
Slashing entire platform	36.64
Spraying paraquat (Gramoxone)- 2.25 L/ha + 2,4-D (Fernoxone) - 1.25 kg/ha in entire platform	31.14
Spraying glyphosate (Round up) 2 L/ha in entire platform	33.31
Slashing interspaces and scraping plant basin	34.21
Slashing interspaces and applying paraquat - 2.25 L/ha + 2,4-D - 1.25 kg/ha in plant basin	34.42
Slashing interspaces and applying glyphosate - 2 L/ha in plant basin	36.04
CD (P=0.05)	4.22

* Values transformed angularly

6.2 Control of lemon grass in immature rubber

A new experiment was started in young rubber where infestation of lemon grass (*Cymbopogan citratus*) was a severe prob-

lem. The experiment was laid out in randomized block design with seven treatments and four replications. The plot size was 96.04 m^2, *i.e.* area between three rows of three plants each. The weed control treatments were manual (uprooting and slashing), chemical (glyphosate at two doses, *viz.* 2 L/ha and 3 L/ha) and combination of manual and chemical (glyphosate 2 L/ha and 3 L/ha after slashing at 10 cm height).

Pre-treatment observations on intensity of weed infestation and girth of rubber plants were recorded.

6.3 Control of *Mucuna bracteata* in immature rubber

A new trial was initiated in a four-year-old plantation to find out economically feasible control measures required for a satisfactory year-round control of *Mucuna bracteata* along the planting lines of rubber. The experimental design was randomized block design with eight treatments and four replications. The individual plot size was 50m^2 and the treatments were : T1 - manual slashing, T2 - glyphosate 2 L per ha, T3 - glyphosate 1 L per ha, T4 - glyphosate 0.5 L per ha + urea 1.25 kg per ha, T5 - paraquat 2.25 L per ha + 2,4-D 1.25 kg per ha, T6 - paraquat 2.25 L per ha, T7 - 2, 4-D 1.25 kg per ha and T8 - 2, 4-D 2.50 kg per ha.

Visual scoring of growth rate of *Mucuna* was done and the treatments T1, T3 and T4 were reimposed when the growth was above 50 per cent during the four months time. For T6, three rounds of spraying were essential to keep the cover crop under control.

7. Cropping systems

7.1 Intercropping coffee in mature rubber

The experiment on intercropping two varieties of coffee, *viz. Coffea arabica* var. *cauveri* and *Coffea canephora* var. *robusta* in mature rubber plantation is being continued. The growth and yield of rubber was not influenced by intercropping. The coffee plants were deep-pruned at 15 cm height as they were overgrown.

In 1996, a block trial was initiated at Shaliacary Estate, Punalur with the following treatments.

T1 - *Coffea canephora* var. *robusta* in a single row 3 m apart (450 plants/ha)

T2 - *Coffea arabica* var. *cauvery* in a single row (750 plants/ha)

T3 - *Coffea arabica* var. *cauvery* in double rows (1500 plants/ha)

T4 - Rubber alone

The establishment of coffee seedlings has been good.

7.2 Cropping system model

An experiment on model cropping system was initiated in 1993 at CES, Chethackal. Intercrops included banana for the first two years, pineapple up to fifth year, tuber crops during the fourth and fifth year, pepper and coffee as permanent crops, cover crop in the narrow inter-row, and grass and teak along the boundary. The stand per ha of rubber is retained as 406.

After taking two crops of banana during the first and second year, *Amorphophallus, Colocasia* and *Dioscorea* were planted during the third year in the space previously occupied by banana.

The growth of rubber plants in the intercropping system continued to be superior to that of rubber in the monoculture (Table Ag.5).

Chemical analysis of the soil in the intercropping system indicated an increase in the organic carbon and available phosphorus status and a decline in the available

Table Ag.5. **Girth of rubber (1996)**

Treatment	Girth (cm)
Rubber near pineapple	21.27
Rubber near banana	20.88
Rubber in monoculture	19.67
CD (P=0.05)	1.10

potassium status of the soil within 30 months after commencement of the system (Table Ag.6).

Table Ag.6. **Changes in chemical composition of the soil**

Parameter	Initial	30 months later
Organic carbon (%)	2.12	2.87
Available P (mg/100 g)	0.30	2.71
Available K (mg/100 g)	8.82	5.96
Available Mg (mg/100 g)	1.78	1.71

8. Integrated nutrient management

8.1 Comparison of organic and inorganic sources

The trial started in 1994 at Shaliacary Estate, Punalur is being continued. The treatments were combinations of different levels of N and P fertilizers alone and in conjunction with farm yard manure in split plot design. Girth did not show significant difference between treatments.

8.2 Nutrient recycling

The experiment conducted during 1994 at CES, Chethackal, in mature plantation was repeated during 1996. Microplots were marked during January 1996 in a field planted with 15-year-old RRII 105 plants. The leaves fallen during wintering were allowed to deposit in microplots. After wintering, the surface of the microplots was covered with plastic net to prevent further addition of leaves. Nutrient content of the litter, nutrient release and the mass loss were also studied on a monthly basis (Tables Ag.7, 8 and 9).

Table Ag.7. **Dry weight of litter (kg/ha)**

February	September	Quantity disintegrated	Per cent disintegrated
4988.20	293.3	4694.90	94.12

Table Ag.8. **Nutrient composition of leaf litter**

Nutrient	February	September
N %	2.02	1.72
P %	0.06	0.07
K %	0.97	0.21
Ca %	1.31	1.45
Mg %	0.34	0.27
Mn mg/kg	346.00	524.00
Cu mg/kg	87.00	154.00
Zn mg/kg	62.00	90.00

Table Ag.9. **Nutrient content in litter and quantity released (kg/ha)**

Nutrient	February	September	Qty. released
N	100.64	5.04	95.60
P	2.99	0.21	2.78
K	48.39	0.62	47.77
Ca	65.35	4.25	61.10
Mg	16.96	0.79	16.17
Mn	1.73	0.15	1.58
Cu	0.43	0.05	0.38
Zn	0.31	0.03	0.28

The quantity of leaf litter disintegrated was 4694.9 kg per ha.

9. Ground cover management

The growth of *Calopogonium caeruleum* was extremely poor compared to that of *Pueraria phaseoloides* after two years and its spread in the plantation was also not satisfactory.

10. Forms and methods of fertilizer application

10.1 Comparison of water soluble and insoluble forms of P fertilizers

Comparative efficiency of three P sources, *viz.* Mussoorie rock phosphate, super phosphate and ammophos was studied through two field experiments on immature rubber at two locations (Table Ag.10). P and N were supplied through different sources (40 kg/ha each).

Table Ag.10. **Girth increment during 1989-97 (cm)**

Treatment	Location	
	Vaniampara	Kinalur
Rock phosphate + ammonium sulphate	42.35	48.02
Rock phosphate + urea	41.72	50.35
Ammonium phosphate (20:20)	42.58	49.58
Single super phosphate + ammonium sulphate	41.65	49.17
Single super phosphate + urea	42.42	49.07
CD (P=0.05)	NS	NS

No significant difference was observed between water soluble and insoluble forms of phosphatic fertilizers in both the locations. Soil and leaf analyses indicated that there was no significant difference between different P sources. However, continuous application of P fertilizers registered an increase in soil P status irrespective of the source.

10.2 Bowl sludge as a source of P

The fertilizer value of bowl sludge, a waste product from latex centrifuge factories was evaluated both in immature and mature rubber. The trial was started in 1988. The data on girth increment for the period from 1989 to 1996 and mean yield for 1996 are presented in Table Ag.11.

Table Ag.11. **Effect of bowl sludge on girth increment and yield**

Treatment	Girth increment* (cm)	DRC** (%)	Dry rubber yield** (g/tree/tap)
Single super phosphate	44.04	32.70	22.14
Mussoorie rock phosphate	44.22	33.60	22.17
Bowl sludge	45.34	33.80	25.46
Control	40.40	33.80	20.34
CD (P=0.05)	3.16	NS	3.22

* 1989-96 ** 1996

The results indicated that sludge is on par with super phosphate and Mussoorie rock phosphate in increasing the girth of plants. Bowl sludge application significantly increased the rubber yield while the effect of the other two P sources was not significant.

A block study was also started in 1994 on mature rubber at CES, Chethackal with the objective of comparing bowl sludge with Mussoorie rock phosphate and it was found that the yield for both the treatments is comparable.

10.3 Comparison of different rock phosphates

10.3.1 Incubation experiment

An incubation experiment was conducted to evaluate the dissolution pattern of four indigenous rock phosphates *viz.* Rajphos, Maton rock phosphate, Megaphos and Mussoorie rock phosphate and two imported rock phosphates *viz.* Gafsaphos and Jordan rock phosphate at three levels of P *i.e.* 50, 100 and 150 kg P_2O_5 per ha. Samples were drawn at 15, 30, 45, 60, 75, 90 and 120 days of incubation and P was estimated (Bray II method).

The dissolution pattern clearly indicated that among the different phosphate rocks, Gafsaphos was superior in P availability. The

four indigenous P sources *viz.* Rajphos, Maton rock phosphate, Megaphos and Mussoorie rock phosphate were almost similar in their P dissolution pattern. For all the sources, the P availability was maintained up to 45th day and a reduction was noticed from 60th day.

10.3.2 Effect on cover crops

A pot culture experiment was initiated in the glass house to study the effect of three levels of rock phosphate *i.e.* 0, 30 and 45 kg P_2O_5 per ha on the nodulation and biomass production of three cover crops - *Pueraria phaseoloides, Mucuna bracteata* and *Calopogonium caeruleum.* The pre-treated seeds were sown in the pots and thinned down to three plants per pot. The treatments were imposed one month after sowing.

10.4 Comparison of rock phosphate sources

Rock phosphates from different sources were evaluated in a seedling nursery trial at Regional Nursery, Perumpulickal during 1995-96. The residual effect of the applied phosphorus was studied during 1996-97 without further addition of P sources and diameter of the seedlings recorded during 1997 revealed response of plants to the residual phosphorus also (Table Ag.12). However, the diameter of the plants during 1996-97 was lower compared to that recorded during 1995-96.

Table Ag.12. **Effect of different rock phosphates on diameter of seedlings**

Treatment	Diameter (mm)	
	1995-96	1996-97
No phosphorus	11.65	10.68
Mussoorie RP	14.29	11.36
Gafsaphos	13.84	11.36
Maton RP	14.69	12.43
Jordan RP	13.78	11.25
Rajphos	13.48	11.17
Megaphos	14.03	11.94
CD (P=0.05)	1.56	0.96

10.5 Use of slow release fertilizers

Two field experiments on immature rubber are in progress for comparing the relative efficiency of NPKMg pellets, Nimin-coated urea and neem cake-coated urea. Girth increment data from the field experiment at CES, Chethackal did not show significant differences between treatments (Table Ag.13).

Table Ag.13. **Effect of controlled release fertilizers on girth increment**

Treatment		Girth increment (cm) (1993-96)
Urea		8.05
NPKMg pellets	100%	8.02
NPKMg pellets	75%	8.57
Nimin-coated urea	100%	8.85
Nimin-coated urea	75%	8.46
Neem cake mixed urea	75%	7.87
Control (no manure)		7.29
		NS

Another field experiment comparing different slow release fertilizers and different application time is also in progress. The treatment effect on growth is presented in Table Ag.14. The treatment effects were not significant in this experiment also.

10.6 Effect of N-inhibitors

The effect of neem cake in increasing the N-use efficiency of urea was studied in a mature plantation. The yield data monitored during the initial period did not show significant difference between treatments.

11. Discriminatory fertilizer recommendation

11.1 Advisory service

Advisory service to large estates through soil testing and leaf analysis-based fertilizer recommendation is being continued. Dur-

Table Ag.14 Effect of controlled release fertilizers on girth increment (cm)

Treatment	Dose*	Girth increment (1994-96)
Urea		19.69
NPKMg pellets	75 (single)	20.15
NPKMg pellets	75 (two)	19.71
NPKMg pellets	50 (single)	18.95
NPKMg pellets	50 (two)	19.86
Nimin-coated urea	100 (two)	18.66
Nimin-coated urea	75 (two)	19.01
Neem cake - mixed urea	100 (two)	19.05
Neem cake - mixed urea	75 (two)	18.86
Control (no manure)		15.87
		NS

*Percentage of the recommended level in single or split applications.

ing the year, fertilizer recommendations were issued to 36 estates covering 963 fields. A total of 1336 soil samples and 1224 leaf samples were analysed.

11.2 DRIS approach for fertilizer recommendation

The leaf analytical values obtained so far were grouped clonewise and analysed for variation in nutrient values. The CV was low, indicating uniformity of the data. Significant clonal variation for all the nutrients studied *viz.* N, P, K, Ca and Mg was observed. However, the mean values were in the same range indicating that, for the sufficiency range approach of discriminatory fertilizer recommendation, the same rating can be used for all the clones.

12. Standardisation of analytical methods

The variations in nutrient concentrations among individual trees for N, P, K, Ca and Mg at each sampling period were estimated. The variations in nutrient concentrations between different sampling periods were also worked out. The results indicated that there is a possibility of extending the leaf sampling period by 20-30 days, *i.e.* the sampling period from August to October can be extended to November also.

BIOTECHNOLOGY DIVISION

The thrust areas of research in Biotechnology Division include micropropagation of elite *Hevea* clones, genetic transformation with agronomically important genes, protoplast culture etc. Attempts are also being made to identify molecular markers and genes for various characters.

1. Somatic embryogenesis

Several refinement experiments were conducted on the existing pathways of somatic embryogenesis from different explant sources, as a result of which the efficiency of this system has been increased considerably. More work is going on in this direction.

2. Genetic transformation of *Hevea*

Agrobacterium-mediated transformation system has been standardised using experimental marker genes. Various parameters, *viz.* (a) target tissue giving better incorpora-

tion and subsequent stable expression, (b) *Agrobacterium* strain most suited for gene incorporation into rubber tissue, (c) concentration of *Agrobacterium* inoculum to be infected with rubber tissue and period of inoculation and (d) concentration of various antibiotics in the pre-selection and selection media, have been standardised using the GUS marker gene.

Based on the above standardised techniques, transformation experiments using agronomically useful genes for rubber have been initiated.

3. Protoplast culture

Several refinement experiments on the protoplast to plant regeneration system were carried out. Some of these experiments have given good results suggesting existing protocols could be further improved. More experiments are being initiated for further optimisation of the culture conditions.

4. Shoot tip culture

The ongoing work for generating plants every year, utilising the existing plant regeneration protocol has been continued. Standardisation of various parameters namely, temperature, humidity, light intensity, *etc.* in the newly constructed green house were carried out.

5. Identification and cloning of a DNA marker conferring tolerance to tapping panel dryness

Two random amplified polymorphic DNA (RAPD) markers were identified which are linked to tapping panel dryness (TPD). DNA from *Hevea* lines differing in tolerance to TPD was screened for RAPD markers using 200 random decamer primers. Two independent populations of *Hevea* plants derived from polyclonal seedlings and each individual representing a genotype planted in 1969 and 1971 were used for this study. One additional band of 1.3 kb size was detected with one primer in tolerant plants derived from the population planted in 1969. With the same primer, in the tolerant plants of the population planted in 1971, another polymorphic band having 1.6 kb size was observed. The 1.3 kb polymorphic band was isolated, purified and cloned into the EcoR V site of the pBluescript KS$^+$ and amplified after transforming the bacterium DH5α.

6. Isozyme screening of tissue culture plants

Isozyme screening was continued to identify isozymes as biochemical markers during somatic embryo geneis. Out of the 25 isozymes tested, four isozymes, *viz.* aryl esterase, peroxidase, shikimate dehydrogenase and superoxide dismutase were found to be efficient for screening tissue culture material.

7. Pathogenesis-related proteins of *Hevea brasiliensis*

Eleven new proteins were identified in clone RRII 105 during hypersensitive response to pathogen attack (*Phytophthora meadii*). Western blotting experiments indicated the presence of chitinases and PR 1 group of acidic defence proteins induced in the host during the defence response.

8. Genomic stability (tissue cultured vs. bud grafted)

Genomic stability of tissue culture plants as well as bud-grafted plants in the field was analysed using isoelectric focusing technique. Two clones of *Hevea*, PB 235 and RRIM 600, were selected for the study. High percentage or degree of genomic stability was observed in the tissue culture plants when compared to the bud-grafted plants.

BOTANY DIVISION

The major thrust area of research in Botany Divison is genetic improvement through hybridization and ortet selection. Emphasis is being given for evaluation of clones having more yield than RRII 105. Studies on propagation, anatomy and cytogenetics are also being continued.

1. Evolving high yielding clones for traditional area

1.1 Hybridization and clonal selection

Monthly yield recording was continued in the 1985-planted small-scale trial of hybrid clones. The promising hybrid clones in the above trial continued to exhibit superior trend in yield as compared to RRII 105. A preliminary study was made on heterosis for test tap yield of 24 hybrid clones belonging to 12 cross combinations during the early phase of 44 months after field planting. Seventeen clones out-yielded the control clone RRII 105. The heterotic increase ranged from 2 to 292 per cent (Table Bot.1). A growth index of the above clones was computed at 14 months growth based on plant height, girth, number of leaf flushes and number of leaves, where 11 hybrid clones recorded growth indices (Table Bot. 1) above the general mean (16.07). RRII 105 exhibited a growth index of 14.21. High growth index indicates a reduction of immaturity period and thereby early attainability of tapping.

Hand-pollinated seedlings of 1996 hybridization programme were maintained in nurseries. During 1997, hand pollinations were carried out incorporating nine genotypes from wild germplasm with RRII 105 and RRIM 600. These wild genotypes were selected based on their superior performance in nursery level using girth, number of latex vessels, bark thickness and tolerance to *Phytophthora*. The small-scale trial of HP clones of 1994 hybridization was continued.

Table Bot.1. **Heterosis and growth indices of hybrid clones**

Clone	At the age of 44 months		At the age of 14 months
	Yield	Std. heterosis	Growth index
86/52	25.08	24.59	16.67
86/68	46.81	132.54	19.31
86/70	32.32	60.56	15.73
86/72	21.99	9.24	13.68
86/98	20.41	1.39	13.09
86/99	26.78	33.64	15.79
86/103	9.42	-50.20	11.53
86/109	55.54	175.91	15.99
86/179	8.38	-58.37	10.85
86/188	55.59	176.51	18.59
86/191	46.20	129.45	16.37
86/225	20.66	2.63	16.04
86/400	46.31	130.05	18.15
86/470	21.14	5.01	15.28
86/491	25.60	27.17	15.64
86/599	78.85	291.70	18.86
86/672	16.54	-17.83	18.43
86/674	33.47	66.27	16.39
86/701	13.84	-31.25	14.46
86/718	17.80	-11.57	17.79
86/727	21.20	5.32	13.32
86/834	18.66	-7.30	15.68
86/597	53.12	163.88	19.89
86/749	7.76	-61.45	19.97
RRII 105	20.12	-	14.21

1.2 Ortet selection

Monthly yield recording was continued in the small-scale trials of ortet clones at Cheruvally Estate and Mundakayam Estate. A total of 10 ortet clones in the 1992 small-scale trial was subjected to test tapping at the age of 4.5 years after assessing girth and other secondary characters. Data revealed that three clones recorded an average yield of 125.00, 226.80 and 122.50 g per

tree per 10 tap in comparison with 109.44 g for RRII 105, the control clone.

Gap filling was carried out in 1995 small-scale trial of ortets selected from smallholdings. Budwood was collected for multiplication from a smallholding at Pathanamthitta to observe the reported ortets. All other trials on immature ortets were continued.

1.3 Special techniques in breeding

Annual girth recording was carried out in the trial on irradiated materials (1985). Clones having better yield than RRII 105 were multiplied for further evaluation.

In the field trial on evaluation of selected clones resultant of mutation and polyploidy, girth recording was carried out. Three clones were found to be more vigorous in growth than the control RRII 105.

2. Evaluation of clones

Regular recording of yield, girth and other secondary characters was undertaken in the large-scale trial of Sri Lankan clones. Latex samples were collected to study latex properties. In the large-scale trial of Sri Lankan clones laid out in 1976, RRIC 104 (111.02 cm) and RRIC 52 (105.61 cm) recorded maximum vigour. RRIC 100 (54.35 g/tree/tap) and RRIC 7 (52.31 g/tree/tap) clones emerged as the highest yielders. Lowest yielder was GT 1 (40.48 g/tree/tap).

Regular recording of yield and secondary characters was continued in the mixed clone trial. In 1995-96, PR 261 and PB 235 (78.76 cm and 76.72 cm girth respectively) emerged as the most vigorous clones. Highest yields were obtained from PR 255 (70.17 g/tree/tap) and PB 310 (69.28 g/tree/tap). These two clones surpassed RRII 105 in yield (62.46 g/tree/tap).

In the selections from 1956 hybrid clones, RRII 208 (72.86 g/tree/tap) and RRII 203 (71.08 g/tree/tap) continued to record promising yield in the renewed bark (Table Bot.2). Five clones showed significantly more yield than the control (PR 107) with respect to yield.

Table Bot.2. **Mean yield of selections from 1956 hybrid clones in panel BI-2**

Clone	Mean yield over 3 years (g/tree/tap)
RRII 201	58.41
RRII 202	66.02
RRII 203	71.08
RRII 204	64.66
RRII 205	44.96
RRII 206	71.96
RRII 207	70.61
RRII 208	72.55
RRII 209	71.86
PR 107	42.47
SE	8.07
CD (P=0.05)	23.97

A field trial comprising of 34 clones of 42-month-old trees recorded 50 per cent or more yield than RRII 105 under test tapping, at the Regional Research Station, Padiyoor.

Field planting was completed in the large-scale clone trial 1996 and the trial was continued. In the 1992 trial on evaluation of selected clones annual girth recording was carried out.

Polybag plants of 10 clones of which six clones, *viz.* RRIC 110, RRIC 130, BPM 24, PR 255, PR 261 and RRIM 600 were introduced through the bilateral clone exchange programme and ortet clones were raised for a small-scale trial for 1997 planting.

3. Performance of clonal composites

Girth was recorded in the trials on multi-clone planting at Central Experiment Station, Chethackal. The clonal combination and proportion under different blending are given below:

Trial I	13 clones
RRII 105	40%
RRIM 600 GT 1 PB 235 PB 28/59 PB 217 RRIM 703	48%
PR 255 PR 261 RRII 5 PB 260 PB 280 PB 311	12%

(Completely randomized planting)

Trial II	13 clones
RRII 105	40%
RRIM 600 GT 1 PB 235 PB 28/59 PB 217 RRIM 703	48%
PR 255 PR 261 RRII 5 PB 260 PB 280 PB 311	12%

(Clonewise planting)

Trial III	7 Clones
RRII 105	40%
RRIM 600 PB 28/59 PB 217	48%
PR 255 RRII 5 PB 280	12%

(Completely randomized planting)

Trial IV	7 Clones
RRII 105	40%
GT 1 PB 235 RRIM 703	48%
PR 261 PB 261 PB 311	12%

(Completely randomized planting)

Trial V

Design	RBD
Replication	35
Clones	13 (same as that in Trial I)

Trial VI Monoclonal plot of RRII 105

Mean girth of one compact block of RRII 105, the control clone, under different combination are given in Table Bot.3. The clones exhibited different girthing pattern under different clonal combinations.

