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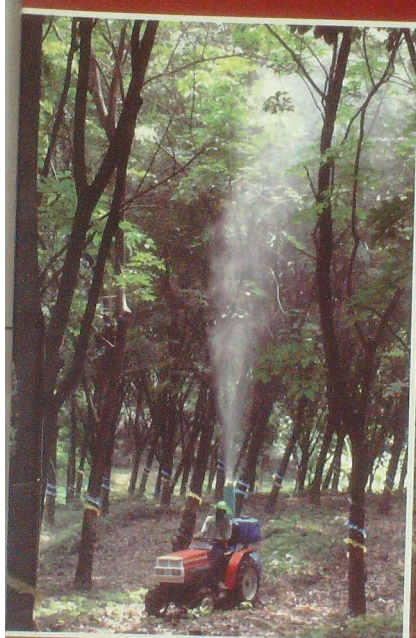

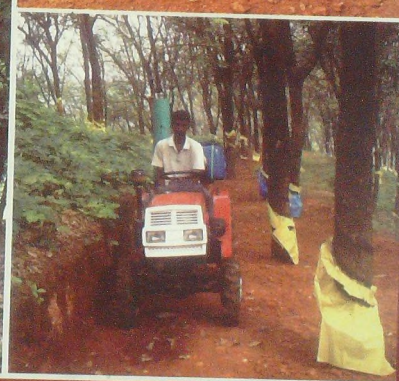

RUBBER RESEARCH INSTITUTE OF INDIA

Rubber Research Institute of India

The Rubber Research Institute of India (RRII), under the Rubber Board (Ministry of Commerce and Industry, Government of India), had its inception in 1955. With a very modest beginning, the RRII is now capable of handling most of the problems associated with natural rubber (NR) production technology, primary processing and product development. The steady growth of RRII in its scientific worth and research contributions has won it the recognition as an International Centre of Excellence in NR research.

Location

The RRII is located on a hillock 8 km east of Kottayam town in Kerala State and is easily accessible by road. Kottayam is connected to all major cities in the country by rail. There are two International Airports, one at Thiruvananthapuram, 160 km south and the other at Nedumbassery, 95 km north of RRII.

Organization

For the efficient discharge of its functions, the RRII has established major research divisions and research supporting sections at its headquarters and regional research establishments at appropriate locations where *Hevea brasiliensis* is commercially grown or is likely to be grown.

Continued on inside back cover

ANNUAL REPORT
2013-2014

RUBBER RESEARCH INSTITUTE OF 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 18 April 1947. This Act was amended in 1954, 1960, 1982 and in 1994. The Act was further amended by the Rubber (Amendment) Act, 2009 which came into force on 22nd January 2010.

Organization

The Chairman is the principal executive officer and exercises control over all departments of the Rubber Board. The Research Department, (Rubber Research Institute of India) works under the administrative control of the Chairman.

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PREFACE

At a time when rubber prices are rather low, scientific innovations assume significance in improving the revenue from rubber cultivation. This can be best achieved through improving productivity and reducing cost of production. Rising costs of inputs and labour limit the scope of reducing cost of production. Therefore, improving productivity becomes central to better returns from rubber cultivation.

The various R & D programmes taken up by Rubber Research Institute of India (RRII) under Rubber Board have a strong bearing on improving productivity and reducing costs, even as sustainability of rubber cultivation is ensured. I congratulate RRII for embarking upon two ambitious new projects namely, fertility mapping of rubber growing soils and *de novo* sequencing of whole genome of *Hevea brasiliensis*. These are two distinctly diverse projects, yet having direct applications for sustaining soil health and improving the genetic potential of natural rubber for better yield and tolerance to pests/diseases and climate stress. I am pleased to note that RRII has started working on mapping natural rubber holdings in Kerala, Tamil Nadu and Karnataka using satellite-based remote sensing technology, a capability that it has mastered recently.

I understand that soil fertility data would be made available "on-line" which will be highly useful for growers. I am happy to note that the "on-line Rubber Clinic" is also visited by large number of growers. Information and communication technology tools such as these should be increasingly used in agricultural extension. These are cost efficient and effective ways of reaching out to a larger population cutting geographic barriers.

Kochi
16 April, 2015

Dr. A. Jayathilak, IAS
Chairman, Rubber Board

DIRECTOR'S REVIEW

Natural rubber prices continued its declining trend for a third consecutive year during 2013-14. Among the three factors that determine the net income from cultivating any crop, namely productivity, cost of production and market price of the produce, grower has control only on productivity and to some extent on cost of production. He has practically no control on price. Various research projects being taken up by Rubber Research Institute of India have the objective of increasing productivity and reducing cost of production.

Agronomy/Soils Division continued their research to evolve improved agro-management techniques for better growth and yield of rubber in different agro-climatic regions, reduce cost of cultivation and sustain soil quality. Soil sample collection (@ one sample per 50 ha) for soil fertility mapping was completed. The fertility data will be uploaded in Rubber Board's website so that growers can remain informed about the soil fertility status of their regions. Experiments on nutrient management in nurseries and young and mature rubber holdings and experiments on cropping systems/mixed planting with timber trees are in progress. Experiments to develop an agronomic package for reducing the gestation period of rubber were also continued. The Fertilizer Advisory Group analysed 5752 soil and 1214 leaf samples and offered 3826 site-specific discriminatory fertilizer recommendations.

Breeding and clone evaluation programmes progressed well both in the traditional and non-traditional regions. The fourth phase of the participatory clone evaluation programme involving growers with 23 pipeline clones was initiated in seven locations. Breeding programmes for abiotic and biotic stress tolerance were intensified, especially in the area of polycross breeding. Studies on response to stimulation in some promising pipeline clones gave encouraging results. New inroads were made in the area of plant propagation with recommendation of the polyhouse technology for rubber nurseries and further research on modification in terms of the container and potting media in root trainer planting technology.

Germplasm Division continued to focus on management of the genetic resources of *Hevea* comprising the 1981 IRRDB wild *Hevea brasiliensis* germplasm collection, domesticated clones derived from the original Wickham stock and five other *Hevea* species. Alternative natural rubber yielding plants species suitable for marginal lands are also being explored.

The Biotechnology Division attempted somatic embryogenesis and plant regeneration from viable leaf cultures. Maturation and germination of embryos (70%) was achieved in the earlier standardized medium containing ABA (0.2 mg L^{-1}) and several plants could be regenerated *in vitro*. Attempts were made for the production of haploids in *Hevea*

brasiliensis from embryo sac isolated from mature female flowers and unfertilized ovule of clones RRII 105, 414 and 430. Multiple gene integration in *Hevea brasiliensis* was achieved through *Agrobacterium* mediated genetic transformation with *MnSOD* and *hmgr*1 gene constructs and a few plantlets were developed. Abiotic stress induced over-expression of *cdpk* gene in *Hevea brasiliensis* was assessed by inducing cold stress. Temporal expression of this gene showed maximum expression after 24 hours of cold stress.

In the Genome Analysis laboratory a large number of SSR and SNP markers were developed using the transcriptome resources generated recently in rubber. Candidate gene based approach for SNP identification in rubber biosynthesis genes also revealed the presence of SNPs and this aided in the identification of haplotypes in popular clones. DNA methylation studies in rubber indicate the possibility of a correlation between the promoter methylation of HMG CoA Reductase and its expression. Construction of genetic linkage map using a segregating progeny population derived from an interspecific cross between RRII 105 (*H. brasiliensis*) X F4542 (*H. benthamiana*) has been continued. In the area of biotic stress tolerance, characterization and functional validation of differentially regulated NBS-LRR transcripts involved in tolerance to Corynespora leaf disease were carried out. A new project on whole genome sequencing has been initiated using NGS platforms for deciphering *Hevea* genomic architecture, essential for dissecting genetic regulation of complex traits which will speed up genetic improvement research through molecular breeding and market assisted selection.

Crown budding experiments at Malankara estate, Thodupuzha and at CES, Chethackal recorded significantly high leaf retention during ALF season. Observation on ALF disease in the newly recommended clones in the on farm trials in small grower's field showed highest retention in the clone RRII 430 (70 to 90%). A Mist blower attachment on mini-tractor for low volume spraying in rubber plantations which can deliver the spray fluid to a height of 95 to 100 feet (fitted with Aspee make atomizer and micronair type atomizer) was recommended for use. The total number of visits to on-line Rubber Clinic during the period was 10882.

Evaluation of six months old polybag plants of RRII 400 series clones by subjecting to water deficit stress for 10 days indicated that RRII 430 may have a better potential for drought tolerance among them. The average canopy level net ecosystem exchange (NEE) of CO_2 in a rubber plantation at CES, Chethackal, measured using the Eddy Covariance system and was about 10.2g CO_2/ m^2/day, which is equivalent to 37 MT CO_2/ ha/year.

The Latex Harvest Technology Division started a new demonstration programme on low frequency weekly tapping in smallholdings. Various grades of biodegradable polythene were developed in a collaborative programme with a private entrepreneur. Two mechanised and two motorised tapping tools were short listed for further field evaluation.

Studies on deproteinization of natural rubber (DPNR) through combined gamma ray irradiation and enzymatic hydrolysis showed that DPNR produced by this method had good raw rubber properties as well as very good mechanical and dynamic properties. The modified coagulant developed was effective in achieving faster coagulation of natural rubber latex.

The Technical Consultancy Division continued testing and R&D activities on industrially important rubber based products and testing/certification of rubber products. Studies found that small amount of nano ZnO will give identical properties when compared with vucanizates made from micro-dispersions of ZnO. The Division gave testing support to 578 clients by testing 1508 products.

An interim report on rubber nurseries by Economics Division suggested introduction of an optional control of rubber nurseries to ensure good quality of planting materials. Analysis of the channel-wise import of natural rubber found an increase in the share of imports through the duty paid channel from less than one per cent in 2008-09 to 47.3 per cent in 2012-13. A study on external trade showed that India has been gradually emerging as a net exporter of latex concentrates and importer of latex based value added products.

During this year a new research discipline, Climate Change and Ecosystems Studies was started. Studies related to identification of suitable agro-climatic regions for rubber cultivation through satellite-based remote sensing techniques, climate risk analysis, climate resilient agricultural techniques, integrating remote sensing and geographic information system technologies for ecosystem management, climate change, carbon sequestration by rubber plantations, water balance of rubber holdings, biodiversity conservation etc. come under this new Division. Mapping of rubber holdings in the traditional areas using latest satellite images is in progress.

The Central Experiment Station Chethackal continued to serve the research requirements of various disciplines. Evaluation of location-specific clones and agro management techniques were the prime activities of the Regional Research Stations. The various Regional Research Stations continued their research activities in their respective priority areas to cater to the requirements of the region. The library, through its information services and publications, continued to serve as a major source of scientific and technical information on natural rubber.

Two issues of *Rubber Science* were brought out during the year under review. RRII published 57 scientific articles in addition to participation and presentation of papers in national and international conferences. The Institute continued its academic association with national and international research institutes and universities.

AGRONOMY AND SOILS DIVISION

The various research programmes of the Division are aimed at development and periodic refinement of agromanagement practices to improve growth and yield of rubber in different agroclimatic regions, reduce cost of cultivation and sustain soil quality. Soil sample collection for soil fertility mapping of rubber growing areas in South India was completed and analysis of soil samples is in progress. Experiments on nutrient management in nurseries, young and mature rubber were continued. Various experiments on cropping systems and mixed planting with timber trees were also in progress. Experiments on planting techniques and ground cover management and stress management were in progress. Experiments to develop an agronomic package for reducing the gestation period of rubber were continued. The Division also functions as a centre for dissemination of knowledge on various soil and crop management techniques, undertakes feasibility studies on cultivation of rubber and intercrops in various agroclimatic regions and investigates specific field problems.

1. Nutrient management

Experiments initiated during 2011, to study the effect of supplementing secondary and micronutrients in areas low in their status, on growth and yield of rubber were continued at four locations. Application of the secondary and micronutrients during first year of planting showed residual effect and maintained the soil status in sufficiency level during the third year also in all the locations. There was no significant difference between the treatments on girth of plants in the four locations.

The field experiment at CES, Chethackal to study the effect of long term use of inorganic and organic manures on the growth and yield of rubber and on the physico-chemical properties of soil was continued. The treatment, 25 per cent recommended dose of chemical fertilizers with 75 per cent FYM continued to be superior in growth over all other treatments. With respect to yield, this treatment and 50 per cent recommended dose of chemical fertilizers with 50 per cent FYM were comparable and significantly higher than the recommended practice with 100 per cent chemical fertilizers (Table Ag. 1).

Table Ag. 1. **Effect of integrated nutrient management on yield of rubber**

Treatments	Yield (g $t^{-1}t^{-1}$)
T_1- No fertilizer/no manure (Control)	24.1
T_2- Farm yard manure (FYM) alone	24.1
T_3- Fertilizers (recommendation)	25.6
T_4- 25% Fertilizers + 75% FYM	30.4
T_5- 50% Fertilizers + 50% FYM	29.9
T_6- 75% Fertilizers + 25% FYM	26.6
SE	1.4
CD (P=0.05)	4.2

Field experiment on use of coir pith organic manure (CPOM) as soil amendment in marginal soils, at Thanneermukkom, Cherthala showed that CPOM and FYM were comparable in promoting growth of rubber plants.

A study was initiated on rhizosphere chemistry and growth of natural rubber

under varying pH and base status. Soil samples were collected from various locations and analysis is in progress.

In the polybag experiment to study the effect of different soil pH on growth of rubber plants, it was observed that the girth and other growth parameters at pH 7.34 and 5.40 were significantly superior to that at pH 4.34.

2. Soil and water conservation

The field experiment to assess the effectiveness of different vegetative hedges for soil conservation in rubber plantation was continued. The establishment of vegetative hedges *viz.* vetiver, guinea grass, pineapple and *Strobilanthes sp.* significantly reduced the rate of soil erosion (Table Ag. 2) and among the vegetative hedges, vetiver and guinea grass were superior.

Table Ag. 2. **Effect of vegetative hedges on soil erosion (2013)**

Treatments	Quantity of soil eroded ($t\ ha^{-1}$)
1. Rubber + Vetiver	1.0
2. Rubber + Guinea grass	1.2
3. Rubber + Pineapple	1.4
4. Rubber + *Strobilanthes sp.*	1.8
5. Rubber alone	2.3
SE	0.12
CD (P=0.05)	0.38

3. Intercropping and cropping systems

The experiment initiated to develop a multi species rubber based cropping system for Tamil Nadu region was in progress. The establishment of intercrops *Morinda citrifolia* (Noni), *Anona muricata*, *Dracaena messangeana*, *Heliconia sp.*, cinnamon and cocoa did not influence the growth of rubber up to four years.

The experiments to evaluate the feasibility of growing perennial intercrops and timber trees with rubber were in progress.

An observational trial was initiated to study the feasibility of cultivating diverse tuber crops and medicinal plants in mature rubber. Five varieties of shade tolerant medicinal plants *viz.*, *Trichopus* zeylanica (Aarogyapacha), *Alpenia galanga* (Kolinchi), *Coleus zeylanicus* (Iruveli), *Kurkuma aromatica* (Kasturimanjal) and *Kaempferia galanga* (Kacholam) and coleus were established in mature rubber plantation. All the crops established well in mature rubber plantation.

4. Ground cover management

The field experiment on the effect of legume covers and natural flora on growth of rubber, soil physico-chemical and biological properties, biomass and nutrient turnover, laid out during 2010 at the Central Experiment Station of Rubber Research Institute of India, was continued. Growth of the plants, 18 months after planting was significantly affected by the presence of weeds and the growth reduction was 20 per cent.

The observational trial initiated at Malankara estate, Thodupuzha during 2009 to explore the feasibility of establishing *Mucuna* under partial shade was continued. Soil moisture in this field was found to be higher than that in the adjacent field without *Mucuna* during summer season. A field trial was initiated at CES, Chethackal for the evaluation of *Calopogonium caeruleum*. It established well in the field and survived during dry season and the rate of growth was found to be less compared to that of *Mucuna*.

Studies on the effect of ground covers on soil acidity showed that *Mucuna* lowered soil pH, *Pueraria* did not change and natural cover increased soil pH in young rubber plantations in 4 years. In mature rubber plantations, *Mucuna* reduced soil pH and increased soil organic carbon status significantly compared to plantations without *Mucuna* and with regular weed control.

The project on comparison of rubber plantations with and without control of weed flora was continued at the two new locations, Paika near Palai and Thumppassery estate, Punalur. It was observed that OC, total N, available forms of P, K, Ca and Mg were significantly higher in no-weeded fields compared to clean-weeded fields in both locations. In an experiment to study the effect of different weed control measures on soil properties, it was observed that soil respiration declined in glyphosate and 2,4-D applied treatments while an increase noted in weed cutter treatment (Fig. Ag. 1).

5. Planting techniques

The experiment initiated to assess the effect of mechanized land preparation on soil erosion and physico-chemical properties of rubber growing soils was continued. Different land preparation methods did not show any significant effect on growth of rubber plants. The rate of soil erosion continued to follow the same trend as that of last year. In the experiment for evaluating different planting design, twin and triangular systems of planting continued to be superior.

6. Development of agromanagement technique for reducing the gestation period

The field experiment laid out at Malankara Estate, Thodupuzha during 2005 for evolving an agronomic package to reduce the immaturity period of rubber was continued. The growth of rubber under the integrated management continued to be significantly superior followed by irrigation + enhanced nutrient application,

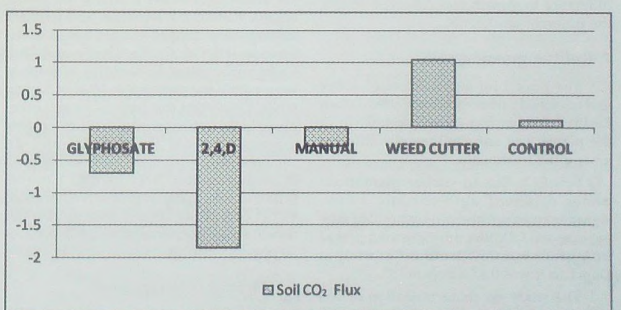


Fig. Ag. 1. **Changes in soil respiration (μmols m^{-2} s^{-1}) 30 days after weeding treatments**

irrigation and conservation oriented tillage which were comparable. Preliminary yield did not indicate any significant difference among treatments. The field experiment initiated at CES, Chethackal during 2008 to reduce the immaturity period of rubber was also in progress. Direct-seeded green budded plants under integrated management was significantly superior to all others and 67 per cent of the plants reached tappable girth in five years and nine months as against 17 per cent in the control (budded-stumps raised in polybags under the current recommended practices).

The field experiment investigating the comparative field performance of one-whorl, two-whorl and three-whorl polybag and root trainer rubber plants initiated at CES, Chethackal during 2008 was continued. The superiority of three-whorl polybag plants over all other planting materials continued.

The field experiment initiated to evaluate the performance of rubber plants budded on stock plants of different age was also in progress and no significant difference in growth was observed among the different treatments.

7. Rubber growing soils

The project on management of active and microbial carbon pools at Pottamkulam Estate, Yendayar was continued. Girth of the plants was not significantly different among the treatments.

Soil CO_2 flux in rubber plantations under different agro-climatic zones, Agratala and Dapchari was quantified. The average soil CO_2 flux during winter period in Agartala was 0.97 µmols m^{-2} s^{-1} while in Dapchari it was 0.67 µmols m^{-2} s^{-1}.

The study on characterization of soil organic matter in rubber plantation was continued. Spectroscopic studies indicated more humification in mature plantation than in immature plantation. Among the various immature systems, rubber – *Pueraria* system showed more aliphatic nature than rubber- banana and rubber – pineapple systems. An incubation study was conducted to estimate the soil carbon mineralization in different rubber based systems. The rate of carbon mineralization was in the order, immature rubber + *Pueraria* > immature rubber + banana = immature rubber + pineapple > mature rubber.

A glass house experiment was conducted to study the effect of higher levels of soil copper on growth of polybag plants of *Hevea*. Graded levels of copper (50, 100, 150, 200, 400 and 800 ppm) were applied to soil as copper sulphate and used for filling polybags. Diameter of plants recorded two months after planting was comparable for control, 50, 100 and 150 ppm Cu levels, while it was significantly lower for Cu levels >150 ppm. After four months, the plant growth was comparable for control and 50 ppm Cu level, while significantly lower for Cu levels >50 ppm.

Analysis of locally available samples of organic manures, P fertilizers and fertilizer mixtures was carried out for heavy metal contents (Pb, Cd, Cr, Zn, Cu, Fe and Mn). Cadmium content in samples of rajphos were within the permissible limit of 5 ppm, while it exceeded this limit in several other phosphatic fertilizers. Analysis of organic manures showed that Cd, Cu and Zn contents were within the permissible limit in urban compost. Very high Cr contents (>1000 to 3000 ppm) were observed in about 40 per cent of the organic manure samples tested, while the permissible limit of Cr is 50 ppm.

8. Drought management

Two field experiments, one with RRII 105 (Experiment 1), a drought susceptible

clone and the other with RRII 430 (Experiment II), a drought tolerant clone initiated at Chimoni Estate, Puthukkadu during 2012 to study the effect of different types of agricultural mulch materials *viz.* coco tree mat, polypropylene woven fabric, coir pith and dry leaf mulch on growth of rubber, soil moisture conservation and weed control were continued. Higher soil moisture content was observed under polypropylene woven fabric compared to dry mulch. Weed regeneration was also less under polypropylene woven fabric (Table Ag. 3). Coco tree mat remained in the field for one year only.

Table Ag. 3. **Effect of different mulches on weed count and DMP (ExperimentI)**

Treatment	Weed count ($No.\ m^{-2}$)	Weed DMP ($g\ m^{-2}$)
Dry leaf	39.8	26.0
Coco tree mat	20.3	8.9
Polypropylene woven fabric	14.7	7.6
Coir pith	40.8	22.7
SE	3.7	3.5
CD (P = 0.05)	11.1	10.4

9. Soil fertility mapping and soil health monitoring of traditional rubber growing regions of Kerala, Tamil Nadu and Karnataka (Collaborative project of RRII with NBSS & LUP, ICAR)

Soil sample collection was completed for soil fertility mapping of rubber growing soils of South India and analyses of soil samples are in progress. Determination of gravel content and digitization of questionnaires are in progress. For soil health monitoring, profile samples were taken from 100 monitoring sites in different agroclimatic regions for analysis of soil physico-chemical properties.

FERTLIZER ADVISORY GROUP

The group provides site-specific fertilizer recommendation on the basis of soil and leaf analysis for optimization of fertilizer use in rubber plantations for both large estates and smallholdings. Dry rubber content of latex samples are also determined at the regional laboratories. The facility is provided through the laboratory at RRII and the nine regional laboratories. Two mobile soil testing laboratories are also functioning for the benefit of the small growers. The details on sample output are provided in the Table FAG. 1.

- Offered fertilizer recommendation to 24 large estates covering 1200 fields by analyzing 500 soil samples and 750 leaf samples.
- Analyzed 5252 soil samples and offered 2626 discriminatory fertilizer recommendation to smallholdings.
- Analyzed 464 leaf samples from smallholdings and offered fertilizer recommendations
- 57072 latex samples were tested for DRC.

Table FAG. 1. **Details on soil, leaf and latex analysis**

Parameter	Number
Soil	5752
Leaf	1214
MST program	50
DRC of latex samples	57072

CLIMATE CHANGE AND ECOSYSTEM STUDIES

The Rubber Research Institute of India has established a new research discipline, "Climate Change and Ecosystems Studies", on 6th January, 2014 for conducting research on climate change and its variability, its impact on rubber cultivation, environment impact assessment, ecosystem services *etc.* Thrust areas of research include identifying suitable agro-climatic regions for rubber cultivation through satellite-based techniques, climate risk analysis, climate resilient techniques, integrating RS & GIS technologies in suitable land and ecosystem management and climate change mitigation policies. It also undertakes studies on carbon sequestration by rubber plantations, water balance of rubber holdings, biodiversity conservation, simulation modeling and natural resource management.

1. Development of rubber based information system using Remote Sensing and GIS

Estimation of natural rubber growing areas of Maharashtra and Goa were carried out using Resourcesat-II L-3 images for the year 2013 having spatial resolution of 23.5 x 23.5m. Satellite based NR area of Maharashtra was estimated to be 1133 ha compared to ground survey statistics of 2098.0 ha indicating 965 ha lower than the ground statistics.

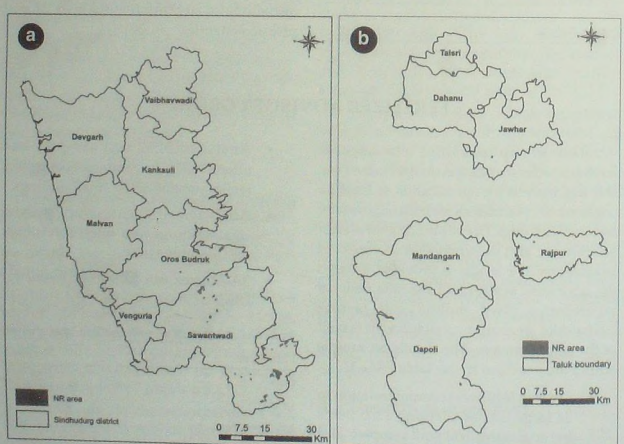


Fig. CCES. 1. **Spatial distribution of NR areas in Maharashtra (a) Sindhu durg district (b) Other taluks**

Table CCES 1. **District-wise NR area statistics for Kerala and Tamil Nadu (2012-2013)**

District	Ground survey statistics (ha)	Satellite based rubber area 2012-2013 (ha)	Variation compared to ground survey statistics in ha (%)	Date of acquisition of satellite data
Thiruvananthapuram	31585	27657	-3928 (-12.4)	25th Feb 2012
Kollam	36960	38998	2038 (5.5)	25th Feb 2012
Pathanamthitta	50700	53718	3018 (6.0)	3rd Mar 2013
Alapuzha	4455	6792	2337 (52.5)	3rd Mar 2013
Kottayam	114105	110724	-3381 (-3.0)	3rd Mar 2013
Idukki	40270	40274	4 (0.01)	3rd Mar 2013
Ernakulam	59555	63623	4068 (6.83)	1st Feb 2011
Thrissur	15410	15734	324 (2.1)	20th Feb 2012
Palakkad	37330	32119	-5211 (-13.96)	20th Feb 2012
Malappuram	42120	38835	-3285 (-7.80)	20th Feb 2012
Kozhikkode	21630	20895	-735. (-3.4)	20th Feb.2012
Wayanad	10610	7567	-3043 (-28.7)	20th Feb.2012
Kannur	47170	54292	7122 (15.1)	5th Mar. 2013
Kasargod	33130	25424	-7706 (-23.3)	5th Mar. 2013
Kanyakumari	20770	21948	1178 (5.7)	25th Mar. 2012
Total	565800	558600	7200 (-1.3)	

It is difficult to map immature rubber areas less than 3 years due to poor spectral signature from the plantations. During ground truth survey, lot of new upcoming NR plantings were observed in the Sindhudurg district of Maharashtra, which will be possible to map after 2 to 3 years. However, satellite based NR area statistics of Maharashtra was comparable with that of Rubber Board, after addition of the new planting area (2256 ha). Spatial distribution of rubber areas in Maharashtra is given in figure CCES. 1. Similarly, satellite based NR area statistics of Goa was 424 ha, which showed a variation of 289 ha with that of ground survey statistics.

Latest satellite data (IRS-RI & RII, LISS-III of 2012 & 2013) procured from National Remote Sensing Centre (NRSC) was used for updating NR area statistics of Kerala and Tamil Nadu. Rubber area distribution maps and statistics were generated for Kerala and Kanyakumari districts of Tamil Nadu. District-wise rubber area statistics of Kerala and Kanykumari is given in Table CCES 1. NR area spatial distribution map of Kerala and

Table CCES. 2. **Satellite based NR area statistics of Kerala, Kanyakumari and Karnataka for the year 2012-2013**

State	Satellite based NR area (ha) 2012-2013	Rubber Board Ground survey statistics (ha)	Variation (ha)
Kerala	536652	545030	-8378
Kanyakumari (TN)	21948	20770	1178
Karnataka	31232	44900	-13668

Fig. CCES 2.NR area distribution of Kerala and Kanyakumari district (2012-2013)

Tamil Nadu is shown in Fig. CCES 2. Area under rubber was highest in Kottayam district followed by Ernakulam and Kannur.

2. NR area variability in high resolution and medium resolution

LISS-IV MX merged Cartosat (2.5 m) and Resourcesat L-3 (23.5 m) satellite data were considered for NR area estimation of four Panchayats in Alathur taluk of Palakkad district and given. Generally the spatial resolution of satellite data is different for high (1:10,000) and medium resolution (1:50,000) satellite data. High (≤5.8 m) and medium spatial resolution satellite data were used for site specific and regional developmental planning respectively.

3. Remote Sensing consultancy service to ATMA

Satellite based mapping was carried out in NR growing areas of the states of Kerala, Tamil Nadu (Kanyakumari district) and Karnataka during 2013 using the latest satellite data (2012 & 2013). NR area statistics and spatial distribution map were generated respectively for the three states. The NR area distribution maps for Karnataka is given in Fig. CCES 3. A large deviation in the area of Karnataka (-13668 ha) (Table CCES 2) was attributed to increasing areas of young plantations

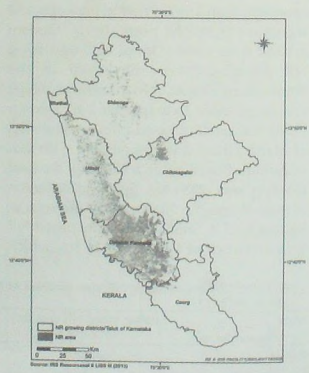


Fig. CCES 3. NR area distribution of Karnataka (2012-13)

comprising ages of less than 3 years in Udupi, Shimoga and Dakshin Kannada districts in Karnataka.

4. Outlook of weather in traditional and non-traditional NR growing regions in India

The major rubber growing areas of Kerala experienced above normal monthly temperature in all months except June (Fig. CCES 4), In Kottayam, annual maximum temperature (Tmax) showed an increase of 1.1 °C above the normal temperature (32.3 °C) in 2013. Highest anomaly was observed during November (2.3 °C) followed by April (1.7 °C). An increase of 0.4 °C in minimum temperature (Tmin) was observed during this year. Annual rainfall recorded was 3229 mm against the normal of 3097 mm. Though the pre-monsoon and post-monsoon period observed a decline in the amount of rainfall, it was well compensated during the South west monsoon. A negative anomaly of 126 mm of monthly rainfall during May was followed by a positive anomaly of 346 mm rainfall during June compared to the normal.

Annual Tmax of 32.8 °C (normal 32.7 °C) was recorded at Parliar. During the month of June and July, a decline in the mean monthly Tmin of 1.9 and 1.1 °C respectively was observed. This might be the effect of the unusual monsoon observed during these months in the State. In general, a decline of 1.0 °C was observed for the annual Tmin. A decline in the monthly Tmin was observed for all months with the highest of 2.1 °C during January. Annual rainfall recorded was 1782 mm against the normal of 1915 mm. The months of June and July registered an increase in rainfall of 131 per cent and 23 per cent respectively. Peak rainfall months of September (159 mm) and October (184 mm) suffered a setback during the year with less amount of rain against the normal of 229 mm and 373 mm respectively.

Annual mean Tmax showed an increase of 0.5 °C at Padiyoor during this

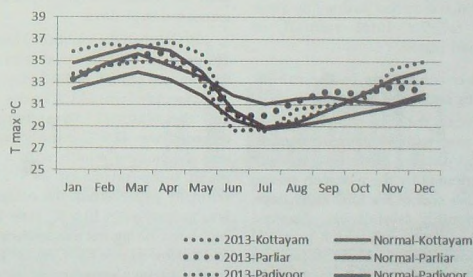


Fig. CCES 4. **Monthly mean Tmax for three rubber growing stations in the traditional region during 2013**

year. A rise in monthly Tmax of 1.6 °C was observed during May and a decline of 0.2 °C was observed in March, the hottest month of the year. Annual mean Tmin showed an increase of 0.1 °C during the year. An annual rainfall of 4076 mm was observed against the normal of 3494 mm. Rainfall received in June and July was 1322 and 1332 mm respectively against the normal of 789 and 915 mm.

In Dapchari, the mean annual Tmax recorded was 32.7 °C against the normal of 33.1 °C. A decline in Tmax of 2.0 and 1.8 °C was observed in June and July respectively. Annual mean Tmin observed during this year was on par with that of the normal (20.6 °C). Tmin showed a decline of 0.2 to 1.7 °C during the peak winter months of December and January. Annual rainfall was 3518 mm against the normal of 2591 mm.

