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Rubber Research Institute of India

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Antagonism of an actinomycete to *Corticium salmonicolor*, the pathogen of pink disease.
In the background is a disease infected rubber tree.

Photograph

Mr. K. P. Sreerenganathan

July 1995

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, processing aspects and product applications. The steady growth of the RRII in its scientific worth and research contributions has won it the recognition as one of the international centres of excellence on NR research.

Location

The RRII is located on a hillock 8 km east of Kottayam 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.

Continued on inside back cover

ANNUAL REPORT
1993-94

RUBBER RESEARCH INSTITUTE OF INDIA
KOTTAYAM-686009, KERALA, INDIA

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THE RUBBER BOARD

The Indian Rubber Board was constituted under the Rubber (Production and Marketing) Act, 1947 which came into force on 19th 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

India is poised to sign the General Agreement on Tariff and Trade. In the context of the consequent globalisation of trade, import/export policies are likely to deviate in tune with the general concept of liberalisation, in the immediate future. The Indian rubber plantation industry should therefore gear up to face new challenges by becoming more competitive with regard to both price and quality, in the international as well as the domestic markets. Efforts should be made to reduce the cost of production to the minimum and to further improve the quality of rubber. Intensive research alone would help to achieve these formidable objectives. Evolving of high yielding varieties, optimum plant protection, appropriate fertilization, superior exploitation techniques and holistic management of the plantations only can bring down the cost of production. For quantum improvement in the quality of raw rubber the plantations should adhere to the correct method of processing technology which has already been developed and is available. Concerted research efforts are required in energy management and reduction of time lag in processing rubber. Technological improvements of rubber goods, including blending synthetic rubber with NR, could definitely improve the service life of rubber products and thus reduce the use of raw materials. The research priorities are to be reoriented keeping in mind the impending international competition and the Rubber Research Institute of India has already initiated steps towards this direction.

The Agronomy and Soils Division continued investigations on optimisation of nutritional and water management, intercropping and weed management. No significant clonal difference in nutritional requirement was evident in immature phase. In mature phase, the effect of nitrogen was significant on yield. These indicate scope for further rationalisation of fertilizer management. Significant reduction in immaturity period and enhancement of yield were evident when irrigation was given in non-traditional areas like Maharashtra while no such effect was noticed in the traditional rubber growing regions. Silt pits with or without sawdust improved soil moisture status. The fertilizer recommendations derived through DRIS approach is being compared with the present recommendations. Field experiments with bio-fertilizers are in progress.

Genetic improvement through hybridisation and ortet selections are the main fields of research of the Botany Division. Emphasis is given for evaluation and selection of clones. The progenies obtained from hybridisation programme are being regularly established and evaluated. The juvenile yield of these progenies indicates that some of the clones under evaluation may yield higher than RRII 105, the most popular clone now in wide use. Clones developed through polyploidy and irradiation are being evaluated. Screening of clones for resistance to powdery mildew disease is in progress. Moderate to high values of heritability and genetic advance was evident with regard to various

components of yield. The Biotechnology Division could generate plants by somatic embryogenesis. Integumental tissue of mature pods were used for callus formation. Techniques for generation of plants by shoot tip culture were further refined. Seventy plants were planted in the field during the year for evaluation.

A total collection of 4,709 genotypes are being maintained by the Germplasm Division. Genetic divergence is being studied in the germplasm gardens.

The Mycology and Plant Pathology Division concentrated on futher optimising plant protection schedules. Evaluation of oil based mancozeb as an alternative fungicide for copper is being continued. The Bradyrhizobium culture mass multiplied and distributed for bacterisation of seeds of the cover crop Pueraria is gaining popularity. The phosphate solublising bacteria isolated and tested could reduce application of phosphatic fertilizers. Thai Sac Brood Virus disease caused devastation of Indian honey bee to the extent of near total destruction of colonies in certain locations. The introduction of Apis mellifera colonies is being pursued vigourously.

The Physiology and Exploitation Division carried out studies on different aspects of crop physiology, exploitation techniques and latex biochemistry. A non-destructive method to assess plant moisture was perfected. Multidisciplinary studies on Tapping Panel Dryness (TPD) as a part of an International net-work research programme is in progress. Studies indicate the cytokinin level as a contributing factor controlling TPD.

The Rubber Chemistry, Physics and Technology Division was engaged in attempts to improve primary processing and technological properties of rubber. A solar cum fire wood sheet drying smoke house is being developed and is in final stage of evaluation. Epoxidised natural rubber prepared by this Division is under industrial evaluation. The technological properties of different types of blends of natural and synthetic rubber with or without fibers are being developed for specific purposes.

The Agricultural Economics Division carried out detailed studies on economics of cultural operations in rubber plantations and ancillary products from rubber plantations. Evaluation of planting materials under commercial planting is one of the important studies of this Division.

The Regional Research Stations continued location specific studies for Assam, Tripura, Mizoram, Maharashtra, Orissa, West Bengal and Madhya Pradesh. Clones are being evaluated to select suitable ones for these non-traditional areas. Polyclonal seedlings seem to be more tolerant to the climatic constraints in some of these areas compared to budded plants. Appropriate agromanagement techniques suitable for the non-traditional areas having adverse climatic factors are being developed.

Technical scrutiny of manuscripts and processing and editing of the papers for Volume 6, of the Indian Journal of Natural Rubber Research was completed during the period under review. This volume will contain thirtytwo scientific contributions of which sixteen are related to rubber chemistry and technology. Contributions from U.K., Sri Lanka, Indonesia, Nigeria and Vietnam find place in this Volume. The Institute continued to maintain its academic linkages with several Universities and Research Institutions of research and learning.

The Department of Training organised a total of 20 training courses. The trainees included planters, product manufacturers and supervisory staff of estates. Pre-entry and inservice courses were organised for scientists and technical officers of the Rubber Board. Scientists of the RRII and senior officers of the other Departments of the Board served as faculty members. Regular visits of groups of farmers to the Research Institute were organised with a view to hasten the transfer of nacent technologies.

AGRONOMY AND SOILS DIVISION

The Agronomy and Soils Division continued investigations on the nutritional requirements, irrigation and water requirements, soil and water conservation, intercropping, density of planting and weed management of rubber at various stages of growth in different agroclimatic situations. Investigations on forms and methods of fertilizer application and physico-chemical properties of rubber growing soils were also done. With a view to improving the interpretation of foliar analytical values, work on Diagnosis and Recommendation Integrated System (DRIS) was being continued. Discriminatory fertilizer recommendations were offered to rubber growers through eight regional laboratories and the Central Laboratory at the RRII. Four Mobile Soil and Tissue Testing Laboratories attached to the various centres were in operation for the benefit of small farmers.

1. Nutritional studies (immature phase)

1.1 The experiment to assess the fertilizer requirements of the clone RRII 105 was in progress. Out of the three locations, the trial at Perinthalmanna was discontinued due to the lockout in that estate. In the other two locations, treatments were imposed and growth observations recorded. No significant difference among the different fertilizer treatments was noticed for girth of the trees during this period.

1.2 The two experiments at Koney Estate and the RRII farm were being continued. The fertilizer treatments were incorporated and growth observations recorded. The data on girth (1994) and girth increment (1990-94) for the experiment at Koney Estate were statistically analysed and are presented in Tables Ag. 1 and 2. Significant clonal differences were noticed for both girth and girth increment (Table - Ag. 1). Clones RRIC 100 and RRII 203 were found to be more vigorous in growth than all the other clones. In the case of the average effect of the manurial treatments, the highest level of fertilizer application *viz.* 75 : 75 : 30 kg NPK per ha gave the highe,st girth and girth increment (Table - Ag. 2), only the girth increment being statistically significant. However, there was no significant clonal differences in the nutrient requirements.

In the case of the experiment at the RRII farm also no significant clonal differ-

Table - Ag. 1. **Clonal differences in girth (1994) and girth increment (1990-94) in cm**

Clone	Girth	Girth increment
RRII 5	44.63	34.08
RRII 105	43.40	32.82
RRII 203	50.56	37.29
RRII 208	44.14	33.07
RRII 300	41.39	31.19
RRII 308	38.95	28.59
PCK 1	38.60	29.25
PCK 2	43.54	32.77
PB 311	45.64	35.91
RRIC 100	52.23	40.11
SE1.38	1.08	
CD (P=0.05)4.42	3.46	

ences in girth (1994) were noticed for manurial requirement.

2. Nutritional studies (mature phase)

2.1 Clonal/regional requirements

Out of the seven experiments, six were concluded and the results consolidated. One experiment with clone RRII 105 located at Vaniyampara Estate was being continued. Monthly yield recording and annual girth recording were undertaken. The data on mean yield obtained during 1993 from the experiment at Vaniyampara Estate were statistically analysed and presented in Table - Ag. 3. The effect of N alone was significant.

Table - Ag. 2. **Effect of fertilizer on girth (1994) and girth increment (1990-94) in cm**

$N:P_2O_5:K_2O$ /kg	Girth (1994)	Girth increment (1990 - 94)
75:75:30	45.43	34.99
50:50:20	44.38	33.40
25:25:10	43.41	32.34
Control	44.02	33.33
SE	2.90	0.54
CD (P=0.05)	NS	1.56

Application of N at both 20 and 40 kg levels significantly increased the yield and the highest yield was given by the 20 kg level. The effects of P and K were not significant during the period. Appliciation of N, P and K did not show any significant effect on girth of the trees during 1993 and girth increment during 1987 - 93 period.

2.2 Micronutrient experiment

The field experiment laid out at Cheruvally Estate (Erumely) on clone RRIM 600 to study the effect of 'Boracol BSF - A', a micronutrient mixture containing Fe, Zn,

Table - Ag. 3. **Effect of nutrients on yield (g/tree/tap)**

Levels of nutrients (kg/ha)	K_2O									Mean
	0			30			60			
	P_2O_5			P_2O_5			P_2O_5			
	0	20	40	0	20	40	0	20	40	
0 N	54.05	44.35	57.50	87.15	49.35	52.65	37.15	49.05	76.30	56.39
20 N	76.05	65.00	66.30	51.45	85.75	75.25	67.70	77.40	79.65	71.62
40 N	62.55	64.90	70.65	75.55	72.15	79.60	62.85	56.70	81.90	69.89
Mean	64.22	58.08	64.82	71.38	69.08	69.17	55.90	61.05	79.28	65.89
For N, P and K means				SE 3.59		For N means		CD (P=0.05)	10.528	

Out of the seven experiments, six were concluded and the results consolidated. One experiment with clone RRII 105 located at Vaniyampara Estate was being continued. Monthly yield recording and annual girth recording were undertaken. The data on mean yield obtained during 1993 from the experiment at Vaniyampara

Cu, Mo and B, was being continued. The data on yield from April 1993 to March 1994 were analysed statistically and are presented in Table - Ag. 4. It is seen that the effect of Boracol was not significant.

Table - Ag. 4. **Effect of 'Boracol BSF - A' on yield of rubber**

Treatments (g/tree)	Mean yield (g/tree/tap)
Boracol 50	56.76
Boracol 100	51.90
Boracol 150	60.91
Boracol 200	61.44
No Boracol	62.89
SE	2.91

3. Density of planting, growth and yield

The experiment at Shaliacary Estate (Punalur) was in progress. Yield recording was commenced in the area. The yield data for 1993 has been statistically analysed and are presented in Table - Ag. 5.

Table - Ag. 5. **Effect of density of planting on yield**

Density (trees/ ha)	Spacing (m)	Yield (g /tree/tap)	Yield (kg /ha/tap)
445	6.7 × 3.4	38.02	16.916
489	6.7 × 3.0	37.62	18.395
539	6.1 × 3.0	36.70	19.782
598	5.5 × 3.0	36.82	22.055
SE		0.895	1.541
CD (P=0.05)		—	4.928

The data on yield expressed as g per tree per tap did not show significant difference among the different densities. However, the yield per tree showed a declining trend with increasing density. But the yield per ha per tap gave significant differences among the treatments with the highest density (598 trees per ha) yielding significantly higher. The yield for the other densities was on par.

4. Irrigation and moisture management

4.1 Response to irrigation

The experiment to study the effect of different levels of drip and basin irrigation laid out at Manjoor Estate (Kottayam) was being continued. The data on yield recorded during six months in 1993-94 were statistically analysed and presented in Table - Ag.6. It is seen that irrigation in any form has not significantly improved the yield of rubber.

Table - Ag. 6. **Effect of irrigation on yield**

Treatment	Yield (tree/tap)
Drip at 27 l per day	31.16
Drip at 46 l per day	30.71
Basin at 190 l per week	33.14
Basin at 320 l per week	28.46
No irrigation	28.14
SE	1.39

4.2 Water requirements of immature rubber (Lysimeter technique)

The plant in the Lysimeter was in the third year of growth. Continuous monitoring of water balance was being done. The mean evapotranspiration for the first half of 1993 was 4.09 mm per day

4.3 Soil and water conservation

This experiment started in 1988 was being continued. No run off was collected in any of the plots. Under the different conservation regimes like providing contours in combinations with cover crops and or silt pits/trenches, there was no appreciable difference in the growth of rubber or in the soil moisture status recorded during this period. All the regimes thus appear to be effective in soil and water conservation

4.4 Effect of silt pits

A field trial was started during 1993 in the estate of State Farming Corporation of Kerala (Punalur) to study the effect of providing different intensities of silt pits on soil and moisture conservation with seven treatments (Table - Ag. 7.) and three replications. The size of a plot is a tapping block. The silt pits were taken and saw dust as per treatment was applied in August 1993. The data on soil moisture at two depths recorded during January 1994 are presented in Table - Ag. 7. It is seen that silt pits with or without saw dust have significantly improved the soil moisture status of the top 0-15 cm layer of soil. However, the effect was not significant at the lower depth of soil. Two hundred pits per block with five kg saw dust in each pit recorded maximum soil moisture which was significantly better than hundred pits per block with five kg saw dust.

Table -Ag. 7. **Mean soil moisture (per cent)**

Treatments	0-15 cm depth	15-30 cm depth
100 pits block^{-1}	13.45	13.97
150 pits block^{-1}	13.05	14.08
100 Pits block^{-1} + 5 kg saw dust pit^{-1}	12.92	13.59
150 pits block^{-1} 5 kg saw dust pit^{-1}	14.54	14.11
200 pits block^{-1} + 5 kg saw dust pit^{-1}	14.77	14.71
No pit	11.05	12.15
SE	0.563	0.934
CD (P=0.05)	1.735	NS

5. Weed management systems

5.1 Chemical and cultural control of weeds

An experiment was initiated during 1993 at the Central Nursery, Karikattoor to study the effect of the pre-emergence herbicide Diuron ('Klass' 80 WP) on the control of weeds in rubber seedling nursery. Three doses of the chemical at 1.25, 2.50 and 3.00 kg per ha were applied once as basal application or basal application followed by a second application after eight weeks. An evaluation of the weed regeneration indicated 85 per cent reduction in weed growth with 2.50 kg per ha basal application and 92 per cent with 3.00 kg per ha basal application. The duration of weed control for the basal application lasted for 45 - 60 days. It was also noticed that a second round of herbicide application at 3.00 kg per ha was effective for continued weed control. Rubber seedlings did not show any phytotoxic effect due to herbicide application at any stage.

5.2 Biocontrol of weeds

The released larvae of *Pareuchaetus pseudoinsulata* used for control of the weed *Chromolaena odorata* in rubber plantations failed to establish properly. Problems were also encountered in the hatching of eggs laid by the adults reared in laboratory cages

6. Intercropping in rubber

6.1 Immature rubber (CES, Chethackal)

The growth of rubber continued to be poor in the intercropped plots. Coffee (*Coffea arabica* var. *cauveri* and *Coffea canephora* - *robusta*) and black pepper were growing well and giving satisfactory yield.

6.2 Mature rubber (CES, Chethackal)

The two coffee varieties (*Coffea arabica* var. *cauveri* and *Coffea canophora* - *robusta*) planted in the interrows of rubber trees standing at 6.7 × 3.4 m spacing continued to give satisfactory yield. The data on girth of rubber in 1994, girth increment during 1987 - 94 and the yield of rubber obtained were statistically analysed and are presented in Table - Ag. 8.

The growing of intercrops has not significantly affected either the growth or yield of rubber.

Table - Ag. 8. **Effect of intercrops on growth and yield of rubber**

Treatment	Girth 1994 (cm)	Girth increment (cm)	yield 1994 (g/tree/tap)
Rubber+single row robusta coffee	63.68	17.98	30.99
Rubber + single row cauveri coffee	67.89	19.64	36.85
Rubber + double row cauveri coffee	67.14	20.58	41.06
Rubber + double row cauveri coffee	67.14	20.58	41.06
Rubber alone	65.70	19.41	32.55
SE	2.22	1.68	3.81

7. Forms and methods of fertilizer application

7.1 Effect of methods of application of nitrogenous fertilizers

The experiment to compare different methods of application of nitrogenous fertilizers was concluded.

7.2 Use of controlled release fertilizers

A field experiment on immature rubber was initiated during 1993 at CES, Chethckal on clone RRII 105 to find out the effect of commercially available controlled release fertilizers compared with those of conventional fertilizers on the growth and leaf nutrient content of rubber. An evaluation of the soil nutrient status of the different treatments was also made. The different treatments tried were

T1 - 10:10:4:1.5 kg ha^{-1} of N, P_2O_5, K_2O and MgO as urea, MRP, MOP and $MgSO_4$ at the standard recommended rate in two splits.