4. Polycross progeny evaluation

4.1 Evaluation of progenies of prepotent clones

Girth recording was made in the field trial of prepotent parents and their open-pollinated progeny comprising 150 clones.

4.2 Evaluation of prepotent clones in polyclonal garden

Vacancy enumeration and gap filling were done in the polyclonal garden laid out at HBSS, Nettana.

5. Breeding clones for combining compact canopy with good yield

Girth recording was done in the observational trial on progenies of genetic variants planted at RRII Experiment Station in 1988. Mean girth of morphotypes is 33.58 cm for dwarf, 36.03 cm for semi-dwarf, 42.07 cm for intermediate and 55.90 cm for normal types. RRII 105 recorded a mean girth of 52.27 cm.

Table Bot.3. **Mean girth (cm) of clones at the fourth year of planting**

Clone	Trial					
	I	II	III	IV	V	VI
RRII 105	18.58	20.71	19.60	17.15	18.90	17.40
RRIM 600	17.40	17.56	19.50	-	17.89	-
GT 1	18.75	20.10	-	17.18	18.38	-
PB 235	23.45	16.05	-	19.00	19.73	-
PB 28/59	19.04	14.78	20.66	-	19.30	-
PB 217	17.58	13.30	20.86	-	18.40	-
RRIM 703	17.22	20.94	-	18.87	18.06	-
PR 255	15.67	18.67	15.25	-	5.22	-
PR 261	11.33	24.17	-	18.50	16.63	-
RRII 5	12.25	21.75	17.63	-	15.98	-
PB 260	25.17	22.67	-	22.00	18.48	-
PB 280	20.00	19.67	20.86	-	18.65	-
PB 311	21.17	20.17	-	20.33	19.59	-

6. Breeding for powdery mildew resistance

Disease rating of 20 selected clones for their reaction to powdery mildew was carried out under field condition. Leaf samples were collected for measuring the relative proportion of infection.

7. Investigations on Genotype x Environment interaction

Planting of polybag plants of 12 clones was completed in five locations, *viz.* Kanyakumari (Tamil Nadu), Padiyoor (Kerala), Nagrakatta (West Bengal), Agartala (Tripura) and Bhubaneswar (Orissa). Observations on plant height, girth and number of leaf whorls were recorded. Soil moisture content was also recorded.

8. Estimation of genetic parameters

Data on dry rubber yield of 23 hybrid clones resultant of the cross between RRII 105 and RRIC 100 over the first three years of tapping were subjected to variability studies. The clones exhibited significant clonal variability with regard to yield and yield components favouring better scope for selection. Regression studies of mature yield on early yield (Table Bot.4) revealed that early yield at the age of 4.5 years can be a reliable predictor of mature yield.

The regression equation is

$$y = 6.13 + 3.98 \text{ x } (r=0.9183^{**})$$

where y = mature yield (mean over first three years of tapping)

x = early yield (4.5 years after planting)

r = correlation coefficient between early and mature yield.

Table Bot.4. **Dry rubber yield of hybrid clones in the early and mature phase of evaluation**

Clone	Dry rubber yield (g/tree/tap)	
	Early phase (4.5 years)	Mature yield (Mean over 3 years)
82/3	13.83	64.00
82/4	10.66	56.73
82/5	8.30	30.88
82/7	15.89	66.14
82/8	4.48	26.45
82/10	14.82	56.61
82/11	6.60	37.37
82/14	18.08	88.20
82/15	4.35	20.50
82/17	13.55	60.95
82/18	10.81	39.39
82/19	5.7	20.21
82/20	8.52	32.24
82/21	11.64	61.70
82/22	17.62	78.76
82/23	9.86	44.12
82/24	12.42	54.50
82/25	11.38	53.55
82/26	8.77	42.29
82/27	15.40	62.96
82/28	11.53	44.42
82/29	19.90	78.83
82/30	13.86	71.77
RRIC 105	9.35	38.15
RRII 100	9.85	58.55

9. Cytogenetical investigations

Detailed cytogenetical studies on an inter-specific hybrid of *Hevea* (*H. brasiliensis* x *H. benthamiana*) have been carried out. The hybrid showed close resemblance to *H. benthamiana* in floral characters but attained an intermediate position to either of the parents with regard to fruits and seeds. Meiosis in the hybrid was highly irregular. Sixty per cent of the pollen grains in the hybrid were sterile, while in *H. benthamiana* it was 9.5 per cent and in *H. brasiliensis* 7.2 per cent. Irregularities in meiosis lead to the for-

mation of unbalanced gametes. Formation of 40 per cent fertile pollen is suggestive of partial homology of the parents. The hybrid was found to be highly resistant to diseases.

Chiasma frequency study of the clone RRII 208 has been done. Eleven ring bivalents and seven rod bivalents were observed in the pollen mother cells at diakinesis. Mean chiasma frequency is found to be 27.34 per cell.

10. Anatomical investigations

10.1 Bark anatomical investigations

Five trees of RRIM 600 were selected during September 1996 and the affected portion was debarked by successive tapping leaving the residual bark intact. After six months, the regenerated bark along with the TPD affected bark on rest was tapped. Free flow of latex was observed from the regenerated bark while the affected bark on rest has not recouped. A detailed study on this aspect is in progress.

To study the effect of tapping on normal rhythm of cambial activity, a new experiment was initiated. Twigs and bark samples were collected from trees under different tapping intensities for anatomical studies. A study on intraxylary phloem from the twig samples of 1993 HP was carried out and the data are being processed.

10.2 Evaluation of clones for bark anatomical components

Evaluation of the bark anatomical traits of 23 hybrid clones resultant of a cross of RRII 105 x RRIC 100 revealed significant clonal variation. Mean values of bark thickness and latex vessel rows at opening and at six years after bark regeneration are presented in Table Bot.5.

Table Bot.5. **Bark thickness and number of latex vessel rows**

Clone	Virgin bark (3rd year)		Bark of six years renewal	
	Bark thickness (mm)*	No. of latex rows**	Renewed thickness (mm)**	No. of latex vessel rows**
82/3	7.50	18.25	7.29	13.50
82/4	7.88	14.72	6.95	17.55
82/5	7.79	13.83	7.29	13.55
82/7	8.04	15.39	8.25	16.73
82/8	8.67	18.05	8.92	17.17
82/10	7.84	19.58	8.54	17.38
82/11	7.28	17.05	7.33	16.61
82/14	8.61	21.76	7.85	19.83
82/15	7.18	12.05	6.74	9.49
82/17	8.09	20.49	8.34	18.93
82/18	8.00	16.00	7.42	13.13
82/19	7.21	9.33	6.92	8.94
82/20	7.29	14.16	7.29	15.94
82/21	8.39	20.44	7.55	15.91
82/22	8.18	21.66	7.67	25.86
82/23	7.52	15.44	7.70	14.03
82/24	7.75	16.55	7.58	16.67
82/25	8.21	17.44	7.63	15.33
82/26	7.58	17.22	7.33	16.39
82/27	8.18	16.72	7.34	14.01
82/28	7.40	15.77	7.18	14.72
82/29	7.89	22.00	7.68	21.64
82/30	7.92	18.32	7.38	11.83
RRIC 100	8.17	15.21	8.00	19.38
RRII 105	7.11	15.55	6.61	12.88
Mean	7.83	16.92	7.55	15.90
CD (P=0.05)	0.93	4.27	1.04	3.99

* Clonal variation significant at P = 0.05
** Clonal variation significant at P = 0.01

11. Wood anatomical investigations

To study the effect of ethephon stimulation on rubber wood quality, 20 trees of clones RRII 105 and RRIM 600 were selected for stimulation for a period of five years. Monthly ethephon application is in progress.

Five clones, RRII 105, RRII 203, RRII 208,

RRIM 600 and GT 1 planted during 1973-74 were selected from six locations to initiate a study on latex-timber clones. Wood availability from the standing trees was recorded.

12. Studies on propagation

In the trial on budding height and depth of planting, regular collection of data was discontinued. However, the trial is still being maintained for observing future uprooting to assess the influence of high budding and deep planting on root anchorage. Polybag plants (control) continued to show maximum vigour (57.08 cm). Among high budding, those budded at 45 cm above collar recorded maximum girth (56.63 cm). In the comparative study of twin stock and single stock, secondary characters of the plants were recorded.

Growth characters of the bag plants raised from bench grafts (with green buds) were recorded. The bench-grafted plants under field evaluation were opened for tapping. The yield and secondary characters are being recorded. Girth data collected during 1995-96 were summarised. Bench-grafted trees exhibited marginal superiority (55.13 cm) over nursery-grafted trees (54.50 cm).

In the trial on deep planting of 2-whorled bag plants, girth and other characters were recorded. Deep planted plants showed more growth than the normal planting (35.83 cm). Maximum girth (37.33 cm) was observed for bag plants planted deep up to 10 cm.

From the studies on the effect of delayed opening and pulling out and establishment in polybags of green-budded stumps, buddings opened after 25 days recorded the maximum success (94.71%). Budded plants were planted in polybags for observing their establishment and growth. Control plants recorded budding success of 89.92 per cent.

13. Genetic basis of stock-scion relationship

Yield and secondary characters of the clones on different root systems were recorded. Girth data for 1995 were summarised. RRII 203 on assorted stock recorded the maximum girth of 68.10 cm followed by the same clone on own stock (67.57 cm).

In the 3 x 3 stock-scion combination trial, secondary characters were recorded and girth data summarised. RRII 203 on own stock, on RRIM 600 and RRII 105 recorded 48.41, 45.82 and 43.24 cm girth respectively.

14. Studies on early evaluation

The trial incorporating high, medium and low yielding clones is being continued.

15. Morphological characterization of popular clones

To recognise morphological characters useful for identification of recommended clones, at polybag stage, 10-month-old polybag plants of 19 clones were multiplied and established.

GERMPLASM DIVISION

The Germplasm Division continued its activities on introduction, collection, conservation and evaluation of *Hevea* germplasm.

1. Introduction, collection and conservation of germplasm

1.1 Wickham collections from secondary centres

As part of the germplasm conservation, five germplasm gardens comprising 124 Wickham clones are being maintained at Central Experiment Station of Rubber Research Institute of India. Monthly yield and annual girth were recorded from Garden II and III.

Multivariate data collected from Garden II for analysing the genetic divergence were processed. Data on annual girth, dry rubber yield, total volume, DRC, plugging index, initial flow rate, bark thickness, total number of latex vessel rows (TLVR), density of latex vessels (DLV) and diameter of latex vessels were subjected to Mahalonobis D^2 analysis based on which 35 clones were grouped into nine genetically diverse clusters as shown in Table Ger. 1.

Table Ger.1. **Distribution of clones in genetically divergent clusters**

Cluster No.	No. of clones	Name of clones
I	17	RRIM 501, 513, 519, 526, 600, 604, 605, 607, 620, 621, 636, 701, 704, 705, 707 IAN 717, 873
II	5	RRIM 601, 603, 611, 617, 622
III	4	RRIM 608, 610, 703, Harbeal 1
IV	2	RRIM 615, IAN 713
V	2	RRIM 623, 706
VI	2	RRII 105, RRIM 602
VII	1	RRIM 612
VIII	1	RRIM 632
IX	1	RRIM 519

Table Ger.2. **Genotypic and phenotypic correlations among the various traits**

		Girth	Girth increment	Bark thickness	Yield	TLVR	DLV
Girth	G	1	0.7483	-0.5093	0.7623	0.1885	0.5380
	P	1	0.6962	0.3939	0.6150	0.1690	-0.2237
Girth increment	G		1	-0.7466	0.8656	0.3660	-0.1933
	P		1	0.0028	0.5798	-0.0138	-0.2609
Bark thickness	G			1	0.1221	0.4689	-0.3127
	P			1	0.3484	0.3071	-0.4283
Yield	G				1	0.8306	-0.7800
	P				1	0.5217	-0.3711
TLVR	G					1	-1.1265
	P					1	-0.4260
DLV	G						1
	P						1

G = Genotypic correlation
P = Phenotypic correlation

Table Ger.3. **Direct and indirect effects of morphological and anatomical traits on yield**

	Girth	Girth increment	Bark thickness	TLVR	DLV
Girth	**1.0535**	-1.2623	0.7480	0.3251	-0.1021
Girth increment	0.7883	**-1.6869**	1.0966	0.6311	0.0367
Bark thickness	-0.5365	1.2595	**-1.4687**	0.8084	0.0593
TLVR	0.1986	-0.6174	-0.6886	**1.7243**	0.2137
DLV	0.5667	0.3260	0.4593	-1.9424	**-0.1897**

Residue = 0.5063
Direct effect in bold letters

Table Ger.4. **Annual average girth of IRCA clones at the age of five years**

Clone	Girth
IRCA 111	36.28
IRCA 130	33.44
IRCA 109	32.29
IRCA 230	30.25
IRCA 18	29.05
RRII 105	27.20
CD (P=0.05)	2.09

Genotypic and phenotypic correlations among six morphological and anatomical traits in the IRCA clones of Garden IV were worked out and the results are presented in Table Ger. 2. TLVR showed highest genotypic correlation with yield. Path coefficient analysis showed that TLVR had the maximum direct effect on yield (Table Ger. 3). The annual girth of five IRCA clones along with control is shown in Table Ger. 4. All the clones showed greater values of girth than the control.

The mean annual girth of 20 clones at the age of three years in Garden V is shown in Table Ger. 5. The maximum girth was recorded in RRII 173 which showed 36 per cent more girth than the control (RRII 105).

1.2 Wild Brazilian germplasm from 1981 IRRDB collection

A total of 126 accessions from the wild Brazilian germplasm have been selected for raising planting materials for the proposed evaluation for latex timber traits.

Table Ger.5. **Annual average girth of the clones in Garden V at the age of three years**

Clone	Girth (cm)
RRII 173	15.54
RRIC 100	14.54
RRII 12	14.35
RRIM 609	13.78
RRII 23	12.84
SCATC 88-13	12.69
PB 255	12.59
SCATC 93-114	12.50
RRIC 45	12.34
Haiken 1	12.25
RRII 22	11.81
RRII 27	11.80
RRII 105	11.43
RRII 20	10.96
RRII 108	10.74
RRIC 102	10.05
RRIC 36	08.89
RRII 15	08.45
RRIM 618	08.13
PR 55	07.94
CD (P=0.01)	2.22

2. Evaluation of germplasm

2.1 Preliminary evaluation of 1981 IRRDB collection

Seven evaluation trials are now underway. Test tapping of 64 genotypes

belonging to evaluation trial B was carried out. Leaf and bark samples were collected and processed for anatomical investigations. Stomatal studies have also been initiated in these genotypes. Several genotypes showing more vigour than the control clone RRII 105, were also identified in the trials. Observations on girth, height and height of first branching were recorded in the evaluation trials planted in 1994.

2.2 Large-scale evaluation of 1981 IRRDB collections

The large-scale evaluation trial planted at RRS Padiyoor in 1995 comprises 80 wild genotypes selected for their superior performance for individual trails in the preliminary evaluation stage. Observations on various morphological characters like girth, number of leaves per whorl, number of whorls per plant and number of leaves per plant were recorded.

3. Multidisciplinary / general studies

3.1 Studies on the variation in the anatomical features related to stress, yield, diseases, *etc.*

Recording of bark thickness and collection of bark and leaf samples of the genotypes from evaluation trial B were carried out and the samples were processed for anatomical observations. Bark samples from 25 genotypes of Garden II were also collected.

3.2 Maintenance of national accession register, herbarium and clone museum

The National Accession Register is being maintained. Specimens of 300 wild genotypes were collected and the herbarium was prepared. Leaf samples and budwood of different clones were supplied to Biotechnology, Plant Pathology and Plant Physiology Divisions for various experiments.

3.3 Micromorphological, histological and histochemical characterisation of the IRRDB germplasm of *Hevea*

Processing of the leaf samples from 100 genotypes from evaluation trial A was completed and the recording of the histological observations was initiated.

3.4 Multivariate analysis in *Hevea*

A project on multivariate analysis was initiated in 25 clones of *Hevea* in order to compare the performance of young buddings with the corresponding mature plants. Morphological, anatomical and physiological characters are observed and analysed biometrically. Recording of data from mature plants and corresponding young plants raised in polybags has commenced.

3.5 Studies on drought tolerance in *Hevea* germplasm

A project on genotypic evaluation and screening for drought tolererance in wild *Hevea* germplasm was initiated in order to evolve suitable screening procedures for identifying drought tolerant genotypes. Selected 100 genotypes from evaluation trial A based on summer girth increment.

3.6 Hybridization of wild Brazilian germplasm with Wickham clones

Superior genotypes identified from the wild germplasm have been used as parents in the hand pollination programme with popular Wickham clones, in collaboration with Botany division. A total of 4391 crosses were made involving nine wild genotypes and two Wickham clones.

MYCOLOGY AND PLANT PATHOLOGY DIVISION

The research activities of mycology, plant pathology and entomology units under this Division centred mainly around plant protection aspects, while the microbiology unit was engaged in studies on soil improvement through microbial inoculations, biological treatment of waste water from rubber processing factories to control environment pollution and in getting return by way of biogas.

1. Abnormal leaf fall disease

The incidence of abnormal leaf fall disease was severe in the high rainfall areas. As the southwest monsoon was delayed by one week, the aerial spraying operations in most areas could be completed in time.

The experiment for evaluation of oil-based mancozeb (Indofil M-45) as an alternative for oil-based copper oxychloride (COC) was continued at two locations. In the first, mancozeb alone (5 kg/ha) and mancozeb + COC (5 and 10 kg/ha) were compared with COC (8 kg/ha). The leaf retention in mancozeb-sprayed plots was found to be inferior to COC-sprayed plots. In the other location, mancozeb + COC (5 kg/ha) was on par with COC (8 kg/ha)-sprayed control. Mancozeb alone (5 kg/ha) was inferior with respect to leaf retention. In the first location, the fungicides were sprayed using micron (ground) sprayer while in the second, aerial spraying was done.

A new formulation of fungicide containing 40 per cent COC and 5 per cent metalaxyl (Ridomil Plus) was field-tested in a small-scale trial. The percentage leaf retention is presented in Table Path.1.

Table Path.1. **Percentage leaf retention**

Treatment	Dosage (kg/ha)	Leaf retention
Ridomil Plus	7.5	60
Ridomil Plus	5.0	50
Copper oxychloride	8.0	29

The spray oil manufactured by M/s. Cochin Refineries Ltd. was approved for use after completing both field test and laboratory analysis. Another spray oil sample supplied by M/s. Joys Enterprises, Bangalore was subjected to large-scale field testing in three locations. As the efficacy of this sample was comparable to that of approved spray oil, it was recommended for use in rubber plantations.

A new sprayer manufactured by M/s. Power Mobiles Private Ltd., Chennai was tested for its efficacy. The sprayer could be carried by one worker and could deposit fungicide to a height of 7.5 m. This sprayer is proposed to be used for young rubber plantations (up to four-year-old). Further improvements were suggested to the manufacturer before large-scale field testing, to be taken up during next season.

In the experiment to study the cumulative crop loss on leaving areas unsprayed, the leaf retention in unsprayed plots of RRIM 600, RRII 105, GT 1 and RRII 118 was 17.37, 43.63, 55.69 and 59.33 compared to 29.7, 66.15, 60.90 and 64.78 per cent in sprayed controls respectively. An annual crop loss of 37.29, 8.21 and 16.58 per cent was recorded for clones RRIM 600, GT 1 and RRII 118 respectively. No crop loss was recorded in RRII 105.

In the experiment to assess crop loss in clone RRII 105 in a high rainfall area *vis-a-vis* dosage of COC used for spraying, the

mean leaf retention was 75.36, 65.25, 43.01 and 48.52 per cent in 8, 6, 4 and 2 kg COC-sprayed plots respectively. The yield from sampling trees and the block yield are being monitored.

2. High volume spraying

The experiment to study the effect of mixing spray oil with Bordeaux mixture using emulsifiers was continued at Pudukkad Estate in Palapilly. The treatments were imposed before the onset of southwest monsoon and the final leaf retention in the experimental blocks was assessed after the disease season. The results are furnished in Table Path.2.

Table Path.2. **Percentage leaf retention in high volume spraying**

Treatment	Leaf retention (%)
1. 1% Bordeaux mixture + 1% spray oil	69.0
2. 1% Bordeaux mixture + 2% spray oil	50.0
3. 1% Bordeaux mixture alone	58.0
4. Copper oxychloride in spray oil (1:5 proportion)	45.0

3. Control of shoot rot disease

3.1 Effect of spraying of phosphorous acid on NPK levels in leaves

An experiment was conducted on one-year-old field plants to study the effect of spraying phosphorous acid on NPK level in leaves. Spraying of Bordeaux mixture served as control. Leaf samples were analysed for NPK level before imposing the treatments and again after four months of spraying. The NPK levels at both stages of sampling are presented in Table Path.3.

The data indicated that spraying of phosphorous acid, which contained P, had no influence on NPK levels in leaves.

3.2 Effect of additives in controlling shoot rot disease

An experiment was initiated on first year field plants to assess the effect of using additives with fungicides such as Bordeaux mixture and phosphorous acid in controlling shoot rot disease. The spraying was carried out at fortnightly intervals till the end of disease season. The experimental plants were observed for disease intensity and the mean percentage disease index (PDI) is furnished in Table Path.4.

Table Path.4. **Shoot rot disease control**

Treatment	PDI
1% Bordeaux mixture + Sandovit	12.0
1% Bordeaux mixture + Vinofan	16.0
1% Bordeaux mixture + Delair wet	18.0
1% Bordeaux mixture alone	16.0
Phosphorous acid + Sandovit	12.0
Phosphorous acid + Vinofan	14.0
Phosphorous acid + Delair wet	18.0
Phosphorous acid alone	12.0
	NS

Table Path.3. **NPK levels in leaves (%)**

Treatments	N		P		K	
	I	II	I	II	I	II
Phosphorous acid	3.4931	3.4547	0.24208	0.2325	0.9966	1.2220
(SD)	0.3617	0.3088	0.1738	0.1764	0.0702	0.1126
Bordeaux mixture	3.5644	3.3312	0.2417	0.23708	1.02166	1.2350
(SD)	0.2955	0.3235	0.02453	0.01529	0.14517	0.1470

I = before spraying II = after 4 months spraying

The results indicated that there is no significant difference between treatments.

4. Powdery mildew disease

4.1 Control in mature rubber

An experiment was laid out to compare the efficacy of a new systemic fungicide, hexaconazole (Contaf) two per cent dust formulation, which was earlier found to be one of the best fungicides for the control of powdery mildew disease in the nursery plants, with the conventional sulphur dusting in highly susceptible clone PB 5/51. Four rounds of dusting were given at 10-12-day-interval. It was found that hexaconazole dust formulation was not giving adequate control of the disease when compared to sulphur dusting. Alternate dusting with sulphur and hexaconazole had given better result than dusting with hexaconazole alone (Table Path.5).