In Nettana, the annual mean Tmax showed an increase of 0.8 °C and the rise in Tmin recorded was 0.4 °C. Nettana recorded the highest rainfall of 5173 mm against the normal of 4681 mm. June and July recorded a rainfall of 1129 and 1873 mm respectively and the rainfall recorded during July alone amounts to the total rainfall of Kanyakumari region.

4.1. Weather conditions in the rubber growing regions of NE India

In Agartala the total rainfall received was 1932 mm with 89 days of rainfall, receiving 50 per cent of the total amount being contributed by the monsoon season within 57 per cent of the total rainy days. Highest monthly rainfall was observed during May (582 mm) which was 170 per cent above normal. About 99 per cent of the annual normal rainfall was received during this year. Mean monthly Tmax fluctuated from 26.6 °C during December to 33.6 °C during June 2013. The monthly Tmin fluctuated from 7.7 to 25.6 °C. Highest daily temperature observed was 36.9 °C during 12th June and 23rd July while the lowest of 3.0 °C was observed during 10th January. In this year a total number of 15 extremely hot days (> 35 °C) were experienced with 34 days experiencing less than 10 °C during the winter period. The month of March showed maximum monthly mean sunshine hours of 7.4 per day.

With an average elevation of 350 m above MSL, Tura (Meghalaya) received 75 per cent (2104 mm) of the normal rainfall in 2013 totaling 92 rainy days. The highest rainfall recorded was in the month of May (582 mm) which was 170 per cent above normal. Mean monthly Tmax fluctuated from 23.2 (January) to 31.7 °C (April) while the Tmin recorded a low of 6.4 (January) to 23.4 °C (July). The afternoon relative humidity recorded as low as 47 per cent during the winter period. The 10th of January recorded the lowest temperature of 0.5 °C and the highest was noted on April 14 (35.4 °C). Number of cold days below 10 °C amounted to 55 days.

In Guwhati the month of May received 190 per cent of the normal rainfall with a total annual rainfall of 1485 mm. Seasonal Tmax recorded was 34.1 °C during monsoon and the seasonal lowest temperature recorded was 12.0 °C during winter. June was the hottest month with a monthly mean temperature of 34.9 °C and as normally experienced, the coldest month was January with 10.6 °C. June 12 and 13 registered the highest temperature of 38.6 °C and the lowest was 7.6 °C on 12th January. A total of 49 days experienced extreme hot days (> 35 °C) and extreme cold days (< 10.0 °C) amounted to 17 days.

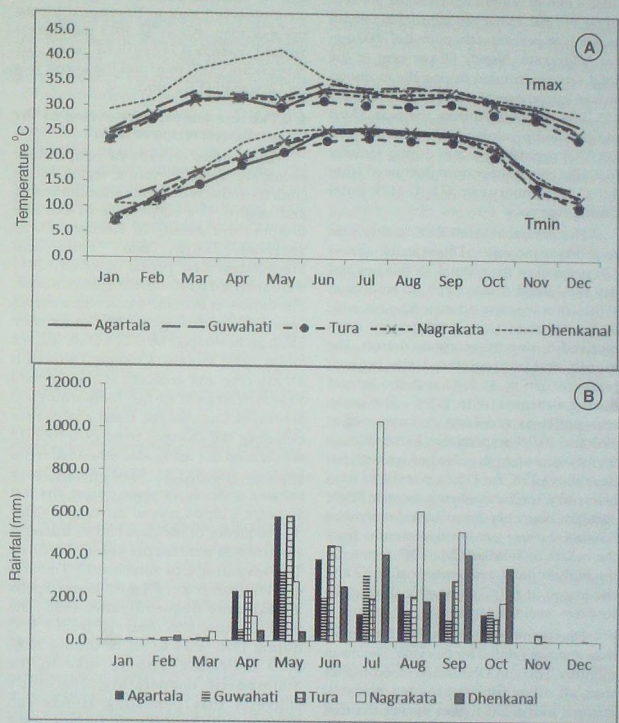


Fig. CCES 5. **Monthly mean Tmax and Tmin (A) and Rainfall (B) for five rubber growing stations in the NE region during 2013**

In Nagrakata the month of July received 1032.4 mm of rainfall which is 102 per cent of the normal. However, the annual rainfall was only 86 per cent of the normal of 3800 mm for Nagrakata. Nearly 80 per cent of the total was contributed during the monsoon season spread over 85 days out of the annual 125 days of rainfall during the year. Mean monthly temperatures peaked during June (33.0 °C) registering a low during January (6.9 °C). Daily temperature fluctuated from 1.0 °C (9th January) to 37.0 °C (13th June) during this year.

The annual rainfall during this year recorded an increase in Dhenkanal to almost 130 per cent of the normal. In this hot and dry sub-humid climate type, an amount of 1699.6 mm was spread over 82 days with 60 per cent of the annual rainy days received during the monsoon season. The month of May registered the highest temperature of 41.3 °C and the lowest during February with 9.7 °C. The mean seasonal Tmax and Tmin also remained at 39.3 and 10.0 °Crespectively. Extremities in temperature were found to be high with hot days above 35°C for 115 days and cold days below 10°C for 36 days during the year. Bright sunshine hours per day exhibited more than 7 hours for four consecutive months from the month of February. May 24th registered the highest daily temperature of 46 °C and the lowest at 8.0 °C constantly during the first two weeks of January.

Dhenkanal station received a higher than average rainfall for this year. The mean monthly Tmax in Dhenkanal stood higher than all other rubber growing research stations in the NE region during the first half of the year (Fig. CCES 5). Overall, the fluctuation of monthly Tmax was from 23 to 41 °C and the Tmin fluctuated from 6.4 to 25.0 °C. Diurnal temperature fluctuations were observed high in Dhenkanal for the pre monsoon season. In 2013 the highest annual rainfall received was for Nagrakata (3253 mm) and the lowest was for Guwahati (1312 mm).

4. 2. Extreme temperature events in the south west region of India

The studies on extreme temperature events are highly relevant at regional scale since the impacts of events are more visible and severe. The occurrence of extreme temperature events in Kottayam was analysed. Daily Tmax, Tmin and precipitation for a period of 1970 to 2010 were analysed for Kottayam district, Kerala. The indices of extreme temperature events were developed using the ClimDex software package developed by ETCCDMI (Expert Team on Climate Change Detection Monitoring and Indices) at the Climate Research Branch of the Meteorological Service of Canada. The trend analysis for detecting the changes from 1970 to 2013 was carried out using Mann-Kendall trend analysis and EXCEL STAT. Mean Tmax showed a steady increase during the last 40 years with an annual increase of 0.035 °C. Frequency of hot days had increased at a rate of 0.56 per cent per year (1970-2010). The magnitude of increase in Tmax is greater than that of Tmin. Warm spells appear more frequently after 1995. The mean increase was observed from 7.8 °C during 1970 -1974 to 9.2 °C during 2006-2010 indicating a sharp hike in the atmospheric temperature. The study suggests that persisting trends can adversely affect small scale farmers in the long run.

BOTANY DIVISION

Genetic improvement programmes for the development of clones possessing high rubber yield, high timber yield and dual purpose clones via conventional methods of hybridization, polycross breeding and ortet selection were continued. The fourth phase of the farmer participatory clone evaluation programme with 23 pipeline clones was initiated in seven locations. The year under report saw intensification of breeding programmes for abiotic and biotic stress tolerance especially in the area of polycross breeding. New experiments to this effect were taken up simultaneously in the non-traditional as well as traditional regions. Studies on response to stimulation in some promising pipeline clones gave encouraging results. New inroads were made in the area of plant propagation with recommendation of the polyhouse technology for rubber nurseries and further research on modification in terms of the container and potting media in the root trainer planting technology were attempted.

1. Evolving high yielding clones for the traditional area

1.1. Hybridization and clonal selection

In one SST of Wx A germplasm hybrids, the top selections *viz*. 90/10, 90/25, 90/34 and 90/271 along with other promising selections, continued to exhibit superior yield over check clone RRII 105. Significant variation in response to ALF disease was observed among the WxA hybrids. Hybrids of full-sib family RRII 105 x RO 142 showed maximum high leaf retention ranging from 59 per cent in 90/21 of family RRII 105 x RO 142, to minimum leaf retention (20%) in 90/168 of family RRIM 600 x RO 87.

In another SST of W x A hybrids, highest girth was recorded in clone 90/55 followed by 90/109 and 90/129. Highest yield was found in RRII 105 (74.3 g t^{-1} t^{-1}) followed by 90/274 (68.8 g t^{-1} t^{-1}) and 90/109 (60.8 g t^{-1} t^{-1}). Out of 34 hybrid clones under evaluation in SST 1995A, 23 clones exhibited significantly higher girth and yield (ranging from 18.7 to 100.1 g $t^{-1}t^{-1}$). Seven clones showed significantly higher yield than the check clone RRII 105. Clone 89/27 continued to yield more than 100 g $t^{-1}t^{-1}$. Clones such as 89/7, 89/27, 89/103, 89/124, 89/308, 89/309 and 89/349 were found promising.

In SST 1998 A, three clones had significantly superior girth than any of the parent clones. Thirteen clones under evaluation showed significantly superior girth than RRII 105. Yield (10^{th} year) ranged from 22.3 to 70.1 g $t^{-1}t^{-1}$ when compared clone RRII 105 (51.9 g $t^{-1}t^{-1}$). Thirteen clones showed comparable yield to check clone RRII 105. In SST 1998B, yield (10^{th} year) ranged from 35.3 to 62.1 g $t^{-1}t^{-1}$ while RRII 105 yielded 36.8 g $t^{-1}t^{-1}$. Three clones were superior in yield to RRII 105. In the 1999 SST 4, hybrids of RRII 105 and RRII 118 showed superior annual mean yield when compared to check clone RRII 105. These clones also exhibited appreciable level of summer yield (Table Bot. 1).

In another SST of 17 hybrid clones from seven cross-combinations planted in 1999,

Table Bot. 1. **Yield of hybrids in the small scale trial (1999)**

Clone	Parentage	Yield (g t^{-1} t^{-1})*,**	Summer yield (g t^{-1} t^{-1})^{ns}
95/306	RRII 105 x RRII 118	102.3 ^{a}	64.3
95/346	RRII 105 x RRII 118	87.9 ^{ab}	41.2
RRII 105	Tjir 1 x Gl 1	66.7 ^{bcd}	43.6

*statistically significant at 5% level; ^{ns}, not significant
**Means followed by a common letter are not significantly different by DMRT

highest yield in the seventh year of tapping was recorded in clones 95/579 (95.3 g $t^{-1}t^{-1}$), 95/95 (89.1 g $t^{-1}t^{-1}$) and 95/131 (84.1 g $t^{-1}t^{-1}$) while the check clone RRII 105 registered 67.9 g $t^{-1}t^{-1}$. The hybridization programme for introgression of genes from Amazonian wild germplasm was continued. Female parents used were RRII 105, RRII 414, RRII 429, and RRII 430 and male parents included three promising WxA hybrids *viz.*, 95/10, 95/34 and 95/274. Ten cross combinations were attempted in 5670 pollinations. A population of 262 hybrid seedlings and 800 half sibs seedlings obtained from two earlier hybridizations under this programme are maintained in seedling nursery for further evaluation and selection. A breeding orchard consisting of 48 clones was established at RRII farm. In order to develop low spreading branches, pruning was carried out at a height of 1.5 meter.

1.2 Ortet selection

In the small scale trials of ortets selected from PCK, Kodumon estate selections, KnO 39, KnO 36 and KnO 49 clones appear to be promising latex – timber clones. They exhibited significantly higher bole volume, better yield and more number of latex vessel rows. Bark thickness of KnO 39 and KnO 36 was comparable to RRII 105. In the SST of ortet selections, O 73 (94.4 g $t^{-1}t^{-1}$) and O 72 (88.1 g $t^{-1}t^{-1}$) continued to exhibit superior yield and girth compared to RRII 105 (65.7 g $t^{-1}t^{-1}$). In the 2007 clonal nursery evaluation at RRII, the clones from Guwahati *viz.*, Guw 4 and Guw 9 and Paraliar (Kanyakumari) *viz.*, Par O 10

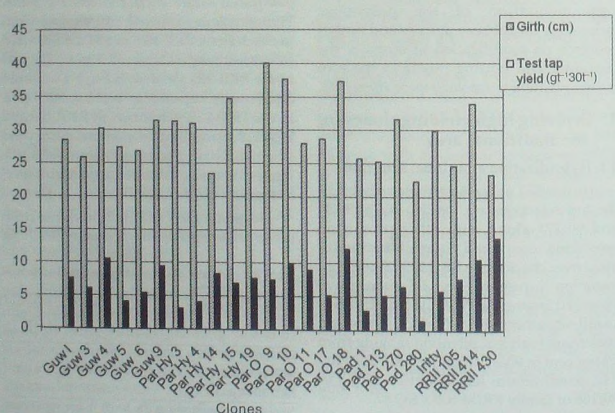


Fig. Bot. 1. **Mean girth and test tap yield of 21 test clones along with controls**

and Par O 18 appeared, promising and comparable to the performance of RRII 430 and RRII 414 in the initial years. The performance of clones from Padiyoor was relatively poor (Fig. Bot. 1).

2. Evaluation of clones

2.1. Large - scale evaluation

The RRII 400 series clones in the first large scale trial at CES, Chethackal were in the first year of tapping in the renewed panel, B.1.1. Clone RRII 105 exhibited a yield of 70.3 – 87.7 g $t^{-1}t^{-1}$. Clones PB 330 (106.8 g $t^{-1}t^{-1}$), RRII 430 (94.2 g $t^{-1}t^{-1}$) and RRII 417 (101.3 g $t^{-1}t^{-1}$) were superior in yield while clones RRII 422, RRII 403, RRII 410 and RRII 52 were on par. Other clones comparable with RRII 105 in terms of yield in the renewed panel were RRII 429 and RRII 427. In terms of girth, clones PB 330, RRII 52, RRII 402 and RRII 407 were superior, while clones RRII 430, RRII 414, RRII 422, RRII 429 and RRII 417 were comparable with RRII 105 in the 20th year after planting.

In another large scale evaluation at CES, Chethackal containing PB clones (1989), yield over 14 years was higher in clones PB 280 (70.7 g $t^{-1}t^{-1}$), PB 312 (70 g $t^{-1}t^{-1}$) and PB 314 (68.8 g $t^{-1}t^{-1}$) which had least pink disease. Clone PB 311 yield 65.5 g $t^{-1}t^{-1}$ with promising yielded stability over the years. This clone was the only promising high yielder with stability in yield over the years. Clone PB 280 excelled in summer yield. While PB 280 had lower TPD incidence (10.73), PB 314 had higher TPD (26.62). Estimates of genetic parameters revealed rubber yield and bole volume a highly heritable trait with $H^2 = 0.7$ for yield over 14 years and 0.8 for summer yield over 11 years.

In the LST (1994) comprising 12 clones, 86/44, RRIM 712 and 86/120 continued to be potential clones. Summer yield of 86/120 (38.3 g $t^{-1}t^{-1}$) was significantly higher than RRII 105 (29.6 g $t^{-1}t^{-1}$). Clone 86/120 also exhibited higher summer yield, more latex vessel rows and lesser pink disease. Wind damage was less in 86/44 and RRIM 712. 86/44 recorded highest yield in RRS, Padiyoor indicating its suitability in diverse agroclimatic conditions. In the 2005 LST of ortet selections from HML Koney, HML Mundakkayam and HML Cheruvally estates, trees were opened for regular tapping. While in trial I, MO 28 recorded a highest tappability of 77 per cent, in trial II Cy O 48 recorded 83 per cent.

2.2. On-farm evaluation

Post release observations on RRII 400 series clones in smallholdings across North, Central and South Kerala were continued. Girth and yield recording was carried out in various locations. In North Kerala, at Ottapalam, Mannarkadu, Tichur, Wandoor and Nilambur, RRII 400 series clones performed well in terms of growth and yield. In all the locations, RRII 400 series clones also had better bark thickness (Tables Bot. 2 & 3).

Regional performance of RRII 400 series clones were evaluated in smallholdings at ten locations in Central Kerala. Mean yield across the locations higher was found for RRII 400 series clones than RRII 105. Highest yield for RRII 414 (71 g $t^{-1}t^{-1}$) was recorded at Ponkunnam; RRII 417 (70 g $t^{-1}t^{-1}$) and RRII 430 (64 g $t^{-1}t^{-1}$) at Malayatoor; RRII 429 (113 g $t^{-1}t^{-1}$) at Aimkombu.

In the 1992 OFT at Shaliackary Estate, yield and girth recording was carried out in six clones (PB 260, PB 280, PR 255, PR 261, RRII 5 and RRII 105). Clone PB 280 continued to perform better than RRII 105. Clone PR 261 also exhibited better yield. In the 1993 OFT (same estate) clones RRII 176 and RRII 50 showed better yield compared to RRII

Table Bot. 2. **Performance of RRII 400 series clones at Pallarmangalam (Ottapalam)**

Clone	Girth (cm)	Tappability (%)	Bark thickness (mm)	Pink disease (%)	Mean yield over 2 years (g $t^{-1}t^{-1}$)
RRII 417	49.3	50.2	8.4	14.4	41.5
RRII 105	44.4	17.4	9.6	22.5	35.2

Table Bot. 3. **Performance of RRII 400 series clones at Wandoor (Malappuram)**

Clone	Girth (cm)	Tappability (%)	Bark thickness (mm)	Mean yield (g $t^{-1}t^{-1}$)			Mean over 3 years
				4^{th}yr	5^{th}yr	6^{th}yr	
RRII 403	55.7	79	-	39.4	56.3	49.9	48.5
RRII 414	57.1	85	9.1	38.9	61.9	47.3	49.3
RRII 422	56.3	85	9.8	43.7	48.6	47.3	46.5
RRII 105	58.7	97	9.5	46.5	67.2	63.1	58.9

105 in the 15^{th} year of tapping. In the OFT at Ayiranalloor (2003), clone PR 261 continued to perform better than RRII 105. In the OFT at Koothattukulam estate, among the 10 clones being evaluated clone 12, RRIC 110 and clone 33/8 exhibited better yield.

New on-farm evaluation of promising clones reflected from in large scale evaluations at HBSS, Nettana was initiated in Udupi District of Karnataka. Eleven selected clones were planted in blocks of 100 plants each. The clones planted in the trial included RRII 105, RRII 203, RRII 414, RRII 417, RRII 422, RRII 429, RRII 430, PB 217, PB 260, PB 312 and PB 314.

2.3. Genetic studies and investigations on genotype x environment interactions

In the multi environment LSTs (1996) initiated to study the G x E interactions, RRII 105 and RRII 430 were found promising high yielders in Kanyakumari. In the North East RRII 429 continued to yield perform better in both the locations. In Nagrakata, RRII 429 had a maximum yield of 87.3 g $t^{-1}t^{-1}$ followed by RRII 417 (83.47g $t^{-1}t^{-1}$), RRII 422 and RRII 430 (75.0 g $t^{-1}t^{-1}$). RRIM 600, the local check recorded 45g $t^{-1}t^{-1}$. Agartala also showed the same ranking with RRII 429 (80.5 g $t^{-1}t^{-1}$), RRII 417 (63.1 g $t^{-1}t^{-1}$), RRII 422 (69.0 g $t^{-1}t^{-1}$) and RRII 430 (61.6 g $t^{-1}t^{-1}$) as against RRIM 600 which recorded 55.3 g $t^{-1}t^{-1}$. In Padiyoor during the 7^{th} year of tapping, RRII 430 was found better yielder (60 g $t^{-1}t^{-1}$) over 7 years of tapping and all the RRII 400 series clones except RRII 429 other showed comparable yield with RRII 105 (51.0 g $t^{-1}t^{-1}$). In Bhubaneswar, RRII 430 and RRII 429 continued to record significantly superior yield compared to RRIM 600 during the 4^{th} year of tapping. However, the trial was discontinued owing to cyclone damage.

A multi environment polybag nursery experiment was conducted for physiological evaluation for drought/cold tolerance in pipeline clones at RRII, Kottayam, RRS, Dapchari and RRS, Agartala. Membrane permeability was measured in 45 pipeline clones after subjecting the polybag plants to drought and cold stress. Further, gas exchange parameters were measured in polybag plants raised at RRS, Dapchari and at RRS, Agartala. Few promising pipeline clones have been identified. The data needs reconfirmation during one more season.

3. Participatory evaluation of rubber clones

Under Phase 4 of the project, for laying out on-farm trials polybag nurseries were established at six locations (Thrissur, Mundakayam, Kulathupuzha and Kozhikode of Kerala; Nettana, Karnataka; Bethany Estate, Kanyakumari) with the central large scale trial at RRII farm, Kottayam. A total of 24 pipeline clones and four check clones (RRII 105, RRII 414, RRII 417 and RRII 430) were raised.

In the Phase 1 PCE trial at Koottickal estate, RRII 414 recorded a highest girth of 45.32 cm (6th year of planting). Three pipeline clones *viz.* P 072, P 026 and P 076 recorded mean girth above 40 cm. In the participatory evaluation of 14 rubber clones, at Kollamkulam estate, Kanjirappally, P 072 and P 026 exhibited better growth (2008 planting). Among the check clones, RRII 414 was found most vigorous (42.7 cm) whereas RRII 105 recorded lowest girth (29.7 cm). In PCE Phase II trial at Vaniampara estate also, RRII 414 showed a highest girth of 33 cm during 4th year of planting. Among the pipeline clones, P 080 showed highest girth (28.8 cm).

4. Breeding for other specific objectives

4.1. Breeding for drought tolerance

Assessment of SST (1998) consisting of fifteen hybrids, hybrids from families involving RRIC 52 and RRIC 104 exhibited higher mean yield compared to other families. Hybrids of family RRII 105 x RRIC 52 showed an average of 47.1 g $t^{-1}t^{-1}$ while those of family RRII 105 x AVT 73 showed an average of 30.1 g $t^{-1}t^{-1}$. Hybrids produced using RRIC 52 and RRIC 104 attained higher girth compared to check clone RRII 105.

Yield performance of hybrids developed for drought tolerance was assessed in the 8th year of tapping in the SST 1998 B of hybrid clones. The hybrid clone 93/58 (98 g $t^{-1}t^{-1}$) continued to yield higher than RRII 105 (75 g $t^{-1}t^{-1}$). In the small scale trial (1998) of ortets selected for drought tolerance from Dapchari (8th year of tapping), Dap 111 continued to record maximum yield (108 g $t^{-1}t^{-1}$) followed by Dap 236 (106 g $t^{-1}t^{-1}$) while RRII 105 yielded 89 g $t^{-1}t^{-1}$.

In a batch of 52 hybrids (from three cross combinations) planted for small scale evaluation in 1999 along with their parents at CES, Chethackal, eight hybrids were found superior in terms of mean yield over six years of tapping. The yield of these clones ranged from 57- 66 g $t^{-1}t^{-1}$. Among these, seven hybrids were of parentage RRII 105 x RRII 118.The best among these hybrids were multiplied and established in polybags at RRS, Dapchari for hot spot evaluation in a large scale trial. In another batch of 14 hybrids evolved from drought tolerant parents (seventh year of tapping at CES, Chethackal), highest yield was recorded in clone 94/44 (109.2g $t^{-1}t^{-1}$) followed by 94/23 (81.7 g $t^{-1}t^{-1}$) and 94/101 (59.1 g $t^{-1}t^{-1}$) while the check clone RRII 105 recorded 56.3 g $t^{-1}t^{-1}$.

In order to develop drought tolerant clones for the non-traditional area, the drought tolerance capacity of the selected progenies from a cross between high yielding parent (RRII 105) and a drought tolerant parent (PB 280) and also its reciprocal (PB 280 x RRII 105) are being evaluated in a clonal nursery trial in the drought prone area (RRS, Dapchari). Forty such hybrid clones along with nine control clones were established in the experimental field at RRS Dapchari.

A study aimed at developing drought tolerant root stocks for the non-traditional area by evaluating the drought tolerance capacity of the seedlings from non-

traditional areas as against the seedlings from traditional areas is being carried out in a nursery trial at RRS, Dapchari. Seeds were collected from three drought prone non-traditional rubber growing areas *viz.*, Maharashtra (RRS Dapchari), Orissa (RRS Dhenkanal) and Karnataka (HBSS Nettana) and from traditional areas *viz.*, Kerala (CES Chethackal) and Tamil Nadu (HBSS Paraliar). Assorted seeds as well as seeds from polyclonal seed gardens and also from drought tolerant clone RRIM 600 and drought susceptible clone RRII 105 were collected from each location. Seeds of drought tolerant clone RRII 203 from Orissa were also collected. The plants were maintained under rain fed condition. Pre-summer data showed that growth of assorted seedlings from Kanyakumari was significantly superior. Source location significantly influenced pre-summer growth. Shoot growth in seedlings from traditional area (Kanyakumari and Chethackal) were significantly superior and non-traditional area were inferior during pre-summer.

4.2. Breeding for disease tolerance

For improving disease tolerance in *Hevea* and for developing a mapping population for molecular breeding, hybridizations were carried out between RRII 400 series clones and RRII 105 (female parents) and Fx 516 (male parent). Since there is asynchrony in flowering between the clones, pollen collected from Fx 516 were stored at various temperature regimes (4 °C, -20 °C, -80 °C and -196 °C) and used for hybridization. Reciprocal cross was also attempted between Fx 516 as female parent and clones *viz.* RRII 414, RRII 105 and RRII 429 as male parents and initial fruit setting was also observed. Open pollinated progenies (272 nos.) were collected from the disease tolerant clone Fx 516 and seedling nursery was raised at CES, Chethackal, for evaluating disease tolerance.

4.3. Polycross progeny evaluation

Study of response to stimulation in clones evolved from progeny of prepotent parents was undertaken by applying three rounds of ethephon as per recommended practice. In Trial 1, clones 116 and 27 showed higher yield and response to stimulation when compared to RRII 105 (Table Bot. 4). Clones 151, 90 and 47 having comparable yield with RRII 105 also recorded better response to stimulation with more than 60 per cent yield increase.

Table Bot. 4. **Response to stimulation in clones under Trial 1**

Clone	Pre stimulation yield ($g\ t^{-1}t^{-1}$)	Yield on stimulation ($g\ t^{-1}t^{-1}$)	% increase
4	71.0	93.1	31.2
37	88.5	120.0	35.6
38	60.8	74.6	22.7
80	78.6	109.5	39.3
106	128.8	157.8	22.5
151	56.5	92.4	63.5
162	51.44	98.2	90.8
147	117.6	136.2	15.8
172	128.9	148.9	15.6
116	80.4	141.4	75.9
90	47.1	76.2	61.7
35	35.9	47.8	33.1
47	56.1	92.7	65.3
27	83.3	125.8	51.0
RRII 105	61.3	91.0	48.4

In Trial 2, high yielding clones, *viz.* clones 191, 69, 112, 188, 19 and 180 recorded better response to stimulation compared to RRII 105 with 71, 53, 71, 58, 78 and 76 per cent yield increase respectively (Table Bot. 5). Other high yielders such as 161, 132, 93, 199, 82 and 117 recorded lesser response to stimulation than RRII 105. Few low

yielders such as 40, 140, 89 and 81 recorded very high response and attained higher yield under stimulation.

The polycross progeny trial (1995) consisting of progenies from nine clones from a polyclonal seed garden was opened for tapping in September, 2012. Almost all the polycross progenies exhibited comparatively better yield than RRII 105. Similarly, half-sib families of polyclonal origin showed better girth.

In order to estimate outcrossing rates between various clones, open-pollinated polycross progenies were collected from polyclonal seed garden at Kanyakumari (Tamil Nadu) during 2013. A seedling nursery trial consisting of a total of 453 open pollinated progenies was established at CES in 2013.

Polycross breeding was intensified in various locations for evaluation and selection of the best genotypes for developing location specific clones. Open pollinated seeds were collected from poly-clonal seed gardens and multi-clone trials of various locations. Seeds were collected from Agartala, Mizoram, Nagrakata, Tura, Guwahati, Dapchari, Nettana, Kanyakumari, CES and RRII. Over 6000 germinated seeds were transported to Dapchari, Nagrakata and RRII. Germinated seeds were planted for nursery evaluation in the fields (RBD design with three replications) in three locations.

5. Anatomical investigations

Bark samples were collected from four trials and structural parameters were recorded for 68 clones. A total of 27 clones recorded higher values for bark thickness (7.8 mm for PB 217) and 26 clones for latex vessel rows (17.61 for clone 272) over control clone RRII 105. A pioneering study revealed that a large number of particles dispersed in the viscous medium of sieve tube are in a continuous state of motion. These objects showed both linear and chaotic motion, developing spatial display of patterns with respect to time. Histochemical characterization of these objects both in healthy and Tapping panel dryness (TPD) affected conditions was carried out.

Anatomical study of roots developed in the modified root trainer plants (MRTP) was undertaken. Three months after planting MRTP in the field, the root system of the plant attained a total length of 134 cm. Anatomical studies revealed that lateral roots are different from tap root (developed adventitiously from the callus tissue of the tap root) irrespective of its site of collection from the lengthy root core. Distinct unilayered epiblema with lot of fine

Table Bot. 5.**Response to stimulation in clones under Trial 2**

Clone	Pre stimulation yield ($g\ t^{-1}t^{-1}$)	Yield on stimulation ($g\ t^{-1}t^{-1}$)	% increase
161	119.4	150.7	26.2
191	63.0	107.6	70.8
81	36.5	65.2	78.7
93	74.3	107.9	45.4
132	127.9	166.8	30.4
140	35.3	67.6	91.8
199	71.4	98.4	37.8
82	120.2	144.4	20.1
69	88.9	135.9	52.9
112	113.7	194.8	71.3
188	71.5	112.7	57.7
19	75.8	134.6	77.6
89	36.2	92.6	155.7
180	81.7	144.00	76.2
40	32.6	79.8	144.6
52	46.0	54.3	18.1
117	134.3	182.7	36.0
RRII 105	51.9	76.5	47.4
RRII 105	45.7	76.6	67.7

roots, cortex, single layered endodermis and pericycle, quadrangular stele with four protoxylem points, quadrangular pith devoid of starch grains, pith cells with birefringent property under polarized light etc. are characteristic to lateral roots. Development of cork cells, circular stele with the development of secondary tissues, single layered endodermis, multilayered pericycle, circular pith devoid of birefringent property, occurrence of starch both in the xylem and pith cells were the characteristic features found in the lateral roots developed in Root Elongation Tube (RET) and in the soil.

6. Investigations on rubber wood

Studies on variation in timber production and wood quality parameters of RRII 400 series are concluded. Bole volume of all the test clones was found superior to RRII 105. The green moisture content of the RRII 400 series clones except RRII 422 was on par with traditional clones. RRII 430 and RRII 417 recorded maximum basic density of (664 kg m^{-3}) followed by RRII 414 (653 kg m^{-3}). RRII 105 recorded 641 kg m^{-3} whereas RRIC 100 recorded a lower density. The density of RRII 430 and RRII 417 was significantly superior to that of RRIC 100. Volumetric shrinkage values in green to air dry (G-AD), green to oven dry (G-OD) and air dry to oven dry (AD-OD) conditions of the test clones were on par with that of the parental clones.

Clonal variation was significant for the major mechanical properties also. RRII 105 (755.9 kg cm^{-2}) and RRII 430 (748.8 kg cm^{-2}) recorded maximum values for Modulus of Rupture (MOR) and were significantly superior to RRII 414 and RRII 422. RRII 417 and RRII 429 were on par with both RRII 105 and RRIC 100 while RRII 422 recorded the lowest value (576.0 kg cm^{-2}). Modulus of elasticity values ranged from 47573 to 65790 kg cm^{-2}. In general, except RRII 422 the new clones had strength properties comparable to RRII 105. The high timber volume, high density and comparable mechanical properties of RRII 430 and RRII 417 with that of RRII 105, make them qualify as latex timber clones while RRII 414 and RRII 429 were moderate.

In order to identify wood traits for genetic improvement, heritability of fibre and related traits were assessed using a mature full-sib population of *Hevea*. Fibre traits (length, lumen width, wall thickness) were recorded and analysed using Nikon NIS-Elements Image Analyser. Based on heritability estimates using various parent-offspring combinations, fibre width was found to have very high heritability compared to other traits (Table Bot. 6).