T_2 - 10 : 10 : 4 : 1.5 standard recommended dose as NPK Mg pellets supplied by FACT, in two splits.

T_3 - 75% of T_2 in two splits.

T_4 - 10 : 10 : 4 : 1.5 dose as nimin coated urea, uncoated MRP, MOP and $MgSO_4$ at the standard recommended rate in two splits.

T_5 - 75% of T_4 with respect to nitrogen alone in two splits.

T_6 - 75% of N alone as neem cake mixed urea and MRP, MOP and $MgSO_4$ at the standard recommended rate in two splits.

T_7 - No fertilizer control.

The treatments were imposed during October, 1993.

A leachate analysis study was also started to compare the nutrient loss from different fertilizers through leaching. Recording of observations on growth and analysis of soil and leaf is being undertaken.

7.3 Effect of water soluble and insoluble forms of phosphatic fertilizers on the growth

The experiment was started in 1989 at Kinalur and Vaniampara Estates to evaluate the efficiency of Mussoorie rock phosphate, super phosphate and ammophos on growth of rubber.

Data on girth increment for the period 1989 - 94 are presented in Table - Ag. 9

No significant difference in girth increment was observed between different sources in both the locations.

7.4 Source of phosphorus for rubber and associated cover crops

The field study initiated in 1988 to evaluate the effectiveness of bowl sludge, a waste product from latex centrifuging, is

Table - Ag. 9. Girth increment (cm) 1989-94 period

Treatments	Kinalur Estate	Vaniampara Estate
40 P_2O_5 (MRP) + 40 kg N (As) + 20 kg K_2O ha^{-1}	37.92	31.12
40 kg P_2O_5 (MRP) + 40 kg N (urea)+ 20 kg K_2O ha^{-1}	36.35	30.52
40 kg P_2O_5 + 40 kg N (AP 20:20)+ 20 kg K_2O ha^{-1}	36.08	31.55
40 kg P_2O_5 (SSP) + 40 kg N (AS) + 20 kg K_2O ha^{-1}	34.92	30.78
40 kg P_2O_5 (SSP) + 40 kg N (urea) = 20 kg K_2O ha^{-1}	39.97	30.12
SE	3.20	1.81

being continued. Data on girth increment data for the period 1988-93 are furnished in Table - Ag. 10.

Table - Ag. 10. Effect of different sources of phosphorus on girth increment

Treatment	Girth increment (cm)
Super phosphate	35.59
Mussoorie rock phosphate	35.94
Bowl sludge	36.92
Control (No phosphorus)	32.53
SE	0.92
CD (P=0.05)	2.77

The results indicate that bowl sludge as a phosphate source is on par with super phosphate and Mussoorie rock phosphate in increasing the girth of rubber plants. The data also show the response to phosphorus application in terms of girth increment.

7.5 Comparative study of different soures of rock phosphate on seedling vigour

A field trial was initiated at Central Nursery (Karikattoor) to compare the effect of different sources of rock phosphates. The data on girth recorded during March, 1994 are presented in Table - Ag. 11.

Table- Ag. 11. Mean girth of seedlings

Treatments	Girth (cm)
No phosphorus control	2.63
Musoorie rock phosphate (20 per cent P_2O_5)	2.69
Rajaphos (22 per cent P_2O_5)	2.75
Meghaphos (20 per cent P_2O_5)	2.85
Meghaphos (24 per cent P_2O_5)	2.64
Ghafsaphos (30 per cent P_2O_5)	2.73
SE	0.09

However, there was no response to application of P in this nursery probably due to the high content of available P (11.3 mg per 100 g soil) in the top 0-15 cm soil layer.

7.6 Dynamics of K in rubber growing soils and other related studies

The experiment started in 1990 to study the effect of graded levels of pottassium viz. 0, 15, 30, 45, 60, 75 and 90 kg K_2O per ha on the yield of rubber is being continued. After three years of treatment imposition it was observed that the yield is the highest with 60 kg K_2O ha^{-1} followed by 30 kg K_2O ha^{-1}. The pattern of response to the application of K was the same for three years but the difference among the treatments narrowed down during the third year. Soil and leaf samples were collected and analysed for the nutrient status. Positive significant correlations were recorded between the rate of K supply and leaf K concentration (r=0.81) and available K status (4n=0.729) during 1993. The available K status in the surface soil (0-30 cm) increased to medium level due to the application of 45 kg and higher rates of K_2O ha^{-1} during the third year of application.

7.7 Effect of liming on nutrient uptake, biomass prduction and nodulation in *Pueraria phaseoloides*

A pot culture study was initiated during 1993 to study the effect of liming and

the consequent changes in soil pH, on the availability of nutrients and on the nodulation and biomass production of the cover crop *Pueraria phaseoloides*. Lime requirement of the soil was found to be 1275 kg per ha. The treatments of five levels of lime *viz.*, 0, 25, 50, 75 and 100 per cent requirement were incorporated. Seeds of Pueraria were inoculated with rhizobium culture and the plants established in pots and harvested after 3 months. Biomass production, nodule number and nodule weight were recorded. Analysis of soil, shoot and root samples for major nutrients were carried out. Liming was found to have a significant positive effect on availability of phosphorus, potassium and magnesium. Similarly, the highest shoot and root weight was recorded in the treatment where 100 per cent lime requirement was given.

8. Physico-chemical properties of rubber growing soils

8.1 Effect of continuous cultivation on soil properties

The study was initiated to investigate the effect of continuous cultivation of rubber on soil properties. The sequential changes in organic carbon content in different cycles of rubber plantation were assessed. For this, soil samples were collected at 3 depths 0-5, 5-10 and 10-15 cm, 3 different sites, Nilambur, Punalur and Cheruvally from rubber and adjacent natural forest with similar physiographic features. Rubber estates were of first and second replanting cycle. Organic carbon content of the soils was estimated and the statistically analysed data is furnished in Table - Ag.12.

Table - Ag. 12. **Depthwise distribution of soil organic carbon in forest and rubber soils**

Depth (cm)	Forest	Rubber 1st cycle	Rubber 2nd cycle	Mean
0-5	2.61	2.14	1.76	2.17
5-10	2.48	1.93	1.36	1.92
10-15	2.03	1.71	1.17	1.64
Mean	2.37	1.93	1.43	
CD for comparison of situations =				0.17
CD for comparison of depths =				0.17
CD for comparison of situations within each depth =				0.30

The results indicate that there is a significant reduction in the organic carbon status of soil between each cycles and also with respect to forest soils. Soils under the first and the second cycles of rubber contain only 81 and 60 per cent of the organic carbon content of the forest soil, ie. there is a decrease of nearly 20 per cent in each cycle. In each depth also the differences among the forest and the two cycles of rubber was significant. The relative decrease in organic carbon content with respect to forest was more in 5-10 cm layer compared to the other two layers.

It was noticed that compared to forest, exchangeable clacium, magnesium and potassium were found to be significantly lower in continuously rubber cultivated area.

8.2 Study on the subsoil acidity and aluminium toxicity in rubber growing soils and its amelioration using phosphogypsum

The project was initiated with the objective of studying the subsoil acidity in relation to aluminium toxicity in rubber growing tracts and its amelioration using phosphogypsum. The work was initiated in 1992-93 and the preliminary survey conductd during that period in the major agroclimatic zones revealed that the subsoil layers contain appreciably high concentration of exchangeable aluminium. On the basis of this observations, profile samples were collected from two regions and filled into PVC columns at thickness equivalent to the horizon thickness of the soil profile. The soil was

compacted to get the bulk density equivalent to field levels and quilibrated, after wetting the soil to field capacity.

The suitability of phosphogypsum, a waste material of phosphoric acid industry as an ameliorant was assessed and the material was found good.

In order to characterise the toxicity of aluminium on young rubber seedlings observations were made on young rubber seedlings grown on Hoagland solution containing varying levels of Al. At concentations above 50 ppm growth of the plants were severely retarded.

9. DRIS approach for interpretation of foliar analytical data and diagnosis of nutrient balances

Simple agronomic evaluation trials to compare the fertilizer recommendations derived through diagnosis and recommendation integrated system approach with the present recommendation derived through the sufficiency range approach and the blanket recommendation is being continued. Verification of the DRIS norms through the factorial field experiment attempted with the data already available is in progress.

10. Collaboration studies

The Division collaborates with the Institute's project on tapping panel dryness, multidisciplinary evaluation of modern clones and yield constraint analysis of *Hevea* in different agroclimatic zones of the traditional area.

12. Advisory work

Analysis of 8800 soil and 2080 leaf samples were conducted in regional laboratories for offering discriminatory fertilizer recommendation. In the Central Laboratory at RRII, 700 leaf and 1100 soil samples were analysed and fertilizer recommendations offered.

13. Sustainable agriculture

With a view to study the possibility of reducing the input of chemicals and to introduce a sustainable agriculture system in rubber plantations, a study on the use of biofertilizers was initiated. Field experiments were laid out in both immature and mature rubber and treatments were incorporated during post monsoon season in 1993. The growth and yield of rubber are being assessed periodically.

Two experiments were started at CES., Chethackal and at Chithalvetty estate of State Farming Corporation, Punalur, including various intercrops in rubber plantation with the object of attaining economic sustainability. Rubber was planted in twin rows at 5.75 m feet apart, the twin rows being separated by a distance of 10 m feet, where the intercrops are accomodated. Intercrops such as cocoa, pepper, pineapple and banana were planted in the wider interrows and cover crop in the narrow interrows.

BIOTECHNOLOGY DIVISION

1. Somatic embryogenesis

Integumental tissue of the immature fruits of *Hevea* were used for the induction of callus from which globular embryoids were obtained . The embryoids developed into plants. However, extensive procedural refinements are warranted to improve this pathway. This pathway can be utilized for (a) synthesising transgenic plants (b) after appropriate refinements, this may prove useful as an alternate propagation system.

2. Shoot tip culture

Shoot tips were utilized for generating plants. Over two hundred plants were obtained during this period by this pathway and about 70 bigger plants from this population were planted in the field and the remaining smaller plants were raised in polybags for planting during the next season.

3. Biochemical investigation on brown bast

Since brown bast is considered a serious problem facing this crop, two directional approaches have been initiated to elucidate this problem. Firstly, a genetic map of the brown bast tolerant and susceptible clones need to be prepared in order to ascertain whether any gene level differences exist between the tolerant and susceptible plants. Since cytokinin level in the stock is suspected to be a major contributing factor controlling the reaction of plants to brown bast, measures to estimate cytokinins have been initiated as a second approach. Since levels of cytokinin are too minute a quantity in plant systems, measurement of such small levels is complex and time consuming.

BOTANY DIVISION

The Botany Division continued research activities on genetic improvement through hybridization and ortet selection. Emphasis had also been given for evaluation and selection of clones. Investigations on propagation, anatomy and cytogenetics were also in progress.

1. Evolving high yielding clones for traditional area

1.1 Hybridization and clonal selection

Monthly recording of yield from the 1985 small scale trial of hybrid clones was continued. Total volume, DRC and plugging index were recorded periodically. Eight clones exhibited superior performance over RRII 105 for yield during the first year of tapping. Standard heterosis for yield ranged from 4-28 per cent (Table - Bot. 1) . A total of 149 clones incorporated in the 1989 small scale trials were subjected to test tapping after measurement of girth at the age of $3^{1}/_{2}$ years. Data revealed highly significant clonal differences for girth and juvenile yield. Among a set of 49 hybrid clones, 18 per cent recorded juvenile yield higher than that of the best parent clone, RRII 105. Girth and juvenile yield in one clonal nursery evaluation trial of 15 clones, recorded at the age of one year, revealed highly significant

Table - Bot. 1. **Mean yield and standard heterosis of eight clones during the 1st year of tapping**

Clones	Mean yield (g tree^{-1} tap^{-1})	Standard heterosis(%)
82/2	61.94	4.39
82/14	79.68	25.68
82/17	65.26	9.26
82/21	61.91	4.35
82/22	80.39	26.33
82/27	62.49	5.23
82/29	82.09	27.86
82/30	65.79	9.98
RRII 105	59.22	

clonal differences. A total of six clones recorded juvenile yield, comparable to or more than that of RRII 105. The hybrid seedlings (250 nos) in seven cross combinations resultant of 1993 hybridization programme were established in a seedling nursery. During the 1994 flowering season a total of 1070 hand pollinations incorporating six cross combinations were attempted. The final fruit set recorded was 4.3 per cent.

1.2 Ortet selection

Experiments on ortet selection were continued. At Cheruvally estate, ortet clones revealed highly significant clonal differences in girth, bark thickness, total volume, DRC and yield. From among the 21 clones studied, clone no. 35 recorded the highest mean girth (46.33 cm), total volume of latex (116.50 ml) and yield (41.80 g/10 tappings) in comparison to a general mean of 40.65 cm, 98.33 ml and 20.66 g respectively. Out of 47 ortet clones in 3 small scale trials at Koney estate, 31 clones showed relatively better girth when compared with RRII 105 and 17 clones exhibited better girth when compared with GT 1, at the age of 2.5 years. Significant clonal differences for girth and yield were noticed in two field experiments.

Out of 49 selections from 75 potential mother trees in a large estate, 16 clones were multiplied and a small scale trial was laid out in a suitable statistical lay out. The remaining ortets were multiplied and a polybag nursery was established for further studies. From Kaliyar and Malankara estates 165 and 44 promising mother trees respectively were identified and the trees were being subjected to further observations.

1.3 Special techniques in breeding

Monthly yield recording and annual girth measurements were continued in all the field experiments of polyploid population and the clones developed from seed irradiation. Incorporating five selections, a large scale trial was laid out at Central Experiment Station. Two selections from the 1977 trial continued to give more yield than RRII 105. Of the trial laid out in 1985, 28 clones gave higher initial yield than the general mean (30.30 g/tree /tap). Another trial planted with 7 selected clones resultant of irradiation, was maintained properly.

2. Evaluation of clones

2.1 Large scale trials

Two large scale trials, comprising nine and eight clones planted at CES during 1989, were subjected to test tapping. Data on total volume, DRC, yield, girth and bark thickness revealed highly significant clonal differences. Among the nine clones in trial I, PB 312 gave the highest mean yield of 12.10 g in comparison to 9.66 g per tree per tap for RRII 105. In trial II, RRII 105 recorded the highest mean yield among the eight clones.

In the two multidisciplinary evaluation trials of 13 clones at RRII farm, data on juvenile yield revealed highly significant clonal differences. RRII 308 recorded the highest mean value (18.55 g) followed by

PCK 2 (15.17 g), PCK 1 (15.11 g) and RRII 105 (14.75 g/tree/tap) in trial I. In trial II, PB 314 recorded the highest mean yield followed by RRII 105, PB 280, PB 312 and PB 255. Mean yield over two years (1992 & 1993) of selections from the 1956 hybrid clones showed that compared to the control PR 107, all the selections were performing well except RRII 205. (Table - Bot. 2). RRII 203 and RRII 208 recorded an yield of above 60 g per tree per tap.

Table - Bot. 2. **Yield of selections from the hybrid clones evolved in 1956**

Clones	Mean yield over two years (1992 and 1993) (g/tree/tap)
RRII 201	56.26
RRII 202	64.52
RRII 203	61.70
RRII 204	78.34
RRII 205	43.88
RRII 206	78.24
RRII 207	73.14
RRII 208	66.24
RRII 209	73.62
PR 107	49.61
SE	7.17
CD	21.30

The long term performance of clone RRII 105 and half sibs resultant of the 1954 hybridization programme was evaluated over 18 years of tapping. Of the eight clones studied, RRII 105 showed the highest yield (Table - Bot. 3). In the Sri Lanka clone trial laid out in 1976, RRIC 100 gave the highest yield of 64.47 g per tree per tap during 1992-93. In the mixed clone trial laid out in 1981, RRII 105 (54.27 g) out yielded all other clones followed by PB 310 (53.08 g), PCK 1 (52.45g) and RRII 45 (52.45 g /tree/tap). Around 1,100 polybag plants were raised for laying out large scale trials at Arasu Rubber Corporation, Keeriparai.

Table - Bot. 3. **Long term performance of hybrid clones**

Clone	Parentage	Rubber yield mean of 18 years (g/tree/tap)
RRII 101	Tjir 1 × AVROS 255	17.40
RRII 102	Tjir 1 × G1 1	23.48
RRII 105	Tjir 1 × G1 1	54.24
RRII 106	Tjir 1 × Mil 3/2	27.32
RRII 109	Tjir 1 × Mil 3/2	53.74
RRII 110	Tjir 1 × Hil 28	40.81
RRII 111	Tjir 1 × Hil 28	44.24
	Tjir 1(Control)	Primary clone 31.11
	General mean	37.36
	Variance ratio	3.42**
	** Significant at P = 0.01	

Three RRIM clones, RRIM 712, RRIM 722 and RRIM 728 were introduced from the Rubber Research Institute of Malaysia. These clones were multiplied. In reciprocation, four RRII clones (RRII 109, RRII 176, RRII 208 and RRII 308) were exported to Malaysia. Incorporating the newly introduced clones and nine other promising selections, a polybag nursery was raised at Central Experiment Station, Chethackal for field evaluation experiments proposed for 1994.