Table Path.5. **Powderly mildew disease control in mature rubber**

Treatment	Percentage disease index (PDI)		
	Beginning of the season	Mid-season	Final
S-S-S-S	0.00	73.39	47.13
C-C-C-C-	0.73	94.04	81.02
S-C-S-C-	0.43	78.39	60.52

S-Sulphur C - Hexaconazole (Contaf)

4.2 Control in immature rubber

An experiment was conducted to evaluate the most effective fungicide for the control of powdery mildew disease in one-year-old RRII 105 plants. Different fungicides, *viz.* carbendazim (Bavistin 50 WP) 0.075 per cent ai, myclobutanil (Systhane 10 WP) 0.04 per cent ai, wettable sulphur (Sulfex 80% WP) 0.10 and 0.20 per cent ai, penconazole (Topas 10% EC) 0.025 and 0.05 per cent ai, hexaconazole (Contaf 5% EC) 0.005 per cent and 0.01 per cent ai, validacin (3 per cent EC) 0.01 per cent ai were tried. Four rounds of spraying were given at 10-12-day-interval and percentage disease index (PDI) was tabulated for each spraying. It was found that all fungicides were equally effective in controlling the disease and were on par with conventional sulphur spraying.

4.3 Control in nursery plants

Experiment was conducted to identify the most effective fungicides for the control of powdery mildew disease in nursery plants using different fungicides. Four rounds of spraying were given at 10-12-day-interval and the disease incidence was assessed at different seasons. It was found that all fungicides tried were very effective in controlling the disease. Among systemic

Table Path.6. **Powderly mildew disease control in nursery plants**

Treatment	Percentage disease index (PDI)			
	Dosage (% ai)	Beginning of the season	Mid-season	Final
Carbendazim	0.075	38.83	31.92	10.75
Myclobutanil	0.04	35.92	13.67	9.33
Wettable sulphur	0.10	44.68	26.25	21.67
Wettable sulphur	0.20	38.00	15.50	11.00
Penconazole	0.025	36.42	17.75	7.33
Penconazole	0.05	33.83	15.50	12.08
Propiconazole 25 EC	0.025	43.50	13.67	11.00
Propiconazole	0.05	39.33	9.25	6.25
Hexaconazole	0.005	37.08	15.17	14.83
Hexaconazole	0.01	36.08	16.92	8.08
Validacin	0.01	36.25	35.58	16.67
Control (unsprayed)		37.25	62.17	42.08

fungicides, validacin, all other fungicides were equally effective in controlling the disease. Among different fungicides tried, propiconazole 0.5 per cent, penconazole 0.05 per cent, mycobutanil 0.04 per cent, hexaconazole 0.01 per cent were the best treatments and were superior to conventional sulphur dusting (Table Path.6).

5. Pink disease management

The experiment to evaluate the efficacy of some new systemic fungicides for the control of pink disease was continued. The percentage recovery of trees in various treatments is given in Table Path.7.

Table Path.7. **Pink disease control (% recovery)**

Treatment	% recovery of trees
Myclobutanil	78.0
Hexaconazole	81.0
Validacin	81.0
Thiram	70.0
Tridemorph	65.0
Bordeaux paste	55.0

In another experiment, the efficacy of three carriers was compared using the effective fungicides like validacin and tridemorph (Table Path.8).

Table Path.8 **Efficacy of carriers in the control of pink disease**

Carrier	% recovery of trees	
	Validacin	Tridemorph
Rubberkote	63.0	65.0
Dipicol	75.0	70.0
Vinofan	81.0	66.0

6. Panel diseases and their control

A panel protectant and wound dressing compound supplied by M/s. Thirumani Asphalts and Felts (P) Ltd., Coimbatore was field-tested and as it gave satisfactory panel protection, it was approved for large-scale use. Another new sample was tested for phytotoxicity and was found non-phytotoxic.

7. Dry rot disease

A field experiment was conducted for the control of dry rot disease caused by *Ustulina duesta* in RRIM 600, the most susceptible clone. Mild, moderate and severely infected plants were treated with hexaconazole (4 ml Contaf 5 EC/kg of Rubberkote), thiram (10 g Thiride 75 WP/kg), propiconazole (8 ml Tilt 25 EC/kg), validacin (20 ml Validacin 3 EC/kg), myclobutanil (6 g Systhane 10 WP/kg), tridemorph (12.5 ml Calixin 80 EC/kg) and penconazole (4 ml Topas 10 EC/kg) and it was found that when mildly or moderately infected plants were treated, all tested fungicides were equally effective in controlling the disease. When severely infected plants were treated, hexaconazole, tridemorph and penconazole gave high percentage of disease control.

8. Host-parasite relationship

Field trial to study the role of nitrogenous fertilizer on the incidence of *Corynespora* leaf disease on rubber seedlings was continued at Central Nursery, Karikkattoor. The disease incidence was observed to be proportional to nitrogen fertilization. The trial is being repeated.

Collection of different isolates of *C. cassiicola* was made from rubber plantations in Karnataka and different nurseries in Kerala. Studies were initiated on the occurrence of physiological races of the pathogen. Isolates obtained from Karnataka sporulated more than the isolates from Kerala.

In vitro studies on the effect of different amino acids on cultural growth of *Corynespora* were attempted. Among the

different amino acids tested, cysteine, asparagine, tryptophan, histidine and phenylalanine reduced the growth while glycine, methionine, glutamine and aspartic acid favoured the growth of the fungus at 500 ppm level.

9. Minor leaf spot diseases and their control

9.1 *Gloeosporium* leaf spot disease

9.1.1 Disease survey

A survey on *Gloeosporium* leaf spot disease was conducted during 1996, in major rubber growing areas of Kerala, Tamil Nadu and Karnataka. The survey was made in eight selected regions comprising 98 sites. The percentage disease incidence was calculated based on the frequency of the occurrence of the disease in each site and percentage disease index (PDI) is presented in Table Path.9. The result indicated that the highest disease incidence was in Thodupuzha region and least in Kulasekharam region. The clones RRII 105, PR 255, PR 261, PB 270 and PB 235 were more susceptible to *Gloeosporium*.

Table Path.9. **Regionwise incidence of *Gloeosporium* leaf disease**

Region	No. of sites surveyed	Disease incidence (%)
Calicut	14	63.07 (52.82)
Kulasekharam	12	29.17 (32.61)
Mangalore	9	60.33 (50.98)
Mundakayam	10	73.20 (59.74)
Punalur	12	67.25 (55.20)
Ranni	8	77.25 (61.25)
Thodupuzha	16	83.12 (66.20)
Thrissur	14	73.29 (58.10)
G. Mean		65.91 (54.91)
SE		6.24

Figures in parentheses are transferred values

9.1.2 Disease control

A field trial was carried out at Manikal Estate, Mundakayam to evaluate the efficacy of different fungicides for controlling the disease. The results indicated that all the fungicides significantly reduced the disease as compared to unsprayed control. Alternate use and combination of mancozeb and carbendazim were comparable to their separate use in controlling the disease (Table Path.10).

Table Path.10. **Control of *Gloeosporium* leaf spot disease**

Treatment	% disease index
Mancozeb 0.2% (Indofil M-45)	20.80
Carbendazim 0.05% (Bavistin)	22.80
Mancozeb (1%) + carbendazim (0.25%)	17.73
Hexaconazole 0.2% (Contaf)	29.87
Metalaxyl+mancozeb (0.1% Ridomil MZ	35.33
Metalaxyl+mancozeb (0.1% Ridomil MZ	24.93
Mancozeb (0.2%) and carbendazim (0.05%) (alternate spraying)	17.07
Bordeaux mixture 1%	22.93
Unsprayed control	45.33
CD (P=0.05)	7.46

9.2 *Corynespora* leaf fall

In India, *Corynespora* disease is a common leaf disease in seedling and budwood nurseries and was considered as minor in importance till 1995. From 1996, severe outbreak of the disease is being noticed in mature rubber in many parts of Karnataka state. Clones like RRII 105, RRII 118, PB 311, PB 260, PB 235, PR 255, PR 261, RRII 308, RRIM 600, a few ortet selections and polyclonal plantings were observed to get infected.

A survey on *Corynespora* leaf fall was

carried out in Karnataka Forest Development Corporation (KFDC) and *Hevea* Breeding Sub-station, Nettana, Karnataka. Survey indicated that the highest per cent disease incidence was in RRII 105, PR 255 and PR 261. Haiken 1 and KRS 15 were found free from *Corynespora* infection.

A nursery trial was carried out at Central Experiment Station, Chethackal including systemic and non-systemic fungicides to evaluate their efficacy in controlling the disease. All the fungicides tested were significantly superior to unsprayed control. The fungicides used and results are given in Table Path.11.

Table Path.11. **Control of *Corynespora* leaf spot disease**

Treatment	% disease index
Carbendazim 0.05%	21.61
Carbendazim 0.02%	28.67
Mancozeb 1% + carbendazim 0.25%	23.75
Mancozeb 0.2%	20.43
Hexaconazole 0.01%	40.08
Tridemorph 0.1%	35.19
Bordeaux mixture 1%	37.21
Phosphorous acid 0.08%	41.83
Thiram 0.2%	47.25
Hexaconazole 0.02%	35.62
Unsprayed control	56.95
CD (P=0.05)	7.02

Conducted a field trial for *Corynespora* leaf fall disease control at KFDC farm, Nettana, Karnataka in the clone RRII 105. Four fungicides, carbendazim (0.05%), mancozeb (0.2%), copper oxychloride WP (0.125%) and Bordeaux mixture (1%) were tested with fortnightly applications. Initial and final observations on disease incidence were made and the data are being analysed.

10. Root diseases and their control

Observations on the root disease control trial at Manikal Estate is being continued. The neighbouring treated plants remain healthy.

High incidence of purple root disease was observed in Rajagiri Estate, Konni, affecting the sprouting of the bud patch in nurseries and also causing death of plants. A trial has been started to control the disease. The different fungicides used are tridemorph (Calixin 3 ml/L), propiconazole (Tilt 4ml/L), hexaconazole (Contaf 2 ml/L) and thiram (Thiride 10 g/L). The affected seedlings in the nursery were uprooted, pruned and roots dipped in fungicide solution and planted in polybags. The soil in the polybag was also drenched with the respective fungicide solution. The untreated plants formed the control.

Fungicide bio-assay against purple root disease pathogen showed complete inhibition by tridemorph at 50 ppm and by propiconazole and hexaconazole at 250 ppm.

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

11.1 Screening of germplasm material

Observations on leaf fall and shoot rot due to *Phytophthora* were made in the experimental area in Central Experiment Station (CES) in the five blocks. Low susceptibility was observed in 125 genotypes which included 84 MT genotypes. Powdery mildew observation was also made in two experimental sites in CES. No tolerant genotype could be noticed.

11.2 Multidisciplinary evaluation of clones

Leaf fall due to *Phytophthora* was recorded in Trial I and Trial II during the season. It was observed that RRII 105, RRII 5, RRII 300, RRII 308, PB 217, KRS 25, PB 311, PB 312, PB 235 and KRS 128 showed low incidence of the disease (Table Path.12).

Table Path.12. **Percentage disease intensity of *Phytophthora* leaf fall**

Clone	% disease index	Clone	% disease index
RRII 105	18.62	PB 217	23.42
RRII 5	26.39	RRII 105	23.91
RRII 300	31.13	KRS 25	29.48
RRII 308	31.13	PB 311	29.52
SCATC 88-13	41.54	PB 312	31.06
PR255	43.76	PB 235	31.69
RRII 208	44.66	KRS 128	34.10
RRII 118	46.57	PB 255	45.29
SCATC 93-114	50.18	PB 310	45.44
RRIM 600	51.76	PB 260	45.84
PR 261	52.59	KRS 163	46.19
Haiken 1	73.02	PB 314	53.84
RRIM 703	77.31	PB 280	56.26
CD (P=0.05)	16.54	CD(P=0.05)	11.24

Powdery mildew incidence was also recorded in the above trials.

12. Biological control of diseases

12.1 Fungal antagonists

Various species and strains of *Trichoderma* isolated from different rubber growing tracts and *Trichoderma* spp. obtained from Tamil Nadu Agricultural University (TNAU), Coimbatore, were screened against various rubber pathogens like *Phytophthora* spp., *Corticium salmonicolor* and *Gloeosporium* sp. and it was found that all antagonists used were very effective against various pathogens tested. Promising strains of the *Trichoderma* are being used for further studies. Both antagonists and pathogens were screened with various fungicides, *viz.* penconazole, phosphorous acid, carbendazim, hexaconazole and myclobutanil up to 2000 ppm. It was found that phosphorous acid even at 2000 ppm did not inhibit the growth of antagonists whereas the growth of all pathogens were inhibited even at 50 ppm. All other fungicides screened were inhibiting the growth of both antagonists and pathogens at 50-100 ppm concentration.

12.2 Bacterial antagonists

Five strains of *Pseudomonas fluorescens* obtained from the TNAU were screened against *Phytophthora* sp., *Corticium salmonicolor* and *Gloeosporium* sp. It was found that all strains were very effective in controlling the pathogens screened under *in vitro* condition. Promising strains are being used for further studies.

13. Crown budding experiment

The intensity of abnormal leaf fall and powdery mildew diseases was assessed in the crown bud area in clone PB 311 at Malankara Estate.

Latex samples collected from the crown bud experimental areas at Kaliyar and Malankara were analysed for the physical properties. The results are furnished in Table Path.13.

Table Path.13. **Physical properties of latex from crown-budded trees**

1. Trunk clone : PB 311

Crown	Properties		
	Po	PRI	Mooney viscocity
PB 311	52	65	76
RRII 33	55	67	76
Fx 516	48	75	73

2. Trunk clone : RRIM 628

Crown	Properties		
	Po	PRI	Mooney viscocity
RRIM 628	49	82	76
RRII 33	56	68	74
Fx 516	49	75	61
F 4542	50	88	55

Table Path.14. **Evaluation of *Bradyrhizobium* isolates for *Mucuna bracteata* (after 40 days' growth)**

Rhizobium isolates	Shoot length (cm)	Shoot weight (g)	Root length (cm)	Root weight (g)	Nodule no.	Nodule weight (g)	Nitrogenase activity (n mol)
1	50	7.5	7.0	1.0	12	0.4	482
2	45	6.4	6.5	0.8	8	0.3	396
3	40	6.0	6.8	0.6	6	0.3	284
4	50	7.8	6.8	1.2	11	0.4	494
5	62	9.2	8.6	1.8	16	0.6	746
6	45	6.2	5.3	0.7	7	0.3	384
7	56	8.0	7.4	1.4	10	0.5	514
8	74	10.8	10.0	2.4	18	0.8	836
9	42	6.0	6.5	0.5	6	0.4	312
10	35	5.2	5.8	0.4	5	0.2	284

14. Microbiology of leguminous cover crops

Bradyrhizobium sp. specific for *Mucuna bracteata* was tested for its effects on nitrogenase activity, nodulation and growth under glass house condition. *Bradyrhizobium* strains 5 and 8 were found to be the best among the ten isolates tested (Table Path.14). Nodulation was compared on the rooted cuttings and the seed germination after inoculation of *Bradyrhizobium* sp. Seed inoculation was found to be better than the cuttings. However, application of *Bradyrhizobium* with cow dung after sprouting has also given good results.

15. Mushroom culture

Ganoderma mushroom was successfully cultivated on rubber wood sawdust following the method adopted for oyster mushroom cultivation. It took two months for the production of mushrooms, with an average yield of 400 g of mushroom per kg of sawdust. The mushrooms are leathery and dark brown in colour with white edges.

16. Pollution studies

A 3 m^3 Deenabandhu model biogas plant was fed with sheet processing effluent, keeping a hydraulic retention time (HRT) of 40 days. The quantity and quality of the gas produced and the effluent parameters after biomethanation were assessed. The characteristics of water coming out of the biogas plant were within the safe limit (Table Path.15).

Table Path.15. **Characteristics of effluent in the biogas plant**

Parameter *	Raw effluent	After bio-methanation
pH	6.1	7.2
Chemical O_2 demand	3145	92.5
Biochemical O_2 demand	1485	42.7
Total solids	2438	1475.5
Dissolved solids	1832	850.4
Suspended solids	536	85.3
Sulphate	Nil	Nil
Chloride	Nil	Nil
Oil & grease	Nil	Nil

* (all values except pH are in mg/L)

Five laboratory biogas plants having 24L digester volume were filled initially and charged daily with sheet processing effluent keeping 40 day (HRT). The plants were run for 60 days to establish methanogenesis. They were further run for 50 days at different HRT between 5 and 25 days using

different volumes of ingoing effluent. The data on the performance of biogas plants at different HRT are presented in the Table Path.16 which shows the maximum daily biogas production at 10 day HRT. HRT shorter than 10 days resulted in accumulation of volatile fatty acids (VFA), whereas at HRT longer than 10 days, the digester capacity of the plant was not fully utilized (Table Path 16).

Table Path.16. **Performance of biogas plants at various HRT**

Plant No.	1	2	3	4	5
HRT day	5	10	15	20	25
Biogas produced (L/day)	10.2	15.3	14.6	13.2	12.8
Methane content (%V/V)	56	55	54	52	52
pH of the fermenting liquid	6.5	7.1	7.1	7.3	7.4

Biologically inert materials like glass marbles, stone pebbles and plastic mesh added to the sheet processing effluent, yielded 10-15 per cent more gas than the control.

Calcium hydroxide was mixed with soil, sawdust and china clay at various concentrations, made to pellets and tested for the absorbance of hydrogen sulphide (H_2S) in the biogas. Calcium hydroxide and fine soil in 1:1 ratio was found to be the best in absorbing H_2S.

17. Improvement of cover crops and rubber through microbial inoculants

17.1 Investigations on non-symbiotic nitrogen fixing organisms

More isolates of the non-symbiotic nitrogen fixing *Azotobacter* sp. were collected from different rubber growing areas. The nitrogen fixing ability of five morphologically different *Azotobacter* cultures in broth culture was studied at four different pH, ranging from 4 - 7 using gas chromatograph. The nitrogenase activity after 1 h incubation is given in Table Path.17.

Table Path.17. **Nitrogenase activity (n moles of ethylene produced) of different isolates of *Azotobacter* sp. at different pH.**

Isolate	pH4	pH5	pH6	pH7
Azotobacter sp.1	8	67	708	289
Azotobacter sp.2	826	971	449	400
Azotobacter sp.3	21	232	348	277
Azotobacter sp.4	561	1012	1379	970
Azotobacter sp.5	6.0	374	689	945

Among the different isolates, *Azotobacter* sp. isolate 4 showed maximum nitrogen fixation at pH 5 and 6. Maximum nitrogenase activity at pH 4 was shown by *Azotobacter*. Except *Azotobacter* isolate 5, all other isolates preferred acidic pH. This initial study shows the possibility of using these different isolates in the acidic soils of rubber growing areas.

In order to study the phosphate solubilizing capacity of these nitrogen fixing *Azotobacter* culture, they were inoculated to apatite agar containing tricalcium phosphate as precipitate. On incubation, all the inoculated cultures exhibited clear zones of phosphatic solubilization around the colonies. Further studies on the effect of solubilization of Mussoorie rock phosphate are in progress.

Continued the studies on the effect of inoculation of a selected *Azotobacter* sp. on the growth of rubber seedling at different levels of urea application. Periodic observations on the girth and height of plants and survival of the bacteria in soil are recorded.

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

An experiment was initiated on polybag plants to study the effect of three mycorrhizae, *viz. Glomus caledonium, Glomus fasciculatum* and *Glomus* sp. on the growth of rubber seedlings. The plants were raised in unsterilized soils. Soils containing spores and infected roots were used as inoculum. Periodic observations on the height and girth of mycorrhizae-inoculated and control plants were taken and the experiment is in progress.

Different host plants *viz. Sorghum bicolor, Zea mays, Pueraria phaseoloides* and *Pennisetum polystygon* were tested for the mass multiplication of *G. fasciculatum*. Vermiculite soil mixture was used as growing medium. Soil samples and roots of plants were collected after 40 days and spore count as well as root infection were recorded (Table Path.18).

Table Path.18. **Root colonization and spore count after 40 days in soil upon *G. fasciculatum* inoculation on various host plants (mean of 5 replications)**

Treatment	Per cent infection	Spore count (vermiculite soil mix ml^{-50})
P. phaseoloides	82	428
S. bicolor	92	882
Z. mays	88	826
P. polystygon	86	780

The results showed that good root colonization and AM spore count in soil vermiculite mixture was recorded when *S. bicolor* was used as host plant. Isolated different phosphate solubilizing bacteria and fungi from various rubber growing areas for further studies.

18. Bee-keeping in rubber plantations

Out of the five colonies of Indian honey bee, *Apis cerana indica* maintained at RRII farm, three colonies were lost due to Thai Sac Brood Virus (TSBV) disease. The remaining two also had mild attack of TSBV disease.

The performance of *Apis mellifera* under different conditions in various regions in Kerala was studied. The colony development and honey production were good at two regions *viz.* Chittarickal and Muttuchira due to the availability of enough natural nectar and pollen. Bee-eating bird *Merops* sp. was recorded as a major predator of *Apis mellifera*.

The development of *A. mellifera* colonies at RRII farm was not satisfactory. Even with the supply of artificial pollen and sugar syrup, the brood development and honey collection were very poor due to the scarcity of natural pollen and nectar sources and the attack by bee-eating birds. Two of the colonies were shifted to CES, Chethackal on an experimental basis where there are more pollen and nectar sources than at RRII. Further studies on their performance in pollen carrying capacity and brood rearing activity are in progress.

19. Minor pests

19.1 Termites

An experiment was laid out at Vaniyampara Estate, Trichur district on termite control (*Odontotermes obesus*) infesting budded stumps planted in 1996. Chlorpyriphos (Classic and Cyphos), fenvalerate and endosulfan were drenched at various concentrations at the base of plants. The post-treatment effect was evaluated after seven and 30 days and it was found that all these treatments were effective in giving 90 per cent control (Table Path.19).

Table Path.19. **Effect of insecticides against termites affecting rubber seedlings**

Treatment	Dose	Mean per cent control after 7 days	after 30 days
Chlorpyriphos (Classic 20)	0.06	100	78.88
	0.10	100	100
	0.14	100	100
	0.20	100	100
Chlorpyriphos (Cyphos 20)	0.06	100	90.05
	0.10	100	100
	0.14	100	80.62
	0.20	100	100
Fenvalerate 20 EC (Sumicidin 20)	0.02	100	81.61
	0.04	100	100
Endosulfan 35 EC (Spic sulpha 35)	0.10	100	100
	0.175	100	100
Control (untreated)		4.64	9.59

19.2 Bark feeding caterpillar

The experiment on control of bark feeding caterpillar, *Aetherastis circulata*, infesting rubber trees was continued at the caterpillar-infested areas of Velimala Estate, Kanyakumari district, Tamil Nadu. The trial revealed that methyl parathion 2D at 10 kg per ha was the best in controlling (88.88%) the caterpillar (Table Path.20). This was followed by fenvalerate 0.4D at 10 kg per ha (77.19%).

19.3 Rainguard damaging crickets

The crickets, *Gryllacrys* sp. are damaging the rainguards in many rubber growing areas. The effect of following insecticides was tested for control of the crickets, *viz.* neem oil 10 ml/L, malathion 0.1 per cent, methyl parathion 0.1 per cent, dimethoate 0.1 per cent, fenvalerate 0.02 per cent, BHC 0.2 per cent and phorate 2g/L. The applications of these materials on the tapping panel once in a week during the monsoon season showed that neem oil, dimethoate, malathion and methyl parathion were effective in the order of its efficacy. It was also proved that these insecticides are compatible with mancozeb fungicide used on the tapping panel for protection from black stripe (Table Path.21).