7. Studies on propagation

Polyhouse technology offers cost effective production of quality planting materials of rubber. It is profitable and eco-friendly mainly due to lesser investment on

Table Bot. 6. **Narrow sense heritability (h^2) of fibre traits in *H. brasiliensis***

Parental combinations	h^2			
	Fibre length	Fibre width	Fibre lumen width	Fibre wall thickness
Offspring - 'mid-parent' mean	0.15	0.70	**	0.50
Offspring - female parent	0.19	0.35	**	**
Offspring - male parent	**	0.19	0.56	0.27

controlling leaf diseases, weeds and water requirement. Number of plants generated for sale under the polyhouse condition was higher than the outdoor conditions. Net profit from production of 1000 green budded plants $year^{-1}$ in polyhouse was Rs. 45,950/- in a five year period.

MRTP with a lengthy root system characterized by 10-15 stiff vertical roots, large number of laterals and fine roots were developed. Root architecture was found modified in the root elongation tube (RET) which is attached to the root trainer cup. A field trial at RRS, Dapchari was initiated with MRTP to study its early establishment and subsequent growth performance under irrigated and unirrigated conditions.

When both natural and synthetic materials were tried as potting medium, better root core was recorded for coir pith as potting medium (50.8cm) followed by PVC dust (25.3), thermocole (24.7), black soil (19.9), red soil (18.9) and the least value for tyre dust (13.6).

In a study on single root stock vs. double root stock plants, the mean girth of the plants was found to be statistically comparable during the first four years of tapping. On excavation after 17 years, only less than 27 per cent of the twin stock were found to have two separate root system and in other cases, either the two roots were united or one root aborted (Fig. Bot. 2). The present study revealed that twin stock does not have any advantage.

Fig. Bot. 2. **Comparison of the size of root system (a) single stock (b) twin stock**

GERMPLASM DIVISION

Management of the genetic resources of *Hevea* comprising the 1981 IRRDB wild *Hevea brasiliensis* germplasm collection, domesticated clones derived from the original Wickham origin and five other *Hevea* species is the focus of the Division. Alternative natural rubber yielding plant species suitable for semi-arid stress prone areas and marginal lands are also being explored.

1. Introduction, conservation and documentation

1.1. Domesticated genepool (Wickham collection) from secondary centers

This genepool comprises 183 Wickham clones being conserved in a clone museum at RRII, Kottayam and two germplasm gardens at CES, Chethackal.

In the Germplasm Garden 1992, among the five IRCA clones evaluated,

IRCA 130 and IRCA 111 continued to show superiority over RRII 105 for vigour, dry rubber and timber yield. In the Germplasm Garden 94, statistically significant clonal differences were recorded for girth and yield. In the 10th year of tapping, among the 20 clones, RRIM 609, RRIC 100 and RRII 23 were superior to the remaining clones (85.7-81.9 g $t^{-1}t^{-1}$) for yield and PB 255, RRII 23 and RRIC 100 were superior in terms of girth (101-99.7 cm). Control clone RRII 105 had an average girth of 74.5 cm and yield of 49.0 g $t^{-1}t^{-1}$. RRIC 100, RRII 23 and RRIM 609 were identified as the best clones for yield and girth.

1.1.1. Formulation of DUS testing norms in Hevea

The juvenile data collected from the three locations is being compiled and a few other potentially useful traits were also examined for consistency. Data on 16 trunk and branch traits and wintering pattern in a set of 25 mature clones at RRII, were taken to identify those that can be used for DUS, of which 10 showed relatively more consistency and may be tested in the DUS MLT. Quantitative data on girth and height have also been recorded to measure GxE effects for these clones, along with pre and post winter and summer data.

1.2. IRRDB 1981 wild gene pool

1.2.1. Conservation nurseries

3576 wild accessions are being maintained in different field conservation-cum-source bush nurseries (SBNs). Re-establishment of the conservation nurseries has been carried out. The first three re-established nurseries (SBNs 2003, 2004 and 2005) comprising of 550, 975 and 701 wild accessions respectively, were cut back, after ensuring proper identity. The fourth set of 806 accessions planted in SBN 2006 in an augmented RBD with four controls is maintained properly. Accessions AC 3123 and MT 745 from this nursery recorded 50 per cent test tap yield of RRII 105.

1.2.2. Arboretum

An arboretum comprising the entire *Hevea* germplasm including wild germplasm accessions and Wickham clones, is being established at Teksragre farm, Tura, Meghalaya. This germplasm repository is for studying the tree architecture, and for hybridization and generation of open pollinated seeds. 106 wild accessions and 6 Wickham clones were multiplied as the first set and a polybag nursery was established at Ganolgre Farm, Tura for field planting in May 2014. Another arboretum established earlier at CES, Chethackal comprising of 120 accessions is being maintained.

1.3. Other *Hevea* species

This genepool, comprising 6 accessions of 5 other species available at RRII (*H. benthamiana, H. spruceana, H. nitida, H. camargoana* and two accessions of *H. pauciflora*), along with five natural putative interspecific hybrids, two *H. brasiliensis* clones, and FX 516 (an interspecific cross between *H. brasiliensis* and *H. benthamiana*), are being conserved in an arboretum planted at CES in 2006.

2. Characterization and preliminary evaluation

At RRS, Padiyoor, monthly yield and annual girth was recorded in 171 wild accessions in PET 2000A. Accession MT 4219 recorded the highest girth (78.0 cm) followed by AC 4140 (76.5 cm) and MT 387 (75.3 cm). Highest annual yield was recorded in accession RO 2786, AC 2670 and RO 2136. Yield and girth were recorded in PET 2000B at RRS, Padiyoor. Among the 166

wild accessions, accession AC 341 recorded the highest yield (61.1 g $t^{-1}t^{-1}$) and the remaining potential yielding accessions were MT 4351(34.0 g $t^{-1}t^{-1}$) and RO 210 (36.5 g $t^{-1}t^{-1}$). Among the check clones, RRII 105 recorded 38.1 g $t^{-1}t^{-1}$ whereas yield of RRIM 600 was 28.6 g $t^{-1}t^{-1}$ and RRII 208 recorded 26.4 g $t^{-1}t^{-1}$. Accessions AC 647 and RO 2883 continued to be the timber potential clones. In PET 2002, AC 567, AC 1964 and AC 824 recorded the highest girth.

3. Further evaluation and selection

3.1. Clonal nursery evaluation

The first round of test tapping was carried out in the clonal nursery planted in 2010 at CES, Chethackal, comprising 15 selected wild accessions from SBN 2004 having 50-80 per cent test tap yield of RRII 105, along with three check clones planted at a spacing of 2.5 x 2.5 m. The highest yielder was MT 5078 (8.7 g $t^{-1}10t^{-1}$) followed by AC 3211 (7.7 g $t^{-1}10t^{-1}$) and AC 2199 (7.6 g $t^{-1}10t^{-1}$) whereas the check clone RRII 414 recorded the highest yield (24.5 g $t^{-1}10t^{-1}$) followed by RRII 430 (22.3 g $t^{-1}10t^{-1}$) and RRII 105 (11.2 g $t^{-1}10t^{-1}$). MT 5078 recorded the highest girth (18.5 cm), while among the check clones RRII 414 had the highest girth (21.5 cm).

3.2. Further evaluation trials

In the further evaluation trial FET 1995 at RRS, Padiyoor, biochemical parameters of 8 relatively high yielding wild accessions and 5 low yielders were measured (Table

Table Ger. 2. **Mean dry rubber yield of potential accessions**

Accessions	Dry rubber yield (g $t^{-1}t^{-1}$) during various tapping years		
	6th year	7th year	8th year
AC 166	58.8 (90.7%)	63.7 (99.7%)	65.3 (101.9%)
AC 2004	57.6 (88.9%)	57.9 (90.7%)	54.9 (85.7%)
RO 2385	54.2 (83.7%)	57.1 (89.38%)	61.1 (95.5%)
RO 2908	53.5 (82.8%)	54.8 (85.89%)	54.6 (85.2%)
RRII 105	64.8	63.9	64.0
CD(P= 0.05)	16.01	17.99	20.06

* Figures in parentheses : % of the yield of the check clone, RRII 105

Table Ger. 1. **Latex biochemical parameters in different germplasm accessions**

Category	Accessions	Yield (g $t^{-1}t^{-1}$)	ATP (µM)	Sucrose (mM)	Thiol (mM)
High yielding accessions	AC 166	53.4 ± 9.1	265.9 ± 7.1	12.6 ± 2.6	0.126 ± 0.003
	MT 1020	36.3 ± 4.8	175.9 ± 4.2	7.9 ± 0.9	0.12 ± 0.009
	MT 179	31.6 ± 8.8	183.1 ± 12.3	13.9 ± 2.2	0.146 ± 0.021
	RO 2629	44.9 ± 1.3	230.8 ± 16.8	9.4 ± 0.5	0.129 ± 0.014
	AC 675	32.5 ± 2.5	191.5 ± 5.0	12.3 ± 2.3	0.138 ± 0.015
	RO 2385	26.1 ± 5.6	241.6 ± 7.5	13.9 ± 2.5	0.197 ± 0.045
	AC 2004	35.7 ± 4.6	270.8 ± 3.9	8.8 ± 0.6	0.160 ± 0.024
	AC 655	37.6 ± 8.7	197.8 ± 6.9	11.2 ± 1.1	0.135 ± 0.021
Low yielding accessions	AC 707	4.8 ± 1.0	128.8 ± 3.8	11.3 ± 1.8	0.131 ± 0.012
	AC 637	8.5 ± 1.2	110.0 ± 3.7	24.2 ± 4.4	0.159 ± 0.032
	AC 158	5.6 ± 1.4	150.8 ± 7.2	16.0 ± 0.7	0.116 ± 0.001
	AC 661	7.2 ± 2.6	137.9 ± 3.5	6.1 ± 0.2	0.103 ± 0.011
	AC 162	4.7 ± 0.7	147.9 ± 7.5	19.1 ± 2.8	0.374 ± 0.051
Control	RRII 105	64.8 ± 3.8	263.2 ± 5.6	7.7 ± 1.1	0.171 ± 0.024

Ger. 1). ATP levels of AC 166 and AC 2004 were on par with RRII 105. Annual girth, dry rubber yield and volumetric timber (bole) yield were recorded and analysed at the age of 19 years (10th year after tapping). Four accessions showed better performance for dry rubber yield in the 6th, 7th and 8th years of tapping (Table Ger. 2) and these potential accessions were selected as male parents for Wickham X Amazonian (W X A) hybridization programmes. Of these, AC 166 has been put into on-farm trials. The timber yield of 10 wild accessions which gave better timber yield than RRII 105, is given in Table Ger. 3 along with the corresponding yield levels.

Table Ger. 3. **Potential accessions for timber yield (16th year of planting)**

Accessions	Timber yield (bole volume m^3)	Dry rubber yield ($g\ t^{-1}t^{-1}$)
MT 941	0.16	15.4 (24.0%)
RO 1347	0.14	14.8 (23.0%)
MT 199	0.14	8.9 (13.9%)
MT 1630	0.14	5.3 (8.3%)
AC 661	0.14	2.0 (3.13%)
RO 255	0.13	24.7 (38.6%)
MT 915	0.13	18.9 (29.5%)
MT 68	0.13	2.9 (4.6%)
MT 1032	0.13	10.9 (17.1%)
AC 3013	0.13	32.7 (51.1%)
RRII 105	0.08	64.0
CD(P= 0.05)	0.04	20.06

* Figures in parentheses : % of the yield of the check clone, RRII 105

Two Mato Grosso accessions showing resistance to *Phytophthora* leaf disease (95% leaf retention) were also selected as male parents for disease breeding programmes.

Monthly yield and annual girth was recorded in the FET 2003 comprising 22 wild accessions and three controls. RO 287 (73.2 cm), RO 2629 (62.5 cm), MT 999 (62.4 cm) and AC 163 (61.5 cm) recorded the highest girth while RO 2629, RO 3804, AC 716 and AC 4149 recorded the highest yield.

Analysis of annual girth in FET 2005 comprising 22 wild accessions and three controls showed highly significant clonal differences. AC 2004 followed by MT 4788 had the highest girth (64.9 and 56.5 cm respectively), on par with the best check PB 260 (59.6 cm). Seven other accessions, including AC 2004 and MT 4788, showed tappability ranging from 25.4-46.7 per cent. Out of the 26 wild accessions in FET 2008, AC 176 (38.3 cm), RO 2846 (37.2 cm), AC 159 (36.9 cm) and MT 200 (35.4 cm) recorded the highest girth.

13 wild accessions selected from SBN 2004 with more than 80 per cent test tap yield of RRII 105, and planted in FET 2010 at CES, Chethackal along with the check clones RRII 105, RRII 430 and RRII 414 are under evaluation. The highest girth was recorded by RO 1769 (12.4 cm) followed by AC 3146 (12.1 cm). 10 accessions had girth higher than RRII 105 (9.1 cm). However, modern clones RRII 430 and RRII 414 were superior in girth which recorded 18.7 cm. and 15.8 cm respectively. Another set of 22 selected wild accessions along with 3 control clones were planted in FET 2013 at CES, Chethackal employing simple lattice design.

Planting material for 22 wild accessions selected on the basis of test tap yield from SBNs 2003 and 2005, along with 3 control clones, were multiplied and raised in poly bag nursery at RRS, Dapchari for planting in the FET 2014, during ensuing season.

3.3. On-farm trials

On-farm trials have been established at five locations *viz.*, B.C. Cheruvally estate, Erumely, Malankara estate, Thodupuzha, Mooply estate, Trissur, Calicut estate,

Kozhikode and Bethany estate, Kanyakumari for evaluating the performance of the three selected IRCA clones (IRCA 130, IRCA 111 and IRCA 109) and one wild accession (AC 166) at multi locations. Girth of the clones was recorded in all the five locations. At Mooply estate, among the test clones wild accession AC 166 recorded the highest girth of 26.4 cm and the lowest girth was in the clone IRCA 109 (20.5 cm). Among the check clones RRII 430 recorded the highest girth (29.1 cm) followed by RRII 414. Clone IRCA 109 was found to be susceptible at Mooply, as revealed by the highest mortality rate. At Malankara estate, among the test clones IRCA 111 recorded the highest girth of 22.8 cm and the lowest girth was in the clone IRCA 109 (20.2 cm). Among the check clones RRII 414 recorded the highest girth (32.9 cm). At Calicut estate, the clone IRCA 130 showed better growth performance similar to that during the previous year followed by IRCA 109, IRCA 111 and the least in AC 166.

4. Screening for stress tolerance

4.1. Screening for biotic stress tolerance

To confirm field tolerance to *Corynespora*, a set of 41 short listed wild *Hevea* accessions along with 2 control clones were planted in a hotspot evaluation trial during 2013 employing CRD at Ulickal nursery, Iritty.

4.2. Abiotic stress resistance

4.2.1. Drought tolerance

A clonal nursery comprising of 40 potential half-sibs of 9 clones and 7 hybrid seedlings is being evaluated along with four RRIM 600 checks *viz*, RRII 105, RRII 430 and RRII 414 for their drought tolerance potential at RRS, Dapchari. Girth at third year after planting ranged from 10.2 cm - 24.5 cm among the 47 clones. The family of clone PB 5/51 recorded the highest mean girth. Among the check clones RRII 430 continued to be superior under drought condition.

Another clonal nursery comprising of 29 potential half-sibs and 2 hybrid progenies are under evaluation at RRS, Padiyoor. Girth ranged from 7.5 cm – 15.0 cm. The highest girth was recorded by PB 5/51 (15.0 cm) followed by the clone raised from hybrid 93/10 (14.8 cm). Among the four check clones, the highest girth was recorded by RRIM 600 (13.9 cm) followed by RRII 430 (12.5 cm). Test tap yield ranged from 1.3 – 17.3 g $t^{-1}10t^{-1}$. Half –sib raised from clone PB 5/51 recorded highest yield (17.3 $gt^{-1}10t^{-1}$) whereas the top yielding check clone RRII 414 recorded 10.0 $gt^{-1}10t^{-1}$.

In the ongoing programme at RRS, Dapchari on evaluation for drought tolerance of open pollinated progenies of wild and Wickham clones of the 2007 trial, around 150 OP seeds were collected and raised in a seedling nursery at 1 x 1 m spacing.

In the further field evaluation of selected *Hevea* clones at RRS, Dapchari in collaboration with Botany Division, the growth during the summer and peak period of growth in the 34 selected *Hevea* clones comprising 23 wild accessions, 5 HP clones and 6 check clones *viz.*, RRII 430, RRII 414, RRII 105, RRIM 600, RRII 208 and Tjir 1 was assessed. Out of 34 clones in this trial, after experiencing six summer periods from 2008 – 2013, 9 wild accessions and 4 HP clones recorded girth higher than the proven drought tolerant clone RRIM 600. Accession MT 4856 recorded highest girth at 6th year (29.7 cm) under unirrigated condition at Dapchari. Among the modern clones, RRII 430 showed significant growth difference from RRII 414 under Dapchari conditions with a girth of 30.1 cm and 26.1 cm respectively. Among the five hybrid clones, clone 93/270 recorded the highest girth (27.7 cm) followed by 93/105 (27.1 cm).

4.2.2. Cold tolerance

Sixty four wild *Hevea* accessions in two cold evaluation trials were under evaluation for growth and yield at Regional Experiment Station, Nagrakata, West Bengal. Higher annual girth was observed in RO 2902, MT 5105 and RO 2387 as compared to the check clones SCATC 93/114 and RRIM 600 in trial 1. In trial 2, accession MT 915, RO 2727 and MT 900 recorded the highest girth compared to that of the controls Haiken 1 and RRIM 600.

5. Screening for timber characteristics

5.1. Field screening

Annual girth, monthly yield and timber volume were recorded at the age of 12 years.

6. Utilisation of *Hevea* germplasm

6.1. Hand pollination programmes

Growth and test tap yield was monitored in the 75 progenies of the 2009 hand pollination programme along with their respective OP seedlings at CES, Chethackal, involving 3 wild accessions and 6 cultivated Wickham clones. Five high yielding cross combinations with higher than the population average (ranging from 14.03 - 29.74 g $t^{-1}10t^{-1}$ respectively) were identified.

At RRS, Padiyoor 29 progenies derived from 2 crosses in 2009, along with 25 OP seedlings of RRII 105, are under evaluation in a seedling nursery. Mean girth (32.9 cm) and test tap yield (28.2 g $t^{-1}10t^{-1}$) were higher in the combination of RRII 105 x AC 675 than the progenies of RRII 105 x RO 368 (29.6 cm and 24.5 g $t^{-1}10t^{-1}$ respectively). Recovery of superior seedlings with respect to test tap yield was 38 per cent in the combination of RRII 105 x RO 368 and 37 per cent in the other hybrid combination whereas it was 41 per cent in the OP seedlings. There were exceptionally superior progenies in all the three groups.

The two potentially high yielding wild accessions RO 4599 and MT 4788 from PET 2000 and another accession AC 4833 with relatively high number of latex vessels, were used during this season for crop improvement programme by hybridization with RRII 105. 1201 crosses were made, with an average initial fruit set of 132 fruits. 53 progeny resulting from the between the first two accessions and RRII 105, crosses made during last season were planted in the seedling nursery for evaluation.

6.2. Generation of mapping population

Growth of the 96 seedling progeny generated in the 2009 HP between *H. brasiliensis* (RRII 105) and *H benthamiana* (F 4542), was monitored. Girth ranged from 8.0- 46.0 cm, with an average of 27.7 cm. These seedlings were subjected to the second round of test tapping, along with 10 planted in 2010: HP 09/04 and HP 09/34 gave the highest test tap yields of 14.8 and 13.8 g $t^{-1}t^{-1}$ respectively in the 4th year of growth, while another three yielded 5.3-5.1 g $t^{-1}t^{-1}$. Another 72 seedlings, resultant of last season's HP, were planted in the seedling nursery, bringing the total population to 178 so far. The cross was repeated this year. Of the 1701 crosses made, the initial fruit set assessed after one month was 129.

7. Other studies

7.1. Feasibility of ratooning in *Hevea*

Ratoons continued to be superior to the conventionally raised polybag plants for girth recording an average of 81.4 and 58 cm respectively. 134 ratoon plants (98.5%) have attained tappability, while only 156 (76.8%) of the interplanted polybag plants of the same age have attained it.

7.2. Assessment of the performance of new rubber plantations of ITDA, AP

In a collaborative project with ITDA, growth of rubber plantations was assessed in 12 randomly selected farmers' fields (2008 plantings at RC Varam) by the Integrated Tribal Development Agency (ITDA), Govt. of Andhra Pradesh. In the 6th year of growth, Farm 7 recorded the highest girth of 40.1 cm and Farm 12 recorded the lowest girth 16.4 cm.

7. 3. Studies on alternative sources of natural rubber yielding plants

Two accessions of guayule rubber (*Parthenium argentatum*) were established in the nursery at RRII. Field planting of Ceara rubber (*Manihot glaziovii*) was done at RRII. Correspondence were made with National Arid Land Plant Genetic Resource Unit, Parlier, Fresno, California, USA for importing 18 potential accessions of guayule rubber to RRII.

BIOTECHNOLOGY DIVISION

Major objective of biotechnology research at RRII is the genetic improvement of *Hevea brasiliensis* using modern tools. The major ongoing research programmes are: i) development of *in vitro* propagation methods for elite *Hevea* clones; ii) development of transgenic *Hevea* plants for better adaptation to environmental stresses, tapping panel dryness, latex yield and disease tolerance; iii) development of haploid plants, *in vitro* fertilization techniques and embryo rescue to complement conventional breeding programmes; iv) study of molecular mechanism and characterization of genes controlling tolerance to diseases, abiotic stresses and latex biosynthesis; and v) study of laticifer cell specific gene expression and characterization of laticifer cell specific promoters.

1. Somatic embryogenesis and plant regeneration

Somatic embryogenesis and plant regeneration was attempted during the year, from newly initiated sterile and viable leaf cultures. Callus induction, proliferation and embryogenic callus initiation was obtained from several proliferated callus clumps of clone RRII 105 with 70 per cent embryo induction in the earlier standardized medium. Callus texture was improved during proliferation by repeated subculture in medium where sucrose concentration and cytokinin/auxin ratio were gradually increased and water stress provided by PEG and phytagel. Maturation and germination of embryos (70%) was achieved in the earlier standardized medium containing ABA (0.2 mg L^{-1}) and several plants could be regenerated *in vitro*. Regenerated plants after 2-3 weeks *in vitro* growth were transferred to sand: soil mix for hardening.

The cotyledonary stage embryos were given desiccation treatments by culturing on medium containing 1) ABA (0.2 mg L^{-1}) and PEG (5.0-10.0 g L^{-1}), (2) slow desiccation in sealed petri plates and (3) fast desiccation by air drying in laminar flow hood. Slow desiccation in sealed petri plates for three days increased size of the embryos and germination was obtained within two weeks. PEG (8.0 g L^{-1}) also helped faster

embryo germination but did not favour plant regeneration. Ratio of GA_3/IAA was optimized in the germination medium and optimum concentration of amino acids and phloroglucinol were identified for inducing lateral roots in germinating embryos. Rooting enhancement was observed in the embryos after desiccation treatment, in MS medium containing glutamine (300 mg L^{-1}), arginine (80 mg L^{-1}) and phytohormones GA_3 (0.5 mg L^{-1}), IAA (1.0 mg L^{-1}) in presence of 0.2 mg L^{-1} IBA. 40 per cent lateral root induction was obtained in this medium when supplemented with 100 mg L^{-1} phloroglucinol.

Three basal media such as MS, WPM and Chu N6 containing picloram and phytohormones such as BA, NAA, TDZ and IAA at different concentrations were tried for direct embryo induction in leaf explants. In all the basal media containing picloram (0.5 mg L^{-1}) alone, the leaves expanded with nodules. In modified Chu N6 medium containing picloram (3.0 mg L^{-1}) along with NAA and either of the cytokinins TDZ/BA, the leaf sections swelled with nodules and initiated globular embryo like structures when transferred to light. Culture initiation in the dark and transfer of cultures to light after nodule induction favored induction of embryos.

To test the effect of picloram on somatic embryogenesis, a two way factorial experiment was carried out. Picloram and BA was included in the medium ranging from 1.0-4.0 mg L^{-1}. Ten anthers were inoculated in all combinations and experiments were replicated thrice and cultures were incubated under darkness. Two months after culture, callus was induced and maximum callus induction was occurred on medium containing 2.0 mg L^{-1} picloram along with 1.0 mg L^{-1} BA. After callus proliferation on the same medium, the calli were subcultured for embryogenesis and embryo induction was achieved on medium containing 0.5 mg L^{-1} each BA and picloram. In an attempt to shorten the regeneration system, few experiments were also carried out. Results showed that addition of 350 mg L^{-1} calcium nitrate induced friable callus.

2. *In vitro* approaches to complement conventional breeding programmes

2.1. Induction of polyembryony in *Hevea brasiliensis*

During the current year 20 uniform plantlets were raised through the induction of multiple embryos. Plants were further multiplied by budding. The genetic fidelity of the multiple seedlings and their bud grafted counterparts were assessed through RAPD analysis and the epigenetic variation if any were assessed using DNA methylation studies. Preliminary studies indicated no epigenetic variation among the polyembryony derived plants. But variation in the methylation pattern was observed among the budgrafted counterparts.

2.2. Development of haploids in *Hevea brasiliensis*

2.2.1. In vitro/ ex vitro *pollinations for haploids* oids

Self pollinations were carried out in RRII 105 plants with irradiated pollen grains. Fruits were collected at immature stages and the immature seeds were cultured for the rescue of embryos following half *ovulo* embryo culture technique. The rescued embryos were kept for germination. Interspecific crosses were also carried out in RRII 105 plants using H. *benthamiana* and H. *spruceana* pollen grains. Immature fruits were collected and the developing seeds were cultured for embryo rescue.

2.2.2. *Pollen protoplast culture for developing androgenic haploids*

Micro-calli (Fig. Biotech. 1a) developed from cultured pollen protoplasts were proliferated and then transferred to embryo induction media. Embryogenic callus was obtained in KPR medium with BA (1.0 mg L^{-1}), NAA (0.5 mg L^{-1}) and GA_3 (1.4 mg L^{-1}). Emergence of globular and heart shaped embryos (Fig. Biotech. 1b) was noticed

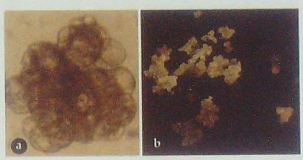


Fig. Biotech. 1. **(a) Micro-callus from pollen protoplast; (b) Emergence of embryos from proliferated callus**

when the embryogenic callus was transferred to medium with reduced growth regulators and increased phytagel levels. Actively proliferating embryogenic callus was subjected to cytological analysis which confirmed the haploid nature (n= 18) of the callus.

2.2.3. *Embryo sac culture for the development of gymogenic haploids*

Callus could be induced (Fig. Biotech. 2b) from embryo sacs (Fig. Biotech. 2a) isolated from the mature female flowers of clones RRII 105, 414 and 430. Proliferated calli were subcultured for embryogenesis. Embryogenic callus could be induced (Fig. Biotech. 2c) from RRII 105 and 414 clones. Emergence of embryos occurred in clone RRII 105 and those embryos have been transferred to maturation medium (Fig. Biotech. 2d). Cytological analysis of the embryogenic callus has proved that it is haploid in nature, with chromosome number 18.

2.2.4. *Development of haploids through mature unfertilized ovule culture*

When the mature unfertilized ovules of clone RRII 105 and 414 were subjected to temperature shock, callus formation was obtained from the haploid cells of the embryo sac (Fig. Biotech. 3 a) with a callus induction frequency of 6 per cent. Proliferation of the callus was achieved in the basal medium fortified with 2,4-D, BA and GA_3 (Fig. Biotech. 3 b). The unfertilized ovules of clone RRII 430 showed different

Fig. Biotech. 3 a-b. **a. Callus from the embryo sac; b. Proliferated embryogenic callus**

Fig. Biotech. 2 (a-d) **a. Embryo sac; b. Callus from the E. sac; c. Embryogenic callus; d. Haploid embryos**

cultural response, swelling was observed in majority of the cultured ovules.

2.2.5. Development of haploids through pollen culture

Haploid callus was obtained from the irradiated pollen grains of clone RRII 430 and 414. The callus proliferation was slow. The exposure of the anthers of clone RRII 430, 414 and 105 at two different developmental stages (early uni nucleate and bi nucleate stage) to starvation medium for 72 hrs at 4 °C and subsequent culture on callus induction medium resulted in callus formation (Fig. Biotech. 4).

Fig. Biotech. 4. **Callus formation**

2.3. *In vitro* induction of polyploids

Experiments were conducted for *in vitro* induction of polyploidy in diploid callus of *Hevea* through chemical treatment using colchicine. Parameters like colchicine concentration and exposure time were optimized. Colchicine treated cultures first turned white in color and later gave rise to friable yellow calli which were further proliferated and subcultured for embryogenesis. Several embryos could be induced from these cultures, some of which have advanced to maturation and germination stages and a few of them regenerated into plants. Cytological analysis for ploidy determination has been initiated using proliferating embryogenic callus as well as actively growing root tips.

2.4. *In vitro* development of triploids

2.4.1. Endosperm culture

Endosperm tissue from mature fruits of *Hevea* were separated, cut into thin slices and cultured for callus induction in MS basal medium fortified with different levels of 2,4-D, NAA, BA and Kin. Callus induction at low frequency was obtained in the presence of 2.0 mg L^{-1} 2,4-D and 3.0 mg L^{-1} kinetin. Upon transfer to embryo induction medium, few embryos were developed which have been subcultured for further development.

3. Genetic transformation

3.1. Genetic transformation of *Hevea brasiliensis* with osmotin gene

Expression studies were carried out in transgenic callus integrated with *osmotin* gene. Proline estimation was carried out in transgenic and non-transgenic callus under normal and stressed conditions. High proline accumulation was observed in the transgenic callus subjected to salt and PEG stress.

3.2. Genetic transformation of *Hevea brasiliensis* with *hmgr*1 gene

The expression of the transgene was studied in the *hmgr*1 transgenic plants using northern analysis. Total RNA was extracted from the leaves of one transgenic and one control plant using the method described by Venkatachalam *et al.* (1999). The RNA was transferred from the gel to the nylon membrane and probed with the ^{32}P labelled *hmgr*1 gene probe. Development of a strong hybridization signal in the transgenic plant indicated a higher transcript level in the

leaves of the transgenic plant. The hybridization signal was absent in the untransformed control (Fig. Biotech. 5).

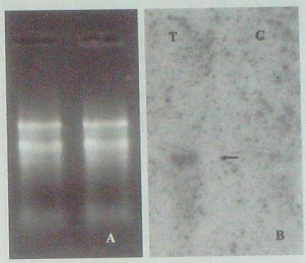


Fig. Biotech. 5. **Northern analysis of the transgenic plant with untransformed control plant A. RNA isolated from the transgenic and control plant; B. Northern blot showing the transcript level in the transgenic plant**

3.3. Multiple gene integration

Agrobacterium infection was carried with *MnSOD* and *hmgr*1 gene constructs together using *Hevea* anther callus. The infected calli were cultured over selection medium containing kanamycin and the antibiotic resistant callus lines emerged were selected and cultured over proliferation medium. The *MnSOD* and *hmgr*1 gene integrated transgenic embryos obtained earlier by repeated genetic transformation were cultured over different media combinations. Embryo maturation was obtained from two cell lines. The mature embryos upon culture over plant regeneration medium, a few plantlets were obtained.

New A*grobacterium* infections were carried out for incorporating *MnSOD* and *ipt* genes using proliferated friable fresh leaf callus. Infected callus tissues were recovered free of bacterial over growth, transgenic callus and embryo induction obtained. Leaf explants collected from bud grafted plants grown in glass house were pre cultured for one week and explants (leaf and root) taken from *in vitro* somatic plants were used as target tissues for *Agrobacterium* infection. The leaf explants, after pretreatment was found amenable as target tissue for *Agrobacterium* infection. Kanamycin 50 mg/l was optimal for transgenic tissue selection. Repeated transformation was carried out in root sections of *in vitro* developed ipt transgenic plants for *MnSOD* gene integration. Embryogenic callus could be obtained from the transgenic callus and integration of both genes validated by PCR. Plant regeneration experiments are being continued with the transgenic embryogenic callus incorporated with *MnSOD* and *ipt* genes.

3.4. Development of antibiotic marker free transgenic plants

The functional validation of the binary vector with Cre/LoxP was carried out in tobacco plants. *Agrobacterium* infection was carried out using tobacco leaf disc and callus. The antibiotic resistant callus/leaf disc were selected and cultured for plant regeneration. Plants were regenerated from the callus lines as well as from the infected leaf discs. Transgene integration was confirmed by performing PCR with *nptII* and *cre* gene specific primers using the DNA isolated from the putatively transgenic and control plants. PCR amplification was obtained with *npt*II and *cre* gene specific primers. For developing antibiotic marker free transgenic *Hevea* plants, *Agrobacterium* mediated genetic transformation was carried out with the binary vector using *Hevea* anther callus derived from clone RRII 105, RRII 414 and 430. The kanamycin resistant callus lines emerged were selected and cultured over proliferation medium.