2.2 On - farm evaluation

In the block trial at Malankara Estate RRII 105 continued to record the higest mean yield among 11 clones. At Koothattukulam Estate (1973) also RRII 105 continued to be the highest yielder followed by RRII 203. In another block trial at Chithalvetty consisting of 12 clones, RRII 1 recorded the highest mean yield during the first year of tapping followed by PCK 1 and PCK 2, whereas the highest girth was recorded by PB 235 followed by PB 260. In the 1983 block trial at Myladi, RRII 105 and PB 235 recorded comparable yield during the third year of

tapping. In another block trial consisting of 8 clones at Manikkal, RRII 105 recorded the highest yield followed by PB 235 during the first year of tapping. Girth was the highest in PB 235 followed by RRII 300.

Around 8,500 polybag plants of different experimental clones were raised for laying out block trials at Arasu Rubber Corporation, Keeriparai and Shastamkotta.

3. Performance of clonal composites

3.1 Studies on the performance of multiclone blends in comparison to monoclone population of RRII 105

Four blocks of clonal composites were planted at RRS, Nagrakatta, West Bengal. Gap filling was carried out in the area planted during 1992. Around 3500 polybag plants were raised at Arasu Rubber Corporation, Kanyakumari District, Tamil Nadu, for laying out the field experiments on clonal composites. Five trials on varying proportions of multiclones were laid out at Chemoni Estate.

4. Polycross progeny evaluation

4.1 Evaluation of progenies of prepotent clones

Seedling progeny analysis of 20 clones in a previous study enabled the identification of 9 clones as prepotents. With a view to confirm the prepotency of the parent clones based on performance of their progenies at maturity, two field trials were laid out at Central Experiment Station. The experiments were laid out in a compact family block design with 3 replications and 5 trees per plot. A total of 160 clones comprising progenies and parents were included in the field trials.

An experiment was initiated for the comparison of polyclonal seeds collected at the beginning and at the end of seed fall with assorted seeds. Seed lots collected during the two periods were subjected to an assessment of the proportion of seeds from the different parent clones in the garden, based on seed characters. The two sets of polyclonal seedlings along with assorted seedlings were planted for nursery evaluation in a split plot design with five replications.

5. Breeding clones for combining compact canopy with good yield

Growth attributes and test tap yield were recorded from the different morphotypes of genetic variant planted at Central Experiment Station, Chethackal. Normal and intermediate types were more vigorous than the control (Table - Bot. 4). Normal types showed higher growth index compared to the control. From the open pollinated seedlings, plants having compact crown and high vigour were multiplied and

Table - Bot. 4. Mean values of different characters and growth index at the 8th year after planting

Morphotypes	Girth (cm)	Bark thickness (mm)	Petiole length (cm)	Leaf area (cm^2)	Growth index
Dwarf	26.17	5.11	8.46	141.21	6.01
Semidwarf	33.21	6.04	7.37	148.84	6.80
Intermediate	49.28	7.26	12.16	147.04	8.63
Normal	53.34	8.06	14.75	180.18	9.73
Control	48.35	7.35	12.62	182.42	8.78
GM	42.07	6.77	11.07	159.94	7.99
SE	4.57	0.47	1.29	15.56	-
CD	13.50	1.41	3.87	-	-

raised in polybags for further evaluation. Twenty two hybrid seedlings resultant of hand pollination were maintained in the nursery. For studying the root system and root shoot ratio of different morphotypes the seedlings were raised in polybags.

6. Breeding for drought tolerance

Periodical observations on girth recorded from 35 clones were analysed for identifying those with high summer girth increment index indicative of drought tolerance. The clones, in general, recorded 34.68 per cent of the annual growth, in terms of girth increment, during the summer period, with clones IAN 713 and RRIM 704 showing more than 50 per cent of the annual girth increment during summer.

As part of the breeding programme, crosses were attempted among parent clones possessing desired physiological attributes related to drought tolerance. Fifty seedlings from families resultant of hybridization carried out in 1993 were being maintained in the nursery. The hybridization programme was repeated in 1994 wherein a total of 2800 hand pollinations were attempted.

7. Breeding for powdery mildew resistance

With a view to screening clones for mildew resistance, a field experiment incorporating 20 clones along with PB 5/51, a susceptible clone, was laid out employing a randomized block design with three replications. Spreader rows of PB 5/51 were also planted so as to ensure sufficient inoculum while screening the clones in the field.

8. Evaluation of popular clones

The data on yield and secondary characters of 8 popular clones *viz.*, RRII 105, PB 217, PB 235, PB 260, PB 311, PB 28/59, RRIM 600 and GT 1 from 10 estates were collected for commercial evaluation of the clones.

9. Estimation of genetic parameters

9.1 Genetic studies

9.1.1 Variability, correlation and heterosis for yield and yield components

An evaluation of 14 hybrid clones resultant of a cross GT 1 × RRIC 100 at an early phase of 4.5 years revealed significant clonal variation for yield and yield attributes *viz.*, rate of latex flow, dry rubber content, girth at opening, number of latex vessel rows and bark thickness. Rate of latex flow exhibited the highest value of coefficient of variation (53%) followed by number of latex vessel rows and yield (43 and 38% respectively). Yield, rate of latex flow and number of latex vessel rows exhibited moderate to high values of heritability and genetic advance (Table - Bot.5). Out of the 14 hybrid

Table - Bot. 5. **Genetic parameters for yield and yield attributes in 14 hybrid clones of the cross GT 1 × RRIC 100 at 4½ years**

Characters	Range	Mean	Variance ratio (clones)	Coefficient of variation (%)	Heritability H^2(%)	Genetic advance % over mean
Yield (g tree^{-1} tap^{-1})	5.87 - 14.55	10.18	3.49**	38.47	45.39	26.42
Girth (cm)	27.96 - 37.67	32.53	3.08**	14.01	40.98	8.76
DRC	31.45 - 45.90	38.83	2.55*	15.47	32.67	8.09
Rate of flow	8.03 - 22.75	12.79	5.65**	52.66	60.77	44.25
No. of latex vessel rows	3.84 - 10.89	7.25	9.91**	43.20	74.81	42.07
Bark thickness (mm)	3.04 - 5.05	4.06	2.27**	22.36	29.68	10.83

* Significant at 5% level ** Significant at 1% level

clones, 10 exhibited standard heterosis for yield ranging from 4 to 48%. A performance index based on yield, rate of latex flow and number of latex vessel rows was revealed to be a dependable criteria for early detection of potential hybrid clones (Table - Bot. 6).

Table - Bot.6. **Mean yield and performance index of 14 hybrid clones of a cross of GT 1×RRIC 100 at 4½ years**

Clones	yield (g/tree/tap)	Performance index
82/40	10.44	11.67
82/44	7.65	8.14
82/45	11.75	13.01
82/46	11.58	11.91
82/47	9.57	11.06
82/48	5.87	8.13
82/49	13.28	14.59
82/50	10.34	14.36
82/51	11.59	9.61
82/52	7.21	7.17
82/53	14.55	12.12
82/54	12.15	12.58
82/55	10.34	9.67
82/57	10.25	11.45
GT 1	7.42	10.73
RRIC 100	9.29	12.07
RRII 105 (Control)	9.85	12.76

9.1.2 Genetic analysis of hybrid progenies

A field experiment consisting of 28 clones each from eleven selected families resultant of 1986 hand pollinations and 14 corresponding parent clones was laid out employing a simple lattice design.

9.2 Estimation of combining ability for parental selection

One round of test tapping was carried out in the 1990 trial laid out at HBSS, Nettana at the 3rd year of planting. Out of the 12 parent clones PB 235 recorded the highest yield of 60 g per tree per 10 tap whereas IAN 45-873 recorded the lowest yield of 17.22 g per tree per 10 tap. Among the progenies, those of PB 242 recorded the highest yield of 49.78 g per tree per 10 tap whereas progenies of RRIM 600 recorded the lowest yield of 14.78 g per tree per 10 tap. However, progenies of clones PB 242, PB 86 and IAN 45-873 recorded superior performance compared to their respective parent clones (yield in g per tree per 10 tap being 49.78, 28.33 and 25.22 respectively for progenies of PB 242, PB 86 and IAN 45-873 whereas that of parents was 36.11, 20.55 and 17.22 respectively).

10. Cytogenetic investigations

Detailed karyomorphological analysis of eight clones *viz.*, RRIM 600, RRII 203, GT 1, PB 235, PB 314, PB 217, G/1 and Tjir 1 were carried out. All the eight clones are diploid with a somatic chromosome complement of 2n = 2x = 36. The length of the chromosome ranged from 1.5µm to 3.7µm. The chromosomes differed from one another in size and shape. Three types of chromosomes *viz.*, metacentric, submetacentric and subterminal chromosomes were observed. The total chromosome length of the haploid complement ranged from 40 - 50µm. They showed different karyotype formulae. Studies on pollen morphology and germination of diploid and tetraploid were being carried out.

11. Floral biology and fruitset

Fruits were collected at different developmental stages after pollination for microscopic observations of ovule development.

12. Bark anatomy

12.1 Variability, correlations and path coefficient analysis for yield in relation to anatomical characters with imphasis on TPD, diseases and drought tolerance

High frequency of latex vessel formation and enhanced permeability of cell wall were observed as immediate effects of ethrel application on young rubber plants.

Subsequently sclerifications increased and high rate of latex vessel degenrations was effected.

Possibility of grafting TPD affected trees with healthy bark to replace affected bark was tried. Two successful grafts (out of six trees grafted) were observed. Six more grafts have been made.

To study the variability and correlation of bark anatomical traits, bark samples have been collected from 25 popular clones, at the age of three years.

12.2 Studies on bark renewal

A study was carried out to elucidate the structural aspects of bark regeneration. Regeneration of the bark was due to the combined activity of wound phellogen and vascular cambium. Newly differentiated sieve tubes and ray cells were comparatively larger in size. Structurally virgin and renewed bark showed variation in the proportion of soft and hard bark, amount and distribution of sclerides, tannin cells and crystals.

12.3 Evaluation of clones for structural components

Characterisation of clones (14 hybrid clones and two control clones), planted in the 1985 small scale trial, for the number of latex vessel rows and bark thickness at the immature stage was done (Table - Bot.7)

Table - Bot. 7. **Anatomical parameters of hybrid clones at $4\frac{1}{2}$ years**

Clone	No. of LVR	Bark thickness (mm)
82/40	7.89	3.62
82/44	5.06	4.04
82/45	8.50	4.75
82/46	7.11	3.67
82/47	7.78	3.92
82/48	3.61	3.38
82/49	9.89	4.09
82/50	10.89	3.92
82/51	4.56	4.42
82/52	3.84	4.30
82/53	7.02	3.04
82/54	8.22	4.34
82/55	6.06	5.05
82/57	7.61	4.25
GT 1	7.56	4.09
RRIC 100	8.06	3.46
RRII 105	7.61	4.68
SE	0.812	0.489
CD	1.6507	0.994

13. Wood anatomy

To study the effect of ethrel application on rubber wood quality, stimulation was carried out. Wood samples were collected from ethrel applied trees to study density, specific gravity and other physical properties.

14. Studies on propagation

Growth characters of the plants in the trial on budding height and depth of planting were recorded. Data on girth indicated that bag plants continued to exhibit maximum girth (47.68 cm) among all treatments. Among budded stumps those budded at 45 cm above collar recorded maximum girth (45.07 cm).

Dry weight of shoot and root collected by destructive sampling of polyclonal and assorted seedlings at the age of 5 months showed that polyclonal seedlings had more dry matter production. Shoot weight was 16.51 and 19.71 g and root weight was 14.17 and 17.65 g respectively for assorted and polyclonal materials.

Green budding carried out adopting bench grafting technique showed that success was comparatively less in bench grafts (74%) compared to nursery grafts (94%). Delaying the removal of the bandage after budding was found to influence budding success favourably.

Evaluation of secondary characters of the bench grafted plants in the field was carried out. Girth data collected in 1992-93 revealed that bench grafts were marginally better than nursery grafts (33.90 and 33.62 cm respectively).

Growth data recorded from the trial on deep planting of two whorled bag plants were analysed and it was found that the deep planted ones continued to put on more girth than the control (normally planted bag plants). Average girth of deep planted plants was 13.56 cm while that of the control was only 12.35 cm. Among the different depths of deep planting, those planted 10 cm deep recorded maximum girth.

The trial for comparative study on twin stocks and single stocks was laid out and planting was carried out with seeds in the seed at stake plots. Stock plants were raised in seedling nursery as well as in bags and twin-grafting was done wherever required. Bag plants were also subsequently budded and cut back to produce two whorled bag plants.

15. Genetic basis of stock scion relationship

15.1 Performance of certain modern clones with different root systems

Recording of monthly yield and annual girth measurement were continued. Annual girth data of 1992-93 revealed that the combination of RRII 203 as scion on its own root stock recorded the highest girth followed by RRII 203 on assorted stock. Mean yield over the first year of tapping revealed significant clonal differences. The stock scion combination RRII 105 on RRII 105 recorded the highest yield followed by RRII 203 on RRII 203 and RRII 118 on RRII 118.

15.2 3 x 3 stock scion combination trial

Growth characters of the plants in the trial were recorded. Summarisation of girth data collected during 1992-93 period was undertaken. RRII 203 as scion in combination with all stocks recorded more girth. Girth was maximum on RRII 203 stock (18.53 cm) followed by RRIM 600 stock (17.83 cm) and RRII 105 stock (17.33 cm). The combination of RRIM 600 scion on its own stock seedlings recorded minimum girth (10.84 cm).

16. Studies on early evaluation

16.1 Juvenile vs mature performance

Juvenile growth characters viz., plant height, girth, number of whorls, number of leaves and juvenile yield by test incision method were recorded in the field trial consisting of 10 clones coming under high, medium and low yield groups. Data on height and juvenile yield revealed highly significant differences among clones (Table - Bot.8) - Performance index computed based on these three characters was the highest for RRII 105 followed by PB 260.

Table - Bot. 8. **Data on juvenile characters at the age of one year**

Clones	Height (cm)	Girth (cm)	Yield (g/test incision)
RRII 105	130.27	5.31	0.18
PB 235	135.83	5.24	0.05
PB 260	143.13	5.15	0.09
RRIM 600	140.67	5.09	0.07
GT 1	99.33	4.66	0.09
PB 217	132.80	4.85	0.05
PB 5/51	116.27	4.54	0.05
RRII 33	124.93	5.30	0.04
RRII 38	109.07	4.85	0.04
General mean	125.81	5.00	0.07
Variance ratio	4.36**	1.58	4.44**
CD	21.32	-	0.03

** Significant at 1% level

GERMPLASM DIVISION

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

1. Introduction, collection and conservation of germplasm

1.1 Wickham materials from the secondary diversity centres

Regular maintenance of the existing clones in the clone museum was carried out. For gap filling in the clone museum sufficient materials were raised. Two seedling trees of *H. brasiliensis* growing wild in a drought affected area in Mettur Hills, Tamil Nadu were collected and being multiplied for further studies. These genotypes were multiplied and conserved in the germplasm museum.

1.2 Wild germplasm from 1981 IRRDB exploration

A total collection of 4709 genotypes received at RRII is being maintained in the source bush nurseries at the Central Experiment Station.

2. Evaluation of germplasm

2.1 *In situ* conservation gardens

Evaluation of the elite clones introduced from various geographical areas conserved in the three gardens was continued. Annual girth and monthly yield were recorded for all the clones. Data collection for genetic divergence studies in garden II was completed and the data were being processed. Genetic divergence study initiated in garden III is being continued.

Observations on the morphological characters *viz.*, plant height , girth, total number of whorls, total number of leaves per whorl and estimated leaf area were collected from the evaluation trial of IRCA clones at quarterly intervals. The data were being statistically analysed.

Planting materials were raised for laying out a new germplasm garden. Studies on floral morphology in certain clones were started.

2.2 Nursery evaluation, juvenile characterisation and cataloguing

A preliminary study was carried out on 56 genotypes selected randomly from the wild germplasm collection. The morphological and anatomical characters studied were single leaf area, specific leaf weight, bark thickness, girth, number of latex vessel rings, density of latex vessels per ring per 1 mm circumference of the plant, diameter of latex vessels and yield. It was found that none of the genotypes yielded as much as the control, though there were individual genotypes that performed better than the control for all other traits. Coefficient of variation was the highest for yield (149.4%) and the lowest for diameter of latex vessels (6.57%). Coefficient of variation for the other characters ranged from 9.69 to 28.64 per cent (Table - Gplm. 1).

Another preliminary study involving 75 randomly selected genotypes for the characters plant height (m), height at first branching (m), girth (cm), bark thickness (mm), single leaf area (cm^2) and yield (g/tree/tap) was taken up. Visual scoring in the field conditions for abnormal leaf fall and secondary leaf fall diseases was also conducted. Juvenile characterisation of these genotypes was done.