Table Path.20. **Effect of insecticidal applications against bark feeding caterpillar**

Treatment	Dose	Mean per cent reduction of caterpillars after 2 days	after 30 days
Endosulfan 4D	7kg/ha	5.74	48.21
Endosulfan 4D	10kg/ha	18.06	67.64
Fenvalerate 0.4D	7kg/ha	10.20	65.10
Fenvalerate 0.4D	10kg/ha	21.37	77.19
Methyl parathion 2D	7kg/ha	13.44	71.74
Methyl parathion 2D	10kg/ha	26.87	88.88
Control (untreated)		3.12	18.29

Table Path.21. **Effect of insecticides against rainguard damaging crickets**

Treatment	Per cent damage after 7 months
Neem oil 10ml/L water	3.6
Malathion 0.1%	6.4
Methyl parathion 0.1%	7.6
Dimethoate 0.1%	5.2
Fenvalerate 0.02%	8.4
B.H.C. 0.2%	7.6
Phorate 2g/L	12.0
Control (untreated)	16.36

19.4 Nematodes

Four systemic nematicides, *viz.* carbofuran, phorate, aldicarb and sevidol at 6, 10 and 15 kg/ha applied two times at the same rate for a period of six months against root-knot nematode, *Meloidogyne incognita* in rubber nursery at Kadackamon were evaluated. In general, all the treated plants recorded significant increase in plant growth but plants treated with phorate at the rate of 15 kg/ha recorded maximum plant growth compared to all the other dosages. Carbofuran at the rate of 15 kg/ha is found very effective in decreasing root-knot infestation in rubber seedlings and soil nematode population, followed by phorate 15 kg/ha and carbofuran 10 kg/ha. Thus application of carbofuran or phorate at the rate of 15 kg/ha is good for the release of nematode-free seedlings from infested rubber nurseries.

A survey was made in 10 rubber growing nurseries to evaluate the frequency and distribution of plant parasitic nematodes. Nematode species of five different genera, *viz. Meloidogyne* sp., *Helicotylenchus* sp., *Hemicriconemoides* sp., *Aphelenchus* sp. aand *Tylenchus* sp. were recorded. *Meloidogyne* sp. is recorded as the most predominant parasitic nematode and its population density is found ranging from 110 in Paraliar to 2100 in Kanhikulam nursery. *Helicotylenchus* sp. and *Hemicriconemoides* sp. were also found in large numbers whereas the population of *Aphelenchus* sp. and *Tylenchus* sp. was comparatively low.

An *in vitro* study was conducted with the aqueous extracts of *Pongamia glabra, Azadirachta indica* and *Mucuna bracteata* against root-knot nematode, *Meloidogyne*

Table Path.22. **Effect of plant extracts on mortality of *M. incognita* larvae**

Treatment (plant extracts)	Dilution	Per cent mortality of nematodes/exposure period in h.				
		3	6	12	24	48
Pongamia glabra	1:1	64	80	84	88	96
	1:5	52	68	76	84	87
	1:10	28	47	56	76	80
	1:25	0	20	44	64	76
	1:50	0	0	32	55	60
	1:100	0	0	0	20	28
Azadirachta indica	1:1	56	68	72	80	84
	1:5	40	48	60	72	82
	1:10	20	44	52	64	68
	1:25	0	16	36	48	56
	1:50	0	0	20	28	40
	1:100	0	0	0	12	20
Mucuna bracteata	1:1	32	40	52	68	76
	1:5	20	32	48	56	68
	1:10	12	28	36	44	52
	1:25	0	0	12	20	36
	1:50	0	0	0	8	24
	1:100	0	0	0	0	12

incognita. The toxic effect of the extract of *P. glabra* is found to be more than that of *A. indica* and *M. bracteata*. The per cent mortality is found to be more with increase in concentration and exposure periods (Table Path.22).

20. Rubber wood preservation

The sap stain fungus, *Botryodiplodia theobromae* is causing much degradation to the rubber wood planks. The planks after diffusion treatment with benzylon 2PW 20 per cent, benzylon DW 33 per cent, propiconazole 25 per cent and hexaconazole 5 per cent at different concentrations revealed that benzylon DW 33 per cent at 250 ppm, propiconazole 25 per cent at 500 ppm and hexaconazole 5 per cent at 500 ppm protected the treated rubber wood planks from *B. theobromae* for two years. The mould fungi *viz. Fusarium* sp. and *Aspergillus* sp. infection, however, occurred at low rate.

21. Vermiculture

Among the three worms, *viz. Eisenia foetida, Perionyx sansibaricus* and *Eudrilus eugeniae* was found more efficient in converting organic wastes into vermicompost in a short time. Laboratory trials with *E. euginiae* revealed that it can convert rubber wood sawdust into vermicompost. However, the nitrogen values are less as in the case of rubber wood sawdust itself. In confirmatory studies with *E. euginiae*, it was observed that N, P and K contents of the vermicompost were 0.13 per cent, 19 mg/100 g and 640 mg/100 g respectively (Table Path.23).

Table Path.23. **Nutrient level variations in vermicompost* using different worms**

Worm	Nitrogen %		Phosphorus mg/100 g		Potassium mg/100 g	
	I	II	I	II	I	II
Perionyx sansibaricus	0.043	0.14	20	28	230	400
Eisenia foetida	0.032	0.11	18	25	340	510
Eudrilus eugeniae	0.028	0.13	13	19	315	640
Control (without worm)	0.042	0.062	15	18	280	315

* Substrate - rubber wood sawdust I - before vermicomposting II - after vermicomposting

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	1:25	0	16	36	48	56
	1:50	0	0	20	28	40
	1:100	0	0	0	12	20
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	1:10	12	28	36	44	52
	1:25	0	0	12	20	36
	1:50	0	0	0	8	24
	1:100	0	0	0	0	12

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PLANT PHYSIOLOGY AND EXPLOITATION DIVISION

1. Ecophysiology of *Hevea*

1.1 Influence of field drought and high temperature

In continuation of the earlier studies to analyse the effects of drought on growth and yield, a few more experiments were conducted to study the water relation and photosynthesis aspects of drought effect in relation to irrigated trees.

During peak summer, photosynthesis of intact leaves in irrigated trees was 10.8 µmol/m^2/s at a light intensity of 1500 mol/m^2/s, but at the same light intensity, rainfed trees were respiring @ 1.2 µmol/m^2/s. When the light intensity was reduced to 100 µmol/m^2/s photosynthetic rate came down to 2.7 µmol/m^2/s in irrigated trees and rainfed trees also started photosynthesising (0.52 µmol/m^2/s). Such a response of rainfed trees is an indication of high light-induced inhibition of photosynthesis due to drought.

Table Phys.1. **Influence of atmospheric and soil drought on growth and yield**

Parameter	Irrigated	Rainfed
Photosynthesis (µmol/m^2/s)		
at light=1500 µmol/m^2/s	10.72	-1.2
at light=100 µmol/m^2/s	2.73	1.2
Root biomass (g/m^3 soil)	610	617
Pre-dawn leaf water potential (bar)	-15.65	-18.60
Pre-dawn latex solute potential (bar)	10.4	13.22
Pre-dawn turgor pressure (bar)	7.0	5.5
Yield (kg/ha/year)	1058	Yet to be opened

Details of the water relations of irrigated and rainfed trees are given in Table Phys.1. Irrigated trees were opened for tapping at the end of eighth year while rainfed trees have not attained tappable girth even after nine years. Growth and yield details are given in Table Phys.1.

1.2 Molecular level responses of *Hevea* to low tissue water status

Biochemical parameters (glutathione, sugars, phenols, amino acids, protein, peroxidase and polyphenol oxidase activities) were estimated in the leaf and bark samples of irrigated and unirrigated plants from RRS, Dapchari during April and October 1996 in clone RRIM 600. Enzymatic antioxidants, super oxide dismutase, catalase and ascorbate peroxidase were also estimated in leaf and bark during October 1996. The data showed that in plants that were subjected to drought stress, there was increased accumulation of amino acids, phenols, sugars, protein and peroxidase and a decrease in glutathione and polyphenol oxidase activities in bark during April 1996. A similar pattern was observed in leaf except glutathione and sugar content. Sugar and glutathione were less in unirrigated plants. In October 1996, there was decrease in the content of amino acids, phenols and proteins in bark. Peroxidase activity was not significantly altered in irrigated and unirrigated plants in bark. In leaf, increased accumulation of glutathione and amino acids, sugar, protein and proxidase activity were noticed. Summary of the results is shown in Table Phys.2.

Chloroplasts and thylakoid membranes were isolated from leaves of irrigated and unirrigated trees and their protein profiles

Table Phys.2. **Changes in the biochemical composition of leaf and bark tissues in response to drought stress**

Parameter	Bark		Leaf	
	April '96 (Summer)	October '96 (Monsoon)	April '96 (Summer)	October '96 (Monsoon)
Glutathione				
Unirrigated	0.513	0.765	1.501	3.65
Irrigated	0.787*	0.999*	1.660*	2.15*
Amino acids				
Unirrigated	1.25	0.823	6.61	3.18
Irrigated	0.666*	0.948*	4.17*	2.60*
Phenols				
Unirrigated	3.05	2.88	4.01	3.96
Irrigated	2.44*	3.11*	3.09*	3.95NS
Sugar				
Unirrigated	36.66	11.87	27.50	41.78
Irrigated	29.74*	7.72*	33.29*	36.41*
Protein				
Unirrigated	16.19	11.211	17.95	22.206
Irrigated	11.76*	11.913NS	9.69*	21.998NS
Peroxidase				
Unirrigated	3.51	0.395	7.41	4.93
Irrigated	1.78*	0.389NS	5.26*	8.37*
Polyphenol oxidase				
Unirrigated	0.043	0.055	0.261	0.103
Irrigated	0.065*	0.094*	0.419*	0.112*

All figures are in mg/g fresh weight except peroxidase and polyphenol oxidase which are in units (change in OD/min/mg protein)

were resolved by SDS-PAGE. It was found that there was a relative loss of polypeptides with molecular weights (approximate) 23-25 kDa and 32-34 kDa in the drought stress compared to irrigated plants. These polypeptides may very well be related to the light harvesting antenna pigment complex and reaction centre components of photosystem II. A loss in these components, obviously as a consequence of stress would certainly lead to reduced photosynthetic capacity and high light-induced photoinhibition of photosynthesis as observed in the present study. Attempts are being made to compare the protein profiles of the photosynthetic apparatus of drought resistant and susceptible clones to understand the mechanism of drought tolerance.

1.3 Physio-biochemical comparison of drought tolerant and susceptible clones of *Hevea*

Leaf and bark samples were collected from polyclonal trees that are classified as high and low yielders and high and low girth types, identified from the polyclonal field trials at RRS, Dapchari. Biochemical composition of leaf and bark (glutathione, sucrose, phenols, amino acids, protein) and enzymatic antioxidants catalase, peroxidase, ascorbate peroxidase and superoxide dismutase were estimated with an objective to understand the molecular level mechanism of improved tolerance to drought stress. Results are being analysed.

1.4 Studies on cell membrane stability

The multiple stress tolerance studies were continued in *Hevea brasiliensis*. As reported earlier, the combined effect of drought and high temperature stresses was greater than the single stress. In one of the experiments conducted in this laboratory, light stress was used along with the high temperature treatment under humid conditions.

The cell membrane injury was measured according to the method of Martineau *et al.* (1979). The high temperature treatment was carried out in Hotpack growth chamber at 50°C using leaf discs and fitted with an internal light source from a fluorescent lamp (250 µmol/m²/s). The samples that

do not require the light treatment are not exposed to the fluorescent lamps. The leaf electrolyte leakage was measured using Global-DCM 900 conductivity bridge at 60 min, 90 min, 120 min and 240 min intervals. High temperature with light enhanced the leakage of electrolytes from the leaf tissue and thereby decreasing further the cellular membrane stability in *Hevea*. Maximum difference was obtained at 2 h of treatment of the leaf discs. However, the light alone could not influence any leakage at normal temperatures. Based on these observations the treatment temperature of 50°C for 2 h with 250 µmol/m²/s light will be used for the screening of clones in *Hevea*. Further studies are in progress.

1.5 Influence of chilling winter conditions on growth and yield

To study the effects of cold stress on photosynthesis and water relations of two clones of rubber (RRIM 703 and RRII 105), a few experiments were conducted at RRS, Agartala. During winter, trees were exposed to chilling temperatures in the night and days with high light intensity. Such a climatic condition will affect the photosynthetic rates. Leaf photosynthetic rates were negligible under full sunlight, but it increased when the light intensity was reduced to 200 µmol/m²/s (Table Phys.3). Growth and plant-water relation aspects in two clones are shown in Table Phys.3.

Table Phys.3. **Influence of low winter temperature on photosynthesis and plant-water relations**

Parameter	RRIM 703	RRII 105
Girth (cm)	70.12	70.65
Photosynthesis (µmol/m²/s)		
at 100 µmol/m²/s	0.56	0.29
at 200 µmol/m²/s	2.18	2.26
Pre-dawn leaf water potential (bar)	-12.56	-12.45
Pre-dawn latex solute potential (bar)	-6.86	-10.78
Pre-dawn turgor pressure (bar)	7.12	7.03

1.6 Molecular level responses of *Hevea* to low temperature

Leaf and bark samples of clone RRIM 703 and RRII 105 were collected from RRS, Agartala during January 1997 and analysed the biochemical parameters (amino acids, sugars, phenols, glutathione, proteins) and activities of superoxide dismutase, catalase, ascorbate peroxidase, peroxidase and polyphenol oxidase. Data analysis is in progress.

2. Physiology of growth and yield

2.1 Characterization of *Hevea* clones

2.1.1 Experiment 1

Evaluation of yield, yield components and growth performance of 12 clones was continued for the year 1996-97. Mean annual yield (cup lump) was found higher in clone PB 235. Lowest yield of 15.9 g/tree/tap was recorded in clone RRIM 612. The popular clone RRII 105 ranked second in the yield list. All other clones yielded between 30-40 g except PR 107 and Gl 1. The peak yielding season was between December to January and the lowest in March to April months. Mean initial flow rate (IFR) was greater in RRII 105. IFR was comparatively low in clones like RRIM 703, RRII 118, RRII 300, RRIM 612 and RRIM 501. Clones RRII 118, RRII 300, PR 107 and Gl 1 have 40 per cent or more dry rubber content (DRC) in latex. Lowest mean plugging index (PI) was recorded in clone PB 235 and highest in RRIM 612. All other clones fall under this range.

2.1.2 Experiment 2

Yield and yield components such as IFR, DRC and PI were studied in six clones, *viz.*

LCB 1320, RRII 105, PB 28/59, RRIM 605, BD 10 and HP 20 at Central Experiment Station, Chethackal. The trees were being tapped on BO-2 panel with mean absolute girth varying from 68 cm for RRII 105 to 83 cm for LCB 1320.

Highest mean yield was recorded in clone LCB 1320 and lowest in HP 20. RRII 105 ranked second with annual mean of 42 g/tree/tap. Higher mean initial flow rate was noticed in clone RRIM 605 (0.115 ml) and lowest in PB 28/59 (0.076 ml). Generally, the IFR decreased in February to April months. The clone PB 28/59 maintained higher DRC throughout the year. However, in high yielding clones like RRII 105 and LCB 1320, the DRC was higher in summer than in wet season. Low PI and high yield were observed in LCB 1320, RRII 105 and PB 28/59 than in clones RRIM 605, BD 10 and HP 20 where the yield was comparatively less and the PI was found more.

2.2 Elevated CO_2 studies to increase the initial growth rates of *Hevea brasiliensis*

Nursery seedlings were exposed to elevated CO_2, relative humidity and warmer temperature every day between 1530 to 1030 IST the following day for eight months continuously following germination. A UV-stabilized polyhouse with a transparency of 80 per cent to sunlight was used to grow seedlings with and without fertilizers and to trap the CO_2 produced from the decomposition of organic matter.

Using the above described system, a significant increase in the leaf area and biomass was obtained (Table Phys.4). The CO_2 effect was more in plants grown with normal dose of fertilizer than the plants without any fertilizer. The allocation of biomass into the roots was significantly higher in seedlings grown with elevated CO_2 and fertilizer, but not in plants grown without it. This technique may be useful in obtaining more robust seedlings for budding while the increased allocation of resources into roots in plants grown in elevated CO_2 could be of agronomic value in drought-prone areas.

Table Phys.4. **Response of seedlings after eight months exposure to elevated CO_2, RH and warm temperature grown with and without normal dose of fertilizers**

Parameter	Elevated CO_2		Control	
	Normal dose of fertilizer	Zero fertilizer	Normal dose of fertilizer	Zero fertilizer
Leaf area (cm^2/plant)	3651[AB]	2011	1970	1237
Drymatter (g/plant)	93.7[AB]	70.64	63.13	48.01
% biomass diverted to root	25.55	21.00	21.00	23.00

A - Significantly different between the fertilizer levels at 1% error

B - Significantly different between the treatments at 1% error

2.3 Clonal variations in leaf photosynthetic capacity

Variability in photosynthesis and related biochemical parameters was tested in 12 different polybag-grown *Hevea* clones, RRII 51, RRII 105, RRII 176, RRII 203, RRIC 100, RRIM 600, PB 217, 82/14, 82/17, 82/22, 82/29, 82/30 under ambient CO_2 concentration and light intensity. All gas exchange measurements were made using portable photosynthesis system LI 6400 (LICOR, USA). The variability in photosynthesis was observed. Photosynthesis at saturating light intensity computed from A/PFD curves ranged from 10.79 in RRII 51 to 14.71 µmol/m^2/s in RRII 203 showing about 36 per cent

increase. Significant variation in light compensation point was also recorded ranging from 25 in RRIC 100 to 36 µmol/m²/s in clone 82/22.

There were detectable differences in photosynthesis when measured at saturating CO_2 concentration. It ranged from 19.5 in RRII 51 to 25.92 µmol/m²/s in RRII 105. The *in vivo* carboxylation efficiency (dA/dCi) calculated from A/Ci response curves also showed significant variation. The carboxylation efficiency was highest in RRIM 600 and was lowest in clone 82/17 when compared to other clones. A positive correlation between the rate of photosynthesis and *in vivo* carboxylation efficiency was observed (r=0.714). CO_2 compensation of 12 different clones also differed significantly. The leading clone RRII 105 had a minimum and clone 82/30 had a maximum compensation point.

Different clones of *Hevea* showed significantly varied stomatal conductances and stomatal limitations to photosynthesis. There was also variability in instantaneous water use efficiency (WUE) calculated using the gas exchange data.

Photosynthesis recorded on the nursery grown polyclonal seedling population ranged from 8.9 to 18.9 µmol/m²/s. In polyclonal seedlings, photosynthesis was significantly related to total buffer soluble protein and total chlorophyll content.

3. Tapping panel dryness (TPD) syndrome

3.1 Biochemistry of TPD

Healthy and TPD affected trees of RRII 105, GT 1 and RRIM 600 were identified at the Central Experiment Station, Chethackal. The TPD affected and normal trees were identified by tapping observations. Fresh latex samples were collected from the field from healthy and late dripping trees and brought to RRII in ice and their biochemical compositions were analysed following standard techniques. Bark tissues from normal and TPD affected trees were taken carefully from the tapping panel and brought to RRII laboratory under ice and stored at -56°C. Soft bark tissues were excised, powdered in liquid nitrogen and homogenized in appropriate buffers/solvents for various biochemical assays.

The studies were mainly concerned with the biosynthesis of latex in relation to TPD and the effect of stimulation on formation of latex. The latex samples used for analysis were from the normal and TPD affected RRII 105 trees.

The data showed a higher peroxidase activity in the bark and latex tissues of TPD affected trees belonging to RRII 105 and GT 1. Peroxidase activity could be related to the loss of functional integrity of the membrane systems. The enhanced enzyme activities in TPD affected plants may be the result of biochemical regulation of enzyme and/or the effects at transcriptional or translational levels. Bark phenol content was also found to be higher in the TPD affected trees. Enhanced phenol content may be the result of biochemical regulation of secondary metabolites due to biotic stress induced by TPD. The inverse relationship of t-ZR content (observed in the TPD affected tissues) with peroxidase activity or with phenol content alone is inadequate to suggest whether they catalyse any of the metabolic reactions to maintain a low tissue cytokinin level in TPD affected bark tissues.

The total rubber transferase (RuT) activity was calculated in the latex using ^{14}C-labelled IPP. The analysis showed that RuT activity appeared to be in higher levels in latex as TPD progresses. Similarly, the RuT

activity was measured by assaying the GGPP dependence of ^{14}C IPP incorporation in the washed rubber particle (WRP) to analyse the limitations of RuT in relation with the TPD incidence and stimulation effects. As compared to the normal, RuT activity during the initial stage of TPD (T1) was found to be at reduced level. However, the enzyme activity gradually increased towards the later stages of TPD (T2 & T3) and found to be the maximum at stage T4. Rubber particle bound RuT, an insoluble form of this enzyme, was reported to catalyse the transfer of cis-1,4-polyisoprenyl-PP to isopentenyl-PP with the elimination of inorganic pyrophosphate. The reaction is occurring at the surface of the rubber particle. The higher RuT activity in the WRP of late TPD samples indicated the ability to the formation of more polyisoprene units. But the substrate availability for the chain elongation may be limited due to TPD incidence.

The soluble prenyltransferase activity was assayed in the C-serum of the latex sample by measuring the DMAPP dependence of ^{14}C-IPP incorporation. Compared to the normal, TPD samples showed low prenyltransferase activity in the initial stages (T1 & T2) and increased activity towards the later stages (T3 & T4). The elongation of cis-1,4-polyisoprene requires a small trans allelic diphosphate as initiator which being catalysed by the trans-prenyltransferase enzyme. The analysis showed that the formation of the initiator for the polyisoprene synthesis is not inhibited due to the TPD incidence. The results indicate that the initiation and elongation steps in the rubber biosynthesis were related to TPD incidence.

The particle size analysis in the latex and WRP also showed differences related to TPD incidence. The analysis showed that the rubber particles, on the average, become comparatively smaller towards the later stages of TPD. The mean diameter of normal was 0.90 µm and the diameter changes from 0.99 µm to 0.76 µm towards the later stages of TPD. Earlier analysis in the RuT activity showed an inverse relation with the particle size. Therefore, in the TPD samples, the variation in the particle size can be directly related to the chain elongation processes. During the later stages of TPD, chain elongation may be interrupted due to the relatively low availability of substrate which in turn results in smaller particle size. The analysis of the ethylene-stimulated latex sample also showed some changes in the distribution frequency of particle size which closely resemble the early TPD sample.

3.2 Stress-induced proteins in healthy and TPD affected *Hevea*

Studies were undertaken with an objective to understand heat stable bark protein profiles of healthy and TPD affected *Hevea*. Soft bark tissues (2-3 mm thick laticiferous tissue adjacent to the cambium) were collected from fully dry and healthy trees of clone RRII 105. The tissue was homogenized in borate buffer (pH 9.0) and the total buffer soluble protein was extracted and estimated. The extract was then subjected to first, 85°C and then 95°C heat treatment for 20 min. The heat stable proteins were collected and estimated. The crude extract and heat stable fractions (HSF) were further analysed by electrophoretic separation (SDS-PAGE).