4. Molecular Studies

4.1. Molecular mechanism of disease tolerance

4.1.1. Gene expression of signal transducers related to abiotic stress tolerance in Hevea brasiliensis

One of the potential genes responsive to multiple abiotic stresses is the calcium-dependent protein kinase (CDPK) gene. Therefore, attempts were made to isolate the full-length CDPK gene from genomic DNA of *H. brasiliensis*, clone RRII 105. A 5.1 kb gene was amplified, cloned, sequenced and characterized. The isolated sequence was aligned with the earlier isolated cDNA sequence using the ClustalW tool to identify the intron regions. The results showed that the sequence contained seven introns with splice junctions starting with GT at the 5′ end and ending with AG at the 3′ end. The base pair length of introns ranged from 20 to 1260 bps. The position and phase of introns were compared with the *Arabidopsis* CDPK members and showed that it was exactly similar to the members of the Group II subfamily of CPDK proteins. The promoter region of the gene was isolated from the genomic DNA of *Hevea* RRII 105. The 2 kb fragment was amplified, cloned and sequenced. The fragment was subjected to the promoter analysis tool, PLACE and showed the presence of stress-responsive MYBCORE, DREB/CRT and WRKY boxes indicating that the isolated gene could be responsive to multiple stresses.

The amino acid sequence for the isolated nucleotide sequence was deduced using the ExPASY translate tool. It has a total of 556 amino acids. The sequence contains the characteristic domains of a CDPK protein – the N-terminal kinase domain, an auto inhibitory junction domain and a C-terminal calmodulin-like domain with 4 EF hands to bind calcium ions. Further blastp analysis showed that the sequence matches with CDPKs from several other species. The presence of myristoylation site indicates that the proteins involved in protein-protein interaction, playing a major role in signal transduction. The NLS-predictor tool predicted the presence of Nuclear Localization Signal (NLS) in the auto inhibitory junction domain and the subcellular localization of the protein predicted using the PlantmPLoc tool showed that the protein could be present in the nucleus. Stress responsive CDPKs studied in *Mesembryanthemum* and *Arachis* showing similar NLS regions in the junction domain further evidences the fact that the isolated nucleotide sequence could also transcribe a stress-responsive protein.

For studying the gene expression of the isolated CDPK gene, real-time PCR was attempted on cold stressed leaf callus cultures initiated from RRII 105 leaves. Juvenile, immature leaf explants initiated were inoculated on CI medium; initial callus growth was observed after 2 weeks. After 1 month, appreciable amounts of friable calli were subcultured onto CPA medium. Subsequent subculturing was done at regular intervals. For inducing cold stress, the calli were kept at 16°C. Samples were collected at 0, 6, 12, 24, 48, 72, 96 and 168 hrs to study the difference in temporal expression of the gene when cold stressed. RNA was isolated from samples and cDNA was prepared. Real-time PCR was conducted with three biological replicates for each sample. A gradual increase was observed at each interval with the highest expression at 24 hrs followed by a gradual decrease and then a high peak at 168 hrs (but less than 24 hrs). Further investigations need to be carried out with callus from stress tolerant clone RRIM 600 to thoroughly study the difference in expression.

GENOME ANALYSIS LABORATORY

In the Genome Analysis laboratory the research activities are grouped under four major research programs: (I) development, optimization and validation of molecular tools for the assessment of genetic diversity in rubber, clonal identification and genome mapping, (II) development of genetic markers for biotic and abiotic stress tolerance and understanding the stress adaptation processes through transcriptome analysis, (III) cloning and characterization of agronomically important genes and (IV) whole genome sequencing and *de-novo* assembly of rubber genome.

I. Development, optimization and validation of molecular tools for the assessment of genetic diversity in rubber, clonal identification and genome mapping

1.1. Development of microsatellite markers and its application in the characterization of *Hevea* germplasm

1.1.1. Transcriptome derived microsatellites Predicting polymorphic SSRs in silico

Large scale identification of SSRs containing transcripts, derived from *Corynespora* treated and control leaf transcriptomes of two rubber clones RRII 105 and GT 1 was performed. Common and unique microsatellite bearing transcripts were extracted from all 9 transcriptomes (leaf, latex and bark transcriptomes of different rubber clones) using in-house pipeline. *In silico* analysis revealed 191 polymorphic SSRs.

1.1.2. Genetic characterization of popular clones and wild accessions

SSR genotyping of 40 Wickham clones and 60 wild accessions was performed for analyzing allele frequencies at 18 microsatellite loci. Wild accessions showed more allelic diversities than the cultivated clones for majority of the loci, which could be a resource for allele discovery of functional markers.

1.2. Single nucleotide polymorphisms (SNPs) in *Hevea*

1.2.1. SNP calling using transcriptome data

Variant calling was carried out for disease transcriptome data. They were filtered based on mapping quality (>=25), read depth (>=5) and strand level evidence. Number of SNPs identified between control transcriptomes of RRII 105 and GT 1 (C1-C2) was 110357 and between pathogen challenged transcriptomes of RRII 105 and GT 1 (T1-T2) was 136390.

1.2.2. Identifying SNPs in disease resistance transcripts

Twenty-four transcripts belonging to NBS-LRR class derived from disease transcriptome, were amplified from four rubber clones RRII 105, RRII 430, RRIM 600 and GT 1 for SNP identification and sequenced using Genetic Analyzer 3500xL.

1.2.3. Single nucleotide polymorphisms (SNPs) and haplotype structuring in the latex biosynthesis genes of Hevea brasiliensis

Five haplotypes consisting of 32 SNP loci were predicted in rubber elongation factor (*REF*) gene and two recombination sites were detected using DnaSP program.

Sequence analysis of the genomic region of mevalonate kinase (*MK*) gene from five clones revealed 21 base

substitutions. The clone RRII 105 showed maximum heterozygosity for the SNP loci analysed.

Twenty-one SNPs were identified in the cloned fragment (1.4kb) of *cis-prenyl transferase* gene from five *Hevea* clones. No introns were observed in the gene. Fifteen SNPs (10 SNPs were from the coding sequences) having complete phase information were used in haplotyping and 5 haplotypes were detected.

One SNP each from three rubber biosynthesis genes: *FDPS*, *GGDPS* and *HMGR* were studied by high resolution melt curve analysis (HRM) as a genotyping methodology confirming the sequencing results.

1.3. Construction of a consensus genetic linkage map for understanding genetic architecture of quantitative trait loci controlling disease resistance, latex yield and timber quality in rubber (*Hevea brasiliensis*)

Construction of genetic linkage map using a segregating progeny population derived from a diverse interspecific cross between RRII 105 (*H. brasiliensis*) X F4542 (*H. benthamiana*) has been continued, Parental genotypes RRII 105 (*H. brasiliensis*) and F4542 (*H. benthamiana*) were screened with 108 SSR markers and 446 Operon arbitrary primers for polymorphisms. Sixty-seven SSR markers and 294 Operon primers generating 664 bands were found polymorphic between these two parents. Genotyping of segregating progeny population is in progress. Out of 94 progenies characterised with SSR markers, 8 were found non-hybrids or false progenies and thus removed from the experiment.

2. Development of genetic markers for biotic and abiotic stress tolerance and understanding the stress adaptation process through transcriptome analysis

2.1. Development of molecular marker(s) linked to the locus conferring resistance to fungal diseases in *Hevea*

2.1.1. Resistance gene analogue (RGA) in rubber

2.1.1.1. Characterization and functional validation of differentially regulated NBS-LRR transcripts involved in tolerance to Corynespora leaf disease, identified through transcriptome sequencing.

Nucleotide-binding site (NBS) and leucine rich repeat (LRR) containing proteins are classified under defense response in plant. In total 76 unique transcripts encoding NBS, LRR domains were identified in control transcriptomes of RRII 105 (C1: 28 nos.) and GT 1 (C2: 15) and *Corynespora* challenged transcriptomes of RRII 105 (T1: 15 nos.) and GT 1 (T2: 18 nos.). These encoded proteins were found to be completely down regulated in T1 in comparison to T2 transcriptome based on DGE. In total seven disease resistant protein (grouped under RGA2, RPS2, RPM1), five leucine-rich repeat containing proteins and seven TMV resistance protein N were found up regulated in T2.

2.1.2. Genes involved in host tolerance to Corynespora leaf disease

2.1.2.1. Transcriptome analysis

Transcriptome sequencing of *Corynespora cassiicola* challenged leaf samples along with control was performed for identification and functional analysis of disease responsive genes. Analysis of gene expression of RRII 105 (susceptible clone) and GT 1 (tolerant clone) in response to *Corynespora* infection revealed that they responded differently upon

infection. Major transcription factor genes were triggered and up regulated in GT 1, which could be associated with enhanced immunity against the pathogen. Other than the upregulation of transcription factors, ATP binding proteins along with putative uncharacterized proteins were also found to be significantly expressed. Upon pathogen infection 414 and 877 differentially expressed genes were significantly expressed in RRII 105 and GT 1 respectively. The highly enriched gene ontology terms which were common between GT 1 and RRII 105 challenged clones largely fell into the major categories: (i) defense response, (ii) response to stress and (iii) response to stimulus. Besides these, other GO categories containing cellular catabolic process, RNA biosynthetic process, carbohydrate metabolism etc. were enriched only in GT 1 challenged samples.

Transcripts which were annotated as "putative protein" from C1T1, C2T2 and T1T2 data were aligned against entire "nr" protein database from NCBI. From the blast search, it was observed that four transcripts (Locus ID: 13251 and Transcripts 2/11, 3/11, 4/11, 11/11) from T2 were having homology with "cullin-1-like protein (*Hevea*) and derived from a single locus of the genome. Heatmap representation based on hierarchical clustering has been created for significantly enriched proteins.

2.1.2.2. *Microarray gene signatures for Corynespora disease tolerance in rubber*

DNA microarray experiments were designed based on differentially expressed transcripts derived from *Corynespora* challenged and control transcriptomes of both susceptible and resistant clones of rubber. For probe designing, 4000 differentially expressed transcripts based on DGE analysis and 6000 transcripts from both susceptible and tolerant clones showing similar expression levels having 90% mapping with *Hevea* genome were selected. Beside these transcripts, around 400 disease related transcripts identified using DD-RTPCR, RGA and RT-RGA developed in our earlier studies were also included.

2.2. Characterization of stress-tolerant clones of *Hevea* using molecular markers and gene regulation under abiotic stresses

2.2.1. *DNA methylation in response to abiotic stress*

2.2.1.1. *Quantitative PCR studies for establishing the correlation between DNA methylation and gene expression*

QPCR experiments were performed to understand the relationship between the gene expression patterns of HMG CoA reductase *(HMGR)* and their promoter methylation (CCAAT box) in the clone RRIM 600 and PB 260 (two plants each) before and after inducing cold stress. It was noticed that in RRIM 600, gene expression as well as CCAAT box methylation status of *HMGR* (un-methylated) remained unchanged before and after cold stress in both the plants. In the clone PB 260, the first plant (PB 260-1) showed stable expression rate, whereas the second plant (PB 260-2) showed 50% reduction in expression level after the induction of cold stress. It is interesting to note that both the plants were un-methylated before cold stress induction but PB 260-2 got methylated after the stress. The initial results from this study indicate the possibility of a correlation between the methylation of *HMGR* promoter region and its gene expression in individual plants.

2.2.2. *Identification of genes responsible for* de-novo *DNA methylation and de-methylation in rubber*

Sequence of the partial cDNA fragments of DRM transferase and DNA N-glycosylase amplified from rubber was BLASTed

against the whole genome shotgun sequence (WGS) data of RRIM 600 available in GenBank. Respective contigs containing these genes were identified and primers were designed to amplify both the genes.

2.3. Methylation sensitive AFLP for identification of grafting induced epigenetic changes in rubber genome

A study was conducted to identify the epigenetic impact of root stock over the scion of genetically uniform tissue culture derived polyembryonic plants. Methylation sensitive AFLP (MS-AFLP) analysis of five polyembryonic plants was performed with 12 primer combinations. Variations in the AFLP pattern could be detected among these plants indicating changes in DNA methylation pattern in one year old plants.

Two polymorphic fragments from the gel were eluted, cloned and sequenced to identify the target region. BLASTX analysis of the 312 bp fragment revealed its similarity to arginyl-tRNA synthetase gene whereas the fragment of 265 bp had match with a portion of the 1.17 kb contig No: AJJZ010201713.1 of the *Hevea* whole genome shotgun sequences reported earlier.

3. Cloning and characterization of agronomically important genes

3.1. Cloning and characterization of lignin biosynthesis gene(s) in *Hevea* for their over-expression in timber clones

Two *caffeic acid O-methyltransferase (COMT)* genes from rubber, designated as *HCOMT1* and *HCOMT2* were identified and full-length cloning of *HCOMT2* cDNA was reported. A bacterial expression cassette was successfully developed for the gene using pRSET vector. High level expression of HCOMT2 recombinant protein in *E.coli* was confirmed through SDS PAGE followed by Western blotting. All three key genes encoding CAD, CCR and COMT involved in cell wall lignification through phenylpropanoid pathway were cloned and characterized for their further use in genetic transformation studies for timber quality improvement.

4. Genome Sequencing and *de-novo* assembly of rubber (*Hevea brasiliensis*) genome

Hevea genome sequencing has been initiated with M/s. Xcelris Labs Ltd. to generate a draft sequence of rubber clone RRII 105 using Next Generation Sequencing platforms. Sequence data generation was performed on Roche GS-FLX system for shotgun *Hevea* genomic library of 800 bp and a pair-end library of 20 kb fragments. Sequencing of 300 bp library was also performed on MiSeq system. In total 5 Gb (4.1 Gb shotgun and 0.9 Gb pair-end) GS FLX sequence data and 22.2 Gb MiSeq pair-end data were generated. More than 95% Roche shotgun reads were mapped against the draft genome of RRIM 600 (GCA_000340545.1).

PLANT PATHOLOGY DIVISION

The Division is mainly concentrating on evolving efficient and cost-effective disease and pest management strategies, improved mechanization of plant protection equipment, improvement in the growth of rubber using microorganisms and in design and development of efficient treatment technologies for waste water from RSS processing and urban solid waste management.

1. Leaf diseases

1.1. Abnormal leaf fall (ALF) disease

Trials were carried out at three locations to evaluate the efficiency of ALF disease control by the split application of oil-based COC in two clones, RRII 105 and RRIM 600. The treatments included spraying of two rounds of COC (4 kg) in spray oil (20 L) at 30 day interval, two rounds of COC (3.3 kg) in spray oil (20 L) at 15 day interval, standard recommendation of one round of COC (8 kg) in spray oil (40 L/ha) and untreated control. Observation on the leaf retention showed that split application was superior in checking the ALF disease in the clone RRIM 600.

Studies on yield loss due to ALF disease was continued at RRS Padiyoor. The leaf retention was only 12.4 per cent and 6.2 per cent in the unsprayed areas of RRII 105 and RRIM 600, respectively. Overall crop loss in RRII 105 for the year was found to be 26.9 per cent whereas it was 48 per cent for RRIM 600. During the months from August to October, individual crop loss was up to 44 per cent in the clone RRII 105. Reduction in girth increment was also noticed in the unsprayed plots of all the clones. The yield loss studies in clones RRII 414, RRII 422, RRII 429 and PB 260 are in progress. The treatments were imposed by dividing the experimental trees to accommodate sprayed and unsprayed blocks. Significant difference in leaf retention was noticed between sprayed and unsprayed blocks thus effecting yield loss up to 15 per cent.

The crown budding experiments at Malankara estate, Thodupuzha (Clone PB 311) and at CES, Chethackal (Clone PB 260) recorded significantly high leaf retention in crown-budded trees. Higher yield was recorded in crown budded PB 260 trees than control. Studies on latex properties in different crowns did not show a definite trend. Attempts to raise crown-budded plants in root trainer cups (800 cc) did not succeed indicating the requirement of bigger cups.

Observation on ALF disease in the newly recommended clones in the on-farm trials showed the highest retention in clone RRII 430 and the lowest for clone RRII 422 in all the locations. The per cent leaf retention of RRII 430 ranged from 70-90, for RRII 422 it was 40-70 and for RRII 417 was 75-90. In RRII 105 the leaf retention ranged from 30 - 70 per cent. In the participatory clone evaluation trial, the per cent leaf retention in five-year-old plants of RRII 414 and RRII 430 was found to be significantly better than RRII 105, a clone considered relatively tolerant to ALF disease. Assessed the ALF disease intensity of clones in the Phase I at 7 locations and identified five clones highly susceptible (60-80 per cent leaf fall) to ALF disease.

1.2. Powdery mildew disease

Trials were conducted at two locations to evaluate the efficacy of two bacterial biocontrol agents along with recommended fungicide and untreated control. Treatments

were imposed in 8- days interval and disease intensity was assessed on a 0-5 scale. The control of disease obtained was 50 per cent with the bacterial isolate RH 34 and was comparable to the recommended control.

1.3. Colletotrichum leaf disease

An experiment was carried out at TR&T estate, Mundakayam to understand the relationship between disease incidence, severity and weather factors. Recommended fungicides alone and in combination with systemic fungicides were imposed on the three-year-old plants of RRII 105 at weekly intervals. Observation on the disease incidence/severity recorded at weekly intervals showed that the effect of individual application of fungicides were on par with combination of contact and systemic fungicides. Favourable weather conditions prevailed during susceptible light green stage of leaves aggravated the disease to epidemic proportions.

The evaluation of new generation fungicides against Colletotrichum leaf disease on the third year plants of RRII 105 at TR&T estate, Mundakayam,was continued for the third year and the efficacy of the fungicides tebuconazole + trifloxystrobin and the treatments involving tebuconazole and mancozeb was confirmed.

The experiment to study the impact of Colletotrichum leaf disease on the growth of rubber at TR& T estate in the clone RRII 105 was continued. The treatments were imposed at weekly intervals to accomodate one block protected from Colletotrichum leaf disease and the other left unsprayed. The disease severity in the protected block was less than 25 per cent whereas it was around 80 per cent in the unprotected block. Significant difference in girth and height of the plants between protected and unprotected was observed

1.4. Corynespora leaf fall disease

Evaluation of efficacy of new fungicides against Corynespora leaf fall disease on rubber seedlings was continued at Ulickal nursery for the third year. The results showed that the fungicides pyraclostrobin + metriam and thiophanate methyl were effective in controlling the disease.

Field evaluation of three new chemical fungicides *viz*. pyraclostrobin + metriam, thiophanate methyl and tebuconazole at different doses against *Corynespora* leaf fall disease was carried out at three locations in Karnataka state. The results indicated that thiophanate methyl is effective in controlling the disease.

Amplification and sequencing of cassiicoline gene from aggressive and non-aggressive isolates of *Corynespora* was attempted. Isolated the pathogen from different locations of rubber growing areas of Kerala and Karnataka during the disease season. The aggressiveness of the isolates was studied by leaf - wilt bioassay using crude toxin. Total RNA was extracted from the 100 mg of mycelia from selected aggressive and non-aggressive isolates using the trizol RNA extraction procedure and cDNA was synthesized. The PCR amplification yielded ~128 bp bands from all aggressive / non aggressive isolates.

Studies on transcriptome sequencing were continued to understand the response of RRII 105 (susceptible clone) and GT 1 (tolerant clone) to *Corynespora*. Differential gene expression data followed by gene ontology term enrichment with the annotated genes revealed that majority of the transcripts in both the clones upon challenge inoculation were enriched for defense response, response to stimulus and response to stress. The genes encoding disease resistant proteins, leucine-rich repeat domain containing proteins *etc*., were

significantly over-expressed in resistant clones, whereas these transcripts were either completely suppressed or down regulated in susceptible clone upon pathogen infection.

2. Pink disease

Field evaluation of new generation fungicides for its curative nature at Mundakayam estate, Mundakayam on 3-year-old plants was continued. The fungicides were mixed in rubberkote thoroughly and applied on the disease infected portion of the plants. Observation on the recovery of plants showed that the fungicide trifloxystrobin + tebuconazole gave better recovery followed by tebuconazole.

3. Pests of rubber

Conducted field studies to evaluate the comparative efficacy of *Metarhyzium anisopliae* ($28x10^5$) and *Beauveria bassiana* @50g/ L water (10^8 cfu/g) on the larvae of mooply beetles, *Luprops curticollis*. Each treatment was replicated three times. Recorded mortality of larvae after 3rd and 7th day of application. *Metarhyzium anisopliae* (45% mortality) was comparatively better than *Beauveria bassiana* (20% mortality) in the control of mooply larvae.

Conducted surveys on the occurrence of natural enemies and other bio agents for the management of bark feeding caterpillar, *Aetherastis circulata*. Collected pre pupal and pupal stages of bark feeding caterpillar from the infested trees from January to April 2014 and the samples were kept in the laboratory condition for the emergence of adult moths or the parasitoids. 69.23 per cent of the pupae were found dead due to the attack of some entomopathogenic fungus. The fungus was isolated and identified as *Aspergillus flavus*. It was the first report for this fungus as entomopathogenic from *Aetherastis circulata*.

A field experiment in completely randomized design was laid out for the control of borer beetles in a highly infested area with six treatments and five replications. The treatments were applied on the affected portions by swabbing using a brush. The per cent reduction of borer attack in swabbed trees was estimated.

Reduction of borer infestation with 0.25 per cent quinalphos was the best followed by 0.25 per cent after 10 and 20 days of treatment. The bioagent, *Beauveria bassiana* was found to be the least effective among the treatments (Table Path. 1).

4. Microorganisms for improving growth of rubber and cover crops

Eighty five actinomycetes and 1287 rhizobacteria collected from roots and rhizosphere of rubber from different

Table Path.1. **Comparative efficacy of different insecticides and a bio-control agent on the control of borer beetles in rubber trees after 10 and 20 days**

Treatment	Dose	Mean per cent reduction after 10 days	Mean per cent reduction after 20 days
Beauveria bassiana	50 g L^{-1} water (10^8cfu g^{-1})	20.7 (26.6)	30.9 (33.5)
Imidacloprid	0.18%	69.1 (56.9)	90.8 (72.6)
Quinalphos	0.25%	83.7 (66.8)	98.2 (86.1)
Carbosulfan	0.25%	64.0 (53.4)	89.8 (72.4)
Deltamethrin	0.025%	77.9 (62.8)	94.0 (79.1)
Control(untreated)		+22.2 (+27.3)	+36.6 (+36.8)
CD (P=0.05) 5%	_	11.4	11.4

(Figures in parentheses are arcsine transformed values and '+' indicates per cent increase in untreated trees)

plantations of N. Kerala and S. Karnataka were checked for antagonism against the root pathogen, *Phellinus noxius* and two isolates *viz.* actinomycete 134 and bacteria KR 664, which consistently showed higher zone of inhibition, were selected. 172 bacterial isolates collected from the cauloplane of rubber trees from Mundakayam, Chethackcal, Iritty and RRII were tested for antagonism against the pink pathogen and selected two antagonists in the primary screening.

Evaluated the efficiency of 10 PGPR isolates and two consortium on the growth of root trainer plants at Vadakel nursery, Poovathilappu along with uninoculated and full fertilizer applied plants as controls. Plants inoculated with RH34, Ri 25 and RH 104 recorded more girth and height of the plants than the full fertilizer applied plants. All the plants treated with the isolate RH 34 reached buddable girth and showed 100 per cent budding success. The root volume and root fresh weight were higher for the inoculated plants than the two controls. The different bacteria inoculated in root trainer plants were found to survive in the potting mix but their population varied with the isolates.

All the selected phosphofungal isolates from Karnataka soils showed solubilization of ferric, aluminium and tricalcium phosphate and fertilizer form of rock phosphate. The acid phosphatase activity ranged from 29.8-50.7 μg^{-1} of PNP released ml^{-1} of culture broth. Based on the different tests carried out under *in vitro*, seven phospho fungal isolates were selected and evaluated their growth promoting efficiency in root trainer plants. The seedlings treated with Pf 11 showed more buddability and budding success. Root volume and fresh weight were also generally more for the inoculated plants. In the biofarming trial, plants in the integrated treatment showed more growth (35.08 cm) followed by chemical (31.55 cm) and biological (31cm) treatments which were on par.

Seven hundred and thirty bacterial isolates collected from the drought prone areas of South Karnataka and North Kerala, were tested for ACC deaminase activity and 38 isolates were selected. Fifty ACC positive isolates collected in the previous year were evaluated for their effect on drought tolerance in rubber seedlings during the summer season and 11 effective isolates were selected for further evaluation.

5. Waste management in rubber processing

5.1. Design and development of throughout treatment technologies for the efficient treatment of waste water from NR processing

The integrated waste water treatment system installed in the group processing centre was evaluated during its operational period and found to be functioning successfully. All the pollution parameters of the final water were well within the specified safe limits for the discharge. In view of avoiding the mechanical aeration system for the treatment of the anaerobically digested waste water, a newly designed reed bed system planted with Vetiver was constructed. The system was allowed to get the sufficient root growth of Vetiver.

5.2. Design and development of economically viable urban solid waste management system

Urban solid wastes especially the food wastes take a long time for decomposition both aerobically or anaerobically. Experiments were carried out to hasten the aerobic decomposition of food wastes by using specific microbial inoculants and adding medium like coir pith and saw dust that facilitate natural aeration and maintaining optimum moisture and

temperature. The aerobic composting in the natural condition by keeping the waste and special aeration medium like coir pith and saw dust mixed with microbial inoculum one over the other took 30 days for the decomposition. The decomposed material contained nitrogen (2.96 %), phosphorous (0.5 %), potassium (1.2 %) and calcium (1.05 %). Decomposition in the specially designed prototype mechanical device was completed by 12 h. The device could maintain temperature between 35 to 40 °C, moisture content between 50 per cent (beginning) and 5 per cent (at the end) with good aeration. The nutrient contents were also found comparable with the decomposed material formed by the other systems.

6. Farm mechanization

The final version of the mist blower attachment on the mini tractor was assembled with the specially designed centrifugal pump which gets drived from the PTO of the tractor along with the impeller of blower assembly through the same gear box unit. The equipment was field trial tested by large-scale field. The fungicide delivery height obtained with the conventional atomiser was 96 ft, and above 100 ft with micronizer type atomiser. Leaf retention after the disease season in the sprayed area was 60 per cent whereas the retention was only 15 per cent and 5 per cent in area sprayed with conventional micron sprayer and unsprayed area respectively. The technology was recommended for the adoption.

7. Web-based 'Distance Diagnostic Identification System (Rubber Clinic) for rapid diagnosis of pests and diseases of NR

Pest and disease problems from the growers were attended through the online rubber clinic. The total number of visits to the site was 10882 with an average of 30 visitors/day during April 2013 to March 2014. Visitors from 84 countries utilized the facilities in the clinic in which 85.2 per cent of the visitors were from India. The clinic diagnosed 235 cases through 'Assisted Diagnosis' and 355 cases through 'Self Diagnosis' accounting for a total of 590.

PLANT PHYSIOLOGY DIVISION

The Plant Physiology Division is focusing its studies on environmental and stress physiology, physiology of growth and yield, ecosystem level flux analysis, tapping panel dryness, gene expression analysis in relation to abiotic stresses and rubber biosynthesis and secondary metabolites.

1. Environmental physiology

1.1. Developing early screening tools for drought tolerance in *Hevea*

A chloroplast heat shock protein (hsp) was validated as a physiological marker for drought tolerance in a few elite clones. Further as a measure of screening germplasm accessions for drought tolerance, young plants of six different wild *Hevea* accessions (*viz.* RO 3261, RO 3157, RO 3184, AC 612, RO 3242 and MT 1619) grown in polybags were subjected to water deficit stress by withholding irrigation for 10 days during summer season (March, 2014). Western blot analysis showed that expression level of the stress protein had prominent appearance in stress tolerant accessions than relatively susceptible ones.

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

Six month old plants of relatively tolerant and susceptible (3 nos. each) *Hevea* germplasm accessions along with check clones in polybags were subjected to drought stress for 10 days. Quantitative gene expression analyses were performed for NAC tf, LEA 5 and WRKY tf. The result showed significant up-regulation of these genes in drought tolerant check clones (RRII 430 and RRIM 600) and germplasm accessions (RO 3261, AC 612 and RO 3157) under water deficit conditions.

1.2.1. Investigations on microRNAs in Hevea brasiliensis*: Role in gene regulation during abiotic stresses*

To identify novel and conserved miRNAs that are expressed in control and drought imposed plants of *Hevea*, small RNA sequencing was carried out using Illumina Hi seq method. A total of 29 known miRNA families and 17 novel miRNAs were observed in control whereas 32 known miRNA families and 25 novel miRNAs were identified in drought imposed sample. Four conserved miRNAs (miR160, miR2118, miR528 and miR6476) were identified exclusively in drought samples whereas miR1432 was present only in control plants.

1.3. Evaluation of modern *Hevea* clones for drought tolerance

1.3.1. Physiological evaluation of RRII 400 series clones for drought tolerance - Field trial at CES Chethackal

The RRII 400 series clones recorded better girth (4th year) compared to check clones RRII 105 and RRIM 600. Among the 400 series clones, the highest girth was observed in RRII 430.

1.3.2. Studies on RRII 400 series clones for drought tolerance - Plants raised in polybag

To identify suitable drought tolerant clones for establishment in the drought prone areas, five *Hevea brasiliensis* clones (400 series) were evaluated along with the popular clone and a known drought tolerant check clone, RRIM 600. Six months old polybag plants of these clones were subjected to water deficit stress for 10 days by withdrawing irrigation. Among the clones, RRII 430 recorded significantly higher epicuticular wax content than other 400 series clones and RRII 105. It also had significantly higher levels of ascorbic acid and super oxide dismutase activity. Under drought stress, this clone showed maximum photosynthetic rate and stomatal conductance compared to other 400 series clones. Overall the results indicated that the modern clone RRII 430 is the most potential drought tolerant clone among the RRII 400 series clones.

1.4. Identification of physiological, biochemical and molecular factors associated with drought tolerance in *Hevea* germplasm accessions

Relatively drought tolerant (6 nos.) and susceptible (4 nos.) germplasm accessions along with check clones were raised in polybags. Young plants were subjected to drought stress by withholding irrigation and analyzed for drought responses. Analysis of leaf pigments showed higher carotenoid and anthocyanin contents in tolerant accessions compared to susceptible accessions. The accession RO 3261 showed higher total chlorophyll, carotenoid and anthocyanin contents than the tolerant check clone RRII 430.

1.5. Ecosystem Flux measurements

1.5.1. Sap-flow measurements in mature rubber plants

The water use of mature rubber plants of clone RRIM 600 was estimated using TDP-

sap flow system in a dry sub-humid climatic region, at RRS, Dapchari, Maharastra during September 2013 to April 2014. The average water mining rate (clone RRIM 600) of irrigated trees (27 L tree $^{-1}$ day $^{-1}$) was significantly higher than unirrigated trees (20.5 L tree $^{-1}$ day $^{-1}$).

1.5.2 Measurement of CO_2 and water vapour flux in rubber plantation

The ecosystem level carbon dioxide and water vapour flux and canopy level net ecosystem exchange (NEE) of CO_2 in a rubber plantation at CES, Chethackal were measured using an eddy covariance system. The average NEE was 10.2 g CO_2 m^{-2} day^{-1} which is equivalent to 37 MT CO_2 ha^{-1} year^{-1}. The evapo-transpiration (ET) rate of this plantation was 3.3 mm per day. The amount of carbon sequestered by the rubber trees was estimated for the same period by estimating the annual shoot biomass increment. The CO_2 sequestration realized from shoot biomass increment alone was 22 MT CO_2 ha^{-1} year^{-1}.

1.6. Studies on adaptive mechanisms in *Hevea* for drought and cold stresses

The study was conducted with an objective to understand existence of any common adaptive mechanisms of abiotic stress tolerance in *Hevea*. A poly bag nursery of different *Hevea* clones was subjected to drought imposition at two whirl stage. One week drought imposition resulted in reduction of effective quantum yield of PS II in all the clones studied. The reduction in quantum yield was less in RRII 400 series clones compared to check clones. Among the clones RRII 430 showed better chlorophyll stability index followed by RRIM 600, RRII 422 and RRII 208. Anthocyanin content showed gradual increase in response to the progress of drought and higher in relatively drought tolerant clones. Xanthophyll pigments studies indicated that increase of zeaxanthin (Z) and anthraxanthin (A) with progressive increase in light intensities having a role in avoiding photo damage of photosystems. With respect to xanthophyll cycle pigments, RRII 422, RRII 430, RRIM 600 and RRII 208 had relatively better adaptive photosynthetic machinery.