Table. Gplm. 1. **Variability of the 1981 collection**

Traits	Range	Mean	Standard deviation	Coefficient of variation (%)	Control
Single leaf area (cm^2)	59.73 - 169.96	99.09	29.96	24.18	63.38
Specific leaf weight (mg/cm^2)	3.83 - 7.45	6.12	0.73	11.91	6.19
Bark thickness (mm)	2.50 - 5.67	4.12	0.71	17.25	5.83
Girth (cm)	23.93 - 48.20	34.20	6.43	18.79	43.87
Number of latex vessel rows	2.33 - 6.67	4.18	1.08	25.82	6.67
Density of latex vessels	23.00 - 34.33	28.36	2.75	9.69	33.33
Diameter of latex vessels (µm)	19.50 - 25.93	22.72	1.49	6.57	23.20
Distance between latex vessel rows (mm)	0.15 - 0.55	0.27	0.08	28.64	0.24
Test tap yield (g)	0.19 - 73.15	10.08	15.06	149.45	134.95

Observations were made on another set of wild genotypes for the characters girth, bark thickness, test tap yield, seed weight, length and breadth of the seeds and disease incidence. Among the three provenances - Acre, Rondonia and Matto Grosso, the genotypes from Matto Grosso showed a general superiority with respect to vigour, yield and tolerance to *Phytophthora*. The genotypes exhibited variations in weight, length and width of seeds. The Matto Grosso genotypes were found to be late flowering types compared to Acre and Rondonia genotypes. Floral morphology and seed characters were studied in certain genotypes of wild germplasm. Morphological variations were noted and the study is being continued.

2.3 Field evaluation of Brazilian germplasm

Two evaluation trials were laid out in 1992 with 143 wild genotypes and 50 ortets belonging to wild Brazilian germplasm. Quarterly observaions on morphological characters such as height of the plant, collar diameter, number of whorls per plant, number of leaves per whorl, and leaf area were recorded. Quarterly recording of girth was continued in 175 genotypes in the evaluation trial laid out in 1990. The data were being statistically analysed. Morphological characterisation of 143 genotypes was done at the age of one year after planting to study the juvenile 'plant type' of the wild clones based on the description prepared for the characters *viz.*, habit of the plant, nature of auxillary buds and leaf scars, shape and appearance of leaf storey and leaf characters. Specific variations were noted for the genotypes from the three provenances of Acre, Rondonia and Matto Grosso.

3. General studies

3.1 Collection, conservation and evaluation of Ceara rubber germplasm

Ten genotypes of Ceara rubber (*Manihot glaziovii*) germplasm collected from a seimi-arid hill tract of Tamil Nadu were multiplied and conserved in the museum.

MYCOLOGY AND PLANT PATHOLOGY DIVISION

Mycology and Plant Pathology Division carried out both basic and applied research on plant protection and cover crops improvement. Plant Pathology and Entomology Sections made attempts to control pathogens and pests using pesticides and biological agents and assessed yield loss due to plant diseases. Mycology Section was engaged in investigations on causative agents of new plant diseases and screening germplasm and hand pollinated clones for resistance to common diseases of *Hevea*. Investigations on soil improvement through micro-organisms and utilization of wastes from rubber industry were carried out by Microbiology Section.

1. Abnormal leaf-fall disease

Copper fungicides were in use for the control of abnormal leaf fall disease for quite a long period. This may lead to accumulation of copper in soils under rubber and may affect the beneficial microorganisms sensitive to this heavy metal. Attempts were made to find out alternative fungicides to control abnormal leaf fall disease. An oil disperisible formulation of Mancozeb, Dithane (Indofil M. 45), was tested in the field using the clone PB 235. The results indicated that oil based mancozeb is as effective as oil based copper oxychloride at the same active ingredient levels. The leaf retention recorded under different treatments is given in Table - Path.1.

Trunk painting with systemic fungicides was also attempted for control of abnormal leaf fall disease. The fungicide tested included (1) phosphorous acid (2) metalaxyl and (3) fosetyl - Al, each at 60 g ai/l. The leaf retention assessment showed

Table - Path. 1. **Leaf retention in abnormal leaf fall control experiment**

Treatments	Dose(kg ai/ha)	Leaf retention(%)
Control (No protection)		18.43
Mancozeb	2.24	42.39
Copper oxychlor	2.24	46.04
Mancozeb	3.36	42.68
Copper oxychloride	3.36	42.91
Mancozeb	4.5	42.14
Copper oxychloride	4.5	49.15

that this method is not effective for controlling abnormal leaf fall disease. Two new spray oil samples developed by M/s. Indian Oil Corporation were field tested in a small scale trial. Both the samples were found to give higher leaf retention. These samples were recommended for large scale field testing.

2. High volume spraying

Zinc - Bordeaux mixture (0.5% Bordeaux mixture + 0.5% zinc sulphate) was compared with other copper fungicide formulations for controlling abnormal leaf fall disease. The percentage of leaf retention in zinc - Bordeaux mixture treatment was on par with Bordeaux mixture (1%) treatment (Table - Path. 2).

Table - Path. 2. **Comparative efficacy of different fungicides**

Treatments	Spraying system	Leaf retention(%)
Bordeaux mixture 0.5%	High volume	51.0
Bordeaux mixture 0.5% + Zinc sulphate 0.5%	High volume	64.0
Oil based copper oxychloride	Low volume	78.0
Bordeaux mixture 1%	High volume	61.0

The experiments were conducted to control the shoot rot disease using various systemic fungicides at Mundakayam and Palapilly. The phosphorous acid at higher doses gave significantly higher control (Table - Path. 3).

Table - Path. 3. **Effect of systemic fungicides on shoot rot disease**

Chemical	Dose	Disease index %	
		Mundakayam	Palapilly
Phosphorous acid (Akomin)	2ml/l	19.3	27.5
Phosphorous acid (Akomin)	4ml/l	18.7	26.7
Phosphorous acid (Akomin)	8ml/l	10.8	18.4
Phosphorous acid (Phosjet)	1ml/l	22.2	29.6
Phosphorous acid (Phosjet)	2ml/l	23.0	27.2
Phorphorous acid (Phosjet)	4ml/l	17.1	19.4
Fosetyl - Al (Aliette)	2g/l	23.0	24.7
Metalaxyl M (Ridomil - MZ)	3g/l	17.8	18.6
Bordeaux mixture		14.6	17.4
CD (P=0.05)		2.77	2.97

3. Evaluation of panel protectant/ wound dressing compounds

Tapping during rainy days in high rainfall areas in rainguarded trees predisposes the plants to black stripe diseae and necessitates suitable protection measures. An experiment was conducted to evaluate fungicides for the control of black stripe disease in clone RRIM 600 at Lahai Estate. The results indicated that phosphorous acid formulations at 0.08 per cent ai is effective. Mancozeb is also effective at a concentration of 0.375 per cent ai as is seen in Table-Path. 4.

Table - Path. 4. **Comparative efficacy of different fungicides in black stripe control**

Treatments	Dose (% ai)	Leaf retention (%)
Mancozeb (Indofil M. 45)	0.750	32.97
Mancozeb (Indofil M. 45)	0.375	33.55
Phosphorous acid (Akomin -20)	0.080	40.44
Metalaxyl (Apron 35 WP)	0.105	36.22
Phosphorous acid (Phosjet -40)	0.160	36.89
Phosphorous acid (Phosjet -40)	0.080	40.00
MEMC (Emisan 6 WP)	0.015	40.33
CD		NS

Phosphorous acid was found to be efficient in the black stripe disease control in block trials on PB 28/59.

A new panel protectant formulation "Well coat" was tested in the field and was recommended for large scale use.

4. Pink disease

In the recent years this disease was found to attack many high yielding clones like RRII 105 and hence much emphasis was given for its control measures. Both prophylactic and curative measures were tried to protect the plants.

The experiment initiated during the previous year to evaluate prophylactic spraying to protect young rubber from this disease was continued. The application of fungicide in 4 year old plantations was found to be difficult even when mist blower was used. The spraying did not provide adequate protection of the tertiary branches.

Trunk painting of the systemic fungicides tridemorph (Calixin 2%), Propiconazole (Tilt 0.5%), Oxycarboxin (plantvax) 2.5%) and Bordeaux paste (10%) for prophylactic protection of rubber trees from pink disease was attempted. This method did not provide adequate protecion.

A systemic fungicde Validacin was tried as curative treatment against pink disease in a small scale trial. This fungicide was found to provide good protection at 2 per cent concentration of the formulation (0.06% ai).

Large scale field experiment to study the effect of prophylactic premonsoon application of Bordeaux paste *vis-a-vis* conventional therapeutic Bordeaux paste application in pink disease management was continued on the same plants (3 years old) which were treated while they were two year old. In the case of prophylactic treatment the Bordeaux paste was applied on ail the forks leaving the lower most one and also the branches where brown portion merges with the green portion. Prophylactic treatment showed considerable reduction in the incidence of pink disease in 2 and 3 year old plants, severe infection which can lead to tree loss, percentage of gaping wounds exposing wood and percentage of reinfection (Table - Path. 5).

An experiment was initiated to find out the effect of plant extracts on the control of pink disease and recorded the disease incidence. In the field experiments to control pink disease using wood extracts and cultural practices, the best result was recorded in lime washing with copper sulphate (100 g copper sulphate in 10 l lime water) followed by lime washing alone along with preventive Bordeaux paste. Among different wood extracts, Teak wood and Jack wood extracts were found effective.

5. Powdery mildew disease

The experment to evaluate integrated schedule of application of systemic and non-systemic fungicides in Wynad district, a high elevation area, was continued. The integrated schedule using tridemorph 1.5% dust with sulphur dust and both these fungicides in combination were found to effect better protection than conventional dusting with sulphur. The mixed fungicide treatment was more economical.

In spraying experiments to protect nursery plants from this disease penconazole (Topas 0.05% ai) carbendazim (0.05% ai) and carbendazim + wettable sulphur (0.025% + 0.125%) were equally effective and markedly superior to spraying of wettable sulphur alone.

6. Yield loss due to diseases

The experiment to assess yield loss due to abnormal leaf fall disease in clones RRIM 600, RRII 105, GT 1 and RRII 118 was continued. Crop loss was recorded in clones RRIM 600 (32.46%) and RRII 118(7.04%). The daily leaf fall due to infection during the monsoon season was monitored.

Table - Path. 5. **Percentage of disease incidence (1992 & 1993)**

Location	Total disease incidence (%)		Severity of disease incidence (%)		Gaping wounds (%)		Reinfection (%)	
	Prophy-lactic	Curative	Prophy-lactic	Curative	Prophy-lactic	Curative	Prophy-lactic	Curative
Madukakunnu	26.00	55.00	1.50	28.00	1.50	27.00	1.00	18.5
Pulikalkavala	08.50	42.00	2.00	23.50	2.00	22.50	0.50	4.50
Kayyoor	07.00	19.50	2.50	11.00	3.50	05.00	1.00	6.50
Mean	13.66	38.83	2.00	20.83	2.33	18.70	0.83	9.83

7. High pressure injection for disease control

The third generation budded plants of the mutant are maintained. Forth generation budding of plant is being arranged. The field planted mutants and their RRIM 701 controls show satisfactory growth. Observations on growth and disease incidence are being recorded.

8. Physiological specialisation of *Phytophthora meadii*

Based on the abnormal leaf fall disease incidence in nature ten different *Hevea* clones were selected *viz.*, RRII 105, RRII 33, FX 516, G1 1, BD 10, PB 217, GT 1, RRIM 600, PB 86 and RRIM 701. These clones were budded and established at CES, Chethackal as well as RRII Experiment Station for physiological specialisation studies.

9. Biological control of rubber diseases

Detailed studies on the inhibitory activity of *Trichoderma koningi* on *Phytophthora meadii* were carried out. Dual culture studies on agar medium showed wide inhibitory zone caused by *T. viride* against *P. meadii*. Another study showed mutual intermingling of colonies of a *Trichoderma* sp. and *P. meadii* and over growth of antagonist on the pathogen. The same antagonist caused lysis of oospores of *P. meadii*.

In vitro studies on the effect of culture filtrate of *Trichoderma* sp. on the growth of brown root disease pathogen, *Phellinus noxius* was carried out. 10 per cent concentration caused complete inhibition. Incorporation of culture filtrate of *Trichoderma* sp. with potato dextrose agar inhibited the growth of *P. meadii* upon inoculation.

10. Host parasite inter-relationship

The effect of graded levels of nitrogenous fertilizer and infection by *Corynespora cassiicola* on biochemical changes in rubber seedlings was studied. Leaf samples were collected periodically from the time of inoculating the leaves with the spore suspension of the pathogen and analysed for total phenols, *ortho* dihydroxy phenols, amino nitrogen, sugars and starch. *C. cassiicola* infection in plants at different levels of nitrogen application led to considerable change in the biochemical constituents of the leaves.

11. Root and collar disease

During August 1993, severe incidence of dieback of young rubber seedlings was recorded at Rubber Board Central Nursery, Karikkatoor, *Pythium* sp. was isolated from the infected plants and its pathogenicity established. *Botryodiplodia* was isolated from infected budded plants collected from another nursery. Both the cultures were sent to IMI for identification.

12. Multidisciplinary evaluation of clones

Periodic observation and recording of powdery mildew and pink disease incidence were carried out in the two clone evaluation experiments.

13. Screening of germplasm materials/ HP seedlings

Observations on natural incidence of powdery mildew disease were made during the disease season in five blocks in the 1989 Source bush nursery at CES, Chethackal. Mild incidence of powdery mildew disease was noticed on all the clones.

14. Minor leaf spot diseases and their control

Gloeosporium leaf spot disease was found to attack young rubber plants in many

areas. A field trial was conducted to control this disease at Manikal estate, Mundakayam with weekly and fortnightly application of five different fungicides. They included (1) metalaxyl (Ridomil Mμ 0.02%), maneozeb (Indofil M-45 0.2%), carbendazim (Bavistin 0.05%), tridemorph (Calixin 0.1%) and Bordeaux mixture (1%). Encouraging results were obtained with weekly application of metalaxyl, Bordeaux mixture and mancozeb.

15. Microbiology of leguminous cover crops

A new fast growing legume *Mucuna aterrima* was tested for growth, nodulation and nitrogenase activity. It grew very fast producing large foliage and roots at the nodes. The nodulation and nitrogenase activity were more than that of *M. bracteata*. The plants started drying after six months of growth. The plants, on an average produced 500g seeds.

Bradyrhizobium culture was mass multiplied using lignite powder as base and were distributed to rubber growers as 200 g packets.

Dipping the cuttings of *M. bracteata* in *Bradyrhizobium* slurry increased their percentage of establishment. A study on the selection of carriers for *Bradyrhizobium* indicated that coconut coir dust with soil rich in organic carbon and calcium carbonate can be used. The *Bradyrhizobium* population increased upto 1 month of storage and maintained upto three months. Six *Bradyrhizobium* isolates among 32 tested showed more nodulation and nitrogenase activity of *M. bracteata*.

A fast growing acid tolerant *Azotobacter* sp. was isolated and it is found to survive better in soil at RRII Experiment Station.

In the experiment on the effect of different cover crops on soil moisture at Palghat, soils under *M. bracteata* showed more moisture. Weed growth was completely eliminated in these plots. The population of *Azotobacter* was also higher in soils under *M. bracteata*.

The field trial with dual inoculation of *Pueraria phaseoloides* seeds with *Bradyrhizobium* sp and *Beijerinckia* sp. was continued. Enhanced growth of *P. phaseoloides* under the influence of dual inoculation augmented microbial activity in soil and reduced the weed biomass. Soil nitrogen level was also higher in such treatments.

16. Mushroom culture

Experiments were conducted to improve the quality of mushroom spawn by addition of organic supplements like rice bran, wheat bran, maize meal and red gram powder to wheat grains. Red gram powder added to wheat grain promoted the mycelial growth of the oyster mushroom (*Pleurotus florida)* and reduced the time taken for full growth of spawn. Another experiment conducted to find out the keeping quality of mushroom spawn showed yield reduction after 10 days of attaining spawn growth.

The technique for the cultivation of milk white mushroom (*Calocybe indica*) was perfected. Mushroom yield upto 350 g per bed was recorded in the first flush. Shitake mushroom (*Lentinus edodes*) culture was collected from different places and attempts were made to grow them on rubber wood and rubber wood saw dust. Under sterile condition these fungi grew well on rubber wood and its saw dust. Though there was profuse growth, sporocaups did not develop.

Attempts were also made to cultivate *Ganoderma* sp. on saw dust from rubber wood. Mushrooms were not formed even

after 6 months growth of this fungi on sterile saw dust.

17. Pollution studies

The studies on the effect of solid concentration, source of starter and diluents from rubber processing factories on biogas production were completed. Enhanced biogas production was directly proportional to anaerobic bacterial activity, cellulose enzymes and volatile fatty acid content. The spent liquor contained good amount of nitrogen, phosphorus and potassium which can be used as manure.

Detailed investigations on the failure of the biological treatment system in a rubber factory near Trichur was conducted and overloading with the effluent was found to be the cause. A recommendation given based on various parameters to increase the size of the aeration tank and to introduce trickling filter containing coconut shells and roof tiles was observed to work well.

18. Rhizosphere studies

A field trial conducted to find out the effect of phosphate solubilising bacteria on the growth of rubber seedlings under 4 different levels of rock phosphate showed that 50 per cent rock phosphate application along with phosphobacteria inoculation is comparable with application of higher doses of rock phosphate alone in influencing the girth of rubber seedlings (Table - Path. 6).

Pot culture experiments were carried out to evaluate the effect of 11 different isolates of VAM fungi on growth, biochemical constituents (total phenols, *ortho* dihydroxy phenols, sugars, amino nitrogen, starch etc.) and nodulation and nitrogen fixation in *P. phaseoloides*. VAM inoculation augmented growth, nodulation, nitrogenase activity, amino nitrogen, sugars and chlorophyll content.