The buffer soluble protein content did not differ significantly either in the crude extract or HSF at 85°C. There was 25 per cent reduction in the protein content in the crude extract as against 31 per cent in case of TPD affected bark. At 95°C, these reductions were 51 per cent and 58 per cent in the healthy and TPD affected bark, respectively. These results suggest that the bark proteins

of *Hevea* are remarkably tolerant to heat shock.

The protein profile analysis by SDS-PAGE revealed presence of a protein (approx. 70kDa) in TPD affected bark in relatively higher quantity which seems to be relatively heat stable. In addition to this, some new set of heat stable proteins in the lower molecular weight range (30kDa) were also noticed in TPD affected bark.

3.3 Stress-induced late embryogenesis abundant (LEA) proteins

A study was conducted with an objective to test the presence of stress-induced late embryogenesis abundant (LEA) groups of proteins in the C serum and soft bark tissues of *Hevea*. Soft bark tissues (2-3 mm thick laticiferous tissue adjacent to the cambium) and C serum from clone RRII 105 were collected. To extract the total buffer soluble protein, the bark tissue was homogenized in borate buffer (pH 9.0). The extracts were immunologically tested for the presence of stress-induced LEA group of proteins. A dot-blot and western blot analysis using LEA-1, 2, 3 & 4 groups polyclonal antibodies revealed the presence of LEA proteins in the C serum and bark. LEA groups of proteins are known to impart stress tolerance in many annual crop plants. Their role in perennial tree species like *Hevea* is being investigated.

RUBBER CHEMISTRY, PHYSICS AND TECHNOLOGY DIVISION

The Division continued the work on primary processing, chemical modification, rubber technology and product development.

1. Studies on drying of raw natural rubber

Evaluation of the 96 sheets-capacity solar-cum-smoke dryer under different seasons and loadings was continued. For drying of sheet rubber in sunlight, trolleys are used. A low cost smoke house is being designed to continue smoke drying of the sheets loaded on trolleys during night.

2. Studies on different forms of natural rubber

Treatment of crumbs of field coagulum with tetraethylene pentamine (TEP) improved both initial plasticity (Po) and plasticity retention index (PRI), but did not prevent storage hardening. Treatment with hydrazine hydrate increased Po and also prevented storage hardening, but no improvement in PRI was observed. The change in plasticity increased with concentration of TEP from 0.25 to 1 per cent for an immersion period of 10 min. In the case of hydrazine hydrate, optimum concentration was found to be 0.25 per cent with an immersion period of 10 min for increase in plasticity.

Studies on breakdown behaviour of different forms of NR have been completed. Comparison of RSS 4, EBC IX and ISNR 20 showed that the breakdown energy was maximum for EBC IX(DC) followed by ISNR 20(DC). A highly signifi-

cant correlation existed between Po and the energy required for mastication of RSS 4. ISNR 20(DC) showed the maximum dependence of breakdown parameters on raw rubber properties. Breakdown properties of skim rubber showed a higher level of inconsistency in raw rubber properties but was more consistent in processability. The PRI was inversely related to the initial rate of breakdown. The effect of peptiser was less in skim rubber compared to ISNR 5. Comparison of the breakdown properties of different grades of epoxidised natural rubber (ENR) showed that ENR 50 and ENR 60 exhibited an increase in Po and gel content when masticated at high temperature. The rate of breakdown increased with epoxy content but within a particular grade the rate decreased as the temperature increased. The bahaviour of ENR 50 in presence of peptiser was similar to that of NR.

Studies on the effect of mastication on processing and vulcanizate properties of ISNR 5 and ISNR 20 have been completed. The maximum reduction in molecular weight and Po was attained during the initial period of mastication. ISNR 20 contained higher gel content. In both grades, compression set and retention in tensile strength after ageing were found to be more affected by the extent of mastication.

Use of liquid natural rubber (LNR) instead of raw NR, for the production of chlorinated rubber, ensured early dissolution and higher output. Properties of the product were comparable to that prepared from raw NR. Rubber modified bitumen was prepared at different concentrations of LNR and their properties were investigated. Incorporation of 5-10 parts of LNR was found to be optimum and the modified bitumen showed improvement in adhesion strength.

3. Development of epoxidised natural rubber (ENR)

Two sets of different grades of ENR, *viz.* ENR 10, 25, 50 and 60 containing 0.25 phr antioxidant HS were prepared, one set with 0.5 phr of calcium stearate and another set without calcium stearate, for studying their storage behaviour. The properties such as gel content, epoxy content, Po, PRI, accelerated storage hardening, acidity, cure characteristics and vulcanizate properties are being assessed at frequent intervals.

4. Blends of natural rubber with other elastomers and thermoplastics

The suitability of SBR latex for manufacture of latex foam was investigated. Studies showed that latex foam conforming to BIS : 1741 could be prepared using a 60:40 blend of centrifuged NR latex and creamed SBR latex.

Studies on ternary blends of NR/ENR/PVC showed that strength properties and other technological properties were improved on incorporation of ENR in a 70/30 NR/PVC thermoplastic blend. A definite concentration of ENR is required for attaining optimum properties. Ageing and ozone resistance of NR/PVC blend were also improved considerably on incorporation of ENR.

5. Natural rubber technology

Presence of fillers such as precipitated silica, china clay and whiting decreased the tensile strength and elongation at break but increased modulus of the pre-vulcanized latex film. Leaching of the films improved the tensile properties. Stress relaxation rate

was slightly higher for the film containing precipitated silica followed by those containing china clay and whiting. Morphology of the films revealed a more uniform distribution of precipitated silica in the rubber matrix.

A new method for devulcanization was developed by the Division for reclamation of vulcanized rubber. The results were encouraging as compared to that obtained using recently commercialised devulcanizing agent 'Delink R'.

6. Composites based on natural rubber

Rubberised bitumen samples were prepared by incorporating buffing powder of different particle size from retreading units. The samples containing buffing powder of 60-mesh size exhibited better properties compared to 340-mesh size buffing powder. Reclaimed rubber prepared using the newly developed devulcanizing agent was also used to prepare rubberised bitumen and its properties are being assessed.

AGRICULTURAL ECONOMICS DIVISION

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

1. Evaluation of planting materials under commercial cultivation

In this ongoing study since 1974, the already constructed database covering fieldwise yield and related information on a monthly basis has been updated. A comprehensive report on commercial yield evaluation is nearing completion.

2. Operational efficiency of rubber plantations at different levels of management

The main survey of the study covering 750 small growers selected from the list of growers generated through the reconnaissance survey in five locations in the traditional rubber growing regions is completed. A comprehensive database is being built using the collected data.

3. Institutional assistance to rubber growers

3.1 The input subsidy scheme and adoption of improved cultural practices : A comparative analysis of rubber smallholdings in Kerala

The study analysed the differences in cultural practices, processing and marketing of rubber among the member growers attached to Rubber Producers' Societies (RPS) and the non-members. The study was based on a field survey conducted during 1993-94 covering five regions and 375 randomly selected growers consisting of 250 member growers and 125 non-members. The adoption of major cultural practices was comparable between the two categories in the pre-scheme period, except in the case of fungicide application (82% and 60%) and rainguarding (14% and 4%). The institutional framework conceived in the form of

RPS was found effective in popularising modern cultural practices through distribution of subsidised inputs. Compared to non-members, the member growers exhibited better adoption of cultural practices such as cover crop establishment (90% and 69%), soil and leaf analyses (72% and 22%) and application of straight fertilizers (54% and 18%) having cost reducing effects. The relatively higher share of rainguarded tapping (70% and 39%) and processing of graded sheets (71% and 47%) among member growers had income-augmenting effects. The explicit gain of the scheme was evident from a statistically significant (at 5% level) mean difference in yield between member growers (1902 kg/ha) and non-members (1751 kg/ha) for the clone RRII 105. The results of the comparative analysis in terms of the implicit and explicit gains in the backdrop of a gradual reduction in the rate of subsidy underline the need for actively supplementing the scheme with extension work providing guidelines on the practices and potential gains from improved cultural practices.

3.2 Market intervention, value addition and consolidation : The interface between small rubber growers and the cooperative sector in Kerala

The major contributions of the cooperative sector in Kerala to the dominant rubber smallholdings were analysed in the broader context of the NR economy of India, the Government's price policy and salient features of the primary market. One of the major deficiencies in the primary market was the dominance of the intermediaries extracting margins on the smallholder's crop. Various policy changes on the price and market intervention since 1970s marked the graduation of the cooperative sector from its initial supplementary role in the primary market to a price stabilising institution in the 1990s. The establishment of Rubber Producers' Societies since 1986-87 was also complementary to the marketing operations of the cooperative sector. Another significant contribution of the cooperative sector is the value addition to the smallholders' raw rubber. The cumulative effect of the entry of the cooperative sector in the primary market (Table Age.1) and raw rubber processing appears to have the implicit effect of increasing the net income of the smallholders while explicitly it is instrumental in sustaining the emerging structure in the production sector through consolidation of market power.

Table Age.1. **Trends in the volume of rubber sales by cooperative sector**

Year	Volume of sales (t)	Sales as % of total NR production	
		Kerala	India
1965-66	1778	3.79	3.52
1975-76	5545	4.31	4.03
1985-86	21036	11.40	10.49
1994-95	55934	12.63	11.86

4. Analysis of NR price in India

The time-series data on NR prices in India from 1968-69 to 1994-95 were analysed for delineating the trends and identifying different phases of price movement and the underlying factors. NR price in India did not show any significant pattern or movement consistently towards a particular direction in the long-run. Two broad phases, *viz.* 1968-69 to 1984-85 and 1985-86 to 1994-95 of price movement were identified based on the observed trends. Wide but less frequent fluctuations and mild but frequent fluctuations were the characteristics of the first and second phases respectively. Different economic variables, *viz.* production, consumption, stock, import and

world price of NR were tested for stationarity by employing error correction model and the production of NR was found to be the most significant variable influencing NR price (Table Age.2). No significant statistical relation could be obtained between import and world price.

Table Age.2. **Inter-relationship between price and explanatory variables (error correction model)**

Variable	Coefficient	T-value
Production	-1.941	-3.410
Consumption	1.278	2.266
Stock	-0.248	-2.027
Import	-0.025	-1.875
World price	-0.039	-0.331
R^2		0.654
DW		2.116

5. Monitoring of the ancillary products

5.1 Annual estimations - 1996-97

Monitoring of the ancillary products sector has been continued. The potential availability of rubber wood was estimated to be 1.25 million m^3 during 1996-97. The production of rubber seed oil and cake was estimated to be 2630 and 4283 t respectively. The production of rubber honey increased from 1000 to 1250 t during the year (Table Age.3).

Table Age.3. **Production of ancillary products**

Production	Quantity
Rubber wood	1.21 million m^3
Rubber seed oil	2630 t
Rubber seed cake	4283 t
Rubber honey	1250 t

The consumption pattern of stem rubber wood shows that 55.4 per cent of the stem wood is consumed by the packing case industry (Table Age.4).

Table Age.4. **Consumption pattern of stem rubber wood**

Consuming sector	Consumption (%)
Packing cases	55.4
Safety matches	10.0
Plywood	21.3
Processed wood*	11.3
Others	2.0

* Inclusive of 4% diffusion-treated wood

5.2 Status report on processed wood sector

The field survey covering 41 rubber wood treatment units is completed and the data analysis is in progress.

5.3 Status report on rubber seed sector

Data collected from estates, dealers and processors of rubber seed and consumers of rubber seed oil are being analysed.

The Division has initiated two research projects, *viz.* trends in the extent of subsidy to rubber plantations and a study of labour in the unorganised sector during the reporting period.

RESEARCH COMPONENT OF THE WORLD BANK-ASSISTED RUBBER PROJECT

1. Exploitation studies

Field experiments on low frequency tapping trials laid out in Kottayam, Pathanamthitta and Kollam in Kerala and Kanyakumari district of Tamil Nadu progressed well. Stimulation treatments as per schedule were imposed in the trial areas. Monthly monitoring of yield and gravimetric determination of DRC were continued. The data collected from various trials are being processed.

An experimental farm unit was established at the Rajiv Gandhi Institute of Technology (RIT) campus at Pampady, Kottayam. Nearly 6000 tappable trees were marked for different tapping experiments. Five experiments comprising 270 plots on different aspects of exploitation were statistically laid out in the farm. Normal cultural operations were also carried out. Yield is being recorded.

Under latex diagnosis (LD) studies, three experiments, two at Malankara Estate and one at Kumbazha Estate were laid out to fix the base values of LD parameters of clone RRII 105. A new experimental area was selected in Padinjarekara Estate, Chembakapara for clone RRII 105, in BO-1 panel. Data are being processed.

2. Clone evaluation

The large-scale clone trials, one block trial and one on clone blend, in Kanyakumari region, were maintained. Regular recording of monthly growth was continued. In the large-scale trial, out of 11 component clones, IRCA 111 continued to have better tree girth (16.10 cm), while the control clone RRII 105 showed the lowest girth of 11.70 cm. The mean girth over 11 clones at the end of the year was 14.0 cm. Due to adverse climatic conditions, high percentage of casualty was recorded. RRII 105 and RRIM 703 recorded nearly 50 per cent casualty while clone PR 255 showed almost no mortality. In general, the PB clones were tolerant to drought.

At RRS Padiyoor, planting was completed in 1996. In the onfarm trial in Tamil Nadu, monthly recording of growth characters was continued. The highest girth was recorded for clone PB 235(18.40 cm) and the lowest for PR 261(8.90 cm). The mean girth of 13 clones was 13.20 cm.

Under the sub-project 'Trial at different agroclimatic regions', the block trials laid out in Thirumbadi Estate, Pullengode Estate, Suranad and Mallappally, were well maintained. Four more sites were selected in Mavelikkara taluk, two at Vallikunnu and two in Tamarakulam panchayath for laying out block trials of experimental clones. The planting materials proposed to be used are clones RRII 351, RRII 357, 82/22 and 82/40.

The trial on identification of clonal composites in Tamil Nadu was maintained. Annual girth was recorded and a summary of eight clonal composites/blends is given in Tables Wbp.1 and Wbp.2.

The range of girth of the composites is narrower when compared to the girth of the clones grown independently.

For survey of large estates, available data on yield of six clones from six estates, covering three regions, *i.e.* Kanyakumari,

Table Wbp.1. **Growth of plants in clonal composites**

Clonal composites	Mean girth (cm)	% of loss due to drought	% of small plants*
PR 255, PB 28/59 & RRII 105	13.05	32.08	21.4
PR 255, PB 235 & RRII 105	13.31	30.94	4.05
RRII 5, PB 28/59 & RRII 105	15.05	31.55	9.43
RRII 5, PB 235 & RRII 105	13.89	18.05	3.13
PR 261, PB 28/59 & RRII 105	12.50	41.17	3.90
PR 261, PB 235 & RRII 105	13.24	38.99	3.27
PB 311, PB 28/59 & RRII 105	13.56	29.73	3.60
PB 311, PB 235 & RRII 105	13.82	22.88	3.00
Mean	13.55	30.67	6.47

* Plants which had not attained brown colour at 150 cm height

Table Wbp.2. **Clonewise growth details of clonal composites**

Clone	Girth (cm)	% damage	% of small plants
PR 255	13.49	29.28	7.11
PB 28/59	15.91	28.62	8.78
PB 235	15.34	15.04	5.30
RRII 5	13.00	19.69	9.85
PR 261	11.48	51.36	3.60
PB 311	15.49	2.68	Nil
Mean	14.19	24.45	5.77

Trichur and Palakkad were collected. In the northern regions of the traditional rubber tracts of Kerala, yield performance of the PB clones, *viz.* PB 28/59, PB 217 and PB 235 are comparable to RRII 105. Survey in smallholdings was initiated and data were collected from a few holdings of Malabar and Kanyakumari region. In the north-eastern state of Tripura, yield recording was continued for three popular clones, *viz.* RRII 105, RRIM 600 and GT 1. Among the three popular clones, RRIM 600 performed well in terms of yield and growth. All clones showed locationwise variation for yield and growth. Lowest yield was recorded for GT 1 while RRII 105 had the lowest girth.

3. Biotechnology

3.1 *In vitro* plant regeneration

In the glass house, standardisation of humidity, light intensity, temperature, *etc.* has been completed using control as well as *in vitro* plants. *In vitro* plants were maintained under the standardised conditions to evaluate the mortality rate. Initial observations have shown that mortality rate was less and these plants were performing better.

3.2 Somatic embryogenesis and transgenic plant synthesis

More extensive work in the area of protoplast culture has already been started so that the protoplast to plant system can be utilised to bring about transformation of rubber plants. Attempts have been made to generate as many explants as possible for transformation experiments. Different target tissues were infected with *Agrobacterium* to identify the specificity of *Agrobacterium* towards the target tissue. Transformation using two genes has been tried in this way. The infected tissues were transferred to the selection media for further regeneration of the transformed tissue.

4. Germplasm/Genome analysis

The 'Hot spot trial' having 36 genotypes laid out at the Regional Research Station,

Sukma, Madhya Pradesh representing a drought zone, was maintained. There were significant variations in stem diameter, number of whorls and leaves among genotypes after nine months of field planting. Control clone PB 260 and Brazilian clone RO 3172 had the highest stem height and girth. Clone AC 707 had the lowest recording of the above characters. In general, genotypes showed appreciable growth and good adaptability. Life-saving irrigation was given to selected plants.

Standardisation of the techniques in connection with genome analysis is being carried out.

5. DRIS fertilization

A new regional laboratory was set up at Kanjirappally (central Kerala). Facilities of central laboratory at Kottayam, four regional laboratories and five satellite laboratories were strengthened further. Three regional laboratories are now capable of providing computerised fertilizer recommendation. All the laboratories were engaged in soil and leaf testing and fertilizer recommendations were given in most of the cases. A total of 11797 soil samples and 1972 leaf samples were received. The corresponding number of samples analysed were 10925 and 560 respectively. Dry rubber content was estimated for 36 samples. Mobile soil testing camps were organised regularly and fertilizer recommendations given. Awareness camps were also organised for smallholders and Rubber Producers' Societies.

For DRIS experiments, pre-treatment yield data were recorded from two estates. DRIS indices were calculated for individual nutrients, on the basis of leaf analysis. To ensure quality of analytical work ('round robin' cross-checks) samples were sent to all regional laboratories and satellite laboratories. Samples were also tested at CPCRI Kayamkulam and UAS Bangalore.

6. Rubber-based sustainable farming system

Two field trials using different cropping system models were laid out at Tripura. In the first model, emphasis was given for high density planting of rubber to withstand high wind speed prevalent in the region. Interspaces were filled with two rows of pineapple and one row of banana. Local tree species were planted as wind belt. In the second model, planting density was altered with different orientation of intercrops and absence of wind belt. In the trial area, pigsty were constructed and piglets raised. In the available pond, fishery was also introduced. Paddy was grown in the furrows and vegetable crops introduced on the bank of fish pond. Casualty filling of budded stumps was made using polybag plants. Health and growth of pigs and fish were monitored periodically.

7. R&D activities on rubber processing

7.1 Improvement of drying conditions of sheet rubber in smallholdings

7.1.1 Solar drying

Evaluation of the ready-made smoke house modified as a solar-cum-smoke dryer was continued. The results indicate that as the number of sunny days increases, a substantial reduction in firewood consumption is possible.

7.1.2 Sun-cum-smoke drying of sheets

As a part of this work, the effect of UV irradiation on the quality of raw sheets has been studied separately. The results are being analysed.

7.2 Basic studies on drying of raw rubber

7.2.1 Comparative evaluation of electric and oil-fired dryers for crumb rubber

Basic informations about the electric and diesel dryers established in the Indiar Crumb Rubber Factory at Palai and the Mamparambil Rubber Industry at Pizhaku have been collected. Sixteen samples were collected from the Indiar factory and eight from the Mamparambil factory during the period under report. For collecting these samples, the same batch of rubber crumbs was used in both the dryers after making sure that the material is uniform in quality. These samples after drying, have been tested for Po, PRI, volatile matter and breakdown behaviour.

In both the factories, diesel drying leads to a slightly higher PRI, although there are certain individual results going against the general trend. However, the difference in breakdown behaviour was not significant.

7.2.2 Breakdown behaviour of different forms of natural rubber

The data generated on breakdown properties of different forms of natural rubber were statistically analysed.

The dependence of raw rubber properties on breakdown characteristics was tested by working out the correlation coefficients. Most significant correlations could be arrived at in thé case of plasticity, Po and energy required for masticating the rubber to a fixed minimum torque value in each case. It was found that the same is significant in four cases except EBC (FC). Very strong dependence of Po on mastication energy is observed for ISNR 20 (FC). Least dependence was observed for EBC (DC).

The magnitude of the correlation coefficient (dependence of Po and initial breakdown) for the above parameters is very high for ISNR 20 (DC) samples followed by RSS 4. Other samples showed less dependence. No significant correlation could be attained for any of the forms between plasticity, Po and heat generated during mastication. No significant correlation was obtained between PRI and breakdown properties.

7.3 Modified forms of natural rubber

7.3.1 Storage behaviour of ENR

ENR samples with 10, 25, 50 and 60 mole per cent epoxidation have been prepared in the pilot plant in 25 kg batches. These four batches have been divided into two, one with calcium stearate as stabiliser and the other control. These eight samples will be used for the studies on storage behaviour of ENR. A schedule has been prepared for the testing of the samples periodically. ENR 10 and 25 samples have been found to be containing lumps. Therefore, fresh batches of these samples are being prepared.

7.3.2 Blends of ENR with other polymers

To investigate whether ENR can serve as a general modifier for blends of other hydrocarbon polymers with PVC, the following blends were examined and details are furnished in Table Wbp.3.

Results show that ENR-50 can serve as a modifier for SBR/PVC and BR/PVC blends as well.

Ozone resistance study of 70/30 (NR+ENR)/PVC ternary blend was carried out. Natural rubber part of 70/30 NR/PVC blend was substituted with 2.5, 5, 10, 15, 20 and 70 parts of ENR. Ternary blend with 15 parts of ENR onwards showed very good ozone resistance.

Ageing resistance studies of the thermoset blends of 70/30 NR/PVC and (NR+ENR)/PVC with varying proportions

Table Wbp.3. **Properties of blends with ENR as modifier**

Base polymer	Blend ratio	Modulus (N/mm^2)			Tensile strength (N/mm^2)	Elongation at break (%)	Tear strength (N/mm)
		100%	200%	300%			
SBR 1502/PVC	70/30	1.65	2.05	—	2.40	290	14.50
SBR 1502/ENR-50/PVC	65/5/30	3.10	5.20	6.60	7.10	345	29.50
Polybutadiene/PVC (cisamer 1220)	70/30	1.77	—	—	2.15	145	11.00
Polybutadiene/ENR-50/PVC	65/5/30	2.15	3.60	—	4.20	230	26.00

of ENR were carried out. NR/PVC binary blends and ternary blends having very low concentration of ENR showed very poor ageing resistance while ternary blends above a limiting concentration of ENR exhibited very good ageing resistance comparable with that of 70/30 NBR/PVC blends.