1.6.1. Foliar application of nutrients and growth regulators to mitigate drought

A study was initiated to find out the effect of foliar application of nutrients and growth regulators toward amelioration of drought stress in young plants of *Hevea*. The experiment was conducted using polybag plants of clone RRII 417 at two whirl stage. Based on the preliminary trial, MOP was selected as the source of potassium (K). Plant growth regulators like salicyclic acid (SA) and abscisic acid (ABA) were used in the study. Kaolin, an antitranspirant was also included in this trial. Water deficit stress was imposed by withholding irrigation for a week. Leaf water potential was better in Kaolin treatment. Kaolin applied plants were on par with control plants with respect to chlorophyll content, chlorophyll/carotenoid ratio and chlorophyll stability index.

1.7. Evaluation of modern *Hevea* clones for drought tolerance

1.7.1. Studies on drought effects on Hevea in relation to oxidative stress and antioxidant responses

Characterization of xanthophyll cycle pigment composition in leaves of control and drought imposed plants was carried out. A higher level of anthraxanthin (A) and zeaxanthin (Z) was observed in the leaves of drought imposed plants compared to control plants. Midday measurements showed significant accumulation of A+Z in the leaves of all the clones studied.

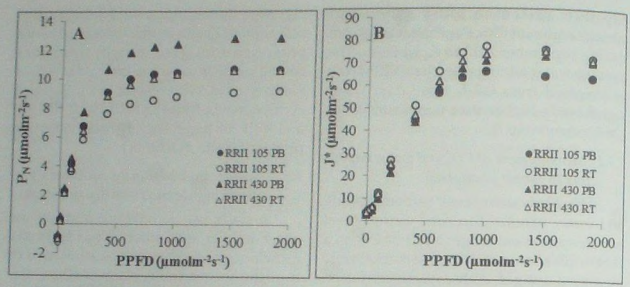


Fig. Phy. 1. **Rates of (A) Net photosynthetic rate (P_N), and (B) excess electrons (J*) *versus* photosynthetic photon flux density (PPFD) in leaves of root trainer and polybag – plants of two *Hevea* clones (n=4) PB: polybag, RT: root trainer (values are average of 4 independent readings)**

Xanthophyll pool size (V+A+Z) was significantly higher under drought condition. RRII 430 and RRIM 600 had higher level of V+A+Z compared to RRII 414 and RRII 105. De-epoxidation rate was increased under drought stress in all the clones with higher level in RRII 430 followed by RRIM 600.

1.8. Physiological evaluation of root trainer plants

The physiology of root trainer grown rubber plants in comparison to polybag plants was studied using two popular clones, RRII 105 and RRII 430. There was very little variation in leaf water relations among poly bag and root trainer plants. Total chlorophyll content and chlorophyll *a/b* ratio were higher in polybag plants than root trainer plants of both clones. Polybag plants showed higher light saturation point when gas exchange was measured at different photosynthetic photon flux densities. Though there was no variation in effective quantum yield of PS II, the root trainer plants of RRII 105 showed more excess electrons at higher light intensities. Photosystem II activity and photosynthetic carbon assimilation rates were always less in root trainer plants under open light and shaded conditions (Fig. Phy. 1).

1.9. Drought survey in young rubber plantations

During summer season of 2013-14, drought survey was carried out in northern Kerala; Kozhikkode, Nilambur, Manjeri and Kasaragod regions in one year old rubber plantations (n=130). Most of the plantations surveyed in this area were planted with clone RRII 105. The percentage of planters resorting to irrigate the young plants was nearly 13 per cent. Majority of the planters were following recommended management practices like mulching, shading except cover-cropping. The availability of water during summer was low in this region especially in Manjeri and Kasaragod regions and the casualty of young plants during summer was around 4 per cent. Intercropping in the initial year is followed by 30 per cent of planters in

this part of Kerala. More than 75 per cent of the plots surveyed showed different stages of leaf yellowing, with lower intensities of leaf tip dryness and leaf shedding.

1.10. Studies on excess electron flow across PS II

Simultaneous measurements of CO_2 assimilation and PS II activity were made in intact and excised leaves of *Hevea brasiliensis* and *Phaseolus* sp. The PS II reaction centre always produced more number of electrons than what was needed to sustain the observed rate of CO_2 assimilation. The excess electrons increased further as the light intensity was increased. It was inferred that possibility of over-estimating PS II activity (and thus electron flux across PS II) by fluorescence technique or cyclic electron flux around PS II reaction center itself.

1.11. Screening of *Hevea* germplasm lines for intrinsic drought tolerance traits

A group of 15, 12, 2 and 1 top ranking accessions from SBN 2003, 2004, 2005 and 2006, respectively was selected by field scoring for drought tolerance and further subjected to laboratory screening at CES, Chethackal for intrinsic tolerance traits. Leaf discs were incubated in 60 per cent PEG (polyethylene glycol 6000) and exposed to light. Percentage reduction in effective quantum yield of PS II (Φ PSII) was estimated and the accessions were sorted out and ranked for intrinsic tolerance. Accessions that were exhibiting less reduction were ranked top as most intrinsic tolerant ones and *vice-versa*. Accessions RO 2793, AC 3116, AC 4403, AC 4039 and RO 4429 in SBN 2003, accessions RO 1316, RO 2864, RO 3188, AC 2090 and AC 2268 from SBN 2004 and accession RO 1413 from SBN 2005 were selected as top ranking ones.

1.12. Multi-location physiological evaluation of ortets for abiotic stresses

Sixteen ortets selected from five different locations were planted at CES, Chethackal as part of a multi-location trial. Leaf chlorophyll content was estimated both in the months of October and March. Total chlorophyll content decreased in summer due to prevailing high light and temperature compared to October. Maximum reduction in chlorophyll content was noticed in clone RRII 105 (33.8%) and minimum in ortet GH 3 (8.6%). Epicuticular wax content was estimated calorimetrically in ortets grown in field. Higher wax content was observed in RRII 430 (78.3 $\mu g\ cm^{-2}$) followed by ortets NGK 47 (78.2 $\mu g\ cm^{-2}$) and GH 1 (77.8 $\mu g\ cm^{-2}$). Comparatively, ortet RRSA 315 (48.1 $\mu g\ cm^{-2}$) and clone RRII 417 (47.5 $\mu g\ cm^{-2}$) exhibited less wax content on leaves. Presence of higher wax content on the laminar surface of leaf is a beneficial drought tolerance trait in rubber plants as it reflects excess incident light.

1.12.1. Photosynthetic measurements in ortets at Dapchari and Nagrakatta

Photosynthesis measurements of 23 ortets including check clones were carried out at RRS Dapchari and RRS, Nagrakatta during non-stress period (September). CO_2 assimilation rates varied from 8 to 13 $\mu mol\ m^{-2} s^{-1}$ among different ortets/clones and stomatal conductance varied from 0.06 to 0.23 $molm^{-2} s^{-1}$ at RRS Dapchari. Higher CO_2 assimilation rates were shown by ortets RRST 39, DAP 1, RRST 37 NGK 1 while maximum stomatal conductance was recorded by ortets DAP 1, RRST 37, RRSA 585 and RRST 39 at Dapchari. At Nagrakatta the assimilation rate varied from 11.5 $\mu mol\ m^{-2} s^{-1}$ to 15.8 $\mu mol\ m^{-2} s^{-1}$ and stomatal conductance in the range of

0.2 to 0.4 mol $m^{-2}s^{-1}$, with maximum value recorded by RRST 39, followed by RRST 37, RRSA 98 and RRSA 585. There was no much variation in effective quantum yield of PS II (Φ PSII) among the clones/ortets at Dapchari as well as Nagrakatta during stress free season.

1.12.2. Biochemical studies: Antioxidant defense mechanism in ortets/clones

Leaf samples were collected from 16 ortets and seven check clones (Nagrakatta and Dapchari during stress and stress free seasons). From CES Chethackal, leaf samples were collected during stress free season (as control). The biochemical mechanisms associated with drought and cold stresses in these clones were studied. During winter at Nagrakatta, ortets GH 9, RRSA 585 showed better antioxidant defense mechanism. RRSA 98, GH 1 and RRSA 315 recorded higher antioxidant enzyme activities compared to other clones/ortets at CES, Chethackal. At Dapchari, GH 3 and RRSA 585 showed better antioxidant defense system.

1.13. Experimental cultivation of high yielding varieties of rubber plants for establishment in higher elevation

Five clones of *Hevea* were planted in 2006 at Heileyburia tea estate, Elappara at Idukki, a high altitude location in the traditional belt. The overall growth of rubber plant was not satisfactory. Annual trunk girth was recorded in March, 2014. Among the clones, PB 260 (25.0 cm) and RRIM 600 (25.4 cm) continued to perform better than all other clones. In 2007 trial RRIM 600 (23.0 cm) performed better than all other clones. The polyclonal seedlings (30 cm girth) planted along with tea garden performed better than the hybrid clones. However, the traditional shade trees, silver oak (40 cm girth) planted between the rows of tea were found superior to polyclonal rubber seedlings.

1.14. Proteomic studies of *Hevea brasiliensis* under drought stress

Among the five clones studied, net photosynthesis (P_N) rate was better in clones RRII 430 and RRIM 600 than Tjir 1, RRII 414 and RRII 208. Relative water content (RWC) in leaves was better in clones RRII 430, RRIM 600 and RRII 208 than Tjir 1 and RRII 414 upon drought imposition up to 12 days. Leaf samples were collected in respective days and proteome studies are in progress.

1.15. Growth alteration in *Hevea brasiliensis*

Soil application of paclobutrazol in young rubber (*Hevea brasiliensis*) plants resulted in short and compact plants having dark green leaves, with more fibrous root development (Fig. Phy. 2). Three months after treatment the leaves showed increased chlorophylls (25.9%) and carotenoids (33.6%) content over control plants. The height increment in paclobutrazol (50 mg) treated plants was significantly lesser than control plants of same age, whereas, the girth increase was significantly higher (10.9%) in 50 mg treated plants. Paclobutrazol treatment remarkably increased root dry weight (maximum of 132% with 50 mg) and root-to-shoot ratio (Fig. Phy. 2). The results indicated that paclobutrazol with a concentration of 50 mg active ingredient was optimum for more fibrous root development without any significant changes in stem girth and leaf number. The enhanced root system development along with other physiological modifications may likely to add advantages to young *Hevea* plants in terms of drought tolerance in field condition.

2. Production Physiology

2.1. Intercropping tree crops in rubber

The girth and annual girth increment of rubber trees grown with perennial tree intercrops, and rubber tree (52 cm girth)

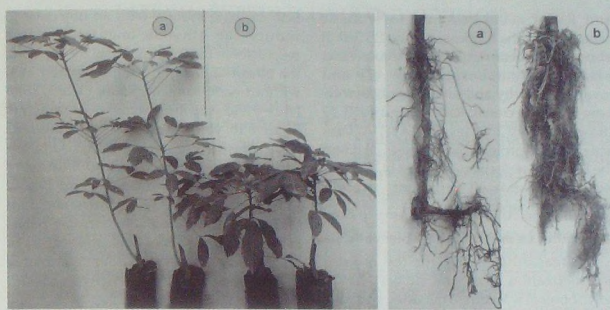


Fig. Phy. 2. **Control (a) and paclobutrazol-50 mg treated (b) polybag plants and modified root system of *Hevea*, six months after application of paclobutrazol**

alone did not exhibit any significant difference in growth. However, the rubber yield of trees varied among the treatments with decrease in yield in intercropped area. About 16-23 per cent reduction in yield was noticed in mahogany and pathimugom intercropped area. The growth of mahogany trees (44 cm girth) was found satisfactory compared to pathimugom (22 cm) and die-back of pathimugom trees was observed in highly shaded areas.

2.2. On farm trial for the selection of Latex-Timber clones

With an objective of selecting Latex-Timber clones in the traditional rubber growing region, four clones were selected in Malankara estate to find out the existence of any relationship between yield and annual girth increment. The clones were under tapping on S/2 d3 system. The annual girth increment and block yield during 2013-14 were recorded. Among the clones, RRII 105 was shown to be the highest yielding clone closely followed by PB 235. The annual shoot biomass increment was the highest in PB 235 possessing desirable character as an L-T clone.

2.3. Clonal variation in latex regeneration mechanism in *Hevea brasiliensis*

Analysis of the data on rubber yield and biochemical parameters related to latex regeneration showed a significantly high rubber yield in clones RRII 105, PB 260 and RRIM 600 compared to other clones. Among the RRII 400 series clones RRII 422 and RRII 430 showed higher yield than the check clone RRII 105.

Sucrose content was the highest in clones PB 217 and RRIM 600 and the lowest in PB 260. The low yielding clone RRII 38 and RRII 33 also showed a higher sucrose content in latex. In clone PB 260, the sucrose level is very low (2.6 mM) and it showed high ATP and invertase activity. Among the RRII 400 series clones, RRII 422 and RRII 430 showed higher ATP and invertase in latex. The highest ATPase and pyrophosphatase activity was observed in clones RRII 105

and RRIM 600. Protein biosynthetic capacity was the highest in clone PB 260. It also showed better utilization of sucrose as evidenced by increased latex ATP and invertase activity and low level of sucrose. Low yielding clones RRII 38 and RRII 33 showed a very low level of ATP, ATPase activity and protein biosynthesis. Among the RRII 400 series clones, RRII 414, 429 and RRII 430 showed efficient protein biosynthetic capacity in latex.

2.4. Studies on *in vitro* rubber biosynthesis

A feasibility study for the *in vitro* polymerization of natural rubber (cis 1,4 polyisoprene) was carried out using synthetic isoprene, initiators and cofactors. The natural isopentenyl pyrophosphate (IPP) monomer was replaced with synthetic isoprene and allylic initiator farnesyl pyrophosphate and other cofactors. Whole latex and washed rubber particles were used for the study. The *in vitro* biosynthesis of rubber was very low only at milligram level.

2.5. Studies on rubber biosynthesis: Gene expression studies

Expression analyses of five genes involved in rubber biosynthetic pathway showed significantly high level of expression for hmgr1 and diphospho mevalonate decarboxylase in high yielding (RRII 105 and PB 217) than in low yielding (Tjir 1 and RRII 38) clones.

3. Tapping Panel Dryness

3.1. Location specific stimulant application on ethylene induced stress responses in the tapping panel of *Hevea* trees

The experiment was continued at CES, Chethackal in clone RRII 105 under S/2 d3 6d/7 tapping system with an objective to reduce the ethylene mediated stress responses in the tapping panel by applying the ethephon away from the tapping area without compromising latex yield. Total latex yield and biochemical parameters related to yield and stress components were measured in latex and bark samples. Among the treatments, bark application of 5 per cent ethephon above and below showed very low sucrose content and high MDA and peroxidase activities compared to normal stimulation. Bark application of 2.5 per cent ethephon above and below showed less stress components and better tolerance mechanism.

3.2. Investigation on the molecular physiology of tapping panel dryness syndrome (TPD) in *Hevea brasiliensis*

In order to identify genes/factors associated with tapping panel dryness (TPD), bark RNA from normal and tress with different levels of TPD (10-20%, 40-60% and 80-100%) were subjected to transcriptome sequencing. Bioinformatics analysis of the transcriptome sequencing data is in progress.

4. Secondary metabolites

4.1. Quantification and identification of inositol in *Hevea*

A preliminary market evaluation of the inositol compound (L-quebrachitol) obtained from rubber latex was conducted in collaboration with Biotechnology Consortium of India Limited (BCIL). The result was found encouraging that a large consumer sector is available for the compound. Further action was taken to license the technology.

LATEX HARVEST TECHNOLOGY DIVISION

The Division was very active in the research and advisory services on all aspects of crop harvesting. After successfully completing the collaborative programme on d3 frequency tapping in smallholdings, an ambitious and challenging similar programme on low frequency weekly tapping in smallholdings was undertaken. Development of various grades of biodegradable polythene in collaboration with a private entrepreneur is another major development. In the farm mechanization programme, two mechanical and two motorised tapping tools were short listed for field evaluation to be conducted during 2014. All the programmes progressed well.

1. Low Frequency Tapping

The Division continued experiments, onfarm and advisory trials on Low Frequency Tapping. The comprehensive study on frequencies ranging from alternate daily to weekly tapping at Koney estate of Harrisons Malayalam Ltd continued successfully. From the current year (third year of tapping) onwards the stimulation frequency was reduced to 12 rounds per year for weekly (d7) tapping, and to 10 rounds per year for once in six days (d6) tapping. In addition to the yield and its components, tolerance of the laticiferous system under the different tapping frequencies and yield stimulation were studied. As in the previous years, yield under all frequencies except in S/2 d3 without yield stimulation were comparable. Bark consumption was directly related to the frequency, i.e. higher the frequency higher was the bark consumption. There was no indication for accumulation of stress indicators like proline and phenol even under weekly tapping with higher rounds of yield stimulant application.

1.1. Collaborative programme of RRII and Regional Offices of Rubber Board in popularizing weekly tapping with stimulation in smallholdings

The programme on identifying suitable plots of growers interested in implementing weekly tapping was initiated. Interested growers were briefed on do's and don'ts for the successful conduct of weekly tapping. Six plots were already finalised and efforts were intensified to have atleast two plots per regional office from April, 2014.

1.2. Exploratory trial on Low Frequency Tapping system (d10) in clone RRII 105

In the exploratory trial on once in 10 days tapping (d10) at Central Experiment Station (CES), Chethackal in clone RRII 105, yield of 2442 kg trees^{-400} trees was obtained with annual average drc of 39.2 per cent during 3rd year of tapping on BI-1 panel. Overall mean yield of twelve years tapping was 2506 kg trees^{-400} (6.3 kg tree^{-1}). Tapping Panel Dryness (TPD) is very low (< 2 %)

1.3. Demonstration trial on Low Frequency Tapping (d6) in clone RRII 105

The demonstration plot under weekly tapping with monthly stimulation at Central Experiment Station (CES), Chethackal continued to give promising yield. With 12 rounds of yield stimulation and 52 tapping days, the annual yield was 2474 kg trees^{-400} (6.2 kg tree^{-1}) and mean drc was 38.3 per cent during the year. Incidence of tapping panel dryness is 3.3 per cent. Mean yield of twelve years of tapping was 2653 kg trees^{-400} (6.6 kg tree^{-1}).

2. Controlled Upward Tapping (CUT)

An RBD experiment on LFCUT (d10) with four treatments and five replications was laid out at EFU, RIT, Pampady. Significant yield variation was observed between the treatments. Under d10 treatments yield ranged from 80 g $t^{-1}t^{-1}$ to 285 g $t^{-1}t^{-1}$. Higher per tap yield (kg tap^{-1} $trees^{-400}$) was also observed under d10 frequency. However dry rubber yield (kg $tree^{-1}$ and kg $trees^{-400}$) were observed to be significantly higher under d3 system which warrants refinement in stimulation technology under d10.

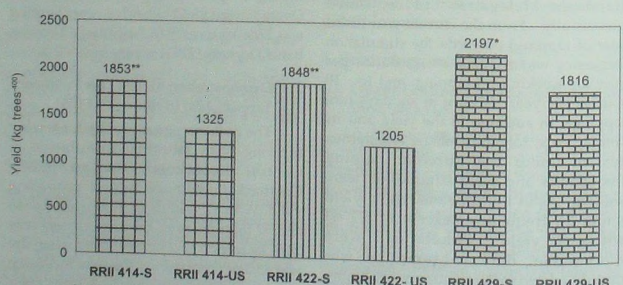
All India coordinated project on CUT was continued in all locations and the yield performance under periodic panel change system is similar to that in previous year. A recent survey has indicated that above 50 per cent of tapping area in India is occupied by old and senile rubber trees with below average productivity. This is one of the major reason by which India is pushed to third position in productivity. By a quantum leap in implementing CUT, and resultant increase in yield national productivity can be enhanced further.

3. Other Experiments

3.1. Onfarm evaluation of reduced spiral tapping

At the two onfarm locations, Piravom and Ottappalam, S/4 d3 tapping with 6 rounds of 2.5 per cent ethephon application is being continued successfully. From October, 2013 onwards, S/4 d3 tapping programme was initiated in two fields (one each on clone RRII 105 and RRII 414), at Mundakkayam estate of Harrisons Malayalam Ltd. Similarly, another grower at Shimoga is carrying out S/4 d4 tapping under our guidance. Initial information from these locations are also promising.

All the available information will be compiled and after approval is proposed to be issued as recommendation.



S - Stimulated US - Unstimulated

**: Significant at P<0.01; *: Significant at P<0.05

Fig. LHT. 1. **Response of RRII 400 series clones to yield stimulation**

3.2. Response of RRII 400 series clones to yield stimulation

Response of different RRII 400 series clones (RRII 414, RRII 422 & RRII 429) to yield stimulation varied at CES, Chethackkal. Among the unstimulated trees, yield was higher in RRII 429 followed by RRII 414 and RRII 422. But with two rounds of yield stimulation with ethephon 2.5 per cent, yield was high in clone RRII 429 followed by RRII 414 and RRII 422 (Fig. LHT. 1). Yield increase over unstimulated control for RRII 414, RRII 422 and RRII 429 were 40 per cent, 53 per cent and 21 per cent, respectively.

Decrease in dry rubber content by yield stimulation was by 3 per cent in RRII 429 and RRII 414 clones, whereas in RRII 422 decrease was only by 1.5 per cent. During the month of July and August, drc was less than 30 per cent in RRII 414, RRII 422 and RRII 429.

In another block trial at HML, Kumbazha estate in clone RRII 430, yield increase by one round ethephon application was only 8 per cent whereas it was 19 per cent increase by two rounds of stimulation, compared to unstimulated blocks.

3.3. Comparison of needle tapping (d3) with conventional tapping system (S/2 d3)

Preliminary observation on 'needle tapping' with stimulation under d3 frequency of tapping showed significant yield decrease. The average yield was only 24 g $t^{-1}t^{-1}$ with needle tapping as against 52 g $t^{-1}t^{-1}$ in conventional tapped trees (S2).

3.4. Evaluation of non- conventional tapping methods : Evaluation of vertical tapping

The RBD experiment on vertical tapping under d3 system of tapping initiated with five treatments and five replications at EFU, RIT was continued. Dry rubber yield data from all tapping days were collected, compiled, processed and statistically analysed. Dry rubber yield of 48 g t^{-1} t^{-1} could be obtained with vertical tapping cut of 10 cm with 36 rounds of yield stimulation (with ethephon) and was observed to be at par with 56 g t^{-1} t^{-1} obtained under normal downward half spiral tapping cut. The dry rubber yield obtained under vertical tapping cut of 10 cm and 22 cm with higher levels of stimulation were comparable and statistically at par with that of normal down ward half spiral tapped trees under d3 frequency of tapping during the year 2013-14. Preliminary results indicated that, it is feasible to obtain comparable yield under vertical tapping with appropriate stimulation (Table LHT. 1).

3.5. Testing and evaluation of products : testing and evaluation of Ethephon (new brands)

The RBD experiment with four treatments and six replications laid out at

Table LHT. 1. **Dry rubber yield under conventional (half spiral) and vertical tapping systems**

Sl. No.	Treatments	Dry rubber yield (g t^{-1} t^{-1})
1	S/2 (RG) d3 6d/7 ET. 2.5 % Pa 3/Y	55.9 a
2	Vert. (22 cm) (RG) d3 6d/7 ET. 2.5 % Pa 12/Y	35.3 b
3	Vert. (22 cm) (RG) d3 6d/7 ET. 2.5 % Pa 24/Y	47.8 ab
4	Vert. (10 cm) (RG) d3 6d/7 ET. 2.5 % Pa 24/Y	44.5 ab
5	Vert. (10 cm) (RG) d3 6d/7 ET. 2.5 % Pa 36/Y	48.0 ab
LSD	(P= 0.05)	17.3

CES, Chethackal to test and evaluate Ethephon 10 per cent formulated and marketed by two firms in comparison with already tested and evaluated ethephon and control (unstimulated), under d3 frequency of tapping was continued. It was observed that, all the makes of ethephon were significantly effective in enhancing the yield ($g\ t^{-1}\ t^{-1}$) and has resulted in 25-29 per cent yield increase over the unstimulated control trees.

3.6. Long-term response of yield stimulation in clone RRII 105

Two products (Vitex and Agrowin gel) were evaluated in comparison with ethephon. With higher levels of Agrowin gel application, higher yield could be obtained. No significant difference in yield could be observed between ethephon (3/Y) and Vitex (6/Y).

3.7. Development and evaluation of biodegradable polythene

Though the material evaluated during 2012-13 fully served the purpose of rainguarding, the degradability started very late, i.e. only after one year after removing from the tree. Initiation of biodegradability atleast within three months is desirable. Hence, in collaboration with M/s Everest polymers, Managalore, seven different grades of polythene with different levels of additive was prepared, which will be evaluated during 2014-15.

RUBBER TECHNOLOGY DIVISION

In the current year, the activities of the Division were focused mainly on evolving improved techniques in processing of rubber, radiation vulcanisation of latex, latex stage incorporation of fillers, reinforcement of NR using polymeric filler and silica, scorch control of peroxide vulcanisation and rubber nanocomposites based on modified clays.

1. Primary processing

1.1. Deproteinised natural rubber (DPNR) processed through combined gamma ray irradiation and enzymatic hydrolysis

An attempt was made to deproteinise natural rubber through hydrolysis of proteins by the combined effect of enzyme treatment and γ-ray exposure. Fresh natural rubber latex was exposed to low doses of γ-radiation. The latex was then creamed after dilution. The creamed latex was treated with a protein hydrolyzing enzyme, diluted, coagulated, dried and processed in the conventional way. The results showed that deproteinised rubber (DPNR) produced by this method had good raw rubber properties. (Table Chem. 1) The DPNR produced by this method showed very good mechanical and dynamic properties like low compression set, and low heat build up in a carbon black filled mix (Table Chem. 2 and Table Chem. 3). The

Table Chem. 1. **Raw rubber properties of creamed latex before and after gamma** ray irradiation

Parameter	Before exposure	After exposure
Nitrogen content (%)	0.3	0.2
Initial plasticity (P_o)	29	33
Gel content (%)	2	36
Acetone extractable (%)	3.9	5.9

Table Chem. 2. **Formulation of carbon black filled mixes**

Ingredients	Carbon black filled
Rubber	100
ZnO	5
Stearic acid	1
Antioxidant	1.2
SRF black	40
N oil	2
CBS	0.9
Sulphur	2.5

Table Chem. 3. **Mechanical properties of carbon black filled mixes**

Parameters	DPNR-IE*	DPNR-E**	ISNR 5
Modulus 300 %, MPa	8.5	9.3	8.3
Tensile strength, MPa	29.0	27.9	27.1
Elongation at break (%)	752	682	740
Tear strength, N/mm	100	94	104
Hardness, Shore A	59	62	61
Din abrasion loss, mm^3	116	135	124
Heat Build-up, ΔT °C	14	16	17
Compression set (%)	42.6	39.0	43.2

* DPNR produced by combined gamma irradiation and enzymatic hydrolysis of proteins
** DPNR produced by enzymatic hydrolysis of proteins

improvement in mechanical and dynamic properties is attributed to these chemical changes that take place during γ-ray irradiation and enzyme treatment.

1.2. Superior processing rubber (SP rubber)

Superior processing (SP) natural rubber was prepared by blending different proportions of fresh and radiation vulcanised natural rubber latex, followed by coagulation and drying. The Mooney viscosity of SP rubbers increased as the proportion of crosslinked rubber increased. Crosslinked and uncrosslinked rubbers blended in 20/80 proportion (NR 20) has recorded very good mechanical and processing characteristics compared to pure NR (Table Chem. 4). The better processing characteristics were attributed to the higher viscous nature of the modified rubber in gum and carbon black filled mixes as observed from the data recorded using a Rubber Process Analyser.

The frequency sweep for compounded rubber as per ACS1 formulation measured at a strain of 100 per cent (Fig. Chem. 1) recorded a noticeably higher tan δ for NR 20 and NR 40 compared to pure NR. At higher frequencies also a higher tan δ was shown by NR 20 and NR 40 but there was lower difference in the tan δ values for the different mixes.

1.3. Modified coagulant in sheet making

A modified coagulant based on surface active agents was used to achieve faster

Table Chem. 4. **Mechanical properties of carbon black filled mixes for superior processing rubbers**

Particulars	NR 20	NR 40	NR 60	NR 80	NR
Modulus , MPa	2.8	2.9	3.0	2.7	2.4
Tensile strength, MPa	24.5	22.6	22.6	21.4	20.1
Elongation at break (%)	615	580	585	585	640
Tear strength, N/mm	113	108	98	83	83
Hardness, Shore A	62	62	62	60	58
DIN abrasion loss, mm^3	135	132	133	144	125
Compression set, % 22 h at 70 °C	40.9	41.5	42.6	42.2	41.0
Heat build-up, Δ T, °C	18	19	18	17	17
Solvent absorbed, % (after 24 hours in toluene)	192	190	183	180	193

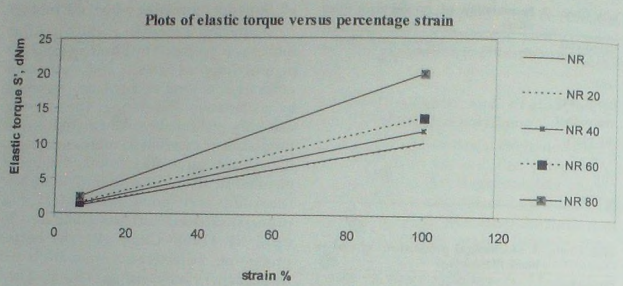


Fig. Chem. 1. **G' vs Strain of un-vulcanized SP rubber samples**
(NR 20, NR 40 , NR 60 and NR 80 crosslinked and uncrosslinked rubber in 20/80,40/60, 60/40 and 80/20 proportions)

coagulation of NR latex, early maturation of the wet coagulum thus resulting in a fast sheet making process. The P_0, PRI and Mooney viscosity of the sheets prepared using the modified coagulant were comparable to that of the sheets prepared by conventional formic acid coagulant (Table Chem. 5).

Table Chem. 5. **Raw rubber properties of rubber sheet prepared using the modified coagulant and formic acid coagulant**

Raw rubber properties	P0	PRI	ML4 100
Formic acid coagulant	55	89	85
Modified coagulant	53	89	83

Table Chem. 6. **Mechanical properties of the blend**

Parameters	RVNRL/SVNRL			
	100/0	90/10	80/20	0/100
Modulus 300%, MPa	1.1	1.1	1.1	1.1
Modulus 500%, MPa	1.5	1.5	1.55	1.58
Tensile strength, MPa	24.02	24.12	24.80	29.6
Elongation at break, %	1280	1290	1300	1400

Table Chem. 7. **Leachable proteins**

Type of RVNRL film	Extractable protein content µg/g
RVNRL films Unleached	312
RVNRL films*	40
RVNRL/SVNRL films 80/20*	45
RVNRL/SVNRL films 60/40*	48

*After leaching in water for 24 hours

2. Latex technology

2.1. Radiation vulcanised latex (RVNRL)

Standardised a method to improve quality of RVNRL films using centrifuged latex prepared from fresh NR latex exposed to low doses of γ-radiation. The properties with regard to strength could be enhanced by blending with conventional sulphur prevulcanised latex. Pure SVNRL showed a higher tensile strength than RVNRL. As the proportion of SVNRL in the RVNRL/SVNRL increased from 10 to 20 parts the tensile strength

increased proportionately. It was observed that by suitable leaching process the leachable proteins could be reduced to very low values (Table Chem. 6&7).

3. Rubber Technology

3. 1. Reinforcement

3.1.1. ENR/ Polymeric filler system

The effect of polymeric filler on epoxidised natural rubber (ENR) was studied in to a tyre tread formulation. The concentration of polymeric filler used was 10 phr along with two types of modifiers at very low concentrations. Both the modifications did not adversely affect the cure characteristics of the compounds. The vulcanisates gave excellent mechanical properties such as tensile strength, modulus, elongation at break, tear strength etc. however, the abrasion resistance and flex resistance was inferior (Fig. Chem. 2).

3.1.2. Latex filler masterbatches

For latex masterbatches as there was *in-situ* formation of long chain fatty acids, it was observed that good level of vulcanisation was obtained with lower dosage of stearic acid (Table Chem. 8).