Table-Path. 6. **Effect of phosphobacteria inoculation on growth of rubber seedlings**

Treatments	Girth(mm)	Height (cm)
Rock phosphate $^1/_4$ dose	12.75	138.5
Rock phosphate $^1/_2$ dose	12.75	134.25
Rock phosphate $^3/_4$ dose	14.75	141.75
Rock phosphate full dose	16.50	154.25
Rock phosphate $^1/_4$ dose + Bacteria	14.75	138.75
Rock phosphate $^1/_2$ dose + Bacteria	16.75	149.75
Rock phosphate $^3/_4$ dose + Bacteria	16.75	150.50
Rock phosphate full dose + Bacteria	17.75	149.75
CD (P=0.05)	1.75	7.01

A pot culture study was also initiated to identify the effect of VAM inoculation on the growth of rubber seedlings.

19. Biological control of white grubs

A field experiment was carried out to control white grubs using the entomopathogenic fungus *Beauveria brongniartii*. A heavily infested nursery area was selected and treated with the spores of the entomopathogenic fungus. Results indicated that the plots applied with *B. brongniartii* recorded the highest plant survival (92.8 to 95.6%) and lowest grub population (0 to 0.05 grubs/30 cm^3 soil) compared to control plots, recording 12.28 per cent plant survival and the highest grub population (2 grubs/30 cm^3 soil).

20. Vertebrate and non-insect pests

Field trials were conducted to find out the efficacy of brodifacum, bromadiolone and flocoumafen for the control of *Bandicota bengalensis* infesting rubber seedling. The results given in Table - Path. 7 shows that all the three second generation anticoagulants were highly effective in reducing rat population.

Table-Path. 7. **Effect of three second generation anticoagulants in rat control**

	Bait used g/burrow	Number of active burrows		Population decline %
		Pre-treatment	Post-treatment	
Brodifacum 0.005 % bait	20	172	2	98.7
Bromadiolone 0.005% bait	20	85	3	96.5
Flocoumafen 0.005% bait	20	155	2	98.7

21. Bee keeping in rubber plantations

A regionwise survey conducted to evaluate the occurence and devastation of Thai Sac Brood Virus disease (TSBV) in the states of Kerala, Tamilnadu and Karnataka revealed that 75 per cent colonies of *Apis cerana indica* were lost due to this disease. In Kerala, Calicut, Trivandrum and Kottayamn districts accounted for 95.36, 94.27 and 93.65 per cent loss of bee colonies respectively. Studies on the introduction of European bees, *A. mellifera* and the disease resistant variety of Indian bees, *A. cerana indica* were initiated. European bees were found to frequently visit rubber trees.

22. Minor pests

Severe infestation of borer beetles was recorded in PB 28/59 and GT 1 clones at Lahai Estate. Application of HCH 50 per cent WP at 5 per cent concentration effective controlled the beetles.

Crickets that caused wide spread damage to plastic rainguards were identified as *Gryllacris* sp.

An experiment conducted to control the termite, *Odentotermies* sp. revealed that the application of either aldrin, chlordane, heptachlor or chlorpyriphos at 0.1 per cent is effecitve in controlling the termites.

23. Nematodes infesting rubber seedlings

Frequency of occurrence and population density of plant parasiitic nematodes was studied in soils from rubber nurseries and the results are given in Table - Path.8. Considerable variations were observed in the frequency and population density in nursery soils from different regions.

Table-Path. 8. **Nematodes population in rubber nursery soils**

Location	Frequency of occurrence (%)	Population (cc)	
		Plant parasitic	Non-parasitic
Manjeri	100	1800	1400
Kanhikulam	100	4400	2800
Perumpulickal	100	3000	2000
Peruvannamoozhy	90	4200	2200
Kadakamon	100	2400	600
Karikatoor	40	666	1000
Chethackal	60	400	600
Ulickal	100	333	666
Paraliar	30	333	333

A pot culture study conducted to find out the inoculum potential of *Meloidogyne incognita* on the growth characters of *P. phaseoloides* under pot culture condition revealed that initial inoculum level of 10 larvae per pot and above increased root galls and adversely affected the growth of *P. phaseoloides* (Table - Path 9).

24. Slugs and snails

The efficacy of lime powder was tested for the control of slugs and snails attacking rubber. The preliminary results showed that the lime applied at the base of rubber stumps at the rate of 20 g per plant is effective in controlling this pest.

Table-Path. 9. Effect of *M. incognita* on the growth of *P. phaseoloids*

Inoculum level	Shoot			Root			
	Length(cm)	Fresh wt.(g)	Drywt. (g)	Length(cm)	Fresh wt.(g)	Drywt. (g)	galls/g. root
0	166.2	12.94	3.84	39.20	4.53	1.27	..
10	143.8	7.96	2.77	29.84	3.04	0.81	3.2
100	116.6	4.91	1.83	23.74	2.13	0.39	12.2
1000	102.2	3.60	1.23	15.30	1.38	0.14	23.0
10000	78.8	1.91	0.79	10.20	0.57	0.06	39.4
CD(P= 0.05)	9.80	1.29	0.42	5.07	0.51	0.27	4.89

25. Rubber wood preservation

Different combinations of wood preservatives were tested on rubber wood. A combination of Na, PCP, borax and boric acid completely eliminated fungal population and insect borers. Copper sulphate and borax treatment gave protection from insect borers only and not from fungi.

Observation on the incidence of sap stain fungi and borer beetle attack on rubber wood injected with copper sulphate before felling was continued. Even after 6.5 years the treated wood was free from insect attack and fungus infection.

The pressure injection equipment was remodelled and the injection technique was standardised. Six number of mature rubber trees each were injected with extracts of heartwood of rosewood, teak , jack, anjali and subabul and copper sulphate solution. The trees were cut and stored for further observations.

PLANT PHYSIOLOGY AND EXPLOITATION DIVISION

The Physiology and Exploitation Division continued research on biochemistry, crop physiology, stress physiology, water management, stock-scion interaction, exploitation, tapping panel dryness (TPD), introduction of medicinal plants for intercropping etc. in addition to the routine assignments on testing of materials, training, adivisory work and other extension activities. Further, effort was put in successfully for popularising controlled upward tapping (CUT). The Division undertook many onfarm trials on CUT in small and large holdings. New studies on stock-scion interaction were taken up.

1. Early prediction of yield and stress tolerance

In continuation of earlier studies on tolerance to drought and heat, membrane thermostability of young and mature leaf discs of the clones RRII 105 and RRIM 600 were studied using electrolyte leakage method. Young leaves were found more sensitive to elevated temperatures. There was gradual increase in the thermostability of leaf tissue with age attaining maximum stability in two months.

In another method, the tolerance to

combined drought and heat stress was assessed by subjecting leaf discs to thermal shock in presence of PEG 6000. In the presence of osmotic stress, membrane becomes more susceptible to thermal injury. This was a major problem in the Konkan and other non-traditional regions. Young leaves were tolerant to water stress. When temperature was high this advantage was nullified. The method seems to be a new approach and promising in the field of stress physiology of *Hevea brasiliensis*.

Determination of bark water potential was identified as a suitable, easy, fast, reliable and non-destructive method to assess plant moisture status in *Hevea* and can be used as a screening method.

2. Changes in latex diagnosis parameters in relation to tapping intensity

Changes in DRC, yield and latex diagnostic parameters *viz.*, thiols, inorganic phosphorus and sucrose were monitored under 1/2 S d/1 6d/7, 1/2 S d/2 6d/7 and 1/2S d/3 6d/7 systems of tapping in four clones (RRII 105, RRII 203, GT 1 and RRII 118). After two years of imposition of the treatment, there was a fall in DRC under d/1 system in all the clones yield (g/tree/tap) also showed a drop under d/1 system in all the clones under study. However, under d/2 system no such drop could be noticed from the beginning of the experiment, whereas under d/3 system, clones RRII 203, GT 1 and RRII 118 showed an increase in per tree per tap yeid, unlike RRII 105, from the d/2 system. There was no difference in the level of thiols and sucrose between the treatments, whereas inorganic phosphorus showed a significant increase in the d/1 system compared with the d/3 system.

3. Physiological evaluation of clones

The highest mean annual yield was observed in the clone RRII 105 at Central Experiment Station (Table - Phy. 1).

Table - Phy. 1. **Dry rubber yield (g /tree/ tap) at CES**

Clone	Annual mean*
RRII 300	37.0
PB 235	46.6
RRII 105	56.3
RRIM 600	36.7
GT 1	31.1
PR 107	19.7
G1 1	28.4
RRIM 501	28.6
RRII 118	29.9
RRIM 703	51.4
Tjir 1	30.8
RRIM 612	18.5

*Dry rubber yield

4. Performance of clones at high elevation

Annual mean yield recorded at Mullenkolly (Wynad) is presented in Table - Phy. 2. Clone RRIM 600 showed the highest yield among the clones.

Table - Phy. 2. **Mean yield (g/tree/tap) at high altitude (Wynad)**

Clone	Yield*
PB 28/59	16.6
RRII 203	17.1
PB 619	13.4
RRII 105	16.0
RRIM 612	13.0
RRIM 501	14.2
RRIM 605	16.4
G1 1	12.2
PB 5/51	13.2
PR 107	14.1
GT 1	14.2
RRIM 600	19.7
RRIM 623	13.9
Tjir 1	14.9
LCB 1320	13.0
RRII 118	14.7

*Mean of 7 months

5. Soil moisture stress, growth and yield

Leaf area index, girth and turgor pressure were recorded in four year old *Hevea* clones at immature phase during wet season. Variation in growth and leaf area index was noticed among the clones. Leaf area index ranges from 1.12 to 3.48 and showed positive relationship with girth (Table - Phy.3).

Table - Phy. 3. **Leaf area index (LAI), turgor pressure and girth during wet season of 1993 (Trials I and II)**

Clone	LAI*	T.P. (bar)	Girth (cm)
Trial I			
RRII 5	3.08	5.30	36.5
RRII 118	2.96	7.02	39.7
RRII 208	2.18	5.44	31.3
RRII 300	2.34	6.10	32.2
RRII 308	2.83	7.83	36.2
RRIM 600	1.99	7.77	32.0
RRIM 703	1.75	7.08	32.1
PCK 1	2.59	6.23	33.3
PCK 2	3.48	7.27	32.0
SCATC 88	1.61	6.14	30.4
SCATC 93	2.13	5.06	29.6
Haiken 1	1.87	5.87	30.5
RRII 105	2.69	7.35	33.3
CD (P=0.05)	1.07	0.26	5.3
CV (%)	26.10	6.6	9.5
Trial II			
PB 217	2.73	8.38	34.6
PB 235	2.21	5.10	39.1
PB 255	1.75	6.99	37.2
PB 260	1.53	5.90	32.7
PB 280	1.66	5.62	35.8
PB 310	2.34	6.51	33.3
PB 311	1.79	6.43	33.3
PB 312	2.62	7.62	38.1
PB 314	2.92	5.24	38.8
KRS 25	1.30	5.58	31.3
RRS 128	1.12	6.29	30.5
KRS 163	1.65	6.30	32.8
RRI 105	2.27	7.38	33.8
CD (P=0.05)	0.74	0.58	5.0
CV (%)	22.0	5.3	8.4

* The values are only relative

6. Exploitation systems and yield

Yield of dry rubber from trees under 1/2S d/2 6 d/7 and 1/2S d/3 6d/7 continued to show comparable yield. However, yield under the quarter cut change over system was much higher (Table - Phy. 4).

Table - Phy. 4. **Yield and TPD in a small trial area at CES in RRII 105**

Treatment	Block yield kg/300 tree	TPD% '93	Girth increment '90-93'
1/2S d/2 6d/7	2926.00	20.83	15.19
1/2S d/3 6d/7	2991.85	11.67	17.60
2 × 1/4S d/2 6d/7	3698.75	8.33	18.97

The block level experiment comprising shorter cuts and weekly tapping in comparison with ordinary d/2 and d/3 system is in progress. 1/3S d/2 6d/7 system gave significantly higher yield compared to all other systems of tapping, and was followed by 1/2S d/2 6d/7. Yield under 1/2S d/2 6d/7 and 1/3S d/3 6d/7 + ET were also comparable (Table-Phy. 5). TPD was significantly lower in 1/2S d/7 and 1/3S d/2 6d/7 compared to 1/2S d/2 6d/7 system of tapping. Low intensity tapping system, in general, showed better girth increment. 1/2S d/7 + ET system showed higher DRC throughout the year as compared to d/2 system in the peak yielding time.

Table - Phy.5. **Dry rubber yield and incidence of TPD under various tapping systems in RRII 105 (block trial)**

Treatment	Yield (kg/block) 1993	TPD Tree/blcok (average) 1993
1/2S d/2 6d/7	2454.1	42.0
1/2S d/3 6d/7	1946.4	28.5
1/3S d/2 6d/7	2951.5	14.5
1/3S d/3 6d/7+ET	2369.6	24.3
1/2S d/7+ET	1897.7	6.5
CD (P=0.05)	301.45	18.75

Table - Phy. 6. **Yield, girth increment and plugging index in RRII 118 during 1993-94**

Treatment	Yield (kg/block) 1993 - 94	Girth increment (%) 1987 - 93	Plugging index 1993-94
1/2S d/2 6d/7	1795.14	48.96	2.975
1/2S d/3 6d/7	1810.11	53.21	3.044
1/2S d/2 6d/7	1647.86	44.34	3.409
1/4S d/3 6d/7	1003.26	49.28	3.633
1/4S d/2 6 d/7 + ET 5% ha. 6(-) 12/y (m)	2532.20	47.74	2.419
Untapped control	--	49.281	--

Studies on different exploitation systems on K and C factors in the clone RRII 118 showed that yield is the highest for 1/4 S d/2 6d/7 + ET system followed by 1/2 S 6d/7 and 1/2 S d/2 6d/7 system. 1/4 S d/3 6d/7 recorded the lowest yield (Table-Phy. 6). In the experimental area TPD was less than 10 per cent.

Experiment on periodic tapping rest on yield showed that monsoon rest with no rainguards and summer rest with rainguards resulted in comparatively better yield even with less number of tappings per year (Table - Phy. 7). Continuously tapped trees however showed less girth increment. Maximum girth increment was noticed in 1/2 S d/3 6d/7 and minimum in 1/4S 6d/7.

Clones planted for undertaking studies on biomass partitioning and yield components under different exploitation systems in Karnataka region showed that growth, as indicated by girth, was significantly higher for PB 235 and PB 260. In general, RRII clones under this trial showed poor growth compared to that of PB clones. Pink disease incidence and casualty were also higher in RRII 105. Among the clones studied, PB 235 recorded outstandingly higher girth followed by PB 260 (Table - Phy.8). In the second trial, RRII 118 showed higher girth increment as compared with the other clones (Table-Phy.9).

The experiment on depth of tapping yield and TPD was also continued.

Table - Phy. 7. **Effect of periodic tapping rest on yield**

Treatment	Yield*(kg/block) 1993 - 94	Tapping days/year
Continuous tapping with rainguard (R.G)	3593.97	145
1 Months rest in summer with R.G.	3546.18	132
2 Months rest in summer with R.G.	3268.32	120
2 Months rest in monsoon without R.G.	3013.06	108
2 Months rest in monsson with 1 month rest in summer without rainguard	2948.45	96
2 Months rest in monsoon with 1 month rest in summer with no R.G. and 1 additional tapping per week during Oct-Dec.	3352.53	108

*Cup lump weight

Table - Phy. 8. **Growth performance at Dakshina Karnataka (1987 planting)**

Clone	Vacancies in the sixth year(%)	Girth in the sixth year(cm)	Pink incidence
RRII 105	33.33	37.01	9
RRII 300	24.07	32.39	4
PB 235	5.55	43.69	3
PB 311	3.70	39.54	5
PB 260	1.85	42.69	3
CD (P=0.05)	17.23	4.52	

Table - Phy. 9. **Girth increment in the fifth year of planting at Dakshina Karnataka (1988 planting)**

Clone	Girth increment (1990-93)
PCK 2	20.73
PCK 1	19.32
RRII 118	25.03
RRIC 36	17.80
RRIC 45	17.33

A comparative evaluation trial on 1/2 S d/4 and 1/2 S d/6 system of tapping with stimulation was initiated in a mixed clone area at Kulasekharam in Tamil Nadu state. The mean yield under 1/2 S d/4 + ET was higher compared with 1/2 S d/6 + ET system of tapping.

The trial to evaluate long-term impact of rainguarding on growth, yield and TPD in *Hevea* was continued and extended to other locations.

A new trial to evaluate comparative effectiveness of different stimulation methods under low frequency tapping system was also commenced.

7. Tapping system for small growers

The study was taken up with a view to realise maximum sustainable productivity with less incidences of TPD and better growth under high intensity tapping. The experiment was continued during the year and the trends were the same as in the previous year. Four years data were analysed. Though the cumulative yield was higher in double cuts with panel change, it had disadvantages like poor tree growth, higher rate of bark consumption and incidences of TPD. Yield and other parameters were comparable in trees opened at normal (125 cm) and lower (90cm) height. Cumulative yield from 1/2 S d/2 6d/7 was lower with high bark consumption and incidence of TPD. Total yield was 47% higher under 1/3 S d/1 6d/7 compared to 1/2 S d/2 6d/7. Girth increment was the highest and all the other assessed parameters were comparable to conventional system. Short-run and long-run net income analysis and ranking based on various indicators highlighted 1/3 S d/1 6d/7 as the best and sustainable tapping system for the clone RRII 203. This system with one more BO-panel, seemed to be promising for clones with poor renewed bark yield.