8. UPASI component

The project staff visited various regions and enlightened the growers on the need for discriminatory fertilizer use. Field demonstrations on scientific sample collection methods were also undertaken.

Technical assistance was given to 13 estates/RPS for sample collection, on specific requests. Samples from the smallholdings of different regions were collected and brought to the laboratory for analysis. Samples were also received from large and medium growers and fertilizer recommendations were given based on this. The total number of soil and leaf samples analysed included 1673 soil and 902 leaf samples.

Seven personnel were trained at RRII for soil and leaf analyses and two for fertilizer recommendation.

9. Consultancy services

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

Three locations covering plantations of 5, 10 and 30 years of age have been selected for the study. A total of 354 surface soil samples, 90 profile samples, 30 latex samples, 40 leaf samples and 75 water samples were collected. Samples are being analysed. Other chemical parameters like organic carbon, pH and CEC have been done in selected samples of surface soils and profile samples at the rate of five per location. For foliar analysis of copper, the leaf samples have been preserved.

Samples have been subjected to a detailed study of the arthropods and nematodes in the Department of Agricultural Entomology. The enumeration and evaluation of microorganisms are being attempted.

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

The following works have been completed during the period under report:

1. Traversing of rubber growing areas
2. Submission of inception report
3. Submission of first status report and

4. Procurement of satellite imagery IRS 1-B

Interpretation of imagery and toposheets was done based on separations on physiography (Mid lands, High lands), Geology (Charnockites, Khondalites, Archaeans, Laterites) and based on slope characteristics.

An orientation programme for field scientists was held for three days in March 1997 at the Rubber Research Institute of India. Scientists from the NBSS & LUP and RRII conducted classes on various topics. One-day field trip was also arranged for the benefit of the scientists of the NBSS & LUP.

Pre-field check of interpretation was carried out by the interpretation team to verify correctness of interpretation and finding out modifications, in area of survey.

Methodology for field work was discussed and finalised.

9.3 Rubber database

Preliminary work for setting up a rubber database has been initiated.

10. Training programme

10.1 Computer training

First batch of 61 staff completed a short-term computer training programme at five centres in January 1997. A second batch of 59 were sent for training in four centres during 1997.

10.2 Visit/Training abroad

Mr. Toms Joseph, Economist has undergone training in crop modelling at the Research Institute of Agro-biology and Soil Fertility (AB-DLO), the Netherlands for a period of three months.

Dr. M.R. Sethuraj, Director of Research visited the Department of Pomology, University of California, Davis, USA for nine days in connection with the review of progress of the collaborative project on biotechnology/molecular biology during October 1996.

Smt. V. K. Rajalekshmy, Mycologist visited Indonesia for a training on "Management of leaf fall disease on *Hevea brasiliensis*". Also attended International Conference on *Corynespora* leaf disease held at Medan, Indonesia.

Dr. N.M. Mathew, Jt. Director (Rubber Technology) visited Malaysia and Indonesia for making on the spot study of latest developments in processing, manufacture, quality control and effluent treatment.

Dr. R. Kothandaraman, Dy. Director (Plant Pathology) visited CIRAD, Montpellier, France to familiarise with the use of molecular markers for identification of root diseases and advance researches in *Corynespora* leaf disease and other major plant diseases.

Dr. R. Krishnakumar, Asst. Biochemist, Plant Physiology Division was deputed to USDA, California for advanced training in biochemistry and molecular biology of natural rubber biosynthesis.

CENTRAL EXPERIMENT STATION, CHETHACKAL, KERALA

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

During the period under report, the total crop realised from the station was 133939.700 kg. A total of 299 tapping days was possible in the year and 12606 tappers were engaged for tapping. There are 209 permanent workers and 166 casual workers in the rolls during the period. The total mandays engaged during the period for different operations was 70036.5. The monthly rainfall received during the period under report is given in Table CES.1.

Table CES.1. **Rainfall distribution**

Month	Year	No. of rainy days	Rainfall (mm)
April	1996	14	406.5
May	"	7	147.8
June	"	20	495.0
July	"	23	558.2
August	"	22	309.3
September	"	21	370.0
October	"	18	323.4
November	"	14	245.1
December	"	5	101.7
January	1997	Nil	Nil
February	"	2	44.2
March	"	10	140.1
Total		156	3141.3

The medical unit functioning in the station catered to the needs of 10411 patients during the period under report.

REGIONAL RESEARCH STATION, GUWAHATI, ASSAM

The thrust areas of research are evaluation of clones, assessment of nutritional requirements and development of disease and pest management strategies.

1. Multidisciplinary evaluation of clones

Among the 10 different clones in the 1985 trial, RRIM 600 showed highest girth (61.16 cm) followed by PB 86 (60.79 cm), RRII 118 (60.75 cm) and lowest in PB 5/51 (46.39 cm). From this trial, highest yield (g/tree/tap) was recorded in RRIM 600 (37.49) followed by RRII 105 (33.76), PB 235 (29.81), GT 1 (29.05) and minimum in Gl 1 (20.92).

In the 1986 trial, girth was maximum in RRIC 102 (64.6 cm) followed by RRII 118 (63.16 cm) and minimum in RRII 105 (54.96 cm). In this trial, highest yield was noticed in PB 311 and lowest in PR 255.

2. Nutritional studies (mature phase)

Two trials were initiated as onfarm basis in order to study the optimum requirement of NPK grown under natural cover in this region. First one at Mendipather (Meghalaya) was laid out with clone RRIM 600 in three-factorial randomized block design. Second one is located at Nayekgaon, Kokrajhar district (Assam) where clone RRII

105 was used with four levels of nitrogen and three levels of phosphorus and potassium.

The cumulative girth data generated from these two trials indicate a positive significant response on growth for the higher doses of N (Table Nea.1). However, possible response due to P and K and their interaction on growth is found to be non-significant.

Table Nea.1. **Effect of different levels of N on girth**

Nitrogen level (kg/ha)	Girth (cm)	
	Nayekgaon	Mendipather
0.0 (control)	45.38	48.93
20.0	48.57	—
30.0	—	52.68
40.0	50.18	—
60.0	50.60	56.66
CD (P = 0.05)	1.851	2.373

3. Interaction between K and Mg

Two trials were laid out, one at RRS Sorutari and another onfarm trial at Nayekgaon, in order to find out the interaction between the two important cations K^+ and Mg^{++} and their effect on growth and yield of *Hevea*. Clone RRII 105 was taken as study material. Girth of plants was recorded from both the experimental sites which revealed that the combination of highest dose of potassium (40 kg/ha) with magnesium (7.5 kg/ha) gave maximum growth at Sorutari whereas highest dose of magnesium (15.0 kg/ha) and no potassium resulted in maximum growth at Nayekgaon.

Percentage tappability was more on the onfarm trial area at Nayekgaon (70%) than the RRS Sorutari (25%). This may be due to effect of slope as plantation at Sorutari is grown in a hillock having gradient more than 50 per cent, whereas plantation at Nayekgaon is grown under zero gradient (plane).

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

Two trials are being conducted to compare the efficiency of different sources of phosphatic fertilizers on growth and yield of *Hevea*.

The cumulative data on girth obtained from the trials at Sorutari Research Farm and at Nayekgaon showed that insoluble form of phosphatic fertilizers (MRP) recorded higher girth increment for former while water soluble form of phosphatic fertilizer (SSP) was more effective in case of latter. However, no significant difference in absolute girth was observed. The experimental trees at Sorutari was opened for tapping in 1996. Initial yield data showed that highest yield was recorded for plants receiving water insoluble forms of phosphatic fertilizers (MRP) as well as 1:1 (MRP:SSP) phosphatic fertilizers.

5. Survey of diseases and pests

Pest and disease survey was carried out in 50 locations in Assam, Meghalaya, Tripura and West Bengal and the damage caused by them was assessed by visual scoring.

Powdery mildew disease caused by *Oidium heveae* was noticed on tender leaves in all stages of growth of rubber plants in all the locations surveyed. High intensity of disease was noticed during March-April at Bagma, Tulakona, Madhuban and Taranagar in Tripura and in some locations in Assam (Gorgomarme, Sorutari) and Meghalaya causing repeated massive premature defoliation and die-back of twigs and branches. High intensity of leaf fall disease caused by *Colletotrichum gloeosporioides* was noticed

on tender leaves during June to September in nursery plants. Leaf blight disease caused by *Periconia heveae* was noticed on tender leaves in nurseries and young plantations in some locations in Assam and Meghalaya during December to March causing repeated premature defoliation and die-back in severe cases. Pink disease caused by *Corticium salmonicolor* was noticed during August in five-year-old rubber plants at the fork region of the main stem in Meghalaya (Jenjitchegre) and it was the first report from Garo Hills.

Incidence of brown root disease caused by *Phellinus noxious* was found in some plantations at Rani and Tulakona in Tripura and Darangiri in Assam.

Mild infestation of scale insect (*Saissetia nigra*) was noticed in nursery plants from May to August and it was controlled naturally by an entomogenous fungus (*Hypocrelia reineckiana*).

6. Control of powdery mildew disease

For evaluation of economic feasibility of agricultural grade sulphur (85%) dusting, a trial in clone RRIM 600 was initiated at Sorutari Research Farm. Arrangements are being made for collection of pre-treatment yield (g/tree/tap) from two blocks during June to December 97. Dusting of sulphur was carried out in other experimental trials for the control of powdery mildew disease at Sorutari farm. After completion of four rounds of dusting, the incidence of *Oidium* SLF disease was assessed and found below 30 per cent.

7. Role of zinc in the management of *Oidium* SLF disease

A trial for control of *Oidium* SLF disease using zinc was initiated in seedling nursery plants at Sorutari Research Farm. The inci-

Table Nea. 2. **Effect of zinc and other protection chemicals on seedling growth and *Oidium* incidence**

	Treatment												CD
	C	S	WSB	A_1	A_2	A_3	A_4	B_1	B_2	B_3	B_4	$CS(A_3)$	$CS(B_3)$	(P=0.05)
Disease incidence(%)	100.0	0	23.25	100.0	90.75	18.75	18.0	100.0	100.0	43.0	42.25	0	0	7.79
Severity	5.0	0	0.6	4.12	3.37	0.31	0.18	5.0	4.95	2.8	2.35	0	0	0.68
Height (cm)	97.97	120.15	112.41	109.82	119.73	147.98	155.77	95.98	110.3	113.95	131.22	151.81	138.0	5.92
Diameter (cm)	0.75	1.25	1.17	0.93	0.97	1.38	1.51	0.77	0.87	1.29	1.34	1.5	1.38	0.05

C - Control; WSB - Wettable sulphur alternate with carbendazim (Bavistin); A_1 - Chelazin liquid 0.51 ml; A_2 - 2.5 ml; A_3 - 5 ml and A_4 - 7.5 ml/L of water; B_1 - Chelazin powder 100 mg; B_2 - 500 mg; B_3 - 1 g and B_4 - 1.5 g/L of water; $CS(A_3)$ - Chelazin liquid alternate with sulphur dust; $CS(B_3)$ - Chelazin powder alternate with sulphur dust.

dence of *Oidium* SLF disease and its severity were assessed in April/May. The seedling growth in terms of height and diameter was also measured in June. Application of zinc containing Chelazin liquid alternate with agricultural grade sulphur powder controlled *Oidium* SLF disease completely and seedling plants also showed better growth and vigour when compared to other treatments (Table Nea.2).

8. Performance of polyclonal materials

For evaluation of the performance of polyclonal seedlings under agroclimatic conditions of Assam, yield was recorded from 163 polyclonal seedlings. The yield recorded indicates that some of the polyclonal seedlings are promising.

9. Introduction and evaluation of germplasm

The Brazilian germplasm materials were maintained at Sorutari Research Farm and out of this 520 Brazilian germplasm materials were test-tapped at 35 cm height during February-March, 1997.

10. Isolation, identification and maintenance of pathogens

Routine isolation of fungal pathogens was made from various diseased samples of *Hevea* plants collected from different locations at the time of survey and identified them through cultural studies at laboratory. Fungal isolates associated with various diseases were maintained as stock cultures for further studies.

REGIONAL RESEARCH STATION, AGARTALA, TRIPURA

The Regional Research Station, Agartala (Tripura) undertakes research mainly on Agronomy/Soils, Plant Breeding and Plant Physiology. The station has a library, mobile soil and tissue testing laboratory, an automatic weather station and computer facility besides the research farm at Taranagar having an area of 84.83 ha with 29 tapping blocks, nursery and processing centre.

1. Nutritional studies

1.1 Mature phase

The fertilizer trial laid out with clone RRIM 600 consists of three levels of N (0, 30, 60 kg/ha); P (0, 30, 60 kg/ha) and K (0, 20, 40 kg/ha). The data on mean yield is presented in Table Net.1. Application of 60 kg N and 40 kg P significantly increased the

Table Net.1. **Effect of different levels of nutrients on mean yield (g/tree/tap)**

Level of nutrient	0 K			20 K			40 K		
	0 P	30 P	60 P	0 P	30 P	60 P	0 P	30 P	60 P
0 N	28.70	28.87	31.85	25.43	32.40	35.45	33.60	37.50	31.48
30 N	33.63	32.71	33.87	29.71	38.58	33.23	32.62	33.22	30.07
60 N	28.08	34.08	37.73	39.72	35.58	34.37	31.14	33.16	38.17

N, P and K SE 17.34; CD (P=0.05) 2.42; interaction CD (P=0.05) 7.25

yield and girth. The soil and leaf nutrient analyses are being carried out.

1.2 Effect of higher levels of nutrients

The field experiment laid out at NRETC Demonstration Farm, Tulakona with clone RRIM 600 was aimed at studying the response of *Hevea* plants to higher doses of nutrients. The annual data on girth and yield (Table Net.2) revealed that the treatment 60, 60, 60 kg/ha NPK gave the highest response. Statistical analysis, however, showed no significant difference between the treatments.

Table Net.2. **Mean girth and girth increment (1996-97)**

Treatment (N, P, K)	Girth (cm)	Girth increment (cm)	Average yield (g/tree/tap)
30,30,30	55.74	3.49	50.35
30,30(15),30	55.75	2.81	51.53
60,60,60	59.49	4.36	56.67
60,60(30),60	58.81	4.30	47.85
90,90,90	58.67	4.82	50.52
90,90(45),90	57.76	3.66	49.53

Water soluble form of phosphorus in parentheses.

2. Density-cum-nutritional trial

Recorded monthly yield and girth at six-monthly interval in the experiment at Taranagar farm having two clones (C1 - RRII 105 and C2 - RRII 118) laid out in three densities (D1 - 420; D2 - 606; D3 - 824 plants/ha) and three levels of NPK (M1 - 40, 40, 20 kg/ha; M2 - 60,60,30 kg/ha and M3 - 80,80,40 kg/ha). The average girth is presented in Table Net.3. Significant differences were observed among the treatments for density as well as clone. Maximum girth was observed in D1 which was significantly higher than D2 and D3. RRII 118 recorded higher girth and the difference was significant. However, different fertilizer levels did not show significant difference in girth.

Table Net.3. **Effect of density and clone on girth**

Density	Girth (cm)	
	RRII 105	RRII 118
D1	55.43	58.47
D2	51.43	55.58
D3	47.21	52.42

Density CD (P=0.05)-2.49; CV - 6.59
Clone CD (P=0.05)-1.43; CV - 5.38

3. Forms and placement of fertilizer

3.1 Mode of fertilizer application (N and P)

This onfarm trial was started in 1990 at Tulakona with clone RRIM 600 to find out the effect of different forms and placement of fertilizer on immature rubber. Recommended dose of K was also applied along with different forms of N and P. Significant difference in girth was observed among placement. The girth from the treatment - band application - was significantly higher than 15 or 30 cm pocket application. However, there was no significant difference in girth due to different forms of fertilizer. The average girth data recorded during 1996-97 is presented in Table Net.4.

Table Net.4. **Effect of placement and form on mean girth (cm)**

Treatment	Band	15 cm pocket	30 cm pocket
Amm. sulphate Super phosphate	50.40	46.97	47.98
Amm. sulphate Rock phosphate	51.06	48.65	45.25
Urea, Super phosphate	49.66	46.07	45.94
Urea, Rock phosphate	47.27	47.09	44.09

For fertilizer CV - 4.67; placement CV - 5.35
CD (P=0.05)-1.86

4. Agro-ecological and socio-economic impacts

4.1 Impact of rubber cultivation on agro-ecological aspects

Profile soil samples were collected from different plantations *viz.* rubber, sal, acacia, cashew and teak along with barren land. The available nutrients *viz.* P, K, Ca, Mg (mg/100 g soil) and organic carbon (%) were estimated. Soil pH from different soil samples was also determined. The results are presented in Table Net.5.

The results indicate that there was no significant difference in percentage of organic carbon and available phosphorus present in the soil among the different plantations at 0-15 cm depth. In the case of potassium, significant difference was not observed between the plantations of rubber, acacia, sal and teak. In pH, there was no significant difference between rubber, teak, and cashew. However, there was significant difference in the case of Ca and Mg of the soil at 0-15 cm depth between rubber and others.

5. Clone trials

5.1 Clone trial (1979)

The data on mean yield of different clones over six years revealed that PB 235 is the highest yielding clone followed by RRII 118, RRIM 600, RRII 203, RRIM 703 and RRII 105. The yield of RRII 118 showed an increase in the BO-2 panel. The yielding pattern of RRII 118 has to be studied further incorporating seasonal differences prevailing during winter and non-winter seasons. Data on girth increment revealed RRIC 52 attained maximum girth over a period of 15 years followed by RRII 118.

5.2 Clone trial (1987)

Girth data from six clones (RRII 208, RRIM 600, PR 107, SCATC 88-13, SCATC 93-114 and Haiken 1) exhibited various levels of ecovalence with PR 107, Haiken 1 and SCATC 93-114 as the most stable clones (Table Net.6). However, first year yield indicates that RRII 208 as the highest yielder followed by SCATC 88-13 and Haiken 1 when compared to RRIM 600.

Table Net.6. **Stability of clones towards girth increment**

Clones	Ecovalence
RRII 208	6.6066
RRIM 600	5.9685
PR 107	0.8256
SCATC 88-13	3.3930
SCATC 93-114	1.8721
Haiken 1	0.8001

6. Breeding and selection

6.1 Full-sib progeny evaluation

Twenty seven cross combinations involving six clones (PB 86, SCATC 88-13,

Table Net.5. **Analytical results of soil samples at 0-15 cm depth**

Plantation	O.C.	P	K	Ca	Mg	pH
Rubber	1.10	0.30	3.45	12.59	1.92	4.86
Acacia	0.94	0.20	2.95	3.36	0.61	4.66
Sal	0.79	0.21	3.60	2.66	0.65	4.62
Teak	1.10	0.16	3.66	43.50	7.31	4.75
Cashew	1.03	0.19	2.33	4.80	0.63	4.80
Barren land	0.83	0.11	1.96	7.15	1.13	4.68
CD (P=0.05)	NS	NS	0.81	2.78	0.54	0.12

Gl 1, RRIM 600, RRII 208 and RRII 105) were multiplied and laid out in a comparative evaluation trial during 1996 along with parents in a simple lattice design with two replications. Quarterly morphological data are being recorded.

6.2 Half-sib progeny evaluation

This trial was laid during 1994 to identify useful recombinants (half-sib) from five female parents (RRII 203, PB 5/51, PB 86, RRIM 600 and GT 1) of 1979 clone trial. A total of 49 half-sibs along with their female parents and probable males (all 15 clones) were included following 8 x 8 simple lattice in two replications. Quarterly girth recording revealed that the progenies of RRIM 600 attained the highest average annual girth increment (Table Net.7).

Table Net.7. **Growth during third year**

Clone	Mean girth increment (cm)	
	Parent	Progeny
RRIM 600	4.07	5.99
PB 5/51	4.75	5.46
PB 86	6.14	5.73
RRII 203	6.81	5.85
GT 1	7.55	6.50

6.3 Evaluation of polyclonal seedlings

In the polyclonal seedling garden having 591 seedlings planted in 1987, tapping was started in 1994. A total of 403 seedling trees are currently under tapping following 1/2S d/2 system. The yield data of first two years revealed a mean of 21.185 g/tree/tap. Periodic recording of secondary characters was carried out. Based on yielding pattern over the past two years, 11 high yielding trees were selected for further evaluation. Growth and yield as well as secondary characters are being recorded.

6.4 Investigations on G x E interactions in *Hevea*

This trial was initiated in 1996 as part of the multilocational project to study the nature of G x E interactions in *Hevea*. A total of 13 clones (RRII 105, RRII 203, RRII 176, RRII 51, RRIM 600, PB 235, PB 217, RRIC 100, 82/14, 82/17, 82/22, 82/29 and 82/30) were included in this trial. Early growth characters are being recorded at fixed intervals.

6.5 Investigations on low fruit set in *Hevea*

This study was envisaged during 1996 to find out the reasons and causes of low fruit set. Histochemical observations on ovule development were made to assess the time of embryo abortion which revealed that abortion occurs during 30 to 40 days after anthesis. The abortive ovules have the tendency to develop nucellar adventive embryos which were in turn abortive. It was also observed that all three ovules need to be fertilized and developed for the fruit to attain maturity. The clones defoliating early bear more fruits.

7. Germplasm collection and evaluation

This station has a collection of 256 accessions of wild Brazilian genotypes from 1981 IRRDB expedition, planted during 1989. Two trials were laid out in lattice design with 24 and 63 genotypes with RRIM 600 as control. Quarterly morphological observations were made.

8. Exploitation studies

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

With an aim to formulate an appropriate exploitation system to withstand the cold stress in this region, an experiment is being conducted considering three tapping systems

(d/1, d/2, d/3) in combination with winter tapping rests when temperature falls in the range of 20-20°C, 15-15°C and 10-10°C. It seems when the low temperature is imparting cold stress to the plant, less frequent tapping has no beneficial effect. Observation on cup lump yield per week for one year showed that though the d/1 system is showing fairly better yield than that of d/2 and d/3 systems, the occurrence of TPD is more in d/1, followed by d/2 and d/3 respectively. Preliminary data on yield after rest shows that 20-20°C and 15-15°C rests are superior. The yield per tree per week showed a seasonal variation in different tapping systems.

8.2 Effect of stimulation and intensive tapping on TPD

In an attempt to understand the role of free radical and its associated scavenging systems, studies have been undertaken estimating free radical (FR) in EPR spectrometer and simultaneous gel electrophoretic assessment of superoxide dismutase (SOD) in the laticiferous cells/latex. It was observed that the bark of rubber, when over-exploited shows more amount of free radical and a concomitant decrease in the level of SOD.

8.3 Effect of soil moisture and agroclimatic parameters on yield

The experiment was initiated to study the effect of soil moisture, agroclimatic conditions and their interactions on yield. Periodic estimations of sugar, thiols, inorganic phosphorus, TSC and mineral elements *viz.* Ca, K, Mg and Cu from the latex were made. Besides recording yield, soil moisture and agrometeorological parameters were also monitored.

9. Prediction of yield by antecedent atmospheric parameters

A project has been initiated to find out the closely related atmospheric parameters with daily yield patterns and to build a simple model for the forecast of yield based on the antecedent atmospheric parameters with the minimum lead time with respect to reliability.