Table Chem. 8. **Mechanical properties of master batch in comparison with dry rubber mix**

Parameter	Masterbatch* Stearic acid , phr		
	0	0.5	1.0
Modulus 300 %, MPa	12.1	12.9	12.6
Tensile strength, MPa	28.9	29.7	29.6
EB,%	550	500	505
Heat build-up, $\Delta\,^{0}C$	16	16	16
Abrasion loss, mm^3	135	115	120
Tear strength, N/mm	106	105	110

* contains 40 phr ISAF black and 10 phr silica filler (All compounds contain ZnO-5 phr, CBS-0.9 phr. and Sulphur 2.5 phr as other compounding ingredients)

3.1.3. Silica reinforcement of Natural Rubber

Studies on silica reinforcement of natural rubber was continued. Silica filled

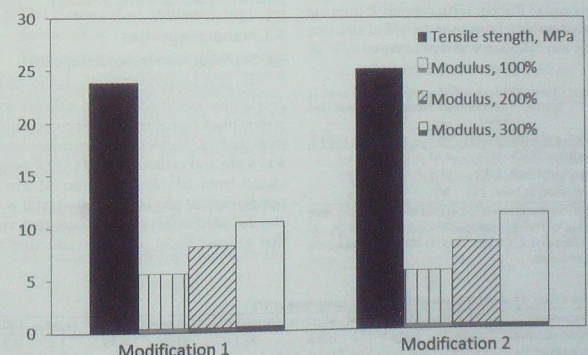


Fig. Chem. 2. **Mechanical properties of ENR vulcanizares containing polymeric filler with two modifiers**

natural rubber was prepared through Latex-filler masterbatch route. Natural rubber with varying proportions of silica viz; 40 to 60 parts of silica per hundred rubber were prepared. Sulphur vulcanizates prepared from these composites were evaluated for its mechanical properties. These composites exhibited properties comparable to that of the dry mixed (Table Chem. 9).

Table Chem. 9. **Mechanical properties of latex stage incorporated silica mixes**

Property	Silica loading, phr			
	40	45	55	60
Modulus, 100%, N/Pa 2	2.1	2.4	2.5	2.8
Modulus, 300%, N/Pa 2	7.5	9.3	9.0	11.2
Tensile strength, N/Pa 2	29.5	30.5	26.2	27.5
Elongation at break (%)	840	805	750	630

3.1.4. Reinforcement of Natural Rubber using modified silica

Silica was modified using varying amount of Rubber serum obtained from the sheet making process and dried in air oven. The modification was characterised by TGA analysis which showed that the serum components on the silica surface varied from 2.5 to 6 percent. Rubber compounds prepared using modified silica (containing 6 per cent rubber serum components) showed improvement in various vulcanizate properties like tensile strength, modulus etc. with respect to the control (Table Chem.10.).

Table Chem. 10.**Mechanical properties of rubber compounds containing modified silica**

Mechanical properties	VN3 *	Modified silica *
Modulus 300%, MPa	2.62	4.4
Tensile strength, MPa	18.8	25.3
Elongation at break (%)	905	886

Both the compounds contained Stearic acid-2, Zinc Oxide-4, HSL-1, Naphthenic oil-5, Ethylene glycol-5, Sulphur-2.5, CBS-0.7, TMTD-0.2 as compounding ingredients

3.2. Peroxide vulcanization

Di (tert-butyl peroxyisopropyl) benzene /TEMPO/ TMPTMA cure system has been has been developed with sulphur accelerator like scorch control during vulcanisation (Table Chem. 11) and excellent ease of mould release. The vulcanisate properties of the TEMPO containing vulcanisates are comparable with that of the control compound which does not contain TEMPO (Table Chem. 12). This cure system offers a convenient peroxide cure system which can be used by the rubber products manufacturing industry.

3.3. Nanocomposites

3.1. Nantural rubber nanocomposites

Synergistic effects of nanoclay (octa decylamine modified layered silicate) and carbon black on natural rubber compounds were studied. Nanoclay concentration used was 4 phr and carbon black (HAF) loading varied from 10, 15, 20, 25 and 30. For a comparison 50 phr HAF filled system was also included in this study. It was observed that at least 20-30 per cent reduction in

Table Chem. 11. **Cure characteristics of bulk compound at 175°C**

Compound	M_L,dNm	M_H,dNm	M_H-M_L,dNm	Tc100,Min	Tc90,Min	Ts_1,Min	Ts_2,Min	CRI
EPDM (Control)	25.7	128.2	102.3	32.1	11.7	0.89	1.0	9.2
EPDM/BBPIB/ TEMPO/TMPTMA	19.2	105.0	85.8	47.2	16.3	3.4	3.7	7.8

Table Chem 12. **Vulcanisate properties**

Properties	EPDM control	EPDM/di (tert-butyl peroxyisopropyl) benzene /TEMPO/TMPTMA
Tensile strength, MPa	16.3	17.3
100% Modulus, MPa	3.7	2.7
200% Modulus, MPa	10.2	6.7
300% Modulus, MPa	-	12.3
Elongation at break, %	269	383
Tear strength, N/mm	27.6	28.4
Hardness, Shore A	67	64
Compression set, 100°C, 72 h	8.3	14.1
Thermal ageing properties, 100°C, 72 h		
Tensile strength, MPa	16.5 (101%)*	16.9 (97%)
100% Modulus, MPa	2.4 (65%)	1.9 (72%)
200% Modulus, MPa	5.6 (55%)	3.9 (60%)
300% Modulus, MPa	10.7 (NA)	6.8 (55%)
Elongation at break, %	379 (141%)	523 (137%)
Hardness, Shore A	64 (96%)	62 (97%)

*Percent retention of property after ageing

carbon black loading can be achieved without sacrificing the physical properties.

4. Collaborative project

4.1. Development of rubber mounts for submarines

Formulations of Silicon rubber mounts were further modified to meet the stringent fire resistance properties of the components. Trial mounts made from the improved composition were evaluated by the end user and reported to have satisfactory performance.

5. Collaborative work with rubber industry

Based on the findings made in the Institute, initiated technology transfer with different rubber industries in the following areas.

1. Reinforcement of natural rubber using polymeric fillers.
2. Filler masterbatch from fresh natural rubber latex.
3. Deproteinised natural rubber.

6. Development / advisory work

6.1. Tested and report given for the damage of 8 nos of tyres referred from various Consumer Disputes Redressal Forums.

6.2. Tested and report given for 30 nos of polythene samples for the RP Department.

TECHNICAL CONSULTANCY DIVISION

The Division provides consultancy services to small and medium enterprises, individual entrepreneurs, central and state government departments and agencies. The services provided are R&D activities on industrially important rubber based projects and testing/certification of rubber products as per relevant standards. The Division caters to the needs of new entrepreneurs as well as existing rubber goods manufacturers. The services offered include (i) testing support to industries as per national and international standards; ii) product development-demonstration/ practical training for quality improvement; (iii) evaluation of chemicals; (iv) preparation of project profiles and technical bulletins to entrepreneurs; (v) advisory services and; (vi) conducting awareness meetings/lectures to entrepreneurs regarding trouble shooting/ cost reduction of factory processes.

1. Testing support to industries

For the testing of raw materials and rubber compounds/products, consistent support was offered especially to small and medium level entrepreneurs.

Different types of dry rubber products tested in the Division are pre-cured/ conventional tread, bonding gum, black vulcanizing cement, tyre flaps, inner tubes, rubber channels/ tubes, floor mats, Hawaii soles, sponge rubber, O-ring, bushes, engine mounts, automobile components *etc.* The main latex products tested include examination and surgical gloves, latex adhesive, latex thread, balloons and condoms. Protein analysis of latex products and evaluation of chemicals/latex based paints are also done. Total number of samples tested and the revenue collected during the reporting period are given in Table TC. 1.

Table TC. 1. **Total number of samples tested and the revenue collected (2013-14)**

No. of clients	578
No. of products tested	1502
No. of parameters analyzed	7451
Total revenue collected (Rs.)	2756605

2. Product development

As required by the clients, 28 different types of rubber products were developed as per the specifications and the know-how were transferred to the clients.

3. Evaluation of chemicals

In the reporting period, 19 chemicals from various clients were analysed and their suitability in rubber was evaluated and the detailed reports were communicated to the clients.

4. Project profiles/Technical bulletins

As per the request of the entrepreneurs, 11 project profiles and 10 technical bulletins were issued on payment basis.

5. Advisory services

Appropriate guidance on matters relating to various aspects like selection of raw material, dosage of ingredients, processing conditions, recent regulations etc. were given to the clients.

6. Seminars/ Workshops

A one day workshop on "Latex dipping and Foam manufacture was organised and over 200 delegates attended the workshop.

7. Participation in scientific seminars / symposiums

i. Deputy Director participated in NRC 2013, Chennai and delivered

lecture on "Quality control tests on NR latex products".

ii. Officers from TC Division attended training programme on "Laboratory management system and internal audit as per ISO/IEC 17025: 2005", held at Chennai.

iii. Concerned officials attended the seminar on "Role of R&D in the indigenization of ship building" organized by NIRDESH, Kozhikode on 18th July 2013.

iv. Officers from TC Division attended the seminar on "Formic acid for rubber industry" conducted by BASF, India at Kottayam and the IRSD 2013 organised by Rubber Asia at Kochi on 7th September 2013.

v. Deputy Director presented a paper on "Recent development in rubber nano-compound" at Kochi and he has also delivered an invited talk on "Preparation and applications of nano-ZnO in latex technology" in the 8th International Latex Conference held at Kuala Lumpur, Malaysia.

vi. Officers from TC Division attended the three day training on "Competence development in technical service delivery" organized by the Rubber Training Institute.

8. Industry visits

M/s Coco latex, Moonnilavu, M/s Alleppy Latex Pvt. Ltd, Kottayam and M/s Rubco, Pampady, Kottayam were visited in connection with trouble-shooting in the factory process and coir foam preparation.

9. NABL accreditation

In connection with the filing of application for NABL accreditation, following documents have been prepared. i) Quality Manual, ii) Quality System Procedure, iii) System Operating Procedures, iv) Formats and Work Instructions and v) Test Procedures. In addition to these, officers in the Division have attended various training programmes on laboratory management system and internal audit as per ISO/IEC 17025: 2005.

10. Research projects

10.1. ZnO nano dispersions

The performance of the dispersions of ZnO in the nano-meter scale was compared with the conventional latex vulcanizates. It has been found that small amount of nano ZnO (1/10th of normal) will give identical properties when compared with vulcanizates made from micro-dispersions of ZnO.

10.2. Peroxide vulcanization of rubbers

The effects of temperature and concentration on the cure kinetics and physical properties of peroxide cured natural rubber have been investigated. Dicumyl peroxide (DCP) having 40 per cent activity was used as the crosslinking agent. The Monsanto Rheometer was used to investigate the kinetics of the peroxide vulcanization. It was found that thermal decomposition of the peroxide followed a first order free radical decomposition reaction and therefore, half-lives at various temperatures were estimated from the kinetic data. The optimum mechanical properties can be achieved by completely decomposing the peroxide in the vulcanizates. Moreover, as the concentration of peroxide increases the addition mechanism competes with abstraction mechanism, producing a stiffer vulcanizate with lower mechanical properties.

10.3. Design of cost effective tread formulations as per national specifications

All possible blend proportions of NR/PB were formulated along with essential rubber chemicals and testing was carried out as per national specifications.

10.4. Rubber compounds with improved flex crack resistance

Nitrile rubber is generally used for oil contact applications. Certain products require flex-crack resistance in addition to oil resistance. It has been observed that by using GPF (General Purpose Furnace) black filler at a loading of 50 phr, the flex-crack resistance of nitrile rubber products can be improved significantly.

10.5. Cell structure and performance of expanded rubber

Expanded rubber products are used in many household applications as well as in automotive industry. The technological properties of expanded rubbers are largely depended on the cell structure, which in turn is a function of the blowing agent used. In the present study three types of blowing agents are used. In the initial phase, the effect of blowing agent (DNPT) has been studied. It has been found that as the loading of DNPT increased above 6 phr, the technological properties were found to deviate from the BIS specification for the expanded rubber.

10.6. Electromagnetic interference shielding composites based on natural rubber

With a loading of 15 wt per cent expanded graphite, the tensile strength improved over the virgin NR by 22 per cent, whereas incorporation of expanded graphite did not reduce the elongation significantly. The composites also showed significant improvement in tear strength and hardness from that of virgin elastomer. At 15 phr expanded graphite loading, the total electromagnetic interference shielding effectiveness reaches -18dB. The effective dielectric constant and loss of the composite is derived over the frequency range and it can be clearly seen that the increased absorption emanates from the increased conductivity of the composite. Expanded graphite, which is cheaper reinforcing filler than carbon nanotubes, can find application in EMI shielding materials.

10.7. Quantification and characterization of blooming in rubber compounds

Variation of cure-time and temperature on blooming of a typical V-strap compound has been studied. Effect of certain chemical ingredients which promote blooming has been studied. Accordingly, design of bloom free formulations for various products are in progress.

10.8. Variation of particle size/extractable protein in different processing/product development techniques used in natural rubber latices

The protein content of the latex films prepared from different concentration methods was estimated and a relationship was established. The results were confirmed by FTIR analysis. Heat sensitized dipped films were also subjected to protein analysis using FTIR technique. For the study of storage stability of field latex, it was preserved for two months with different concentrations of ammonia. The preserved field latices were subjected to particle size analysis and viscosity study for two months.

ECONOMICS DIVISION

The five major thrust areas of research of the Division were: (i) farm management; (ii) primary processing and marketing of NR; (iii) rubber products manufacturing industry and foreign trade; (iv) intercrops and by-products; and (v) inter-divisional collaborative projects. Five projects were completed and reported during the period. The summaries of the results are given in the following sections.

1. Optional control of rubber nurseries in India

The preliminary results of the multi-disciplinary study on the rubber nurseries highlighted the important changes since the decontrol of rubber propagation in 1986. The important outcomes of the decontrol had been the transformation of rubber propagation into a trading activity and the consequent growth in the production and distribution of spurious planting materials. The absence of a regular monitoring mechanism to ensure the quality of planting materials has implicitly nullified the potential gains from technological shifts in vegetative propagation like root trainers developed by the Rubber Board. Hence, it was suggested to introduce an optional control of rubber nurseries to ensure the quality of planting materials produced and distributed. Given the large number of private nurseries, voluntary participation in the certification process is intended in the short-run. The certification scheme will be an annual process and a certification fee will be charged from every certified nursery.

2. Supply side rigidities, shift in tariff policy and surge in India's imports through duty paid channel: The case of natural rubber

The quantum jump in the share of NR imports into India through duty paid channel since 2009-10 has been unprecedented for the contributory factors and the implications. The magnitude of change in the share of the imports through the duty paid channel is underlined by the increase from 7.0 per cent in 2004-05 to 47.3 per cent in 2012-13 (Table Eco. 1). The observed trend during the past four years has been in sharp contrast to the hitherto

Table Eco. 1. **Channel-wise imports of NR (tonnes)**

Year	Imports (MT)		
	Duty free	Duty paid	Total
2004-05	67725.9 (93.0)	5109.0 (7.0)	72834.9
2005-06	43472.8 (96.0)	1811.7 (4.0)	45284.6
2006-07	86809.0 (96.7)	2990.2 (3.3)	89799.2
2007-08	75179.7 (97.3)	2121.3 (2.7)	77301.0
2008-09	77052.2 (99.1)	709.8 (0.9)	77762.0
2009-10	150837.8 (85.2)	26292.2 (14.8)	177130.0
2010-11	135602.0 (72.0)	52735.1 (28.0)	188337.0
2011-12	145961.8 (71.1)	59470.4 (29.0)	205432.2
2012-13	114489.9 (52.7)	102873.7 (47.3)	217363.6
Growth (%)	13.0	66.2	20.6

Figures in parentheses are the shares

unperturbed pattern of more than 90 per cent NR imports routed through duty free channel facilitated by duty exemption and remission schemes.

The available evidences on the recent increase in NR imports through duty paid channel are indicative of supply side rigidities in the NR production sector and the shift to the optional non *ad valorem* duty since 2010. The emerging trends in the growth and composition of NR imports underline the need for reinvigorating the NR production sector to confront the challenges of market integration.

3. Institutional interventions, growth in household income and extent of access to infrastructures: The case of beneficiary households under block planting scheme in Tripura

The study was an explorative analysis to understand the availability of infrastructural facilities at the village level and accessibility to the same by the beneficiary households of Block Planting Units (BPU) and Group Processing Units (GPU). Relevant data from 13 selected villages and 161 rubber growers attached to 11 BPU/GPU from West Tripura and South Tripura districts during the year 2010-11 were collected for the analysis. Tables Eco. 2 and 3 show the estimated infrastructure indices of the selected villages and BPU/GPUs.

Table Eco. 2. **Village-wise infrastructure indices**

Village	Score
Barabhaiya	117.7
Dakshin Rani ADC	103.4
Madhapur N	99.9
Kamalasagar	77.8
Madhapur S	77.2
Sipai Para ADC	77.0
Kaliram ADC	69.8
Devipur	65.7
Laxmandepha	59.7
Bagma ADC	44.0
Bhagaban Choudury Para ADC	39.0
Amtali ADC	36.8
Paschim Radhamohanpur ADC	24.2

Table Eco. 3. **BPU/GPU-wise infrastructure indices**

BPU/GPU	Score
Rajarshi GPU	108.0
Dariabagma	97.7
PS Para	95.2
Khamberbari	95.1
RS Para	94.3
Kamalasagar	93.8
Rani	87.7
Janmabhumi GPU	87.5
Laxmandepha	78.2
Kariyamura II	77.0
Rambabu Para	53.4

The results of the study showed that the beneficiary households under the BPU/GPU had better access to the selected infrastructural facilities in the region compared to the availability and accessibility at the village level. The beneficiary households overcame the given infrastructural constraints at the village level by virtue of higher household income. However, the higher household income had not been effective in utilising the available infrastructures for diversification of the sources of income. It was observed that the impact of higher household income from NR cultivation was confined to consumption linkages and the main reason for the same was found to be the nature and quality of human capital available among the beneficiary households.

4. Changing dimensions of external trade in India's latex and latex based products

The study showed that India has been gradually emerging as a net exporter of

latex concentrates and importer of latex based value added products. The observed trend is in sharp contrast to the pattern prevailed during past four decades. During the period 2002-03 to 2011-12 the pattern of trade exhibited a remarkable growth rate in the export of NR latex and a significantly higher growth rate in the imports of latex based value added products. Table Eco. 4 shows the trends in the external trade of NR latex and latex products during 2002-03 to 2011-12.

Table Eco. 4.**Trends in the external trade of NR latex and latex products (US $ million)**

Year	Export		Import	
	NR latex	Latex products	NR latex	Latex products
2002-03	3.6	47.3	2.0	3.3
2003-04	11.6	53.5	3.8	4.8
2004-05	7.4	47.9	1.6	5.2
2005-06	20.4	62.0	0.2	10.7
2006-07	16.5	60.5	0.9	13.6
2007-08	34.3	68.8	0.4	20.7
2008-09	34.9	135.0	1.2	21.8
2009-10	22.0	79.1	5.1	23.2
2010-11	29.5	91.3	5.6	34.2
2011-12	39.5	72.2	3.8	48.8
Average	22.0	71.8	2.5	18.6
CAGR	30.5	4.8	7.2	34.8

The underlying factors behind the observed trend indicated that the ongoing structural adjustments in the latex processing and product manufacturing segments, as evidenced by the changes in the composition of the external trade, underline the need for a critical assessment of the issues involved in collaboration with representative organisations of the respective industries.

5. Planting density of natural rubber in the traditional belt

The study was confined to Kerala and Tamil Nadu of the traditional belt. The database pertained to the growers who availed subsidy under the Rubber Plantation Development (RPD) Scheme of the Rubber Board during the seven year period from 2004 to 2010 was used. It covered 1,30,658 RPD permits with an area of 57,369.67 ha. The analysis of planting density of rubber in smallholdings for the period 2004-2010 indicated multifaceted features over time. In the traditional belt, except in North Kerala, the planting density of new planting was higher than that of replanting. After the release of RRII 400 series in the year 2005, significantly higher planting density was adopted for it in South Kerala. In all other regions, no significant difference in planting density was noticed between RRII 105 and RRII 400 series in the case of new planting, but higher density was adopted for replanting of RRII 105. An inverse relationship was observed between the size of holdings and planting density.

Advisory work

- A methodology for construction of index for ranking of weed cutters was developed and presented in the 55th Scientific Advisory Committee.
- As requested by Dy. RPC, Mangalore, net present value (NPV) of yield and timber were provided for four holdings as per court direction. The NPV was estimated for 22 years of productive life.
- Estimated estate-wise, block-wise and girth-class-wise timber volume and upset value of rubber trees in 230 ha of rubber area of State Farming Corporation of Kerala (SFCK), Punalur.
- A detailed list and relevant details of rubber and rubber products going to be placed under zero tariff regime were compiled and submitted to the Rubber Board for sensitizing all the concerned stakeholders.

CENTRAL EXPERIMENT STATION, CHETHACKAL

The Central Experiment Station Chethackal, located near Ranni at a distance of about 56 km from Kottayam, was established in 1966 to cater the research needs of the different Divisions of RRII. The Station has a total land area of 254.8 ha which is planted for different research projects.

The Station meets the needs of the scientists of various disciplines of Crop Improvement, Crop Management, Crop Protection, Crop Physiology and Latex Harvest Technology. The Station is divided into two divisions, A and B of almost equal area. Apart from clone trials and maintenance of bud wood nursery of pipeline clones, trials on low frequency tapping, CUT, disease management, fertilizer dosages and huge collection of germplasm accessions, both indigenous and introduced make up bulk of the experimental areas. Specialized trials on intercropping and techniques for immaturity reduction etc. also occupy part of the experimental area. A three part tree crown budded area with canopy from FX 516 is laid to study disease resistance mechanisms. An Eddy covariance tower gives micro environmental data.

During the reporting period, the total crop realized was 238349 kg PFL, 75808.4 kg (scrap) and 13399.5 kg coagulum. A total of 302 tapping days was possible in the year and 47 tappers (per day) were engaged for tapping.

REGIONAL RESEARCH STATION, GUWAHATI, ASSAM

1. Crop improvement

1.1. On- farm evaluation of selected clones of *Hevea* in Assam

Juvenile growth of four 400 series clones of *Hevea* (*viz.* RRII 417, RRII 422, RRII 429 and RRII 430) planted in four locations of Assam was found better in Umsiang and Bhakuagoog when compared to Byrnihat and Sonapur.

1.2. Evaluation of potential primary ortets in clonal nursery

In the evaluation of potential primary ortets (eight ortets) in clonal nursery trial (Table Ghy. 1), Ortet RRSG 9 followed by RRSG 8 had better girth and juvenile yield than RRII 429 and RRIM 600.

Table Ghy. 1. **Juvenile girth and yield of potential primary clones of *Hevea* after five years of planting in clonal nursery**

Sl. No.	Clones	Mean of juvenile girth (cm)	Mean of juvenile yield ($g\ t^{-1}\ t^{-10}$) after stimulation
1	RRSG 1	25.6	76.1
2	RRSG 3	22.5	49.2
3	RRSG 4	27.0	90.7
4	RRSG 5	25.8	63.7
5	RRSG 6	28.8	68.0
6	RRSG 8	30.5 *	111.5 *
7	RRSG 9	35.9 **	184.3 **
8	RRSG 10	20.1	29.5
9	RRIM 600	25.1	76.7
10	RRII 429	29.8	49.6
CD (Pe" 0.05)		3.79	30.55

* Significant at 5% level in comparison to RRIM 600;
** Significant at 1% level in comparison to RRIM 600

1.3. Performance of clone RRII 429 at grower's field in Assam

Girth and girth increment were found better in RRII 429 when compared to RRIM 600. In terms of mean yield, RRII 429 performed better than RRIM 600.

2. Crop management

2.1. Physico-chemical characteristics of dolomite deposited areas of North Bengal

Soil profile samples were collected from the dolomitic material deposited area at Sarugaon Tea Estate, North Bengal and analyzed. Soil texture ranged from sandy loam to silty loam and colour was dominantly grey for all the horizons. Organic carbon was medium (0.9%) in the surface horizon and low in all the sub surface horizons. Soil reaction was alkaline up to a depth of 50 cm and almost neutral below it. Ca^{2+} and Mg^{2+} were the dominant cations in the soil.

2.2. Quantitative and qualitative aspects of earthworm cast inside rubber plantations

Earthworm activity was observed under different vegetation *viz.* rubber, forest, paddy field and grazing land. Seasonal variation in the earthworm activity was very prominent and the highest activity was observed immediately after the monsoon was over. OC, available P and K were higher in the earthworm casts than the adjacent soil (Table Ghy. 2). pH was also higher in the earthworm cast.

Table Ghy. 2. **Available nutrient status and pH of earthworm cast (EWC) and soil inside rubber plantation**

Parameters	EWC	Soil
OC (%)	1.2	1.0
Av P (mg 100 g^{-1})	0.5	0.3
Av K (mg 100 g^{-1})	7.4	5.1
pH	5.3	4.5

2.3. Development of an Integrated Nutrient Management system for young rubber

The experiment on integrated nutrient management initiated in 2008 was continued. Girth at 150 cm height showed that there was significant difference between treatments at 5th year after planting.

2.4. Development of locally viable and adoptable root trainer technique for propagation of rubber

Budded stumps of RRIM 600 were planted in earthen and bamboo root trainers in different media at Sarutari farm under RRS, Guwahati. After bud sprouting, plants were established in the root trainers. Data on bud sprouting was recorded. Seedling plants were raised in these two types of root trainers and budding initiated.

3. Crop protection

3.1. Survey on pests and diseases of rubber

Survey on pests and diseases of rubber was carried out in 29 pockets covering 19 locations in Assam, Meghalaya and northern part of West Bengal. Severity of powdery mildew disease (PDI) was in the range of 20 to 70 % in most of the locations. Incidence of brown root disease (0.5 to 1.7%) was noticed on five/six-year-old rubber plants with maximum at Rampur (1.7%) in Assam. Incidence of Periconia leaf blight disease (20 to 100%) was noticed on tender leaves in nurseries in some locations with maximum at Ganolgre Research Farm in Meghalaya with heavy defoliation of infected leaves. Minor incidence of Colletotrichum leaf spot (10 to 20%) was noticed in nurseries in certain locations. Incidence of purple root disease (0.5%) was observed on seven-year-old plants at RRTC, Hahara in Assam. High infestation of white grubs (40%) was observed on one-year-old rubber plants in two pockets in a private

plantation at Udalguri in Assam. Infestation of scale insect (5 to 10%) was found in some locations in Assam, Meghalaya and northern part of West Bengal during the study period.

Isolation and identification of fungal pathogens from diseased samples collected during disease survey was carried out. Leaf samples of GT 1 with raised spot symptoms were collected from budwood nursery at Sarutari Research Farm and *Colletotrichum acutatum* was isolated from all the samples with raised spot symptom.

3.2. Evaluation of wild germplasm against tolerance to powdery mildew disease

The wild accession of *Hevea* germplasm AC 587 short-listed for high level of tolerance to powdery mildew disease was raised in polybag nursery for further assessment of the disease. The disease intensity in AC 587 was found to be only 12.5% when compared to 75% intensity in the susceptible clone PB 5/51.

3.3. Management of purple root disease of *Hevea* in immature plantation

In the experiment for the control of purple root disease in the clones RRIM 600 and RRII 105 at RRTC Hahara, root system of all treated plants was found to be healthy and fructification of *Helicobasidium compactum* was not observed at the plant base in the treated plot as seen in untreated plot. Microbial population in soil was high in healthy (not infected) plot than treated plot.

3.4. Dynamics of microbial status in the soils of Assam and North Bengal under rubber tea, forest and barren area

Microbial status under four different habitats *viz*. forest, rubber, barren and tea growing soils was studied. Seasonal variation of microbial population was observed. However, there was no significant impact on the composition of fungal species. Both qualitatively as well as quantitatively, the forest habitat harboured the highest population and was minimum in the barren soil. The soils of all the habitats were found to be acidic in nature.

3.5. Exploitation of naturally occurring antagonistic agents against diseases of rubber

Bacterial and fungal species were isolated from the rhizosphere of rubber and tested their antagonistic activity by dual culture technique against the brown root pathogen *Phellinus noxius*. All the organisms tested showed antagonistic activity against the pathogen.

Plant growth promoting rhizobacteria were isolated from the rhizosphere of rubber soil. *Bacillus subtilis, Proteus* sp. and *Pseudomonas fluorescens* were mass multiplied in the NA broth for nursery evaluation.

4. Crop physiology

4.1. Effect of application of stimulant away from the tapping panel

Effect of stimulation on different areas of bark away from the tapping panel was

Table Ghy. 3. Effect of stimulation on yield of rubber

System of stimulant application	Yield (g t^{-1} t^{-1})
A. Bark application of 5% Ethephon above 125 cm from the bud union	46.2
B. Bark application of 5% Ethephon on the bud union	50.2
C. Bark application of 5% Ethephon at both A and B positions	44.1
D. Bark application of base material (diluent oil) at both A and B positions	43.1
E. Unstimulated trees.	45.1
F. Panel application of 2.5% Ethephon (standard practice)	52.0
SD	3.5

evaluated based on the result over three years. The experiment was conducted in clone RRIM 600 and six different treatments were adopted along with unstimulated trees as control. The tapping system followed was S/2 d3 in blocks in BI-1 panel. The yield data over three years (Table Ghy. 3) showed that yield in treatments B and F was significantly higher than that of the unstimulated (E) trees.

REGIONAL RESEARCH STATION, AGARTALA, TRIPURA

The Station conducted various research programmes under crop improvement, crop management, latex harvesting technology, ecosystem evaluation and economics of rubber cultivation. Advisory services on latex analysis and discriminatory fertilizer recommendation were offered to rubber growers in this region.

1. Crop improvement

1.1. Development of clones

Development of high yielding genotypes is achieved through hybridization and selection, ortet selection and polycross breeding. In the clonal nursery evaluation of selected hybrids (2008), 98/46 (18.9 g t^{-1} t^{-1}) had the highest mean test tap yield among hybrids and was on par with RRIM 600 (19.4 g t^{-1} t^{-1}). In the clonal nursery evaluation of selected hybrids (2009), 99/1/24 (13.4 g t^{-1} t^{-1}) had highest test tap yield and was on par with RRIM 600 (14.9 g t^{-1} t^{-1}). Presently, 3892 genotypes including hybrids and half-sib progenies are under seedling nursery evaluation and 350 selections were made based on test tap yield in the seedling nursery for further evaluation.

Eleven selected ortets were evaluated in SST with check clone RRIM 600. Ortet 114 (55.2 g t^{-1} t^{-1}) gave significantly higher yield compared to RRIM 600 (42.9 g t^{-1} t^{-1}). Among the 13 ortets from North Eastern region, RRSG 248 recorded highest mean test tap yield (17.9 g t^{-1} t^{-1}) followed by RRST 37 (15.9 g t^{-1} t^{-1}). In the clonal nursery evaluation of selected ortets and hybrids from traditional region (2009), RRII 407 recorded significantly higher test tap yield (22.2 g t^{-1} t^{-1}) compared to RRIM 600 (14.6 g t^{-1} t^{-1}). Among the ortets, P 132 recorded the highest test tap yield (18.9 g t^{-1} t^{-1}) and was on par with RRIM 600.

1.2. Evaluation of clones

Ten clones are under evaluation in a

Table Agar. 1. **Yield and growth performance of 13 clones in LST (1996)**

Clone	Girth (cm) February 2014	Mean yield (g t^{-1} t^{-1}) 2013-14	Mean yield (g t^{-1} t^{-1}) over 11 years
RRIM 600	71.8	59.8	44.2
RRII 429	77.0*	68.5#	**51.6***
RRII 203	75.1#	40.1	34.8
PB 217	73.1#	44.9	33.4
RRII 51	68.8#	35.2	30.0
RRII 414	66.9	45.3	35.9
RRII 430	64.7	52.7#	44.1#
RRIC 100	74.7#	52.7#	41.0#
RRII 422	68.5#	68.0#	**52.1***
RRII 105	67.7#	42.8	40.3#
RRII 417	71.2#	63.1#	46.6#
RRII 176	81.8*	44.0	35.2
PB 235	72.8#	42.0	39.2
CD (0.05)	4.4	13.1	4.6

*Significantly higher than RRIM 600

#On par with RRIM 600

large scale trial (LST) planted in 1995 and among the clones SCATC 88/13 (56.1 g $t^{-1}t^{-1}$) recorded highest mean yield and was on par with RRIM 600 (54.4 g $t^{-1}t^{-1}$). In the LST planted in 1996 (GxE trial), comprising of 13 clones, clone RRII 429 (68.5 g $t^{-1}t^{-1}$) had the highest mean yield (Table Agar. 1) and was on par with RRIM 600 (59.8 g $t^{-1}t^{-1}$).