8. Controlled upward tapping (CUT)

The large scale trial on CUT was continued. Trees tapped on 1/3S + 1/2S d/2 6d/7 continued to give better yield compared to other systems. Evaluation of CUT in field where severe TPD was noticed indicated 1/4 S d/2 6 d/7 as a better system. In such areas, tapping shade was found unsuitable for CUT.

9. Studies on introduction of medicinal plants in mature stands

The experiment on intercropping of medicinal plants at CES was continued. Package of practices for intercropping three types of medicinal plants in mature stands were evolved.

10. Multi-disciplinary studies on tapping panel dryness

Estimations on the content of total phenols, extent of lipid peroxidation and the activity of catalase in the bark samples of normal and partially dry trees in the clone RRII 105 were carried out. Total solids content, thiols, inorganic phosphorus, sucrose, magnesium and lipids in the bottom fraction of latex samples and the activity of superoxide dismutase in bark samples were estimated in healthy trees of the clone RRII 105 growing in two fields with 30 and 80 per cent TPD respectively. Further studies were in progress.

As a part of the international programme on TPD, monitoring of changes in physiological and biochemical parameters associated with incidence of TPD was continued. Protein content and polypeptide profile of C-serum and lutoid membrane in 25 trees of the clone RRII 105 were monitored at monthly intervals in normal and partially dry trees. The data showed that the protein content of C-serum in partially dry trees was less when compared to that in normal trees. The polypeptide profile of C-serum showed 21 bands with mol. wt. ranging from 14-150 KD and amount from 300-1500 ng. Lutoid membrane showed 12 polypeptides with mol. wt. ranging 14-160 KD and their quantity from 20-1500 ng. The profile and the quantity of protein (intensity of bands) in some partially dry trees were different (absence of bands and low intensity), but the pattern was inconsistant. Further studies are in progress.

The experiment to monitor changes in latex diagnostic parameters associated with tapping panel dryness in normal and partially dry trees were continued. It was observed that the level of thiols increased in partially dry trees whereas no change was recorded in the levels of inroganic phosphorus and sucrose compared to normal trees.

11. Studies on stock-scion interaction

A rapid technique to vegetatively propagate *Hevea brasiliensis* by air-layering technique with higher success rate (70%), using sphagnum moss as rooting medium was standardised. Further studies were in progress.

12. Tapping system on a panel parallel to the inclination of latex vessels

The experiment was being continued. On the BO-2 panel also an approximate yield increase of one kg per month from the 35 trees was observed in the new method compared to the control. No adverse effect was noticed in girthing or brownbast incidence.

13. Experiment on upward tapping on inclined panel on virgin bark

A tapping experiment was started at the New Ambady Estate, Kulasekharam in a block of 350 trees of RRII 105 by opening inclined panel at 7° from bottom upwards. A control with conventional vertical downwad tapping of equal number of trees is also maintained.

RUBBER CHEMISTRY, PHYSICS AND TECHNOLOGY DIVISION

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

1. Solar drier for sheet rubber

The 800 kg solar drier was modified for continuous operation. It was observed that with firewood backup, sheets could be dried in 4-5 days. Firewood consumption, under such conditions, was found to be 0.11 kg. per kg. of dry rubber. Under bright sunlight, sheets could be dried in 6-7 days with solar energy alone, when the maximum temperature realised in the chamber was 50°C. The quality of sheets was similar to that of sheets obtained from a smoke house, except that colour was lighter for sheets dried in the solar drier.

A readymade smoke drier with a capacity of 96 sheets was procured and evaluated for firewood consumption, which was found to be one kg of firewood per kg. of dry rubber. In order to accelerate the drying using solar energy, efforts were in progress for attaching solar panels to the drier.

A low cost smoke drier of ferrocement construction, designed and fabricated by a private firm was evaluated for sheet drying. The firm was requested to incorporate several modifications and the modified model was found working satisfactorily. This model was recommended for inclusion under the subsidy programme of the Rubber Board.

2. Sulphuric acid as an alternative latex coagulant

Studies on storage and ageing behaviour of sheet rubber prepared using sulphuric acid was continued. Ageing behaviour of vulcanizates was studied using a silica-filled formulation. Results indicated that sheets prepared using sulphuric acid under different conditions were comparable to sheets prepared using formic acid, with respect to ageing behavious, both in raw stage and after vulcanization.

3. Epoxidation of natural rubber

Several batches of ENR - 50 have been produced in pilot plant and were characterised. Though the Mooney viscosity of the raw rubber was high and showed batch to batch variation, the vulcanizate properties showed little variation as is evident from Table - Chem. 1. The reaction conditions using lower concentration of reagents have been optimised which could reduce the cost of production.

The effect of addition of different phenolic and amine types of antioxidants on the plasticity retention index of ENR showed that 0.25 phr each of 2,6 - di-t-butyl-p-cresol and polymerised 2,2,4-trimethyl-1, 2- dihydro quinoline or 0.5 phr of styrenated phenol can impart PRI values within the accepted range (Table - Chem. 2).

4. Studies on rheological behaviour of LNR

Rheological behaviour of nitrile rubber (NBR) compounds containing liquid

Table- Chem. 1. **Batch to batch variation in properties of ENR 50**

Property	Batch 1	Batch 2	Batch 3
Mooney viscosity, ML (1+4) 100°C of raw ENR 50	99	112	122
Mooney viscosity, ML (1+4) 100°C of compound	58	58	55
Mooney scorch time at 120°C, Min.	6	8.5	7
Optimum cure time at 150°C, t_{90}, Min.	6	7	6.5
Hardness, Shore A	60	60	60
Modulus at 100% elongation, MPa	2.41	2.37	2.4
Modulus at 300% elongation, MPa	8.04	8.00	8.10
Tensile strength, MPa	21.30	20.90	21.00
Elongation at break, %	746	739	743
Tear strength, N/mm	42.60	41.40	45.60
Resilience at room temperature, %	41.10	36.1	40.50
Goodrich heat build - up at 50°C, Δ T, °C	33.60	33.50	35.10
DIN abrasion loss, mm^3	121.46	121.20	107.80
Compression set at 70°C, 22h, %	22.00	25.60	25.30

Formulation : ENR 50/100, Calcium stearate - 5, Stearic acid - 2, Zinc oxide - 5, Antioxidamt HS - 2 Antioxidant 4010 NA - 2, Paraffin wax - 3, FEF black - 50, Aromatic oil - 5, Sulphur - 1.5 and MOR - 1.5)

Table- Chem.2. **Effect of antioxidants on PRI of ENR 50**

Antioxidant type	Concentration, phr	P0	P30	PRI	Staining behaviour
ENR 50	0	44	9	20	
Polymerised 2,2,4 - trimethyl 1,2 - dihydroquinoline (Antioxidant HS)	0.25	45	34	76	low
	0.50	46	30	65	high
	1.00	52	48	92	high
N-Isopropyl - N'- phenyl - p phenylene diamine (4010 NA)	0.25	40	30	75	high
	0.50	41	29	71	high
	1.00	40	38	95	high
2- Mercaptobenzimidazole (MBI)	0.25	15	melted	-	Nil
	0.50	11	melted	-	Nil
	1.00	10	melted	-	Nil
Zinc salt of 2-mercaptobenzimidazole (ZMBI)	0.25	10	melted	-	Nil
	0.50	10	melted	-	Nil
	1.00	8	melted	-	Nil
Stynenated phenol (Antioxidant SP)	0.25	40	10	25	Nil
	0.50	41	21	50	Nil
	1.00	40	16	40	Nil
2, 6 - Di-tert-butyl - p-cresol (Antoxidant KB)	0.25	40	20	50	Nil
	0.50	42	27	64	Nil
	1.00	42	29	69	Nil

natural rubber (LNR) had been studied. NBR compounds containing LNR and dibutyl phthalate (DBP) as plasticiser in varying amounts (0-25 phr) were prepared and tested using a capillary rheometer. Viscosity measurements of the compounds containing 15 phr each of LNR and DBP and of a control compound were made at different shear rates and the results are given in Table - Chem. 3. It was found that LNR acts as a plasticizer and viscosity modifier in nitrile rubber compounds improving its processability.

Table - Chem.3. **Viscosity of NBR compounds at different shear rates**

Shear rate s^{-1}	Viscosity, cps		
	Control	LNR	DBP
8.33	9219	3940	5575
83.30	2535	1181	2168
833.00	507	302	415
83333.00	69	53	59

5. Effect of storage on properties of latex

Periodic testing of high ammonia and low ammonia preserved centrifuged latex during different seasons, was continued. Period of storage was found to influence the properties of vulcanized latex film. Post treatments like heating, leaching, backing and subsequent heating of films prepared from prevulcanized latex improved the properties. Table - Chem 4 indicates the influence of period of storage on physical properties of vulcanized latex film.

6. Comparative evaluation of different forms of NR

The sample collection and testing for raw rubber, vulcanizate and rheological characteristics of different forms of natural rubber collected form various sources have been completed. The precessability properties of black-filled compounds of different grades of natural rubber were also studied using a Brabender Plasticorder.

Statistical analysis of the data is being completed. The results show that the sheet grades are superior in raw rubber properties except volatile matter and plasticity and in technological properties except heat build up. Sheet is also found to have almost comparable level of consistency with that of ISNR 20 in raw rubber and vulcanizate properties. Although ISNR 20 was expected to be more consistent with respect to raw rubber properties, the present processing practices being adopted in the factories do not bring this superiority.

7. Short sisal fibre-natural rubber composites

A mould has been designed for the development of timer belt from short sisal

Table - Chem.4. **Effect of storage of latex on tensile properties of vulcanized films**

Period of storage (months)	Modulus at 100% elongition (N/mm^2)		Tensile strength (N/mm^2)		Elongation at break (%)	
	HA	LATZ	HA	LATZ	HA	LATZ
0	0.72	0.72	31.9	30.7	1252	1225
1	0.72	0.72	31.6	31.6	1275	1283
2	0.73	0.71	30.0	29.5	1240	1217
4	0.74	0.74	32.7	29.1	1265	1243
6	0.70	0.69	29.2	28.7	1246	1213
12	0.59	0.61	20.3	18.5	1117	1096
18	0.54	0.54	14.0	13.0	989	974

fibre-natural rubber composite. Trial runs were taken. Minor modification in the design of the mould was required to improve the quality of the belt.

8. Rubber modified slow release fertilizers

Most of the conventional fertilizers, especially urea, suffer losses through leaching and volatilisation, when applied in field. One approach to delay the rate of release of nutrients is coating of fertilizers with rubber, plastics, resin etc. A project was initiated to prepare natural rubber modified slow release fertilizers. Urea was treated with different forms of natural rubber and its release patterns in soil was investigated. The volatilisation loss of nitrogen from NR modified urea was also compared with that from conventional urea.

9. Rubber blends

Blends of ENR/PVC and NBR/PVC (70/30 each) were compared with polychloroprene (CR) rubber in unfilled condition. NBR/PVC was found to have a slight superiority over CR in the physical properties except flexibility, compression set and flammability. ENR/PVC showed poor ageing properties compared to the NBR/PVC blend.

10. Rubber-to-metal bond failure analysis

Existing standard test methods measure breaking force as an index of bond strength, which may vary with the test piece geometry. Fracture mechanics analysis was attempted on rubber-to-metal bond test pieces (ASTM D 429 method B, ISO 1747 and Goodyear tyre cord adhesion test) to evaluate the bond tearing energy as a measure of bond strength and to express it independent of test piece geometry. Bond tearing might be due to the difference in the nature of failure behaviour of rubber. The visual and microscopic studies also supported this view. This work was done under a UNIDO funded project and was carried out at MRPRA, U.K.

11. Production and applications of rubberised bitumen

For the disposal of vulcanized rejects from industry and also to prepare a suitable composition of rubberised bitumen, a project was undertaken to develop suitable techniques for incorporation of vulcanized rubber with bitumen. For the incorporation of waste rubber such as microcrumb and buffing dust into bitumen, different methods like direct addition at elevated temperature (160°C) and addition after swelling in different solvents, are being tried.

12. Studies on heat transfer and vulcanization of NR compounds

Fillers such as acetylene black, aluminium powder and HAF black were found to improve the thermal conductivity of NR compounds. Physical properties of the vulcanizates were satisfactory at optimum loading of the above fillers. Extent of vulcanization at the centre portion of a 50 mm cube, as measured by the volume fraction of rubber of the swollen vulcanizate, was found to correleate with the thermal conductivity of the compounds. Development of retread compounds with improved thermal conductivity and having the best balance of technological properties is in progress.

13. Development of rubber products

Work was in progress for the development of rubber seals for bearings. A formulation for online leak sealant rubber compound was developed and this has been tried under field conditions by a private firm. Efforts have also been made to transfer the technology for this product to the firm.

AGRICULTURAL ECONOMICS DIVISION

The Agricultural Economics Division concentrated on studies relating to economic aspects of natural rubber cultivation, processing, marketing and end uses. Another important area of research was monotoring of ancillary sources of income such as intercrops and bye-products. Inter-divisional collaborative projects were also undertaken.

1. Commercial evaluation of planting materials

This has been a continuous study undertaken by the division since 1974 with the objective of generating information on the commercial yield of prominent planting materials. The third report of the study was published in 1990 and a comprehensive fourth report is under preparation. A massive database is being created covering details on tapping system, stand, clonal, regional and seasonal variations in yield in terms of latex and field coagulam. The data-base consists of field-level information from 45 large estates for a period of 26 years (1966 -1993). The data pertaining to 1500 fields were added to the computerised data base during the period under review.

2. Economics of tapping systems

The economics of six different tapping systems was analysed on the basis of four year experimental data on RRII 203 provided by the Plant Physiology Division. The estimated short run and long run net income and other performance criteria for first four years of tapping had shown that 1/3S d/1 6d/7 is a relatively more suitable mode of tapping for the small growers. This study has to be extended to popular clones like RRIM 600 and RRII 105.

3. Ancillary products

A study on the status of rubber wood processing industry in India was completed. The projected availability of rubber wood upto 1997-98 is given Table-Age. 1

During 1993-94, there were 31 rubber wood processing units and the gross installed capacity of the industry was only around 15 per cent of the available sawn timber suitable for processing and the capacity utilisation was only 37 per cent. The growth of vertical intergration within the industry was not significant as is evident from the small number of units having attached sawmills/down stream manufacturing facilities. The study highlights the importance of setting up a promotional agency with regulatory powers supplemented with a full fledged R & D wing for the sustained growth of the industry.

Table - Age 1. **Projections of available rubber wood ('000 m³)**

Form of rubber wood	Year				
	1993-94	1994-95	1995-96	1996-97	1997-98
Total rubber wood	1235	1376	1504	1607	1706
Stem wood	741	826	902	964	1024
Sawn timber suitable for processing	259	288	316	337	358

The unit price of rubber wood logs for different end users is presented in the Table - Age. 2.

Table - Age. 2. **Unit price of rubber wood logs for different end uses**

End use	Price range (Rs./m^3)
Packing cases	1300 - 1400
Plywood	1750 - 2250
Treatment industry	2000 - 2500
Grower's realisation	875 - 1050

No significant variation was observed in the rubber seed sector compared to the previous year. Production of rubber honey has shown signs of recovery after the steep decline consequent to Thai sac-brood virus epidemic. The estimated production of rubber honey during 1993-94 was 550 t.

4. Other studies

The other major research programmes included evaluation of the insurance scheme in the context of damage from natural calamities census of planting materials used by small rubber holdings in India during 1989, input subsidy and extent of adoption of modern technology, market structure of medicinal plants, foreign trade in rubber products and operational efficiency of rubber plantations under different levels of management.

CENTRAL EXPERIMENT STATION

The Central Experiment Station of Rubber Research Institute of India at Chethackal, Ranni (Pathanamthitta District) has an area of 254.8 hectares. Several long term field experiments of Agronomy, Botany, Germplasm, Pathology and Plant Physiology Divisions are laid out here. The Station also maintains a germplasm collection of 4000 genotypes and 102 clones of Wickham materials. A team of Chinese delegates, Tree crop specialists from World Bank and Director, Institute of Biological Studies, UK, visited the station. During the period under report, several batches of trainees also visited the station.

During 1993-94, an effective area of about 20 ha was planted for different experimental purposes. The total crop production during the period was 200.98 t. The total rainfall received during the period under report was 3535 mm distributed as shown in Table - Ces. 1.

There were 209 permanent workers and 204 casual workers in the rolls, during the period. The total mandays engaged for different operations in the station during 1993-94 was 74777.50.

The medical unit functioning in the station provided medical services in 14,088 cases during the year.

Table - Ces. 1. **Rainfall distribution**

Month	Year	Rainfall (mm)
April	1993	182.70
May	1993	223.30
June	1993	689.10
July	1993	906.10
August	1993	259.30
September	1993	187.60
October	1993	519.50
November	1993	239.50
December	1993	40.20
January	1994	109.40
February	1994	159.90
March	1994	18.40
Total		3535.00

REGIONAL RESEARCH STATION, ASSAM

The Regional Research Station in Assam concentrated mainly on evolving agro-management technology of *Hevea* rubber specific to this region.