10. Raw rubber processing

A project is initiated to study the problems associated with the raw rubber processing in this region. The study includes a survey of existing status of raw rubber processing, factors affecting the quality of sheets, collection and processing of scrap rubber. The possibilities of processing latex into different grades of sheets and other forms are also aimed at. Tapping and processing has already been started at RRS Agartala, Kolasib and Tura.

REGIONAL RESEARCH STATION, TURA, MEGHALAYA

The Regional Research Station, Tura, Meghalaya is concentrating on various projects to evaluate the location-specific clones for Garo Hills in Meghalaya.

1. Field experiments at Ganolgre

1.1 Multidisciplinary evaluation of clones

In the 1986 clone trial, maximum girth was recorded in RRIC 105 (63.90 cm) followed by PB 311 (59.33 cm), RRII 208 (59.28 cm) and PB 310 (57.57 cm) while RRII 5 (49.84 cm) and PR 255 (46.27 cm) showed minimum girth among the ten clones.

1.2 Performance of polyclonal seedlings

The average girth of the polyclonal plants was 27.56 cm. The overall growth behaviour is quite satisfactory.

1.3 Block plantation

The clone RRIM 600, planted during 1987, have attained an average girth of 54.68 cm.

1.4 Rubber-based cropping system

Under this trial where rubber (RRIM 600), tea and orange were planted together in 1987, the growth of rubber and tea plants was satisfactory while orange growth was found retarded. Tea leaves were harvested periodically and fetched net income of Rs.3410/-. Seventy per cent trees of RRIM 600 have not attained the tappable girth.

2. Physiological investigations

2.1 Effect of different aspect of slopes

The girth of RRIM 600 clone has been recorded from North-North East and West-South West aspect of slope at 600 m elevation during different months (Table Nem.1). The plants growing lower side of the slopes attained more girth than upper side and its differences are more in West-South West aspect of slope than North-North East aspect of slope.

2.2 Effect of altitude on growth of *Hevea*

A comparative growth analysis of five clones *viz.* RRIM 600, PB 235, PB 5/51, RRII 118 and Gl 1 was carried out at two altitudes (2000 ft. Tura and 180 ft. Guwahati).

2.3 Evaluation of yield

The yield analyses have been carried out in various clones under 1/2S d/2 tapping system from 1985 clone trial during monthly intervals.

During November, all clones showed higher DRC, TSC, yield and total latex volume. However, RRIM 600, RRII 118 and

Table Nem.1. **Mean girth (cm) of 10-year-old RRIM 600 plants grown under different aspect of slope**

Month	North-North East aspect			West-South West aspect		
	Lower	Upper	Difference	Lower	Upper	Difference
May 1996	49.41	47.50	1.91	51.13	47.52	3.61
Aug. 1996	53.06	50.80	2.26	53.23	50.00	3.23
Nov. 1996	55.00	53.30	1.70	55.80	51.60	4.20
Feb. 1997	55.16	53.48	1.68	56.10	51.73	4.37

PB 235 performed better compared to other clones. The yield and DRC decreased in all the clones from December to March and the lowest DRC (below 25) was recorded in GT 1 and PB 86 during January which may be due to low temperature. Maximum plugging index was recorded during the month of April and its trend was similar in all the clones.

2.4 Effect of wintering

During the winter (November-March), almost all clones showed negligible girth increment ranging from 0.05 to 0.11 cm. Defoliation occurred in all clones during last week of January when the minimum temperature was below 10°C and its pattern varied from clone to clone while refoliation occurred in last week of February when minimum temperature exceeded 10°C.

3. Experiments in plant pathology

3.1 Plant diseases

No serious outbreak of diseases was recorded. The incidence of powdery mildew was mild and a few plants of PB 28/59 were seen infected with pink disease. The disease was brought under control by timely application of Bordeaux paste.

3.2 Mushroom cultivation

Mushroom spawn was prepared on wheat grains and preserved for further mushroom culture. The pure cultures of *Pleurotus flabellatus, P sajor-caju* and *P. ostreatus* were also maintained.

3.3 Microbiological studies

The microbiological study of different forest soils revealed that apparently the above ground vegetation of the forest types did not exert any influence on the composition of fungal flora. Total count of the microflora exhibited a decreasing trend along with increase in soil depth. Amongst the species *Aspergillus, Penicillium, Cladosporium, Cephalosporium* and filamentous yeasts were dominant and well distributed in all the forest types studied.

4. Experiments in botany

4.1 Ortet selection

Selected 15 mother plants from Baghmara and Tebronggre plantations under Soil Conservation Department and parameters like girth, bark thickness, panel length, latex volume, DRC, PI, initial flow rate and duration of flow were recorded.

4.2 Genetic improvement in *Hevea*

A study has been initiated for cross-pollination among the clones PB 235, RRIM 600, RRII 105, GT 1, PB 5/51 and PB 86 to incorporate wind as well as cold resistance with high yield.

5. Block plantation at DDC, Jenggitchakgre (Onfarm trial)

During the year 1990, 2000 plants of RRII 105 clone were planted at DDC, Jenggitchakgre. The growth of RRII 105 clone is satisfactory and the plants have so far attained an average girth of 45.33 cm.

REGIONAL RESEARCH STATION, KOLASIB, MIZORAM

The Regional Research Station, Kolasib, Mizoram is concentrating on various projects to develop a low input agro-technology for rubber cultivation suited for this region.

1. Multidisciplinary evaluation of clones

This trial was started in 1985 with 10 clones for identification of the clones suitable for Mizoram condition. The clone RRII 118 recorded highest girth (69.5 cm) followed by PB 86 and RRII 203. Girth increment from April 1996 to February 1997 was higher in RRII 118 and lower in Gl 1.

2. Polyclonal seed garden

The clone SCATC 93-114 recorded the highest girth in all three slopes (foothill, mid-hill and hill top) whereas girth increment over a period from January 1996 to February 1997 was highest in RRII 105 in mid-hill, RRII 118 in foothill and RRII 300 in hill top (Table Nez.1).

Table Nez.1. **Mean girth under different slopes**

Clone	Girth (cm)		
	Foothill	Mid-hill	Hill top
RRII 105	53.4 (6.6)	51.8 (10.6)	48.3 (4.1)
RRIM 600	44.1 (2.5)	44.9 (6.1)	52.6 (6.8)
SCATC 93-114	60.0 (7.6)	61.0 (8.8)	61.4 (8.2)
RRII 300	55.1 (6.8)	55.5 (6.7)	57.6 (10.8)
RRII 118	59.5 (8.3)	57.1 (7.4)	53.3 (2.1)
GT 1	53.9 (6.2)	57.2 (5.4)	53.2 (5.1)
PB 235	58.7 (6.9)	57.1 (8.1)	55.7 (5.9)

Figures in parentheses indicate girth increment

3. Influence of physiographic features on growth

The girth as on February 1997 and girth increment from January 1996 to February 1997 are given in Table Nez.2. Plants in the eastern slope has the highest (47.5 cm) absolute girth followed by plants in the western aspect (46.3 cm). Girth increment over a period from January 1996 to February 1997 was highest among plants planted towards south direction.

Table Nez.2. **Influence of aspect of slope on girth**

Aspect	Mean girth (cm)	Girth increment (cm)
North	37.9	7.6
South	45.5	10.5
East	47.5	8.0
West	46.3	7.0

4. Nutritional trial

The girth as on February 1997 and girth increment over a period from January 1996 to February 1997 are given in Table Nez.3.

Table Nez.3. **Effect of split application of fertilizer on the growth of immature rubber**

Treatment	Mean girth (cm)	Girth increment (cm)
50:50:25 in 2 splits	32.8	8.08
50:50:25 in 4 splits	30.6	8.07
75:75:37.5 in 2 splits	32.8	8.10
75:75:37.5 in 4 splits	27.9	7.48
100:100:50 in 2 splits	29.0	7.16
100:100:50 in 4 splits	32.2	8.31

Fertilizer applied in two splits at the rate of 50:50:25 and 75:75:37.5 kg NPK per ha

gave the highest girth (32.8 cm). However, girth increment was higher in case of four split doses at higher rates (100:100:50 kg NPK per ha).

5. Establishment of cover crop

It has been observed that (Table Nez.4) rubber trees grown with single strip of cover crop were recorded highest girth at both 15 and 150 cm height from the bud union followed by cover crop planted in double strips.

6. Agrometeorological observatory

An agrometeorological observatory has been maintained and data were recorded regularly on every day at specified timings.

Table Nez.4. **Influence of cover crop planting on growth of immature rubber**

Treatment	Mean girth (cm)	
	at 15 cm	at 150 cm
Cover crop grown in single strip	31.1 (12.1)	25.5 (9.9)
Cover crop grown in double strips	29.1 (11.1)	24.2 (9.9)
Cover crop grown in patches (1 m area)	29.3 (10.6)	23.9 (8.7)
Cover crop cuttings in single strip	29.3 (10.4)	24.3 (9.2)
Cover crop cuttings in double strips	28.2 (11.3)	23.0 (9.2)

Figures in parentheses indicate girth increment

REGIONAL RESEARCH STATION, NAGRAKATTA, WEST BENGAL

This Station is concentrating mainly on studies to assess the potential of rubber cultivation in the northern part of West Bengal. Among the 10 research projects in progress, two are on nutritional aspects, six on evaluation of various clones and one each on exploitation system and weed management.

1. Nutritional studies

Experiment was laid out in 1989 with four levels of nitrogen (0, 20, 40 and 60 kg/ha), three levels each of phosphorus and potassium (0, 20 and 40 kg/ha) in factorial RBD. The clone RRIM 600 was taken as the experimental material. Girth was significantly influenced by different levels of nitrogen but phosphorus and potassium and their interaction did not show any effect (Table Nag.1). Significantly higher stem girth was recorded with 60 kg/ha but was on par with the 20 and 40 kg N/ha.

Another experiment was laid out in 1993 with four different schedules of fertilizer application to find out the optimum number of splits needed for better growth of rubber under Dooars area. Two split applications resulted in significantly higher plant girth over control and single application but on par with three and four split applications. Similarly, two split applications recorded higher annual girth increment. However, bark thickness, branching height, canopy height and diameter were not significantly influenced by the application of fertilizer in different splits. Two split applications recorded higher girth over single split and control indicating the better response of two split applications over other split treatments.

Table Nag.1. **Influence of different levels of nutrients on rubber growth (cm)**

Level of nutrient	0P				20 P				40 P				Mean of N
	0K	20K	40 K	Mean	0K	20 K	40 K	Mean	0K	20K	40K	Mean	
0 N	43.5	44.5	42.0	43.2	41.4	44.4	44.7	43.5	43.2	45.8	44.3	44.4	43.7
20 N	44.1	47.0	45.0	45.4	46.1	45.1	45.7	45.6	44.4	45.3	46.3	45.3	45.4
40 N	44.2	48.0	45.2	45.8	45.5	45.3	47.4	46.1	48.4	47.0	45.0	46.8	46.2
60 N	46.5	47.4	48.1	47.3	45.9	45.3	46.8	46.0	47.0	45.7	46.7	46.5	46.6
Mean	44.5	46.7	45.0	45.4	44.7	45.0	46.1	45.3	45.7	45.9	45.5	45.7	

	N	P	K	NP	NK	PK	NPK
SEm	0.49	0.42	0.42	0.85	0.85	0.73	1.50
CD (P=0.05)	1.35	NS	NS	NS	NS	NS	NS

2. Evaluation of clones

2.1 Clone trial (1990a)

Annual girth increment was found to be more in RRIM 703, PB 5/51 and PB 235. PB 235 and PB 311 showed partial wintering (6-25%) compared to 76-95 per cent wintering observed in PB 5/51. Rest of the clones showed moderate wintering.

2.2 Clone trial (1990b)

Stem girth varied significantly among clones, RRIM 605 and RRII 208 recording higher girth over Gl 1 and PR 107 but on par with other clones. Contrastingly Gl 1 and PR 107 recorded more annual girth increment compared to RRIM 605 and RRII 208. Wintering pattern also differed among clones, Gl 1 and PR 107 recording 76-95 per cent and 51-75 per cent wintering respectively compared to 25-50 per cent recorded by RRII 105 and RRIM 612.

2.3 Clone trial (1991)

Clonal differences in girth was found to be not significant. Annual girth increment ranged between 6.5-8.5 cm. Wintering showed variation among the clones, RRIM 612 and PR 107 recorded more wintering (76-95%) compared to RRII 208 and PB 235. Rest of the clones showed moderate wintering.

2.4 Clone trial (1993)

Stem girth showed significant variation with RRIM 600 and RRII 105 recording significantly higher girth over RRIC 104, PR 261, RRII 308 and PB 280. Similarly, wintering is more for RRIC 104 (90-100%) compared to partial wintering observed in RRIM 600 and RRII 105. Bark thickness showed no significant variation among the clones.

3. Exploitation system

A trial with RRIM 600 clone has been laid out in 1991 to find out the best system of exploitation under northern parts of West Bengal. The plantation has not yet attained the tapping stage.

4. Effect of spray additive on herbicide efficacy

This trial was laid out in 1996 to evaluate the effect of adding urea (10 kg/ha) as a spray additive on the weed control efficiency of glyphosate herbicide with manual weeding as control. Glyphosate was tried at 0.5, 1.5, 2.5, 3.5 and 4.5 L/ha and urea was added as spray additive with 0.5, 1.5 and

2.5 L/ha. Application of glyphosate 2.5 L/ha with or without urea effectively controlled the weeds up to four weeks after treatment, compared to manual weeding and 0.5 L glyphosate with or without urea. Addition of urea to 2.5 L glyphosate recorded 62 per cent weed control efficiency and was on par with 3.5 and 4.5 L glyphosate alone resulting in the saving of 1-2 L herbicide.

However, addition of urea to lower doses of glyphosate (0.5 and 1.5 L) showed no improvement in weed control efficiency. At eight weeks after treatment no significant difference in weed control was observed due to shift in weed population to dicots. However, even at 10 weeks after treatment all the treatments except 0.5 L glyphosate with or without urea maintained their effectiveness in controlling monocot weeds.

5. Trial on Genotype x Environment interaction

This trial was started in 1996 with 12 different clones planted in RBD. Girth, plant height, number of leaves and whorls per plant recorded in field plants showed no significant difference among the clones.

REGIONAL RESEARCH STATION, DAPCHARI, MAHARASHTRA

The Regional Research Station, Dapchari concentrates research on evolving strategies for the establishment and upkeep of rubber plantations in Konkan region.

1. Irrigation systems

The plants under basin irrigation treatment recorded comparatively good growth and yield than drip irrigation (Table Dap.1). Growth of plants under different treatments of irrigation was significantly superior to control plants. Plants under 0.25 ETc level of irrigation attained tappable girth late as compared to other levels of irrigation. Control plants have not yet attained the tappable girth. The mean annual girth increment was found to be lower in tapped plants under irrigation treatment than control and 0.25 ETc level of irrigation.

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

Treatment	Mean girth (cm)	Girth increment (cm)	Mean dry rubber yield (g/tree/tap)
Control (No irrigation)	46.16	2.70	No tapping
1.00 ETc, Basin	58.09	1.90	39.46
0.75 ETc, Basin	58.21	2.30	38.38
0.50 ETc, Basin	56.13	1.80	33.15
0.75 ETc, Drip	55.91	2.00	32.44
0.50 ETc, Drip	56.66	2.00	30.49
0.25 ETc, Drip	53.84	2.80	28.72
SE±	1.28	0.42	
CD (P=0.05)	2.79	0.915	

2. Effect of irrigation on yield and yield components

Hose irrigation treatment with three levels *viz.* 1.00 ETc, 0.75 ETc and 0.50 ETc was continued in two clones, RRII 105 and RRII 118. RRII 118 was vigorous in growth whereas RRII 105 performed better with respect to yield (Table Dap.2).

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

Treatment	Mean girth (cm)		Mean dry rubber yield (g/tree/tap)	
	RRII 105	RRII 118	RRII 105	RRII 118
Control (No irrigation)	48.79	53.24	33.70	31.30
1.00 ETc	59.23	68.34	51.97	39.33
0.75 ETc	58.07	70.56	46.63	45.23
0.50 ETc	56.46	61.03	49.33	35.83
For irrigation				
SE ±		3.80	3.99	
CD (P=0.05)		9.31	9.78	
For clones				
SE ±		1.23	0.96	
CD (P=0.05)		2.84	2.22	

3. Clone trial (1985)

Among the 15 clones, RRII 208, RRIC 52 and RRII 6 recorded better growth than other clones. The clones PR 261 and RRII 308 recorded poor growth (Table Dap.3).

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

Clone	Mean girth (cm)
RRII 5	46.86
RRII 6	51.11
RRII 105	47.59
RRII 208	55.00
RRII 308	44.69
RRIM 605	45.30
PB 260	45.49
PB 310	45.22
PB 311	45.82
RRIC 52	51.51
RRIC 100	49.59
RRIC 102	50.20
RRIC 105	46.53
PR 255	45.46
PR 261	44.14
SE ±	3.04
CD (P=0.05)	6.22

4. Effect of silt pits on soil and water conservation

A field experiment was laid out in polyclonal field to study the effect of different frequency of silt pits on soil and moisture conservation (Table Dap.4).

Table Dap.4. **Effect of silt pits on soil and moisture conservation**

Treatment	Mean soil moisture(%)		Silt deposited	
	Depth (cm)		kg/pit/year	t/ha/year
	0-30	30-60		
No pits	13.32	15.58	-	-
100 pits*	11.43	14.51	27.80	2.79
150 pits	17.00	18.92	25.32	3.79
200 pits	13.42	17.86	22.14	4.43
100 pits + 10 kg saw dust**	13.41	16.81	44.78	4.48
150 pits + 10 kg saw dust	11.05	17.91	35.90	5.38
200 pits + 10 kg saw dust	10.85	13.71	32.96	6.59
SE ±	2.37	2.30		
CD (0.05)	NS	5.01		

* per ha ** per pit

Significant improvement in the soil moisture was observed at 30-60 cm depth. However, the effect was not significant for 0-30 cm depth. Silt deposited during one year period gave an estimate of 4.58 t/ha/pit/year.

5. Physiological evaluation of clones

This trial was established in 1982. Among the existing eight clones (PB 235, RRII 300, GT 1, PR 107, RRIM 501, RRIM 600, Gl 1, RRIM 612), RRIM 612 recorded maximum yield of 1929 kg/ha/year. Various physiological parameters studied such as bark turgor, latex and leaf solute potential, plugging index (PI) and initial latex flow revealed that high yielding clones are stable in their physiological characters during summer months also.

6. Cost evaluation

A trial was laid out in 1987 to estimate the cost of cultivation of *Hevea* under irrigated and unirrigated condition. Tapping was started in irrigated trees (mean girth 59.31 cm) from May 1994. Unirrigated trees have not attained tappable girth (mean girth 45.63 cm). Expenses incurred towards various inputs, farm practices, irrigation, *etc.* were recorded.

7. Polyclonal seedlings for selection

The growth and yield data were pooled from the polyclonal plantation. Selection of the trees on the basis of girth and yield has been done for further multiplication and study.

REGIONAL RESEARCH STATION, DHENKANAL, ORISSA

The Regional Research Station located at Dhenkanal, Orissa gives priority on research on agromanagement techniques and clone evaluation specific for drought prone areas in central Orissa. This station has a research farm at Kadalipal with an area of 30.8 ha.

1. Evaluation of clones

In the 1987 clone trial the same growth trend continued, with maximum girth recording in RRIM 600 followed by GT 1 and RRII 105.

Among the ten clones of 1990 trial, RRIM 600 (33 cm) and SCATC 93-114 (33 cm) continued to record higher girth followed by RRII 5 (32 cm) and PR 255 (32 cm) while the lowest girth was recorded in SCATC 88-13 (24 cm).

2. Polyclonal seedlings

In the polyclonal seedling area of 1988-89 planting, 347 polyclonal trees had attained tappable girth (55 cm) at a height of 50 cm during March 1997. A total of 431 plants having girth of 50 cm or above have been identified and marked for purpose of further propagation and yield evaluation from individual trees.

In the 1991 trial, RRII 300, RRIC 102, polyclonal trees and GT 1 have attained maximum girth while PR 255 and PR 261 showed the minimum girth.

3. Nutrient management using organic manures

Due to extreme hot climate and non-availability of organic manures, the trial has been abandoned.

4. Investigations on Genotype x Environment interaction in *Hevea* - onfarm trials

An onfarm trial was started at Regional Research Laboratory (RRL), Bhuvaneswar with 12 clones during 1996 to study the

Genotype x Environment interaction pattern in *Hevea* for evaluating the adaptability and stability of clones and to identify widely adapted clones.

5. Nursery

The budwood nursery was established during August 1990, where 20 selected genotypes are being maintained. Mulching and life-saving irrigation are being given during summer.

A seedling nursery has been established during the period for generating planting material.

6. Agrometeorological observatory

The general weather conditions during 1996 at the Regional Research Station, Kadalipal (Dhenkanal), Orissa are summarised in Table Ori.1.

The total rainfall during the period was 420.4 mm with only 68 number of rainy days. The highest maximum temperature (mean) of 40.5°C was recorded during May 1996. The highest minimum (mean) of 27.1°C was observed in May 1996 against the lowest minimum of 10.6°C in December 1996 at Kadalipal Research Farm.

Table Ori.1. **Weather condition at RRS, Orissa (Dhenkanal)**

Month	Temperature(°C)		Rainfall (mm)	Relative humidity(%)	
	Maximum	Minimum		7.10 AM	2.10 PM
January	27.4	15.5	10.5	88	85
February	30.5	16.1	4.0	86	71
March	36.2	20.7	3.0	84	56
April	38.3	24.1	11.4	89	-
May	40.5	27.1	8.4	91	-
June	38.7	25.7	128.8	92	73
July	32.0	25.7	60.1	92	78
August	30.5	25.3	122.4	93	85
September	32.7	25.0	41.2	90	79
October	31.3	22.2	16.6	87	76
November	29.9	-	14.0	86	69
December	26.8	10.6	0.0	84	67

REGIONAL RESEARCH STATION, SUKMA, MADHYA PRADESH

The Regional Research Station, Sukma, Bastar district, Madhya Pradesh concentrated its research activities on screening of *Hevea* germplasm for drought/cold tolerance, phenology, architecture, G x E interaction, niche analysis on growth and yield components.

1. Multidisciplinary evaluation of clones

The clone evaluation trial was started in 1990 with RRII 105 and RRIM 600. Clones are showing good growth, as average girth recorded were 40 cm and 35 cm for RRIM 600 and RRII 105 respectively.

2. Screening of *Hevea* germplasm for drought tolerance

Selected genotypes of Brazilian germplasm together with a few modern clones were planted in polybag nursery during June/July 1995. The existing germplasm materials showing large variations were planted in field during July 1996. First year observation indicated RO 5363 and MT 196 to be better in growth and AC 707 poor in growth.

3. Germplasm budwood nursery

Budwood nursery of 73 selected Brazilian genotypes and modern clones of *Hevea* has been established to meet the future needs of research experiments.