Potential clones are being evaluated in four on-farm trials. In Killamura block plantation (1997), RRIM 600 recorded the highest yield (1069 kg ha^{-1} yr^{-1}). At TFDPC plantation, Bagafa, South Tripura (2000), RRIM 600 (29.9 g $t^{-1}t^{-1}$) gave the highest mean yield. In the on-farm trial at TRPC plantation, Pathalia (2005), comprising of RRII 400 series clones, RRII 429 recorded the highest mean girth (53.3 cm) as well as tappability (74%). At Hirapur Block plantation (2009), RRII 203 recorded the highest mean girth (30.3 cm). Among the four clonal nursery evaluations involving 87 clones, PB 255, P 021, P 060 and BPM 24 exhibited better test tap yield while P 107 had better vegetative growth.

Field trial involving 57 clones for the identification of reliable juvenile and mature characteristics for clone identification is also in progress.

2. Crop management

The experiment on integrated nutrient management in young rubber was concluded. Significant improvement in girth of rubber plants were noted in the treatment with 50% N and P, 100% K and biofertilizers (a consortium of *Azotobacter, Phosphobacteria, Pseudomonas* and VAM) compared to the control and the treatment with biofertilizer alone. The treatment with full dose of inorganic fertilizers alone also recorded similar girth as in the case of integrated treatment. Significant improvement in leaf nitrogen content (3.24%) was observed in treatment with integrated application of biofertilizer and dose of N, P and K compared to control and biofertilizer alone tratments. Integrated application of bio-fertilizers with reduced doses of inorganic fertilizer is beneficial for rubber in the initial five years.

Soil moisture profile under various age group of rubber plantation (2-25 years) was investigated for two consecutive years. Annual mean soil moisture content ranged from 8.6 to 32.8 % up to a depth of 90 cm. Field capacity of these soils varied between 23.9 and 29.8 %, whereas permanent wilting point of soils ranged from 8.6 to 13.1 %. Available water content of these soils ranged from 15.2 to16.6 % and available water storage capacity under rubber varied from 159.2 to 226.7 mm m^{-1}. It was observed that 65 to 71% soil moisture under rubber plantation were desorbed at 500 KPa suggesting moderate water storage capacity of rubber soils in Tripura.

In the intercropping experiment, *Colocasia* recorded highest benefit cost ratio (BCR) (3.2), followed by cowpea (2.0), maize (1.86), rice (1.82), and *Amorphophallus* (1.7) after six years in the cropping system model. Among the short term crops banana recorded higher BCR (2.6) over pineapple (1.8) in cropping system models. The yield declining trend was continued in tea intercropping experiment due to shading of rubber canopy. Tea yield was 65 kg ha^{-1} for intercrop and 1680 kg ha^{-1} for tea monocrop. Yield of clone RRIM 600 (1731 kg ha^{-1}) and PB 235 (1529 kg ha^{-1}) were significantly higher in comparison to other clones like GT 1 (1317 kg ha^{-1}) and RRII 105 (1073 kg ha^{-1}).

The zero tillage experiment was initiated to study the effect of pit size on

early growth of rubber plants. The polybag plants were field planted in medium size circular pits (25 x 60 cm) and in the recommend large sized pits (75 x 75 x 75 cm). Another set of root trainer plants were planted after one year in smaller size circular pits (10 x 30 cm). It was observed that the girth of two year old root trainer plants in smaller pits (11.9 cm) was on par with three year old polybag plants in medium and large size pits.

In another trial on mulching it was observed that the mean girth of vertical mulched plants was 15.8 cm while it was 14.6 cm in conventional mulching and 10.7cm in control. The mean soil moisture during rain free Nov-Feb period in 0-60 cm depth in vertical mulching, conventional mulching and control was 14.4%, 13.1% and 9.3% respectively.

In the trial on identification and standardization of potting media for root trainers, it was observed that the root and shoot parameters of rubber plants were comparable in various combinations of top soil and cow dung *viz.* 8:2 and 7:3 and also in the 7:2:1 combination of top soil, cow dung and rice husk. However, the combination of top soil with cowdung and rice husk appeared to be better for compactness of soil in root trainer.

3.1. Latex Harvest Technology

Effect of stimulation on latex yield was conducted with an objective to reduce the ethylene mediated stress on tapping panel, where the stimulant was applied away from the tapping area. The trees were tapped under d3 system of tapping in BO-2 panel without rest in clone RRIM 600. Four years results showed that the mean rubber yield was higher (2820 kg ha^{-1}) in panel application (ET 2.5% Pa 3/Y) (standard recommended method) followed by trees stimulated at both the regions (ET 5% Ba 3/Y) above (150 cm above the bud-union) and below (on the bud-union) the tapping area, which recorded an yield of 2152 kg ha^{-1}.

In shallow tapping experiment, high yield was observed under continuous tapping (S/2 d2 6d 7) followed by tapping rest for two months and shallow tapping for six months (October to March) during the stress period of the year.

Under experiment on different systems of tapping, clone PB 235 continued to give highest yield in S/2 d3 system of tapping compared to S/2 d4 and S/2 d6 system of tapping. In other experiments, yield of S/2 d3 system tapping was at par with S/2 d2 system and higher than S/2 d4 system in clone RRIM 600 and RRII 429.

Relationship of latex ATP with rubber yield was studied in polyclonal population available in this Station. The population was grouped on the basis of their yield potential and ATP was analysed in polyclonal trees of the group of different yield potential. The data showed high latex ATP in high yielding and medium yielding polyclonal trees compared to low yielding trees. Positive correlation between latex ATP and yield of grouped trees was observed.

3.2. Ecosystem study

A study on prediction of Natural Rubber (NR) plantation distribution in Southern (SI) and Northeast (NE) India using ecological niche modeling is in place. In this study, the major emphasis was to identify contributory factors for NR plantation distribution. The climate variables are the major attributing factors for NR distribution apart from other physiographic, edaphic and social parameters which play a role in deciding the suitability of an area for further

expansion of NR cultivation. Among all climatic variables, precipitation during summer months and temperature seasonality are most important climatic factors that determine the NR distribution in NE region. In addition to altitude, soil depth and socio-economic factors such as labour availability and village population contribute to NR distribution model of NE. On the contrary, NR tree distribution in SI region is mainly influenced by the climatic variables such as mean diurnal range of temperature, temperature seasonality, precipitation during coldest and driest quarter. This study clearly indicates that NE will offer significant potential for NR cultivation and scope will be limited in SI region in the years ahead under the changing climate scenario.

Improving the spatial transferability of Maxent Model was another priority of the study. To achieve this, we followed (1) reduction of model complexity by minimizing the number of input variables through principal component analysis and (2) calibrating the model with present existing niche (SI and NE region in India) versus actual fundamental niche of Natural Rubber i.e., Amazonian basin of Brazil for projecting the distribution in Indian regions. A better model transferability indicated by Transferability Index (TI) was achieved by reducing the model complexity in terms of number of predictive variables. As the realized niche of the crop is rapidly expanding over time, better spatial prediction accuracy of the model could be achieved by calibrating the model with most current existing niches (NE region) and the prediction of species occurrences appeared to be more realistic. It is postulated that shifting niche based prediction of species distribution may be more realistic for cultivated tree species like Natural Rubber.

4. Economics

4.1. Commercial yield evaluation of NR in Tripura

Yield data was collected from 105 NR growers from West Tripura and 82 growers from South Tripura. The 187 growers from whom data was collected belonged to 23 RPS from 2003-04 onwards. It was observed that only one clone of *Hevea* (RRIM 600) was prevalent in the study area. Since the members didn't sell scrap to the RPS, data on scrap were not available. The yield data pertaining to 22 years of tapping showed three distinct phases. They are initial yield increasing phase followed by yield stabilizing phase and yield declining phase. Maximum yield observed was 1606 kg ha^{-1} during 12th year of tapping. Average annual yield over 22 years is 1237.5 kg. ha^{-1} in the state.

4.2. Trends in area under NR and food crops in Tripura: an assessment

A sample survey covering 191 households in West Tripura, Sepahijala, South Tripura and Gomati districts was completed. Trends in area under NR cultivation of the sample household showed that 64 % of the household area under NR was previously waste land (barren land) and 18 % of household NR area was uncultivated bamboo land. The economic feasibility of NR over the other crops is the main reason for encouraging NR cultivation of the state.

5. Advisory work

Discriminatory fertilizer recommendation based on soil was offered to 278 rubber growers of this region. A total of 2039 latex samples were analysed for drc and other latex parameters. Total 2515 m of bud wood of high yielding clones were supplied to the growers.

REGIONAL RESEARCH STATION, TURA, MEGHALAYA

The Regional Research Station, Tura continued its research activities on evaluation of clones, polyclonal population, latex harvest technology and crop management.

1. Crop improvement

1.1. Polycross progeny evaluation

In the 2008 polycross progeny evaluation trial, the juvenile yield in three year old plants varied from 0.2 to 9.2 g t^{-1} t^{10} with an average yield of 2.3 g t^{-1} t^{-10}. On the basis of juvenile yield, a total of 34 top yielders were selected and multiplied for further evaluation. The polyclonal seeds brought from the Poly Clonal Seed Garden of Kolasib, Mizoram did not show appreciable sprouting.

1.2. Clonal nursery evaluation

A clonal nursery trial was initiated with the best ortets from Tura, Agartala and Guwahati along with RRIM 600 as the check. The juvenile yield ranged from 9.7 to 50.2 g t^{-1} t^{10} with an average yield of 27.8 g t^{-1} t^{-10} (Table Tura. 1).

Table Tura. 1. **Girth and juvenile yield of primary ortets**

Mother ortets	Girth (cm)	Juvenile yield (g t^{-1} t^{10})
T1X1	15.2	23.0
T8RRSA121	17.3	37.0
T2X2	18.5	28.6
T9RRSA315	16.4	9.7
T3X3	17.7	23.2
T10RRSA461	17.3	27.0
T4X9	20.6	42.7
T11RRSA585	20.5	50.2
T5RRST24	18.0	19.1
T12RRIM600	20.3	36.6
T6RRST37	19.0	36.9
Mean		27.8
SD	1.8	14.1

1.3. On-farm evaluation of selected clones

Trial I included blocks of six clones, *viz.*, RRII 417, RRII 422, RRII 429, PB 235, RRII 203 and RRIM 600 in Mendipathar (North Garo Hills) and trial II included four clones *viz.* RRII 417, RRII 422, RRII 429 and RRIM 600 in Bolchugre (West Garo Hills). In North Garo Hills, highest girth was recorded in RRII 429 (Table Tura. 2) while in West Garo Hills highest girth and number of branches were recorded in RRII 417 followed by RRII 422 (Table Tura. 3).

Table Tura. 2. **Growth of different clones in the on-farm trial at Mendipathar, North Garo hills**

Clones	Girth (cm)		Girth increment (cm)	
	Rabha	Momin	Rabha	Momin
PB 235	31.6	36.5	8.8	9.4
RRII 417	26.4	38.0	7.9	9.3
RRII 429	28.2	40.1	8.6	9.7
RRII 422	21.2	32.0	6.7	9.5
RRII 203	28.9	36.7	9.5	9.5
RRIM 600	28.7	35.1	8.4	10.5
LSD*P<0.05	6.3		0.9	
CV (%)	19.7		10.4	

Table Tura. 3. **Growth of different clones at Bolchugre, West Garo hills**

Clones	Girth (cm)	Number of branches
RRII 417	19.0	5.8
RRII 422	16.3	5.1
RRII 429	13.8	4.1
RRIM 600	14.7	4.3
LSD (*P=0.05)	3.2	1.2
CV (%)	20.6	26.0

1.4. Evaluation of polycross progenies from four stations of NE region

The promising seedlings collected from four locations in the NE region (*viz.*, RES Nagrakata, RRS Agartala, RRS Guwahati and RRS Tura) were screened on the basis of test tap yield.

1.5. Fundamental studies on the nature of wintering, flowering and seed germination in *Hevea* clones in Garo Hills of Meghalaya

Clonal variation was observed in wintering and flowering pattern. Refoliation started a little late in all the clones except PB 86, Gl 1 and GT 1 in which refoliation was initiated during the 1st week of March.

1.6. Germplasm Arboretum in Teksragre farm

In order to maintain a Germplasm Arboretum under the agroclimate of North Garo Hills, 1265 budded stumps belonging to 96 wild accessions and 6 control clones were planted and maintained.

2. Crop physiology and Latex Harvest Technology

2.1. Effect of low winter temperature on yield of rubber at high altitude

Severe low winter temperature is one of the main constraints for yield depression in *Hevea* grown under the agroclimate of Garo Hills. The annual average yield and drc was 53.7 g $t^{-1}t^{-1}$and 33.2 % respectively for this year. During defoliation and refoliation period, drc ranged from 27.1 to 28.1 %. Lowest soil moisture was recorded during February/March.

2.2. Study on controlled upward tapping system

The data showed that maximum yield under S/4U d2 with ethephon application (La 5%) at 21 days interval (T1) followed by same system of tapping with monthly yield stimulation (T2) (Table Tura. 4). Under CUT 33-60 % yield increase was observed over normal tapping yield.

Table Tura. 4. **Annual yield (g $t^{-1}t^{-1}$) under different treatments of Ethephon application in Controlled Upward Tapping system**

Month	Treatments				LSD (5%)
	T1	T2	T3	T4	
April	68.4	63.1	64.7	62.8	
May	84.2	86.3	80.9	72.9	
June	86.7	83.1	75.8	74.0	
July	85.6	80.2	70.0	67.8	
August	93.9	84.4	78.6	72.7	
September	82.6	76.8	79.8	67.4	
October	96.3	87.3	85.2	79.2	16.59
November	92.8	75.8	74.9	66.8	
December	115.0	105.2	98.2	82.9	
January	75.8	69.1	70.8	55.3	
February	68.2	77.2	67.8	53.4	
March	101.9	111.5	104.3	84.6	
Mean	87.6	83.3	79.3	72.5	4.88

T1: S/4 U d2 6d/7 ET 5% La. 3W/6m, S/2 d2 ET 2.5/Pa 2/y
T2: S/4 U d2 6d/7 ET 5% La. m/6m, S/2 d2 ET 2.5/Pa 2/y
T3: S/3 U d2 6d/7 ET 5% La. m/6m, S/2 d2 ET 2.5/Pa 2/y
T4: S/3 U d2 6d/7 ET 5% La. 6W/6m, S/2 d2 ET 2.5/Pa 2/y

2.3. Shallow tapping – an option to stress alleviation in *Hevea* plantations during winter in NE

There was no significant difference between treatments. Maximum yield was recorded in normal tapping system followed by normal continuous tapping and LFT + normal tapping and lowest was in shallow + normal tapping system. DRC was low in normal continuous tapping and was high in shallow + normal tapping system. Normal continuous tapping system showed higher TPD (8.4 %) followed by the

shallow + normal tapping system (6.8 %) and LFT + normal tapping (5.9 %) and minimum was in normal tapping system (5.2 %).

2.4. Location specific stimulant application

Experiment on ethylene induced stress response at the tapping panel of the *Hevea* trees was initiated with the aim to reduce the stress in tissues in the tapping panel. In RRIM 600, six treatments were adopted with bark applications of 5 % ethephon. There was no significant difference in drc between treatments.

3. Crop management

3.1. Nutritional studies (On farm trial at Borgang, Assam).

The study was continued and the results indicated that the highest girth, girth increment, yield and drc were observed in the combination of $N_{60}P_{30}K_{45}$ kg ha^{-1} while the lowest in $N_0P_0K_0$ (Table Tura. 5). Significant improvement in the OC content and available forms of P and K were noted in fertilizer applied fields compared to control.

Table Tura. 5. **Effect of N, P, and K combinations on girth, girth increment, yield and drc under the Central Brahmaputra Valley zone of Assam during mature phase**

Treatments	Girth (cm)	Girth increment (cm)	Yield (g t^{-1}t^{-1})	DRC (%)
T1 (0:0:0)	72.9	1.3	22.7	31.7
T2 (0:0:15)	74.5	1.4	24.2	31.8
T3 (0:15:0)	69.5	1.4	25.8	32.0
T4(15:0:0)	76.0	1.6	27.6	32.1
T5 (0:0:30)	75.8	1.7	29.3	32.2
T6 (0:30:0)	79.1	1.7	31.1	32.4
T7 (30:0:0)	81.6	1.8	33.3	32.6
T8(15:15:15)	80.7	1.9	35.2	32.7
T9 (30:15:30)	85.4	2.0	37.0	32.9
T10 30:30:30)	86.1	2.1	39.7	33.1
T11(45:15:30)	88.7	2.2	42.2	33.2
T12(45:30:45)	88.7	2.3	44.9	33.6
T13 (60:15:30)	89.7	2.3	47.5	33.7
T14.(60:30:30)	91.0	2.6	50.3	33.9
T15.(60:30:45)	96.3	2.7	53.3	34.0
CD (P=0.05)	7.8	0.1	5.5	0.2

3.2. Soil moisture retention characteristics of the rubber growing areas of Meghalaya

An increasing trend in soil moisture was observed with increasing depth of soil in all the months. Maximum soil moisture content was recorded during September and minimum was in February and March during 2013-14. Annual mean of soil moisture was between field capacity (28.5%) and permanent wilting point (14.0%) at all the depths *viz.* 0-15, 15-30 and 30-60 cm.

3.3. Analytical/ Advisory work for fertilizer recommendation:

Analysis of 22 soil samples from the rubber growing areas indicated that the OC content was in the medium range (0.94 to 1.32 %) in the surface soil (0-30 cm) while available P was in low (2.5 to 6.8 mg kg^{-1}) and available K was in medium range (44.0-86.2 mg kg^{-1}). The soil is acidic in nature with pH ranging from 4.6- 5.2. Fertilizer recommendations were offered to farmers.

REGIONAL EXPERIMENT STATION, NAGRAKATTA, WEST BENGAL

1. Crop improvement

1.1 Evaluation of clone

In the multidisciplinary clone evaluation trials I and II (1990) (comprising of 18 clones), all clones were found superior to RRII 105 in terms of growth. Highest girth was recorded by RRIM 612 (93.2 cm) followed by RRII 118 (86.8 cm), whereas highest yield was observed in RRII 208 (45.1 g t^{-1} t^{-1}) followed by REYAN 88/13 (44.1 g t^{-1} t^{-1}). In Clone trial III (1991), maximum girth was recorded in REYAN 93/114 (83.6 cm) followed by PB 235 (77.0 cm). In yield PB 235 (51.5), PB 310 (48.5) and RRII 208 (42.7g t^{-1} t^{-1}) were found superior. In clone trial IV (1993), REYAN 93/114 (75.2 cm) and Haiken 1 (73.6 cm) were found superior in girth while Haiken 1(56.8 g t^{-1} t^{-1}) had significantly higher yield.

1.2. Evaluation of germplasm

In an evaluation trial of 21 wild germplasm accessions, RO 3172 (85.8 cm) RO 2890 (82.6 cm), AC 619 (76.9 cm) and MT 196 (26.69 cm) showed superior girth. RO 5363 was the highest yielder among all accessions. In general, Rondonia accessions were found superior to the Acre and Mato Grosso accessions.

1.3. Performance of polyclonal seedlings

Mean girth of the 23 year old polycross seed trial (1990) was 71.3 cm and the average yield was 35.3 g t^{-1} t^{-1}. Selected ortets were maintained at the nursery for further evaluation.

1.4. Multi trait screening of half sib progenies for cold tolerance and yield attributes

There was no significant difference in chlorophyll content, number of leaves, number of whorls and girth. However, RRII 208 had better height, number of whirls and chlorophyll content.

1.5. On farm evaluation of promising clones

In a field trial (2012) of seven promising clones (Sarugaon Tea Estate, Ethalbari, Jalpaiguri, West Bengal), no significant difference was observed among the clones. However, clone RRIM 600 (3.7 cm), RRII 417 (3.7 cm) and RRIM 605 (3.5 cm) had better girth.

1.6. Intraclonal variability studies

Tree to tree variability in yield and yield related components (volume, drc and yield) in three clones cultivated under the climatic condition of Sub-Himalayan West Bengal was studied. Volume of latex in RRII 105 was more variable (range between 8.3-229.3 ml) than PB 311 and RRIM 600. However, RRIM 600 was more consistent in terms of drc (10.2 CV %) and yield than PB 311 and RRII 105.

2. Crop management

2.1. Nutritional trial-1989

The experiment on NPK in three factorial design was continued. No significant difference in girth or yield was noted among the treatments.

2.2. Inter-planting trial

The interplanting trial on rubber + tea was continued. Green tea leaf yield in inter-planted plots T2, T3 and T4 was significantly lower than that of the pure plot due to heavy shade imposed by the mature rubber trees and also due to severe pest attack in tea (Table Nag. 1). Rubber girth in T3 and T5 was significantly higher than pure rubber and annual yield in T3 and T4 was

Table Nag. 1. **Growth and yield of rubber and tea**

Treatments	Spacing	Tea yield (kg ha^{-1})	Rubber girth (cm)	Rubber yield (kg ha^{-1})
T1 (Pure rubber)	Rubber - 5 x 5 m		65.3	1745.1 (100%)
T2 Rubber + Tea	Rubber - 10 x 2.5 m Tea – 10 x (1.0 x 0.6) m	1922.2 (70%)	62.9	1229.2 (72%)
T3 Rubber + Tea	Rubber - 12 x 2.5 m Tea – 12 x (1.0 x 0.6) m	2144.4 (72%)	70.6 *	900.4 (62%)
T4 (paired row) Rubber + Tea	Rubber - 18 x (3 x 3) m; 2 rows Tea – 18 x (1.0 x 0.6) m	3456.2 (72%)	65.8	1374.0 (68%)
T5 Rubber + Tea	Rubber - 10 x 5.0 m Tea – 10 x (1.0 x 0.6) m	3187.9 (70%)	73.9 **	538.4 (35%)
T6 (Pure Tea)	Tea - 1.0 x 0.6 m	8691.0 (100%)		
CD (P≤0.05)			5.5	464.3

* Significant at 0.05% level; ** Significant at 0.01% level
Data in parentheses denote plant stand per treatment

significantly lower than the T1 (pure rubber).

3. Crop physiology

3.1. Performance of polycross progeny raised from seeds of locally adapted mature rubber plantation

A comparative study on the performance of seedling plants raised from locally adapted poly-cross seeds along with traditional seeds was conducted. Girth was recorded at 50 cm height and no significant difference was observed among the seedlings. However, Kanyakumari seedling showed superior girth over the seedlings of other three places *i.e.* Tura, Nagrakata and Assam and was narrowed down from 5th year of growth. The second year's juvenile yield of the seedling plants showed that the yield and yield efficiency of plants of Kanyakumari source was higher than that of other sources.

3.2. Physiological evaluation of rubber clones in abandoned tea growing areas of Dooars belt of North Bengal

There was no significant difference between the girth of clones planted in high pH and normal soil, though girth of plants grown in high pH soil was better than that of the control block. However, the girth of RRII 422 was significantly higher in high

Table Nag. 2.**Growth pattern of different clones growing in high pH soil and normal soil**

Clones	Girth of plants in field after 12 months of planting (cm)		Chlorophyll Content Index (CCI)	
	High pH soil	Normal soil	High pH soil	Normal soil
RRII 208	22.5±1.8	16.0±1.5	46.3±1.4	54.8±0.7
RRII 417	16.7±1.2	14.0±2.0	43.6±1.2	57.4±0.6
RRII 422	16.4±1.1	5.4±1.4	41.5±0.9	51.9±0.7
RRII 429	20.2±1.6	17.6±1.7	46.5±0.6	58.1±0.5
RRIM 605	17.7±2.4	10.4±2.0	42.5±0.9	60.0±0.6
RRIM 600	12.8±1.7	11.1±1.6	43.5±0.8	50.6±1.2

pH soil than that of the control plot. The chlorophyll content index (CCI) data showed that it was high in control than that of the high pH soil (Table Nag. 2).

3.3. Evaluation of Ortets for abiotic stress tolerance in different agro-climatic regions

In order to study the field performance of ortet selections from Nagrakata, Tura, Agartala, Guwahati (cold) and Dapchari (drought) polybag plants were cultivated under the sub-Himalayan climate of West Bengal. The girth of Ortets from Guwahati was better than RRSA, RRII and RRST. Effect of cold on chlorophyll content Index (CCI) was prominent. Reduction in CCI from post monsoon to winter for RRSA 585 was minimum followed by RRST 39 and RRSD 35. Maximum reduction was observed in RRSN 47.

3.4. Effect of stimulant applied away from tapping panel

Experiment was initiated with six different treatments along with unstimulated trees as control; stimulant was applied 2 times in a year before onset of cold. The experiment was conducted under S/2 d3 system of tapping in blocks of 40 plants for each treatment. Plants of all the treatment were of uniform girth. The 3rd year yield data showed that yield in treatment A (Bark application of 5% Ethephon above 125 cm from the bud union) 59.5 g t^{-1} t^{-1}, treatment B (Bark application of 5% Ethephon on the bud union) 57.5 g t^{-1} t^{-1} and in treatment C (Bark application of 5% Ethephon at both A and B positions) 65.4 g t^{-1} t^{-1} were significantly higher than that of the unstimulated treatment E (unstimulated trees) 46.0 g t^{-1} t^{-1} trees in Nagrakata. Plants showing above 70% TPD was high in F (Panel application of 2.5% Ethephon (standard practice) 45.33 g/t/t.

3.5. Shallow tapping - an option to stress alleviation in *Hevea* plantations during winter season in NE regions

In order to understand whether shallow tapping during winter rest period would compensate the yield loss during the rest period, different systems of tapping were adopted. The data showed that there was no significant difference between the treatments. Plants showing above 75% TPD was more in shallow / continuous (S/2 d2 as well as S/2 d3) tapping compared to normal tapping with rest (Table Nag. 3).

Table Nag. 3. **Pattern of yield in different tapping systems**

Treatments	Yield (kg ha^{-1}) (400 tress ha^{-1})	% of plants showing above 75% TPD
Shallow tapping under S/2 d2 tapping system from winter tapping rest period (from Mid-January till annual defoliation-refoliation rest) followed by normal tapping.	2272	4
Continuous tapping in S/2 d2 without winter tapping rest.	2756	7
Normal tapping in S/2 d2 followed by S/2 d3 tapping system from winter tapping rest period (from Mid-January till annual defoliation-refoliation rest)	2404	3
Normal tapping under S/2 d2 tapping system with annual defoliation-refoliation rest.	2826	3
CD (P≤0.05)	268.6	
SD	268.6	

3.6. Water mining of rubber trees in north Bengal: Sap flow system

To measure the quantum loss of water through transpiration by rubber tree, sap flow measurement system was installed. The measurement was made on 16 year old trees of two clones, RRII 429 and RRII 417. The mean water consumption was 18.6 L tree^{-1}day^{-1} for five months. Maximum rate of sap flow per day was observed during May followed by April and the minimum in the month of July. Considering the average field stand the mean water consumption of rubber plantation was 2.7 x10^{6} L ha^{-1} year^{-1} from April to August of the reporting year assuming 400 trees ha^{-1}.

REGIONAL RESEARCH STATION, DAPCHARI, MAHARASHTRA

The mandates of this Station are to develop and screen suitable clones that can overcome drought and stress, and to develop location specific agro technology. The experiments on crop improvement (screening of wild *Hevea* accessions, evaluation of clones and polyclone, pipeline clones and selected ortets) for growth and yield performance under dry and subhumid conditions; environmental physiology (irrigation requirement and methods, drought studies, physiological evaluation of selected ortets from various agroclimates of India) and crop management (practices to mitigate the drought and soil moisture conservation) are being carried out.

1. Environmental Physiology

1.1. Drip and basin method of irrigation

The experiment on ET_c based irrigation scheduling with the objectives to standardize and evaluate the advantages of drip irrigation over basin irrigation was started during 1987. Though higher girth was registered by basin irrigation at 1.0 ETc (80.3 cm), it is on par with same irrigation method at 0.3 and 0.5 ETc (75.8 cm, 75.7 cm respectively) and 0.8 ETc drip irrigation (74.7 cm). Different levels of basin irrigation resulted higher girth as compared to drip system and rainfed control. A significantly higher yield (39.8 g t^{-1}t^{-1}) was recorded with basin irrigation scheduling at 0.5 ETc than control (32.8 g t^{-1}t^{-1}).

1.2. Cost evaluation trail

A trial was started during 1987 to find

Table Dap.1. **Effect of different depth of soil to different irrigation schedule on yield of rubber**

Months	Yield (g t^{-1}t^{-1})		
	Group A	Group B	Group C
	Rainfed	Deep soil	Shallow soil
April	9.8	17.3	14.3
May	7.6	15.2	12.3
June	14.1	23.4	19.6
July	15.5	16.7	16.2
August	13.5	11.7	13.4
September	13.2	14.4	19.3
October	11.6	17.3	16.8
November	15.2	25.0	18.4
December	21.3	32.3	30.1
January	26.4	43.5	37.3
February	18.3	45.9	27.4
March	15.2	35.2	26.1
Mean	15.1	24.8	20.9
Yield (kg ha^{-1}yr^{-1})	705.2	964.9	737.2
SE±	1.5	3.4	2.2
SD	5.0	11.7	7.7
Summer yield (g t^{-1}t^{-1})	15.4	31.4	23.5
Summer yield (kg ha^{-1}yr^{-1})	247.1	502.5	375.4
SE±	3.3	6.5	4.6
SD	7.4	14.4	10.3

out the expenses incurred towards various inputs, farm practices and irrigation. The treatment contains irrigated (reduced irrigation of 1/5th ET_c -deep soil and 1.0 ET_c –shallow soil) and unirrigated trees of RRIM 600. The results indicated a better summer and annual yield for the trees under 1/5th ETc irrigation in deep soil area than 1.0 ETc irrigation in shallow soil area (Table Dap. 1).

1.3. Evaluation of environmental stress tolerance and physiological adaptations of cold and drought tolerant ortet under varying agro-climates in India

This trial was started in 2011 to evaluate the physiological and biochemical adaptation potential and common mechanisms involved in cold and drought tolerant traits using molecular physiology/ biochemical tools for ortet selections from cold and drought by interchanging the clones to different agro-climatic regions and to study the G x E interaction for growth and yield under varying agro-climates. Higher girth was noticed in selection RRSA 98 (30.5 cm) while the lowest was for RRST 24 (12.0 cm). Among the control clones, highest girth was recorded by RRII 414 (30.9 cm) and RRII 430 (29.8 cm). The lowest height was registered by RRST 24 (367.5 cm) while RRII 414 recorded highest height of 999.99 cm followed by RRSA 98 (924.9 cm) and RRII 430 (906.4 cm). Total chlorophyll differed non significantly in the range of 2.6 to 2.3 mg gm fr. wt. $^{-1}$ in RRII 414 and Dap 1 respectively. In general, ortet RRSA was noticed superior in all growth characters followed by NGK, GH, DAP and RRST. No yellowing was seen in RRST 39 while the highest was recorded in RRSA 585 (28.9%). The lowest level of yellowing was observed in RRST 24 (7.0%).

2. Latex Harvest Technology

Demonstration trial on Controlled Upward Tapping (BI 1 panel of RRII 105 planted in 1983) is being carried out since 2009 with RBD. The objective is to identify suitable CUT practice for this region along with enhancement of yield during low yielding phase (regenerated bark) and to optimize the stimulation schedule for further reduction in cost of production and for better economic life without stress to the trees. Tapping was under periodic panel change system.

Results showed that, treatment T2 – S/ 3U d3 6d 7 ET 5% La with application of ethephon once in three weeks recorded higher yield of 52.4 g t^{-1} t^{-1} (1424.2 kg ha^{-1}) than the other treatments (Table Dap. 2). Lower yield was recorded under T3 - S/4U d3 system with stimulation of once in a month (36.3 g t^{-1} t^{-1}, 986.3 kg ha^{-1}).