1. Multidisciplinary evaluation of clones

In the 1985 clone trial, maximum girth was recorded in the clone RRIM 600 (52.31 cm) followed by PB 265 (51.72 cm). In the 1986 trial, RRII 118 showed maximum girth (49.50cm) followed by RRIC 195 (49.17 cm). Plants which attained 50 cm girth at 125 cm height were opened for tapping during July 1993 on a 1/2s d/2 system. The yield/tree was highest in the clone RRIM 600 (85.43 ml) followed by PB 235 (70.07ml) where as DRC was higher in PB 235 (28.30) followed by PB 5/51 (27.48)

2. Nutritional studies (immature phase)

In the trials laid out at Mendipather Pather (1986) and at Nayekgaon (1987) higher doses of nitrogen (60 kg N) gave higher absolute girth. A combination of highest doses of N and P together with higher doses of K (60 kg N, 60 kg P_2O_5 and 40 kg K_2O per ha) showed better result at Mendipather. However, at Nayekgaon a combination of highest doses of N, P and K gave maximum growth.

3. Interaction between potassium and magnesium

The observations from the two trials showed that there is a slight depression in girth in cases of highest dose (40kg/ha) of K in both the trials although higher doses of K gave maximum absolute girth. Highest dose (15 kg/ha) of Mg seems to be more effective for giving maximum girth at Nayekgaon trial though a dose of 7.5 kg per ha gave maximum girth at Sorutari. A combination of highest dose of K (40 kg/ha) with a dose of 7.5 kg Mg gave maximum increment in girth (23.35%) at Nayekgaon, whereas at Sorutari a combination of highest doses of K with no Mg gave maximum girth increment (23.12%).

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

The objective of these trials is to compare the efficiency of different sources of phosphatic fertilizers and their combinations.

The trial at Sorutari, started in 1986, revealed that water insoluble phosphatic fertilizer gave highest absolute girth (50.85 cm) which may be due to residual effect of rock phosphate mineralized and made available to plants for a considerable time.

The trial at Nayekgaon, started in the year 1987 with seven treatments showed that water soluble phosphorous with a dose of 60 kg per ha gave highest absolute girth (40.59 cm) though acid soluble phosphorous (60 kg/ha) showed maximum girth increment during the year (21.61%).

5. Genetic transformation of *Hevea* cells by *Agrobacterium tumefaciens*

Eight strains of *A. tumerfaciens* were regularly cultured and maintained in the laboratory. Virulence of each strain was studied by infecting the *Hevea* seedlings and it was proved that *Hevea* cells could be

transformed by introducting *A. tumefaciens* into it.

6. Survey of pests and diseases

Pests and diseases survey was carried out in 66 plantations in Assam, Meghalaya, Arunachal Pradesh and West Bengal and the damage caused by them was assessed by visual scoring.

Repeated massive defoliation of tender leaves caused by *Oidium heaveae* was noticed in most of the locations surveyed. Flowers were also dried up due to attack of *Oidium*. Secondary leaf fall (SLF) disease caused by *Collectotrichum gloeosporioides* was also noticed in most of the plantations surveyed during June to September.

Occurrence of leaf blight disease caused by *Periconia heveae* was noticed in nursery plants in some locations of Assam and Meghalaya which caused pre-mature defolication and die-back. Incidence of brown root rot disease caused by *Phellinus noxius* was noticed in some plantations.

Mild attack of termites, slugs and snails was noticed in some plantations of Assam, Meghalaya and Arunachal Pradesh. Scale insect (*Saisatia nigra*) infestation was noticed by the end of April and it increased gradually in nursery plants upto the end of July and then decreased due to activity of an entomogenous fungus (*Hyprocrelia reineckiana*) which controlled scale insect population biologically.

7. Isolation, identification and maintenance of pathogens

Thirty five fungal isolates associated with various diseases of rubber trees were maintained as stock cultures at laboratory for further mycological studies. Seven more isolates were sent for necessary identification. Screening of *Oidium* and *Gloeosporium* leaf fall disease resistance in different clones of *Hevea* is in progress.

8. Control of powdery mildew

Sulphur dusting was carried out in Sarutari farm for protection against powdery mildew disease. Uneven wintering of different clones necessitated spot dusting even after four rounds of regular dusting. The incidence of powdery mildew disease was below 10 per cent. Spraying the nursery seedlings with a zinc compound chelazin either as powder or as liquid was found to influence powdery mildew incidence.

9. Performance of polyclonal materials

The girth of the plants planted during 1987 varied from 25 to 50 cm at 90 cm height. Plants which attained 50cm girth at 90 cm height were opened for tapping during July 1993. It was found that DRC of latex in individual plants varies from 18/31 per cent. Other yield components were also monitored.

10. Introduction and evaluation of germplasm

Brazilian (650 nos) and Wickham (40 nos) germplasm were maintained in the germplasm nurseries at the experimental farm at Sarutari.

Three hundred and thirty genotypes were test tapped at a hieght of 35 cm from the bud union during April-May 1993. Cup lumps were collected for five tapping days (excluding first 5 tapping days), dried and weighed. Latex density, colour and flow rate were estimated. Plant height and number of whorls and leaves were also recorded.

11. Genetic variability through hybridization

Trees were selected for cross polli-

nation. Twelve different combinations of clones were tried for cross pollination. Though some of the crosses were successful, most of them were destroyed after a few weeks due to the incidence of *Oidium* disease.

12. Influence of stocks on scion

Budding was done on 400 seedlings classified in four classes based on morphological characters by using budwoods of RRIM 600. It is proposed to record plant height, total leaf number, whorls number, leaf area and total protein at three months interval to monitor the effect of stock on the performance of the scion.

REGIONAL RESEARCH STATION, TRIPURA

The Regional Research Station, Tripura situtated at Rubber Board Complex at Bhallukiatilla, Agartala, concentrated on location specific research on various aspects of rubber cultivation. The reasearch farm at Taranagar was expanded by acquiring 18.61 ha making the total area 85 ha.

1. Nutritional studies

1.1 Mature phase

This trial is laid out in a 3^3 factorial design using the clone RRIM 600. The treatments are 3 levels on N (0, 30, 60 kg/ha); P (0, 30, 60 kg/ha) and K (0, 20, 40 kg/ha). The average yield during the period under report is presented in Table - Net. 1. The trial is being continued.

Table - Net. 1. **Average yield (g/tree/tap) for May 1993 to Jan. 1994**

Nutrient	Levels		
	0	1	2
N	34.86	37.53	40.10
P	34.32	39.93	38.25
K	37.36	37.20	37.94

1.2 Immature phase (polybag plants)

The trial was started in 1986 in Tulakona nursery with a view to monitor the response of *Hevea* plants to hgiher doses of nutrients. The mean girth and girth increment for the year 1993-94 are presented in Table-Net. 2.

Table - Net. 2. **Effect of nutrients on girth and girth increment (cm)**

Treatment	Mean girth		Girth increment
	Aug. 93	Feb. 94	
T_1—30:30:30	44.92	46.70	1.78
T_2—30:30(15):30	46.21	47.87	1.66
T_3—60:60:60	48.18	49.86	1.68
T_4—60:60(30):60	47.13	48.84	1.71
T_5—90:90:90	44.92	46.95	2.03
T_6—90:90(45):90	47.41	48.79	1.38

Water soluble form of phsophorus in parantheses

2. Density-cum-nutritional trial

The trial was started in 1987 at Tranagar farm with an objective to study the effect of three densities (D_1:420 plants/ha; D_2:606 plants/ha and D_3:420 plants/ha) and three levels of N P K (M_1 - 40 : 40 : 20; M_2 - 60 : 60 : 30 and M_3 - 80 : 80 : 40) on the growth and performance of two clones RRII 105 and RRII 118. The data on absolute girth and girth increment are presented in Table - Net. 3.

The lower densities D_1 and D_2 have attained the higher absolute girth and girth increment in both the clones. This may be due to the reduced competition between plants.

3. Forms and placement of fertilizers

3.1 Phosphatic fertilizers (immature phase)

From the data collected there does not

Table - Net. 3. Growth of two rubber clones in response to nutrients (March 1993 to March 1994)

Densities	D_1			D_2			D_3		
Levels	M_1	M_2	M_3	M_1	M_2	M_3	M_1	M_2	M_3
RRII 105									
Average girth	38.09	39.18	39.93	36.04	37.23	38.70	35.08	36.82	36.63
Girth increment	10.83	10.11	9.26	8.54	9.36	7.92	6.95	5.74	6.01
RRII 118									
Average girth	40.60	41.64	41.62	39.07	40.50	36.54	38.98	39.47	39.83
Girth increment	11.44	11.56	10.88	9.20	10.22	8.77	6.88	7.73	7.01

seem to be any marked effect of the different source of phosphetic fertilizer on girth and girth increment in clone RRIM 600 planted in 1986 at RRS, Taranagar.

3.2 Mode of fertilizer application (N and P)

This trial was started in 1990. It was observed that plants receiving ammonium sulphate + single super phosphate as band application still had the highest absolute girth as seen in the previous year also. However, the girth increment show variation with the maximum increment being observed during the year, in plants receiving Urea + Mussorie rock phosphate as 30 cm deep pocket placement. The trial is being continued.

4. Agro-ecological and socio-economic impacts

4.1 Impact of different models

The project was started at Nehalchandranagar farm to study the impact of different models of rubber cultivation on soil productivity. The different models of cultivation selected are rubber grown in association with cover crops, with cover crop and banana cultivation, with no cover crop or intercropping, and adjacent area which is barren, *Acasia* platnation which is grown all around the block planting area as energy plantation and a teak and sail plantation adjacent to the site.

Soil profile samples will be excavated and observation on infiltration, soil nutrient status, soil physical properties shall be monitored over the years.

4.2 Litter fall, accumulation and decomposition

In order to study the total rubber litter fall, nutrient recycling and the rate of decomposition, a trial was initiated during 1993. The experiment aims to quantify the total litter fall in a mature rubber plantation and to evaluate its rate of decomposition and nutrient content. The observations accumulated during the period are presented in Table - Net. 4.

5. Evaluation of planting material

5.1 Clone trial (1979)

Tapping was started during 1989. During the current year BO1 panel was completed and tapping was shifted to BO2 panel.

A selection of clones was attempted using the available information on yield and stability (Table - Net. 5). Based on an index combining yield and stability, RRIM 703 was the most stable among all clones. Higher the yield more was the stablity variance.

5.2 Clone trial (1987a and b)

Among the sixteen of the 1987a clone trial, RRIM 612 showed absolute maximum girth of 48.78 cm followed by RRII 118 with 48.17 cm. Reaction of clones for different climatic factors were also observed.

In 1987b trial, RRII 118 showed maximum absolute girth of 46.03 cm followed by SCATC 93-114 with 44.77 cm.

Table - Net. 4. **Litter fall in rubber plantations**

	Total litter fall ha/year	Mean litter (kg)/ha of standing crop	Annual decay constant
Leaves	10,320.2	6,120.1	1.69
Twigs	390.0	284.3	1.37
Petioles	763.3	437.5	1.74
Total	11,473.5	6,842.8	1.68

Table - Net. 5. **Selection parameters for yield and stability**

	Dry rubber yield g/tree/tap	Stability variance	Index 1 (yield +stability ranks)
PB 235	45.81	127.70	16 (S)
RRIM 600	36.85	72.38	16 (S)
RRII 105	33.61	41.49	15 (S)
RRII 703	33.16	5.97	6 (S)
RRII 203	32.64	11.78	11 (S)
RRII 118	29.37	6.73	10 (S)
RRIC 105	28.57	6.45	10 (S)
RRIM 605	27.02	29.48	18
PB 86	26.68	11.97	16
RRII 5	22.31	24.67	19
PB 5/51	22.14	0.10	12
GT 1	20.59	16.44	20
RRIC 52	19.87	31.56	24
Harbel 1	19.05	9.37	19
G1 1	17.00	54.09	28

S : Selected clones

The stability of twelve clones for the agro-climatic conditions prevailing in the region is monitored constantly in the 1987 b clone evaluation trial. One of the major constraints is tropical high velocity winds. RRII 118 was found to suffer more wind damages.

6. Breeding and selection

6.1 Half-sib progeny evaluation

Field planting of the parents and progenies multiplied for evaluation is expected to be undertaken in current planting season. Morphological characters of each candidate is being recorded.

6.2 Full-sib prgeny evaluation

A total of 14 cross combinations invloving RRII 208, PB 86, RRII 105, G1 1, HK 1 and SCATC 88/13 were made. A total of only 352 pollinations could be made due to intermittent rains and mild incidence of powdery mildew disease. Eighteen genotypes are being brought up in the nursery.

6.3 Evaluation of polycolonal seedlings

The seedlings which attined tappable girth are being opened. The trees are proposed to be evaluated on individual basis and on population basis in comparison with a monoclonal garden.

7. Germplasm conservation,evlauation and maintenance

Among the wild Brazilian clones from IRRDB 1981 collections, 366 clones are now maintained at this station. For field evaluation, 24 genotypes are included in one experiment and 80 in an other.

8. Exploitation systems

The components were recorded during April, May, June and July. Sucrose and inorganic phosphorus contents were also analysed from the latex samples. Highest yield (g/tree/tap) was observed in RRII 105 under d/3 system during November. The experiment was concluded in March '94 and a detailed report is being prepared.

9. Growth physiology

9.1 Effect of low temperature

An experiment to study the effect of low temperature on growth was started during November 1993. Data on photosynthesis and other parameters were recorded in 15 clones during November, December, January and February. Clonal differences in photosynthetic efficiency were observed. All these 15 clones will be planted in field during the current season.

Another experiment was started in October 93 to study the effect of low temperature on yield and yield components in ten clones from the 1979 clone trial. Data on yield components were recorded from October to January. Sucrose and inorgainc phosphorus contents were also estimated from latex. Among the clones, PB 235 and RRIM 600 showed higher yeild. Maximum yield was recorded during the month of November.

REGIONAL RESEARCH STATION, MEGHALAYA

The following field experiments were carried out at the Regional Research Station, Tura, Meghalaya.

1. Field experiments at Ganolgre farm

1.1 Multidisciplinary evaluation of clones

Among the ten clones of *Hevea* planted during 1985, PB 235 (51.23 cm) attained the highest average girth which is followed by RRIM 600 (50.20 cm) and RRII 203 (50.07 cm), while the minimum girth was recorded in PB 5/51 (41.15 cm). On the other hand, in 1986 clone trial, RRIC 105 (48.45 cm) attained the maximum average girth among the ten clones, while the least girth was recorded in PCK 1 (34.08 cm). The girth increment was retarded to a considerable extent due to low temperature during the winter seasons.

1.2 Performance of polyclonal seedlings

To study the performance and suitability of polyclonal seedlings in West Garo Hills of Meghalaya, polyclonal seedlings were planted in 1990 and its growth is satisfactory. The seedlings have attained an average height of 225 cm and girth of 8.25 cm. During winter period partial leaf fall was noticed along with growth retardation.

1.3 Rubber based cropping system

The growth of tea, orange and rubber (RRIM 600) under this trial is satisfactory. The performance of tea seedlings is better than rubber and orange. During the year, 465 kg of green tea leaves were harvested. Although orange plants started flowering in the month of February 1994, there was no fruit set.

1.4 Bulk plantation

The clone RRIM 600 has attained average girth of 31 cm and its growth is satisfactory. During winter period girth increment was adversely affected by low temperature.

2. Field experiments at Darachikgre farm

2.1 Multidisciplinary evaluation of clones.

Among the ten clones planted only 45 plants have survived. Their average girth is 26 cm. The high elevation is found to affect adversely the cultivation of rubber in this area.

2.2 Intercropping with perennial crops

Tea is growing well while orange trees have been damaged due to landslide. Polyclonal rubber seedlings did not survive due to low temperature.

3. Experiments in plant breeding

3.1 Hybridization

Although hand pollinations were attempted, cyclones adversely affected their success during the year.

3.2 Ortet selection

Mother trees were initially selected from Baghmara, Wageasi and Karkutta Estates in Meghalaya for ortet selection. Further screening on the basis of yield, rate of flow, panel length etc is in progress.

4. Experiments in plant pathology

4.1 Mushroom culture

Attempts were made to perfect the techniques for preparation of spawn in

polypropylene bags. During the year 12.75 kg of mushroom were produced.

4.2 Plant disease

During the year a survey of rubber disease was conducted in West Garo Hills district. Incidence of powdery mildew disease was noticed in the older plantations in Baghmera and Wageasi regions. No serious disease occured in RRS, Ganolgre farm.

4.3 Soil microflora

A comparative study of microflora of forest of different age against rubber indicated that the age of the forest has no effect in the composition of fungal species. The microbial populations were found to gradually decrease with the soil depth.

4.4 Decomposition of rubber leaf-litter

The litter bag study indicated that it takes about Seven to eight months for complete mineralisation of rubber leaf -litter under natural conditions. The decomposition rate is higher during June-August. The soil mycoflora which helps to accelerate the process of decomposition is being studied.

5. Experiments in plant physiology

5.1 Effect of winter

It has been observed that due to low temperature in winter season defoliation occurred earlier in PB 5/51, RRII 118, and Gl 1 than other clones in 1985 clone trial. In 1986 clone trial, early defoliation occurred in all clones as compared to 1985 clone trial but amongst the ten clones PCK 1 and RRIC 102 defoliated earlier. A temperature of 15°C was required for refoliation irrespective of clones. During winter period girth increment was almost nil because low temperature affected the growth of *Hevea* plants.