4. Screening *Hevea* germplasm for cold tolerance

The budded stumps of *Hevea* genotypes were raised/generated at this station and sent to Regional Experiment Station, Nagrakatta for the field planting in 1997 to evaluate the cold tolerance.

5. Polyclonal seedling plantation

Polyclonal seedlings were field planted to evaluate the growth and yield under the stress conditions. Lack of rain has resulted in poor sprouting and growth.

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

Variation in morphology of plants has been observed at early stage.

REGIONAL RESEARCH STATION, PADIYOOR, KERALA

The Regional Research Station at Padiyoor, Kannur, Kerala covering an area of 40 ha was started in 1994-95. Field trials in this station have commenced with the planting of germplasm materials in 4 ha area in 1995. About 16 ha area was planted with different planting materials in 1996 in connection with various trials. Long-term field experiments on screening and evaluation of Brazilian germplasm, investigation on Genotype x Environment interaction in *Hevea* and experiments on evaluation of potential hybrid clones have already been laid out. A budwood nursery is also being maintained.

HEVEA BREEDING SUB-STATION, NETTANA, KARNATAKA

The station, having 50 ha planted area, concentrates mainly on screening of clones evolved through ortet selection and hybridization. An agrometeorological observatory and budwood nursery are also being maintained here.

1. Trials on growth, yield and exploitation systems

There are two field experiments, with five clones in each, planted during 1987 and 1988 under this category. In 1987 trial, PB 235 continued to grow well registering an average girth of 60.25 cm and RRII 300 (50.68 cm) the least. In 1988 trial, average girth ranged from 40.77 cm (PR 255) to 54.50 cm (RRII 118).

Incidence of leaf spot disease caused by *Corynespora cassiicola* was noticed in both the trials during summer. In 1987 trial, moderate infection was found in RRII 105, PB 260 and PB 311. PB 235 and RRII 300 showed mild infection. In 1988 trial, PB 261 had severe infection while PR 255 showed mild infection. The infection on RRII 118, RRIC 36 and RRIC 45 was low.

2. Evaluation of ortet clones

Three trials are in progress for screening the ortet clones. Two trials have 17 ortets each and the third has 14. RRII 105, RRIM 600 and GT 1 are the control clones. GT 1 recorded highest growth in all the experiments and RRIM 600 the least. In the first experiment, ortets 017 (57.09 cm) and C42 (57.06 cm) performed well. Other clones which performed better than GT 1 (52.14 cm) are : 034 (53.09 cm), 041 (53.70 cm), 047 (54.19 cm) and T2 (56.61 cm). In the second experiment ortet T1 recorded the highest mean girth (57.60 cm) while GT 1 recorded 52.73 cm. Other ortets which are on par with GT 1 are PO (50.57 cm), C150 (51.24 cm) and 054 (51.80 cm).

In the third experiment, ortet C140 recorded the maximum average girth of 56.52 cm followed by 055 (55.15 cm) and 026 (53.08 cm) while control GT 1 recorded 53.12 cm. Severe *Corynespora* attack was noticed in this trial. Few clones suffered extensive damage. The severely infected clones were 011, C3/10, 038, 014 and clones like 04, 09, C150, PO and 05 showed no infection while RRIM 600 and GT 1 had mild infection.

3. Large-scale clone trials

These trials included two experiments, the first comprising of 14 clones planted during 1989 and the second with 15 clones including second selection clones after hybridization planted during 1990. The mean performance data of individual clones are presented in Table Kar.1.

In 1989 trial, the clone RRII 203 recorded the highest mean girth of 52.59 cm and the lowest by Haiken 1 (32.9 cm). RRII 308 recorded highest annual percentage growth (17.7). In 1990 trial, PB 260 performed better, recording a girth of 40.2 cm, while Gl 1 had the lowest (29.35 cm). Highest percentage of annual growth was recorded for the clone Hil 28 (28.51).

Moderate *Corynespora* attack was noticed in 1989 trial, while in 1990 trial, the incidence was very mild. In 1989 trial, RRII 105 and PR 261 had severe damage and RRII 308 and RRIM 600 had moderate infection. RRII 203, KRS 25, KRS 163, SCATC 93-114, SCATC 88-13 and Haiken 1 had very mild infection.

4. Composite clone trials

This include three trials of small-scale clone evaluation. First trial consisted of 36

Table Kar.1. **Mean performance of clones in large-scale evaluation trials**

1989 trial			1990 trial		
Clone	Mean girth (cm)	Annual growth (%)	Clone	Mean girth (cm)	Annual growth (%)
RRII 105	43.05	14.47	RRII 105	35.15	22.29
RRII 203	52.59	14.36	HP 185	34.36	22.88
RRII 300	47.09	12.63	HP 187	33.19	23.71
RRII 308	42.97	17.74	HP 204	32.72	25.32
RRIM 600	41.47	16.48	HP 223	35.79	24.85
PB 255	45.59	13.53	HP 372	33.52	25.08
PR 255	37.08	15.21	PB 217	33.15	20.53
PR 261	43.68	15.26	PB 235	37.07	23.84
KRS 25	44.06	15.64	PB 260	40.20	19.63
KRS 128	47.36	15.91	PB 311	36.78	20.23
KRS 163	45.73	15.09	Hil 28	32.00	28.51
SCATC 88-13	38.39	16.16	Mil 3/2	34.75	21.50
SCATC 93-114	38.31	13.47	GT 1	38.51	18.00
Haiken 1	32.91	15.90	Gl 1	29.35	23.81
			Tjir 1	33.48	22.81
Mean	42.81			34.67	
SE	2.412			2.406	

clones and second and third with 13 clones each. RRII 203 recorded highest girth of 38.41 cm followed by PB 235 (37.76 cm). RRIC 36 recorded the lowest girth of 27.59 cm in the first experiment. In the second, the average girth ranged between 27.89 cm (PB 5/139) to 33.77 cm (RRIC 102). In the third trial, highest girth was observed for HP 88/224 (35.58 cm) and the least for AVROS 49 (26.75 cm). No severe incidence of *Corynespora* was noticed in this trial.

5. Estimation of genetic parameters

The trial consists of 12 clones and their half-sibs. Among clones, PB 235 performed well and in half-sibs, those of GT 1 performed well.

6. Poly-cross garden

The garden laid out in 1995 consisting of nine clones has been maintained.

HEVEA BREEDING SUB-STATION, PARALIYAR, TAMIL NADU

The major research activities of the station are hybridization and indepth investigation of floral biology and fruit set in *Hevea*.

1. Evolving high yielding clones

The plants in breeding orchard-I were pollarded continuously and canopy of trees are being shaped for easy hand pollination. Experiments were initiated to induce off-season flowering.

Hand pollinations in all possible combinations were carried out. The seedlings of hand pollination series were subjected to test tapping. The seedlings obtained from the hand pollination carried out during 1996 were raised in nursery for evaluation.

2. Clone evaluation

The clone PB 260 continued to record better growth in this trial. Performance of PR 255 was poor. The small-scale clone trial (1995) consisting of 15 potent mother trees was maintained and vacancies were supplied during 1996.

3. Studies on floral biology and fruit set

Natural pollination in *Hevea* was found to be only through insects. Pollination by means of other agents like wind, birds, *etc.* were negligible. The effectiveness of insect repellents to keep away the natural pollinating agents was analysed with a view to use them as an alternative for emasculation and post-pollination plugging of flowers.

The low fruit set in hand pollination (Table Par.1) in spite of relatively better pollen transfer was found to be due to the damage caused to the panicles and flowers during the process of emsculation, pollination and post-pollination plugging of flowers.

Table Par.1. **Fruit formation in open and hand pollinations**

Particulars	Fruit formation (%)	
	Open pollination	Hand pollination
Stigma with no pollen	89.22	63.30
Stigma with pollen in the range 1-5	7.63	14.10
Stigma with more than 5 pollen	3.15	22.66
Total successful pollinations	10.78	36.70
Percentage of fruit set in relation to total successful pollination	20.96	9.31
Percentage of fruit set in relation to the flowers pollinated with more than 5 pollen	72.01	16.00

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PR 261	43.68	15.26	PB 235	37.07	23.84
KRS 25	44.06	15.64	PB 260	40.20	19.63
KRS 128	47.36	15.91	PB 311	36.78	20.23
KRS 163	45.73	15.09	Hil 28	32.00	28.51
SCATC 88-13	38.39	16.16	Mil 3/2	34.75	21.50
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3. Studies on floral biology and fruit set

Natural pollination in *Hevea* was found to be only through insects. Pollination by means of other agents like wind, birds, *etc.* were negligible. The effectiveness of insect repellents to keep away the natural pollinating agents was analysed with a view to use them as an alternative for emasculation and post-pollination plugging of flowers.

The low fruit set in hand pollination (Table Par.1) in spite of relatively better pollen transfer was found to be due to the damage caused to the panicles and flowers during the process of emsculation, pollination and post-pollination plugging of flowers.

Table Par.1. **Fruit formation in open and hand pollinations**

Particulars	Fruit formation (%)	
	Open pollination	Hand pollination
Stigma with no pollen	89.22	63.30
Stigma with pollen in the range 1-5	7.63	14.10
Stigma with more than 5 pollen	3.15	22.66
Total successful pollinations	10.78	36.70
Percentage of fruit set in relation to total successful pollination	20.96	9.31
Percentage of fruit set in relation to the flowers pollinated with more than 5 pollen	72.01	16.00

LIBRARY AND DOCUMENTATION CENTRE

During the year 1996-97, 213 new books were added to the stock of the library, making a total collection of 21421. The library subscribed 163 journals and eight dailies and about 90 other journals were also received in the library either as gift or exchange.

Seven issues of Documentation List, four numbers of Rubber Alert and one issue of List of New Additions were compiled and distributed. About 0.1 million photocopies of information materials were made by the repographic section.

The library is actively participating in the sales promotion of *Indian Journal of Natural Rubber Research, Rubber Wood : Production and Utilization* and *Plant and Soil Analysis*. The library is distributing the Annual Report of RRII.

The library facilities were also extended to planters, manufacturers and others connected with natural rubber industry. Research scholars and students from universities and colleges also utilised these facilities.

ANNUAL EXPENDITURE

Expenditure at a glance 1996-97

Head of Account	Expenditure (Rs. in lakhs)
Non-plan	
General charges	278.42
Schemes	7.19
Projects (CES)	103.48
Department of Training	-
Total Non Plan	389.09
Plan	
General charges	56.13
Schemes	163.41
NERDS Research Component	88.19
Total Plan	307.73
World Bank Project	
Schemes	258.31
Grand Total	**955.13**

PUBLICATIONS

RESEARCH ARTICLES

Alex, R., Geethakumariamma, M.L. and Kuriakose, B. (1996). Effect of chemical treatment on quality of natural rubber. *Placrosym XII*, 1996, Kottayam, India, p.69.

Alex, R., Kuriakose, B. and Kuruppu, W.C.M. (1996). Studies on factors affecting the initial plasticity of natural rubber and their influence on vulcanisate properties. *International Rubber Research and Development Board Symposium*, 1996, Beruwela, Sri Lanka.

Chandy, B., Lekshmi, S. and George, K.T. (1996). The input subsidy scheme and adoption of improved cultural practices : A comparative analysis of rubber smallholdings in Kerala. *Placrosym XII*, 1996, Kottayam, India, p.65.

Chaudhuri, D., Vinod, K.K., Potty, S.N., Sethuraj, M.R., Pothen, J. and Reddy, Y.A.N. (1995). Estimation of biomass in *Hevea* clones by regression method : Relation between girth and biomass. *Indian Journal of Natural Rubber Research*, 8(2) : 113-116.

Deka, H.K., Thapliyal, A.P. and Sethuraj, M.R. Decomposition of leaf-litter of *Hevea brasiliensis* Muell. Arg. under subtropical conditions of Meghalaya. *Placrosym XII*, 1996, Kottayam, India.

Devakumar, A.S., Vijayakumar, K.R. and Sethuraj, M.R. (1996). Enhancing initial growth rates of young *Hevea* plants using elevated CO_2 concentration, relative humidity and temperature. *Placrosym XII*, 1996, Kottayam, India, p.21.

Devi, T.S., Nair, R.B., Kothandaraman, R. and Sethuraj, M.R. (1996). Impact of weather parameters on seasonal and inter-year variations in yield of rubber. *Placrosym XII*, 1996, Kottayam, India, p.36.

Dey, S.K. and Joseph, T. (1996). Agro-ecological zoning for productivity of rubber in India and the economics of tapping systems. AB-DLO Institute of Agrobiology and Soil Fertility, Wageningen, The Netherlands.

Edathil, T.T., Jacob, C.K., Idicula, S.P. and Joseph, M. Efficient management of powdery mildew disease of *Hevea* rubber plants with integrated use of systemic and non-systemic fungicides. *Placrosym XII*, 1996, Kottayam, India.

George, K.T. and Chandy, B, (1996). Market intervention, value addition and consolidation : The interface between small rubber growers and the co-operative sector in Kerala. *National Seminar on Rediscovering Co-operation*, 1996, Institute of Rural Management, Anand, India.

George, K.T. and Mohanakumar, S. (1996). Rubber products manufacturing sector in Kerala : A note on priorities and strategies. *Workshop on the Industrialisation in Kerala*, 1996, Centre for Development Studies, Trivandrum, India.

George, K.T. and Sethuraj, M.R. (1996). Dynamics of world natural rubber economy : Its relevance to India. *Economic and Political Weekly*, 31(22): 1355-1358.

Idicula, S.P., Jacob, C.K. and Kothandaraman, R. (1996). Control of shoot rot disease in *Hevea*. *Placrosym XII*, 1996, Kottayam, India.

Jacob, J. (1996). Simultaneous measurements of photosynthesis and chlorophyll fluorescence : A powerful method to judge the physiological state of plants. *Placrosym XII*, 1996, Kottayam, India, p.25.

Jessy, M.D., Philip, V., Punnoose, K.I. and Sethuraj, M.R. (1996). Multispecies cropping system with rubber : A preliminary report. *International Rubber Research and Development Board Symposium*, 1996, Beruwela, Sri Lanka.

Jose, V.T., Rajalakshmy, V.K., Jayarathnam, K. and Nehru, C.R. (1995). Single and two stage diffusion processes by different chemical combinations for treatment of rubber wood. *Indian Journal of Natural Rubber Research*, 8(2): 109-112.

Joseph, K., Kothandaraman, R. and Mathew, J. (1996). Phosphate solubilisation by *Bacillus circulance*, a leap towards phosphate fertiliser management in rubber plantations. *Organic Farming and Sustainable Agriculture*, 1996, UAS, Bangalore, India.

Joseph, M., Prasad, M.P., Antony, A.P. and Punnoose, K.I. (1995). DTPA extractable soil micronutrients in the traditional rubber growing regions in India. *Indian Journal of Natural Rubber Research*, 8(2):135-139.

Krishnakumar, R., Sreelatha, S., Gopalakrishnan, J., Jacob, J. and Sethuraj, M.R. (1996). Increased peroxidase activity is related to the decreased cytokinin content in TPD affected *Hevea* trees. *Placrosym XII*, 1996, Kottayam, India, p.29.

Lakshmanan, R., Punnoose, K.I. and Mathew, M. (1995). Efficacy of Diuron for weed control in rubber seedling nursery. *Indian Journal of Natural Rubber Research*, 8(2) : 117-122.

Licy, J., Panikkar, A.O.N., Premakumari, D., Saraswathyamma, C.K., Nazeer, M.A. and Sethuraj, M.R. (1996). Genetic parameters and heterosis in rubber (*Hevea brasiliensis* Muell. Arg : 4. Early versus mature performance of hybridclones. *Placrosym XII*, 1996, Kottayam, India, p.3.

Mathew, J., Kothandaraman, R. and Joseph, K. (1996). Environmental impact of natural rubber processing wastes and the strategies of waste management. *Seminar on Latex Processing and Pollution Control*, 1996, Kottayam, India.

Mathew, J., Varghese, L., Kothandaraman, R., Mathew, N.M. and Joseph, K. (1996). Studies on recycling of effluent in pale latex crepe factory. *Placrosym XII*, 1996, Kottayam, India, p.70.

Mondal, G.C., Jose, V.T., Jayarathnam, K. and Sinha, R.R. (1995). Occurrence of *Hypomeces squamosus* (Coleoptera, Curculionidae) on *Hevea* rubber : A new record from India. *Indian Journal of Natural Rubber Research*, 8(2) : 91-93.

Nair, A.N.S., Cyriac, J., Philip, A., Karthikakuttyamma, M. and Punnoose, K.I. (1996). Effect of water soluble and water insoluble forms of phosphatic fertilizers on the growth of *Hevea brasiliensis* during the immature period. *Placrosym XII*, 1996, Kottayam, India, p.50.

Philip, A., Joseph, M., Punnoose, K.I. and Antony, A.P. (1995). Effects of liming on nutrient uptake, biomass production and nodulation in *Pueraria phaseoloides*. *Indian Journal of Natural Rubber Research*, 8(2) : 130-134.

Philip, V., Jessy, M.D. and Punnoose, K.I. (1996). Land resource management for rubber in Kerala. *Seminar on Land Resource Management for Sustainability*, 1996, Kottayam, India.

Philip, V., Prathapan, K., Jessy, M.D. and Punnoose, K.I (1996). Preliminary evaluation of weed control methods in planting strips of rubber. *Placrosym XII*, 1996, Kottayam, India, p.34.

Priyadarshan, P.M., Vinod, K.K., Rajeswari, M.J., Pothen, J., Sudhasoumyalatha, M.K., Sasikumar, S., Raj, S. and Sethuraj, M.R. (1996). Breeding *Hevea brasiliensis* Muell. Arg. in Tripura: 1. Performance of few stress tolerant clones in early phase. *Placrosym XII*, 1996, Kottayam, India, p.13.

Punnoose, K.I. (1997). Reducing immaturity period in rubber. *Seminar on Reduction in Immaturity Period of New Clones of Hevea*, 1997, Kottayam, India.

Rajalakshmy, V.K. and Kothandaraman, R. (1996). Current status of *Corynespora* leaf fall in India. *IRRDB Conference on Corynespora Leaf Fall*, 1996, Medan, Indonesia.

Sathik, M.B.M., Vijayakumar, K.R., Jacob, J. and Sethuraj, M.R. (1996). Membrane stability as measured by electrolyte leakage : A tool for screening *Hevea* clones for cold tolerance. *Placrosym XII*, 1996, Kottayam, India, p.27.

Saraswathyamma, C.K. (1997). Cytological and palynological studies in rubber (*Hevea brasiliensis*). *National Seminar on Fundamental and Applied Aspects of Cell Research*, 1997, Department of Botany, Thiruvananthapuram, India.

Sethuraj, M.R. (1996). Biotechnology in plantation crops research. *Placrosym XII*, 1996, Kottayam, India.

Shyamala, V.K., Bindumol, G.P., George, E.S., Suresh, P.R., Antony, A.P. and Punnoose, K.I. (1996). Comparison of dissolution pattern of rock phosphates. *Placrosym XII*, 1996, Kottayam, India, p.51.

Soman, T.A., Nazeer, M.A., Varghese, Y.A., Licy, J. and Sethuraj, M.R. (1995). Wintering pattern and floral biology of *Hevea* clones. *Indian Journal of Natural Rubber Research*, 8(2) : 94-99.

Thomas, K.T., Varghese, L., Joseph, T., Madhusoodanan, K.N. and Mathew, N.M. (1995). A comparative evaluation of ISNR 20 with conventional forms of natural rubber. *Indian Journal of Natural Rubber Research*, 8(2) : 123-129.

Thomas, M., Sreelatha, S., Simon, S.P., Nair, N.U., Jacob, J. and Sethuraj, M.R. (1996). Availability of photosynthesis and occurrence of tapping panel dryness syndrome in *Hevea brasiliensis*. *Placrosym XII*, 1996, Kottayam, India, p.28.

Varghese, Y.A., Knaak, C., Ecke, W., Saraswathyamma, C.K. and Sethuraj, M.R. (1996). Application of molecular markers with special reference to RAPDs for genetic analysis in *Hevea*. *Placrosym XII*, 1996, Kottayam, India, p.8.

Veeralakshmanan, B., Nair, N.R., Mathew. N.M. and Sasimohan, A.L. (1995). Chlorination of liquid natural rubber. *Indian Journal of Natural Rubber Research*, 8(2) : 85-90.

Veeraputhran, S., Viswanathan. P.K. and Joseph, T. (1996). A comparative analysis of the trends in the adoption of planting materials in the rubber smallholdings sector in India. *Placrosym XII*, 1996, Kottayam, India, p.71.

POPULAR ARTICLES

Chandrashekar, T.R. (1995). Rubber in Uganda. *IRRDB Information Quarterly*, Part 2: 11-12.

George, K.T. (1996). Rubber : An agenda for cooperation. *The Hindu*, December 11, Madras.

Jacob, C.K., Thomas, K.K. and Mathew, N.M. (1996). Natural Rubber : An ecofriendly material. *Planters Chronicle*, 12 : 585-589.

Joseph, T. and George, K.T. (1996). Primary processing of rubber wood in Kerala : Report of a sample survey. *Wood News* (Jan-March).

Mercykutty, V.C. (1996). Planting materials and field establishment. *Rubber*, 361 : 9-12 (Malayalam).

Saraswathyamma, C.K. (1997). Good quality of planting materials. *Rubber*, 374 : 15-17 (Malayalam).

Singh, R.P. (1997). Rubber Board, Regional Research Station, Kolasib, Mizoram at a glance. *Rubber Samachar*, 29 L 7-9.

Thomas, V. and Mercykutty, V.C. (1996). Rubber Seed collection and germination. *Rubber*, 365 : 3-4 (Malayalam).

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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 disease and pests of rubber and associated cover crops and their control. The Plant Physiology and Exploitation Division conducts studies on identification of characteristics related to yield, physiology of latex flow and yield stimulation. The Rubber Chemistry, Physics and Technology Division concentrates on improvement in primary processing of rubber, its chemical modification, rubber product manufacture and quality control of processed rubber. The Agricultural Economics Division undertakes studies on economic aspects related to rubber plantations.

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

Central Experiment Station

The 255 ha Central Experiment Station at Chethackal (Ranni), 50 km away from Kottayam, was started in 1966. Field trials laid out by the research divisions cover almost the entire area.

Regional Research Stations

The RRII has established a Regional Research Station Complex for North East India with headquarters at Guwahati, having regional research stations at Agartala in Tripura, Guwahati in Assam, Tura and Darechikgre in Meghalaya and Kolasib in Mizoram. The RRII has also set up regional research establishments at Dapchari (Maharashtra), Dhenkanal (Orissa), Nagrakatta (West Bengal), Sukma (Madhya Pradesh), Paraliar (Tamil Nadu), Nettana (Karnataka) and Padiyoor (Kerala).

Regional soil testing laboratories have been established at Mangalore, Thaliparamba, Calicut, Trichur, Muvattupuzha, Palai, Kanjirapally, Adoor and Nagercoil. Mobile units for soil and leaf analyses are available at the Calicut, 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 (Trichur), Kerala University (Trivandrum), Mahatma Gandhi University (Kottayam), Cochin University of Science and Technology (Cochin), Indian Institute of Technology (Kharagpur), National Chemical Laboratory (Pune) and Indian Institute of Sciences (Bangalore).

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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