Table Dap. 2. **Yield response of Low Frequency Controlled Upward Tapping and basal tapping in clone RRII 105**

	Treatments	CUT (68 days)			Basal Tapping (34 days)		
		g $t^{-1}t^{-1}$	Kg $tree^{-1}$	Kg ha^{-1}	g $t^{-1}t^{-1}$	Kg $tree^{-1}$	Kg ha^{-1}
T1	S/2 d3 6d/7, S4 U d3 6d 7 ET 5% La (3 w)	44.9	3.1	1222.1	24.4	0.8	331.4
T2	S/2 d3 6d/7, S/3 U d3 6d 7 ET 5% La (3 w)	52.4	3.6	1424.2	23.9	0.8	325.6
T3	S/2 d3 6 d/7, S/4 U d3 6d 7 ET 5% La (m)	36.3	2.5	986.27	17.7	0.6	240.0
T4	S/2 d3 6d/7, S/3 U d3 6d 7 ET 5% La (m)	38.6	2.6	1049.4	19.9	0.7	270.5
	SE +/-	5.8			3.21 NS		
	CD (P=0.05)	17.6					

3. Crop improvement

Development of drought tolerant clones and screening of wild *Hevea* accessions for drought tolerance and future evaluations from modern clones, ortets selection, clones from half sib progeny of prepotent clones along with newly released 400 series, study on unique characteristics of each clones to file a DUS norms continued to be the thrust areas. A total of 10 experiments are being conducted.

3.1. Ortet selection

Trial started during 2008 to evaluate the growth and yield performance of ortets selected from polycross seedling planted at this Station with control clones. OS 37 recorded higher girth of 21.6 cm than RRII 105 (16.3 cm) while lowest girth was recorded in OS 8 (12.8 cm). Among the control clones, RRII 430 recorded highest girth (21.4 cm). In terms of girth, all ortets performed better than RRII 105. While yellowing was more in OS 42 (26.8%) and in OS 236 (24.1%) it was lesser in OS 136 (2.0%).

3.2. Germplasm screening

In the screening of wild *Hevea* accessions (130 numbers) for drought, the 2003 Mato Grosso accessions were found superior in all growth characters than Rondonia and Acre accessions. Twenty five potential drought tolerant accessions were identified for further studies. All the 25 accessions showed a wide variability for all characters studied.

3.3. Clonal nursery evaluation

In the experiment on identification of reliable juvenile and mature characteristics for clone identification in *Hevea*: Standardization of Distinctiveness, Uniformity and Stability (DUS) testing norms for evolving specific guidelines for varietal registration in rubber and morphological data on individual plants in the juvenile stage covering 40 traits was recorded from all three locations in the first year. Data was also recorded for a set of traits from mature plants of the popular RRII clones (RRII 5, RRII 105, RRII 118, RRII 203, RRII 208 and RRII 400 series). Quantitative data on girth and height were recorded to measure GxE effects for these clones.

4. Crop management

The experiment initiated in 2008 to study the effect of vertical mulching and Kaoline spray on moisture conservation, growth and yield of rubber was continued. There was no significant difference between soil moisture conservation practices (SMP) and control plot in terms of girth. The SMP recorded higher relative water content than control. Surface soil moisture content was significantly higher in SMP than control. As in the previous year, no significant difference was noticed in growth of rubber among the treatments.

REGIONAL RESEARCH STATION, DHENKANAL, ORISSA

The Station concentrates its research activities in the field of clone and polycross population evaluation and management for the prevailing dry sub humid climate of the state. The Station's research activities moves further with the particular objective of identifying clones suitable to this region.

1. Crop improvement

Crop improvement includes evaluation of clones and polyclonal population. There are five clone evaluation trials. The trials were laid out to evolve most suitable clones under the dry sub humid climate.

1.1. Clone evaluation

In trial I (1987), the popular clone RRII 105 recorded highest mean yield of 50.0 g t^{-1} t^{-1} while GT 1 recorded the least (30.0 g t^{-1} t^{-1}). In terms of growth, GT 1, RRIM 600 and RRII 105 performed well (Table OR. 1). In another clone trial (1990), clones RRII 208 (54.9 g t^{-1} t^{-1}) and SCATC 88-13 were found high yielding. SCATC 93-114 recorded the poorest yield (28.2 g t^{-1} t^{-1}). However, SCATC 93-114, SCATC 88-13 and RRII 208 performed well.

In the 1991 experiment, performance of rubber clones and polyclonal seedlings were studied. RRII 208 recorded highest yield (70.01 g t^{-1} t^{-1}) among the clones. Popular clones RRII 105 and RRIC 102 had moderate yield. Polyclonal seedlings had lesser yield though they displayed better growth and adaptability when compared to other clones. GT 1 (94.2 cm) and RRII 208 (90.0 cm) showed superior growth.

Table OR. 1. **Yield and growth of elite clones**

Clone	Yield (g t^{-1} t^{-1})	Girth (cm)
RRII 105	50.0	73.1
RRIM 600	38.7	77.0
GT 1	30.0	80.4
C.D. (P=0.05)	5.6	4.0

In the modern clones trial (2000), highest mean yield was observed in RRII 28/59 (39.1 g t^{-1} t^{-1}) closely followed by IRCA 109, IRCA 111 and RRII 105. Among the RRII 300 series, RRII 351 was the highest yielder. The lowest mean yield was recorded in RRII 51 (20.2 g t^{-1} t^{-1}). Highest mean girth was recorded in RRII 300 and IRCA 111. The lowest girth was recorded in IRCA 109 (Table OR. 2).

Table OR. 2. **Yield and growth performance of clones**

Clones	Yield (g t^{-1} t^{-1})	Girth (cm)
RRII 300	32.9	63.4
RRII 208	32.2	54.9
RRII 357	32.1	53.0
RRII 352	34.5	52.2
RRII 28/59	39.1	55.8
RRIM 600	36.5	57.5
RRII 357	31.7	53.6
IRCA 109	38.4	45.1
RRII 105	36.3	51.3
RRII 51	20.2	53.3
IRCA 111	36.0	58.0
C.D.(P=0.05)	9.6	-

1.2. Polyclonal ortet evaluation

To find a most suitable clone for the dry sub humid region, ortets among polyclonal population were selected, multiplied and a field trial was laid down. OR 4, OR 7 and OR 10 recorded good yield under test tapping and suggested scope for development of clone. Better girth increment was found in ortets OR 4 (30.6 cm) followed by OR 8 (31.0 cm) and OR 10 (29.6 cm) (Fig. OR. 1).

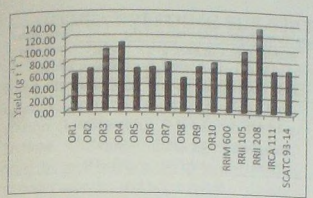


Fig. OR. 1 **Yield performance of ortets**

2. Latex Harvest Technology

2.1. Controlled Upward Tapping trial

CUT in clone RRIM 600 with appropriate ethephon application showed good increase in rubber yield during renewed basal panel stage under the dry sub humid region of Orissa. Treatment T3 [S/3 U d2 ET 5% La (m); S/2 d2 ET 2.5% p.a (2/y)] showed maximum mean annual yield. (Fig. OR. 2).

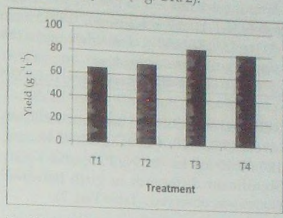


Fig OR. 2. **Yield performance under controlled upward tapping**

REGIONAL RESEARCH STATION, PADIYOOR, KERALA

The research programs for identification of clones suited to the region and evaluation of clonal tolerance to drought and disease incidence continued. Field trials on agro-management practices for reduction of the gestation period in rubber are also in progress.

1. Crop management

1.1. Water requirement studies

The experiment on irrigation in immature rubber with irrigation levels at IW/CPE ratio of 0.3, 0.6, 0.9, 1.2 and an unirrigated control continued into the mature phase. There was no significant differences in girth and yield between treatments (Table Pad. 1).

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

Treatment (IW/CPE)	Girth (cm)		Girth increment (cm)	Mean yield
	13th yr	14th yr	14th yr	g t-1t-1
1.2	62.8	63.8	1.0	53.8
0.9	61.6	62.5	0.9	52.8
0.6	65.9	67.3	1.3	57.9
0.3	61.6	62.9	1.3	57.5
Control	61.4	62.9	1.6	56.5
CD (P=0.05)	NS	NS	NS	NS

1.2. Response to applied fertilizers in high yielding clones

An RBD experiment with 3 replications was laid out in June 2002 with budded stumps as planting material. The treatments comprised of 3 clones (RRII 105,

Table Pad. 2. **Effect of applied fertilizer on growth (12th year)**

Treatment	Girth (cm)		
	RRII 105	RRII 429	RRII 414
30:30:20	57.1	49.8	57.3
60:30:20	53.8	51.0	59.7
90:60:40	49.7	49.5	57.1
120:60:40	54.7	51.5	57.0
CD (P=0.05)	NS		

Table Pad 3. **Water use under open conditions**

Planting material	Source of water (IW/rainfall)	Water use through irrigation/rainfall (L)				Total water IW + RF (L)
		Seeding to budding	Budding to cut back	Cut back to 2 whorl	Total water	
		56 days	137 days	96 days	289 days	289 days
Root trainer	IW /No of irrigations	3.2 (11)	39.0 (69)	12.5 (27)	54.7(107)	64.0
	Rainfall/No. of rainy days	5.0 (29)	2.9 (4)	1.4 (14)	9.3(47)	
Polybag	IW /No of irrigations	1.7 (6)	43.5 (69)	9.8 (22)	55 (97)	64.3
	Rainfall/No. of rainy days	5.0 (29)	2.9 (4)	1.4 (14)	9.3 (47)	

RRII 414 and RRII 429) and four fertilizer levels (30:30:20, 60:30:20, 90:60:40 and 120:60:40 kg ha^{-1} of N, P_2O_5 and K_2O). Significant difference in girth between clones was observed. (Table Pad. 2).

1.3. Water consumption in rubber nurseries

The water utilized for irrigation of nursery plants was monitored in large scale commercial rubber nurseries. Total water use under open conditions was found similar for both polybag and root trainer plants (Table Pad. 3.)

Frequency of irrigation and water use was found higher in root trainer plants raised under polyhouse conditions (Table Pad. 4.)

Table Pad. 5. **Growth performance of modern *Hevea* clones**

Clones	Girth (cm)	Mean annual yield (g t^{-1} t^{-1})	Summer yield (g t^{-1} t^{-1})
PB 255	64.6	67.6	43.7
PB 314	64.2	52.3	30.2
PB 330	71.9	47.5	25.4
PB 28/59	64.3	55.4	32.5
RRIM 703	57.3	42.6	14.3
IRCA 18	69.2	56.8	29.8
IRCA 109	61.7	46.5	30.1
IRCA 111	62.4	42.9	24.7
IRCA 130	71.2	84.7	63.3
IRCA 230	65.8	45.6	23.8
RRII 105	64.2	65.2	40.5
CD	5.3	21.5	11.2

Table Pad. 4. **Water use under polyhouse conditions**

Planting material	Water use through irrigation (L)			Total water (L)
	Seeding to budding (80 days)	Budding to cutback (114 days)	Cut back to 2 whorl (96 days)	
Root trainer	6.7(24)*	44.5(81)	24.6(43)	75.8(148)
Polybag	5.2(24)	26.3(61)	13.5(31)	44.9(116)

2. Crop Improvement

2.1. Large scale evaluation of clones

IRCA 18, IRCA 130 and PB 330 exhibited significant superiority with respect to girth. IRCA 130 also exhibited significantly higher annual and summer yield (Table Pad. 5).

2.2. Evaluation of rubber clones/selections at high altitude situations

Clones RRII 203 and RRIC 100 were found superior (in terms of girth) in the trial planted in 1996 under high altitude conditions (974 m MSL) with 10 selections and 5 clones. Girth of selections P 1, P 213, P 270, P 280, P 296 and Iritty was significantly superior to RRII 105. Mean annual yield of RRII 203 was found to be on par with that of PB 86, RRIC 100, P 270, P 213 and Iritty. Mean annual yield of RRII 203 and RRIC 100 was found significantly superior to RRII 105. Summer yield of RRII 203 was found significantly superior to all other clones/selections.

HEVEA BREEDING SUB-STATION, KADABA, KARNATAKA

Rubber research began in Dakshina Kannada region in 1986 after the establishment of Hevea Breeding Sub-station (HBSS) with a research farm at Nettana. The major challenge of research was the prevalence of drought during summer months and occurrence of diseases especially *Phytophthora* and *Corynespora* leaf fall diseases.

The major soil type is red lateritic and coastal alluvium. Annual rainfall varies from 3000 to 5400 mm. Southwest monsoon contributes to the major part of the rainfall with July getting highest rainfall. The minimum temperature varies from 12 °C to 25 °C and maximum temperature ranges from 21 °C to 43 °C. Northeast monsoon is weak. The conditions prevalent in this region are conducive to *Phytophthora* and powdery mildew disease. Incidence of *Corynespora* leaf disease is a major concern. The farm has a well-established Class B Agro-meteorological observatory and a soil testing laboratory.

The major thrust areas of research in the station are to develop new clones under different biotic and abiotic stress factors and to identify locally adapted clones for South Konkan region. The farm maintains a source bush nursery of 106 clones for generating nucleus planting material.

1. Small scale trial of selected ortet clones (1988A,1988B, 1988C)

In the first trial (1988A), 15 ortet clones and three control clones (RRII 105, RRIM 600 and GT 1) are under evaluation. T2 emerged as highest yielder based on the data over eleven years of tapping, closely followed by O 17 and GT 1. In the second trial (1988B), among the 16 ortet clones and three control clones (RRII 105, RRIM 600 and GT 1) under evaluation (Table Kad. 1), ortet T1 (90.2 g t^{-1} t^{-1}) was found the highest yielding clone followed by GT 1 and RRII 105 (43.4 g t^{-1} t^{-1}). The third trial (1988C) has 14 ortet clones and three control clones. After eleven years of tapping, GT 1 recorded maximum yield followed by ortet C140 and clone RRII 105.

Table Kad. 1. **Performance of clones in the small scale ortet trial (1988B)**

Clone	Girth (cm) at age 25 years (Dec. 2013)	Mean yield 11 years (g t^{-1} t^{-1})
T 1	114.9	90.2
GT 1	95.0	43.4
O 53	99.1	25.0
O 40	88.8	28.8
RRII 105	74.9	43.4
C 150	81.5	23.9
O 38	90.3	34.9
O 54	87.7	27.6
O 16	83.9	33.3
RRIM 600	78.3	33.8
PO	80.7	38.0
O 46	84.9	32.7
O 14	80.5	27.5
O 37	82.8	42.2
C 151	76.3	19.8
O 23	68.4	31.0
O 22	72.6	33.0
O 57	74.1	31.3
C 9	67.7	22.2
CV (%)	10.5	25.4
CD (P<0.05)	13.5	15.9

2. Large scale clone trials (1989, 1990 A)

Fourteen clones are being evaluated in the large-scale trial initiated during 1989 along with check clone RRII 105. Growth and yield performance indicated the superiority of the clone RRII 203 in the tenth year followed by KRS 25 and PB 255. Cumulative data on growth and yield performance of clones in the 1990A large scale clone trial showed that PB 260 recorded a maximum dry rubber yield followed by PB 235 and PB 217. Tjir 1 continued as the lowest yielder. At least two clones (RRII 203 and PB 235) could be selected from these trials based on the long term data base.

3. Trial on estimation of genetic parameters

This experiment planted in 1990 consists of 12 clones and their half-sib progenies. Parent clones PB 235, RRII 203 and RRII 105 were the top yielders. Among the progenies, half-sibs of RRII 203 (HS 3) registered maximum growth followed by half-sibs of GT 1 (HS2) and PB 235 (HS 10). The half-sib progenies of high yielding parents continued their superiority in growth as well as yield in the tenth year while progenies of inferior female parents continued to be inferior.

4. Small scale clone trials of popular clones (1991A, 1991B and 1991C)

Fifty four exotic clones and three control clones are being tested (RRII 105, GT 1 and RRIM 600) were kept as three control clones. In the trial 1991A with 36 clones(both indigenous and exotic clones), clones PB 235, PB 280, PB 314, PB 312 and PB 311 continued to exhibit maximum growth and yield. Data base of PB 235 from other trials also corroborated with this data set. PB 235 could be selected as one of the future planting materials and can be used as control (local check variety) for challenging test clones.

In 1991 B trial comprising 13 clones, RRII 5, RRII 3, HP 83/224 and PB 28/59 performed well.

5. Large scale trial (2000)

In the data of 18 years for the LST (2000) which comprises six 400 series clones (RRII 414, RRII 430, RRII 422, RRII 429, RRII 403 and RRII 407) along with RRIC 100 and RRII 105, maximum growth was found in RRII 414 and RRII 430. Trends in yield data indicated clones RRII 414 and RRII 430 as best performers.

6. Polycross garden (1995)

Seven component clones planted as per Simmonds design constitutes polyclonal seed garden of HBSS Nettana. Clones such as RRII 105, PB 215, PB 217, PB 242, PB 252, PB 5/51, PB 28/83, AVT 93 and Ch 26 are being maintained. Open pollinated seeds are being collected and supplied for different studies. Experiment on nursery evaluation and selections of better female parents for putative stocks are under progress at RRII and other regional stations.

HEVEA BREEDING SUB-STATION, THADIKARANKONAM, TAMIL NADU

1. Genetic improvement of *Hevea brasiliensis* for developing ideal clones

1.1. Conventional breeding in the areas

Five projects were pursued, *viz.*, clone evaluation, hybridization and clonal selection, new generation polyclonal seed garden, participatory clone evaluation and root trainer planting technique.

i. Clone evaluation

This project consists of nine large scale clone evaluation experiments initiated under the agro-climate of Kanyakumari region. Field performance of a total 30 modern high yielding indigenous and exotic clones was studied during the period under report. One large-scale clone evaluation experiment (1994) comprising nine new clones and two established clones was concluded during 2013. In this experiment, one of the newly introduced Malaysian clones namely PB 255 (87.9 g t^{-1} t^{-1}) exhibited significantly higher yield right from the beginning. The consistent yield performance and promising secondary characters justifies up-gradation of this clone to category I, at least for the Kanyakumari region. Out of the five new clones introduced from Cote d' Ivoire, three clones *viz.* IRCA 109 (79.5 g t^{-1} t^{-1}), IRCA 111 (77.6 g t^{-1} t^{-1}) and IRCA 130 (77.5 g t^{-1} t^{-1}), presented promising yield trend throughout the trial.

From the concluded block evaluation experiment (1994) comprising 13 modern popular clones, RRII 105 (68.6 g t^{-1} t^{-1}) and PB 28/59 (63.5 g t^{-1} t^{-1}) were found superior.

In the large scale clone trial (1996) at New Ambadi Estate, RRII 203 (57.7 g t^{-1} t^{-1}) had better yield than RRII 105 (56.92 g t^{-1} t^{-1}) till the 12th year of tapping. Performance of 400 series clones was interior to RRII 105 (Table Par. 1).

Table Par. 1. **The mean girth (January 2014) and mean yield of trial GxE Interaction (1996)**

Clone	Girth (cm)	Mean yield (g t^{-1} t^{-1})	TPD (%)
RRII 414	74.7	44.8	7.0
RRII 417	72.4	48.8	32.5
RRII 422	73.6	50.2	15.0
RRII 429	83.7	42.1	4.5
RRII 430	69.8	50.9	13.6
RRII 51	75.6	36.8	9.8
RRII 176	83.3	46.1	2.5
RRII 203	84.5	57.7	47.5
RRIC 100	76.2	43.5	8.5
PB 217	89.8	40.4	14.0
RRIM 600	78.7	44.2	4.4
RRII 105	74.7	56.9	22.6
Mean	78.0	46.9	15.1
CD	9.7	9.0	–

Nine years data of block evaluation experiment 400 series at Vaikundam Estate (2000) indicated RRII 429 (67.8 g t^{-1} t^{-1}) as best yielder and RRII 414 (54.7 g t^{-1} t^{-1}) as

Table Par. 2. **Mean girth and mean yield for nine years**

Sl. No	Clone	Girth (cm)	Mean yield (g t^{-1} t^{-1}) (9 years)	TPD (%)
1	RRII 414	70.6	54.7	10.8
2	RRII 417	70.0	62.3	10.0
3	RRII 422	68.2	62.9	11.1
4	RRII 427	66.5	51.4	2.4
5	RRII 429	78.1	67.8	27.3
6	RRII 430	68.1	60.0	10.3
7	RRII 105	64.6	59.9	16.0
	Mean	69.43	59.9	12.6
	SE	3.88	8.6	–

poor performer (Table Par. 2). RRII 429 contracted high TPD (27.3%) too. In order to have in-depth studies on the performance of these hybrid clones, the Station had initiated five large scale clone evaluation experiments representing five diverse agro-climatic conditions in Kanyakumari District.

1.2. Hybridization and clonal selection

The breeding orchards (51 parental clones) were well maintained and 1100 hand pollinations were attempted with different parental combinations during the reporting period. The hybrid seeds (72 nos) obtained during 2013 were raised for preliminary evaluation. The hybrid seeds obtained by HPs carried out during 2012 were test tapped to evaluate yield and secondary characters.

1.3. New generation polyclonal seed garden

The seed garden was maintained well. The mother plants raised out of poly-cross seeds collected during 2012 were test tapped and the promising high yielders were pollarded for multiplication and further evaluation.

1.4. Participatory clone evaluation experiment

Juvenile growth of 11 pipeline clones and three check clones planted at Tharuvaiyar (2008) and Vithura (2008) were recorded at quarterly intervals and the data were tabulated. Girth recording was also initiated on the OFT at Bethany Estate during 2010 (Phase II) and 2012 (Phase III).

1.5. Root trainer planting technique

In the field trial initiated at Churulacode (2002), root trainer plants continued to yield better (55.7 g t^{-1} t^{-1}) than polybag plants (54.2 g t^{-1} t^{-1}) during 8th year of tapping. A comparative study was conducted at Vaikundam Estate during 2013 on the root development in polybags and root trainers (Table Par. 3). Though the deformed roots were removed at the point of coiling before field planting, an average of 40% of plants still exhibited coiled tap roots on excavation at different intervals. The polybag plants had 90.4% better girth than root trainer plants at the beginning of the trial. This difference was reduced to 16.2% towards the end of nine months of growth in the field.

Table Par. 3. **Growth and root characteristics of advanced planting materials raised in root trainers and polybags**

Time of examination	Total height (cm)		Girth at collar (cm)		No of tap roots		No of lateral roots		Tap root coiling (%)	
	RT	PB	RT	PB	RT	PB	RT	PB	RT	PB
Before field planting	53.5	96.1	1.7	3.2	1.75	2.11	42.4	36.2	Nil	100
1 month after planting	74	147	3.4	4.6	3.6	7.2	38.4	44.2	Nil	80
2 months after planting	74	147	3.4	4.6	1.2	2.4	38.4	44.2	Nil	Nil
3 months after planting	128.9	191.2	4.6	5.9	1	2.2	45.4	74.8	Nil	100
6 months after planting	208	290	6.9	8.7	1	1	—	—	Nil	20
9 months after planting	—	—	11.2	13.0	—	—	—	—	—	—

ANNUAL EXPENDITURE

Expenditure at a glance (2013-14)

Head of Account		Expenditure (₹ in lakhs)
Non-Plan*		
	Non-Plan RRII	620.76
	Projects (CES)	519.76
	Total	**1, 140.52**
Plan		
	Research Scheme	2, 384.99
	NERDS Research Component	435.89
	Total	**2, 820.88**
	Grand Total	**3,961.40**

*Non-plan expense includes non-plan projects (CES)

poor performer (Table Par. 2). RRII 429 contracted high TPD (27.3%) too. In order to have in-depth studies on the performance of these hybrid clones, the Station had initiated five large scale clone evaluation experiments representing five diverse agro-climatic conditions in Kanyakumari District.

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Before field planting	53.5	96.1	1.7	3.2	1.75	2.11	42.4	36.2	Nil	100
1 month after planting	74	147	3.4	4.6	3.6	7.2	38.4	44.2	Nil	80
2 months after planting	74	147	3.4	4.6	1.2	2.4	38.4	44.2	Nil	Nil
3 months after planting	128.9	191.2	4.6	5.9	1	2.2	45.4	74.8	Nil	100
6 months after planting	208	290	6.9	8.7	1	1	—	—	Nil	20
9 months after planting	—	—	11.2	13.0	—	—	—	—	—	—

ANNUAL EXPENDITURE

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	NERDS Research Component	435.89
	Total	**2, 820.88**
	Grand Total	**3,961.40**

*Non-plan expense includes non-plan projects (CES)

SCIENTIFIC ADVISORY COMMITTEE RECOMMENDATIONS 2013-14

1. Poly house technology for producing good quality planting materials.
2. Four chain saw models for tree felling, cross cutting and pruning operations in rubber plantations.
   i. Echo CS 510 and Echo CS 420 ES – supplied by M/s. Field testing India Pvt. Ltd. Bangalore
   ii. MS 361 and MS 210- M/s. Andreas Stihl Pvt. Ltd., Pune
3. Wood Pecker WPBC 2012 weed cutter model supplied by M/s. Remys Agro Equipments Pvt. Ltd. Kaloor, Kochi for weeding operations in rubber plantations.
4. Mist blower attachment for mini-tractor for disease management of natural rubber for low volume spraying in rubber plantations. The mist blower can deliver the spray fluid to a height of 95 to 100 feet with optimum particles per cm^2 fitted with Aspee make atomizer and mirconair type atomizer, respectively.
5. Cifarelli L3A single man operated mist blower model supplied by M/s. KisanKraft Machine tools, Pvt. Ltd. Bangalore. For spraying of oil-based COC in rubber plantations.
6. Index for ranking the efficiency of weed cutters in rubber plantations.

LIST OF MAJOR EQUIPMENTS AT RRII

Air permeability tester
Atomic Absorption Spectrophotometer
Autoclave (Cylindrical and Horizontal)
Ball mill
Bio – Cabinet
Bio safety cabinet
Biomedical Freezers (-30°C)
BOD Incubator
Brook field viscometer
Carbon Nitrogen Analyser
Centrifuges (High speed refrigerated)
Chemical fume hoods
Chlorophyll Content Meter
Chlorophyll index meter
Climatic chamber
Coir foam testing equipment (indentation hardness, flexing, compression set A & B testers)
Compression set apparatus (25% strain)
De- mattia Flexometers
Deep freezer (-20° & -80°)
Deep freezers
Differential scanning calorimeter
Din Abrasion machines
Disper grader
DMA 50
DNA electrophoresis unit
DNA isolation machine
Eddy covariance system
ELISA reader
Environmentally controlled shakers
Flame photometer
Flash chromatograph &accessories
Fluorescence Monitoring System
Fluorescence spectrophotometer
Freeze Driers
FTIR spectrometers
Gas chromatograph–mass spectrometer
Gel blotting apparatus
Nanodrop Spectrophotometers
Oxygen electrode
Ozone chamber
P700 chlorophyll fluorescence measurement system
PAM-2000 portable flurometer
Particle size analysers
PCR machines
Phase contrast Microscope & accessories
Phosphor Image Analyser
Phosphor imager
Plant growth chamber
Plate reader
Polarizing Microscope & accessories
Projection microscope with accessories
Protein separating systems - 2D
Real time PCR machines
Recirculating Cooler
Refrigerated and Heating Circulator
Refrigerated high speed micro centrifuge
Refrigerated shaker
Refrigerated Table Top Centrifuge
Remote Sensing and Geographical Information System (RS & GIS)
Research microscope and image analyser
Ross flexing Machine
Rotary Evaporator
Rubber Process Analyser
Sap flow meter
Sequencing gel electrophoresis unit
Sequi-Gen GT system (sequencing system)
Soil Respiration Analyser
Sonicator
Specific gravity balance
Spectro radiometer

Spectrophotometer – nanodrop
Gel documentation & image analyzer
Gel documentation systems
Gel Dryer & Pump
Gel electrophoresis apparatus - 2D
Geldoc systems
Genetic Analyzer 3500 XL
Goodrich Flexometers
GPC
Hardeness tester (shore A,D,M,0)
High speed microcentrifuge
High speed Table Top Centrifuges
High Voltage Power Pack
High-Speed Centrifuge
Histo Embedder
HPLC system
Hybridization oven – Incubator shaker
Hydraulic press (14" × 14",)
Image processing and Analysis System
Incubator & Accessories
Incubator shaker with cooling
Infrared thermometer
Inverted MicroscopeIRGA- Portable photosynthesis system
Isoelectric focusing unit
Laminar Air Flow Hoods
Latex foam testing equipment (indentation hardness,flexing, compression set A&B testers)
Leaf area meter
Linear PAR Ceptometers
Liquid scintillation system
Measuring mixer (80 cc)
Micro centrifuge with cooling
Micro pH meter
Microtome – Base sledge
Microtome – Rotary with knife sharpener
Mini IEF electrophoresis unit
Mooney viscometer
Moving die rheometer
Muffle furnaces
Spectrophotometers
Speed vac concentrator system
Stereo Microscope
Submerged Electrophoresis System
Temperature controlled incubator shaker
Temperature Recorder
Thermo gravimetric analyzer
Thermocouple psychrometer
Tissue processor
Two-roll mixing mill (6" × 13")
Ultracentrifuges
Universal testing machines (50N, 100N, 5 kN)
UV Spectrophotometer
Vertical electrophoresis unit
Walk in environmental Growth Chamber
Walk in Fume Hood
Water potential system
Water purification system
Wet sieving apparatus
Zeta potential analyzer

NORTH EAST

Atomic Absorption Spectrophotometer
Chlorophyll content meter.
Flame photometer
Fluorescence Monitoring System
Leaf Area Meter
Luminometer
Nitrogen Analyzer
PAR/LAI Ceptometer
Portable photosynthesis system
Spectronic 20D Spectrophotometer
Stereo microscope
UV-spectrophotometers
Water Potential meter WP4-T

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Front Cover Photo
Tractor mounted spraying, Appella Rubber Estate, Neria P.O. 574 228, D.K. Dist, Karnataka
Photo by
Radhakrishna Hebbar

Back Page Photos
1. Workshop on Pesticide-related Issues in Rubber and Other Crops in South India, 29-30 August, 2013, RRII, Kottayam
2. IRRDB RRIV International Workshop on Latex Harvesting Technology, 18-22 November 2013, RRIV, Binh Duong, Vietnam
3. Rubber Growers' Meet to discuss Issues on Plant Protection, 20 August 2013, RRII, Kottayam
4. Award for developing Mechanised Tapping Tool

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Research divisions and functions

The major research divisions are Agronomy/ Soils, Biotechnology, Botany, Germplasm, Plant Pathology, Plant Physiology, Latex Harvest Technology, Rubber Technology and Economics. Studies on DRIS Fertilisation and Genome Analysis are dealt separately.

The thrust areas of research of Agronomy/ Soils Division are investigations on the nutritional requirements of rubber, irrigation, intercropping, cover crop management, weed control and the study of the rubber growing soils. Development of tissue culture and anther culture systems for propagation and crop improvement of *Hevea* are the important areas in which the Biotechnology Division is engaged. The important fields of research of the Botany Division are breeding, evaluation and selection of new clones, propagation techniques, planting methods, anatomical studies and cytogenetic investigations. The Germplasm Division is concentrating on the introduction, conservation and evaluation of *Hevea* germplasm. The Plant Pathology Division is engaged in investigations on the diseases and pests of rubber and associated cover crops and their control. The Plant Physiology Division conducts studies on both fundamental and applied aspects of *Hevea* tree physiology. The Latex Harvest Technology Division is concentrating on all applied aspects of crop harvesting in rubber. The Rubber Technology Division concentrates on improvement in primary processing of rubber, its chemical modification, rubber product manufacture and quality control of processed rubber. The Technical Consultancy Division provides consultancy services for the promotion of the rubber industry. The Economics Division undertakes studies on economic aspects related to rubber plantations.

The research supporting sections includes Library and Documentation, Instrumentation, Statistics, Computer and Maintenance Wing. There is also a small experimental farm of 33 ha. at the headquarters of RRII.

Central Experiment Station

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

Regional Research Stations

RRII has established a North-Eastern Research Complex with headquarters at Agartala having regional research stations at Agartala in Tripura, Guwahati in Assam and Tura in Meghalaya. The RRII has also set up regional research establishments at Dapchari (Maharashtra), Dhenkanal (Orissa), Nagrakatta (West Bengal), Thadikarankonam (Tamil Nadu), Kadaba (Karnataka) and Padiyoor (Kerala).

Regional soil testing laboratories have been established at Taliparamba, Kozhikode, Thrissur, Muvattupuzha, Pala, Kanjirappally, Adoor and Nedumangad. Mobile units for soil and leaf analysis are available at Kozhikode laboratory, apart from that at the headquarters.

National/International collaboration

RRII is a member of the International Rubber Research and Development Board (IRRDB), an association of national organizations devoted to research and development on natural rubber. Rubber Board is a member of the Association of Natural Rubber Producing Countries (ANRPC) and International Rubber Study Group (IRSG).

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

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