5.2 Effect of different aspects of slope

It has been observed that plants are growing better in West South-West aspect of slope than North North - East aspect at 600 m elevation. West South - West aspect of slope showed higher temperature than North North - East aspect of slope.

5.3 Bud sprouting in polyhouse

To find out the sprouting percentage of budded stumps in polyhouse and outside the polyhouse during winter seasons in Garo Hills, 100 nos. of budded stumps of RRIM 600 were planted in the month of November, December, January and February, at one month interval. It has been observed that 70 per cent sprouting was recorded when planted during February inside the polyhouse while 20 per cent outside, 67 per cent, 57 per cent and 51 per cent sprouting were noticed in November, December and January planted budded stumps inside the polyhouse while outside it was 10 per cent, 6per cent and 10 per cent respectively. Maximum and minimum temperature recorded inside the polyhouse than were higher those outside.

5.4 Cold tolerance

The cold tolerance of clones was assessed on the basis of their growth. At a temperature below 10°C, RRII 203, RRIM 605 and GT 1 performed better while PB 5/51 showed poorest growth. In another trial RRII 5 showed higher growth while PCK1 the least.

6. Experiments in agronomy

6.1 Intercropping

The growth of RRII 105 was evaluated under intercropping with banana or pineapple and compared with that of under cover crop. The average girth was higher (25.04 cm) in *Pueraria* cover crop planted area. In banana inter cropping, the girth was lower (20.0 cm) compared to pineapple inter cropping (22.0 cm). But the damage to rubber

plants due to cyclone was minimum in banana intercropped area. Rabbit rearing using leaves of *Pueraria* as forage was also attempted.

6.2 Weed control

The study indicated that glyphosate 3 l/ha and grammaxone 4 l/ha are effective in controlling lalang grass.

REGIONAL RESEARCH STATION, MIZORAM

1. Multidisciplinary evaluation of clones

This trial was started in the year of 1985 with 10 clones. The girth recorded was highest for clone RRII 118 (55.28 cm) followed by PB 235 (55.00 cm). Nearly hundred plants have attained tappable girth.

2. Polyclonal seed garden

In the polyclonal seed garden established in 1988-89, SCATC - 93/114 showed highest girth (38.62 cm) and RRIM 600 the lowest (29.47 cm) at the foot hill. At the middle, GT 1 (36.44) has shown higher girth while RRIM 600 lower (27.64 cm). On the hill top, RRII 118 (37.13 cm) has shown highest girth and RRIM 600 (28.42 cm) the lowest.

3. Influence of physiographic features on growth

In the trial started in 1987, it has been observed that the plants in the eastern aspect have the absolute highest girth (25.15 cm) (Table - Nez. 1)

Table - Nez. 1. Effect of aspects on girth of rubber

Aspects	Girth (cm)
North	20.33
South	22.30
East	25.15
West	23.68

4. Weed management

This trial was started in 1992, with eight treatments and four replications, 'to study the chemical control of lalang (*Impertata cylindrica*) using glyphosate and gramaxone along with manual weed control. Observations were recorded on the weed drymatter.

5. Nutritional trial

The effect of split doses of fertilizers on the growth of young rubber plants is evaluated in this trial. The girth of plants are recorded annually. It is too early to draw conclusions on the effect of split doses on tree growth.

6. Establishment of cover crop

This experiment was started in January 93 in RBD with five treatments and four replications. The clone used is RRIM 600. The objective of the trial is to identify the most suitable planting technique for early establishement of cover crop in the conditions of Mizoram. The treatment includes either cover crop seeds or cuttings planted in single or double strips and also seeds planted in patches. The data on number of nodules per plant and coverage of cover crop indicate that double strip planting of cuttings is superior. The effect of cover crop establishment on the growth of rubber also is being evaluated.

7. Low input agro-technology

A new on-farm trial was started during 1994 to study the low input rubber planting with the following technology (1) use of polyclonal seedlings (ii) reduced pit size (iii) honey comb terrace (iv) judicious cover crop management and (v) chemical control of weeds.

8. Polybag nurseries

Polybag nurseries are maitained at there locations for meeting local needs of planting material.

REGIONAL RESEARCH STATION, WEST BENGAL

The Regional Experiment Station, Nagrakata, West Bengal concentrated on research projects to evolve an appropriate agrotechnology for rubber cultivation in North Bengal region. The station has a small seedling nursery to cater to the demands of the local rubber cultivation.

1. Nutritional studies

In the 1989 trial significant response of fertilizers was noticed after four and a half years of planting. Maximum girth (33.2 cm) was recorded at 60 kg per ha of N. Response to P and K was not significant though maximum girth (32.4 and 32.6 cm respectively) were recorded at 40 kg per ha level for both. The interaction of fertilizer was not significant.

2. Multidisciplinary evaluation of clones

2.1 Clone trial 1990

The performance of different clones in two trials did not vary significantly in girth. In one trial maximum girth was recorded in clone RRII 118 (26.9 cm) and in the second in PB 86 (26.3 cm).

2.2 Clone trial 1991

Maximum girth (13.2 cm) was recorded in clone CH1 and girth increment per year was 5.5 to 6.5 cm for different clones included in this trial.

2.3 Clone trial 1993

The experiment was laid out in with 11 clones as treatments and three replications in the year of 1993, with a view to find out most suitable clone for Dooars area of North Bengal. Significant differences in girth and height were observed. Maximum girth (3.7 cm) was recorded in RRIM 600 followed by RRII 105 (3.2 cm). Minimum girth was recorded by CH2 and PCK 2 respectively (2.6 cm). RRIM 600 showed maximum height (92.7 cm) followed by RRII 105 (64.5 cm) while PCK 2 had the minimum (36.7 cm).

3. Nutrient use efficiency in relation to method of fertilizer application

The experiment was laid out in RBD with four replication having five different treatments The clone RRIM 600 was planted in the year of 1993. The treatments will be imposed by the begining of 1994.

4. Exploitation system

A trial with the clone RRIM 600 has been laid out in the year of 1991 covering an area of 3.5 ha to find out the best system of exploitation under local condition.

5. Evaluation of clone blends

This experiment was started in the year of 1992 covering an area of about three ha to study the performance of different clone blends incomparison to monoclonal population of RRII 105. About 180 plants were planted. The remaining area will be planted during 1994.

6. Block planting

Three clones *viz.*, RRII 105, RRIM 600 and RRII 300 were planted as block planting in 1993 to study the performance of clones under this agroclimatic condition in respect of yield.

REGIONAL RESEARCH STATION, MAHARASHTRA

The Regional Research Station located at Dapchari concentrated on research in irrigation, plant physiological aspects and clone evaluation.

1. Irrigation systems

Irrigation experiment was continued. Annual girth data recorded showed that the trees treated with basin irrigation at 1.00 ETC showed the maximum girth increment. Even though the trees treated with 0.75 and 0.50 ETC had slight reduction in girth increment they registered comparatively better increment, than the drip irrigated trees. The statistical analysis shows that within 1.00, 0.75 and 0.50 ETC of basin irrigation treatments there is no significant difference in girth. However, there is significant difference between control and basin treatments. Under drip irrigation also there is no significant difference in growth among the plants treated with 0.75, 0.50 and 0.25 ETC. However, significant difference between irrigated treatments and control was observed.

2. Effect of irrigation on yield and yield components

Hose irrigation treatment was continued in which both RRII 105 and RRII 118 were treated with three levels *viz.*, 1.00, 0.75 and 0.5 ETC at 600 l per tree. The data shown in Table - Dap. 1 shows that 0.75 ETC treated plants had maximum girth.

Table - Dap.1. **Mean girth data**

Treatmnent	Girth	
	RRII 105	RRII 118
Control	43.6	47.4
T1 (1.00 ETC)	54.4	59.3
T2 (0.75 ETC)	53.0	61.2
T3 (0.5 ETC)	51.8	52.1

3. Clone trial

The clone trial which had been established in 1985 comprising 15 clones was continued and monthly girth data were collected. The data given in the Table - Dap.2 show that the clone RRII 208 performed better than other clones in this trial. The clones RRII 308 and PCK 2 showed poor performance.

Table-Dap. 2. **Mean girth of *Hevea* clones**

Clone	Mean girth (cm)
RRII 208	47.5
RRII 6	43.8
RRIC 100	42.6
RRIC 52	42.6
RRII 105	41.6
RRIC 105	40.9
RRIC 102	42.3
RRII 5	40.2
RRIM 605	40.1
PB 311	38.8
PCK 1	38.3
PB 310	38.7
PB 260	38.6
RRII 300	37.7
PCK 2	37.6

4. Cost evaluation

The trial laid out to estimate the cost of cultivation of *Hevea* plants (RRIM 600) under irrigated and un-irrigated conditions started at 1987 was continued. The girth was recorded every month. The irrigated plants showed a higher mean grith of 48.4 cm whereas the unirrigated plants showed only 34.8 cm.

REGIONAL RESEARCH STATION, MADHYA PRADESH

At the Regional Research Station, Sukma, Madhya Pradesh the following experiments are in progress.

1. Effect of N on growth

The experiment laid out with RRII 105 during the year in an area of one ha is maintained well. Life saving irrigation was given during the summer season.

2. Effect of cultural operations, cover crops and biofertilizers

A uniform stand and better growth is observed in this experiment compared to other areas. Weeding and maintainance of the area was also undertaken.

3. Bulk planting

The total area under bulk planting is 2.5 ha. The plants planted during 1990 show satisfactory growth.

REGIONAL RESEARCH STATION, ORISSA

1. Experimental planting

Three clones, RRII 105, RRIM 600 and GT 1, are being tested in a field trial laid out in 1987. The maximum girth was recorded for the clone RRIM 600 followed by GT 1.

2. Polyclonal seedlings

The polyclonal trees planted in 1988 have attained an average girth of 41 cm. Plants having girth of 50 cm or above have been identified and marked for purpose of further propagation studies.

3. Clone evaluation

Among the ten clones planted in 1990, RRIM 600, PB 310, SCATC 93/14 and Haiken 1 performed consitently well. Maximum girth was recorded in RRIM 600 (17.93 cm) followed by PB 310 (17.86 cm).

In the field trial started in 1991 with nine clones and a polyclonal seedlings treatment, GT 1, RRIM 600 and polyclonal seedlings performed consitently well. While polyclonal seedlings have attained a girth of 10.85 cm, GT 1 showed maximum girth (10.56 cm) among the nine clones.

5. Organic manures

A new trial was laid out in August 1993 with cake-o-meal varying doses of FYM and cake-o-meal and their combinations as treatments. There was no significant difference in the mean girth of plants among the treatments when observed in March 1994.

HEVEA BREEDING SUB-STATION, KARNATAKA

The station at Nettana, concentrated on location specific breeding and evaluation of *Hevea* clones.

1. Trial on growth, yield and exploitation systems

Observations were recorded from the two trials established in 1987 and 1988. In the 1987 trial, mean grith varied from 46.56 (PB 235) to 38.02 cm (RRII 300) with a general mean of 32.83 cm. A few trees were lost in the two trials due to heavy wind. Wind damage in the trial ranged from 3.2 per cent (PB 260) to 16.03 per cent (RRII 105). In the

1988 trial, mean girth varied from 37.71 (RRII 118) to 29.88 (RRIC 36) and the general mean was 32.83. Wind damage was highest for PCK 2 (3.47%) and lowest for RRII 118 (0.62%).

2. Evaluation of ortet clones

There are three seperate trials, with 17 clones each in two and 13 clones in the third. In all the trials, popular clones such as RRIM 600, GT 1 and RRII 105 were common controls. In trial I mean girth varied from 43.39 to 29.44 cm. In trial - II range of girth was from a highest of 41.58 cm to 24.55 cm. In Trial - III mean girth showed a range from 44.64 to 30.00 cm. Mean girth of the control clones was 32.00 (RRIM 600), 37.80 (GT 1) and 35.22 cm (RRII 105).

3. Clone trials

In the 1989 mixed clone trial out of the 14 clones, RRII 203 recorded the highest girth (34.25 cm) and PCK 1 the lowest (24.44 cm). Mean of all the clones was 28.31 cm.

In the large scale trial of five second selections clones from the1954 hand pollination and parent clones as well as a few modern clones, highest girth was recorded for PB 260 (25.17 cm). Gl 1, one of the parents, recorded the lowest girth of 14.25 cm. The general mean was 18.62 cm.

4. Estimation of genetic parameters

The trial initiated was properly maintained. Three rounds of girth recording were done. One round of test tapping was also attempted.

5. General

The station received a total rainfall of 4765 mm during 1993 with highest rainfalls during July (1294 mm) and August (1110 mm). The maximum temperature recorded was 28.5°C in March and minimum was 10°C during January and February.

HEVEA BREEDING SUB-STATION, TAMIL NADU

1. Breeding orchards

In the two breeding orchards established in 1987 and 1988 at the Sub-station at Paraliar low branches were induced. During the flowering season, hand pollinations were attempted.

2. Clone evaluation

In the large scale trial laid out in 1991, the casualties were supplied with stumped buddings and proper care was taken to minimise further casualties. The area was infested with lalang grass and necessary herbicide application was done to control the weed. Repeated attempts were made to establish more cover crops in the area.

3. Selections

Selections, based on test tap yield on the nursery, were vegetatively multiplied. Data on growth and vigour of polyclonal seedlings and assorted seedlings were recorded for a comparative study.

4. General

For laying out three collaborative field trials at the Arasu Rubber Corporation, planting materials were raised in polybags and maintained. A source bush nursery has also been maintained.

AGROMETEOROLOGY UNIT

Graphical representation of the climate at Kottayam was made using 30 years of data comprising rainfall, maximum and minimum temperature, relative humidity and wind speed. Analysis of the rainfall data showed that South West monsoon contributes 64 per cent of the annual rainfall followed by North East and pre-monsoon, where the contribution is 16 per cent each. December, January and February (Winter) together contribute 3 per cent. Here the distribution is more even comapred to the northern parts of the State. Other meteorological variables like temperature, RH and sunshine hours were also analysed.

The data on daily rainfall of the last 30 years (Kottayam) were fed to the computer and analysis was in the final stage to work out the initial and conditional probabilities of occurrence of dry and wet spells of different amounts of rainfall using Markov chain model.

Rainfall variability studies of traditional rubber growing areas and newly introduced area have been undertaken. Collection of rainfall figures is in progress. Time series analysis is being used to define the trends in rainfall, if any.

LIBRARY AND DOCUMENTATION CENTRE

During the year 1993-94, 123 new books and 224 bound volumes of journals were added to the library and the total collection of books and periodicals in the library was 20837 and 17380 respectively. The library subscribed to 165 journals and 9 dailies. About 130 journals were also received either as gift or as exchange.

Four issues of *Documentation List*, four numbers of *Rubber Alert*, 150 issues of *SDI Bulletin* and two issues of *List of New Additions* were compiled and distributed. As part of information dissemination, 12 scientific articles were sent to different institutions/scientists and about 1.35 lakh photocopies of information materials were made by the reprographic section. A bibliographic database for books and bound volumes of periodicals has been developed. During the period 14450 documents have been indexed. The library circulation system was also computerized.

The library is actively participating in the sales promotion of *Indian Journal of Natura Rubber Research* and books *Rubber wood* and *Plant and Soil Analysis* and distribution of 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 services.

ANNUAL EXPENDITURE

Expenditure at a glance (Rs. in lakhs) 1993-94

Head of Account	Expenditure
Non Plan	
General charges	207.96
Schemes	36.75
Projects - CES	73.03
Department of Training	4.99
Total Non Plan	**322.73**
Plan	
General charges	36.81
Schemes	175.86
NERDS Research Component	84.78
Total Plan	**297.45**
World Bank Project	
Schemes	25.30
GRAND TOTAL	**645.48**

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E K Thankamma	Section Officer
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Research divisions and functions

The major research divisions are Agronomy and Soils; Biotechnoloy; 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 of the nutritional requriements of rubber, irrigation, intercropping, cover crop management, weed control and the study of the rubber growing soils. Development of tissue culture and anther culture systems for propagation and crop improvement of *Hevea* are the important areas in which the Biotechnology Division is engaged. The important fields of research of the Botany Division are breeding, evaluation and selection of new clones, propagation techniques, planting methods, anatomical studies and cytogenetic investigations. The Germplasm Division is concentrating on the introduction, conservation and evaluation of *Hevea* germplasm. The Mycology and Plant Pathology Division is engaged in investigations on the diseases and pests of rubber and associated cover crops and their control. The Plant Physiology and Exploitation Division conducts studies on identification of characterstics 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, and Art/Photography. There is also a small experimental farm of 33 ha at the headquarters of the RRII.

Central Experiment Station

The 225 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 Complex for North East India with headquarters at Guwahati, having regional research stations at Agartala in Tipura, Guwahati in Assam, Tura and Darechikgre in Meghalaya and Kolasib in Mizoram. The RRII has also set up regional research establishments at Dapchari (Maharashtra), Kamakhyanagar (Orissa) Nagrakata (West Bengal), Sukma (Madhya Pradesh), Paraliar (Tamil Nadu), Nettana (Karnataka) and Padiyur (Kerala).

Regional laboratories have been established at Muvattupuzha, Calicut and Nagercoil each with a mobile unit for soil and leaf analysis.

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), Mahathma Gandhi University (Kottayam), Cochin University of Science and Technology (Cochin), Indian Institute of Technology (Kharagpur), National Chemical Laboratory (Pune) and Indian Institute of Science (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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